

# AUTUMN HAWK MIGRATION IN ONTARIO

## STUDIED WITH RADAR

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### INTRODUCTION

The tendency of migrating hawks to concentrate at certain locations is one of the features that makes study of their migration especially interesting. This tendency to concentrate, coupled with their relatively large size and daytime migration, has made them one of the best known groups of birds insofar as migratory habits are concerned. Visual observations at the known concentration points have provided quite detailed information about flight behavior and the timing of migration for each species. This type of information is much less readily obtained for species of birds that do not concentrate and for those that migrate at night.

The number of locations at which major concentrations of migrating hawks have been recorded systematically is quite small. The known concentration points are widely scattered. There are vast intermediate areas over which hawks certainly do migrate to some degree. Thus current knowledge of hawk migration is based on systematic data from only a very few rather unusual locations, scattered observations from other locations, and virtually no data from everywhere else.

There is, for example, little reliable information about how hawks get to the known concentration points, or about where they go from those points. There is rarely more than speculation about what the hawks are doing on days when they are not migrating in significant numbers over the usual concentration points. Are they migrating elsewhere, or are they grounded awaiting more favorable weather? It is difficult to interpret the data from concentration points in the absence of data from elsewhere. There is, for example, no way of determining from a single observation point whether the weather conditions associated with major flights at a concentration point are truly those that induce maximal numbers of birds to fly. They might instead be the conditions that produce maximal concentration over the observation point. Clearly a broader perspective is required in order to examine these questions.

One way of obtaining this broader perspective is that used in the New England Hawk Watch, described in this volume (page 137). This approach can provide very detailed data, but it requires too much manpower to be applied daily throughout a migration season.

The techniques of radar surveillance provide another way of obtaining broad-scale data on bird migration. Radars can provide information about the distribution, numbers, flight paths, speeds, and altitudes of migrants. Eastwood (1967) has provided a good introduction to radar techniques applicable to ornithology, and a review of results to that date.

Radars can detect birds regardless of visibility; hence fog, clouds, darkness, and rain need not preclude observations. On all but the lowest-powered radars, even the highest flying hawks are readily detected. While radars and associated equipment occasionally do break down, they are

basically tireless. By using time-lapse filming techniques, we have often obtained radar data for well over 90% of the hours in an entire migration season.

The lowest-powered radars, which include many marine, airborne and anti-aircraft fire-control radars, are capable of detecting individual hawks out to distances of at least a mile, and sometimes to several miles.

Medium-powered radars, such as are used for air traffic control around airports and for weather surveillance, can in theory detect individual hawks out to distances of about ten miles. In practice this probably rarely occurs, partly because of various technical limitations associated with the difficulty of separating weak echoes from hawks and strong echoes from objects such as trees, buildings, and hills, and partly because these radars usually cannot resolve birds flying within a few hundred feet of one another. However, we have found that medium-powered radars of these types do detect groups of hawks at distances up to 20, 30, or even 40 miles from the radar site.

High-powered radars are used for en route air traffic control in the United States, for air surveillance by the U.S. and Canadian armed forces, and for missile tracking by the National Aeronautics and Space Administration. These installations undoubtedly can detect hawks at even greater ranges, although to our knowledge they have not been used for this purpose.

While radars have these various advantages over visual observers, they have numerous disadvantages as well. Their resolution is sufficiently low that the birds within some minimum volume of airspace cannot be distinguished. Thus one cannot determine the number of birds in any given group with most radars. In general, the higher the radar power and the greater the area surveyed, the poorer the resolution. Furthermore it is very difficult to identify the birds appearing on radar screens. While behavioral differences usually allow one to distinguish major groups such as hawks, waterfowl, shorebirds and passerines, one can rarely make finer distinctions. Finally, radars cannot detect low flying birds at ranges of many miles since these birds are below the radar horizon. I have discussed these and other limitations in detail elsewhere (Richardson, 1972).

Clearly, the radar and visual techniques are complementary. Radar can provide broad-scale and continuous data about flight directions, speeds, altitudes, and concentration areas, and more crudely about numbers aloft. Visual observers can provide detailed but very local information about the species involved, flock sizes, and small-scale flight behavior. Far more can be learned by using both techniques together than by using either alone.

Hawks have been detected with radars by various observers in both Europe and North America (Gehring, 1963; Houghton, 1970, 1974; Alerstam and Ulfstrand, 1972; Evans and Lathbury, 1973). However, the present study in Ontario and the concurrent study at Gibraltar are the first systematic analyses of hawk migration that have employed radar data.

My objectives in this report are two-fold: to describe radar techniques useful in the study of hawk migration, and to present a preliminary summary of our study of autumn hawk migration in Ontario. The latter aspect will be published in detail elsewhere.

