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BIAS IN CHRISTMAS BIRD COUNTS FOR SPECIES THAT VISIT FEEDERS

ERICA H. DUNN[1]

ABSTRACT.—In 1990 and 1991, compilers for 137 Christmas Bird Count (CBC) sites recorded observations of home-based "feeder-watchers" separately from CBC totals. In 29 of 49 species, there were significant positive relationships between the proportion of CBC totals seen by feeder-watchers and an index of feeder-watching effort (feeder-h/party-h). The effect on CBC totals is usually small but can be substantial in some species at high levels of feeder-watching effort, inflating CBC totals to over 67% more than would be the case with no feeder-watching. In addition, 73% of species had higher proportions of CBC totals recorded at feeders at high latitudes (feeder-watching effort held constant). Large changes in feeder-watching effort over time could produce spurious trends in population indices, particularly in northern areas. Suggestions are given for exclusion or correction of CBC data with high feeder-watching effort, but the best long-term solution is to record birds seen by feeder-watchers separately from those reported by field parties in all CBC publications and data bases. *Received 24 Jan. 1994, accepted 22 Aug. 1994.*

Many Christmas Bird Counts (CBC's) have participants who stay at home to observe feeders over prolonged periods. In 1975, CBC data bases began to record the number of these "feeder-watchers" and their hours of effort, but the birds seen by them continue to be incorporated in CBC totals.

A study conducted in Ithaca, New York, indicated that feeder-watching effort could potentially introduce a bias in CBC's. Participants recorded the number of each species seen at feeders, whether by field parties passing them briefly or by feeder-watchers. Results showed that, in some species, feeder-watchers saw as many as seven times more birds per feeder observed than did field parties (Butcher and Dunn, Kingbird, in press). If feeder-watching effort is relatively low, and/or field parties see large numbers of feeder-visiting species away from feeders, the effects of feeder-watching on CBC totals is probably small. In other cases, however, increased feeder-watching effort could potentially inflate CBC totals even though population levels actually remain stable.

Feeder-watching effort may vary geographically, with northern regions likely having a higher proportion of feeder-watching effort relative to field effort. Simultaneously, a greater proportion of local wintering populations may visit feeders regularly in harsher than in warmer climates. Thus, any biases introduced in CBC totals by inclusion of feeder observations might be greater in northern regions than elsewhere.

This paper examines temporal and geographic patterns in feeder-watch-

[1] Canadian Wildlife Service, National Wildlife Research Centre, Hull, Quebec K1A 0H3.

ing effort, and the magnitude of its effects on CBC totals. It also determines whether more birds are seen by feeder-watchers in northern areas even when observation effort is held constant.

METHODS

Data were extracted from *American Birds* for a sample of CBC's done in 1978 and 1991 to determine whether feeder-watching effort changed between those two years. Feeder effort (feeder-h/party-h) was recorded for all sites in three regions (defined in Table 1) which were pre-selected to give approximately equal sample sizes and to represent geographic areas with wide north-south and east-west distribution. One count with over 500 feeder-h was excluded, because that effort was known to have resulted from an active educational outreach program that might have overwhelmed results from other count sites.

To determine the proportion of CBC totals recorded by feeder-watching, all CBC compilers were asked by the National Audubon Society (starting in 1990) to report on a voluntary basis the numbers of each species seen by feeder-watchers. Data from 1990 and 1991 were analyzed for this paper. If a count compiler submitted data in both years, only the first was included for analysis. For each of the 137 remaining locations, data were extracted from *American Birds* for all 89 species known to visit 15% or more of feeders within their winter range (unpubl. data from Project FeederWatch, a continent-wide cooperative survey of bird feeders run by the Cornell Laboratory of Ornithology and the Long Point Bird Observatory). Some of these species were later dropped from analysis because they were reported on fewer than 10 counts in the study sample.

For each species in each count, the proportion of the "reported total" (number published in *American Birds*) that was seen at feeders by home-based observers was calculated and transformed for use in analyses (square root of arcsin transformation, after appropriate adjustment for proportions of 0 and 1; Snedecor and Cochran, Statistical Methods, Sixth Edition. Iowa State Univ. Press, 1967:327–328). The transformed value was the dependent variable in stepwise multiple regression with the following independent variables: index of feeder-watching effort (feeder-h/party-h), latitude, longitude, and second- and third-order terms for each of these three variables to allow for curvilinear fits. To avoid distortion caused by small samples and to limit results to common species within the main part of their winter range all counts with fewer than 10 individuals of a species in the reported totals were excluded from analysis.

