Spring Migration and Weather in Eastern Canada: A Radar Study

*W. John Richardson**

During the past 15 years, radars have been used to study migration in many areas of Europe and North America. Radars can provide continuous and relatively unbiased information about the density, directions, speeds and altitudes of the migrants. Unfortunately, it is usually impossible to identify the birds being detected. Eastwood (*Radar Ornithology*, Methuen, 1967) reviews the radar technique.

While one can survey migration over an area many miles wide by using a single radar, it is possible to obtain an even broader view by using radars at several sites simultaneously. During the spring in 1970 and 1971 I collected migration data from 14 radar sites in Nova Scotia, New Brunswick, Quebec and northern Ontario. While all 14 sites were not used simultaneously, for six weeks in 1971 I used 12 sites.

This report describes briefly the patterns of spring migration in the area of study. It then explores the relationships between the density and direction of migration and the synoptic weather situation. Later publications will examine these and related data in greater detail.

METHODS AND DATA OBTAINED

I have used three types of information in this report:

(i) From late March to early June in 1970 and 1971 I made time-lapse films of the Plan Position Indicator (PPI) display of a high-powered military surveillance radar at St Margarets, N.B. I obtained similar films from Barrington, N.S. in the spring of 1971. Fig. 2 shows the locations of these radar sites. The direction and speed distributions of the migrants and the amount of migration were evaluated several times each day and night from these films. I have found by simultaneous moon-watching and radar surveillance that the St Margarets radar gives a reliable picture of the density and direction of migration.

(ii) The heights of migrants near St Margarets, N.B. were observed from late April to early June in 1970 and 1971 by direct use of high-powered nodding height finder radars. Eastwood (op. cit.) has described such equipment.

(iii) The directions of the migrants near other military radar sites (Fig. 2) were determined each day and night from April 30 to June 9, 1971 from PPI displays showing digitized radar data. I will discuss the technique and its limitations in detail elsewhere. In summary, it is not possible to estimate the density of migration from such digitized displays. However, the directions of samples of the birds near the sites can often be determined. At night strong echoes from birds flying in flocks (eg., waterfowl and shorebirds) are over-represented in the samples. These birds often fly in somewhat different directions from the passerines, and so the nocturnal digitized data are often directionally biased. During the day almost all bird echoes are quite strong, and I have found no bias in the diurnal directional samples.

HOUR TO HOUR VARIATIONS IN DENSITY

At St Margarets, as in many other parts of North America, there is usually much more migration at night than during the day. The density of migration typically increased rapidly about 45 minutes after sunset. It usually remains fairly constant from about one hour after sunset until after midnight. Then a gradual decrease in density begins. Daytime migration is usually densest in the morning, and decreases in the afternoon. These 'average' patterns can be modified by changing weather conditions. In particular, wind shifts and the onset or cessation of rain usually produce modifications of the average temporal pattern.

HEIGHTS

During the night most spring (and fall) migrants at St Margarets fly below 3500 ft. While accurate measurements are not possible during dense movements, the modal height of nocturnal migration is almost always below

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2000 ft. Nevertheless, on most nights there are a few birds up to 7000 ft. or more. The highest echoes are usually quite intense, and probably represent flocks of waterfowl and shorebirds, not passerines.

The birds climb rapidly at the start of the night. An extreme example occurred at St Margarets in the early evening of May 12, 1971. At that time I filmed a bird echo as it climbed 5100 ft. in 19 minutes while moving seven miles horizontally. The height distribution of the migrants reaches its peak by 1½ or 2 hours after sunset. While comparable data are not available in the spring, in autumn the average height decreases in the latter part of the night.

Well-oriented movements frequently occur under total opaque overcast (eg., nights of April 30 and May 12, 14, 16, 21 and 22, 1971 at St Margarets). The heights of the migrants on these nights were not noticeably different from normal. However during light rain I have occasionally recorded light nocturnal movements unusually high (eg., May 25, 1971). Some of these birds are apparently climbing above the rain.

DIRECTIONS

The predominant direction of the nocturnal spring migration of passerines in the Maritime provinces is to the NE, ENE and even E, not to the N. This is explained by the geography of eastern North America. The "east" coast is actually on a NE-SW line, and to the south of the Maritimes is the Atlantic. Very few birds approach Nova Scotia from the south.

