The Condor 104:255–270

DO FEEDER COUNTS RELIABLY INDICATE BIRD POPULATION CHANGES? 21 YEARS OF WINTER BIRD COUNTS IN ONTARIO, CANADA

DENIS LEPAGE[1] AND CHARLES M. FRANCIS
Bird Studies Canada, P.O. Box 160, Port Rowan, ON N0E 1M0, Canada

Abstract. Few monitoring programs in North America track bird populations at a continental scale during the winter, a critical stage of the life cycle for many species. To date, only Christmas Bird Counts (CBC) have been used to index bird abundance in winter across North America. We evaluated another continentwide program, Project FeederWatch (PFW), which monitors many bird species more intensively than CBC. PFW is a survey in which volunteers use standardized methods to count birds visiting feeders every two weeks from November through April. We compared population indices and trends from PFW and CBC data for 43 species in 3 regions of Ontario, Canada, over a 21-year period from 1976–1997. Annual population indices from PFW were significantly positively correlated with similar indices from CBC for about 80% of species for which annual variation in counts was substantially greater than sampling error. Log-linear population trends from both surveys were also well correlated, though the absolute value of the trend estimates tended to be higher for PFW. The high consistency between surveys suggests that both may be suitable for detecting population changes for many bird species in winter, especially irruptive species that show large annual fluctuations, and species with marked population trends. However, some species did not correspond between surveys, despite being measured fairly precisely, highlighting the value of having two independent surveys to corroborate patterns. Christmas Bird Counts have the advantage that they sample more species, but Project FeederWatch has a more consistent protocol and continues through the winter, allowing analysis of changes in populations through the winter.

Key words: *bird surveys, Christmas Bird Count, irruptive species, monitoring, population trends, Project FeederWatch.*

¿Proveen los Conteos en Comederos Información Fidedigna sobre Cambios en las Poblaciones de Aves? 21 Años de Conteos Invernales de Aves en Ontario, Canadá

Resumen. Pocos programas de monitoreo en América del Norte siguen a las poblaciones de aves a escala continental durante el invierno, cuando muchas especies pasan por una etapa crítica en su ciclo de vida. Hasta el presente, sólo los Conteos de Aves de Navidad (CAN) han sido usados para cuantificar la abundancia de aves en el invierno a lo largo de América del Norte. Nosotros evaluamos otro programa a nivel continental, el Proyecto de Observación de Comederos (POC), el cual sigue muchas especies de aves de modo más intenso que los CAN. El POC es un programa de muestreo en el cual voluntarios usan métodos estandarizados para contar las aves que visitan comederos, censándolas cada dos semanas entre noviembre y abril. Comparamos índices y tendencias poblacionales de los datos del POC y de los CAN para 43 especies en 3 regiones de Ontario, Canadá, a lo largo de un período de 21 años entre 1976 y 1997. Los índices poblacionales anuales del POC estuvieron positiva y significativamente correlacionados con índices similares de los CAN para alrededor del 80% de las especies, considerando aquellas para las que la variación anual en los conteos fue sustancialmente mayor que el error de muestreo. Las tendencias poblacionales de ambos muestreos, representadas de modo log-lineal, también estuvieron bien correlacionadas, aunque el valor absoluto de la tendencia estimada tendió a ser mayor para el POC. La alta consistencia entre los programas de muestreo sugiere que ambos pueden ser adecuados para detectar los cambios poblacionales de muchas especies de aves durante el invierno, especialmente para especies eruptivas que muestran grandes fluctuaciones anuales, y para aquellas con tendencias poblacionales marcadas. Sin embargo, algunas especies mostraron diferencias entre los programas de muestreo a pesar de haber sido medidas de modo bastante preciso, destacando el valor de tener dos métodos de muestreo independientes para corroborar los patrones. Los Conteos de Aves de Navidad tienen la ventaja de que

Manuscript received 1 April 2001; accepted 17 January 2002.
[1] E-mail: dlepage@bsc-eoc.org

muestrean más especies, pero el Proyecto de Observación de Comederos posee un protocolo más consistente y se prolonga a través del invierno, permitiendo analizar los cambios de las poblaciones a través de este período.

INTRODUCTION

Monitoring of bird populations in winter is important for conservation and management of North American bird populations in several ways. For some species that breed mainly in the far north, where they are not readily monitored, winter surveys may be the best way to monitor population status (Dunn and Sauer 1997). For other species, comparison of counts in winter with counts on the breeding grounds could provide information on annual variation in productivity or seasonal mortality. Monitoring programs that continue throughout the winter and are carried out on a continental scale could be particularly valuable for providing information on seasonal timing of mortality or movements over the winter season (Hochachka et al. 1999). An integrated monitoring program should provide information not only on changes in population numbers, but the potential underlying causes of those changes, through evaluating all components of the life cycle.

In North America, winter monitoring programs have received little attention compared to monitoring programs during the breeding season. The latter include several programs providing annual population indices, of which the most widespread is the Breeding Bird Survey (BBS; Robbins et al. 1986), as well as a few programs monitoring demographic parameters, including BBIRD which monitors nesting success (Martin et al. 1997), and the Monitoring Avian Productivity and Survival program (MAPS, DeSante et al. 1996), which monitors annual survival and fledgling production. Apart from the Winter Bird Population Study, which only monitors a limited number of sites per year (Engstrom 1989), only two continental winter-monitoring programs for landbirds currently exist in North America: Christmas Bird Counts (CBC) and Project FeederWatch (PFW).

The CBC has been run every year since 1900, with a steady increase in the number and distribution of counts throughout the century (Root 1988a, LeBaron 1997). Parties of observers count birds in as much as possible of the suitable habitat within a 24.5-km (15-mile) diameter circle during a single pre-selected date in late December or early January. The number of distinct individuals of each species that were detected is estimated by the count coordinator at the end of the census day (Arbib 1967). During 1996–1997, 1650 counts were reported throughout North America (LeBaron 1997).

Project FeederWatch (PFW) is a survey in which volunteers across North America record the maximum number of each bird species visiting their feeders over a 2-day period every 2 weeks throughout the winter season. The project was initiated in Ontario, Canada, by Long Point Bird Observatory (now called Bird Studies Canada) during the winter of 1976–1977, under the name Ontario Bird Feeder Survey (OBFS; Dunn 1986). The survey was expanded across North America, as Project FeederWatch, during winter 1987–1988, under a joint initiative of Bird Studies Canada and the Cornell Laboratory of Ornithology. During 1996–1997 PFW participants submitted data for 6309 feeders across the continent (Tessaglia 1997).

In spite of the potential for both surveys to be used as monitoring and research tools, there is still need to evaluate the utility of data collected. Ideally, the merits of these surveys would be evaluated by comparing the counts with actual population sizes, but these are, of course, unknown. An alternative approach is to compare annual population indices derived from the two different surveys. Positive correlations between annual indices from each survey would provide evidence that both surveys track fluctuations in the underlying populations. Previous analyses of these programs (Dunn 1986, Wells et al. 1996, 1998), have reported mixed results, with indices matching for some species but not others. However, all of those studies were based upon relatively short time series (7 years), and could not evaluate whether lack of correlation was due to insufficient data, lack of variation in the underlying populations, or inadequacies in one or the other monitoring program.

