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USING THE SPATIAL FILTERING PROCESS TO EVALUATE THE NONBREEDING RANGE OF RUSTY BLACKBIRD *EUPHAGUS CAROLINUS*

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Abstract. During the nonbreeding period, Rusty Blackbird (*Euphagus carolinus*) occurs predominantly in forested wetland habitats in the southeastern U.S. We used spatial filtering of Christmas Bird Count data to identify areas within the nonbreeding range where the species occurs at higher than expected probability. Spatial filtering is an epidemiological modeling process developed to identify concentrations of cases of a phenomenon, and can be tested for statistical significance using Monte Carlo simulations against a null hypothesis that assumes a uniform distribution of the phenomena. Using separate data sets in which cases were identified as "Occurrence of at least 1 Rusty Blackbird" or as "Occurrence of at least 10 Rusty Blackbirds", we developed annual probability estimates of observed occurrence vs null simulations of the existing cases distributed at random among locations at which Christmas Bird Counts were conducted. We were thus able to identify consistent concentrations of Rusty Blackbird occurrence in the Mississippi Alluvial Valley and in the southeastern Coastal Plain of the Carolinas and Georgia. We were also able to identify and eliminate some of the noise in the data that arises from convenience sampling method used in the Christmas Bird Count. Spatial filtering is a method of considerable utility for investigating spatial distribution of birds and comparing the observed distribution with a null expectation.

Key Words: bird distribution mapping and analysis, Christmas bird count, Rusty Blackbird spatial filtering.

COMO SE REALIZA EL PROCESO DE FILTRACIÓN ESPACIAL PARA EVALUAR EL RANGO NO REPRODUCTIVO DEL ICTÉRIDO *EUPHAGUS CAROLINUS*

Resumen. Durante el periodo no reproductivo el ictérido *Euphagus carolinus* ocurre mayormente en bosques pantanosos del sureste de los EEUU. Aplicamos un análisis espacial de filtración a los datos de Conteos Navideños para identificar áreas adentro del rango no reproductivo a donde se ocurre el ictérido con una probabilidad más alta que la esperada. La filtración espacial es un proceso de modelaje desarrollada para la epidemiología en donde se identifican concentraciones de ejemplares del fenómeno que se probó por su significado estadístico utilizando simulación Monte Carlo contra un modelo nulo en que se asume una distribución uniforme de los fenómenos. Identificamos bases separadas de datos por casos de "Ocurrencia de al menos un ictérido" o de "Ocurrencia de al menos diez ictéridos" por Conteo Navideño. Hicimos cálculos anuales de probabilidad de datos realizados vs. simulaciones nulas de número realizado de casos distribuidos al azahar dentro de lugares de Conteos Navideños realizados en mismos años. Pudimos identificar ocurrencia regular de concentraciones de *Euphagus carolinus* en bosques húmedos de tierras bajas dentro del valle del Rió Mississippi y en la planicie costera de Georgia y las Carolinas. También pudimos identificar y eliminar algo de la variación ya existente en datos de Conteos Navideños introducida por la distribución no al azahar de lugares muestreados. Filtración espacial es una técnica muy útil para investigar la distribución espacial de aves y poder comparar una distribución realizada con un pronóstico nulo.

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INTRODUCTION

The importance of events in the nonbreeding period for bird population regulation is undeniable (Greenberg and Marra 2005), and has long been an important part of the management of waterfowl populations (North American Waterfowl Management Plan, Plan Committee 2004). For Neotropical-Nearctic migratory species events on the nonbreeding grounds have been shown to influence breeding readiness and distribution (Norris et al. 2004); for short distance migrants we should expect similar influences as well (Drent et al. 2006, Lehikoinen et al. 2006).

