THE SPRING HAWK MIGRATION AROUND THE SOUTHEASTERN SHORE OF LAKE ONTARIO[1]

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EATON (1904) was perhaps the first person to indicate the possibility of a major hawk migration along the southern shore of Lake Ontario. In his comprehensive work "Birds of New York" (1910) he makes several references to species of hawks migrating through this area in the spring. Although scattered observations have frequently been made since 1910, little has been done in the way of a concerted study to gain a better understanding of the characteristics of the hawk passage around Lake Ontario. Moreover, the lack of any detailed study of spring hawk migration in North America, especially in relation to meteorological factors, further prompted us to undertake this investigation.

Our study was conducted during the springs of 1963 and 1964 at Derby Hill, which is located approximately 5 miles north of Mexico, in Oswego County, New York (Fig. 1). Derby Hill is a local name for a ridge which fronts on the southeast corner of Lake Ontario and runs away from the lake in a direction slightly east of south. Not only is the crest of this hill the highest land for several miles around, but it is also the only high land which is relatively clear of trees, summer homes, and cottages. The ridge is, however, transected by three low hedgerows running from east to west. The hill drops off as a perpendicular cliff at the edge of the lake. These topographic features provide a favorable opportunity to observe migrating hawks moving along the shoreline.

Observations were made on 45 days between 7 March and 12 May in 1963, mainly on Tuesdays, Thursdays, Saturdays, and Sundays. When possible, observations were made on other days. In 1964, observations were made on 63 days between 25 February and 4 May, and once the hawks began to migrate the only days not covered were those on which inclement weather conditions, such as snow, rain, or high winds, probably prevented the hawks from flying. Scattered data collected by members of the Onondaga County Audubon Society from 1955 to 1962 were generously made available for use in our study.

We kept data on the species composing the flights, the number of individuals passing, the direction and speed of the wind, temperature, cloud cover, and barometric pressure. Temperature was recorded on a thermometer at the study area, as well as on a nearby maximum–minimum thermometer. Wind direction and speed were determined by the use of a Windscope, a device

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TABLE 1

NUMBERS OF HAWKS OBSERVED AT DERBY HILL IN SPRINGS OF 1963–64

Species	Years	
	1963	1964
Broad-winged Hawk (*Buteo platypterus*)	7,289	21,387
Sharp-shinned Hawk (*Accipiter striatus*)	1,335	2,256
Red-tailed Hawk (*Buteo jamaicensis*)	971	1,125
Red-shouldered Hawk (*Buteo lineatus*)	867	489
American Kestrel (*Falco sparverius*)	216	506
Harrier (*Circus cyaneus*)	235	363
Rough-legged Hawk (*Buteo lagopus*)	193	116
Osprey (*Pandion haliaetus*)	53	209
Cooper's Hawk (*Accipiter cooperii*)	116	133
Goshawk (*Accipiter gentilis*)	81	53
Turkey Vulture (*Cathartes aura*)	32	77
Merlin (*Falco columbarius*)	3	19
Bald Eagle (*Haliaeetus leucocephalus*)	4	10
Golden Eagle (*Aquila chrysaetos*)	2	7
Peregrine (*Falco peregrinus*)	0	4
Gyrfalcon (*Falco rusticolus*)	1	0
Unidentified	351	264
Total	11,686	27,018

consisting of an anemometer and a direction indicator. A continuous record of barometric pressure was kept by a recording barometer located in a home a few hundred feet from the study area. Although these local weather determinations were of definite value to the study, the daily weather map published by the United States Weather Bureau was even more useful. The weather map made it possible to obtain a wide view of the weather conditions existing at stations in all directions from the study area.

THE SPECIES OF HAWKS AND THEIR TIMES OF MIGRATION

A major part of our study was concerned with determining the species of hawks using the flyway around the southeastern corner of Lake Ontario, the relative abundance of the different species, and the time of the spring when each species migrates through the area. Such descriptive information is a prerequisite for any kind of analytical study of the factors which influence migration.

Approximately 38,567 falconiforms of 16 species were recorded during the observations in 1963 and 1964. The species totals are given in Table 1. Except for the Broad-winged Hawk, the totals represent actual counts of individuals as they passed over the crest of the hill at the study area. Broad-winged Hawks frequently passed over in flocks, sometimes numbering

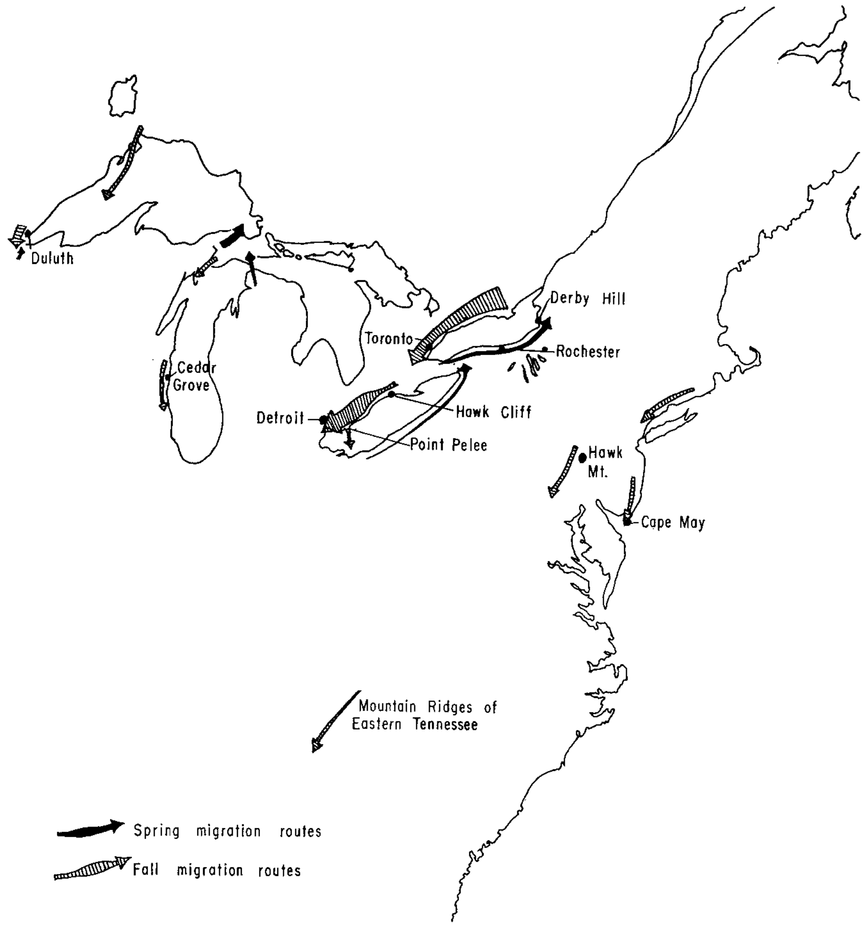

FIG. 1. This map shows the location of major known hawk flyways in eastern North America. The size of the arrows indicates the relative number of hawks using that particular flyway. Well-known points for observing the migration along these flyways are also indicated.

several hundred individuals, and at such times it was often necessary to estimate the number of birds of this species in each flock.

