J. Field Ornithol., 67(2):254–262

CHANGES IN THE WINTER ABUNDANCE OF SHARP-SHINNED HAWKS IN NEW ENGLAND

CHARLES D. DUNCAN
Institute for Field Ornithology
University of Maine at Machias
9 O'Brien Avenue
Machias, Maine 04654 USA

Abstract.—The number of Sharp-shinned Hawks (*Accipiter striatus*) migrating past Cape May, New Jersey and other coastal localities has shown a sharp decline since the mid-1980s. This decline may reflect a population decrease or could result from an increase in individuals remaining to winter in New England. To test this possibility, 18 yr of New England Christmas Bird Counts (CBCs) for Sharp-shinned Hawks were analyzed using linear and multiple regressions, and factorial analysis of variance. New England was divided into eight geographic blocks, and two CBCs per block were randomly selected from those in existence since at least 1975. After adjusting for observer effort, counts were found to be significantly correlated with year, latitude, and longitude. Overall from 1975–1992, Sharp-shinned Hawks wintering in New England increased by more than 500%. Increases were strongest for the southern and western portions of the region.

CAMBIOS EN LA ABUNDANCIA INVERNAL DE *ACCIPITER STRIATUS* EN NUEVA INGLATERRA

Sinopsis.—Ha sido una declinación en el número de los individuos de *Accipiter striatus* migrando por Cape May, Nuevo Jersey, y otras localidades costales, desde el medio de los 1980s. Es posible que sea una indicación de una declinación en la población total de la especie, pero por otra parte es posible que resulte de un aumento en el número de los individuos quedando en Nueva Inglaterra durante el invierno. Para evaluar esta posibilidad, se analizaron 18 años de conteos invernales de aves (CIAs) de *Accipiter striatus,* usando los métodos de regresión lineal y múltiple, y el de análisis de varianza factorial. Se dividió la superficie de Nueva Inglaterra entre 8 secciones geográficas, y se seleccionaron al azar 2 CIAs en cada sección de los existiendo desde, por lo menos, el año 1975. Se encontraron dependencias de los conteos muy significantes del año, de la latitud y de la longitud. Se descubrió que el número de *Accipiter striatus* invernando en Nueva Inglaterra ha aumentado durante la temporada de 1975 hasta 1992 por mas que los 500%. Los aumentos mas grandes se encontraron en las zonas al sur y al oeste de la región.

Long-term population trends for species at risk from environmental change are inherently important but seldom easy to establish. For raptors, the most tantalizing data for consideration are the many careful counts of southward-migrating individuals conducted at various localities (Bednarz et al. 1990, Kerlinger 1989). Interpretation of such data is not simple, however (Hussell 1985, Kerlinger 1989). Neither is it certain that changes in the number of migrating individuals accurately reflect population changes in the regions from which they depart. Such changes could result from changes in observer methods (Bednarz et al. 1990), or in migratory behavior, such as flight altitude (Kerlinger 1989), route, and percentage of birds remaining north of the count sites (Viverette et al. 1994). This last behavior has been labelled "short-stopping."

Concern has been expressed over the precipitous declines since 1985 in counts of migrating Sharp-shinned Hawks (*Accipiter striatus*) at Cape

May, New Jersey (Kerlinger 1992). Although more recent declines have been reported for other coastal migration monitoring sites (Viverette et al. 1994), their statistical significance has yet to be demonstrated. Even so, these local declines have been assumed to reflect a similar decline in the overall population (Kerlinger 1992, Ellison and Martin 1993).

A variety of factors causing the putative decline has been suggested, including an undemonstrated decrease in populations of songbirds, particularly neotropical migrants, on which Sharp-shinned Hawks prey (Chartier 1994, Kerlinger 1992, Viverette et al. 1994). Kerlinger (1992) hypothesized that declining forest productivity in the Northeast United States and Maritime Canada caused by "acid rain" or pesticide spraying for spruce budworm (*Choristoneura fumiferana*) control may be to blame, but no specific test has yet been conducted. Viverette et al. (1994) considered a variety of environmental contaminants as possible causes of Sharp-shinned Hawk population declines. They measured concentrations of *p,p'*-DDE, a metabolite of the organochlorine pesticide DDT, in migrants trapped at Hawk Mountain, Pennsylvania, but, lacking historic values for comparison, could not determine if the measured levels were capable of interfering with Sharp-shinned Hawk reproduction. It is hard, however, to imagine a mechanism causing concentrations of DDT-related contaminants, and associated reproductive failure, to be higher in recent years than during the decade following the "DDT-era" ending in 1972 (Bednarz et al. 1990).

