Wildlife Society Bulletin; DOI: 10.1002/wsb.365

Original Article

Seed and Feeder Use by Birds in the United States and Canada

DAVID J. HORN,[1] *Department of Biology, Millikin University, 1184 W Main Street, Decatur, IL 62522, USA*
STACEY M. JOHANSEN, *Department of Biology, Millikin University, 1184 W Main Street, Decatur, IL 62522, USA*
TRAVIS E. WILCOXEN, *Department of Biology, Millikin University, 1184 W Main Street, Decatur, IL 62522, USA*

ABSTRACT More people feed birds and other wildlife than hunt and fish combined. Despite its popularity, many bird-feeding traditions lack scientific data. We examined seed and feeder use by wild birds in the United States and Canada, and how seed use may change by season and geographic region. Between 2005 and 2008, 173 individuals from 38 states and 3 provinces in Canada made 20,077, 45-minute observations at bird feeders, recording 106 species and 1,282,424 bird visits. Of the 10 seed types most commonly used in bird seed blends, 3 are most attractive to birds: black-oil sunflower, medium sunflower chips, and white proso millet. Other seeds such as red milo are less attractive. Chickadees (*Poecile* spp.), nuthatches (*Sitta* spp.), and larger finches (*Carpodacus* spp.) were most abundant at black-oil sunflower, smaller finches (*Carduelis* spp.) were most abundant at Nyjer® (Wild Bird Feeding Institute, Chicago, IL) and sunflower chips, and sparrows (*Spizella* spp.) were most abundant at white proso millet. Bird-feeding traditions have been widely reported in books, magazines, newspaper articles, and websites. These traditions are often conflicting and have not been verified empirically. Studies such as this can be used to develop scientifically based recommendations that can lead to a better bird-feeding experience and that attract fewer species with known negative ecological consequences. © 2013 The Wildlife Society.

KEY WORDS bird feed, bird feeder, bird feeding, bird food, bird seed, citizen science, feeding birds, supplemental feeding, wild birds.

Wild bird feeding is a popular pastime. In 2011, over 52 million Americans over age 16 fed wild birds or other wildlife around their homes, and spent >US$ 5 billion on bird food, feeders, houses, baths, and other accessories (U.S. Fish and Wildlife Service 2012). Large numbers of books, magazine and newspaper articles, and websites provide information on seed and feeder preferences of wild birds. However, the reported food favorites are not entirely consistent among sources. Harrison and Harrison (1983) indicate that the black-capped chickadee's (*Poecile atricapillus*) favorite seed is sunflower (variety or hulled vs. un-hulled not indicated), and that it also feeds on cracked corn, doughnuts, and suet. Burton (1995) suggests this species is especially attracted to sunflower seeds (variety or hulled vs. un-hulled not indicated), as well as bakery scraps, bones, doughnuts, and suet. Dunn and Tessaglia-Hymes (1999) report that the favorite feeder foods include any type of sunflower (hulled vs. un-hulled not indicated, but especially striped and black-oil), and also safflower, hulled peanuts, suet, peanut butter mixes, bird puddings, and water. One of the reasons for these inconsistencies is that they lack a scientific basis, or use data were not collected to establish differences in bird abundance at different foods. Furthermore, food use may vary by season, region, and the feeder in which the food is offered, and recommendations may not take these factors into account. For example, Horn et al. (2002) found a positive relationship between occurrence and the presence of corn at feeders for several species in Iowa, USA; whereas, other studies have not shown corn to be attractive (Geis 1980). Recommending foods that are not readily consumed can have negative consequences. Unused bird seed in a feeder or on the ground below the feeder may, in turn, attract unwanted mammalian pests or be exposed to conditions that can increase the production of the fungal metabolite, aflatoxins (Henke et al. 2001).

Several scientific studies have examined backyard bird feeding, including research of seed and feeder preferences (Geis 1980, Horn 1999), feeder placement (Cowie and Simons 1991, Dunn and Hussell 1991), how bird feeding may influence survival and nutritional demands (Brittingham and Temple 1988, 1992; Geis and Pomeroy 1993), disease transmission (Dhondt et al. 1998) and population trends, range expansions, and irruptive migrations of birds at feeders (Hochachka et al. 1999, Bonter and Harvey 2008, Robb et al. 2008). In their summary of supplemental feeding studies, Robb et al. (2008) called for large-scale investigations on bird feeding taking place in backyards and noted the limited number of studies that used conditions that emulated how people feed birds.