The passage of a number of species occurred throughout most of the spring migration period and exhibited little evidence of having a well-defined peak. This group includes the Cooper's Hawk, American Kestrel, Harrier, Red-tailed Hawk, and Rough-legged Hawk. The Red-tailed Hawk is typical of the group. Counts of over 100 Red-tailed Hawks were made as early as 17 March and as

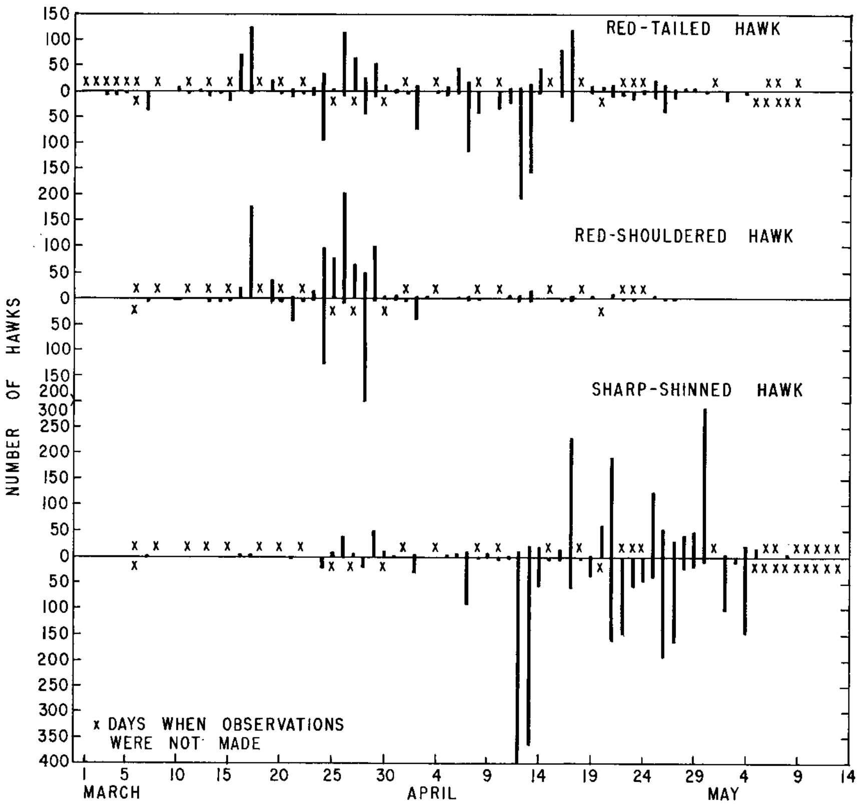

FIG. 2. Comparison of number of Red-tailed Hawks, Red-shouldered Hawks, and Sharp-shinned Hawks observed at Derby Hill in 1963, indicated by bars above the base lines, and in 1964, indicated by bars below the base lines.

late as 17 April Any time between 10 March and 20 April, when weather conditions are favorable, a large number of these buteos is likely to be observed (Fig. 2).

A second category includes those species which exhibit well-defined peaks during their migration periods. Included in this group are the Sharp-shinned Hawk, Osprey, Red-shouldered Hawk, and the Broad-winged Hawk. The Sharp-shinned Hawk was observed in greatest numbers during the last 2 weeks of April, the Osprey during the last week of April, the Red-shouldered Hawk during the last 2 weeks of March, and the Broad-winged Hawk during the last 10 days of April (Figs. 2 and 3).

Because relatively few individuals of the remaining species were observed, it was not possible to determine whether or not they have a definite peak in

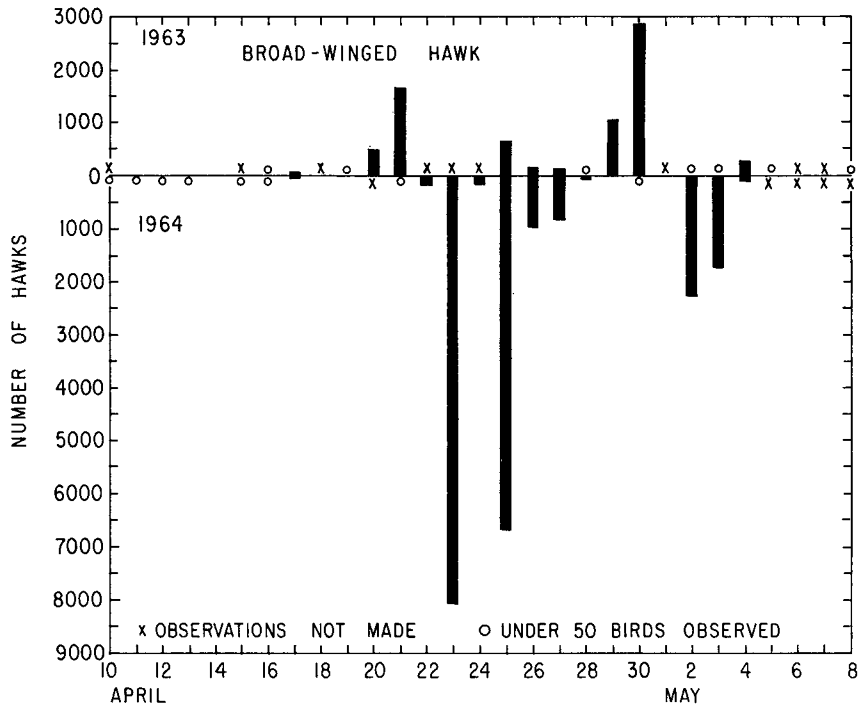

FIG. 3. Comparison of number of Broad-winged Hawks observed at Derby Hill in 1963 and 1964.

their migration. Classified in this category are the Goshawk, Peregrine Falcon, Merlin, Golden Eagle, Bald Eagle, and Turkey Vulture. The Gyrfalcon observed in 1963 was most likely a rare visitant to the flyway along the southern shore of Lake Ontario.

The range and peak period of spring migration are summarized in schematic form for the 10 commonest species in Figure 4.

ASSOCIATION OF HAWK MIGRATION WITH METEOROLOGICAL FACTORS

Modern meteorological study is based on the concept of large moving masses of air (areas of high pressure), the physical properties of which are more or less uniform over large areas but with an abrupt transition occurring between these air masses (Petterssen, 1941). Within these air masses there is a tendency for the air to revolve about a center in a clockwise direction. In the abrupt transition area between air masses, great contrasts of energy are often found, and it is here that low pressure areas or depressions develop. The air circulates in a counterclockwise direction about a low. Usually a