To test the possibility that the declines observed at Cape May, New Jersey, may be associated with changes in migratory behavior and winter distribution, instead of an overall population decrease, I examined the number of individuals wintering in New England. The breeding ground for Sharp-shinned Hawks migrating past Cape May includes New York, New England, Quebec, and the Canadian Maritime Provinces (Clark 1985). "Short-stopping" of migrating Sharp-shinned Hawks would result in increased numbers in New England. In contrast, an overall population decrease would be reflected in a decline in the number of wintering, as well as migrating, individuals. Viverette et al. (1996) have independently considered the same question, comparing and contrasting the number and source of Sharp-shinned Hawks migrating past Hawk Mountain, Pennsylvania, with those seen at Cape May. They examined the pattern of Sharp-shinned Hawks seen in winter not only north of Cape May and Hawk Mountain, as I did, but also in the southeastern U.S.

STUDY AREA AND METHODS

The data I analyzed were collected during Christmas Bird Counts (CBCs): volunteer-conducted counts of all birds encountered within a pre-defined 25-km diameter circle on a single day within approximately 1 wk of Christmas. As a measure of winter bird populations, the method can be criticized on several grounds (Bock and Root 1981, Butcher et al. 1990, Dunn 1995). Nonetheless, the fact that many counts have been conducted continually for decades makes them the only long-term data

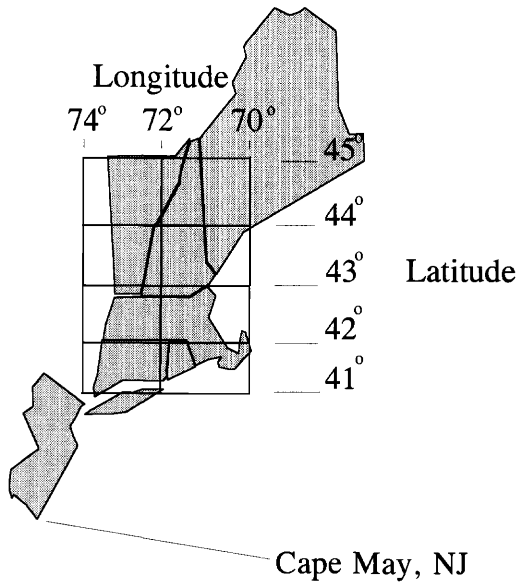

FIGURE 1. Scheme used to stratify New England into eight geographic blocks. Two CBCs were randomly selected within each block.

available for winter distribution of birds in North America. So long as enough count locales are examined to overcome the biases in any one count circle, trends in winter populations are likely to be discernible (Butcher et al. 1990, Drennan 1981). In fact, J. Sauer and B. Peterjohn (pers. comm.) have recently demonstrated significant correlation between continental-scale CBC trends with those based on U.S. Fish and Wildlife Service Breeding Bird Surveys (BBS) strengthening the assumption that CBC results do reflect population changes.

I stratified New England into eight geographic blocks, each 1° of latitude by 2° of longitude (Fig. 1). Within these blocks 45 CBCs established prior to 1976 were still extant in 1992 (published in American Birds, 1975–1992). Using a random number table, I chose two of these CBCs per block, a total of 16 CBCs (Appendix 1). This design allowed me to test the spatial and temporal homogeneity of the counts by determining whether Sharp-shinned Hawk numbers in each geographic block exhibited similar changes across the time period examined. Such an analysis is impossible if only one or two individual sites are studied or if many sites are averaged into a single regression. Using more than two CBCs per block would have shortened the time interval analyzed by one-third (eliminating the earliest 6 years) or required an unbalanced design. Among the more severe drawbacks of the latter are a loss of statistical power and an obscuring of the interpretation of the results of analyses of variance (Wilkinson et al. 1992, Kirby 1993). In particular, the effect of year would be confounded with the effects of latitude and longitude if the number of CBCs per block were unequal.