With data now available from Ontario for OBFS/PFW since 1976, it is possible to examine in more detail, and with more power, the potential of PFW to monitor changes in wintering populations of feeder birds over time. In this paper, we compare annual indices of wintering bird

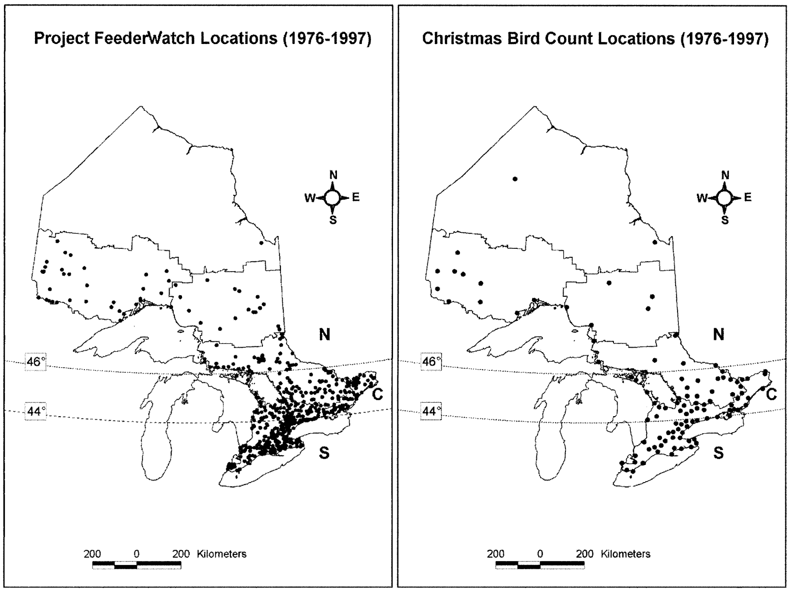

FIGURE 1. Distribution of Project FeederWatch participants and Christmas Bird Count circles from the winters of 1976–1977 through 1996–1997. Northern Ontario (N) is north of 46°N, central Ontario (C) is between 44°N and 46°N, and southern Ontario (S) is south of 44°N.

populations in Ontario based on PFW data, with those derived from CBC data over a 21-year period, from the winters of 1976–1977 to 1996–1997. We also estimate the proportion of total variation in the indices from each count that was not due to sampling error, to determine the amount of agreement that might be expected if both surveys provide reliable population indices. Finally, we compare linear population trends derived from the two surveys.

METHODS

The protocol for data collection with PFW has remained basically the same since its inception in 1976. Volunteer participants count all species of birds visiting feeders in their yards over two consecutive days every two weeks from November through early April. Participants are asked to select their days ahead of time to avoid bias through selecting days based upon the numbers of birds seen. During each 2-day count, participants record the maximum number of birds of each species visible simultaneously in the count area that have been attracted to food provided by participants. OBFS data were unavailable for one season (1986–1987), so that year is not included in the current analyses.

Data from Christmas Bird Counts have been computerized and made publicly available through the World Wide Web (Shipman 1998). The computerized database includes basic information about the count circle (name and geographic location), some information about the participants' effort (total number of party-hours, and distance traveled in various categories), and numbers of all bird species and recognizable forms reported. We supplemented the database with number of hours participants spent watching feeders at each count (feeder-hours) using information published in American Birds or Audubon Field Notes. We used data from all CBCs that took place entirely or partly within the province of Ontario, including a few centered in the adjacent states of Ohio, Michigan, and New York, or in the province of Quebec.

Because bird population densities for many species vary geographically within Ontario, and because levels of coverage by CBC and PFW also vary, we estimated population indices and made our comparisons separately for 3 geographical regions (Fig. 1): southern Ontario (south of 44°N), central Ontario (from 44°N to 46°N), and northern Ontario (north of 46°N; no participant was situated north of 51°15′N).

These divisions roughly correspond to the deciduous forest, the mixed deciduous and coniferous forest, and the boreal forest zones (Chapman and Sherman 1975). They are also roughly associated with isoclines of average winter temperature, which may be an important determinant of bird distributions in winter (Root 1988b).

Project FeederWatch annual indices. For the OBFS and PFW data (hereafter referred to simply as PFW), we calculated for each species the maximum number of birds reported at each PFW location across all of the 2-week periods that were surveyed by the observer (usually all 10) during each year. Following Link and Sauer (1997, 1998), we then assumed that the population of each species in each region could be modeled with a generalized linear model using location and year as discrete independent variables. Including location in the model is important to control for any potential shifts in the geographic distribution of participants which could otherwise bias indices. However, because of changes in the registration system during the project, it was not possible to track individual count sites across all years. We thus used the first three digits of the postal codes as the location, and treated different feeders within a postal code as replicates for each location. In urban areas, Canadian postal codes generally determine the nearest street, while in rural areas they generally indicate the nearest town with a post office.

Bird count data are often log transformed (after adding a constant to avoid problems with zero counts) and then analyzed using models that assume normally distributed residuals. However, Link and Sauer (1994, 1997) showed that this approach is statistically invalid, and can lead to substantial bias in trend estimates. Instead, they suggested that models based on Poisson residuals were more appropriate. We followed their approach, fitting each model using Poisson regression with a log-link function (PROC GENMOD, SAS Institute Inc. 1998). To control for overdispersion of the response variable (the variance of count data tends to be greater than assumed in a Poisson model and often differs among locations) we used the method of iterative reweighting developed by Link and Sauer (1997), as implemented with a SAS program developed by G. W. Pendleton and J. Sauer (pers. comm.). This is important to obtain reliable standard errors. Because the log-link function provides estimates on a log scale, we back-transformed the annual indices to the original scale for presentation.

We did not attempt to control for observer effort with PFW data because effort data were not available prior to 1988 and, in any case, we had no reason to suspect much annual variation or long-term trends in the average number of hours spent watching feeders by individual observers.

Christmas Bird Count annual indices. For CBC data, we again used generalized linear models for each species and region, using location (each CBC circle was treated as a distinct location) and year as discrete independent variables. As with the PFW analyses, we used Poisson regression with iterative reweighting of individual counts to fit the equation for each species and region, and back-transformed the annual estimates to the original scale.

