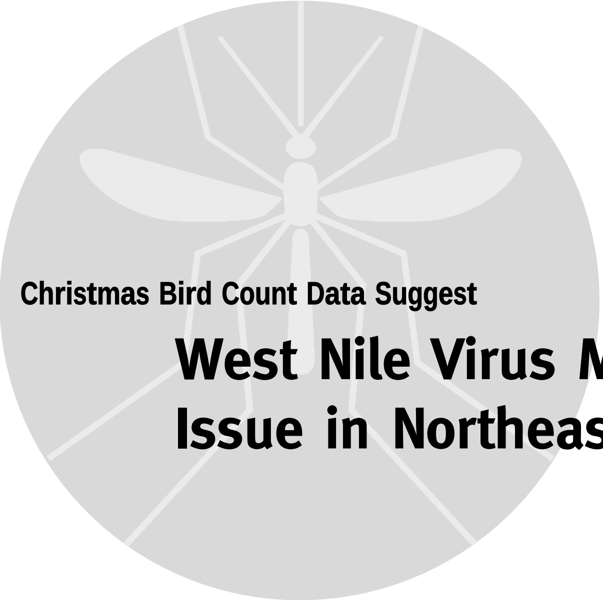
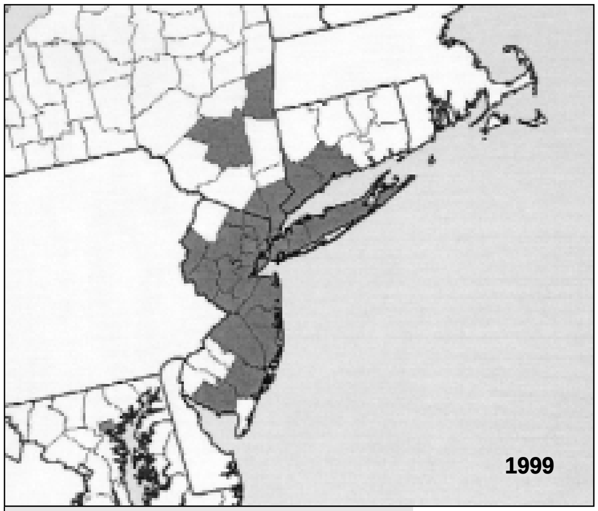


Christmas Bird Count Data Suggest

West Nile Virus May Not Be A Conservation Issue in Northeastern United States



WNV **Figure 1. Original outbreak location and surrounding region**

Carolee Caffrey
Audubon Science Center
545 Almshouse Road
Ivyland, PA 18974
ccaffrey@audubon.org

Charles C. Peterson
Biology Department
The College of New Jersey
P.O. Box 7718, 2000 Pennington Road
Ewing, NJ 08628
petersoc@tcnj.edu

INTRODUCTION

At the end of each year, tens of thousands of people across North America join with others in their communities to spend a day identifying and counting birds. Their purpose is to add their numbers to the longest-running large-scale census of avian distribution and population status: Audubon's Christmas Bird Count. With more than 100 continuous years of early winter population data, and in an era of dramatic environmental changes, the Christmas Bird Count (CBC) database is a potentially powerful tool for tracking changes in the size, distribution, and dynamics of bird populations in response to changing environmental conditions.

However, the very nature of the draw to CBC participants—that which makes counts so pleasurable—constrains the usefulness of CBC data in analyses of population trends. The traditional routes and methods of participants differ among counts, and this affects the numbers of birds counted; for example, routes may be primarily walked or driven, and some, but not all, participants use owl tapes to elicit responses (McKay et al. 2002). In addition, because individual Christmas Bird Counts occur on only a single day of each year, and weather conditions influence bird behavior and detectability, the relationship between the numbers of birds counted and actual population sizes within circles is not consistent within, or among, counts.

Charles C. Peterson, Ph.D., a physiological ecologist, has focused his research on the energetics and evolutionary physiology of various reptiles and amphibians, particularly desert tortoises, garter snakes, mud turtles, and box turtles. See "Determining Impacts of West Nile Virus on Crows and Other Birds," page 12, for information about Carolee Caffrey.