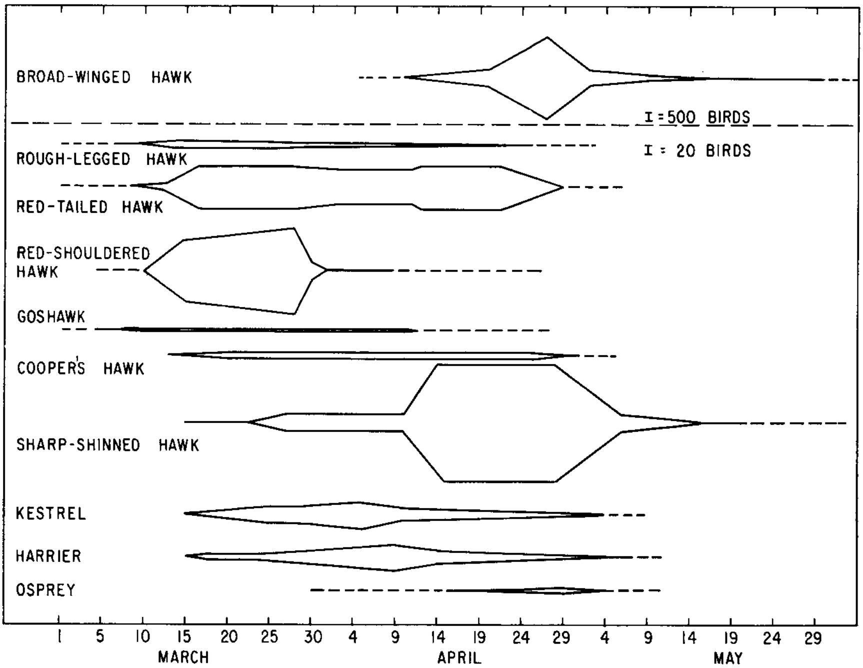

FIG. 4. Schematic representation of the average number of hawks passing Derby Hill on a good migration day during different times in the migration period. The figure is meant to indicate the range and peak periods for each of the principal species. The information used in construction of this figure was obtained from the 1963 study records as well as from various scattered observations made by members of the Onondaga County Audubon Society during the previous 7 years. It should be stressed that this figure does not represent actual counts, but only the average number likely to be seen at a given time during the migration period.

"front" extends from the low and separates the two masses of air. These large masses of air, with their associated fronts and depressions, move across the North American continent in a generally easterly direction.

Within the large air masses, there is a tendency for air to move outward from the center and to disperse in such a way as to make conditions at various points within the air mass similar. By contrast, in the depressions there is a tendency for surrounding air to move inward toward the center with the result that conditions on different sides of the low are markedly different. Thus the low is the boundary of the two air masses, just as is the front which is associated with it.

As an area of high pressure approaches from the west, the air circulation in front of it tends to be from a northerly direction because of its clockwise circulation. The air is generally cool and dry. Once the high has passed on to the east, a southerly flow of air generally develops behind the high. This air is usually slightly warmer than the air in front of the high, but the difference is not great because of the uniformity of the air within the mass. As the high moves farther eastward, a depression usually follows. The counterclockwise circulation of the low reinforces the southerly circulation of the previous high and typically brings warmer and more moist air, which continues until the low also moves on to the east and another northerly circulation occurs between it and the next advancing high.

Hawks migrating north from their southerly wintering grounds encounter Lake Erie and Lake Ontario, which form something of a natural barrier to northward movement, as many species of these birds seem to be reluctant to fly over large expanses of water (see Moreau, 1953, for a detailed account of hawks using short sea passages across the Mediterranean). The combined southern shorelines of Lake Erie and Lake Ontario are over 400 miles long. When confronted with this barrier, many hawks fly in an easterly direction along the southern shores of these lakes and continue their northward movement around the eastern end of Lake Ontario. This tendency for hawks to move around the lakes concentrates the numbers flying on any particular day and provides an opportunity to associate the number migrating with the meteorological patterns outlined above.

Wind direction.—Observations at Derby Hill and at other locations along the southern shore of Lake Ontario have shown a good association between the number of migrating hawks observed and southerly winds (Figs. 5 and 6). In order to determine whether a greater number of hawks do fly on southerly winds, or whether this apparent association is an illusion produced by the hawks simply being concentrated in a narrower flight path along the shore by southerly winds, observations were made at various points inland from the lake when there seemed to be a possibility that some of the hawks were not flying directly along the shore. Even with additional observers watching for hawks inland, the total number observed in association with northerly or westerly winds was much less than the number observed when southerly winds were blowing (Table 2). Such observations indicate that more hawks do fly along the shore of Lake Ontario when winds are from a southerly direction.

In addition, we have observed that hawks usually begin to migrate earlier in the day when southerly winds occur and continue later than they do when northerly or westerly winds are blowing. During our study, an average of 24 hawks per hour was observed between 0800 and 0900 hours on 20 days with southerly winds (before 20 April), but an average of only one hawk per hour was observed during the same time period on 31 days with northerly or westerly winds Likewise, the only days on which migration occurred after

TABLE 2

RELATION OF HAWK FLIGHTS TO WIND DIRECTIONS

Wind direction	Number of days with this wind between 15 March and 20 April	Number of days with over 100 Hawks	Average number of hawks per day
ESE–SSE	14	11	281
S	3	3	469
SSW–WSW	3	3	127
W	12	1	39
WNW–NNW	20	1	24
N	4	1	40
NNE–ENE	1	0	86
E	0	–	–

1600 hours (before 20 April) were days on which southerly winds occurred.

Late in the migration period (after 20 April) there is considerable variability in hawk movements, and some flights do occur on westerly or northwesterly winds. This deviation seems to apply especially to Broad-winged Hawks, which are concentrated in large groups along the southern shore of the lake at this time (see later).

Temperature.—The number of hawks observed during our study shows an association with air temperature. Most large flights of hawks occurred when temperatures were higher than they had been on previous days (Figs. 5 and 6, Table 3). Temperature fluctuations are difficult to evaluate as a possible influence on migration since they tend to be closely associated with wind direction and advancing low- and high-pressure areas.

Barometric pressure.—Falling barometric pressure, associated with an approaching area of low pressure and its frontal system, shows the best relation to the spring movement of hawks past Derby Hill. Only when rain or snow was falling did the approach of a low from the west fail to elicit a large passage of hawks during the migration period. When a low was intense and relatively slow-moving, so that its effect was noted on the local recording barometer for more than one day, the number of migrants was usually significantly greater on the day when the depression was closest to the study area and when the pressure was lowest. Often the situation was complicated, however, by precipitation, which frequently accompanied the low-pressure area. Figure 5 shows that the large hawk flights of 17, 26, and 29 March 1963 occurred when a low-pressure area was close to Derby Hill and the barometric pressure reached a comparatively low point. The migrations on 25 and 27 March were undoubtedly abbreviated, and the observed number of hawks was reduced by precipitation. Figure 7 shows the development and