Research questions that require large geographic areas and/or long timescales may be best addressed using citizen science

Received: 23 July 2012; Accepted: 26 April 2013

[1]*E-mail: dhorn@millikin.edu*

(Bonney et al. 2009, Silvertown 2009, Dickinson et al. 2010). Citizen science is the collection of field data by public volunteers, which can be used by scientists to answer research questions (Trumbull et al. 2000, Bonter and Hochachka 2009, Dickinson et al. 2010). The use of citizen scientists in research has been implemented worldwide within fields ranging from evolutionary biology to global climate change (Silvertown 2009, Dickinson et al. 2010).

We performed a study on seed and feeder use by wild birds in the United States and Canada with the assistance of citizen scientists who collected data. The study, called PROJECT WILDBIRD®, addressed 5 primary questions: 1) Are the number of bird visits within species equivalent at different seed types?; 2) Are the number of bird visits within species equivalent at different feeder types?; 3) Does the number of bird visits at each seed type vary by feeder type?; 4) Does the number of bird visits at each seed type vary by season?; and 5) Does the number of bird visits at each seed type vary by region of the United States and Canada?

Our goal was to assess the accuracy of the generally accepted understanding of bird seed preference accumulated in non-scientific literature, and to develop more empirical recommendations for wild bird feeding that take into account factors not examined in previous studies. By understanding seed and feeder use we can improve a hobby that is engaged in by more Americans than hunt and fish combined (U.S. Fish and Wildlife Service 2012).

STUDY AREA

Our study occurred across the United States and Canada (excluding AK and HI) within 6 geographic regions defined by the Partners in Flight North American Landbird Conservation Plan: Eastern, Intermountain West, Northern Forest, Pacific, Prairie, and Southwest (Rich et al. 2004, see online Appendix for states and provinces within each region). Within a given region, participants lived in a wide range of landscapes with varying degrees of urbanization.

METHODS

Citizen Scientists

We used citizen scientists to collect data for our study, which began in winter 2005 and continued through autumn 2008. Citizen scientists were recruited continuously during the study through newspaper advertisements, press releases, announcements on listserves, word-of-mouth, and the project's website (www.projectwildbird.org). Before being accepted into the study, participants were required to successfully complete 2 phone interviews to confirm their ability to identify birds and successfully follow the requested protocol for monitoring birds. The acceptance rate of participants was approximately 10%. To aid in the successful completion of the protocol, the protocol was mailed to all participants and was also available on the website. In addition, we assisted citizen scientists directly when they had questions.

Seed and Feeders

Individuals selected to participate in the study were provided 4 feeders of the same type and model, 4 shepherd's hooks or poles for hanging or mounting feeders, 4 squirrel or raccoon baffles, and 10 types of bird seed: black-oil sunflower (*Helianthus annuus*), cracked corn (*Zea mays*), fine sunflower chips, medium sunflower chips, Nyjer® (*Guizotia abyssinica*, also known as thistle, Wild Bird Feeding Institute, Chicago, IL), red milo (*Sorghum bicolor*, also known as sorghum), safflower (*Carthamus tinctorius*), striped sunflower (*H. annuus*), white proso millet (*Panicum miliaceum*), and whole peanuts (*Arachis hypogaea*). Fine and medium sunflower chips, also referred to as hulled sunflower or sunflower hearts, were black-oil sunflower seeds whose outer hulls has been removed and the seed chopped. Fine sunflower chips were defined as being seeds that could fit through a 0.125-in. (0.3-cm) round-hole screen and over a 0.094-in. (0.2-cm) screen, while medium sunflower chips could fit through a 0.19-in. (0.5-cm) round-hole screen and over a 0.125-in. screen. Whole peanuts, or peanut splits, were unsalted peanuts that were out of the shell and split in half. The 10 seed types were selected because they are among the most common seeds offered in seed blends, and thus it is likely that birds that use feeders have been previously exposed to the seeds. Bird seed was provided by All Seasons Wild Bird Store, Inc. (Bloomington, MN), Anderson Seed Company, Inc. (Mentor, MN), D&D Commodities Ltd (Stephen, MN), Essex Topcrop Sales, Ltd (Essex, ON), F.M. Brown's Sons, Inc. (Sinking Spring, PA), Perry Brothers Seed, Inc. (Otis, CO), Prince Corporation (Marshfield, WI), and Scott Pet Products (Rockville, IN). Bird seed was provided to participants for the duration of their participation in the study.

The feeders were 1 of 3 general types: tube, hopper, and platform (see below for listing of models within a feeder type). The tube feeders were cylindrical in shape, made of plastic, and the seed was dispersed through metal ports with perches to which birds could cling. Hopper feeders resembled small houses with a wood roof, plastic sides, and seed dispensed at the base of the feeder. Platform feeders dispensed seed on the wire floor of the feeder with plastic or wood borders. Some platform feeders were covered from above, while others were open. In general, the amount of space birds had on which to land and perch increased from tube to hopper to platform feeders.