Northward movements in the Maritimes are never as dense as the strongest NE passerine flights. The N movements are composed primarily of intense and fast-moving echoes. Such echoes are typical of waterfowl and shorebirds, not passerines. At night, passerines produce weak, slow-moving echoes.

In Quebec dense movements to the N occur more frequently than they do in the Maritimes. However even there the predominant direction is east of north. The departure from a N-S axis of flight is therefore not simply the result of birds paralleling coastlines that are within visual range.

Radar studies have shown that "reverse" migration is much more common than was once suspected. Movements to the SE, S and SW in the spring are common throughout eastern Canada under certain weather conditions. However these "reverse" movements are rarely as intense as the nocturnal NE movements that occur under optimal weather conditions.

While we commonly speak of "forward" and "reverse" movements, there is no clear dichotomy between them, at least when one looks at all species at once. Over a season, some birds fly in all directions at all sites.

WATER CROSSINGS

Drury and Keith (*Ibis*, 104: 449-489, 1962) have recorded birds departing from Massachusetts across the Gulf of Maine towards Nova Scotia. I frequently record birds over the Gulf of Maine moving NE-E towards western Nova Scotia. These arrivals usually become denser after midnight, when birds that departed from New England soon after sunset begin to move into the coverage area of the Barrington radar. Reverse movements from Nova Scotia back across the Gulf of Maine to New England are also common. The water crossing from Cape Cod to Nova Scotia is a minimum of 250 miles. However, most birds do not start and stop right on the coasts during either forward or reverse flights. Hence most fly considerably further than 250 miles non-stop.

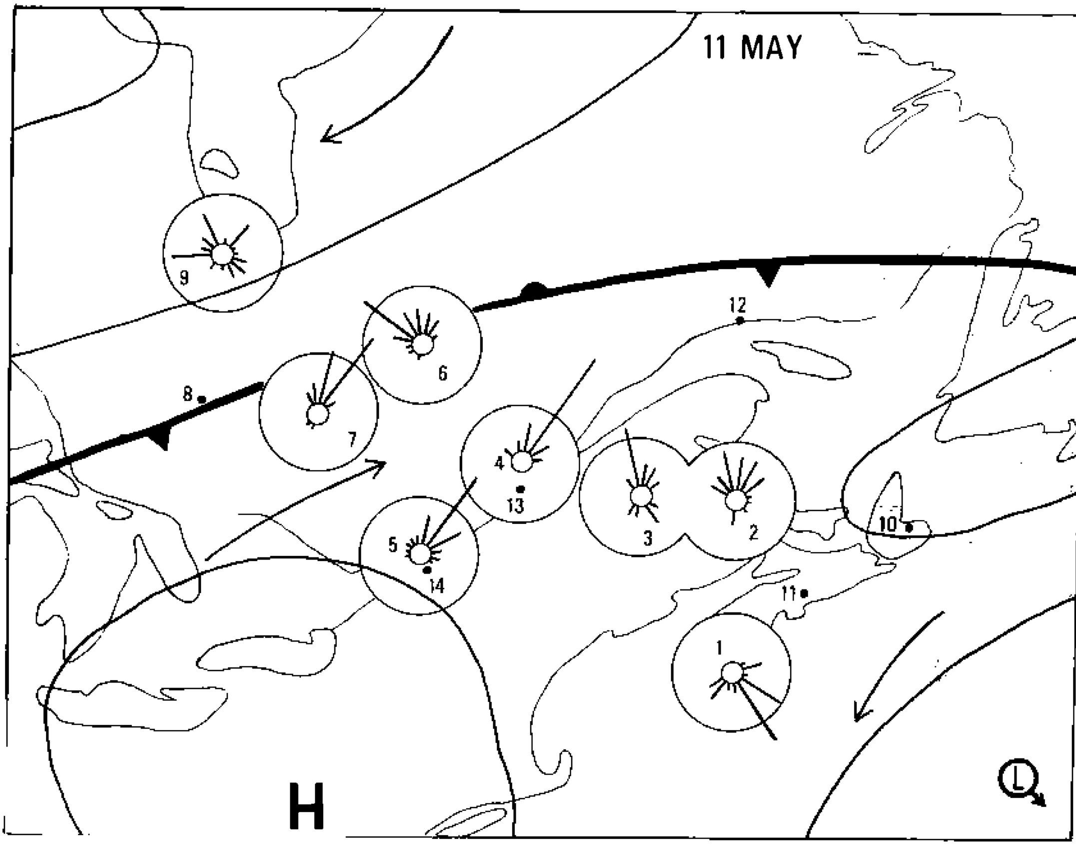
At night many birds move NE from New Brunswick out over the Gulf of St Lawrence. There is a similar nocturnal NE movement from eastern Nova Scotia across the Cabot Straight to Newfoundland. By day comparable (but less dense) movements sometimes occur. However diurnal migrants frequently hesitate or turn at coastlines, something which nocturnal migrants almost never do. By day there are frequent concentrations of migrants moving north (or south) along the east coast of New Brunswick. My field observations have shown that waterfowl, gulls and Gannets are often involved in these coasting movements.