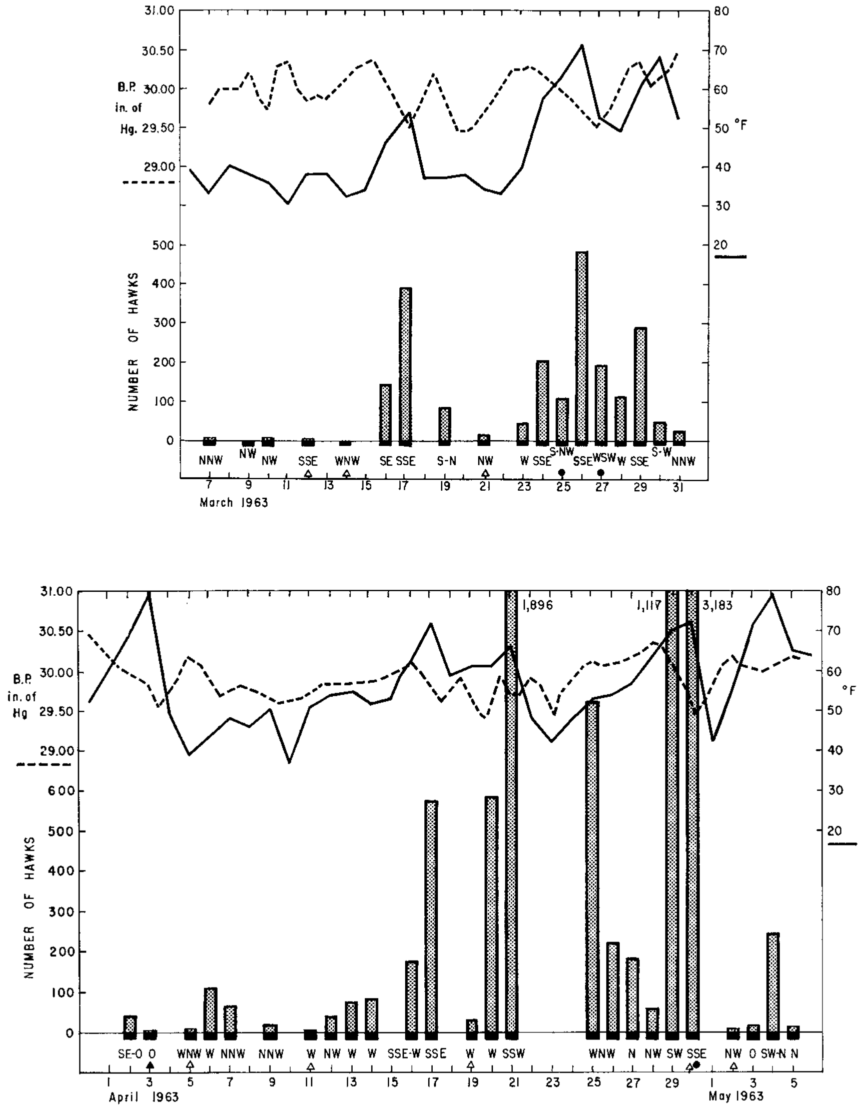

FIG. 5. Relation of the number of migrating hawks in 1963 to barometric pressure, maximum daily temperature, wind direction, and other meteorological factors at Derby Hill. An open circle indicates wind was calm or light and variable. A solid circle indicates the migration was influenced by rain. An open triangle means observations were made for only half the day, and a solid triangle means observations were made for less than 2 hours. Solid bars indicate days of observations.

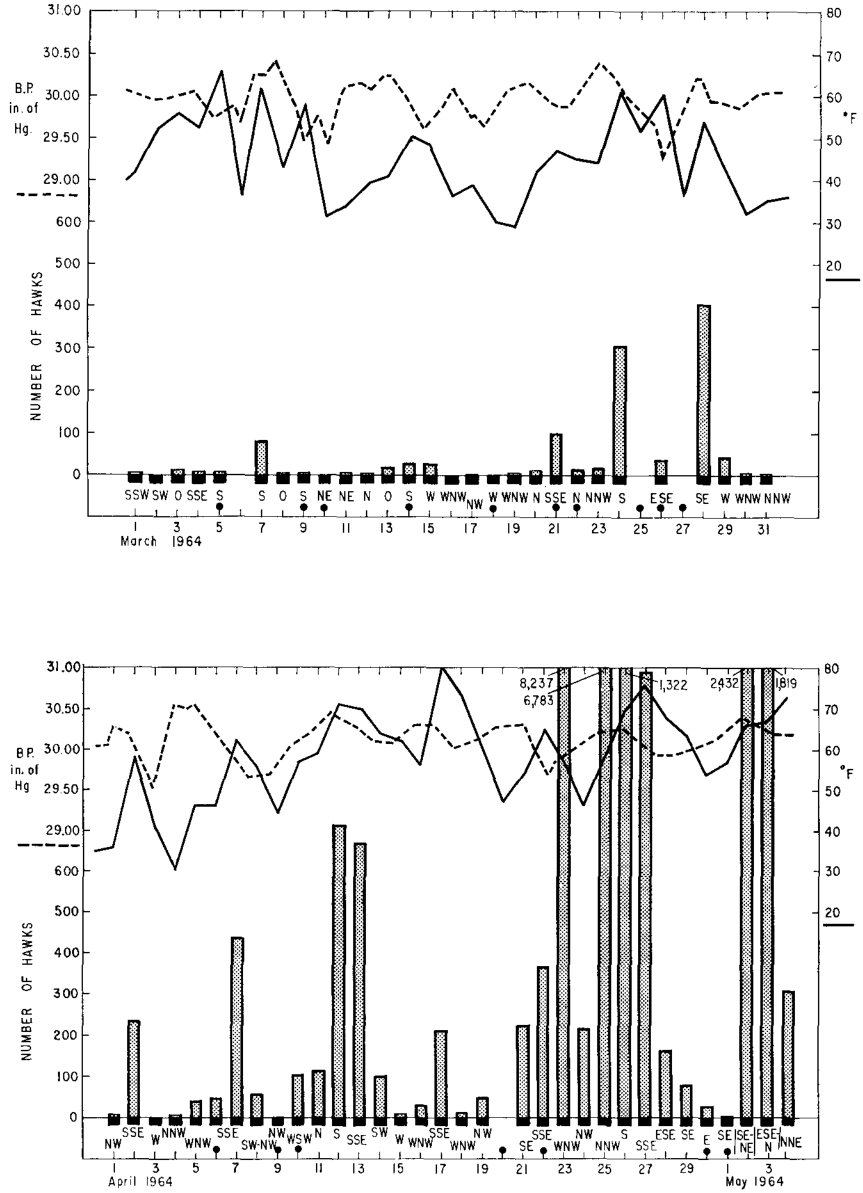

FIG. 6. Relation of the number of migrating hawks in 1964 to barometric pressure, maximum daily temperature, wind direction, and other meteorological factors. Symbols same as in Figure 5.

TABLE 3

RELATION OF HAWK FLIGHTS TO BAROMETRIC PRESSURE AND TEMPERATURE

Weather factor	Number of days with this weather factor between 15 March and 20 April	Number of days with over 100 Hawks observed	Average number of hawks per day
Falling barometric pressure	27	17	235
Rising barometric pressure	23	4	36
Falling temperature	18	3	40
Rising temperature	29	18	207

movement of the low-pressure area which resulted in the hawk movements on 16 and 17 March.