We used the following tube feeder models: Artline 6145 (Hillside, IL), and Droll Yankees A-6F, CJM-15G, and CJM-23G (Plainfield, CT). The hopper feeder models we used included Heath Outdoor Products 152 and 184 (Coopersville, MI), Heritage Farms 7511i (Antioch, IL), a Perky Pet feeder (Lititz, PA), and Wild Bird Centers of America, Inc.'s Mobi Hopper Feeder 2-sided Medium (Glen Echo, MD). Platform feeders included uncovered wood and recycled plastic feeders (31 cm × 38 cm with 5-cm sides) by Backyard Nature Products (Chilton, WI), Cabin Fever Fly-through Feeder (Bozeman, MT), and Droll Yankees GS1, and Wild Bird Centers of America, Inc.'s Covered Platform Feeder. The feeder type provided to each participant was

selected at random and the feeder model within a type was systematically chosen to achieve equivalent numbers of each feeder model. Each feeder model used in the study was able to dispense each of the 10 types of bird seed.

Tube feeders were hung from a shepherd's hook (Erva Tool & Manufacturing Company, Inc., RT3D [Chicago, IL] or Opus 5107-4 [Lititz, PA]), while hopper and platform feeders were either hung from a hook or mounted from below by a pole (Droll Yankees GP, Erva Tool & Manufacturing Company, Inc., FP2, or Opus 5107-4). All feeders were equipped with baffles (Erva Tool & Manufacturing Company, Inc., SB1D or SB2, or Yule-Hyde Associates Company SQ97 [Brampton, ON, Canada]) to prevent mammals from gaining access to feeders.

Seed, feeders, poles or shepherd's hooks, baffles, and shipping were provided free of charge to participants. When the supplies arrived, participants placed the 4 bird feeders 2 m apart from one another in a straight line. Participants were instructed to place feeders in an area close to dense cover such as trees or shrubs if possible (Horn et al. 2003), but no closer than 2 m from the base of any tree or shrub to prevent squirrels from jumping on feeders. All feeders were to be cleaned regularly, kept clear of debris, and filled with dry seed. Feeders were to be filled to the top daily, or in the case of platform feeders, filled so that seed evenly covered all parts of the feeder.

Sampling Protocol

Participants committed to monitoring bird feeders each of the 4 seasons for 1 year. The seasons were autumn (22 Sep–20 Dec), winter (21 Dec–19 Mar), spring (20 Mar–20 Jun), and summer (21 Jun–21 Sep). During each season, participation in the study was expected to take place for 64 days divided into 8 segments with each segment being 8 days long. Each 8-day segment was divided into 4 2-day intervals. During the morning of the first day of each interval, the assigned seeds were placed in the feeders based on an assigned seed rotation schedule. On the second day of each interval, monitoring took place for a 45-minute monitoring session. Thus, seeds were placed in the appropriate feeders in days 1, 3, 5, and 7 of each segment and monitoring took place on days 2, 4, 6, and 8.

The 10 seed types used during the 64-day period were presented and rotated in a systematic manner. Black-oil sunflower and white proso millet were always present in 2 of the 4 feeders. The other 8 seed types were present 2 at a time in the 2 remaining feeders. Specifically, over the course of 4 8-day segments, each of the 8 remaining seed types would be present for 1, 8-day segment. Each season, the rotation pattern was completed twice (i.e., there were 2 replicates of 4 8-day segments). To reduce bias in the number of birds at a feeder based on feeder position, during days 1, 3, 5, and 7 of each segment, the seed was rotated to a new position (e.g., Horn 1995). For example, if the feeder filled with black-oil sunflower was randomly assigned to the position farthest left of the viewing window on days 1 and 2, it would be moved one position to the right on days 3 and 4, one further position to the right on days 5 and 6, and moved to the furthest position to the right on days 7 and 8. On days 1 and 2 of the next 8-day segment, it would return to the position farthest left of the viewing window. In order to reduce bias associated with having certain combinations of seed offered simultaneously, each participant was assigned a unique rotation schedule with the seed combination and initial position of the seed for each 8-day segment randomly assigned. If participants could not complete the 64-day period continuously, individuals would pick-up wherever they left on their assigned rotation schedule.

To reduce the likelihood that birds would stop visiting the yard after the 64-day period each season, individuals were asked to fill the 4 feeders with black-oil sunflower and white proso millet. These 2 seeds have previously been identified in smaller scale studies to be readily consumed by the majority of species that visit bird feeders (Geis 1980, Horn et al. 2002). Thus, the background population of birds visiting feeders is likely to be equivalent when only black-oil sunflower and white proso millet were offered compared with feeders that contain additional seed types. To further reduce bias, birds were not monitored until the second day after seed/feeder combinations were rotated. This was considered ample time for birds to sample among the seed species available (Collins and Horn 2012).