“We tried by three graphical and statistical methods to elucidate an effect of West Nile virus on early winter bird populations in the northeastern United States, as monitored by Christmas Bird Counts. Despite some suggestive hints, we were unable to demonstrate effects warranting conservation concern for any of the ten species examined.” **—Carolee Caffrey and Charles C. Peterson**

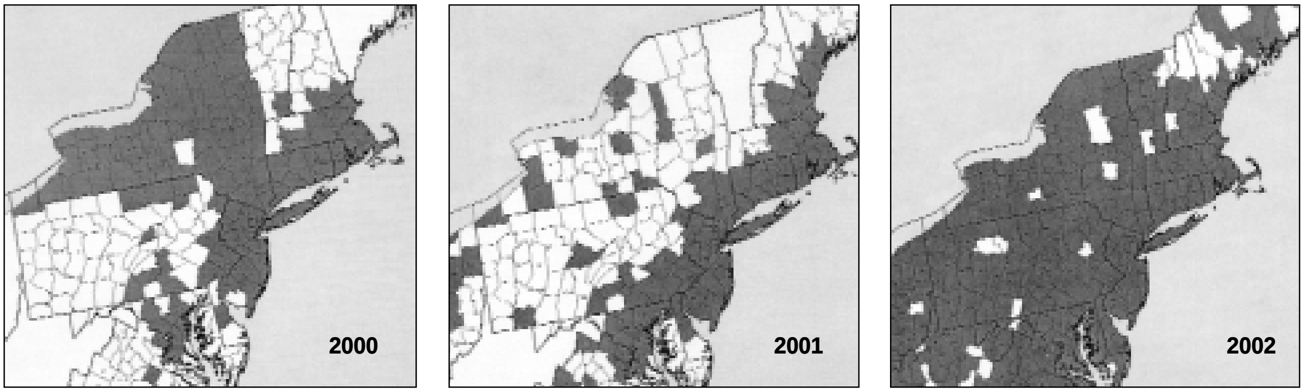


Figure 1 continued. Spread of West Nile Virus through six northeastern states, 2000-2002. Darkened counties indicate WNV presence, as documented by the WNV Surveillance System (see text). Maps courtesy of the U.S. Geological Survey.

Yet the sheer volume of data is powerful in and of itself. The consistency within counts that comes from censusing the same areas each year using the same methods, often by the same people, adds integrity to the numbers. By pooling counts over large geographic areas, so as to overwhelm effects of different data collection methods and to account for the fact that counts are not independent of each other—birds in these early winter populations may be moving, and so may disappear from one count but be picked up on another—some of the “sloppiness” inherent in the data can be ameliorated.

In light of these considerations, and to avoid placing too many demands on the data set, we used a simple approach to look for evidence that West Nile virus (WNV), an emerging pathogen in the New World, has impacted native avian populations. We focused our attention on ten resident bird species in six northeastern states in the United States, the region surrounding the epicenter of WNV’s original outbreak, in Queens, NY, in 1999, and into which the virus first spread (Figure1).

West Nile virus will now forever reside in the Americas. Little is known, as yet, about the short- and long-term consequences of its New World existence, although many dead crows have documented the path of its spread; 57,053 have been collected since 1999 (Eideson et al. 2001; Centers for Disease Control and Prevention 2002a, b; McLean et al. 2002). Yet sick birds tend to seek out quiet places, and crows get very sick and quiet when infected by West Nile virus (N. Komar and R. McLean, personal communications). Thus most dead crows have probably gone unnoticed, as have probably the vast majority of the bodies of smaller, and more cryptic, birds. Coupled with the fact that many public agencies did not collect dead birds other than corvids and raptors, little information exists on the responses of different species to exposure to West Nile virus.

Can such information be gleaned from CBC data?

METHODS

We pooled Christmas Bird Count data from six states (Connecticut [CT], Massachusetts [MA], New Jersey [NJ], New York [NY], Pennsylvania [PA], and Rhode Island [RI]) for each of the years 1989–2002, for each of ten "species": Red-tailed Hawk *(Buteo jamaicensis)*, Great Horned Owl *(Bubo virginianus)*, Downy Woodpecker *(Picoides pubescens)*, Blue Jay *(Cyanocitta cristata)*, American Crow *(Corvus brachyrhynchos)*, Black-capped and Carolina chickadees combined (*Poecile atricapilla* and *P. carolinensis*, respectively), White-breasted Nuthatch *(Sitta carolinensis)*, Northern Mockingbird *(Mimus polyglottos)*, Northern Cardinal *(Cardinalis cardinalis)*, and House Sparrow *(Passer domesticus)*. Eight of the ten species (all but crows and chickadees) were chosen for the analyses because populations tend to be nonmigratory and individuals do not form large winter aggregations, both of which could confound attempts to detect changes in population sizes over time. Crows and chickadees were chosen because anecdotal evidence suggested these birds were being heavily impacted by WNV, and for crows, two field studies of marked populations documented high WNV-related mortality in 2002 (approximately 40 percent: Caffrey et al. 2003; approximately 30 percent in one particular area: K.J. McGowan, A.B. Clark, and D.A. Robinson, unpublished data).