Average effort per count (number of observers and number of hours) has increased over time throughout North America (Butcher and McCulloch 1990). In Ontario, during the study period, average number of party-hours per count increased only slightly (about 10%), but the average hours by observers only watching feeders increased significantly in all three regions, especially in northern Ontario where party-hours at feeders exceeded those in the field in recent years (Fig. 2). The proportion of total observation-hours contributed by people only watching feeders went from about 8% to 24% in central Ontario and from about 35% to 62% in northern Ontario, with an average annual increase of about 1% in both regions. Because increasing effort is likely to produce higher counts (Butcher and McCulloch 1990), it was necessary to take effort into account in the analyses. Many past analyses have corrected for effort by dividing the count by number of party-hours (e.g., Bock and Root 1981, Butcher et al. 1990, Dunn and Sauer 1997), but this implicitly assumes that the relationship between effort and count is linear with a zero intercept (i.e., doubling the effort will double the number of birds counted). In fact, the relationship varies among species, and is not usually linear (Butcher and McCulloch 1990, Link and Sauer 1999). As a result, dividing by party-hours, if there has been a substantial change in effort, could result in more bias than if effort were ignored. Also, this approach cannot cope with multiple measures of effort

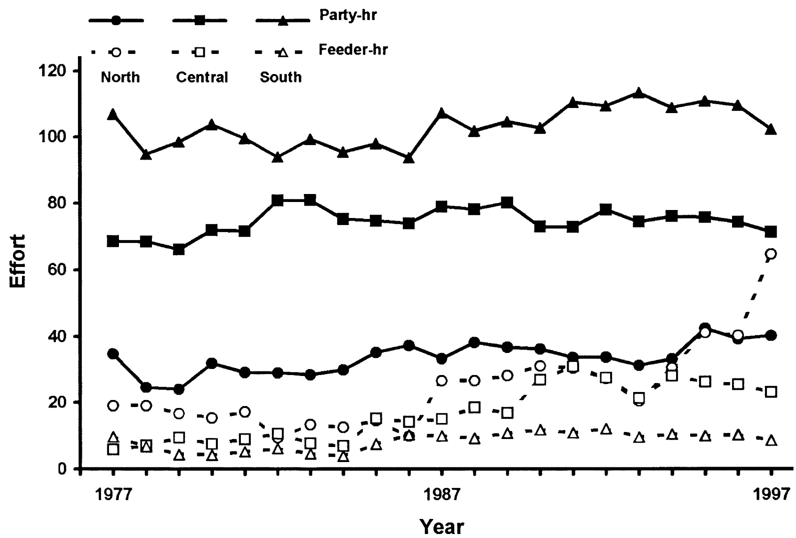

FIGURE 2. Changes in mean party-hours in the field (party-hours) and by people only watching feeders (feeder-hours) per Christmas Bird Count from the winters of 1976–1977 through 1996–1997 for counts in each of the three regions of Ontario defined in Figure 1. The average proportion of total observation-hours contributed by people only watching feeders was 7% in southern, 18% in central, and 42% in northern Ontario, and this proportion tended to increase over the period considered, especially in northern and central Ontario.

(e.g., party-hours in the field and party-hours at feeders). Butcher and McCulloch (1990) suggested using a nonlinear model to determine the relationships with effort for each species, and then using that model to calculate an adjusted count. However, their approach did not consider possible correlations between effort and the true abundance of each species (for example, effort is often higher near urban areas where many birders live, while densities of many birds may be higher in more remote areas, leading to a negative correlation). Instead, we followed the approach of Link and Sauer (1999), treating measures of effort (party-hours and feeder-hours) as covariates in a generalized linear model that also includes terms to allow for different baseline bird counts in each CBC circle (see Appendix 1 for details).

Annual variation in population size. If the true population levels of a species have not varied much from year to year, relative to sampling variation, then little or no correlation would be expected between indices from PFW and CBC, even if both surveys were able to provide reliable indices to the species' population. On the other hand, if annual variation in the species' population is large relative to sampling variation, then lack of correlation between PFW and CBC indices would imply that one or both surveys do not provide reliable indices, or that they are sampling different segments of the population. Thus, to evaluate observed correlations between counts, it is important to estimate the proportion of observed variation in annual indices that is due to variation in the underlying population, as opposed to sampling error (Link and Nichols 1994). This is done by calculating the total variance of the estimates (s^2), estimating the variance due to sampling error, based on the standard errors and sampling covariances of the estimates, and then subtracting this from s^2 to estimate the true population variance (τ^2; see Appendix 2 for details). Thus, the estimated proportion of variation in the indices that reflects real population variation is given by τ^2/s^2. Because these measures were all calculated on a log scale, the value of τ^2 can be interpreted as an index of the total variability in the wintering populations of each species (Link and Nichols 1994).

Population trends. We estimated average population trends over the study period, again using Poisson regression with iterative reweighting, but with year treated as a continuous variable. The slope of the trend (β') was back-transformed to the linear scale and converted to a percentage change per year using $\beta = 100 \times (e^{\beta'} - 1)$.

PFW versus CBC comparisons. To determine how well both surveys track annual fluctuations in populations, we calculated Spearman rank correlations between annual indices derived from PFW and those derived from CBC. Spearman rank correlations have the advantage of being unaffected by the scale of the indices (i.e., linear or log scale). We used one-tailed tests, because we considered correlations significant only if they were positive. Because some of the variation in population indices from each survey is due to sampling error, we would not expect perfect correlations between estimates from each survey even if both provided unbiased estimates of the same population (see above). We approximated the maximum expected r^2 (in %) as $(\tau^2/s^2)_{PFW} \times (\tau^2/s^2)_{CBC} \times 100\%$.

The rationale for this is that if population variation is very large relative to sampling error, then the expected correlation, if both surveys sampled the same population, would be close to 100%; if virtually all of the variation in either survey was sampling error, we would not expect any correlation between surveys irrespective of the precision of the other survey. For all species with a high maximum expected r^2 (we used an arbitrary cutoff of 50%), we tested whether the correlation coefficients were related to the proportion of PFW or CBC counts on which the species was detected or to the absolute magnitude of population variation in the species.

We also compared trend estimates from each survey. We plotted trends from CBC against those from PFW using a reduced major axis regression because neither trend was estimated without error (Sokal and Rohlf 1981). If both surveys estimated trends without bias, then the regression line should have a slope of 1 and intercept 0. We used a Spearman rank correlation (r_s) to assess the level of consistency between the two surveys.

RESULTS

In Ontario, the number of PFW participants between 1976–1977 and 1996–1997 ranged from 245 to 540 with a large proportion (49%) located south of 44°N (Fig. 1). The number of participants increased gradually over the first 10 years, decreased sharply in 1987–1988, corresponding with the transition from OBFS to PFW, when a participation fee was introduced to offset operating costs, and then increased again to over 500. The number of CBCs increased fairly steadily between 1976–1977 and 1996–1997, from 48 to 90 counts. Their distribution among regions was similar to those of PFW (Fig. 1).

Correlations between annual indices from PFW and CBC. We calculated annual indices from both CBC and PFW data for all species ($n = 43$) that were reported by both surveys in at least one region on a regular basis (i.e., at least several times per year most years) during the study period (Table 1; scientific names for species therein). Overall, the annual indices from each survey were significantly correlated ($P < 0.05$) for 26 of 39 species (67%) in southern, 23 of 35 species (66%) in central, and 16 of 26 species (62%) in northern Ontario.

The estimated proportion of variation in the population indices due to variation in the population being sampled, rather than sampling error, varied from almost none to nearly 100% for each survey (Table 1). Some species exhibited very high year-to-year variation such as irruptive finches (e.g., Common Redpoll and Pine Siskin; Fig. 3) or showed major long-term trends in Ontario wintering populations (e.g., Mourning Dove and House Sparrow; Fig. 3). Population indices for all of these species were significantly correlated between surveys. Many other species had much lower, but still significant annual variation in population numbers, and indices for many of them were also significantly correlated between surveys (e.g., Black-capped Chickadee and White-throated Sparrow; Fig. 3).