## RADARS USEFUL IN STUDIES OF HAWK MIGRATION

Three general types of radars can be used profitably in studies of hawk movements: broad-beam surveillance radars, tracking radars, and special-purpose radars. We have used only surveillance radars for studying hawks, although we have used tracking and various special-purpose radars in other studies.

### Broad-beam surveillance radars

Broad-beam surveillance radars are the most familiar types. Medium- and high-powered versions are used for air surveillance and air traffic control. Lower-powered and less sophisticated versions are used on ships for navigation, but can be adapted for ornithological purposes (e.g., Williams *et al.* 1972a). All of these radars involve a beam that is broad in vertical extent and narrow horizontally. This beam is rotated continuously. When an echo is received, the distance of the target is determined from the time taken for the echo to return. The direction is determined by the direction in which the antenna was pointed when the echo was received. Because of the broad vertical extent of the beam, little or no information about altitude can be obtained from this type of radar. The distance and directions of detected targets are displayed on the familiar circular radar display, called a Plan Position Indicator or PPI, which is simply a map of the area. The more sophisticated surveillance radars have Moving Target Indicator circuitry that suppresses all stationary echoes. This permits one to detect aircraft and birds even when they are over areas from which ground echoes are being received.

By observing the PPI at one point in time, one can detect the presence, locations, number, and concentration areas of echoes such as birds. By observing the PPI over a period of time, one can also detect the directions and speeds of motion of the various echoes.

When one is observing an area 30 or more miles in radius, echoes from birds take a long time to move across the PPI. Their motion during the few seconds from one rotation of the beam to the next is almost imperceptible. However, time-lapse filming can provide an excellent record of this motion. The time-lapse technique has the additional advantage that one can reexamine the record for a given period of time as often as desired. Furthermore a continuous record can be obtained by the mere effort of changing the film every one to four days, depending upon filming rates and camera capacity. In most situations time-lapse techniques provide much more detailed information than can be obtained directly or with a still camera.

We normally use 16mm equipment operating at about three frames per minute; thus a 200-foot roll of film, which costs about \$20 to buy and process, will provide a continuous record over a 48-hour period. Solman (1969) has described the filming technique. Williams and Mix (1973) have developed a less expensive system using an 8mm camera.

Hawks migrating across southern Ontario in autumn and over Gibraltar typically appear on radar in a linear pattern readily distinguishable from most other migrants (e.g., Figure 1). Simultaneous visual and radar observations on numerous days around Toronto and at Hawk Cliff on Lake Erie have shown that the vast majority of occasions with such patterns represent hawk flights. Other birds occasionally move in concentrated streams along lake-shores, but these flights usually are not accompanied by simultaneous lines of echoes inland. Furthermore only hawk flights begin at mid-morning; Blue

Jays, crows, swallows, and other potentially confusing species take off at sunrise. Thus I am confident that in southern Ontario, hawks are the birds involved in any movement that first appears on the radar display at mid-morning and includes lines of echoes moving southwest inland. Many of the other isolated echoes moving southwest at the same time as the lines of echoes are presumably hawks. However, we have no way of identifying them, and hence base our analyses on the lines alone.

Data can be abstracted from the time-lapse films using a variety of techniques. Flight directions of individual echoes and the alignment of the lines of echoes can be estimated by eye. Alternatively, directions and speeds can be measured by first tracing them onto a sheet of paper used as a screen, or by various photographic techniques. The positions of concentrations of hawks can be determined by projecting the film onto a map at the appropriate scale, or by recording their distance and direction from the radar site and transferring these coordinates to a map. The number of hawk echoes over the whole display or in specific areas can be estimated on an ordinal scale, or in some cases, by counting the numbers of individual echoes crossing some line perpendicular to the mean flight direction. The latter approach is workable only when the echoes in the lines are distinct. In any event only the number of 'kettles' or flocks, not the number of individuals, can be measured. Thus these radars can provide only a crude measurement of the relative numbers aloft at different places and times. Supplementary visual observations of flock sizes are very useful; the radar can show the number of flocks over a broad area, while the visual observations reveal the sizes of a sample of the flocks.

Medium- and high-powered surveillance radars (peak power 400 kilowatts to several megawatts) cost hundreds of thousands or millions of dollars, require frequent maintenance, and are rarely portable. Thus one is restricted to parasitizing preexisting installations. All major airports and some smaller ones have medium-powered radars. High-powered military surveillance radars are scattered at intervals of about 250 miles across southern Canada, around the perimeter of the United States, and at various other locations. In the U.S. there are additional radars of this type scattered across the country for en route air traffic control. Access to any of these radars usually can be obtained, although it often requires several months of intermittent negotiation.