Rusty Blackbird (*Euphagus carolinus*) is a short-distance migratory bird that breeds in North American boreal forests and spends the nonbreeding residency period in the southeastern U.S. (Avery 1995). Nonbreeding habitats primarily are associated with forested wetland and bottomland hardwood forest systems (Avery 1995). Concern exists for the future persistence of this species because of demonstrated population declines (Greenberg and Droege 1999, Niven et al. 2004, Hamel et al. 2009). Access to Rusty Blackbirds for study occurs primarily in the nonbreeding period, and breeding season monitoring is difficult (Greenberg et al. 2009). The Christmas Bird Count (CBC; Arbib 1981) is a readily available data set for analyzing population trends (Sauer and Link 2002, Link et al. 2006) and possibly evaluating habitat trends as well. Nevertheless, because the distribution of CBC circles reflects the interests of those who established them and the distribution of the human population, it is a decidedly nonrandom sample of the North American continent.

Analysis of clusters of event occurrences using data from a non-randomly sampled spatial distribution is a commonly encountered problem in epidemiology (Martinez-Piedra et al. 2004). We use information from the annual CBC to evaluate the dynamics of Rusty Blackbird distribution across the nonbreeding range. We use methods common in epidemiological investigation to examine the annual distribution of Rusty Blackbirds in the nonbreeding period, provide evidence that the species distribution is indeed dynamic, and show that within the annual dynamics a set of concentrations of occurrence can be defined objectively and mapped.

METHODS

Bird Data

We obtained the CBC data for the Rusty Blackbird from 1900–2001, including the numbers of birds encountered on each count in each year (National Audubon Society 2002). CBC is a system of annual volunteer counts conducted in late December or early January on study areas defined to be circles 15-mi in diameter. Each count represents the efforts of a variable number of observers who spend at least eight hours counting as many birds as they are able to find within the circle on a single calendar day (Butcher 1990). We further obtained lists of all CBCs that were conducted in each year. Because 1946 was the first year in which approximately 100 (n = 99) CBCs were conducted, we used CBC data from 1946–2001 as our sample. In earlier years the data were too sparse for useful analysis. We further confined our analysis to that group of CBC circles that encountered at least one Rusty Blackbird in at least one year; that is, we excluded from consideration those CBC circles that did not record a Rusty Blackbird in any year. The total sample included 1755 CBC circles.

For each year we compiled two data sets, comprised of a) all CBCs in which at least one Rusty Blackbird was encountered during that year (presence–absence data set), and b) all CBCs in which at least 10 Rusty Blackbirds were encountered during that year (minimum abundance data set). Ten Rusty Blackbirds is approximately the median count of Rusty Blackbirds in the entire data set (median = 7, mean = 724 ± 141 SE, n = 13 802) and, as such, distinguishes those CBCs that in a given year demonstrated a greater than median abundance of Rusty Blackbirds from those CBCs that merely recorded incidental occurrences of the species.

Spatial Filtering Process

We carried out the spatial filtering analysis of the Rusty Blackbird CBC data using the Distance Mapping and Analysis Program (DMAP), freely available software developed at the University of Iowa (Department of Geography, University of Iowa 1997). (Note: The use of trade or firm names in this publication is for reader information and does not imply endorsement by the United States Department of Agriculture of any product or service.) The spatial filtering methodology (Rushton and Lolonis 1996, Talbot et al. 2000) employs non-parametric statistical techniques as a tool in exploratory spatial data analysis. This method has been used to study clusters of birth health outcomes in epidemiological research (Ozdenerol et al. 2005). It works well with both aggregated data and individual point data. The method has also been incorporated into other software, such as Satscan (Spatial and Temporal Scan Software 2005)

