Weather and the Migration of Canada Geese across Southeastern Ontario in Spring 1975

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The migration of Canada Geese, *Branta canadensis interior,* through southeastern Ontario in spring 1975 was studied using radar and visual observations. Most geese probably came from migration stop-over areas in northern New York State. Between 22 April and 14 May at least 190 000 Canada Geese were estimated to have moved through the Ottawa area. Migration directions ranged from 340° to 37° with a mean of 16.8°. Migration ended a few days later than usual, probably as a result of a spell of unfavorable weather. Migration volume was significantly correlated with following wind and with change in temperature. With one exception, all heavy migration occurred under or near the west side of a ridge of high pressure. On one day late in the season heavy migration occurred on the west side of a low-pressure area.

Key Words: Canada Goose, *Branta canadensis interior*, spring migration, weather, Ontario.

Canada Geese migrating across southeastern Ontario in spring belong to the mid-Atlantic wintering population which spends the winter along the eastern seaboard of the United States and breeds in northern Quebec. That population consists largely of *Branta canadensis interior*, and totals about 650 000 birds after the hunting season. In winter, about 540 000 of those geese are concentrated in Delaware and Maryland, almost due south of Ottawa (Figure 1). The principal breeding grounds lie in the tundra of the Ungava Peninsula with fewer geese nesting in the boreal forest south to the 50th parallel (Bellrose 1978).

Equipment, designed by the National Research Council of Canada, to detect automatically flocks of migrating birds can be used to provide air traffic controllers with information to prevent bird/aircraft collisions (Hunt 1977). During operational tests of that equipment at Ottawa International Airport in spring 1975, films of the radar display showed several migratory flights of Canada Geese. At the request of the Ministry of Transport, the Canadian Wildlife Service (M. C. Gauthier et al., unpublished report) assessed the hazard to flight safety posed by those migrating goose flocks.

This paper presents some information on the migration stop-over areas, chronology, numbers, and directions of the Canada Geese that migrated across the Ottawa area in spring 1975, and examines correlations with weather conditions during the migration period.

Methods and Materials

Visual Observations

From 18 April to 18 May 1975, biologists, bird watchers, and Air Traffic Control personnel at Ottawa International Airport contributed a total of 66 records pertaining to at least 110 flocks of migrating geese and 10 records of resting goose flocks at or near Ottawa, Ontario. All records are listed by Gauthier et al. (unpublished report).

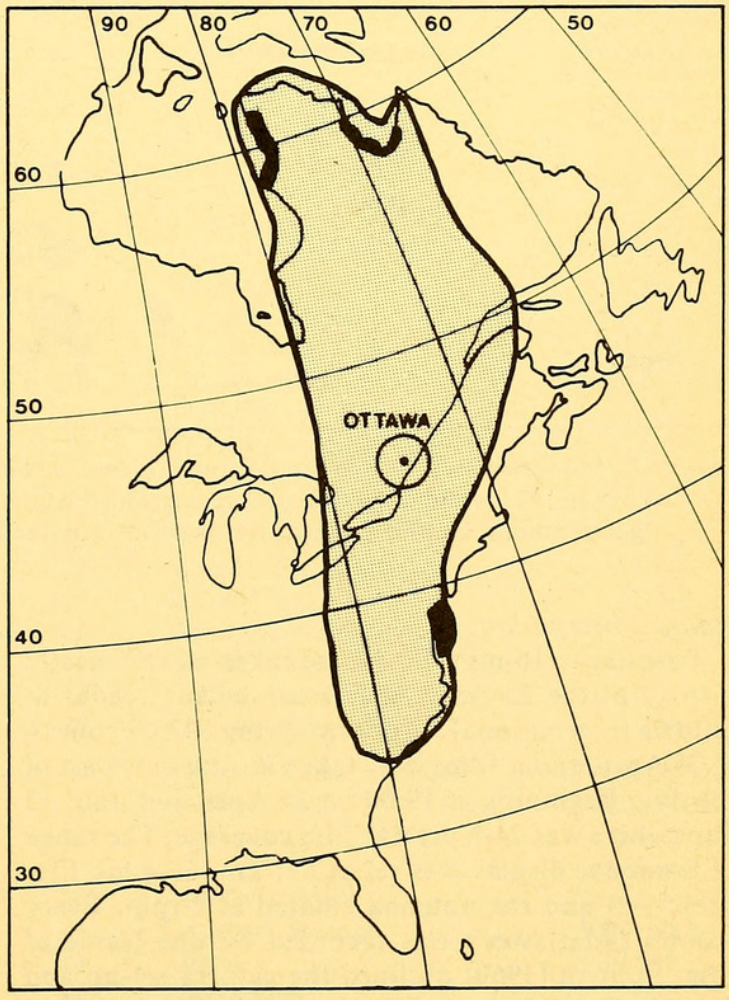

FIGURE 1. Range of the mid-Atlantic population of Canada Geese. Solid black — main wintering area and nesting areas (after Bellrose 1978). Circle — area covered by the Ottawa radar display.