CBC counts for crows can be strongly influenced by the tendency of crows to form large winter foraging flocks and the presence (in some circles and years) of huge winter roosts or pre-roost aggregation areas, all of which may include many migratory individuals (Verbeek and Caffrey 2002). In an attempt to restrict our analysis to resident crows, we also analyzed an edited data set including only absolute counts of 2500 crows or less. (A third analysis of counts with 1500 or fewer crows yielded qualitatively identical results and is not reported.) Similarly, CBC counts of Great Horned Owls are contingent on the variable amount of "owling effort" employed in different circles and years (McKay et al. 2002). Thus to better standardize owling effort, we analyzed a second data set comprising only absolute counts of 35 or fewer Great Horned Owls.

Data from all non-pelagic count circles in all six states were potentially included in the analyses. We used data from all circles where counts had occurred in at least eight of the ten years 1989–1998 (n=191). Within these circles, we excluded the species counts for species that had not been observed in at least five of the ten years prior to the arrival of West Nile virus. Thus the following counts for the following species were excluded:

- Red-tailed Hawk: MASB, NYSL, RIBI.
- Great Horned Owl: MAMV, MANA, NYBR, NYCR, NYHF, NYNA, NYOT, NYQU, NYSB, NYSL, NYSN, NYWA, PAPL, PAVB, RIBI.
- Northern Mockingbird: NYBM, NYCL, NYCR, NYEZ, NYJA, NYJG, NYOO, NYOS, NYOT, NYPL, NYSB, NYSH, NYSL, NYSO, NYWA, PABC, PABU, PABV, PACR, PADU, PAEM, PAER, PALN, PAMA, PAPL, PARC, PATH, PAWM, PAWR.

To adjust raw species counts for differential search effort among years and circles, we first used Pearson correlation analysis to determine, for each species, the stronger covariate of nonzero count data: party-hours or party-miles. On the basis of these results (Table 1), counts of Red-tailed Hawks, Great Horned Owls, and chickadees were normalized by party-miles; all other data sets were normalized by party-hours. Although more sophisticated statistical methods exist for adjusting CBC counts for effort (e.g., Butcher and McCulloch 1990, Sauer and Link 2002), we felt that the wide variation concomitant with the large geographic and temporal extent of the data analyzed here justified the calculation of simple ratios (birds/party-hour and birds/party-mile), an approach that has been used historically (Sauer and Link 2002) and in several recent analyses (e.g., Farnsworth 2002, Pranty 2002)

Normalized data were first plotted as calendar-year averages for each species. Next, we sorted the data relative to the year of arrival of WNV in the county containing each CBC circle's center (see below) and plotted subsets of the data containing circles where WNV had been continuously present for four years (n ≤ 36 circles, depending on species), three years (n ≤ 72), two years (n ≤ 8), and one year (n ≤ 38); a fifth subset comprised circles (n ≤ 35) where WNV was detected one year but not the next, and then again the following year (much of upstate New York; see Figure 1).

West Nile virus surveillance data

The West Nile Virus Surveillance System is a collaborative effort involving the Centers for Disease Control and Prevention (CDC), the United States

Table 1. Correlations between raw species counts and indices of search effort for 191 CBC circles over 14 years. Shown are Pearson correlation coefficients (r) for bird counts versus indicators of search duration (party-hours) and geographic coverage (party-miles). Two data sets were analyzed for Great Horned Owls and American Crows (see text).

Species	Party-hours	Party-miles
Red-tailed Hawk	0.550	0.587
Great Horned Owl (all data)	0.340	0.373
Great Horned Owl (< 35)	0.401	0.411
Downy Woodpecker	0.755	0.595
Blue Jay	0.566	0.518
American Crow (all data)	0.219	0.146
American Crow (< 2500)	0.483	0.446
Chickadees	0.510	0.531
White-breasted Nuthatch	0.597	0.540
Northern Mockingbird	0.671	0.387
Northern Cardinal	0.668	0.503
House Sparrow	0.600	0.458

Geological Survey (USGS), the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA, APHIS), state wildlife agencies, and state and local health and vector control agencies, to monitor the geographic and temporal spread of West Nile virus in the United States. Five different surveillance activities allow the monitoring of the occurrence of West Nile virus by county in: 1) humans; 2) horses, dogs, and cats; 3) wild birds; 4) sentinel chickens; and 5) local mosquito populations (see CDC 2001 for additional information).

Data on the occurrence of WNV in the counties of the six states—CT, MA, NJ, NY, PA, and RI—for the years 1999-2002, were obtained from the CDC. We identified whether WNV was detected, or not, in any of the surveillance categories for each county in each year to determine the year of "arrival" of the virus to each county (Figure 1). From surveillance data we also determined, for each county in each year, the percent of immediately neighboring counties with detected WNV activity. Nantucket Island (MA), Martha's Vineyard (MA), and Block Island (RI) were all scored as having no surrounding counties "positive" for all four years—they are isolated by water from areas where WNV was present—but Staten Island (NY) was given a value of one (all surrounding counties had detectable WNV activity) for 1999-2002 (Figure 1) because of the short distance to neighboring counties and a connecting bridge across which the virus could potentially travel in various hosts and vectors.