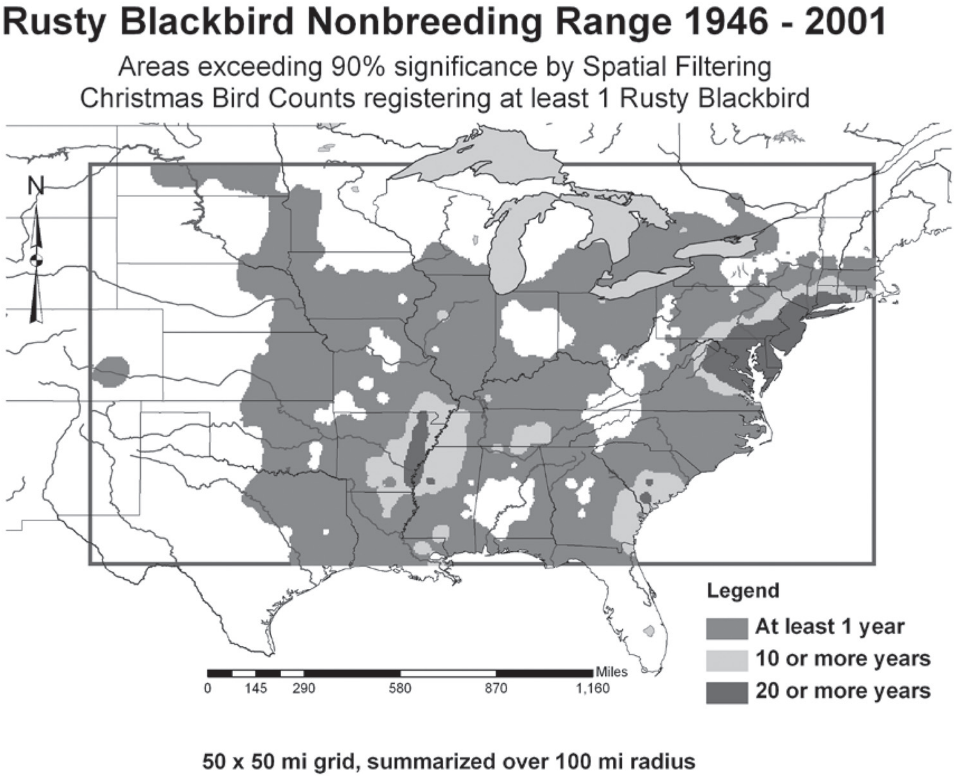

FIGURE 1. Nonbreeding distribution of Rusty Blackbird, determined by spatial filtering analysis of presence-absence of the species on Christmas Bird Counts 1946-2001. Different shading reflects those portions of the range in which the species was recorded at significantly high rates in at least one, at least 10, and at least 20 years. Spatial filtering was accomplished by evaluating occurrence within a 100-mi radius of each intersection point of a 50 mi x 50 mi grid superimposed on the area. Heavy line outlines rectangle of the grid.

Three sorts of data are required for spatial filtering analysis, a) a background grid of points, b) a set of potential occurrences, and c) a set of observed cases. We established the background grid against which we assessed the presence or minimum abundance of Rusty Blackbird. This was a rectangular area extending from 29°51′N to 47°13′ N and 71°W to 105°6′W within which we established intersection points at 50 x 50 mi intervals. This rectangular grid of 929 points approximated the nonbreeding range as Avery (1995) mapped that entire range, and extends generally from North Dakota in the northwest to southern Quebec in the northeast to northern Florida in the southeast to western Texas in the southwest (Fig. 1). Our grid did not cover the entire range. We used the same grid for all years of the analysis, and followed the example of Baldy (2005) in using a spatial filter of 100 mi.

For each year, we conducted two spatial filtering analyses, one each for the presence–absence data set and the minimum abundance data set. The set of potential occurrences consisted of that group of CBCs that were conducted in that year and was the same for each spatial filtering analysis in that year. The set of observed cases consisted of that group of CBCs where the Rusty Blackbird was recorded, either the presence–absence or the minimum abundance data set.