WEATHER AND MIGRATION

Both the amount and the direction of migration are strongly affected by weather. Figure 1 summarizes the 1970 and 1971 nocturnal data from St Margarets. A similar pattern of densities and directions is obtained when the diurnal data are plotted on such a map. Fig. 2-7 show specific examples of weather and the direction of diurnal migration over a wide area.

The diagrams show that at St Margarets dense migration was especially common with S, SW and W winds. Such winds occur on the NE, E, SE and S sides of low pressure areas and on the W, NW and N sides of highs.

Figure 1. Density and direction of nocturnal migration in the springs of 1970 and 1971 at St. Margarets, N.B. with different synoptic weather situations. A generalized weather map was drawn showing most of the common spatial relationships among pressure systems, fronts and wind direction. Each evening the location on the generalized map which best represented the position of St Margarets relative to the actual synoptic features was selected without knowledge of the intensity or direction of migration. At this location I placed a point representing the density and direction of migration one hour after sunset. The density was plotted as below normal, normal or above normal for that part of the season (open, half-filled and solid circles respectively). I used a moving-average technique (see Richardson and Gunn, *Canad. Wildl. Serv. Report Ser.* 14: 35-68, 1971) to determine the density categories. The arrows on the data points indicate the modal directions of migration. When there was more than one mode, secondary modes were shown by shorter arrows. Each point thus represents one night of observation. On evenings when an appropriate map location could not be located, no point was plotted.



Figures 2-7. Directions of diurnal migration at various sites in eastern Canada and Maine, May 11-16, 1971. The length of each line is proportional to the fraction of the birds moving in that direction. Weather maps for the corresponding times showing pressure systems, fronts, geostrophic wind directions and selected isobars are superimposed. Circled pressure system locations are off the map in the direction indicated. The sites numbered on Fig. 2 are: 1—Barrington, N.S.; 2—St Margarets, N.B.; 3—Caswell, Maine; 4-7—Mont Apica, St Denis, Chibougamau and Senneterre, Que.; 8, 9—Ramore and Moosonee, Ont. The large circles indicate the approximate areas within which birds were regularly detected. Spring data have also been obtained from Sydney and Halifax, N.S. (10, 11) and from Moisie, Quebec and Montreal, Que. (12-14).

With these weather conditions the migration was almost invariably to the N, NE or E. Fig. 7 shows a good example of such conditions over a wide area.

Northerly winds occur when there is a high to the west or a low to the east. On the average the migration was much less dense on days or nights with these conditions. Furthermore on these occasions the majority of the birds were flying to the SE, S or SW. Figure 5 shows an example of widespread reverse migration.

Reverse migration almost never occurred without following (northerly) winds. In contrast, forward migration did occur without following (southerly) winds. When it is calm, as it often is near the center of a high, forward migration may be intense. When there are light northerly winds there is often both forward and reverse migration. This forward movement into light northerly winds usually involves strong non-passerine echoes. With strong northerly winds one usually finds only reverse migrants. After allowing for seasonal differences, these observations are comparable to those made by Able (*Bull. Ecol. Soc. Amer.* 51: 43, 1970) in Louisiana and Georgia.