Latitude and longitude coordinates were used to place each circle's center within a particular county (Figure 2).

For Great Horned Owls and American Crows, we looked to see if the numbers of human WNV cases within counties and the percent of immediately neighboring counties with WNV activity in the preceding year were related to year-to-year changes in CBC-estimated population sizes (expressed both as birds/party-mile and as population percentages). Because, especially in 2002, many county health departments ceased collecting and testing dead birds once one or two crows tested positive for WNV, and because horses and testing programs for sentinel birds and mosquitoes were unevenly distributed throughout our study area, these surveillance categories were not considered valid quantitative indices of the prevalence of WNV within counties.

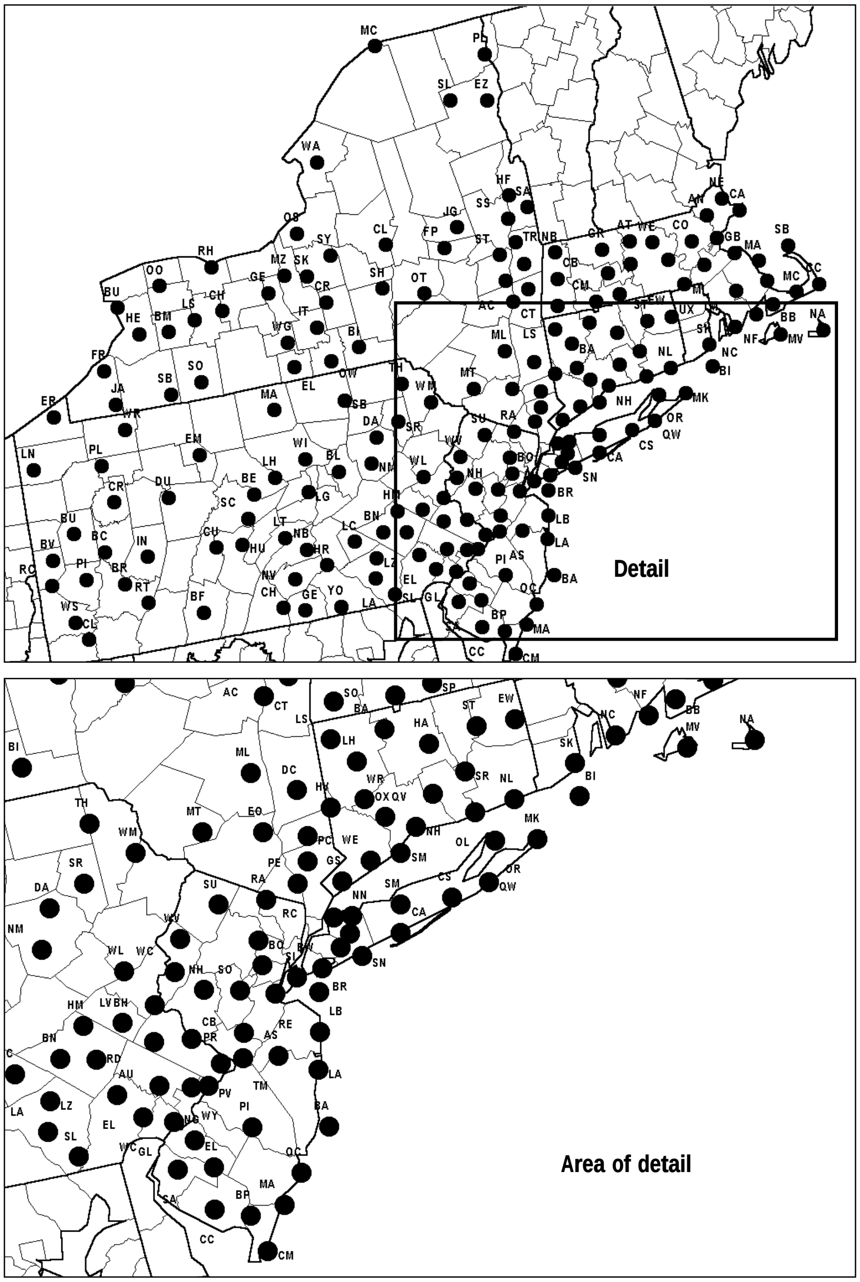


Figure 2. Locations of the centers of CBC circles used in analyses.