Low-powered marine surveillance radars are readily obtainable, new, at a cost of \$5,000 to \$30,000. These radars have peak power output of three to 50 kilowatts, and require very little maintenance. They are portable in a van, and can be run by a small gasoline-powered generator or from normal power outlets. Their range is at most a few miles, but within that range they have higher resolution than do the more powerful surveillance radars. Thus marine radars are well-suited for obtaining more accurate counts of the number of birds passing by within two or three miles of any location to which one could drive a small vehicle. Marine radars generally do not have circuitry for suppressing ground echoes, and hence provision must be made to avoid detecting objects at low elevation. This limits one to surveying moderate or high altitudes.

A useful approach would be to use a moderate- or high-powered radar to survey hawk movements over a general region, a low-powered high-resolution marine radar to obtain more detailed information near concentration points within the coverage area of the more powerful radar, and visual observers to obtain still more localized but more detailed data. No systematic study of this nature has been performed to date.

## Tracking Radars

The second type of radar potentially of great value in studies of hawk migration is the tracking radar. These radars have a narrow beam. Once the beam is aimed at a target of interest, it automatically remains directed at the target. The direction of the beam plus the time required for the echo to return provide a precise measurement of the location of the target in three dimensions. The changes in position over time can be plotted automatically onto graphs in real time or recorded manually every few seconds. Alternatively or additionally, the positions can be recorded onto analogue or digital magnetic tape for future manual or computer analysis. In addition, the strength of the echo received from each pulse of energy can be recorded. The variations in the echo intensity from a target are called its signature. From the signature can be extracted information about size, wing-beat rate, and perhaps the attitude or orientation of the body relative to the radar beam. Bruderer and Steidinger (1972) and Williams *et al.* (1972b) describe tracking-radar techniques in more detail. These techniques are now being applied in the study of hawk migration at Gibraltar (Houghton, 1974).

A high-resolution tracking radar can provide very precise information about flight behavior. For example, the radius of turn, rate of climb and maximum altitude attained in a thermal could be measured easily. These parameters could be compared for different species, different weather conditions, etc. Winds at any altitude of interest aloft can be measured precisely by using the same radar to track an ascending balloon.

Tracking radars are not well suited for general surveillance. Their beams are too narrow to examine more than a small fraction of the sky in any one rotation, and they are not designed for continuous or unattended operation. However, simultaneous observations with a surveillance and tracking radar, such as are now being obtained at Gibraltar, can provide excellent data.

For the purpose of studying hawk migration, a portable, low-powered, high-resolution tracking radar is probably preferable to a fixed, high-powered, moderate-resolution installation. Even the least expensive tracking radars are expensive. Thus the only practical alternatives are to obtain access to a preexisting fixed-base radar, to obtain a mobile radar on loan from NASA or the military, or to buy an obsolete military surplus radar. Each of these three approaches has been used successfully by ornithologists. However, the third alternative, buying a surplus radar, is probably inadvisable because of the difficulty in maintaining old but complex electronic equipment for which parts are not readily obtainable.

## Other types of radar

The third category of radars includes the wide variety of surveillance equipment with something other than vertically-broad beams rotated horizontally. Radars with vertically-narrow beams can provide information about the heights of migrants. However, with some of these radars it is even more difficult than usual to identify birds. The usefulness of any available radar must be evaluated on the basis of its individual characteristics and the data required.

One widely available class of radars, weather radars, provides most of the advantages of surveillance radars plus a limited capability for

height measurements and for determining the size of flocks (Able, 1970; Gauthreaux, 1970).

Military radar sites usually have 'nodding' height-finding radars as well as broad-beam surveillance radars. Eastwood (1967: 197) and Nisbet (1963) have described these height-finders. They can measure the altitudes of birds over broad areas with a maximum possible error of about 500 feet. However, they are often of little use in hilly terrain, where echoes from the ground tend to obscure birds.

#### AUTUMN HAWK FLIGHTS OVER SOUTHERN ONTARIO

##### Results of visual observations

Previous visual observations have revealed massive southwestward and westward flights near and along the north shores of Lakes Ontario and Erie. The best-known observation point is Hawk Cliff, on the north shore of Lake Erie. It is not uncommon to see 10,000 hawks moving west past one point during a single September day, and as many as 70,000 have been reported in one day at Hawk Cliff. The most abundant species is the Broad-winged Hawk, Buteo platypterus. It is widely known amongst local ornithologists that the largest flights are to be expected along the lake shores with northerly winds, cool temperatures, and rising pressure after the passage of a cold front, as a low-pressure area moves away to the east and a high approaches from the west. Gunn (1954) and Haugh (1972) have described autumn migration of hawks across southern Ontario.