Statistical Analyses

Each spatial filtering analysis begins with a calculation of the proportion of CBCs within 100 mi of each grid point that recorded the appropriate number of Rusty Blackbirds. This number is the Observed Rate of Occurrence. The second step in the analysis is a set of 1000 Monte Carlo simulations of the observed data for each year. In each simulation, a number of cases equivalent to those observed overall in that year is randomly reassigned to locations in the set of potential occurrences, and a distribution of Simulated Rates of Occurrence is calculated for each of the points in the grid, as follows. Upon completion of the set of simulations, a significance value is calculated for each point as the probability of the Observed Rate of Occurrence based upon the distribution of Simulated Rates at that point. For each of the 929 grid point locations, 1000 Monte Carlo simulations were made and the 1000 different Rusty Blackbird simulated rates of occurrence were rank-ordered. The percent of the simulated rates of occurrence at each grid location that was less than the observed rate for the same grid location was the level of statistical significance for the grid location in that year. These levels of statistical significance were portrayed as isolines. Because testing the Observed Rates of Occurrence against 1000 simulations is a form of exploratory spatial analysis, methods of representing the results are discretionary, and the investigator can adjust the results based on level of significance. For example, the isolines representing the significance levels of 80%, 85%, 90% and 95% could be color-coded. These probabilities, portrayed as isarithmic maps, show areas that have significantly high rates of Rusty Blackbird occurence. The isarithmic maps have many advantages in comparison with other conventional thematic maps that provide an indication of the level of occurrence by area. They are not constrained by the borders of geographic units, and sudden transitions between levels of two neighbouring areas are avoided.

We interpolated between the points of the grid to develop the isarithmic maps using the inverse distance-weighting function in ArcMAP 9.2 (ESRI 2006). A separate interpolation was conducted for each data set (presence–absence or minimum abundance) for each year of the analysis (1946–2001). From the interpolated surfaces, we then developed a set of polygons that represented the area in the appropriate year-data set combination, in which Rusty Blackbirds were recorded at higher than 90% significance. The set of these polygons for a given year is the set of clusters of significant occurrence for the species in that year.

We aggregated the significant occurrence clusters for each year into a union set of all years, which indicates that portion of the nonbreeding range in which the species occurred at significantly higher than expected frequency or minimum abundance in at least one year. We further aggregated the clusters for each year into an intersection set that comprised those areas where the species occurred at higher than expected frequency or minimum abundance in at least 10 and 20 years of the 1946–2001 period. We chose these periods to illustrate the capability of the technique. As such, the periods are arbitrary. Choosing time periods that are much longer than the 20-year period, however, would reduce the generality of the results given that some CBC that routinely recorded Rusty Blackbird were not sampled for many more years than that length of time.

RESULTS

Significant concentrations in the nonbreeding range of the Rusty Blackbird determined from the presence–absence data set indicate that the birds have occurred at least once at unlikely high frequency in virtually the entire range, with the exception of the upper Great Lakes, northern New England, and the Central Plains (Fig. 1). Within this pattern, the birds occurred at significantly high frequency in at least 20 years in the central Mississippi Alluvial Valley in Arkansas and Mississippi, in the Southeastern Coastal Plain in South Carolina, and in the Middle Atlantic States from Chesapeake Bay to Connecticut. Concentrations extended to the limits of the grid across the southern boundary from Texas to Florida, and along the northern boundary in North Dakota, indicate that the extent of the grid was too small to include the entire union set of significant concentrations.

When consideration was limited to the minimum abundance data set, the entire depicted range was more compact and more southern, with the exception of an extension to the northwest edge of the grid in the Dakotas and another into the vicinity of Lake Erie and southern Lake Huron (Fig. 2). Within this pattern, the birds occurred at significantly high frequency in at least 20 years in five areas: the Chesapeake Bay watershed; the Southeastern Coastal Plain in South Carolina and Georgia; the middle Tennessee River Valley in Alabama, Georgia, and Tennessee; the Mississippi Alluvial Valley from the confluence of the Ohio River to the Louisiana state line; and the Arkansas River Valley on the Kansas-Oklahoma border (Fig. 2). Areas of significant abundance here reached the southern limit of the grid in south Louisiana, and along the south Atlantic Coast in northern Florida. Other areas in the Middle Atlantic States prominent in the presence–absence analysis did not appear in the analysis of the minimum abundance data set.