RESULTS AND DISCUSSION

Temporal patterns in population changes

We began by asking the basic question: Do Christmas Bird Count data show declines in bird populations that might be attributable to the effects of West Nile virus? As a simple first approach, we examined temporal changes in CBC counts of ten resident species in six northeastern states over the ten years preceding the 1999 arrival of WNV to North America and the four subsequent years (Figure 3). We reasoned that a WNV effect strong enough to warrant conservation concern would manifest itself as a detectable decline, beginning in 1999 and increasing over subsequent years as WNV spread further throughout our study area. In light of the apparent disappearance of WNV from many counties in 2001 and its reappearance in 2002 (Figure 1), a population increase in 2001 could also be consistent with a WNV effect. We summarize our examination of Figure 3 for these patterns as follows.

Despite an overall long-term increase in population size, Red-tailed Hawks showed post-WNV population decreases in 2000 and 2002, separated by an increase in 2001 (Figure 3a). Although this is at least consistent with a hypothesized WNV effect, a similarly strong decline occurred in 1996.

Great Horned Owls show declines since 1998 (except for 2001) whether owling-intense CBC circles are included (Figure 3b) or not (Figure 3c); further, these declines reversed general upward trends over the preceding decade. These patterns are highly consistent with predictions for WNV effects. However, owl populations also declined in 1996.

Downy Woodpecker populations have maintained relative stability over the study period (Figure 3d), with small declines in three of the four WNV years and a small increase in 2001, yet they also declined in 1996 and particularly in 1990.

Both chickadees (species combined; Figure 3e) and White-breasted Nuthatches (Figure 3f) show steep declines in 2000 and 2002 and compensatory increases in 2001, and the years subsequent to WNV appear particularly variable, yet population sizes for these years do not differ greatly from those of years prior to WNV. Note that both of these species also declined in number between 1995 and 1996.

Blue Jays have been anecdotally purported to be particularly vulnerable to WNV, but in contrast to large fluctuations in population sizes prior to WNV (declines in 1994, 1996, and especially 1990, and sharp increases in 1993 and 1995), Blue Jay populations in the years subsequent to the arrival of WNV have remained remarkably consistent in size (Figure 3g).

American Crows, the harbingers of the arrival and spread of WNV in North America, are highly susceptible to the virus (Komar et al. 2003). Thousands of dead crows have been collected since 1999, and studies suggest that some resident populations have been severely affected by WNV-induced mortality. The entire data set of crow counts indeed shows an unprecedented and sustained decline since 1999 (Figure 3h). Also noteworthy is the marked decrease in variance among circles (shown as smaller standard error bars) in recent years, suggesting that the decline is due in part to fewer, or smaller, foraging flocks, winter roosts, or pre-roost aggregations being included in recent counts. In an attempt to remove the influence of migratory crows, we plotted a second data set excluding the largest absolute counts. Here, although a slight recent decline reverses a previous long-term increase,