West of Hawk Cliff the buteos tend to spread out inland rather than to change course to the west-southwest and follow the shore towards Point Pelee, although Sharp-shinned Hawks and perhaps others do tend to remain with the shore. Similar behavior has been suspected at Toronto. While hawks are frequently concentrated near and at the shoreline east of and over the city, visual observations suggest that many then move inland rather than follow the shore to the southwest.

On days when the winds have a southerly component, the main flight line along the north shore of Lake Erie is apparently a few miles inland. Haugh (1972) has concluded that varying positions of the main flight line based on wind conditions are a major cause of year-to-year fluctuations in the number of hawks seen. He reported that this was not the case at Derby Hill in spring, where the main flight line was quite distinct and only a mile or so inland with onshore northerly winds.

Unfortunately, the visual data from inland southern Ontario are too sparse to be very useful for comparison with the shoreline data. However, flights of several hundred or even several thousand birds per day have been reported from a location about 20 miles north of the Toronto lakeshore.

##### The radar view

Radar data from London, Ontario, including the Hawk Cliff area, were obtained through the autumns of 1965, 1966, and 1967. Similar data from a radar at Toronto were obtained in the autumns of 1964, 1965, 1967, 1970, and 1973. Both radars were AASR-1 broad-beam Air Traffic Control units, with moderate power (550-kw peak), wavelength 23 cm, and Moving Target Indicator circuitry (see Richardson, 1972 for details). In 1973 at least one and occasionally as many as four observers were in the field

each day from early September to early October, and less regularly at other times. In addition to observing hawks passing specific points, we used real-time radar observations and a radio-telephone to attempt to direct an observer to the inland concentrations of hawks. All radar data in all years were recorded on time-lapse film for later analysis.