For the 18 years from 1975 to 1992, I extracted the number of Sharp-shinned Hawks recorded on each of the selected counts along with the number of "party-hours," the standard measure of observer effort for the count. Two CBCs were missing a single year's coverage. For each, the missing data point was estimated as the mean of the preceding and succeeding years' counts. One degree of freedom was removed for each of the counts so estimated (Sokal and Rohlf 1981).

Statistical analyses were performed with SYSTAT (Wilkinson 1992). Linear regression showed that effort (party-hours), was positively correlated with the counts of Sharp-shinned Hawks. Analysis of variance demonstrated that the number of party-hours was independent of year within each geographic block as well as for the pooled collection of all CBCs ($P > 0.5$). I therefore created an effort-adjusted measure of abundance: count-per-100-party-hours (Bock and Root 1981). Within-block homogeneity of variance was tested across blocks and years for effort-adjusted counts, using visual inspection of residual plots, and Levene's test of variance equality. When these methods showed that the assumption of variance homogeneity was violated, the same tests were applied to the square root and logarithm of effort-adjusted counts. These transformations ameliorated but did not entirely remove the lack of homogeneity. Ranked and logarithmically transformed effort-adjusted counts were therefore used for further analyses, and consistently yielded virtually identical results.

Univariate and multiple linear regressions were used to detect trends across time, latitude, and longitude. I also used orthogonal contrasts to examine the effect of latitude. Three such contrasts were required. I compared the mean of the southernmost pair of blocks with the mean of all other blocks. A second contrast involved the comparison of the mean of the next-to-southernmost pair of blocks with the mean of the four blocks to their north, and the final contrast compared the means of two northernmost pairs of blocks.

RESULTS

Both ranked and log–transformed effort-adjusted counts were strongly correlated with year, latitude, and longitude ($P < 0.01$). Two- and three-way interaction terms were not significant ($P > 0.1$). This result suggested the possibility of using analysis of covariance to compare regression equations of effort-adjusted counts against year from each of the eight geographic blocks. Attempts to linearize the data within the various blocks failed, however, precluding the comparison of the regression lines.

The orthogonal contrasts performed on the log-transformed counts showed that the mean of effort-adjusted counts for each pair of geographic blocks at a given latitude was significantly higher than the mean of those to their north ($P < 0.05$). The mean of the four eastern blocks was 58% higher than that of the western blocks, a significant difference ($P < 0.05$).

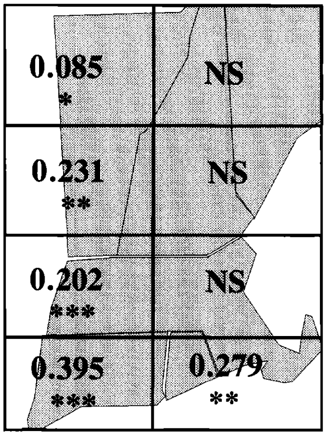

FIGURE 2. Coefficients (hawks/100-party-hours per year) for the regression of CBC counts of Sharp-shinned Hawks with year from 1975 to 1992. Larger coefficients indicate greater increases. Significance levels are shown as $P < 0.05$ *, $P < 0.01$ **, $P < 0.001$ ***.

Multiple regression of count-per-100-party-hours showed that the counts were positively correlated ($r^2 = 0.37$) with year ($P < 0.001$), and negatively correlated with latitude ($P < 0.001$) and longitude ($P < 0.05$). Linear regressions of effort-adjusted counts on year for each geographic block demonstrated significance for five of the eight blocks considered (Fig. 2). Linear regression of pooled effort-adjusted counts from all 16 CBC localities against year was highly significant (Fig. 3; $P < 0.001$, $r^2 = 0.11$), and showed a 515% increase in the counts of Sharp-shinned Hawks per unit effort on New England CBCs from 1975–1992. Finally, the annual mean of the pooled effort-adjusted counts was negatively correlated with the same year's migration count at Cape May, New Jersey (Fig. 4; $P < 0.01$, $r^2 = 0.47$).