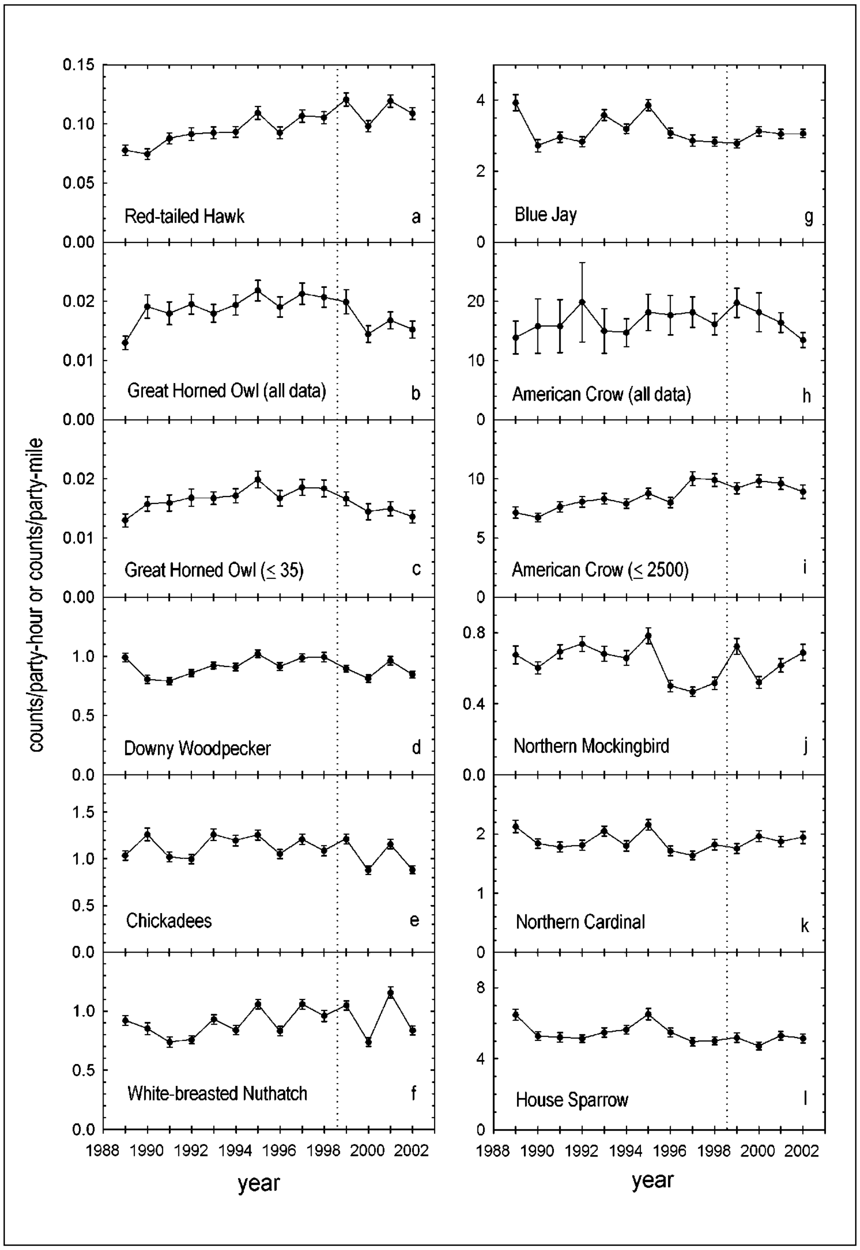


Figure 3. Population trends, as indicated by Christmas Bird Count data, in 12 data sets for 10 species of birds from 1989 through 2002. Shown are annual means ± 1 standard error (n ≤ 191 CBC circles) of bird counts normalized for either party-hours or party-miles (see text). The vertical dotted lines denote the arrival of West Nile virus in North America, preceding the 1999 CBC.

the trend subsequent to WNV is relative stability (Figure 3i).

Plots for the remaining passerine species (Northern Mockingbirds, Northern Cardinals, and House Sparrows) share some features in common: no suggestion of a WNV effect, a good year in 1995, and relatively steep declines in 1990 and 1996. Mockingbird populations also peaked temporarily in 1999.

In general, we found only weak support for the hypothesis of a strong effect of WNV on bird populations. Although several species declined steeply in 2000 (Figures 3a,b,e,f,j), the second year of WNV in North America and a year of considerable spread throughout our study area (Figure 1), similar synchronized declines occurred in 1990 and 1996, some of which were even more severe than declines in 2002. (The presumably climatic causes of those declines are outside the scope of this article, but worthy of elucidation.) Only the data sets for Great Horned Owls (Figures 3b,c) and the larger set for American Crows (Figure 3h) appear to indicate population declines possibly attributable to the spread of WNV.