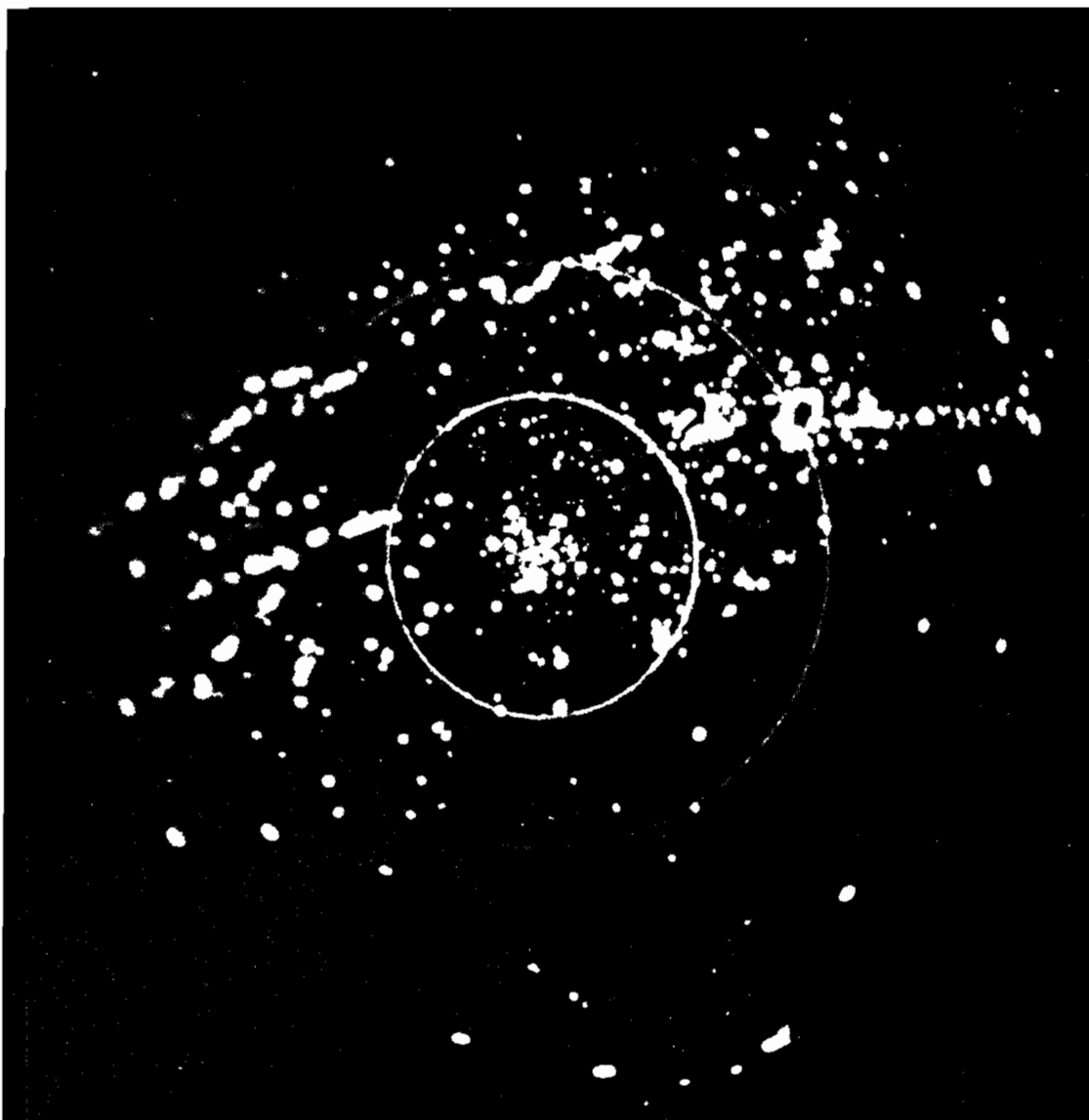
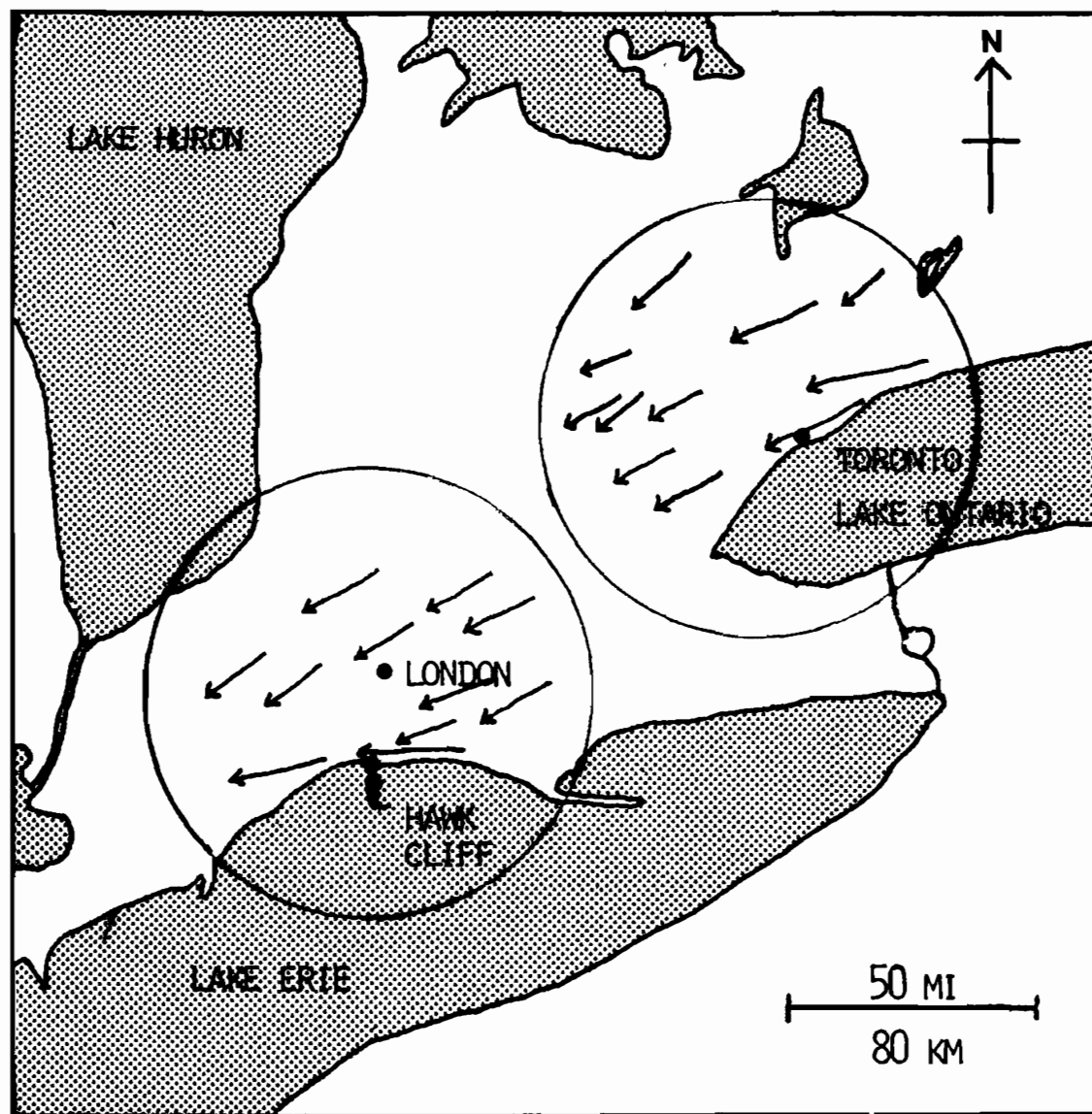