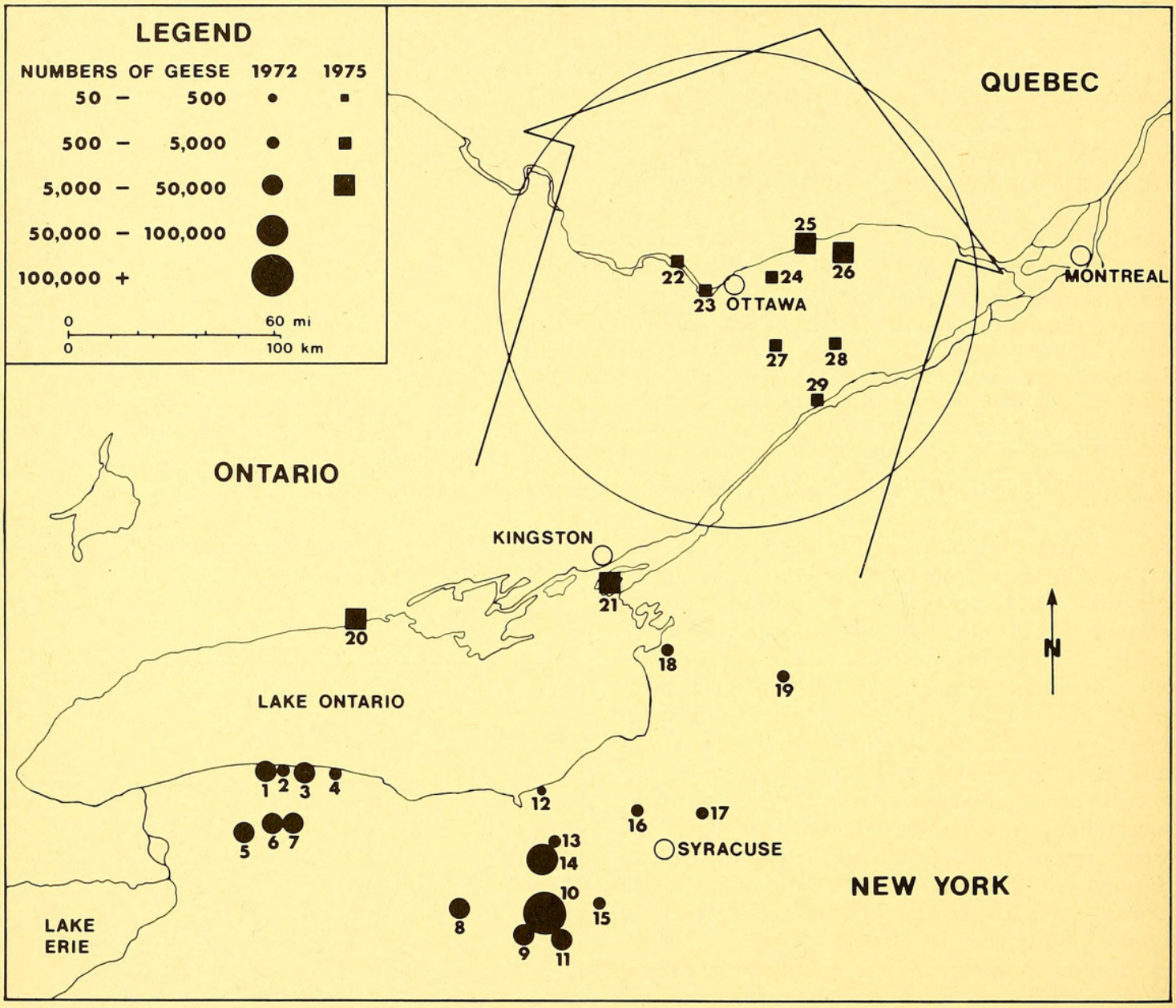

FIGURE 2. Migration stop-over areas of Canada Geese in southeastern Ontario in 1975 (squares) and in north-central New York in 1972 (solid dots), the area covered by the Ottawa radar display in 1975 (circle), and the general direction of "goose echoes" in 1975 (arrow). Numbers identify the locations listed in Table 1.