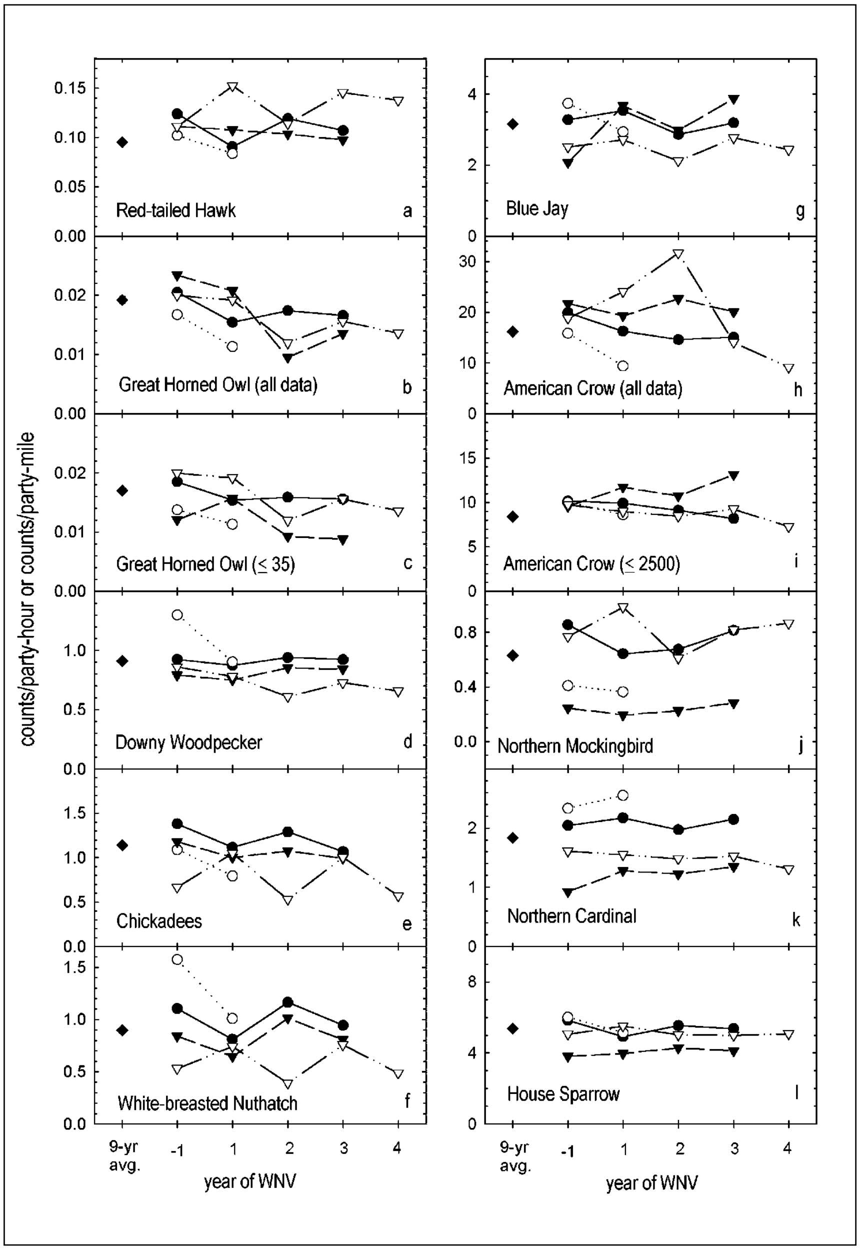


Figure 4. Population trends, as indicated by Christmas Bird Count data, in 4 subsets of 12 data sets for 10 species of birds, with data aligned relative to the local arrival of West Nile virus (see text). Mean normalized CBC counts are depicted for the year preceding and up to four years following local arrival of WNV, with the long-term (9-year) previous mean as a benchmark. Symbols: filled diamond, the mean CBC count for all circles and years from 10 to 2 years prior to the local arrival of WNV (n ≤ 191 circles); open circles (subset 1), CBC circles with only one year of WNV presence (n ≤ 38); filled circles (2), CBC circles with three continuous years of WNV presence (n ≤ 72); open triangles (3), CBC circles with four continuous WNV years (n ≤ 36); filled triangles (4), CBC circles with two WNV-positive years separated by a year in which it was not detected via the WNV Surveillance System (n ≤ 35).

Population changes relative to local West Nile virus status

Our preliminary examination of annual CBC counts (Figure 3) included several years (1999–2001) during which WNV had not yet reached large regions of our study area. It was therefore possible that a subtle but consistent effect of WNV on local bird populations could have been obscured by pooling counts for regions with and without local WNV presence. We thus used surveillance data obtained from the CDC to realign the CBC count data for each circle relative to the first year of documented local (county) WNV presence, instead of by calendar year. Our intention was to compare changes in mean counts between the years before and after the arrival of WNV. However, realignment by the timing of WNV arrival resulted in different groups of circles being included in different "years," and consequent differences in sample sizes. We therefore plotted means for four subsets of the data for each species: 1) circles in counties where WNV first arrived in 2002, 2) circles in counties where WNV arrived in 2000 and persisted over the next two years, 3) circles in counties where WNV arrived in 1999 and persisted over the next three years, and 4) circles in counties where WNV arrived in 2000, was not recorded in 2001, and reappeared in 2002 (Figure 4). (Only eight circles were located in counties where WNV arrived in 2001; the means for this subset are not shown.) We predicted that these plots would reveal a WNV effect by exhibiting 1) consistent declines in population sizes in the first or second years of local WNV presence (i.e., parallel decreases in all subsets between "years" -1 and +1, or +1 and +2) and 2) a difference in temporal pattern between subset 4 and the other subsets (specifically, a possible Year 2 increase in subset 4 versus continuing declines in subsets 2 and 3).