High-pressure areas and rising barometric pressure usually result in limited hawk flights at Derby Hill. During the peak period of the Broad-winged Hawk migration in 1963 only 183 and 58 birds were counted on 27 and 28 April, respectively, as high pressure was centered over the Great Lakes. On 29 April, as a developing low approached from the west and the high moved on to the east, a flight of over 1,000 hawks occurred On 30 April, as the low moved over Lake Ontario, a flight of over 3,000 hawks was observed (Fig. 8). This flight, consisting mainly of Broad-winged Hawks and Sharp-shinned Hawks, took place from 1200 to 1400 hours, between the passage of thunderstorms associated with the nearby low-pressure area and front. After a thunderstorm at 1400 hours, the front passed, and the sky cleared rapidly. The barometric pressure began a rapid rise, and the migration stopped.

A similar situation developed between 4 and 7 April 1964. Only three hawks were observed on 4 April when high pressure was centered over the Great Lakes. As low pressure approached on 5, 6, and 7 April, the number of hawks gradually increased to a peak of 433 hawks on the 7th, the last day before the low-pressure area passed on to the east (Fig. 9).

The above patterns are typical of those observed during our study. They illustrate the importance of low-pressure areas to the spring hawk migration along the southern shore of Lake Ontario.

A situation which occurred on 29 March 1963 is somewhat atypical of the normal pattern and provides further insight into the possible relation of migration to areas of low pressure. On 29 March at 0100 hours a region of high pressure was centered over Vermont and a region of low pressure over Minnesota. At dawn southerly winds and a falling barometer were noted at Derby Hill in connection with the approaching low. It appeared as though the pattern would be a typical one with the low pressure moving over the

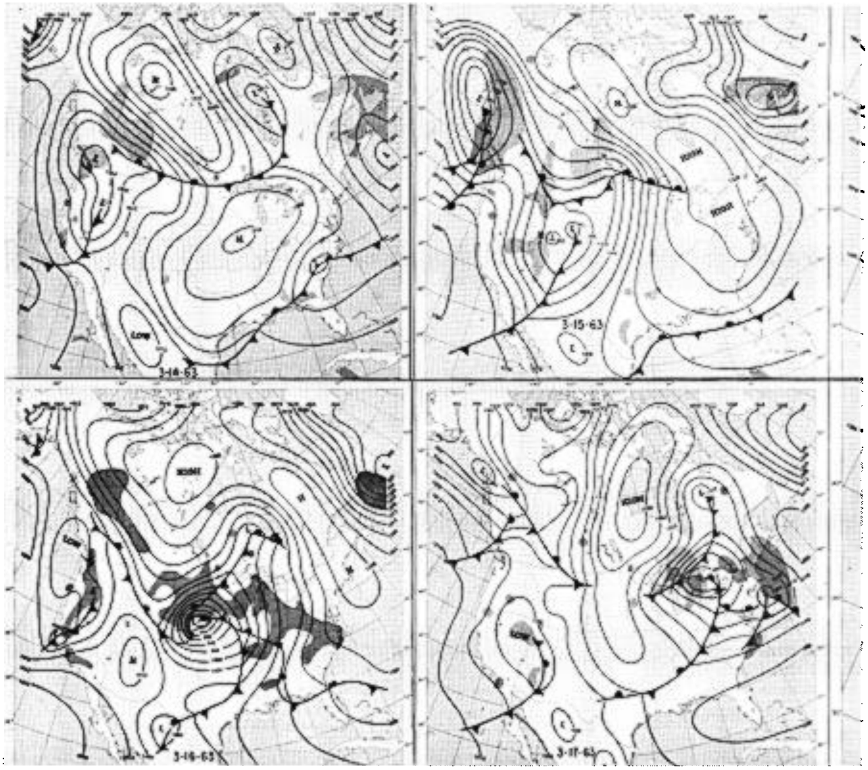

FIG. 7. The weather maps show the normal development and movement of a low-pressure area from 14 March to 17 March in 1963. This system resulted in the first major hawk flights at Derby Hill that spring. Weather maps locate patterns as of 1300 hours Eastern Standard Time.

Great Lakes. The hawk migration began reasonably well in the morning, but then something unusual happened. Instead of continuing its eastward movement, the low moved northeastward so that by late afternoon it was centered over James Bay and moving away from Lake Ontario. Although the wind continued from the south and temperatures continued to increase along the southern shore of the lake, the number of migrating hawks declined rapidly in the afternoon as the low ceased its approach.

On 10 April 1964 the weather was mild during the morning, and winds were variable but generally from a southerly direction. The sky was clear, and there was no sign of an approaching front or low. Later in the morning, however, a small, weak low-pressure area and weak cold front developed and began moving south out of the St. Lawrence Valley. Until this time, only

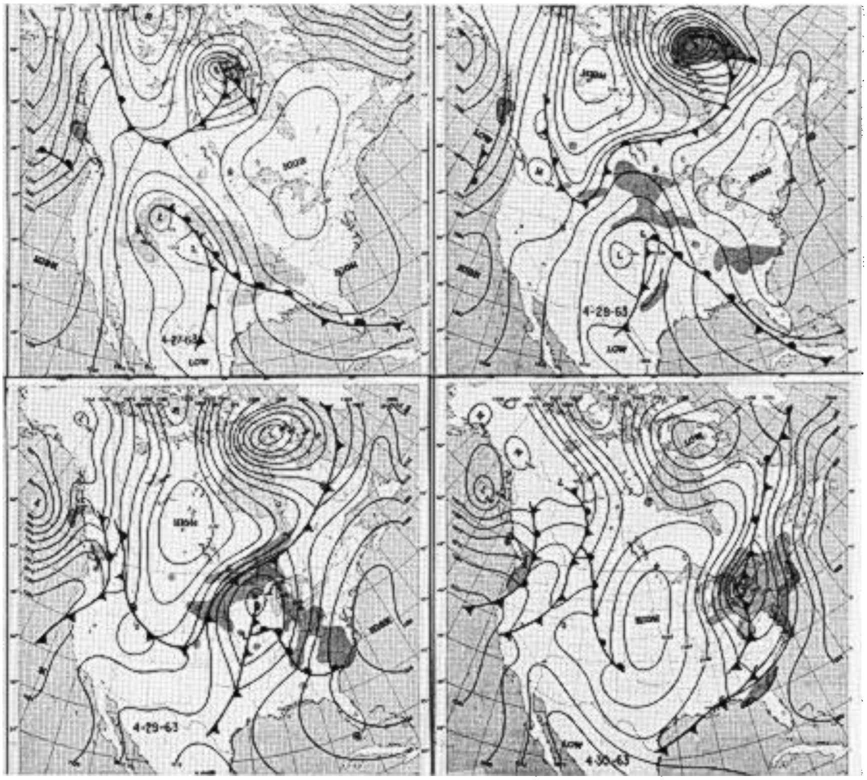

FIG. 8. The weather maps show the movement of pressure patterns from 27 April to 30 April in 1963. The extremely large high-pressure area which covered eastern North America on 27 and 28 April resulted in comparatively few hawks being observed at Derby Hill (see text). As the low-pressure area approached on the 29th and 30th large numbers of migrating hawks flew past the study area. Weather maps locate patterns as of 1300 hours Eastern Standard Time.

17 hawks had been counted in 2 hours of observation. As cloudiness began to develop, 35 hawks were observed in the next 90 minutes. The number of hawks continued to increase, and within the 30 minutes preceding the passage of the front 53 hawks flew past, 30 of which were flying on the leading edge of the front immediately ahead of an approaching rain.