Figure 1. Lines of echoes from hawks visible on the PPI display of the AASR-1 radar at Toronto, 13:30 EST on 14 September, 1973. Almost all of the point echoes also represent birds. The photo is a ten-second time exposure and shows a single revolution of the radar beam. The display shows an area of radius 40 nautical miles (46 statute miles; 74 km), with range rings at ten-nautical-mile intervals. See Figure 2 for a map of the radar coverage area.

Lines of echoes from hawks appeared in the Toronto and London areas both inland and near the lakes on various days in September and October. As expected on the basis of the visual observations, the concentrations along the shoreline were most pronounced east of Toronto and Hawk Cliff. West of these two locations the hawks usually moved inland rather than turning to the left to remain along the shorelines (Figures 1 and 2).

Figure 2. Map of southwestern Ontario showing typical locations of lines of hawk echoes within the London and Toronto radar coverage areas (40-nautical-mile radius) in autumn.



In the London area the main flight line was often directly over the shore from 15 or more miles to the east of Hawk Cliff to Hawk Cliff itself. Near Toronto the main line east of the city was usually a few miles inland rather than directly over the shoreline. On some days it was as far as eight or ten miles inland. Furthermore, in both the London and the Toronto areas, lines of echoes were very frequent even farther inland. In the Toronto area, these lines were often visible as far as 35 nautical miles north-northwest of the radar site, or about 50 statute miles north of Lake Ontario. The echoes in these lines far to the north were usually moving to the southwest, whereas those closer to the lake were usually moving west-southwest.

The locations of the lines well inland from the north shores of Lakes Ontario and Erie were highly variable. Some lines remained in roughly the same location throughout a given day, but there was little tendency for lines to recur on different days at some points to the exclusion of others. Thus on some specific days a few lines would be widely



spaced at constant locations, but during the next hawk flight they might be widely spaced elsewhere in the area.

Furthermore, I frequently detected lines of echoes whose position changed continuously. For example, on numerous days, most of the ENE-WSW aligned lines of echoes moved laterally southwards. The track of an individual bird was therefore somewhat south of WSW, since it moved west-southwest along the line and simultaneously south with the line. On other days most of the lines remained over the same locations from hour to hour, and on a few days the lines moved laterally to the north. The variable locations of inland concentrations of hawks are no doubt in large measure responsible for the infrequency of inland sightings in southern Ontario. Very few inland observation points become recognized as good places to see migrating hawks. Even using real-time radar surveillance and a radio-telephone link between the radar and field observers, we found that it was very difficult to obtain visual sightings on the main inland concentrations. Nonetheless large numbers do move across the area many miles inland from the lakes.

#### Distribution of hawks vs. weather

One of the previously unanswered questions that can be addressed by using the radar data is the effect of weather on flight paths and concentration areas. I examined the relationships of various weather variables to three measurements of hawk behavior and distribution near Toronto:

- (i) the relative numbers within a few miles of Lake Ontario and farther to the north;
- (ii) the degree and direction of lateral motion by the lines of echoes; and
- (iii) the mean flight direction over the ground of the echoes involved in the lines.

Each of three characteristics of hawk migration is likely to be related to a variety of meteorological variables, and perhaps to other kinds of variables. A number of multivariate techniques were used in the analyses, and care was taken to scale variables appropriately and to use procedures such as analysis of residuals to verify the accuracy of the assumptions (Richardson, 1974). The Biomedical (BMD) package of computer programs was used to perform the analyses (Dixon, 1973).

Stepwise multiple discriminant analysis was used to determine whether there was any evidence that any weather variable was related to the north-south distribution of hawks. While the results of the various analyses were less than perfectly consistent, there was strong evidence that there were relatively more hawks near the lake with winds having a northerly component and more inland with winds having a southerly component.

This result was extended by stepwise multiple regression analysis of the lateral motion of the lines versus weather conditions. The regression analysis showed a strong tendency for the lateral motion to be correlated with the north-south wind component and to related variables such as pressure trend and temperature. The lines tended to move laterally southwards with northerly winds, and to remain stationary or move northward with southerly winds.