Radar Observations

Time-lapse 16-mm films were taken of the master display of the 23-cm AASR-1 surveillance radar at Ottawa International Airport in spring 1975. From 14 to 25 April, radar films were taken during only part of the day. Beginning at 19:00 on 25 April and until 13 June, there was 24-h per day film coverage. The range of the radar display was set at 111 km (60 n mi; Figures 1, 2) and the antenna rotated at 6 rpm. Every second radar sweep was recorded on one frame of film. Solman (1969) outlined the camera set-up and Canada Department of Transport (1967) described the AASR-1 radar.

Migrating flocks of geese produce on the screen of an AASR-1 radar relatively large, non-fluctuating echoes moving on a fairly straight course and at a steady speed (Blokpoel 1974). The Ottawa radar films showed many echoes of this kind mostly moving across the screen on a broad front in northerly directions. All such echoes moving in directions between northwest and northeast were considered to be "goose echoes." Heavy movements of "goose echoes" on the Ottawa radar films generally occurred on days and at times when large numbers of migrating Canada Geese were observed visually. Migrating Canada Geese were observed between 22 April and 14 May, and no other geese were observed during that period. No other bird migrates through the Ottawa area during that period in flocks large enough to produce "goose echoes." Hence, we conclude that all or nearly all of the "goose

echoes" on the Ottawa radar films were caused by migrating flocks of Canada Geese. We assume that all or almost all "goose echoes" represented only single flocks of geese. An echo caused by two or more goose flocks is likely to change in size and shape when travelling across the display because the distances between the flocks are likely to change during the flight, but we rarely observed fusion or fission of "goose echoes."

Numbers of "goose echoes" were determined by running the radar film through a Vanguard Film Analyzer and counting the echoes per hour that crossed an imaginary line 30 n mi (54 km) to the south of Ottawa and perpendicular to the average direction of the echoes. Directions of the "goose echoes" were determined by manually tracing the paths of representative "goose echoes" on a sheet of mylar placed over the ground-glass projection screen of the film analyzer.

Weather Data

Weather data included (1) surface and 850-mB maps prepared for 07:00 and 19:00, (2) the standard hourly observations at Ottawa and Syracuse, New York, and (3) upper air winds for Albany, New York, Maniwaki and Montreal, Quebec, for 07:00. In this report, the Ottawa area is the area covered by the radar display (Figure 2). All times are Eastern Standard Time and directions are in degrees from True North.

Results and Discussion

Migration Stop-over Areas

In spring 1975, several stop-over areas near Ottawa were used by Canada Geese (Table 1, Figure 2). The largest concentrations of geese were seen near Plantagenet (approximately 15 000), on the Ottawa River near Thurso (more than 10 000), and near Carlsbad Springs (5000–6000). Farther south in Ontario, 10 000–15 000 resting Canada Geese were reported at Wolfe Island and 10 000–20 000 geese near Colborne.

Counts for 1975 from New York State were not available, but air survey data from 12 and 14 April 1972 give an idea of the usual distribution of geese in north-central New York (Figure 2; S. Browne, personal communication). Largest concentrations occurred near Cayuga Lake. The estimate of nearly 350 000 geese observed during the 1972 survey was undoubtedly low because the survey did not cover the entire area, and because some geese may have left while others had not yet arrived. Evidently northern New York is of major importance as a stop-over area for geese of the mid-Atlantic population, while the Ottawa area is of only minor importance.

Chronology and Time of Day

The visual observations in 1975 indicated that virtually all Canada Goose migration into or across the Ottawa area occurred from 22 April to 14 May. The main migration period was from 23 April to 11 May, the first and last days with considerable migration. The radar films confirmed this, although radar data were incomplete until the evening of 25 April.

Peak numbers of Canada Geese in New York State usually occur in the first two weeks of April. In 1975 the majority of the Canada Geese remained at the staging grounds longer than usual, but most left before 1 May and the last large flights occurred on 10 May (S. Browne, personal communication).