THE INFLUENCE OF LOCAL WEATHER FACTORS ON THE MOVEMENT OF HAWKS

Daily time of migration.—On the average, the hawks usually began flying between 0800 and 0900 hours, but some species start moving earlier than others. In general, accipiters, falcons, and Harriers began moving earlier than soaring species such as buteos. Accipiters frequently were migrating in

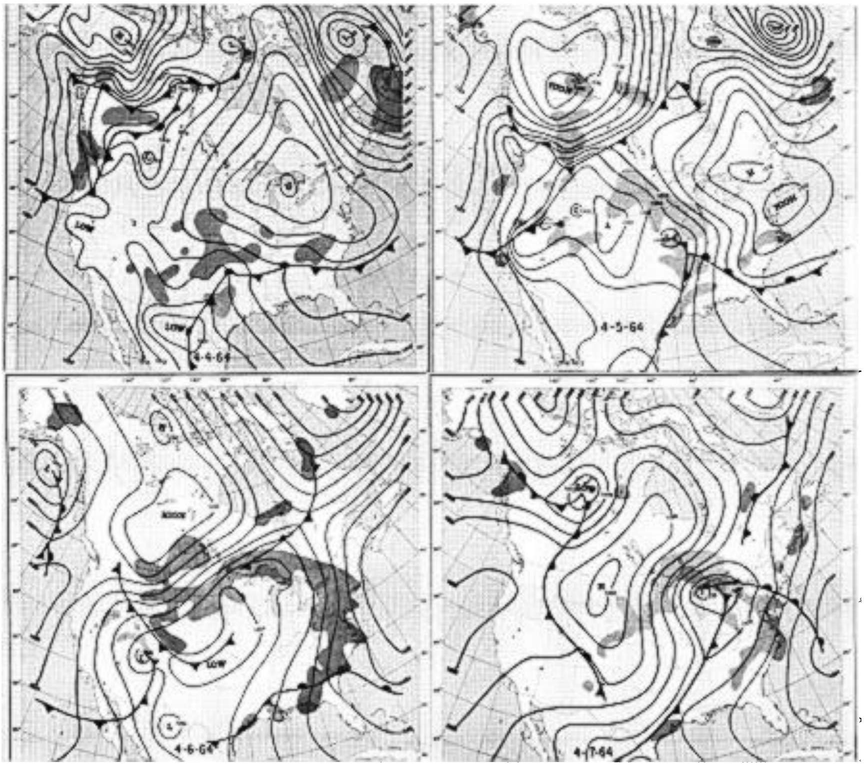

FIG. 9. The weather maps show the movement of pressure patterns from 4 April to 7 April 1964. Only three hawks were observed on 4 April when high pressure was centered over the Great Lakes. As low pressure approached on 5, 6, and 7 April the number of hawks increased to a peak of 433 hawks on the 7th. Weather maps locate patterns as of 1300 hours Eastern Standard Time.

peak numbers by 0900 hours and did not increase significantly after this time. Species more dependent on rising air currents usually did not reach peak numbers until approximately 2 hours after the accipiters (Fig. 10). When a low-pressure area and front were approaching close to the study area, all species generally began to move earlier.

Wind speed and thermals.—Most large hawk flights during our study occurred when the ground wind speed was between 10 and 25 miles per hour. Within this range the wind speed seemed to be relatively unimportant. When winds were in excess of 35 miles per hour, migration usually did not occur. Occasionally, when overtaken by a front with associated high winds, hawks would continue to move for a brief time with winds in excess of 35 miles per hour, especially in the case of Red-tailed Hawks.

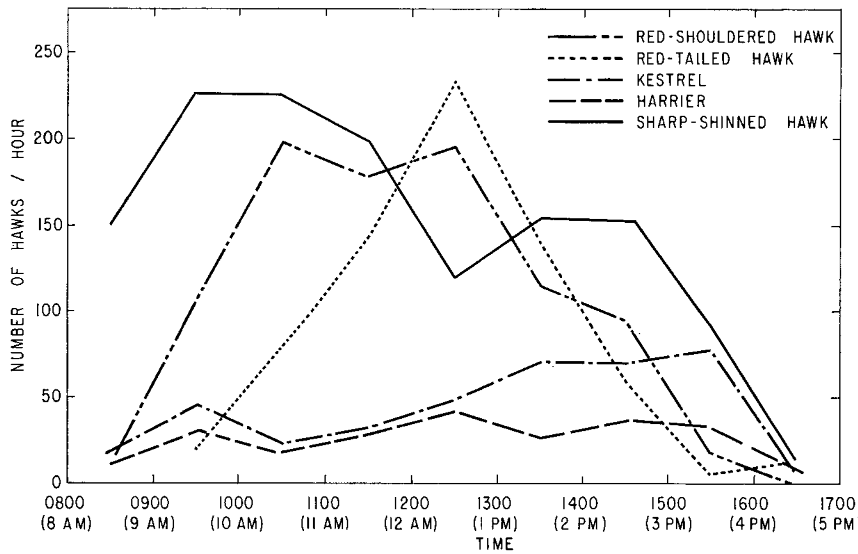

FIG. 10. The daily migration pattern for five species of hawks at Derby Hill. This figure is based on 10 days with southerly winds during the migration period of the Red-shouldered Hawk, Red-tailed Hawk, Kestrel, and Harrier. Since the Sharp-shinned Hawk migrates later, it was necessary to select 5 similar days during its migration period in order to compare it with the other four species.

When surface winds were light and thermal activity well developed, hawks frequently look advantage of the situation to soar to great heights on these rising currents of air. At times in April hawks were observed soaring on thermals at such great heights as to be invisible to the naked eye. An excellent example of such a situation occurred on 26 April 1964. In the morning hawks were flying at moderate heights. By noon the thermal activity had apparently increased, for very few birds were visible to the naked eye. If an observer had arrived at Derby Hill at this time he would probably have assumed that no migration was occurring, unless he was familiar with the conditions and knew enough to search in the right place with his binoculars.

Thermals do not rise equally over all areas but are affected by geographic features so as to be present over some areas and not over others (see Mueller and Berger, 1961). It is interesting to note that hawks passing Derby Hill have sometime been observed to soar to great altitudes on a thermal and then to glide forward (eastward) and downward until they reached the next thermal, at which time they began to soar and gain altitude again.

Wind direction.—Although large flights of hawks may occur on winds from any direction between southeast and southwest, the most spectacular flights during our study have usually been observed on south–southeasterly winds. The easterly component of this wind is a head wind to the hawks moving along the shore of Lake Ontario and caused them to fly lower than they normally would. This head wind also reduced the forward speed of the hawks, so that they were observable for longer periods of time.

Westerly winds, or winds which are very light, resulted in hawks flying extremely high so as to be difficult to observe. With the westerly winds they also moved more rapidly and rarely flapped or soared. Under such conditions, the hawks were often difficult to identify.