During each monitoring session, the number of birds of each species at each feeder was recorded every 5 minutes over a 45-minute session. The mean number of birds of each species from the 10 counts at each feeder was then calculated for each 45-minute session and used in data analysis. Birds perched on the shepherd's hook or on the ground below a feeder were not recorded. Participants only recorded birds they could positively identify. Data were entered by participants on the study's website.

We asked participants to monitor birds at a time when birds were most likely at their feeders based on previous feeding experiences. However, the monitoring time could change throughout the 64-day monitoring period. During the monitoring session, no mammals were allowed on feeders, but monitoring could take place if mammals were on the ground below the feeders. If an avian predator was detected near the bird feeders, monitoring ceased until the predator was believed to have left the area for $\geq$5 minutes. During the study, the only bird feeders allowed in the participants' yard were those provided for the study. While participants were asked to monitor feeders for 1 year, some individuals chose to participate for a second year. These individuals were randomly assigned 4 feeders of another type and model for the second year.

Statistical Analysis

Only species comprising $\geq$0.5% of the total observations of bird visits were used in data analysis. For these species, we conducted 1 of 2 linear mixed-model analyses with restricted maximum likelihood estimation using PASW 18.0 software (SPSS, Inc., 2009). For species that are found in the same geographic region year-round, we used a mixed-model analysis with the following fixed effects—seed type (10 levels), feeder type (3 levels), season (4 levels), geographic

region (6 levels), seed type × feeder type interaction (30 levels), and seed type × season interaction (40 levels). For species that are not found in the same geographic region year-round (e.g., migratory species), we ran the mixed model above without the seed type × season interaction.

In order to determine whether there was a seed × region interaction, a second mixed model was run for each species. Because 72% of our participants were located in the eastern and prairie region, we only used those 2 regions for determining whether there was a seed × region interaction (20 levels). Specifically, for species that are present in both the eastern and prairie regions, we ran a mixed model that included the fixed effects from the first mixed model run and added the seed type × region interaction.

For all of the mixed models, we used the random variable "observer" (173 levels) to account for the repeated measures made by participants at a site, differences among participants among sites, and differences in microhabitat and bird communities among sites. Year was included as a second covariance parameter in all of the mixed models to account for possible yearly differences in the abundance of birds. For all models, only the geographic regions in which the species was present were used in the models for that species. The experimental unit for all mixed models was the mean number of birds of each species per 5-minute interval within a 45-minute session at each feeder.

We considered fixed effects to be significant if $P < 0.001$. To establish differences among treatments within the fixed effects, we used post hoc pair-wise comparisons using least-square difference tests with a Bonferroni adjustment. We considered differences among treatments of main effects to be significant if $P < 0.001$.

RESULTS

The study involved 173 participants from 38 states and 3 provinces in Canada with 46 individuals participating for a second year. Of the participants, 57 were in the Eastern region, 20 in Intermountain West, 18 in Northern Forest, 6 in Pacific, 68 in Prairie, and 4 in Southwest.

Between winter 2005 and autumn 2008, 1,282,424 bird visits of 106 species were recorded during 20,077, 45-minute observation sessions at feeders. Of those 106 species, 23 species accounted for ≥0.5% of the total bird visits recorded and were used in further analyses (Table 1). Collectively, American goldfinch, house finch, and house sparrow accounted for 55% of bird visits.

Table 1. Number of visits by the 23 most common bird species observed in study of seed and feeder use in the United States and Canada, winter 2005–autumn 2008.

Species	Number of visits
House sparrow (*Passer domesticus*)	305,087
House finch (*Carpodacus mexicanus*)	212,140
American goldfinch (*Carduelis tristis*)	187,892
Black-capped chickadee (*Poecile atricapillus*)	79,570
Mourning dove (*Zenaida macroura*)	62,927
Northern cardinal (*Cardinalis cardinalis*)	54,017
Brown-headed cowbird (*Molothrus ater*)	40,108
Pine siskin (*Carduelis pinus*)	30,574
Purple finch (*Carpodacus purpureus*)	30,406
Common grackle (*Quiscalus quiscula*)	30,311
Dark-eyed junco (*Junco hyemalis*)	27,502
Blue jay (*Cyanocitta cristata*)	24,072
Red-winged blackbird (*Agelaius phoeniceus*)	21,457
Tufted titmouse (*Baeolophus bicolor*)	20,246
White-breasted nuthatch (*Sitta carolinensis*)	17,581
Carolina chickadee (*Poecile carolinensis*)	15,106
Chipping sparrow (*Spizella passerine*)	13,302
Song sparrow (*Melospiza melodia*)	9,090
Common redpoll (*Carduelis flammea*)	7,945
Red-breasted nuthatch (*Sitta canadensis*)	7,258
American tree sparrow (*Spizella arborea*)	6,644
Downy woodpecker (*Picoides pubescens*)	6,625
Cassin's finch (*Carpodacus cassinii*)	6,607