The mean flight directions of individual echoes showed no obvious relationship to any weather variables. However, they were related to the

lateral motion of the lines. When the lines moved south, the birds tended to be directed further to the left of WSW than when the lines were stationary or moved north. These results were again obtained using stepwise multiple regression.

The results clearly show that hawks tended to concentrate near Lake Ontario with northerly winds more than they did with other winds. The method by which this concentration occurred is still not clear, partly because we have no clear understanding of the nature of the lines of laterally-moving echoes. However, even the relatively stationary lines of echoes inland over Ontario do not seem to be strongly associated with specific topographic features. This enhances the probability that atmospheric phenomena, or their interactions with topography, were responsible for the concentrations inland. It is probable that there are various reasons for the formation of lines of migrating hawks. None of the phenomena described by John Haugh elsewhere in this volume (page 72) could alone account for all of the situations in which lines of hawks have been detected. Simultaneous visual, long-range surveillance radar, and high-resolution surveillance or tracking radar data would be very useful in clarifying the situation. In addition, more precise data on atmospheric conditions are needed.

#### Volume of migration vs. weather

Another topic that was examined using the radar data was the day-to-day variation in numbers aloft. The analysis was based on the entire Toronto radar-coverage area, whereas visual observers around Toronto and Hawk Cliff have based their conclusions on numbers seen along or near the shore. In September, hawk movements were very significantly more frequent and denser in synoptic weather conditions involving north or east winds than in those involving south or west winds. In other words, there were many hawks aloft after the passage of a cold front as a low moved away to the east, a high approached or moved past to the north, or both. Large numbers were also aloft when there was a high pressure area nearby. These results are similar to those derived by subjective assessment of previous visual observations along the lakeshores.

However, more detailed analysis of the radar data showed that conclusions based on these visual observations alone are biased. Multivariate analysis of numbers versus 15 weather variables showed a strong relationship between the numbers aloft, fair weather, and winds having an easterly component. The greater correlation with easterly than with northerly winds was very clear. This result was confirmed by a more sophisticated analysis, in which we first used factor analysis to identify three basic meteorological dimensions amongst the 15 original weather variables, and then related the numbers aloft to these weather factors using discriminant analysis.

#### Comparison of radar and visual results

Hawk migration was detectable by both radar and visual techniques. Visual observations provided more detailed but intermittent and localized data about the identity of the birds, about flock sizes, and about numbers aloft. Each radar provided more continuous data for all parts of an area about 80 miles in diameter. The radars revealed previously unknown flight paths, and permitted study of migration patterns even on days when only small and visually inconspicuous flights were occurring. If a tracking radar or a surveillance radar with high resolution had been available, more detailed information could have been obtained about flight paths.

The broad-scale data obtained by radar permitted the first systematic

analysis of day-to-day variations in the geographic distribution and flight directions of hawks migrating over Ontario. These results, together with analyses of migration volume, showed that visual observations at known shoreline concentration points provide a biased impression of flight patterns and of weather conditions optimal for migration across southern Ontario as a whole.

Visual observations at Hawk Cliff, Ontario; Cedar Grove, Wisconsin; Derby Hill, New York, and of some species at Hawk Mountain show strong correlations between side winds rather than following winds, and numbers aloft (Mueller and Berger, 1961, 1967a, b; Haugh, 1972). In contrast, peak volumes of migration in species other than hawks are closely related to following winds. The radar study of hawks near Toronto suggests that the apparent relationship of peak numbers to side (northwest and north) winds is an artifact of overly localized observations; maximal numbers do migrate across southern Ontario as a whole when winds are following (NE-E). It is quite possible that similar phenomena occur near the other concentration points noted above. Specifically, weather conditions that concentrate maximal numbers of hawks at known lookouts may not produce the densest movements across the broad area around those lookouts. Radar data from those areas would give a broader perspective and help to answer many of the outstanding questions about the flight behavior of hawks.

#### ACKNOWLEDGEMENTS

Our radar studies were begun by the Associate Committee on Bird Hazards to Aircraft of the National Research Council of Canada under the direction of Dr. W. W. H. Gunn. More recently the studies in the Toronto area were financed by the Toronto Area Airports Project, Canada Ministry of Transport, through a contract with LGL Ltd. M. McLaren assisted with data compilation; R. A. Davis, T. Davis, J. O. L. Roberts, and G. Yaki made the field observations.

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## DISCUSSION OF TELEMETRY AND RADAR

QUESTION: Have broadwings been seen crossing the Great Lakes?

RICHARDSON: No. Sometimes we see them going out as much as a mile and flying parallel to the lake shore, but only when the winds are very strong from the north. But as far as birds heading across the lakes, no.