Northerly and westerly winds resulted in hawks being dispersed over a much broader front than did southerly winds. Even so, this front seemed to have a definite limit to its width. With westerly winds hawks rarely moved inland more than a mile. With northerly winds the width of the migration front may be increased to 3 miles, but appeared not to exceed this distance. Northerly and westerly winds affected different species in different ways. Falcons often continued to follow the shore. Accipiters drifted inland but not as far as buteos.

Southerly winds tended to push birds following the shore out over the water. The degree to which different species resisted this drift was much as would be expected. Species which commonly nest in woodland habitats and have little association with flat open country or large lakes (such as the Accipiters, Red-shouldered Hawks, and Broad-winged Hawks) showed the greatest resistance to a southerly wind and were frequently observed tacking into the wind in order to remain over land. Species which are usually associated with open country or water, and species which are exceptionally strong flyers, showed less resistance and often were observed flying across the corner of the lake.

Cloud cover.—Cloud cover appeared not to reduce the number of migrating hawks to any degree, if it developed after the hawks had already begun to fly. If, however, clouds were heavy at dawn, the number of hawks migrating was reduced or the beginning of the flight was delayed. Few observations have been made under these conditions, and so it is impossible to say whether or not cloud cover was actually the factor of major importance. Cloud cover may only have delayed the development of thermals.

Rain and snow.—Hawks generally ceased migration when they encountered rain or snow. Nevertheless, some exceptions have been noted, especially among Harriers and Broad-winged Hawks. Although Harriers have been observed to fly in light rain or snow at various times during the migration period, most other species only did so when a frontal system was approaching or at times near the end of the migration period for that particular species. It almost seemed as though late-moving hawks were trying to make up for lost time. Since snow does not usually occur late in the migration period of any species, fewer birds have been observed in light snow than in light rain.

DISCUSSION

Various studies in North America have attempted to relate bird migrations to meteorological conditions. Cooke (1888), one of the first workers in this field, found that southerly winds in front of a low-pressure area were favorable for spring migration. Later (1913) he concluded that the spring arrival of birds is associated with rising temperatures, although temperature alone is probably not the factor of major importance. More recently, authors have associated the arrival of birds with the following meteorological factors: (1) frontal movements and pressure areas (Bagg et al., 1950), (2) cold fronts (Bennett, 1962), (3) southerly winds (Robbins, 1949; Bagg et al., 1950; Imhof, 1953; Devlin, 1954), (4) southerly winds and low pressure (Smith, 1917; Dennis, 1954), (5) change in wind direction (Hassler et al., 1953), (6) stable airflow and following winds (Raynor, 1956), and (7) temperature (Main, 1932, 1938).

Although considerable work has been done relating the arrival times of birds to meteorological conditions, relatively few attempts have been made in North America to associate diurnal, visible movement of birds with these factors. Notable exceptions are Hochbaum's (1955) observations on spring and fall waterfowl migrations, Mueller and Berger's (1961) study of the fall hawk migration at Cedar Grove, and Broun's (1951, 1963) observations on fall migrating hawks at Hawk Mountain.

Hochbaum (1955) associated large fall flights of waterfowl with conditions existing after the passage of a low-pressure area and its cold front, that is, rising barometric pressure, falling temperatures, decreasing humidity, and northwest winds. Mueller and Berger (1961) found similar conditions associated with fall hawk migrations, but believe this association is "simply, a correlation with the occurrence of conditions suitable for updraft formation and hence, good conditions for soaring and gliding." Broun (1963) found that large movements of hawks in the fall at Hawk Mountain occur with northwest winds, but stated that a low-pressure area passing to the north a couple of days previously is also important.

Hochbaum (1955) related spring migrations of waterfowl to conditions associated with an approaching low-pressure area, that is, falling barometric pressure, rising temperatures, and southerly winds. Spring hawk movements in North America have not previously been studied in relation to meteorological events.

We have documented the fact that spring hawk migration tends to be associated with a number of concurrent events such as southerly winds, rising temperatures, and the approach of a low-pressure area and cold front. Others, as noted above, have observed that fall hawk migration is associated with falling temperatures and northerly winds, after a low-pressure area and cold front have moved past an observation point.

Although temperature cannot be eliminated as a possible stimulus for the movement of hawks, some observations seem to cast doubt on its importance. Little migration occurred in late February and early March (1964) at Derby Hill, even though temperatures were quite mild for that time of year, sometimes averaging 8 or more degrees above normal. Later in March temperatures were cooler than normal, but migration still occurred. From these observations it appears that temperatures above or below normal for extended periods have little effect on the migration of hawks. If temperature is of significance, its importance probably lies in its day-to-day variations rather than whether or not it is above or below normal for a given time of the year. Sudden temperature changes could serve as a clue to the occurrence of associated atmospheric phenomena which are important for migratory flight.

During the last 20 years most American authors have tended to regard temperature as a relatively unimportant factor in stimulating birds to move, compared with pressure patterns and wind. Nevertheless, it is interesting to note that Lack (1960), after an exhaustive review of the American and European literature, concluded that some northern species of migrants probably respond to immediate temperature changes.

Southerly winds in spring and northerly winds in fall are undoubtedly advantageous to migrating hawks. Even if they were being lifted by rising air currents, they would find it difficult to move forward against a head wind. These "tail winds" enable hawks to fly farther for a given expenditure of energy, and conservation of energy is probably important to migrating hawks, especially those which must make long passages through areas where food is inadequate (see Skutch, 1945).

In eastern North America, most large flights of hawks occur with the approach of a low-pressure area in the spring and after the passage of a low in the fall. Also, we have observed at Derby Hill that when a low-pressure area with its associated front is near, hawks seem to be more stimulated to move. In contrast to this situation, little migration occurs in the spring when high pressure dominates the weather. Likewise, little migration occurs in the fall at Hawk Mountain when high pressure is dominant (Broun, 1963).

If a low-pressure area is important as a stimulus to movement, it would seem to be necessary for the birds to perceive the approaching low. Mueller and Berger (1961) noted, however, that hourly variations in barometric pressure occurring locally are not usually greater than a bird would experience flying from the ground to the top of a tree. This fact does not eliminate the possibility that birds can sense such pressure changes, but it does reinforce the improbability that birds use atmospheric pressure changes as a clue to the approach of a low. It seems more likely that hawks respond to conditions associated with the low.

In our opinion, the most likely explanation for the movement of hawks in spring in advance of a low-pressure area (and cold front) is the advantage of the situation created by the rising air combining with southerly tail winds. The tendency for hawks to move behind low-pressure areas in the fall also argues for this hypothesis. In the fall the "lift" of the low combines with the northerly circulation of the air behind the low to provide the most favorable conditions. Southerly winds occurring on the western portion of a high and northerly winds on the eastern portion lack the "lift" associated with the low. Thus, from the standpoint of energetics it would certainly be advantageous for hawks to fly in front of a low in the spring and behind it in the fall. In both cases, tail winds and rising air currents should enable birds to migrate farther with less effort.