Seed Use

Smaller finches, such as American goldfinch, common redpoll, and pine siskin were most abundant at Nyjer and sunflower chips (Table 2). Larger finches, and species that remove seeds from the feeder to eat elsewhere, such as black-capped chickadee, Carolina chickadee, Cassin's finch, house finch, northern cardinal, purple finch, and red-breasted nuthatch were most abundant at black-oil sunflower. Sparrows and birds that often feed on the ground, such as American tree sparrow, brown-headed cowbird, chipping sparrow, dark-eyed junco, house sparrow, mourning dove, red-winged blackbird, and song sparrow, were most abundant at white proso millet. Three species were most abundant at whole peanuts: blue jay, tufted titmouse, and white-breasted nuthatch, with tufted titmouse and white-breasted nuthatch also being abundant at black-oil sunflower. Downy woodpecker was most abundant at sunflower chips, while common grackle was most abundant at cracked corn.

Feeder Use

Birds that normally feed on the ground, and larger bodied birds, were most abundant at platform and platform and hopper feeders (Table 2). Some examples were American tree sparrow, blue jay, brown-headed cowbird, common grackle, dark-eyed junco, mourning dove, northern cardinal, and red-winged blackbird. A group of small-bodied birds were most abundant at either tube or tube and platform feeders. These species include American goldfinch, house finch, house sparrow, pine siskin, tufted titmouse and white-breasted nuthatch. Black-capped chickadee, chipping sparrow, common redpoll, purple finch, and song sparrow were most abundant at hopper or tube and hopper feeders.

Seasonal Abundance

We would expect to see differences in feeder visits among seasons for species that migrate from one region to another during the course of the year (Table 2). However, we also found differences in seasonal abundance at feeders among the 8 species that are found in the same area year-round. Black-capped chickadee, Carolina chickadee, downy woodpecker, northern cardinal, tufted titmouse and white-breasted nuthatch were more abundant at feeders during the autumn and/or winter months. House finch was most abundant at feeders during the summer, and house sparrow

Table 2. Results of a mixed-model analysis examining seed and feeder use by 23 bird species in the United States and Canada, winter 2005–autumn 2008. Fixed effects included in the model include seed type, feeder type, season, region, and seed × feeder, seed × season, and seed × region interactions. Fixed effects and treatments within fixed effects were considered significant if $P < 0.001$.

	Significant main effects and interactions						
Species	**Seed type[a,b]**	**Feeder type[c]**	**Season[d]**	**Region[e]**	**Seed × feeder interaction[f,g]**	**Seed × season interaction[h]**	**Seed × region interaction[i]**
American goldfinch	N	Tube	Autumn, Winter, Spring	NF, PA	Y	NP	N
American tree sparrow	WPM	Hopper, Platform	Winter	NF, PR	Y	NP	N
Black-capped chickadee	BOS	Hopper	Winter	EA, NF, PA	Y	Y	N
Blue jay	WP	Platform	Autumn	NF	Y	Y	Y
Brown-headed cowbird	WPM	Platform	Spring, Summer	EA	Y	NP	Y
Carolina chickadee	BOS	Not significant	Autumn, Winter	Not applicable	Y	Y	NP
Cassin's finch	BOS, MSC	Platform	Spring, Summer	IW	Y	NP	NP
Chipping sparrow	WPM	Tube, Hopper	Spring	EA, SW	Y	NP	Y
Common grackle	CC, MSC	Platform	Spring, Summer	NF, PR	Y	NP	Y
Common redpoll	FSC, MSC, N	Tube, Hopper	Winter	NF	Y	NP	Y
Dark-eyed junco	WPM	Platform	Winter	PA	Y	NP	Y
Downy woodpecker	FSC, MSC	Not significant	Winter	PR	Y	NP	Y
House finch	BOS	Tube	Summer	SW	Y	Y	N
House sparrow	WPM	Tube	Summer, Autumn	PR	Y	Y	Y
Mourning dove	WPM	Platform	Summer, Winter	EA	Y	NP	Y
Northern cardinal	BOS	Platform	Winter	EA	Y	N	N
Pine siskin	FSC, MSC, N	Tube, Platform	Spring, Summer	SW	Y	NP	Y
Purple finch	BOS	Tube, Hopper	Summer, Autumn	NF	Y	NP	Y
Red-breasted nuthatch	BOS, FSC, MSC	Platform	Autumn	NF, PA, PR	Y	NP	Y
Red-winged blackbird	WPM	Platform	Spring	PR	Y	NP	Y
Song sparrow	WPM	Hopper	Summer	PR	Y	NP	Y
Tufted titmouse	BOS, WP	Tube, Platform	Autumn, Winter	EA	Y	Y	Y
White-breasted nuthatch	BOS, MSC, SS, WP	Tube, Platform	Autumn	PR	Y	Y	Y