The size of the correlation between the two surveys was strongly related to the maximum expected r^2 between the surveys (Fig. 4). The proportion of comparisons with significant ($P < 0.05$) positive correlations increased to 81% among comparisons in which the maximum expected r^2 was at least 50% ($n = 59$; Fig. 4). Nevertheless, for a number of species, the observed correlations were substantially lower than expected if both surveys were sampling the same populations.

To determine which species did not show strong correlations despite a high expected r^2, we carried out further analyses on those species with an expected r^2 greater than 50%. Among these species, the average proportion of surveys which reported the species on either PFW or CBC was positively related to the strength of the correlations between the surveys ($r_s = 0.29$ and 0.30 for PFW and CBC, respectively, $P < 0.03$). This indicates that species that are frequently re-

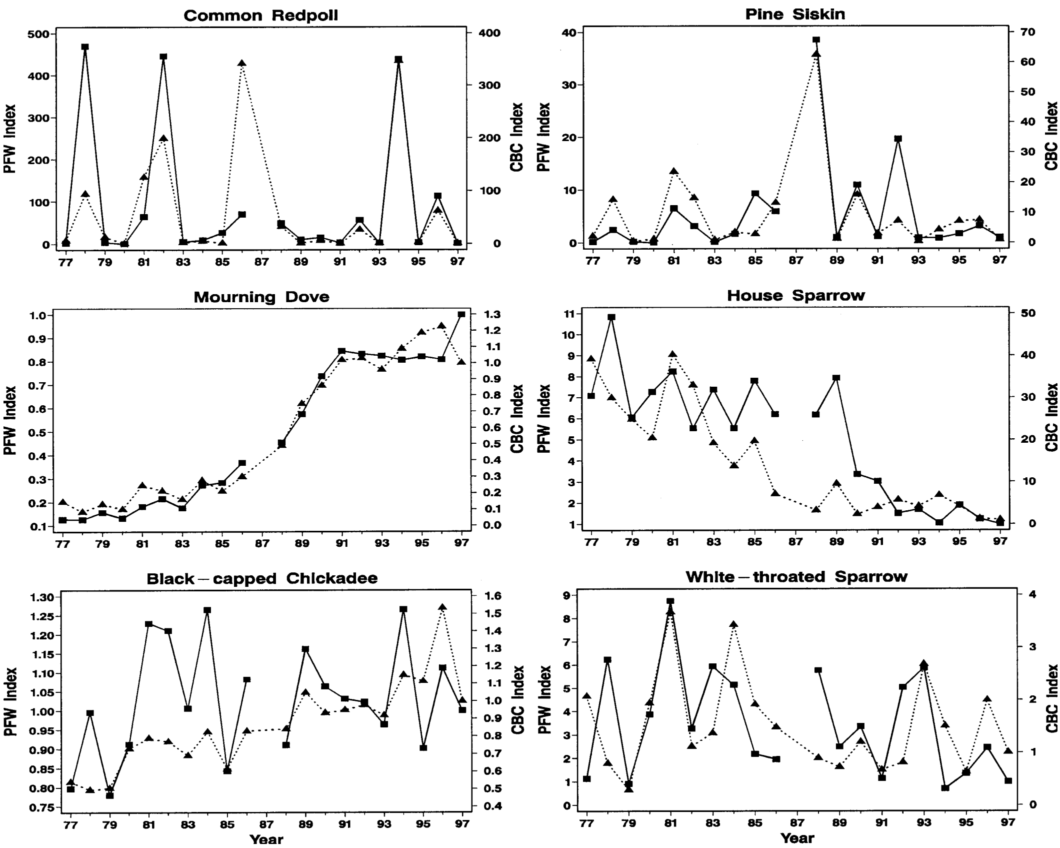

FIGURE 3. Annual indices for selected species in Ontario from 1977–1997 as estimated from Project FeederWatch counts (squares) and from Christmas Bird Counts (triangles). Indices represent the unweighted mean of indices from the three regions of Ontario. Scales vary among graphs because of differences in species abundance.

ported are more likely to show a strong positive correlation than rarely reported species, even when the analysis is restricted to species for which sampling error is small relative to annual variation. Likewise, among this group of species, those that showed a large absolute variability in annual indices (τ^2) calculated from CBC (equivalent to a high coefficient of variation after removing the effects of sampling error) were more likely to be correlated with PFW ($r_s = 0.28$, $P = 0.03$), but the reverse was not true: there was no relationship between the magnitude of variation in PFW annual indices (again, after removing the effects of sampling error) and the correlation among the two surveys ($r_s = -0.04$, $P > 0.7$).

Population trends. Estimated population trends from PFW were significantly correlated with those from CBC in each region (south: $r_s = 0.64$, $n = 39$; central: $r_s = 0.53$, $n = 35$; north: $r_s = 0.71$, $n = 26$; all $P < 0.001$; Fig. 5). There were 55 instances in which trends were significant ($P < 0.05$) from both surveys, of which 47 were consistent in sign, but 8 disagreed in sign: Hairy Woodpecker, European Starling, Field Sparrow, and Purple Finch (southern Ontario); Downy Woodpecker and Boreal Chickadee (central Ontario); Blue Jay and White-throated Sparrow (northern Ontario).

In addition to the positive correlations and general agreement in sign, trends from CBC and PFW tended to be similar in absolute value, as shown by the small deviation of the regression lines from the lines of equality and the small deviation of the intercept from zero (Fig. 5). The slope of the regressions did not differ from 1 in northern ($P > 0.5$) and central Ontario ($P = 0.2$), but the slope was greater than 1 in southern

TABLE 1. Correlation coefficients (r_s) between annual population indices derived from Project Feeder Watch (PFW) and Christmas Bird Counts (CBC) in Ontario from 1976 to 1997, and estimated percentage of variance among annual indices from each survey that is due to variation in the underlying population (i.e., not due to sampling error from each survey).

	Southern Ontario			Central Ontario			Northern Ontario		
		% variance in population (τ^2/s^2)			% variance in population (τ^2/s^2)			% variance in population (τ^2/s^2)	
	r_s	PFW	CBC	r_s	PFW	CBC	r_s	PFW	CBC
Sharp-shinned Hawk *Accipiter striatus*	0.66***	82***	87***	0.66***	67***	70***			
Ruffed Grouse *Bonasa umbellus*	0.43*	100***	92***	0.29	71***	82***	0.52**	99*	72***
Rock Dove *Columba livia*	0.50*	89***	62***	0.44*	30*	51**	0.71***	93***	98***
Mourning Dove *Zenaida macroura*	0.86***	96***	93***	0.94***	97***	97***			
Red-bellied Woodpecker *Melanerpes carolinus*	0.65***	16	88***						
Downy Woodpecker *Picoides pubescens*	0.60**	50**	86***	0.22	34	82***	0.00	0	78***
Hairy Woodpecker *Picoides villosus*	0.16	48***	72***	0.41*	33*	81***	0.28	0	79***
Northern Flicker *Colaptes auratus*	0.58**	46**	71***	0.52**	61**	62***			
Pileated Woodpecker *Dryocopus pileatus*	0.35	99	54**	0.52**	68***	55**	0.65***	40***	78***
Gray Jay *Perisoreus canadensis*							0.15	15***	91***
Blue Jay *Cyanocitta cristata*	0.07	30***	89***	0.58**	80***	87***	−0.39	9**	74***
American Crow *Corvus americanus*	0.87***	92***	95***	0.87***	87***	96***	0.68***	47***	97***
Common Raven *Corvus corax*				0.75***	51***	93***	0.55**	53***	81***
Black-capped Chickadee *Poecile atricapilla*	0.74***	91***	94***	0.44*	70***	95***	0.25	46***	93***

TABLE 1. Continued.