In the Kingston area (Figure 2), the flights of the geese reach their peak at the end of April and beginning of May and ". . . for several days the flocks pass

TABLE 1—Numbers of Canada Geese at migration stop-over areas (*a*) from an aerial survey of northern New York State on 12 and 14 April 1972 — circles in Figure 2 (S. Browne, personal communication) and (*b*) reported for southeastern Ontario between 10 April and 9 May 1975 — squares in Figure 2. WMA — Wildlife Management Area, NWR — National Wildlife Refuge

	Number on Figure 2	Location	Numbers of Canada Geese
(*a*)	1	Thirty Mile Point	23 720
	2	Johnson Creek	2 000
	3	Oak Orchard Creek	7 405
	4	Sandy Creek	1 820
	5	Tonawanda WMA	35 100
	6	Oak Orchard WMA	32 900
	7	Iroquois NWR	22 600
	8	Honeoye Lake	6 206
	9	Seneca Lake	5 595
	10	Cayuga Lake (N. of Shelldrake Pt.)	109 595
	11	Cayuga Lake (S. of Shelldrake Pt.)	25 600
	12	Little Sodus Creek	55
	13	Howland Island WMA	2 400
	14	Montezuma NWR	61 200
	15	Owasco Lake	1 700
	16	Three Rivers WMA	1 300
	17	Oneida Lake	4 335
	18	Crystal Lake	1 100
	19	Lowville-Grenfield	4 200
(*b*)	20	Lakeport (near Colborne)	10 000–20 000
	21	Wolfe Island	10 000–15 000
	22	Luskville	"great numbers"
	23	Lac Deschênes	"hundreds"
	24	Carlsbad Springs	5000–6000
	25	Thurso	> 10 000
	26	Plantagenet	15 000
	27	Vernon	2000–4000
	28	Finch	"thousands"
	29	Morrisburg	1 800

steadily northward. By May 10 most have gone" (Quilliam 1973). Records of bird watchers in the Ottawa area showed that in 1976 good numbers of geese were present by the middle of April with large flights occurring at the end of April and the first week of May. In 1977 most migration again took place in the last week of April and first week of May. These two weeks form the usual migration period for the Ottawa area (H. A. McLeod, personal communication). In 1975, the year of our study, goose migration ended later than usual in that many geese migrated on 8–11 May (Goodwin 1975).

Migration was usually heaviest in the morning: 2451 (88%) of the 2784 "goose echoes" counted in the period with complete radar data (26 April–14 May) occurred from 04:00 to 14:00 with peak numbers between 08:00 and 09:00. Relatively few echoes were seen during the rest of the day: 14:00 to 21:00 — 156 echoes (6%), and 21:00 to 04:00 — 177 echoes (6%). Myres and Cannings (1971) also reported that the spring migration of *Branta canadensis parvipes* across the international border into interior British Columbia was diurnal, while F. C. Bellrose (unpublished report) stated that in spring about half the Canada Goose migration occurs at night and half during the day; however, he also mentioned that diurnal movements of geese are "especially prevalent when skies are overcast at night or when winds, temperature or both have not been conducive to northward migration." Sizeable numbers of "goose echoes" occurred on only two nights (28 April and 10 May), both of which had light following winds. On 28 April there was heavy cloud cover whereas on 10 May the sky was clear. During the main migration period (23 April–11 May) there was only one other night with favorable winds: on 1 May winds were light and following but there was light rain. Hence, our results are generally consistent with Bellrose's statements.

Volume of Migration

We counted a total of 2906 "goose echoes" on the radar films covering the period 22 April to 14 May. Daily totals in the period with complete radar coverage (26 April–14 May) ranged from 0 to 350 (mean = 146.2, SD = 123.5, N = 19). The daily totals of echoes fluctuated but there was no obvious pattern. Three of the 4 d with largest movements were consecutive.

Flock sizes for 88 migrating flocks of Canada Geese were provided by observers. They ranged from 6 to 300 birds (mean = 65.7; SD = 51.0). If each "goose echo" represented one flock and the mean flock size was 65.7, the 2906 "goose echoes" represented 190 924 ± 31 598 Canada Geese migrating through the Ottawa area in spring 1975. We calculated the confidence interval using the formula $\mathrm{Var}\ T = A^2\ \mathrm{Var}\ \bar{x}$, where T is the estimated total, A is the number of "goose echoes" and $\bar{x}$ is the mean flock size (Cochran 1953). The mean flock size may be biased if small flocks were missed more often than large ones, or if high-flying flocks differed in mean size from those within visual range. We have no data to estimate the extent of such biases.