To the extent that feeder-watching effort and latitude or longitude are correlated in the compiler-contributed sample, the regression analysis described above may confuse their effects on proportion of CBC totals recorded at feeders. A stepwise regression of feeder-watching effort on latitude, longitude, and their second- and third-order terms did show a significant relationship with latitude^2; but r^2 was only 0.09. Thus, any confounding of latitudinal effects with distribution of feeder-watching effort should be low. Another approach to this potential problem was to force effort variables into the regressions described in the previous paragraph, before allowing stepwise entry of latitude and longitude. This was tried and gave results similar to those presented here, but fewer species could be analyzed because of sample size constraints.

Results of the regressions were used to calculate the expected proportion of CBC totals that would be seen at feeders with various levels of feeder-watching effort, at 40°N, 90°W (an arbitrarily chosen point in Illinois). In addition, proportions at feeders were calculated for latitudes 45°N and 35°N (with longitude held at 90°W), and at longitudes 80°W and 100°W (with latitude held at 40°N), in both cases with feeder-watching effort set at 0.25 feeder-h/party-h.

TABLE 1

MEDIAN (AND MEAN) CHRISTMAS BIRD COUNT EFFORT BY HOME-BASED FEEDER-WATCHERS, OVER TIME AND BY LATITUDE[a]

Region[b]	1978		1991
North	0.00 (0.15)	**	0.08 (0.29)
	NS		NS
Central	0.06 (0.15)	NS	0.09 (0.16)
	+		***
South	0.00 (0.07)	NS	0.00 (0.06)
All areas	0.01 (0.13)	NS	0.04 (0.17)

[a] Effort measured as feeder-h/party-h. Count was included only if it was done both in 1978 and 1991 and if N feeder-h <500 (see methods). Symbols indicate significance of Kruskal-Wallis test between medians to either side of the symbol: NS = $P > 0.05$, + = $0.005 < P < 0.10$, ** = $P < 0.01$, *** = $P < 0.001$.

[b] Regions and sample size: North = British Columbia, Alberta and Ontario (N = 62 CBC's), Central = Oregon and Pennsylvania (61), South = California south of 37°, North and South Carolina and Georgia (61).

RESULTS

Feeder-watching effort increased between 1978 and 1991 in northern areas and tended to be higher in the north as well (Table 1). Nonetheless, the majority of counts had relatively low levels of effort. The means in Table 1 are much higher than the medians because of highly skewed distribution of effort (solid line, Fig. 1). Five percent of the counts in 1991 had effort indices >1.0. The sample contributed by compilers was biased towards counts with high levels of effort (dashed line, Fig. 1).

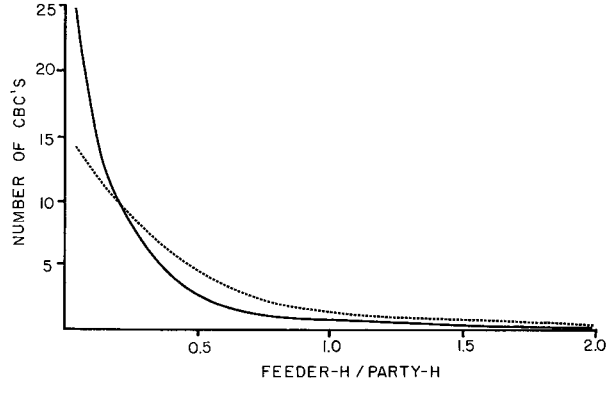

FIG. 1. Frequency distribution of Christmas Bird Counts according to effort expended on watching feeders. Solid line fit by eye to 1991 data from complete sample of feeders from defined areas (Table 1, N = 183); dashed line shows 1990–1991 data contributed to this study by count compilers (N = 137).

Median effort in the latter sample was 0.28 feeder-h/party-h, and 12% of cases had effort indices >1.0.

Analysis of the sample of CBC's contributed by compilers showed that the proportion of CBC totals seen at feeders depended significantly on feeder-watching effort in 29 (59%) of the 49 species analyzed (Table 2). The distorting effects of high feeder-watching effort on CBC totals can be substantial (Fig. 2). At an effort level of 0.1 party-h/feeder-h, only one species was predicted to have its CBC totals inflated by 10% or more above what they would have been without any feeder-watching effort. When feeder-watching effort rose to 0.25 feeder-h/party-h, however, 17% of species totals were inflated by >10%, and the number of affected species increased dramatically at still higher levels of feeder-watching effort (Fig. 2).