	Southern Ontario			Central Ontario			Northern Ontario		
		% variance in population (τ^2/s^2)			% variance in population (τ^2/s^2)			% variance in population (τ^2/s^2)	
	r_s	PFW	CBC	r_s	PFW	CBC	r_s	PFW	CBC
Boreal Chickadee *Poecile hudsonica*				−0.45	83***	86***	0.42*	58***	53***
Red-breasted Nuthatch *Sitta canadensis*	0.61**	91***	87***	0.38*	72***	87***	0.72***	65***	78***
White-breasted Nuthatch *Sitta carolinensis*	0.66***	88***	91***	0.54**	64***	91***	0.70***	43*	78***
Brown Creeper *Certhia familiaris*	0.68***	98**	82***	0.32	30*	86***			
American Robin *Turdus migratorius*	0.58**	91***	85***	0.25	86***	76***			
Northern Mockingbird *Mimus polyglottos*	0.21	13	75***						
Cedar Waxwing *Bombycilla cedrorum*	0.09	78***	55***						
Northern Shrike *Lanius excubitor*	0.25	89**	92***	0.17	58***	88***			
European Starling *Sturnus vulgaris*	−0.46	1**	63***	0.37	57***	90***	0.31	49**	97***
Northern Cardinal *Cardinalis cardinalis*	0.61**	59***	86***	0.91***	88***	95***			
American Tree Sparrow *Spizella arborea*	0.42*	91***	89***	0.41*	82***	86***	0.56**	44***	85***
Field Sparrow *Spizella pusilla*	−0.37	70***	60***						
Song Sparrow *Melospiza melodia*	0.29	36***	74***	0.16	65***	58***			
White-throated Sparrow *Zonotrichia albicollis*	0.86***	79***	87***				0.00	51***	20**
White-crowned Sparrow *Zonotrichia leucophrys*	0.62**	47***	72***						

TABLE 1. Continued.

	Southern Ontario			Central Ontario			Northern Ontario		
		% variance in population (τ^2/s^2)			% variance in population (τ^2/s^2)			% variance in population (τ^2/s^2)	
	r_s	PFW	CBC	r_s	PFW	CBC	r_s	PFW	CBC
Dark-eyed Junco *Junco hyemalis*	0.80***	87***	86***	0.83***	90***	90***	0.29	34***	77***
Snow Bunting *Plectrophenax nivalis*	0.61**	86***	87***	0.29	84***	49***	−0.28	53***	53
Red-winged Blackbird *Agelaius phoeniceus*	0.21	79***	97***	0.10	73***	64***			
Rusty Blackbird *Euphagus carolinus*	0.27	96***	77***						
Common Grackle *Quiscalus quiscula*	0.13	83***	69***	−0.09	86***	21***	0.24	24***	27***
Brown-headed Cowbird *Molothrus ater*	0.41*	69***	31***	0.08	74***	35***			
Pine Grosbeak *Pinicola enucleator*				0.76***	97***	100***	0.69***	91***	96***
Purple Finch *Carpodacus purpureus*	0.28	93***	80***	0.89***	95***	77***	0.61**	87***	88***
House Finch *Carpodacus mexicanus*	0.96***	99***	98***	0.96***	97***	92***			
Common Redpoll *Acanthis flammea*	0.77***	88***	100***	0.86***	89***	94***	0.60**	81***	79***
Pine Siskin *Carduelis pinus*	0.77***	88***	70***	0.79***	95***	82***	0.49*	91***	91***
American Goldfinch *Carduelis tristis*	0.50*	86***	77***	0.88***	97***	95***	0.77***	90***	97***
Evening Grosbeak *Coccothraustes vespertinus*	0.80***	100***	100***	0.51**	86***	98***	0.67***	83***	71***
House Sparrow *Passer domesticus*	0.60**	86***	77***	0.64***	90***	78***	0.69***	84***	94***

Probability that correlation or variance is zero (correlation is 1-tailed test): *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$.

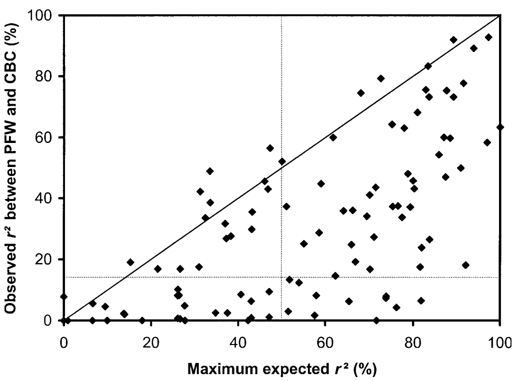

FIGURE 4. Observed r^2 (%) between Project FeederWatch (PFW) and Christmas Bird Counts (CBC) in relation to the maximum expected r^2, based on the product of the percent of variation not due to sampling error in annual indices from each survey. Data points each represent one species from one region (from Table 1). Correlation values above the horizontal stippled line are significant ($P \leq 0.05$). The observed r^2 is not expected to be larger than the maximum expected r^2 (solid line), except by chance. The vertical stippled line is the arbitrary cutoff (50%) for species with a high expected r^2.

Ontario ($P = 0.05$), indicating that PFW produced higher absolute values of the rates of change than CBC. Finally, the intercept of the slope was smaller than 0 in northern Ontario (intercept = −3.5; $P < 0.01$), indicating that PFW more often produced lower trends than CBC in that region. The intercept did not differ from 0 in central or northern Ontario ($P > 0.2$).

DISCUSSION

Overall, we found that annual population indices derived from PFW were significantly positively correlated with those derived from CBC for about 80% of species for which population fluctuations were large relative to sampling error for both surveys. Although significant correlations between indices do not necessarily indicate that either method is a perfect index of bird populations, they do increase our confidence that both reflect, at least to some degree, real variation in bird populations.

In an earlier study, Dunn (1986) carried out a similar comparison between population indices from OBFS and CBC for the first seven years of the data we present here. She found significant correlations for less than a third of 25 common species, although correlations were positive for many additional species. Our analyses confirm her speculation that the lack of correlation for many of these species was due to insufficient variation in population size relative to the precision with which it was measured. With 21 years of data we were able to demonstrate significant correlations for several of the additional species that she examined. We were also able to show that for some of the other species annual variation was so small, relative to sampling error, that correlations would not be expected. We found good correspondence between PFW and CBC for many additional species that were not considered by Dunn (1986). These included several species that were counted relatively rarely (such as the Red-bellied Woodpecker and the Sharp-shinned Hawk), but nevertheless with sufficient precision to detect annual variation.