The estimated 190 000 geese represent almost 30% of the mid-Atlantic population (Bellrose 1978). This is a minimum estimate of the number of Canada Geese that crossed the Ottawa area in spring 1975 because the radar would have missed flocks flying below its horizon and because radar data were incomplete during 22–25 April.

Directions of Migration

Paths of representative samples of "goose echoes" were traced during hours of maximum migration for 29 April, 1, 5, 8, 9, and 11 May. Directions of individual "goose echo" tracks ranged from 340° to 37°. The mean directions of the six samples ranged from 11.0° to 21.4° with a weighted average of 16.8° (total number of echoes traced = 71).

Based on the observed mean direction of the "goose echoes," the periods during which they were recorded on the radar films, the usual time of morning departure of migrating Canada Geese (1 h before to 2 h after sunrise; Bellrose, unpublished report), and their usual ground speed (about 80 km/h; Bellrose 1978), we conclude that most geese flying across the Ottawa area came from migration stop-over areas in northern New York State and along the northeast shore of Lake Ontario (Figure 2). If we assume no change in directions, the flight paths of most of the Canada Geese migrating across the Ottawa area would take them to the shores of Ungava Bay. That area is included in the known breeding range of the mid-Atlantic population (Figure 1).

Weather Variables and Migration Volume

Take-off weather.

We concluded above that most of the Canada Geese migrating across the Ottawa area had probably departed from migration stop-over areas in northern New York State (Figure 2). Syracuse, New York, is a location in that area for which complete weather records were available. Assuming that the geese departed in largest numbers in the early morning, we looked for correlations between weather variables measured at Syracuse at 04:00 and the numbers of geese that apparently departed from the area (i.e., the number of "goose echoes" recorded at Ottawa during 07:00–14:00) for each day during 26 April–11 May. We considered the following variables: temperature relative to normal, change in temperature from that on previous day, relative humidity, change in relative

humidity from that on previous day, cloud cover, change in cloud cover from that on previous day, speed of surface wind (regardless of direction), and expected ground speed in the preferred direction of the geese. Expected ground speed takes into account both the speed and the direction of the wind (cf., Alerstam 1976). We calculated the expected ground speed using the surface wind, a preferred direction of 16.8° (the mean direction of the "goose echoes"), and an air speed of 56 km/h (the air speed for Snow Geese, *Chen caerulescens caerulescens*) (Blokpoel 1974). Only 'change in temperature from that on previous day' was significantly correlated with migration volume ($r_s = 0.628$, $P < 0.01$, N = 16, Spearman's rank correlation test; Siegel 1956). Precipitation and visibility were not considered because the Spearman's rank correlation test could not be applied (only 2 d had precipitation and visibility was usually unlimited).

Weather en route

Considering the Ottawa weather as weather en route, we tested for correlation between migration volume (i.e., the number of "goose echoes" recorded at Ottawa during 04:00–14:00) and weather variables measured at Ottawa at the hour of maximum migration. Weather variables included those considered for Syracuse as well as barometric pressure, change in barometric pressure from that on previous day, speed of upper air wind (regardless of direction), and expected ground speed using upper air winds. Upper air winds were estimated from 850 mB maps for 07:00 and the upper air winds at 07:00 for Albany, Montreal, and Maniwaki. Expected ground speed was the only variable significantly correlated with migration volume ($r_s = 0.611$, $P < 0.01$, N = 16 when using surface winds, and $r_s = 0.441$, $P < 0.05$, N = 16 when using upper air winds). Precipitation and visibility were not considered (all days had no precipitation and visibility was usually unlimited).

Our results are in general agreement with those of a 4-yr study of the spring migration of Snow Geese across southern Manitoba (Blokpoel and Richardson 1978), which indicated that the geese responded to following wind conditions, to fair weather, and to the complex of temperature-humidity-pressure variables.

Richardson (1978) discussed the adaptive significance of flights with various weather conditions. Flying with tail winds has obvious energetic advantages, especially for long-distance flights over inhospitable areas. For Canada Geese that nest in northern Quebec, flying with tail winds is highly adaptive, because their fat deposits are their only source of energy from the time of arrival on the breeding grounds until new plant growth is available (Hanson 1962).