Examination of Figure 4 yields few robust examples of the predicted effects of WNV. Great Horned Owls (Figure 4b) declined consistently among subsets of the data in the first year following the arrival of WNV, and all subsets eventually dropped below the long-term mean, but the "Year 2" difference between subsets 2 and 4 was in the direction opposite from that predicted (i.e., the population declined where WNV "disappeared" and remained stable where the virus persisted). The count-limited dataset for owls (Figure 4c) was more ambiguous. Blue Jays (Figure 4g) did not decline over the first or third years of WNV, but did decline consistently over the second year, even in counties from which WNV disappeared in 2001. The count-limited data for American Crows (Figure 4i) suggest a general post-WNV decline, except in circles where WNV disappeared for a year. Otherwise, these plots do not suggest a strong effect of WNV on early winter populations of these bird species in this area. Recent counts are all consistent with long-term, pre-WNV means. In several cases, evident declines are calendar-year decreases that here are staggered over different "WNV years" for the data subsets. For example, in White-breasted Nuthatches (Figure 4f), the decline in subset 3 between WNV years 3 and 4 is also manifested in subsets 2 and 4 between WNV years 2 and 3, and in subset 1 between years -1 and +1. We interpret such consistent calendar year effects (in this case, the decline between 2001 and 2002) as more likely due to climatic conditions than to WNV.

To summarize, qualitative analyses of the data presented in Figures 3 and 4 do not indicate a strong negative effect of WNV on populations of these resident bird species of the northeastern United States. Only Great Horned Owls and American Crows exhibited temporal patterns that were even suggestive of such an effect.

Relationships between population changes and indices of West Nile virus

If the relatively weak patterns we discerned in the data for owls and crows did, in fact, reflect an effect of WNV, we predicted that year-to-year population changes should track the local intensity of WNV activity. This prediction was tested by correlating annual population changes with annual, county-based indices of WNV prevalence among humans and the proportion of surrounding counties that reported WNV presence during that year. We expressed population changes in both absolute (birds/party-mile) and relative (percent) terms, and examined the correlations for all changes and for declines only. We report only relative changes, the more meaningful of the two measures.

Although a few correlations are "statistically significant" (Table 2), suggesting a possible link between population changes and local WNV intensity, all of the relationships were quite weak ($r \leq 0.15$, $P \geq 0.02$); too weak to survive Bonferroni adjustment. We conclude that there is no strong linkage between available indices of WNV intensity and CBC-documented changes in bird populations.

CONCLUSIONS

We tried by three graphical and statistical methods to elucidate an effect of West Nile virus on early winter bird populations in the northeastern United States, as monitored by Christmas Bird Counts. Despite some suggestive hints, we were unable to demonstrate effects warranting conservation concern for any of the ten species examined. Even the species exhibiting population declines most consistent with a hypothesized WNV effect (chiefly Great Horned Owls and American Crows) yielded only suggestive, not persuasive, evidence.

These negative results may be truly indicative of a lack of large-scale negative effects of WNV on North American bird populations. That would be good news. However, in light of the acknowledged inherent weaknesses of CBC data, it is necessary to consider other potential reasons for false negatives.

Perhaps, for example, the early winter data provided by the CBC are not appropriate for detecting declines in breeding populations; individuals of even traditionally nonmigratory species may move around during the winter.

Table 2. Correlations between annual relative changes in mean CBC counts (percent change) and two potential indices of local (county) West Nile virus activity: the number of reported human cases (including zeros) and the proportion of surrounding counties reporting WNV presence. Shown are Pearson correlation coefficients (r) and (in parentheses) the corresponding P value.

Data set	All changes		Declines only	
	Human cases	Surrounding counties	Human cases	Surrounding counties
Great Horned Owl (all data)	-0.027 (0.581)	0.041 (0.406)	0.106 (0.108)	-0.067 (0.312)
Great Horned Owl (< 35)	-0.019 (0.701)	0.050 (0.318)	0.107 (0.103)	-0.069 (0.293)
American Crow (all data)	-0.026 (0.549)	-0.072 (0.103)	-0.122 (0.043)	-0.138 (0.022)
American Crow (< 2500)	-0.114 (0.020)	-0.093 (0.058)	-0.136 (0.041)	-0.150 (0.025)

Possibly population “floaters”—peripheral individuals without breeding or wintering territories—of some species have moved in to replace lost territory owners, as happens regularly in birds. And perhaps, despite our efforts, persistent variation in crow counts due to migratory individuals and crow sociality, and persistent variation in owl counts due to variable owling effort, are masking underlying patterns of decline. Certainly our negative results for these species are at odds with documented declines within discrete populations of crows (Caffrey et al. 2003; K.J. McGowan, A.B. Clark, and D.A. Robinson, unpublished data) and anecdotal reports of high morbidity and mortality among Midwestern hawks and owls in 2002 (e.g., Hopey 2002).

However, we do not wish to trivialize the contribution that CBC data can make to the ability to track avian population trends. Indeed, our analysis revealed several previously unreported (to our knowledge), relatively large population changes that were synchronized among several species and that beg explanation (e.g., increases in 1995, declines in 1990, 1996, 2000, and 2002; see Figure 3). Thus the lack, so far, of a strong CBC signal associated with the timing of WNV’s arrival and spread constitutes grounds for cautious optimism.

ACKNOWLEDGMENTS

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