[a] Seed types with greatest number of bird visits over other seed types (if multiple seed types are shown, there was no significant difference between those seed types, and those seeds had a significantly greater number of bird visits than did other seeds). Abbreviations for seeds: black-oil sunflower (BOS), cracked corn (CC), fine sunflower chips (FSC), medium sunflower chips (MSC), Nyjer (N), striped sunflower (SS), whole peanuts (WP), and white proso millet (WPM).

[b] The number of 45-min observations at each of the 10 seed types: black-oil sunflower—20,074; cracked corn—4,984; fine sunflower chips—4,990; medium sunflower chips—5,026; Nyjer—5,053; red milo—4,999; safflower—4,992; striped sunflower—5,022; whole peanuts—5,032; and white proso millet—20,077.

[c] Feeder types with greatest number of bird visits. The number of 45-min observations at each of the 3 feeder types: platform—6,484; hopper—7,096; and tube—6,483.

[d] Seasons with greatest number of bird visits. The number of 45-min observations during each season: winter—4,073; spring—5,265; summer—5,368; and autumn—5,346.

[e] Geographic regions with greatest number of bird visits. The number of 45-min observations within each region: eastern (EA)—6,378; intermountain west (IW)—2,092; northern forest (NF)—2,247; pacific (PA)—460; prairie (PR)—8,464; and southwest (SW)—423.

[f] The number of 45-min observations at each of the 10 seed × 3 feeder combinations: black-oil sunflower—6,482, 7,101, and 6,491 at platform, hopper, and tube feeders, respectively; cracked corn—1,628, 1,752, and 1,604; fine sunflower chips—1,613, 1,759, and 1,618; medium sunflower chips—1,639, 1,774, and 1,613; Nyjer—1,619, 1,790, and 1,644; red milo—1,617, 1,746, and 1,636; safflower—1,624, 1,772, and 1,596; striped sunflower—1,621, 1,789, and 1,612; whole peanuts—1,599, 1,802, and 1,631; and white proso millet—6,493, 7,098, and 6,486.

[g] Y = interaction was significant, N = interaction was not significant, NP = interaction was not determined.

[h] The number of 45-min observations at each of the 10 seed × 4 season combinations were: black-oil sunflower—4,074, 5,268, 5,370, and 5,352 in winter, spring, summer, and autumn, respectively; cracked corn—996, 1,314, 1,357, and 1,313; fine sunflower chips—1,005, 1,310, 1,329, and 1,344; medium sunflower chips—1,028, 1,309, 1,342, and 1,347; Nyjer—1,032, 1,334, 1,340, and 1,343; red milo—1,019, 1,315, 1,336, and 1,329; safflower—1,009, 1,290, 1,361 and 1,328; striped sunflower—1,027, 1,316, 1,328, and 1,347; whole peanuts—1,021, 1,333, 1,343, and 1,333; and white proso millet—4,079, 5,272, 5,367, and 5,349.

[i] The number of 45-min observations at each of the 10 seed × 2 region combinations were: black-oil sunflower—6,381 and 8,173 in eastern and prairie, respectively; cracked corn—1,580 and 2,017; fine sunflower chips—1,571 and 2,048; medium sunflower chips—1,587 and 2,054; Nyjer—1,630 and 2,043; red milo—1,589 and 2,027; safflower—1,592 and 2,031; striped sunflower—1,591 and 2,060; whole peanuts—1,606 and 2,042; and white proso millet—6,385 and 8,172.

was most abundant at feeders during the summer and autumn.

Geographic Region

The Northern Forest and Prairie regions each had 8 of 23 species where their abundance at feeders was the greatest (Table 2). The Eastern region had 6 species where their abundance was greatest followed by the Pacific ($n = 4$), Southwest ($n = 3$), and Intermountain West ($n = 1$) regions.