After a cold front goes by, the winds are often from the NW or N. On such occasions reverse migration was frequent (Fig. 1). However, by the time some lows reach the Maritimes, the associated cold front has swept counterclockwise around the depression such that it extends S or even SE from the low. The wind behind these cold fronts is SW or W. The left side of Fig. 1 shows that behind such

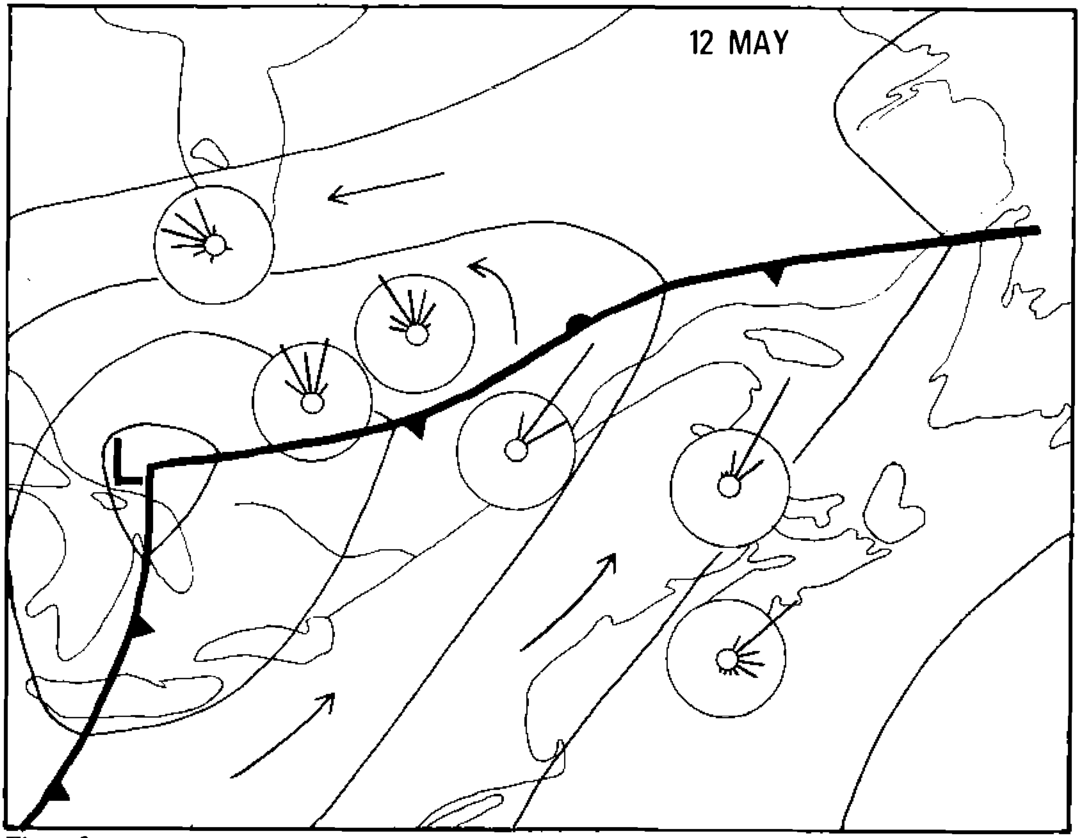


Figure 3

fronts NE migration usually occurred and was sometimes intense. Fig. 4 shows a specific example: On May 13, 1971, the winds in southern Quebec were SW or W behind a front, and I recorded extensive NE migration. The same phenomenon is seen in the NE spring migration of Starlings in Ontario (Richardson and Haight, *Canad. J. Zool.* 48: 31-39, 1970). Thus we must recognize that when the predominant direction of migration is NE, the density of migration is often as great after the passage of cold fronts as ahead of them.

MIGRATION DURING MAY

To further our understanding of the importance of weather factors in determining migration patterns, I have looked in detail at the data from May 1971.

The first intense movement of the month at St Margarets, N.B. (henceforth StM) occurred the evening of May 2 as an approaching low produced light southerly winds. Similar conditions the night of May 4 produced another dense movement. At the Quebec sites, which were behind the low, most of the migration was reverse. Dense migration did not recur at StM until the evening of May 7; this was the first night with southerly winds after May 4. Fairly intense migration occurred at StM each night from May 7 to May 12. This was a prolonged period of warm fair weather with southerly or near calm winds (Fig. 2, 3). The passage of a cold front on May 13 reduced the volume of migration at StM. However the winds behind the front were SW or W (Fig. 4) and forward rather than reverse movement occurred. On May 14 NW winds occurred and reverse movement was recorded over a wide area (Fig. 5). As usual during such conditions, a few birds moved to the north upwind. By the evening approaching favorable conditions were already producing NE movement at the westernmost radar sites. On May 15 the eastward movement of the pressure systems brought favorable winds to most of the sites (Fig. 6), and one of the densest movements of the season occurred at StM.