DISCUSSION

The greatest numbers of wintering Sharp-shinned Hawks per unit effort were found in the southern portions of the region studied, as expected for a migratory species. Less anticipated, the eastern blocks showed significantly higher counts-per-effort than did the western blocks, perhaps reflecting a preference for coastal sites. The high degree of statistical significance for these ANOVA results, as well as for the overall regression of counts-per-effort across time, demonstrates the appropriateness of the two-CBC-per-block design.

The most important finding of this study is the >500% increase in the number of Sharp-shinned Hawks wintering within the study area. Viverette et al (1996) found not dissimilar results using a different suite of northeastern U.S. CBCs with a different statistical method. Although the effort-adjusted count of wintering birds within the study area was greater

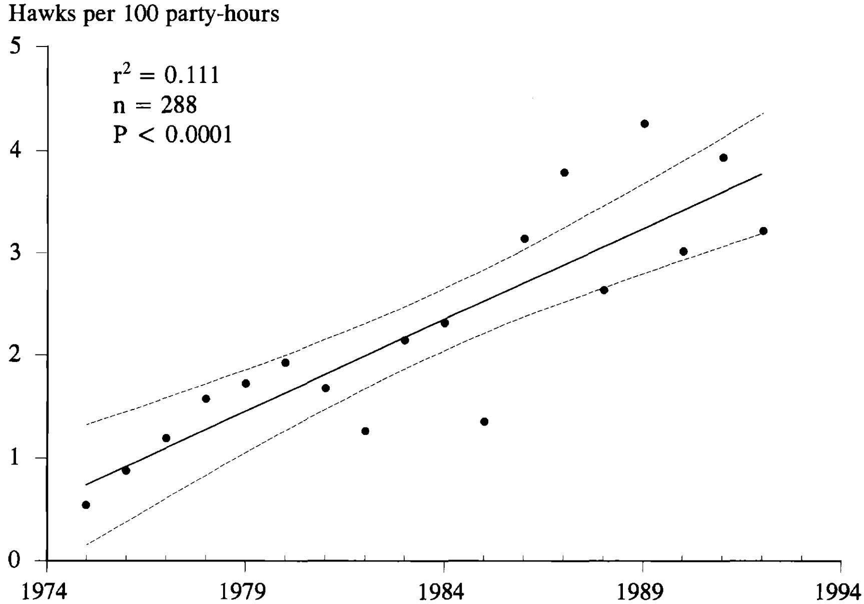

FIGURE 3. New England Sharp-shinned Hawk CBC counts as a function of year. The regression line and significance were calculated from the individual CBCs, but for visual clarity, only the annual means are shown. The dotted curves represent the upper and lower 95% confidence limits.

as one moved south and east, the observed increases over time were strongest in the southern and western blocks. Apparently, there is no simple relation between size of the wintering population and the observed increase in number of wintering Sharp-shinned Hawks over time.

The increase in the New England wintering population may have several causes. It could result at least in part from an increase in the breeding population. No trend significant at the 95% confidence-level has been observed from BBS data for the northeast U.S. (BBS Region 5) either for the period from 1966–1994 (63 routes) or from 1980–1994 (48 routes). Sharp-shinned Hawks, being secretive, uncommon, and not vocal, are not well monitored by such surveys, however, and the number of routes analyzed is small enough to warrant suspicion (B. Peterjohn, pers. comm.).

E. H. Dunn (pers. comm.) has suggested that the numbers of Sharp-shinned Hawks seen on CBCs may be being inflated by increases in numbers of CBC participants watching birds at feeders, where Sharp-shinned Hawks are known predators (Dunn and Tessaglia 1994). She has also mentioned the possibility that Sharp-shinned Hawks may be modifying their behavior, learning to visit feeders more frequently and thereby becoming more detectable both to feeder watchers and field parties. Neither of these possibilities is likely to account for the magnitude and geo-