In 73% of species, higher proportions of CBC totals were seen at feeders at high latitudes (feeder-watching effort held constant). To illustrate the magnitude of this effect, the proportion of CBC totals seen at feeders that was expected at 45°N was divided by the expected proportion at 35°N (Fig. 3).

Longitude affected the proportion at feeders in fewer species (31%). A higher proportion of CBC totals was found at feeders in western areas in Downy Woodpecker, Black-capped Chickadee, Red-breasted Nuthatch, Common Raven, Eastern Bluebird, American Robin, Northern Mockingbird, House Sparrow, Cedar Waxwing, European Starling, Song Sparrow, White-crowned Sparrow and Common Grackle (scientific names in Table 2). Higher proportions were found in eastern areas in American Crow and Bohemian Waxwing.

DISCUSSION

Christmas Bird Count totals can be substantially inflated by high levels of feeder-watching relative to field party effort. Thus, if feeder-watching effort changes markedly over a period of years, spurious population trends could be produced.

These results have to be considered in the context of what is "normal." Over a broad geographic area, median feeder-watching effort was only 0.04 feeder-h/party-h in 1991 (Table 1). The maximum change in median values between 1978 and 1991 was in northern areas (from 0 to 0.08 feeder-h/party-h). These values were used to estimate the resultant degree of inflation expected in field party totals at an arbitrary latitude and longitude (see methods for calculation). CBC totals were predicted to rise by 1% in nine species (Hairy Woodpecker, Blue Jay, Black-capped and Carolina chickadees, Carolina Wren, Northern Cardinal, Dark-eyed Junco, House Sparrow and Pine Siskin), by 2% in two species (Downy Wood-

TABLE 2

SPECIES WITH EFFECTS OF FEEDER-WATCHING EFFORT ON CBC TOTALS[a]

Species (and 4-letter code)	Correction formula[b]
Ring-necked Pheasant (RNPH) (*Phasianus colchicus*)	$0.26E$
Rock Dove (RODO) (*Columba livia*)	$0.02E^3 + 0.19LAT$
Mourning Dove (MODO) (*Zenaida macroura*)	$0.28E + 2.96LAT^3$
Red-bellied Woodpecker (RBWO) (*Melanerpes carolinus*)	$0.29E + 3.23LAT^3$
Northern Flicker (NOFL) (*Colaptes auratus*)	$0.18E + 0.33LAT$
Downy Woodpecker (DOWO) (*Picoides pubescens*)	$0.82E - 0.54E^2 + 0.12E^3 + 1.72LAT^2 - 0.17LONG^2$
Hairy Woodpecker (HAWO) (*P. villosus*)	$0.37E - 0.04E^3 + 3.45LAT^3$
Blue Jay (BLJA) (*Cyanocitta cristata*)	$0.41E - 0.04E^3 + 1.12LAT^2$
American Crow (AMCR) (*Corvus brachyrhynchos*)	$0.11E + 0.65LAT^3 + 0.07LONG^3$
Common Raven (CORA) (*C. corax*)	$0.01E^3 + 0.10LONG$
Tufted titmouse (TUTI) (*Parus bicolor*)	$0.37E + 0.64LAT$
Black-capped Chickadee (BCCH) (*P. atricapillus*)	$0.17E + 1.88LAT^2 - 0.12LONG^3$
Carolina Chickadee (CACH) (*P. carolinensis*)	$0.66E + 0.27LAT$
White-breasted Nuthatch (WBNU) (*Sitta carolinensis*)	$1.13E - 0.93E^2 + 0.23E^3 + 0.88LAT^2$
Carolina Wren (CAWR) (*Thryothorus ludovicianus*)	$0.27E + 3.08LAT^3$
European Starling (EUST) (*Sturnus vulgaris*)	$0.12E + 0.07LONG$
Northern Cardinal (NOCA) (*Cardinalis cardinalis*)	$0.32E + 3.16LAT^3$
Song Sparrow (SOSP) (*Melospiza melodia*)	$0.10E^3 + 3.35LAT^3 - 0.10LONG^2$
American Tree Sparrow (ATSP) (*Spizella arborea*)	$0.03E^3 + 2.05LAT^3$
Field Sparrow (FISP) (*S. pusilla*)	$0.06E^2 + 0.19LAT$
Dark-eyed Junco (DEJU) (*Junco hyemalis*)	$0.26E + 1.27LAT^2$
Brewer's Blackbird (BRBL) (*Euphagus cyanocephalus*)	$0.11E^2 + 0.11LAT$
House Sparrow (HOSP) (*Passer domesticus*)	$0.45E - 0.13E^2 + 0.17LONG$