The weather deteriorated as a low moved across the area on May 16. By the evening

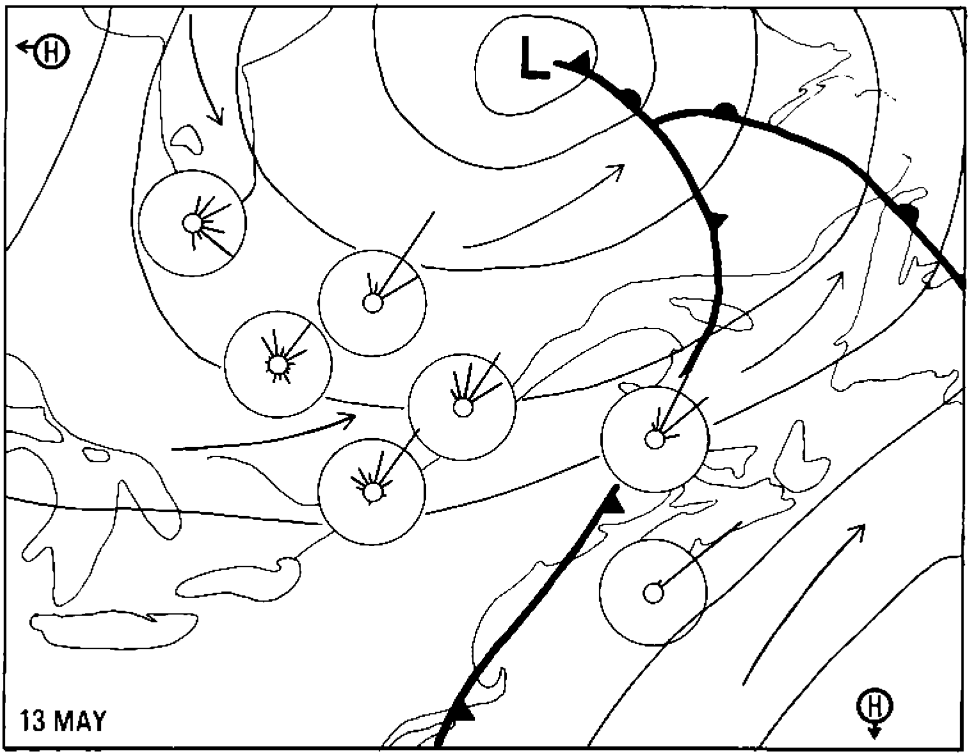


Figure 4

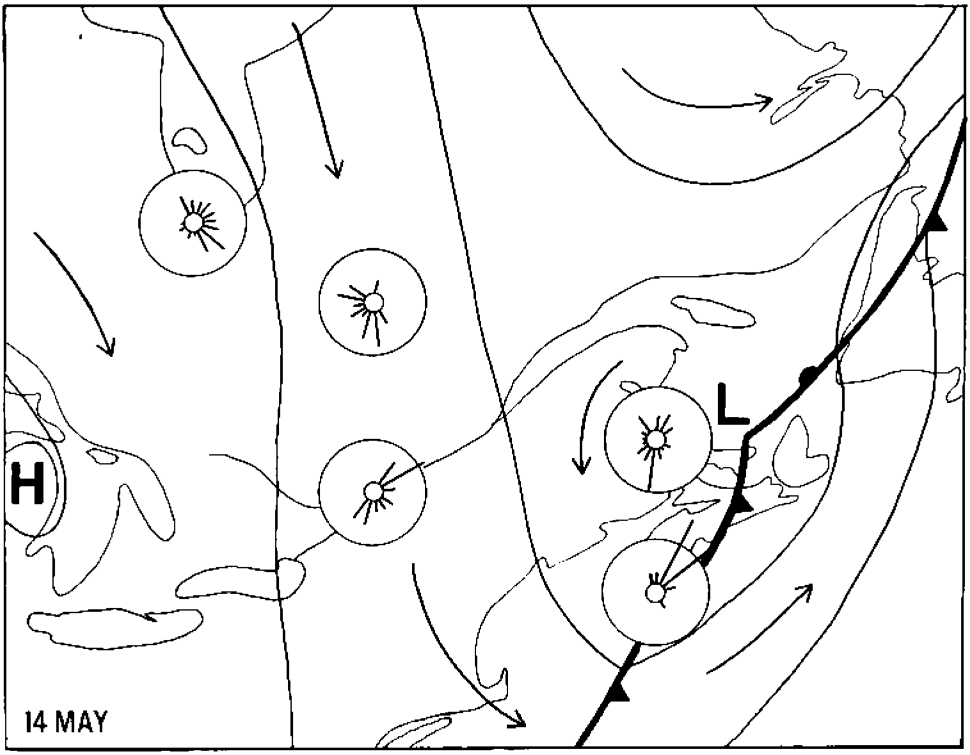


Figure 5

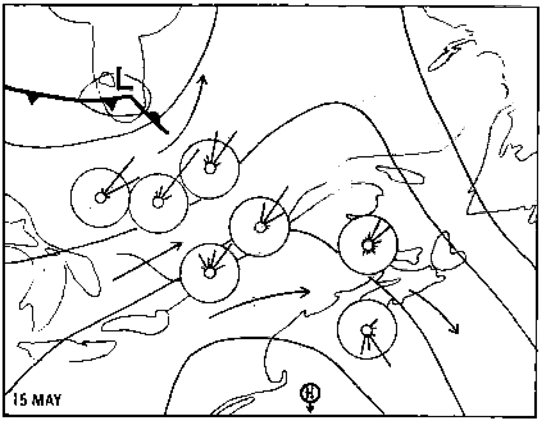


Figure 6

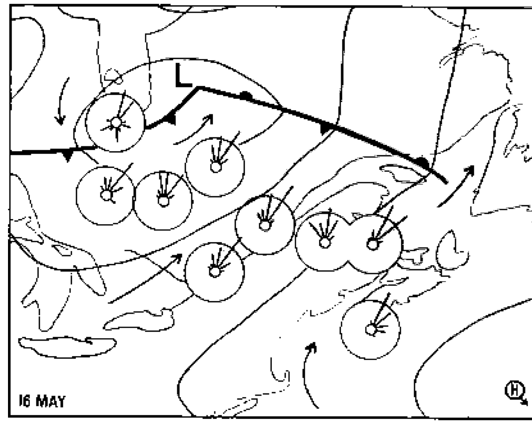


Figure 7

of May 17 the winds were NE at StM, and light reverse migration occurred. Data were incomplete for May 18-20. However a very dense movement did occur at StM the night of May 19 in typical favorable weather conditions. Thereafter dense migration did not recur at StM until May 26. During parts of the interim, reverse migration occurred with northerly winds at most of the sites. Then from May 26 to May 30 there were five successive nights at StM with calm or S, SW or W winds. On each of these five nights there were above-normal densities of migration to the N and NE. While more detailed analysis is necessary, it is clear that the supply of birds ready to migrate is not so depleted after one or two nights of good weather that dense migration cannot continue on subsequent nights.

Finally, on the last day of the month there was widespread reverse migration over Quebec and the Maritimes. On this day northerly winds were produced over the whole area by a low east of Labrador and a high over Ontario. At StM there was both N and SSW movement the night of May 31. The distribution of heights was unusual, in that there were two layers of birds with few in between. Time-lapse films of the height-finder display showed that *the birds in the layer below 3000 ft. were moving SSW, while those forming the upper layer at 5-8000 ft. were moving N.* The surface winds were from the north while the winds aloft were SW. Thus all the birds were probably flying with more or less following winds.

CONCLUSIONS

In this report I have described some aspects of spring migration in eastern Canada. I have emphasized that weather affects not only the numbers but also the directions and sometimes the heights of the migrants. I have tried to point out the usefulness of obtaining data simultaneously from widely-separated points.

All of the information presented here was obtained with radars that were being used concurrently for aircraft control and surveillance. Large numbers of air surveillance and weather radars are operating in North America. Groups of the surveillance radars feed their data to centralized FAA and military control centres. At these control centres one can observe the displays of several radars located over an area hundreds of miles wide. Hence if more ornithologists were interested, data similar to those presented here could be obtained on a much greater scale than is presently being done.

ACKNOWLEDGMENTS

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Dates for 1971-72 Christmas Bird Counts: Saturday, December 18, 1971 to Sunday, January 2, 1972 inclusive. (Three more days than 1970-71.)