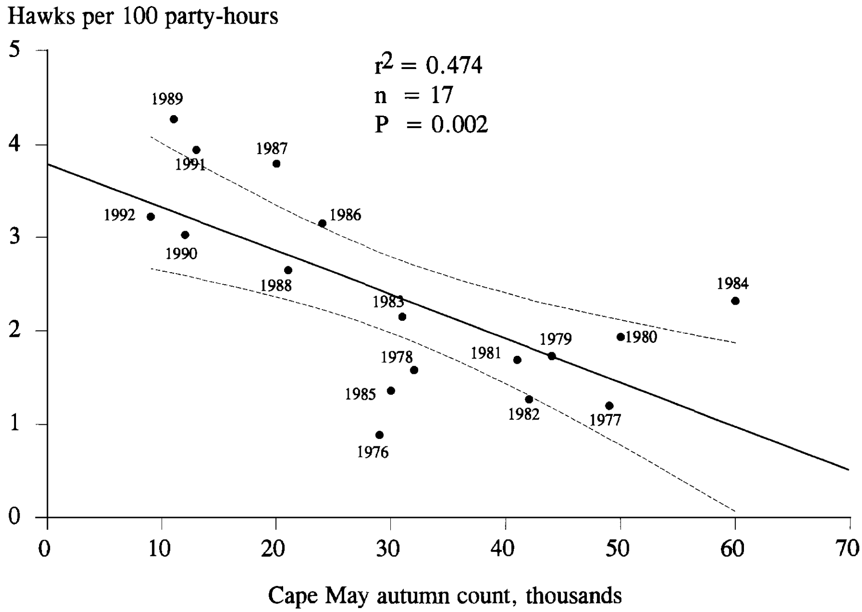

FIGURE 4. New England Sharp-shinned Hawk CBC counts as a function of the same year's autumn migration count at Cape May, New Jersey. The regression line and significance were calculated using the mean of the 16 New England CBCs analyzed. The dotted curves represent the upper and lower 95% confidence limits.

graphic pattern of the changes demonstrated here, however (E. H. Dunn, pers. comm.).

The observed increase in wintering Sharp-shinned Hawks may indeed result from "short-stopping" by Sharp-shinned Hawks, migrating shorter distances or not at all. The New England CBC results show a highly significant negative correlation with the Cape May migration counts of the same year (Fig. 4). The poorer migration years at Cape May are generally associated with the higher totals of Sharp-shinned Hawks wintering in New England, and vice versa. This finding supports the idea that there may have been a change in migratory behavior over the period examined. Such a correlation would not be anticipated if the increases in New England wintering populations merely reflected a growing overall population.

It is tempting to try to estimate the absolute number of individual Sharp-shinned Hawks involved in this increase, that is, the difference in the numbers wintering in 1975 and in 1992. Any such estimate requires knowledge of the ratio of Sharp-shinned Hawks present to those detected on CBCs. The ratio is surely greater than unity, since my results showed that the count of Sharp-shinned Hawks increases with increased observer effort, a finding requiring the presence of uncounted individuals. One thus needs to know the index of detectability of Sharp-shinned Hawks as a function of effort, and there is no reason to believe that this is a linear function. At present then, it is not possible to know if the number of birds now wintering in New England can account, in absolute terms, for those "missing" at Cape May, New Jersey.

Although correlation does necessarily imply causation, the relation between the decline in migrant Sharp-shinned Hawks at Cape May and the increase in numbers of Sharp-shinned Hawks wintering in New England reported here makes it reasonable to argue that the two phenomena are related. Moreover, no matter what its cause, the large increase across time of Sharp-shinned Hawks found per unit effort on New England CBCs is difficult to reconcile with the idea that their population in the area north of Cape May is in "free-fall" (Kerlinger 1992).

ACKNOWLEDGMENTS

The contribution of the many Christmas Bird Count observers whose data were used is greatly appreciated. I thank C. Sutton for calling my attention to this problem. N. Davis extracted the published CBC data. B. Peterjohn was generous in providing BBS data and helping with their interpretation. I am grateful to P. Kerlinger for sharing his Cape May data, to E. Dunn for her thoughtful comments on the use of CBC data, and, particularly, to B. Beal for an education in statistics. These three also made helpful comments on earlier versions of the manuscript, as did D. Tessaglia and an anonymous reviewer. I appreciate K. Bildstein's sharing of a pre-publication manuscript on a related approach to this problem.

LITERATURE CITED

BEDNARZ, J. C., D. KLEM JR., L. J. GOODRICH, AND S. E. SENNER. 1990. Migration counts at Hawk Mountain, Pennsylvania, as indicators of population trends, 1934–1986. Auk 107: 96–109.