DISCUSSION

Investigation of the distributional dynamics of migratory birds is a difficult process because of the great difficulty of adequately sampling the distribution and summarizing variability in space. Understanding these dynamics requires an objective, explicit method to model

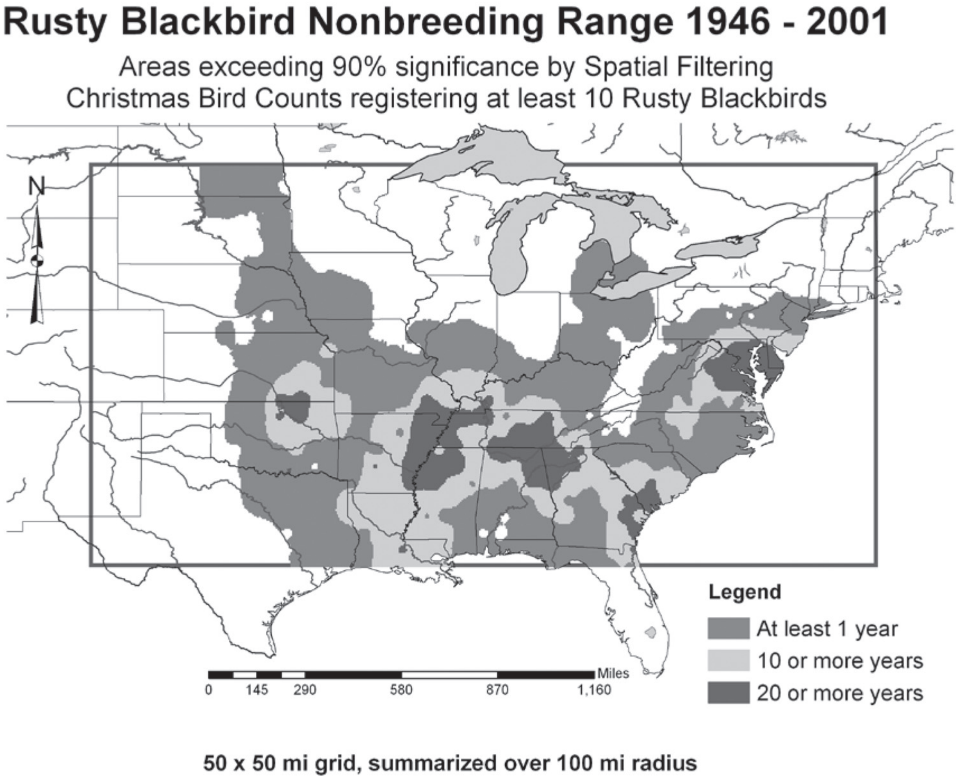

FIGURE 2. Nonbreeding distribution of Rusty Blackbird, determined by spatial filtering analysis of counts reporting a minimum abundance of at least 10 individuals of the species on Christmas Bird Counts 1946-2001. Different shading reflects those portions of the range in which the species was recorded at significantly high rates in at least one, at least 10, and at least 20 years. Spatial filtering was accomplished by evaluating occurrence within a 100-mi radius of each intersection point of a 50 mi x 50 mi grid superimposed on the area. Heavy line outlines rectangle of the grid.

distributions in space; explaining the dynamics further necessitates a method to associate them with covariates. Baldy (2005) was able to show both annual variation in distribution of Cerulean Warblers (*Dendroica cerulea*) within the range sampled by the Breeding Bird Survey (Robbins et al. 1986), a consistent core area of the range, and to relate climatic correlates to that variation.

CBC is a particularly vexing data set for analysis of trends because the distribution of samples varies from year to year in a haphazard manner and the intensity of survey effort in the field varies in amount, distribution, and quality within individual CBCs also annually and unpredictably (Butcher and McCulloch 1990). Attempts to address these issues of variable effort have been made, with some success (Link and Sauer 1999a, Butcher and Niven 2007). Further complicating the situation are changes in protocol that have been instituted since the earliest CBC were conducted. Perhaps most relevant to the sampling here is the lack of systematic reporting of effort in CBC conducted before 1965. We ignored this in our choice of samples, on the grounds that species presence–absence on CBCs is robust with respect to major variations in survey effort. We assume that the effect of variation in effort and in reporting effort, which is more likely to affect our minimum abundance data set, has only a minor effect on the distribution of areas of high concentration in 10 or 20 years (Fig. 2).