Limited studies of PFW data from elsewhere suggest that these results can be generalized beyond Ontario. Wells et al. (1996) showed that estimates of population fluctuations in Varied Thrushes (*Ixoreus naevius*) in western North America were similar, and strongly correlated, based upon PFW, CBC, and BBS data for the period 1988–1989 to 1994–1995. Wells et al. (1998) compared PFW data with BBS data for nine species that are year-round residents in the northeastern United States. They concluded that PFW data were well correlated with BBS data at a spatial scale, but that there was little consistency in year-to-year variations in abundance estimates between PFW and BBS data. However, the only two species for which they found marked evidence of population change did, in fact, correspond between the surveys (Wells et al. 1998). Lack of correlation in other species they examined was likely due to insufficient population variation relative to sampling error, rather than bias in the surveys.

Further evidence that these results may be generalizable beyond Ontario stems from the fact that most of the species with significant annual variation in average counts within each region in our analyses (indicating significant spatial autocorrelation within each region) also showed high spatial autocorrelation at a continental scale (Koenig 2001a).

Because the CBC includes many birds that feed on natural foods, away from feeders, the high general agreement with PFW suggests that annual variation in numbers of birds visiting feeders reflects variation in the total populations of many species. However, this conclusion may

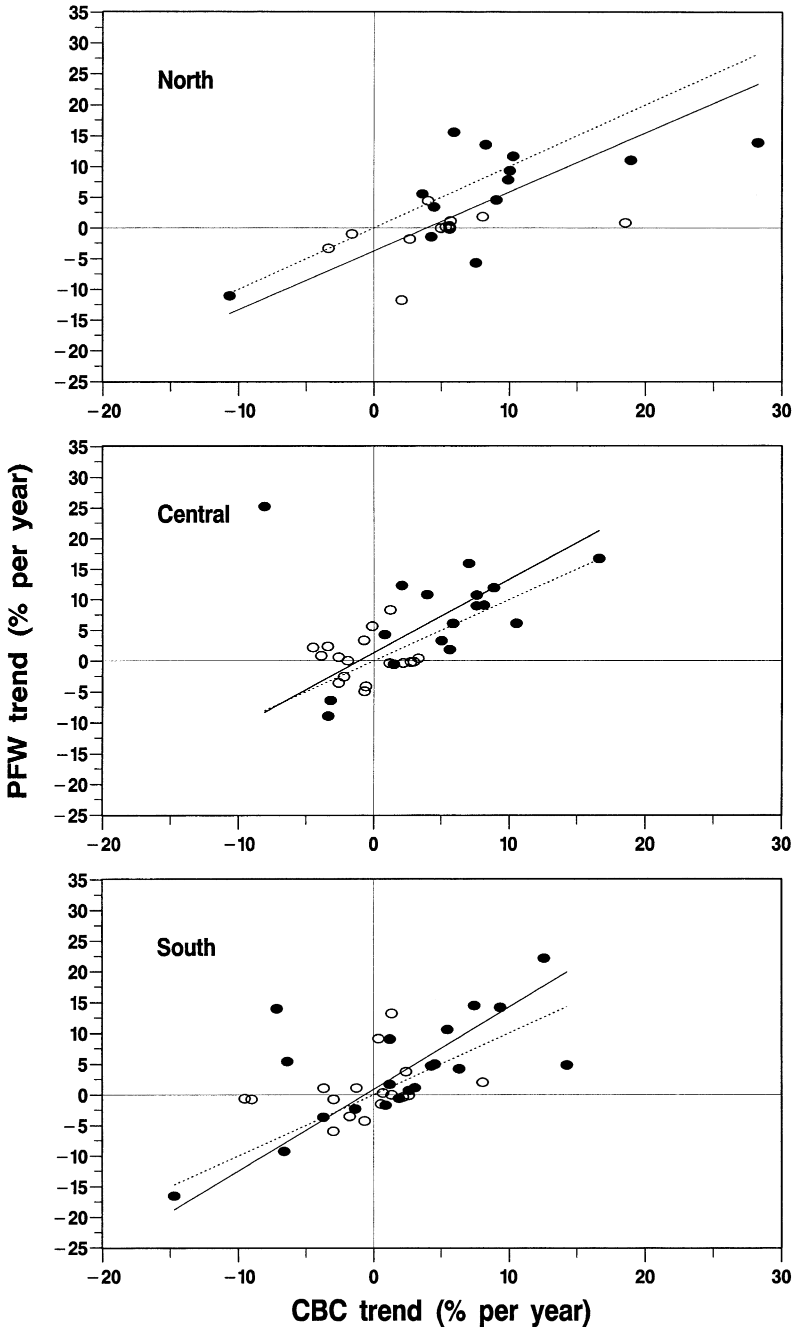

FIGURE 5. Comparison of population trends estimated from Project FeederWatch (PFW) and those estimated from Christmas Bird Counts (CBC) from 1976–1977 through 1996–1997 in each of three regions of Ontario. Graph includes all species for which correlation coefficients were calculated in Table 1. Solid line indicates reduced major axis regression; dashed line is the line of equal trends from PFW and CBC. Solid symbols represent species for which both surveys indicated significant population trends. Trends were significantly correlated between methods ($P < 0.001$) for all three regions.

not be justified if most birds counted on the CBC were counted at feeders (Butcher and Dunn 1995, Dunn 1995). This could happen if birds of the species we studied were much easier to count at feeders than in natural habitats. This cannot be tested directly without information on which birds on each CBC were detected at feeders, and these are not currently gathered. However, we doubt that the correlation between PFW and CBC was due entirely to feeder counts for two reasons. First, most CBC counts put a great deal of effort into finding birds in natural habitats. In our experience, most of the species we included in these analyses are also relatively easy to find and count away from feeders, and thus we would expect those components of their populations away from feeders to be well represented in the CBC. Second, if most of the variation in species counts were due to birds at feeders, we might expect closer correlations between PFW counts and CBC in northern Ontario, where there is relatively much greater effort put into feeder watching than in other regions (Fig. 2), but this was not the case. Thus, we suggest that most of the variation in the observed indices for both CBC and PFW reflects variation in the total regional wintering population. This is further corroborated by the studies of Wells et al. (1996, 1998) which showed significant correlations for several species between indices from PFW and BBS, a survey that is completely unaffected by feeders.

We also found good general correspondence between linear population trends derived from PFW and CBC data, indicating that both surveys may be suitable for detecting long-term population trends. However, at least in southern Ontario, there was a tendency for PFW data to indicate larger population trends (both positive and negative) than CBC. Without knowledge of the true populations, we cannot be certain which survey provides the more accurate estimates. Based upon the data collection protocol for PFW, we might not expect a linear relationship between PFW indices and the true population size. PFW records the maximum number of individuals present at one time at a feeder. Changes in populations could be manifested in changes in numbers of feeders being visited, changes in the mean flock size visiting feeders, and changes in the number of flocks visiting each feeder. The PFW protocol can only detect the first two of these situations, and thus will only measure population increases or decreases to the extent that they are reflected in these components. Of course, it is also possible that CBC counts are not linearly proportional to population sizes if, for example, individuals are more likely to be double counted when populations are large, thus exaggerating population increases. Bias could also have been introduced into the CBC counts if we misspecified the model to correct for changes in effort over time (although we found very similar trend estimates with a number of different models, unpubl. results).