TABLE 2
CONTINUED

Species (and 4-letter code)	Correction formula[b]
Pine Siskin (PISI) (*Carduelis pinus*)	$0.21E + 0.40LAT$
American Goldfinch (AMGO) (*C. tristis*)	$1.12E - 0.88E^2 + 0.21E^3 + 0.88LAT^2$
Common Redpoll (CORE) (*C. flammea*)	$0.14E^2 + 0.25LAT$
Pine Grosbeak (PIGR) (*Pinicola enucleator*)	$0.25E$
Purple Finch (PUFI) (*Carpodacus purpureus*)	$0.43E + 0.73LAT$
House Finch (HOFI) (*C. mexicanus*)	$0.73E - 0.35E^2 + 1.47LAT^2$

[a] Species analyzed but with no effects of feeder-watching effort: Pileated Woodpecker (PIWO), (*Dryocopus pileatus*); Scrub Jay (SCJA), (*Aphelocoma coerulescens*); Black-billed Magpie (BBMA), (*Pica pica*); Brown Creeper (BRCR), (*Certhia americana*); Red-breasted Nuthatch (RBNU), (*S. canadensis*); Ruby-crowned Kinglet (RCKI), (*Regulus calendula*); Eastern Bluebird (EABL), (*Siala sialis*); American Robin (AMRO), (*Turdus migratorius*); Northern Mockingbird (NOMO), (*Mimus polyglottos*); Bohemian Waxwing (BOWA), (*Bombycilla garrulus*); Cedar Waxwing (CEWA), (*B. cedrorum*); Yellow-rumped Warbler (YRWA), (*Dendroica coronata*); Rufous-sided Towhee (RSTO), (*Pipilo erythrophthalmus*); White-throated Sparrow (WTSP), (*Zonotrichia albicollis*); White-crowned Sparrow (WCSP), (*Z. leucophrys*); Eastern Meadowlark (EAME), (*Sturnella magna*); Red-winged Blackbird (RWBL), (*Agelaius phoeniceus*); Brown-headed Cowbird (BHCO), (*Molothrus ater*); Common Grackle (COGR), (*Quiscalus quiscula*); Evening Grosbeak (EVGR), (*Coccothraustes vespertinus*).

[b] To get the expected proportion of CBC reported totals seen by feeder-watchers (in CBC's with >10 individuals in the reported totals), square the sin of the value produced by the formula. E = feeder-h/party-h, LAT = latitude/100 and LONG = longitude/100 (where minutes are converted to tenths of degrees).

pecker and Purple Finch), and by 3% in three species (White-breasted Nuthatch, American Goldfinch, and House Finch).

Over a long period of years, inflation of CBC totals of this magnitude should have little effect on detection of important population trends. However, when the mean (instead of median) values for feeder-watching effort in northern areas (Table 1) were used in similar calculations, predicted inflation of CBC totals was as high as 5–7% in some species (Downy Woodpecker, White-breasted Nuthatch, American Goldfinch, and House Finch).

Clearly there is potential for strong bias in CBC reported totals for feeder species when feeder-watching effort is high. The simplest solution to ensuring that changing levels of feeder-watching do not contribute spuriously to population trends is to exclude from trend analysis any count that includes feeder-watchers. In certain analyses, however (e.g., those limited to northern states or provinces, or to species whose wintering range is primarily in northern areas), excluding counts with high feeder-watching effort may leave sample sizes too small for analysis. In