PERSHING HOFSLUND: Capt. Perkins here has of course traveled the Great Lakes for many many years and kept observations. Maybe he has some comment, too, along this line.

J. P. PERKINS: After two million miles of traveling over the waters of the Great Lakes and book after book of observations of birds, the buteos--I can count my sightings on both hands, and I have five fingers on each hand. Accipters, yes. We saw lots of sharpshins in past years. The sharpshins and kestrels have deteriorated. Maybe once or twice every three years we see a peregrine now. Ospreys and marsh hawks are also frequently seen crossing the lakes. There is a good hawk flyway from the eastern end of Isle Royale to Keweenaw Peninsula--mostly Ospreys, a few roughlegs, marsh hawks, sharpshins, and kestrels. They do cross the lakes in quite large numbers. I see them from my ship. I see them on board. I've photographed them. I did photograph one peregrine. It was late in the evening--got so excited, I forgot to allow for the poor quality of the evening light. But the buteos: on August 20 back in the late 60s a pair of immature Red-shouldered Hawks came aboard, and it was a beautiful afternoon. They were crossing in the Apostle Island region of Lake Superior [off Duluth]. Come nighttime, I captured these two hawks and kept them in my room for 21 days. Jack Hofslund banded them and let them go on Hawk Ridge, Minnesota. I lived with them for 21 days. I have detailed observations on their behavior, and the other crew members could tell anytime I was within range of these two hawks because they started a peculiar whistling noise--I could go on and on telling you about birds over the lakes... And in answer to the radar man, I tell you, when we're using our radar aboard ship, we're not interested in birds. The new...radars we have, and some of the older ones, I can pick up any object on the water that's of interest to the navigator; and you've got to realize it's a potential danger to your ship. So we make an allowance for a target on the water ahead. We can't prove that it is stationary, but we take evasive action, and then to go by and see a seagull sitting on the water--I could wring his damn neck.

DAVID BIRD: [Asks if radar has been used in studying owl migration.]

RICHARDSON: Not that I know of. I don't know that anybody has reported detecting owls on radar. Radars have difficulty in picking up things at low elevations. Even radars such as the ones that we were using still don't pick up things very well if they are flying low-level or over areas where there is intense ground return. And the more short-range, high-resolution radars such as the marine ones, which would be essential or which would be desirable in trying to look for something visually, or trying to identify it, don't have the capacity to suppress the ground echoes.

QUESTION: [On the unit cost of telemetry.]

TOM DUNSTAN: On the average, the way the market looks now, there are about five or six different companies that do this sort of thing. To buy one transmitter would probably range from about \$60 to \$120, depending on which transmitter you want. The receivers will vary from around \$300 to \$600. Now,

the one I had up here was about the \$600 deluxe model, 12 channels, and so on. Three-channel models are around \$300, and I think there is now one that's coming out that's going to bring it down to around \$150 to \$300, which is going to be a good receiver and looks pretty economical. Antennas: as for the Yagi (a Japanese type of antenna that looks like a fish skeleton)-- that goes for \$9.95. Double-Yagis are twice that. A 16-element Yagi for the really long distance stuff...would be about \$19.95. The "push-up"--up to forty feet--would be \$22. The VW [which Dunstan used in his work] I don't know.

TOM CADE: Can you tell us anything about delivery time on transmitters?

DUNSTAN: People are behind, people are ahead. If you get an order in and are lucky, it can be within two or three weeks. What happens is that we get peaks in the fall and peaks in the spring, and then it gets quite slow. You have to commit a person to a date, and you have to hold them to it--any of the companies.

CADE: The real problem, of course, for those of you who don't know and aren't using them, is that there are very few people in the country who can make these things properly. The demand is, I think, outgrowing the ability to produce, right now.

QUESTION: Has anybody tracked hawks on radar, particularly broadwings, in Nova Scotia?

RICHARDSON: I've done a lot of radar work in Nova Scotia, and the answer is no. We picked up some things that might or might not have been hawks... There are big movements of hawks down Digby Neck in the northwest corner of Nova Scotia, and I have picked up what looks like a line of something on the radar, moving southwest there. Whether it was hawks or not, I don't know. It was too late for broadwings.

CADE: There is a telemetry information packet available through the Raptor Research Foundation.

MARK FULLER: The Raptor Research Foundation has a telemetry committee, and recently we put together a package that consists of reports from people around the country that have done, or are doing, or anticipate doing, telemetry research on raptors. Now this covers everything from physiological telemetry to long-range tracking. This little pamphlet runs to about 48 pages and tells about each person's project, what they want to do, where they got their equipment, the approximate costs. This is available for \$1.00 a copy from Byron Harrell:

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