Synoptic Weather and Migration Volume

The synoptic weather that affected the Ottawa area during the main migration period is briefly described. On day 1 (23 April) Ottawa was under the influence of a weak ridge of high pressure (R1) extending from the Atlantic Ocean to northern Quebec and a low (L1) was rapidly approaching from the west. The center of L1 crossed the Ottawa area on day 2 and moved further east on days 3 and 4. On day 3, L1 was still influencing the Ottawa area but on day 4 a new low (L2) had developed on the front to the east of Ottawa but to the west of L1. On days 5 and 6, L2 became stronger while hardly moving. During days 4–6 the weather in the Ottawa area was largely determined by L2. By day 7, L2 had lost some of its intensity and moved further east, while a new weak low (L3) was centered over Minnesota, far to the west. By day 8, L3 had stalled over Minnesota and by day 11 it had moved into Manitoba where it filled in. Thus, during days 7–11 the Ottawa area was positioned between lows far to the east (L2) and far to the west (L3). On days 7–9 the Ottawa weather was mainly influenced by L3 and a ridge of high pressure (R2) extending south from Hudson Bay, and on days 10 and 11 by a weak high (H1) to the south. The center of a new weak low (L4) had moved from the west into southwestern Ontario by day 12. From there L4 moved southeast, reaching the Atlantic Ocean by day 13. There L4 deepened while moving northeast. It had reached Nova Scotia by day 16. During days 13–16 the Ottawa area was situated more or less to the northwest of L4 and was also influenced by a stable high (H2) centered over Hudson Bay. On days 16–19, H2 moved south, reaching northwestern Ontario by day 17, Iowa by day 18, and Arkansas by day 19. On days 18 and 19 a low (L5) centered over Baffin Island far to the north of Ottawa extended its influence southward, while a new weak ridge (R3) had developed south of the Great Lakes on day 19. The Ottawa weather was mainly influenced by H2 on days 17 and 18, and by L5 and R3 on day 19.

The synoptic weather conditions for each of the 19 observation periods are plotted on a generalized weather map (Figure 3). Low-pressure areas are indicated by L, high-pressure areas by H, and ridges of high pressure by R. This map shows a weak low on the left and a strong low on the right. At the top and bottom are highs with ridges of high pressure extending southward and northward. Wind directions generally follow the isobars with the wind blowing clockwise around a high and a ridge, and counter-clockwise around a low.

For each day, the approximate synoptic location of Ottawa at 07:00 was determined using the weather maps for that hour. The migration volume for each