The only major exceptions to the tendency of hawks to move on southerly winds in advance of low-pressure areas in the spring have been observed with the Broad-winged Hawks. Large flights of Broad-winged Hawks occurred in 1964 on west–northwest and north–northwest winds. Perhaps the best explanation for these flights can be found in the migration urge of this species. Broad-winged Hawks migrate a much longer distance than do most other species of hawks (see Bent, 1937). For this reason they arrive on their breeding areas late in the spring and depart early in the fall. Since they have a more limited amount of time in which to nest and raise young, they may experience a stronger drive to complete their migration, regardless of atmospheric conditions, than other species of hawks.

Regarding daily time of migration, the development of rising air currents is probably of importance in delaying the initiation of migration until midmorning in the case of soaring species, but other factors are also possibly involved. We observed that many hawks passing over the study area in the morning had full crops. In addition, many hawks, especially Harriers and Sharp-shinned Hawks, have been observed hunting in the area at this time. Such observations suggest that many hawks may feed, or attempt to feed, before beginning to move. The Broad-winged Hawk seems to be the only species which usually does not feed during passage around the southeastern corner of Lake Ontario.

The tendency for hawks to rise to great altitudes on thermals has already been mentioned. Thermal development appears to be at a maximum with light southerly winds on a clear day, for it is then that hawks have been observed soaring to their greatest heights. The possibility cannot be dismissed that an unknown number of hawks fly by Derby Hill, under these conditions, at such a high altitude that they escape detection by the observers below.

With southerly winds of approximately 10 miles per hour, hawks have been observed to soar on air currents at considerable heights over the lake. Apparently these air currents are thermals which have been displaced over the lake by light southerly winds. Although at such times hawks are nearly always continuing their eastward movement, the possibility exists (although we have no evidence of it) that once hawks reach this great height over the lake they may glide across to the north shore without ever rounding the eastern end.

Little is known about the air which lies over Lake Ontario near its surface, but observations at Derby Hill give some indication of its nature. During the spring the air over the lake is much cooler than that over the land. With a southerly wind blowing toward the lake, the air temperature at Derby Hill was usually within a degree or two of the air temperature at Syracuse, New York, some 40 miles to the south. With a northerly wind blowing from the lake the temperature averaged between 5 and 10 degrees cooler than in Syracuse. The difference in air temperature probably has a profound effect on the flight of hawks.

This cooler air over the lake apparently is like an invisible bubble which extends above the lake to an unknown altitude. Being cooler than the air above, conditions are not favorable for the formation of rising air currents. The lack of such air currents is probably one important reason why hawks rarely cross over the water.

Although the bubble of cool air over the surface of the lake probably reduces the formation of thermals, a possible secondary effect of this cool air may be of importance. It is well known that when a warm mass of air meets a cooler air mass, the tendency is for the warm air to move in over the cooler air or to be deflected upward by the cooler air. It seems logical to assume that a similar situation occurs when a warm southerly airflow comes in contact with the cool bubble of air over Lake Ontario. The general tendency would be for the warm air to be deflected upward and for rising air currents to occur along the shore. Strong southerly winds would probably reduce this effect by causing the cool bubble of air to retreat northward over the lake and also by disrupting updraft formations which would occur with lighter winds. It is interesting to note that we observed hawks to fly closer to the shore and in a narrower flight path when southerly winds were under 15 miles per hour, especially in the morning before they began taking advantage of thermal activity. With wind speeds above 15 miles per hour, hawks sometimes actively seek to avoid the shoreline. The effect of the Great Lakes on air currents over them is well worth further study from the standpoint of understanding hawk movements along their shorelines.

SUMMARY

Although much is known about the fall migration of hawks from studies made at Hawk Mountain, Cedar Grove, and at other locations near the Great Lakes and along the Atlantic Coast, relatively little study has been done on spring hawk migration. The location of a major spring hawk flyway along the southern shore of Lake Ontario presented an excellent opportunity for study.

A promontory on the southeast shore of the lake, known locally as Derby Hill, was selected as a study area, and observations of hawk movements were made during the spring migration periods in 1963 and 1964. Particular attention was focused on the different species of hawks migrating at different times and on the effects of weather conditions upon the movement of the hawks.

It was found that in general each species of hawk tends to migrate within a definite part of the migration season, although occasional individuals may migrate early or late. Some species, such as the Goshawk, Red-shouldered Hawk, Red-tailed Hawk, Rough-legged Hawk, American Kestrel, and Harrier are most common late in March or during the first week of April. Other species, such as the Broad-winged Hawk, Sharp-shinned Hawk, Turkey Vulture, and Osprey are most common during the last week of April or during the first week of May. The Red-tailed Hawk, Harrier, and Cooper's Hawk tend to have migration periods which extend over most of the spring migration season.

Large spring movements of hawks are associated with southerly winds, rising temperatures, falling barometric pressure, and the approach of a low-pressure area and cold front. Because of the tendency for these weather factors to occur together, it has not been possible to isolate any one as being of primary importance in stimulating spring hawk movements. It appears doubtful, however, that temperature or actual change in atmospheric pressure directly stimulates spring movements. More likely, the factors which are of major importance are the southerly winds and rising currents of air which occur in front (east) of an approaching low-pressure area. It would be advantageous for hawks to fly on southerly winds when rising currents of air are also occurring. Such "tail winds" and rising air currents enable hawks to migrate farther for a given expenditure of metabolic energy. The only hawk which frequently does not show a good association with an approaching low-pressure area is the Broad-winged Hawk.

The tendency for hawks to migrate within certain hours of the day is probably related to daily variations in local weather factors and to the methods of flight which the hawks employ, although the feeding and hunting habits of these birds may also be of some importance. Those species which depend largely on soaring fly when updraft formation is greatest. Such updrafts probably result from the general tendency of air to rise in a low-pressure area, from thermal activity, and from the tendency of warm southerly winds to be forced up by the cool air mass over the lake. Species which employ soaring flight less frequently often begin migrating earlier in the day and continue later than those species that depend on the thermals to a greater degree.

Migrating hawks also exhibit other responses to local weather conditions. They tend to remain close to the lake when winds are southerly and to move inland for various distances when winds are from other directions. Hawks generally fly higher and move forward more rapidly when winds are from a westerly direction. It has also been noted that hawks usually cease migration in rain or snow.

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DEPARTMENT OF ZOOLOGY, SYRACUSE UNIVERSITY, SYRACUSE, N. Y., 29 APRIL 1965

LETTER TO THE EDITOR

Dear Sir,

The International Ornithological Congresses have by tradition generally been held in the breeding season, and the host country has organized excursions before and after the meeting, so that visitors have been able to see something of unfamiliar birds in the field under expert guidance. In the three congresses that I have attended British ornithologists have been amongst the chief recipients of this hospitality. It is therefore with shame, as well as regret, that I find that next year's congress, at Oxford, is to be held in July, and that there is to be only one, highly specialized, excursion, so that American visitors will have no opportunity to see the ordinary English birds in the breeding season.

I should like to do what I can to make amends, and am prepared to offer hospitality, in the form of accommodation and transport, so far as my teaching and other commitments allow, to as many American ornithologists as possible. If anyone interested will write to me saying when he will be in England, I will do my best to arrange something. I shall not be available from 19 June through 3 July. My chief interests are in woodland birds.

Yours sincerely,
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