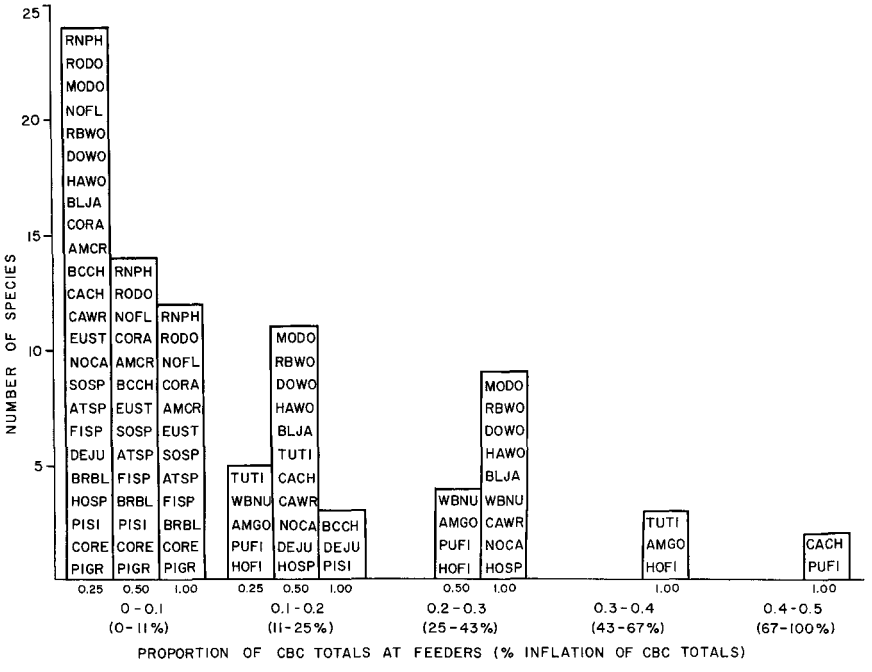

FIG. 2. Predicted proportion of CBC totals recorded at feeders at various levels of feeder-watching effort (feeder-h/party-h shown in small number under each bar). Numbers in parentheses indicate percent by which CBC totals are inflated over expected field totals. See Table 2 for key to four-letter species codes.

such cases, inclusion of counts with feeder-watching effort up to 0.05 or 0.10 feeder-h/party-h should limit inflation to modest levels (Fig. 2). Some counts with higher effort levels might also be included, if feeder-watching effort is more-or-less constant over the time period being investigated.

A limit of 0.1 feeder-h/party-h would still allow analysis to include 64% of the CBC's in the sample extracted from *American Birds* (Table 1) but only 22% of the compiler-contributed sample. In some cases, then, sample size is likely to be an issue, and the investigator will want to include CBC's with higher feeder-watching effort. Estimates of field-party totals alone could be derived from the regression results of this paper (Table 2). This is not recommended as a routine procedure, however, as application of these correction factors to years past is not entirely appropriate. Higher proportions of birds visit feeders in certain areas regardless of feeder-watching effort (e.g., Fig. 3), and the correc-

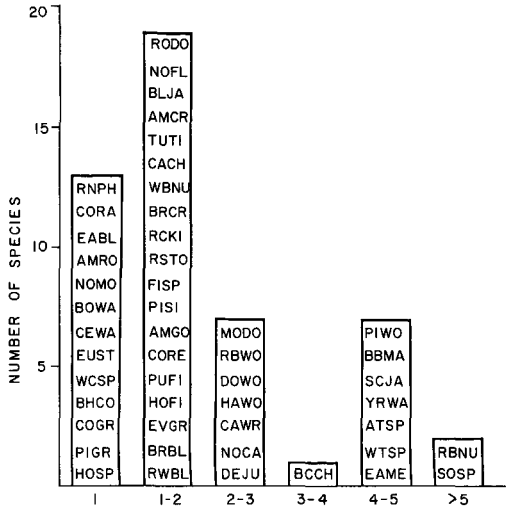

FIG. 3. Effect of latitude on proportion of CBC totals recorded at feeders when feeder-watching effort is held constant. X-axis shows number of times higher this proportion is at 45°N than at 35°N (see text). See Table 2 for key to four-letter species codes.

tion formulae are derived from 1990–1991 data that may have quite different geographic distribution of effort than in the past (see Table 1).

The most effective long-term solution to the problem of bias in CBC's due to inclusion of feeder counts is for observations of home-based participants to be kept separate from those of field parties in all CBC publications and data bases (Butcher and Dunn, in press). This would circumvent any pitfalls associated with the analysis solutions suggested here. An added benefit would be the documentation of any geographic, temporal, or weather-related patterns in numbers of birds visiting feeders compared to their numbers "in the wild."

There probably is another bias remaining in CBC's for feeder species, even after removal of the effects of home-based feeder-watching. Birds visiting feeders may be more visible to field parties than birds elsewhere, and the booming post-war hobby of bird-feeding could have led to increased "countability" of feeder species in the field (Butcher and Dunn, in press). The problem is likely to be most severe in northern areas, based on evidence that higher proportions of wintering populations visit feeders at high latitudes (Fig. 3). The magnitude of this problem is unknown, however, and can be handled only through caution in interpretation of population trends for feeder species that are derived from CBC data, even when home-based observations have been accounted for.

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