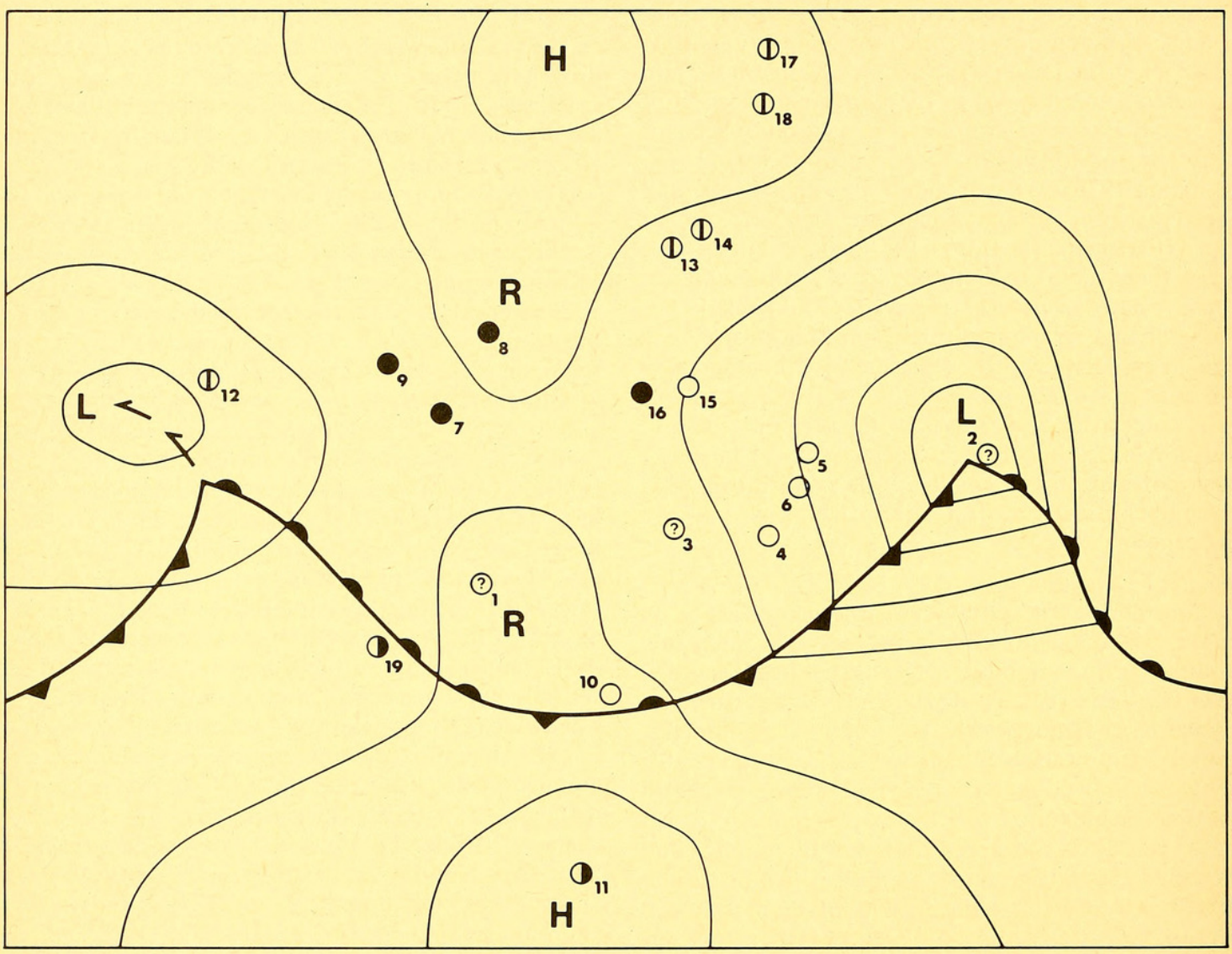

FIGURE 3. Generalized weather map showing high (H) and low (L) pressure systems, ridges (R) of high pressure, and fronts (warm, cold, quasi-stationary). Numbered circles show approximate locations of Ottawa relative to weather systems at 07:00 during 23 April–11 May 1975 (1 = 23 April, 2 = 24 April, etc.) and the number of "goose echoes" during 04:00–14:00: ○ = very light or no migration (0–80 echoes, $\bar{x}$ = 25, N = 5), ◐ = light migration 81–160 echoes, $\bar{x}$ = 132, N = 5), ◑ = moderate migration (161–240 echoes, $\bar{x}$ = 208, N = 2), ● = heavy migration (> 240 echoes, $\bar{x}$ = 303, N = 4), and ⊙ = number of echoes unknown.

day (the number of "goose echoes" during 04:00–14:00) is also indicated on the map, except for 23–25 April (days 1–3), for which radar data were incomplete. Visual observations suggested heavy migration on day 1 and very light or no migration on days 2 and 3.

As Figure 3 shows, heavy and moderate migration occurred to the east of a low, under or near the west side of a ridge (days 1, 7–9, 19), near the center of a high (day 11), and far to the west of a low (day 16). Light and very light or no migration occurred to the west (days 3–6, 15) and east (days 2, 12) of a low, and to the east (days 17, 18), southeast (days 13, 14), and north (day 10) of a high. In other words, large numbers of geese often migrated with a light, warm, more-or-less southerly airflow, whereas few or no geese migrated with a cold, more-or-less northerly airflow. On the 2 d with calm, there was moderate migration (day 11) and very light to no migration (day 10).

Our results are in good general agreement with the findings of many other studies that birds migrating north in spring usually move in largest numbers "in the central and western part of a high, the eastern part of a low, or an intervening transitional area" (see review by Richardson 1978).

Three days (2, 12, 16) clearly deviated from this general pattern. On days 2 and 12 Ottawa, in the eastern part of a low, experienced southerly winds but only a few geese were migrating. On both days there was overcast and precipitation in Ottawa and/or Syracuse. It is likely that this rain and heavy cloud cover

suppressed the migration volume. Markgren (1963) and Blokpoel and Richardson (1978) reported that major goose flights are most frequent with no rain and little cloud. Day 16 was unusual in that heavy migration occurred in the face of a very light headwind. This probably happened because the geese were getting "behind schedule" as they had been delayed by several days of somewhat unfavorable weather (days 12–16 and, to a lesser extent, 10 and 11). As mentioned earlier, the last part of the 1975 spring migration was unusually late.

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