The present effort employs one explicit method to model and map the annual dynamics of nonbreeding distribution of Rusty Blackbird. Extensive variability characterizes the early winter distribution of this species in the southern U.S. over the period 1946–2001. Our choice of a 90% significance level, combined with the 50-year length of sample period, implies that all portions of the modeled range would, by chance, appear at unlikely high significance in approximately 5 years. That some areas never do so indicates portions of the grid area that likely lie outside the nonbreeding range of the species. Because we excluded from consideration CBCs that never recorded a Rusty Blackbird, it is further possible that such particular locations occurred within areas mapped as areas of expected occurrence in certain years. Including all CBCs within the grid rectangle as potentially available to the simulation would permit an examination of this situation; we did not do that examination.

Consideration of all CBCs that reported at least one Rusty Blackbird shows that the majority of the persistent concentration of occurrences exists along the Middle Atlantic Coast from southern Virginia to eastern Connecticut and in the southern Mississippi River Alluvial Valley. When the data set is reduced to consider only counts that reported concentrations of at least 10 Rusty Blackbirds, only that portion of the Middle Atlantic Coast concentration surrounding the Chesapeake Bay remains, and the area of the concentration mapped in the southern Mississippi River Alluvial Valley is reduced. We suggest that the difference between the two depictions shows the effect of greater intensity of sampling in a portion of the range where the birds are present but not particularly abundant, along the Middle Atlantic Coast, and to depict clearly those portions of the range where the birds are more abundant. Thus, this technique of comparing presence–absence with more concentrated abundance serves to indicate spatially those areas in which the nonrandom distribution of CBC circles serves to bias our understanding of the nonbreeding distribution of the species. The problem of variable survey effort in the CBC has been addressed by Link and Sauer (1999b).

In both analyses (Figs. 1, 2) a gap in the distribution appears to coincide approximately with the Appalachian Mountains, indicating a potential division between eastern and western populations of Rusty Blackbirds (Avery 1995). Similarly, we speculate that the pattern of occurrence in at least one year depicted for the minimum abundance data set (Fig. 2) may indicate migratory pathways of the species. Because the CBC is conducted early in the winter, we suspect that some areas in the northern part of the grid we examined are occupied only in the early part of the season, and for this reason may represent migratory pathways along which the birds lingered into the CBC season in some year. Spatial filtering analysis can be extended to incorporate environmental data. For instance, incorporating elevation in these spatial filtering models may be useful in testing the division apparently caused by the Appalachian Mountains. We suggest that investigating Rusty Blackbird early winter distribution in relation to weather conditions at the time and in the preceding autumn period through spatial filtering may provide insight into the movements of this species in relation to weather variability that would be difficult to examine otherwise.

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LITERATURE CITED

Arbib, R. S. 1981. The Christmas Bird Count: constructing an "ideal model", pp. 30–33. *In* C. J. Ralph and J. M. Scott, [eds.], Estimating Numbers of Terrestrial Birds, Studies in Avian Biology 6.

Avery, M. L. 1995. Rusty Blackbird (*Euphagus carolinus*). *In* A. Poole and F. Gill [eds.], The Birds of North America, No. 200. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Baldy, J. J. 2005. Climate preferences of the Cerulean Warbler on Summer Territory. M.S. thesis, University of Memphis, Memphis, TN.

Butcher, G. S. 1990. Audubon Christmas Bird Counts. *In* J. R. Sauer and S. Droege, [eds.], Survey designs and statistical methods for the estimation of avian population trends. U.S. Department of Interior, U.S. Fish and Wildlife Service Biological Report 90(1):5–13. Washington, D.C.

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

Butcher, G. S., and D. K. Niven. 2007. Combining data from the Christmas Bird Count and the Breeding Bird Survey to determine the continental status and trends of North America birds. National Audubon Society, New York, NY. [Online.] <http://www.audubon.org/bird/stateofthebirds/CBID/report.php> (30 March 2009).