BOCK, C., AND T. ROOT. 1981. The Christmas Bird Count and avian ecology. Pp. 17–23 *in* C. J. Ralph and J. M. Scott, eds., Estimating numbers of terrestrial birds, Studies in Avian Biology, No. 6, Cooper Ornithological Society, Lawrence, Kansas.

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 Soc. Bull. 18:129–134.

CHARTIER, A. 1994. Sharp-shinned Hawk declines: an inland perspective. Winging It 6(6): 8–9.

CLARK, W. S. 1985. The migrating Sharp-shinned Hawk at Cape May Point: banding and recovery results. Pp. 137–148, *in* Harwood, M. (ed.), Proc. N. Amer. Hawk Conf. IV, Rochester, N.Y., March 1983. Hawk Migration Assn. N. Am.

DRENNAN, S. R. 1981. The Christmas Bird Count: an overlooked and underused sample. Pp. 24–29, *in* C. J. Ralph and J. M. Scott, eds., Estimating numbers of terrestrial birds, Studies in Avian Biology, No. 6, Cooper Ornithological Society, Lawrence, Kansas.

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

———, AND D. TESSAGLIA 1994. Predation of birds at feeders in winter. J. Field Ornithol. 65:8–16.

ELLISON, W. G., AND N. L. MARTIN. 1993. New England regional report, the autumn migration. Amer. Birds 47(1):62–68.

HUSSELL, D. J. T. 1985. Analysis of hawk migration counts for monitoring population levels. Pp. 243–254, *in* Harwood, M. (ed.), Proc. N. Amer. Hawk Conf. IV, Rochester, N.Y., March 1983. Hawk Migration Assoc. N. Am.

KERLINGER, P. 1989. Flight strategies of migrating hawks. Univ. of Chicago Press. Chicago, Illinois. 375 pp.

———. 1992. Sharp-shinned Hawk populations in a free-fall. The Peregrine Observer 15: 1–2.
KIRBY, K. N. 1993. Advanced Data Analysis with SYSTAT. Van Nostrand Reinhold, New York, New York. 475 pp.
SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry, 2nd ed., W. H. Freeman and Co., New York, New York. 859 pp.
VIVERETTE, C., L. GOODRICH, AND M. POKRAS. 1994. Levels of DDE in eastern flyway populations of migrating Sharp-shinned Hawks and the question of recent declines in numbers sighted. Hawk Migr. Assn. N. Am. Migration Studies, September 1994, 5–7.
———, S. STRUVE, L. J. GOODRICH, AND K. L. BILDSTEIN. 1996. Decreases in migrating Sharp-shinned Hawks (*Accipiter striatus*) at traditional watch sites in eastern North America: a role for migratory short-stopping? Auk 113, in press.
WILKINSON, L. 1992. SYSTAT for Windows, Version 5. SYSTAT, Inc., Evanston, Illinois.
———, M. HILL, J. P. WELNA, AND G. K. BIRKENBEUEL. 1992. SYSTAT for Windows: Statistics, Version 5 Edition. SYSTAT, Inc., Evanston, Illinois. 750 pp.

Received 20 Mar. 1995; accepted 29 Jun. 1995.

APPENDIX 1

Christmas Bird Counts analyzed, arranged by blocks from south to north and east to west.

Count name and state	N. latitude	W. longitude
Newport County, Rhode Island–Westport, Massachusetts	41°32′	71°10′
Buzzard's Bay, Massachusetts	41°39′	70°37′
New Haven, Connecticut	41°18′	72°56′
Hartford, Connecticut	41°46′	72°40′
Worcester, Massachusetts	42°19′	71°47′
Coastal, New Hampshire	42°59′	70°08′
Central Berkshire, Massachusetts	42°24′	73°15′
Athol, Massachusetts	42°35′	72°13′
Biddeford-Kennebunkport, Maine	43°27′	70°28′
Baker Valley, New Hampshire	43°51′	71°53′
Winhall, Vermont	43°10′	73°16′
Hanover, New Hampshire–Norwich, Vermont	43°43′	72°14′
Farmington, Maine	44°42′	70°10′
Erroll–Umbagog, New Hampshire	44°46′	71°08′
Plainfield, Vermont	44°16′	73°16′
Burlington, Vermont	44°28′	73°13′