Nevertheless, for a number of species, the correlation between surveys was substantially lower than expected if both surveys were sampling the same population. For example, in almost all regions, Blue Jay, Hairy Woodpecker, and Downy Woodpecker showed a significant decline based on PFW data, but a significant increase based on CBC data. This suggests that for some species, one or both survey methods do not provide an accurate index of population abundance. This could happen if the proportion of birds visiting feeders has changed over time (perhaps due to changes in natural food supply, changes in climate, or changes in food supplied at feeders), or if populations during the Christmas period do not adequately reflect those at other times of the winter, or if there is a systematic bias in one or the other survey for certain species. For example, PFW counts for species that rely less heavily on feeders in winter (e.g., Northern Shrike, Cedar Waxwing) may be influenced more by the weather conditions that drive birds into feeders (e.g., heavy snowfall) than by the population size of the species involved. In addition, some species such as icterids return north very early in the spring, prior to the end of the PFW count period, and this may cause some of the annual variation in PFW indices.

Our analyses indicate that indices for almost all irruptive species, as well as most species with marked population trends, were well correlated, and suggest that these species are adequately monitored by either method. For other species, there was no obvious pattern that could help to predict whether both surveys would provide consistent results. Therefore, unless one knows *a priori* which species will not be adequately monitored by a particular survey, one can have only limited confidence in the results for any given species from a single survey. This suggests that population studies for these species should use two or more independent surveys to increase the confidence that observed changes in indices actually reflect changes in the underlying populations. If the patterns do not agree, then additional sources of data should be sought to determine the true population trends.

In this paper, we have emphasized similarities between PFW and CBC, but the surveys have many differences and are best viewed as complementary. As a general monitoring tool, CBC has advantages in that it monitors all bird species, even those that do not visit feeders. It also may be better suited for measuring the magnitude of species' population changes, because the counts are not limited to individual flock size. However, it has a less consistent protocol, and analyses are dependent upon appropriate corrections for changes in effort. The approach of a generalized linear model, with appropriate transformations of the effort data (Link and Sauer 1999), has the advantage that it models the relationship based on the data, and can correct for multiple forms of effort, as we have done for feeder-hours and party-hours. However, this model has some limitations because feeder-hours and party-hours are correlated. Developing a functional understanding of the effects of each will not be possible unless CBC compilers tabulate separately birds seen by people watching feeders, and those seen by people away from feeders, as suggested by Dunn (1995). An additional disadvantage of CBC is that it is restricted to a single period in the year, so it cannot detect changes in populations through the winter (Arbib 1967, Bock and Root 1981, Butcher and McCulloch 1990, Dunn 1995).

In both of these respects, PFW has potential advantages over CBC, at least for species that visit feeders on a regular basis. PFW has a standardized protocol for data collection, which should lead to little change in average effort over time. PFW surveys are also repeated throughout the winter season, from November through early April. As a result, PFW has the potential to monitor changes in populations through the winter due to mortality or movement among areas. It may thus be better suited for tracking populations of some erratic species, such as finches, whose abundance can vary dramatically both spatially and temporally within the winter season (Hochachka et al. 1999).

We conclude that both of these surveys provide valuable tools for monitoring North American bird populations, particularly when they are combined. The next step in developing these surveys is to estimate population trends across many regions at once, preferably the whole of a species' wintering range, to differentiate changes in overall population size from movements among wintering areas. Annual changes in wintering areas are well known for many finches that periodically winter in larger numbers south of their normal wintering areas (Bock and Lepthien 1976, Koenig 2001b). Even normally sedentary species such as Black-capped Chickadees occasionally irrupt to the south (Hussell 1996). Long-term changes in wintering distributions have been shown for some species such as the American Goldfinch (Middleton 1977). Wells et al. (1996) showed that population fluctuations in Varied Thrushes were synchronous across their wintering range, and were also detected on breeding survey counts, suggesting that they were due to changes in the overall population size, and not due to movements. The continental scope of both CBC and PFW should allow differentiation of changes in wintering populations from changes in wintering distribution for additional species, at least those species that do not normally winter north of the area covered.

ACKNOWLEDGMENTS

First and foremost, we would like to thank the thousands of volunteers who have participated in OBFS, PFW, and CBC and gathered all of the data used in this analysis, and helped to support the programs through their donations and fees. We also thank the staff and additional volunteers of Bird Studies Canada (Long Point Bird Observatory) and the Cornell Laboratory of Ornithology, who administered the OBFS and PFW programs and processed the data forms. We especially thank Diane Tessaglia, who supplied us with a copy of the computerized Canadian PFW database, and Joan Kauk, Graeme Gibson, and Carolyn Murphy, who assisted with entry of OBFS data. The National Audubon Society, the Biological Resources Division of the U.S. Geological Survey, and the Cornell Laboratory of Ornithology were all instrumental in computerizing the CBC database. The analyses upon which this paper is based were funded largely by the Wildlife Assessment Program of the Ontario Ministry of Natural Resources (OMNR). Margaret McLaren (OMNR) and Michael Bradstreet (BSC) provided encouragement throughout the process. Erica Dunn, Wesley Hochachka, Walt Koenig, Jon McCracken, Len Thomas, and an anonymous reviewer provided helpful comments on our analyses and early drafts of this paper.

LITERATURE CITED

ARBIB, R. S. 1967. Considering the Christmas census. Audubon Field Notes 21:39–42.

BOCK, C. E., AND L. W. LEPTHIEN. 1976. Synchronous eruptions of boreal seed-eating birds. American Naturalist 110:559–571.

BOCK, C. E., AND T. L. ROOT. 1981. The Christmas Bird Count and avian ecology. Studies in Avian Biology 6:17–23.

BUTCHER, G. S., AND E. H. DUNN. 1995. Bird feeders and Christmas Bird Counts: a cautionary tale. Kingbird 45:79–86.

BUTCHER, G. S., M. R. FULLER, L. S. MCALLISTER, AND P. H. GEISSLER. 1990. An evaluation of the Christmas Bird Count for monitoring population trends of selected species. Wildlife Society Bulletin 18: 129–134.

BUTCHER, G. S., AND C. E. MCCULLOCH. 1990. Influence of observer effort on the number of individual birds recorded on Christmas Bird Counts, p. 120–129. *In* J. R. Sauer and S. Droege [EDS.], Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish and Wildlife Service, Biological Report 90(1), Washington, DC.

CHAPMAN, J. D., AND J. C. SHERMAN. 1975. Oxford regional economic atlas: the United States and Canada. Oxford University Press, Oxford, UK.

DESANTE, D. F., K. M. BURTON, AND D. R. O'GRADY. 1996. The Monitoring Avian Productivity and Survivorship (MAPS) program fourth and fifth annual report (1993 and 1994). Bird Populations 3: 67–120.

DUNN, E. H. 1986. Feeder counts and winter bird population trends. American Birds 40:61–66.

DUNN, E. H. 1995. Bias in Christmas Bird Counts for species that visit feeders. Wilson Bulletin 107: 122–130.