Department of Geography, University of Iowa. 1997. Distance Mapping and Analysis

Program (DMAP). [Online.] <http://www.uiowa.edu/~geog/health/demo/dmap.html> (1 August 2008).

Drent, R., A. D. Fox, and J. Stahl. 2006. Travelling to breed. Journal of Ornithology 147:122–134.

ESRI. 2006. ArcGIS 9, ArcMAP 9.2. ESRI. Redlands, CA.

Greenberg, R., and S. Droege. 1999. On the decline of the Rusty Blackbird and the use of ornithological literature to document long-term population trends. Conservation Biology 13:553–559.

Greenberg, R., and P. Marra [eds.]. 2005. Birds of two worlds. Johns Hopkins University Press. Baltimore, MD.

Hamel, P. B., D. De Steven, T. Leininger, and R. Wilson. 2009. Historical trends in Rusty Blackbird nonbreeding habitat in forested wetlands, pp. 341–353. *In* T. D. Rich, C. Arizmendi, D. W. Demarest, and C. Thompson [eds.], Tundra to Tropics: Connecting Birds, Habitats and People. Proceedings of the 4th International Partners in Flight Conference, 13–16 February 2008. McAllen, TX. Partners in Flight.

Lehikoinen, A., M. Kilpi, and M. Öst. 2006. Winter climate affects subsequent breeding success of common eiders. Global Change Biology 12:1355–1365.

Link, W. A., and J. R. Sauer. 1999a. On the importance of controlling for effort in analysis of count survey data: modeling population change from Christmas Bird Count data. Vogelwelt 120:S15–S20.

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

Link, W. A., J. R. Sauer, and D. K. Niven. 2006. A hierarchical model for regional analysis of population change using Christmas Bird Count data, with application to the American Black Duck. Condor 108:13–24.

Martínez-Piedra, R., E. Loyola-Elizondo, M. Vidaurre-Arenas, and P. Nájera Aguilar. 2004. Software programs for mapping and spatial analysis in epidemiology and public health. Epidemiological Bulletin of the Pan American Health Organization 25:1–9.

National Audubon Society. 2002. The Christmas Bird Count Historical Results. [Online.] <http://www.audubon.org/bird/cbc> (30 January 2003).

Niven, D. K., J. R. Sauer, G. S. Butcher, and W. A. Link. 2004. Christmas Bird Count provides insights into population change in land birds that breed in the boreal forest. American Birds 58:10–20.

Norris, D. R., P. P. Marra, T. K. Kyser, T. W. Sherry, and L. M. Ratcliffe. 2004. Tropical winter habitat limits reproduction success in a migratory bird. Proceedings of the Royal Society of London, Series B 271:59–64.

North American Waterfowl Management Plan, Plan Committee. 2004. North American Waterfowl Management Plan 2004. Implementation Framework: Strengthening the Biological Foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambiente y Recursos Naturales.

Ozdenerol, E., B. Williams, S. Kang, and M. Magsumbol. 2005. Comparison of spatial scan statistic and spatial filtering in estimating low birth weight clusters. International Journal of Health Geographics 4:19.

Robbins, C. S., D. A. Bystrak, and P. H. Geissler. 1986. The Breeding Bird Survey: its first fifteen years, 1965–1979. U.S. Department of Interior, U.S. Fish and Wildlife Service Resource Publication 157. Washington, D.C.

Rushton, G., and P. Lolonis. 1996. Exploratory spatial analysis of birth defect rates in an urban population. Statistics in Medicine 15 (7-9):717–726.

Talbot, T. O., M. Kulldorff, S. P. Forand, and V. B. Haley. 2000. Evaluation of spatial filters to create smoothed maps of health data. Statistics in Medicine 19 (17-18):2399–2408.

Sauer, J. R., and W. A. Link. 2002. Using Christmas Bird Count data in analysis of population change. American Birds 56:10–14.

Spatial and Temporal Scan Software. 2005. [Online.] <http://www.satscan.org/> (29 July 2008).