Seed and Feeder Interaction

All 23 species exhibited a seed × feeder interaction (Table 2). As a generalization, when the least used bird seed was offered, feeder visits were low regardless of feeder type. However, when the most used seed was offered, feeder visits

increased and the greatest increase was at favored feeder types. A specific example of this interaction can be described with American goldfinch. American goldfinch were least likely to visit feeders filled with whole peanuts, and the mean number of goldfinch visits/5-minute interval within a 45-minute session at platform, hopper, and tube feeders filled with whole peanuts was 0.2, 0.2, and 0.2, respectively. When feeders were filled with Nyjer, the mean number of goldfinches per session increased to 0.6, 0.7, and 1.3 for platform, hopper, and tube feeders, respectively.

Seed and Season Interaction

Seven species exhibited a significant seed × season interaction (Table 2). The seed × season interaction generally followed the following pattern: seed types with the fewest number of visits had few visits each season of the year. However, during seasons where the species had a greater number of visits to feeders, the number of visits to the most used foods increased. For example, the black-capped chickadee was most abundant at feeders during the autumn and winter and least abundant in the spring and summer. It was also least abundant at feeders filled with red milo and most abundant at feeders filled with black-oil sunflower. The mean number of chickadees per 5-minute interval within a 45-minute session was 0.0, 0.0, 0.0, and 0.0 at red milo feeders in the spring, summer, autumn, and winter, respectively compared with 0.1, 0.1, 0.3, and 0.4 at black-oil sunflower feeders in the spring, summer, autumn, and winter, respectively.

Seed and Region Interaction

Sixteen of 23 species exhibited a significant seed × region interaction (Table 2). As expected, in the region where a species had a greater number of visits to feeders, seed types with the greatest use had more visits at the region where the species was more abundant. For example, the brown-headed cowbird had a greater abundance at feeders in the eastern region compared with the prairie region. It was most abundant at feeders filled with white proso millet and least abundant at feeders filled with whole peanuts. The species' abundance at whole peanut feeders in the prairie and eastern regions was 0.0 and 0.0, respectively, compared with 0.1 and 0.3 at white proso millet feeders in the prairie and eastern regions, respectively.

DISCUSSION

Combining the large number of food choices available to people who feed birds with the vast non-scientific literature on bird feeding has resulted in information that can include less preferred foods. Dunn and Tessaglia-Hymes (1999) listed 24 bird food types that were offered at ≥3% of sites participating in their study. Baicich et al. (2010) lists 10 of the top bird foods as black-oil sunflower, jellies, mealworms, nectar, Nyjer and finch mixes, peanuts and tree nuts, safflower, shelled corn, suet, and white proso millet and cracked corn.

We conclude that 3 of 10 seed types commonly used in seed mixes are most attractive to birds: black-oil sunflower, medium sunflower chips, and white proso millet. In contrast, no species had its greatest number of visits at red milo and only the common grackle had the greatest number of birds at cracked corn.

Seed preferences of wild birds may be a result of seed size (Willson 1972), bill size (Hespenheide 1966), the relationship between seed size and bill shape as it pertains to handling time (Hrabar and Perrin 2002), nutritional content of the food (Schaefer et al. 2003), and foraging behavior of the bird (Foster 2008). Java sparrows (*Padda oryzivora*) selected safflower seeds that were deeper in size (Van der Meij and Bout 2000), while mourning doves and Eurasian collared-doves (*Streptopelia decaocto*) selected corn that was shorter and thinner in size than average (Hayslette 2006). Mourning doves also preferred seeds with lower levels of cellulose–lignin and higher levels of nitrogen-free extract (Hayslette and Mirarchi 2001). Of the 10 seed types used in our study, black-oil sunflower and medium sunflower chips have high levels of fat (43% and 56%, respectively); whereas, white proso millet has lower amounts (4%), indicating that multiple factors are influencing seed visits (D. J. Horn and S. M. Johansen, unpublished data). For example, American goldfinch, house finch, and house sparrow preferred black-oil sunflower varieties 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 (Collins and Horn 2012).

Geis and Pomeroy (1993) found that bird abundance varied with feeder type. In our study, the 3 most abundant birds—American goldfinch, house finch, and house sparrow—were most abundant at tubular feeders over hopper feeders, even though they are able to use all feeder types. The fewer number of bird visits at hopper compared with tube and platform feeders may be a result of several factors. Hopper feeders may hinder the visibility of birds, making them more susceptible to predators; Lima (1985) found that birds are less likely to stay at feeders as predation risk increases. Observations of hopper feeders may also have been subject to more observer error, because participants may have had more difficulty counting birds at hopper feeders. The greater use by species at platform feeders was most likely a result of several larger bodied species being able to readily use platform feeders compared with hoppers and tubes.