DUNN, E. H., AND J. R. SAUER. 1997. Monitoring Canadian bird populations with winter counts, p. 49–55. *In* E. H. Dunn, M. D. Cadman, and J. B. Falls [EDS.], Monitoring bird populations: the Canadian experience. Canadian Wildlife Service, Occasional Paper 95, Ottawa, ON, Canada.

ENGSTROM, R. T. 1989. Preface to the inaugural issue of Resident Bird Counts. Journal of Field Ornithology 60(suppl.):3–4.

HOCHACHKA, W. M., J. V. WELLS, K. V. ROSENBERG, D. L. TESSAGLIA-HYMES, AND A. A. DHONDT. 1999. Irruptive migration of Common Redpolls. Condor 101:195–204.

HUSSELL, D. J. T. 1996. The influx of Black-capped Chickadees at Long Point, Ontario in the spring of 1962: a 35-year perspective on an unusual event. Journal of Field Ornithology 67:614–622.

KOENIG, W. D. 2001a. Spatial autocorrelation and local disappearances in wintering North American birds. Ecology 82:2636–2644.

KOENIG, W. D. 2001b. Synchrony and periodicity of eruptions by boreal birds. Condor 103:725–735.

LEBARON, G. S. 1997. The ninety-seventh Christmas Bird Count. Field Notes 51:138–146.

LINK, W. A., AND J. D. NICHOLS. 1994. On the importance of sampling variance to investigations of temporal variation in animal population size. Oikos 69:539–544.

LINK, W. A., AND J. R. SAUER. 1994. Estimating equations estimates of trends. Bird Populations 2:23–32.

LINK, W. A., AND J. R. SAUER. 1997. Estimation of population trajectories from count data. Biometrics 53:488–497.

LINK, W. A., AND J. R. SAUER. 1998. Estimating population change from count data: application to the North American Breeding Bird Survey. Ecological Applications 8:258–268.

LINK, W. A., AND J. R. SAUER. 1999. Controlling for varying effort in count surveys—an analysis of Christmas Bird Count data. Journal of Agricultural, Biological, and Environmental Statistics 4: 116–125.

MARTIN, T. E., C. R. PAINE, C. J. CONWAY, W. M. HOCHACHKA, P. ALLEN, AND W. JENKINS [ONLINE]. 1997. BBIRD field protocols. ⟨http://pica.wru.umt.edu/BBIRD/protocol/protocol.htm⟩ (14 December 2001).

MIDDLETON, A. L. A. 1977. Increase in overwintering by the American Goldfinch *Carduelis tristis*, in Ontario. Canadian Field Naturalist 91:165–172.

ROBBINS, C. S., D. BYSTRAK, AND P. H. GEISSLER. 1986. The Breeding Bird Survey: its first fifteen years, 1965–1979. U.S. Fish and Wildlife Service Resource Publication 167, Washington, DC.

ROOT, T. 1988a. Atlas of wintering North American birds, an analysis of Christmas Bird Count data. University of Chicago Press, Chicago.

ROOT, T. 1988b. Environmental factors associated with avian distributional boundaries. Journal of Biogeography 15:489–505.

SAS INSTITUTE INC. 1998. The SAS system for windows, release 8.0. SAS Institute, Inc. Cary, NC.

SHIPMAN, J. W. [ONLINE]. 1998. Christmas Bird Count database distribution 5.09. ⟨ftp://ftp.nmt.edu/pub/people/john/cbc/⟩ (24 March 1998).

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry. 2nd ed. Freeman and Company, San Francisco.

TESSAGLIA, D. L. 1997. Project FeederWatch annual report 1996–97. BirdScope 11(4):1–5.

WELLS, J. V., K. V. ROSENBERG, D. L. TESSAGLIA, AND A. A. DHONDT. 1996. Population cycles in the Varied Thrush (*Ixoreus naevius*). Canadian Journal of Zoology 74:2062–2069.

WELLS, J. V., K. V. ROSENBERG, E. H. DUNN, D. L. TESSAGLIA, AND A. A. DHONDT. 1998. Feeder counts as indicators of spatial and temporal variation in winter abundance of resident birds. Journal of Field Ornithology 69:577–586.

APPENDIX 1

ANALYSIS OF CHRISTMAS BIRD COUNT MODELS

Our analyses were based on the approach of Link and Sauer (1999), modified to allow for multiple measures of effort. We used Poisson regression with iterative reweighting of individual counts (to control for overdispersion) to fit the following generalized linear model for each species and region:

$$E(C_{ij}) = A_i + f(t_j) + h(PH_{ij}) + g(FH_{ij})$$

where $E(C_{ij})$ is the expected value of the count at the ith circle, in the jth year of survey t_j. A_i is an index to average population abundance at the ith count circle. The function $f(t)$ describes the index of annual abundance in year j. For a year-effects model, $\varphi_j = f(t_j)$, in which each year was allowed to attain a distinct level. The function $h(PH)$ describes the effect of party-hours (PH), and the function $g(FH)$ the effect of feeder-hours (FH) on the number of birds reported. Because of the asymptotic effect of effort on bird counts, PH and FH were transformed following Link and Sauer (1999), using the Box-Cox family of transformations (Broemeling 1982); thus, we supposed that $H(PH) = H_p(PH) \equiv (\exp(h_p(PH))$ and $G(FH) = G_q(FH) \equiv (\exp(g_q(FH))$, where $h_p(PH) = B(PH^p - 1)/p$ and $g_q(FH) = C(FH^q - 1)/q$. Following Link and Sauer (1999), we used a single value of $p = -1.5$ and $q = -1.5$. We compared that approach with the logarithmic transformation used by Butcher and McCulloch (1990) (which is equivalent to using $p = 0$ and $q = 0$) and modeled the four different permutations of possible transformation for PH and FH, for each species and region. In the majority of cases, the model using -1.5 for p and q had the smallest minimum scaled deviance, indicating the best fit. Even when one of the other models was a better fit, the difference was small, and in any case the resultant annual indices were nearly identical. So, for consistency, we used the value of -1.5 in all analyses of CBC data.

APPENDIX 2

SEPARATING SAMPLING ERROR FROM TRUE POPULATION VARIANCE

Total variance in the annual indices of both Project FeederWatch and Christmas Bird Count is given by:

$$s^2 = \frac{1}{n - 1} \sum_{i=1}^{n} (I_i - \bar{I})^2$$

where I_i is the estimate (on the logarithmic scale) of the annual index in year i and

$$\bar{I} = \frac{1}{n} \sum_{i=1}^{n} I_i.$$

The component of this variation that is due to variation in the underlying population (τ^2) was then estimated by (Link and Nichols 1994):

$$\tau^2 = s^2 - \left(\frac{1}{n} \sum_{i=1}^{n} \mathrm{var}(I_i) - \frac{2}{n(n - 1)} \sum_{i<j} \mathrm{cov}(I_i, I_j)\right)$$

where $\mathrm{var}(I_i)$ is the estimated sampling variance of each of the annual indices, and $\mathrm{cov}(I_i, I_j)$ is the estimated sampling covariance between each pair of annual indices, as provided by PROC GENMOD (SAS Institute Inc. 1998). We had to exclude from this calculation any indices for which we could not estimate the variance because the value was undefined on log scale (i.e., zero or close to zero on the original scale).