Historically, the combination of food and feeder has not been considered when examining the relative attractiveness of supplemental food to birds. Horn (1999) found that increasing the number of bird food–feeder combinations would increase both the number of birds and species that visited a yard. We found that the pairing of a specific bird seed and feeder plays a significant role for all of the species that we examined. However, food was the more important factor influencing visits to bird feeders, and if the food is not attractive to birds, the food will not be used regardless of the feeder type in which it is presented.

Seasonal changes in bird abundance at feeders may be the result of changes in habitat use, shifts in diet, and seasonal food availability (McGraw and Middleton 2009). In

particular, many birds will feed on seasonally abundant insects during the spring and summer months and are less abundant at feeders. During the winter, small birds can have an increased metabolic rate (Dawson and O'Connor 1996, Linkes et al. 2002). Increasing energetic demands necessitate increased metabolic rates (Williams and Tieleman 2000), and demands could be met by birds through supplemental feeding in 2 ways: by consuming more of a preferred seed type or by switching to seed types with a higher fat content. We found little evidence that birds changed their seed use in different seasons. Instead, birds were more abundant at the most used seeds during seasons where they had the greatest abundance at feeders. Similarly, we found limited evidence that birds changed their seed use in different geographic regions.

Because the study was designed to examine the average bird-feeding experience across years, seasons, and geographic regions, there are necessarily many uncontrolled variables. For example, several studies have found that differences in region within a state influence the abundance of particular bird species at feeders (Brittingham and Temple 1989, Horn et al. 2002). In addition, participants in our study had different landscapes with varying vegetation features within their yards and the composition of bird species in any given yard was likely to vary, possibly leading to differences in conspecific interactions. A study in which each participant monitored 10 feeders filled with each of the 10 seed types simultaneously would have allowed for a better test of preferences, but would not be practical to conduct. These and other factors may have increased variability in our data. However, it is highly unlikely that any of these factors would have resulted in a systematic bias in the 20,077 45-minute monitoring sessions conducted by our citizen scientists that would favor a particular seed or feeder type and therefore limit our ability to discern use patterns using a mixed-model analysis.

We recommend that wildlife managers consider citizen science as a potential research approach when appropriate. The use of the general public to conduct research, however, is not without challenges. In particular, substantive time may be spent in logistics (e.g., recruiting individuals, developing easily understood protocols, ensuring protocols are followed correctly, validating data, see Bonney et al. 2009, Bonter and Hochachka 2009, Silvertown 2009). Moreover, the skill sets necessary to run effective citizen scientist projects, such as the development of a technological infrastructure for data management and analysis, may be different from those taught in wildlife management programs (see Bonney et al. 2009, Dickinson et al. 2010). However, the multiple benefits of citizen science, including the engagement of non-professionals in the scientific process and the acquisition of large, publishable data sets, provide an opportunity to extend the field of wildlife management (e.g., Brossard et al. 2005, Bonter and Hochachka 2009, Dickinson et al. 2010). In our case, we could not conduct a 3-year, United States and Canada-wide study of seed and feeder use by wild birds without the assistance of citizen scientists.

MANAGEMENT IMPLICATIONS

By knowing how bird visits are influenced by seed type, feeder type, season, region, and their interactions, we are able to establish scientifically based recommendations for attracting birds through bird feeding. These recommendations are important to establish because current suggestions found in books, magazines, newspaper articles, and websites can lack an empirical basis, leading to large lists of suggested foods that combine foods that are readily consumed with those we found to be avoided. Consumers should select, and retail outlets should supply, individual seeds or seed blends with large proportions of black-oil sunflower and medium sunflower chips. Although the number of bird visits at white proso millet is large, 2 bird species with documented negative ecological consequences, brown-headed cowbird and house sparrow (Lowther 1993, Lowther and Cink 2006), were most abundant at white proso millet. Thus, in areas containing species that may be adversely affected by the presence of brown-headed cowbird and house sparrow, use of white proso millet should be reduced. In the future, tests of bird use at alternative foods such as suet and seed blocks should be performed.

ACKNOWLEDGMENTS

We gratefully acknowledge the dedicated wild-bird feeding enthusiasts throughout the United States and Canada who participated in the study. Funding for this study was provided by the WBFI (Wild Bird Feeding Industry) and its member companies, grants from Kaytee Avian Foundation and National Sunflower Association, as well as individuals who financially supported the WBFI Research Foundation through cash and in-kind contributions. J. D. Brawn, S. M. Hays, G. H. Petrides, Sr., P. Stangel, and J. C. Robinson reviewed previous versions of this manuscript prior to submission.

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Associate Editor: Boal.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

Appendix 1. The states and provinces within 6 geographic regions used to study seed and feeder use by birds in the United States and Canada, winter 2005-autumn 2008.