

-COASTAL HAWK MIGRATION IN MAINE: A FIELD STUDY

ACADIA NATIONAL PARK
RESOURCE MANAGEMENT DIVISION

It is often difficult to make other people understand why we enjoy doing this kind of thing. A rational explanation may make people understand in a way, but cannot make them share the joy. That is, I believe, because our true motives are entirely irrational.

-Niko Tinbergen, discussing field research in The Herring Gull's World

PURPOSE

The main purpose of this entire project is for me to carry out a biological field study from beginning to end. This includes planning and logistics, background research, field research, data analysis, and presentation of my results, both to the scientific community and to more general audiences. The purpose of the field research itself was to learn more about migratory behavior in hawks, and to try to apply what I could learn from literature on the subject to what I could see in the field. Also, by going through the process of data analysis myself, I hoped to gain a better understanding of the actual meaning of the presentation of data in various papers.

The habitat chosen (a barren offshore island) to carry out this study in was very different from those typically used in studies of hawk migration. An effort was made to compare the migration in this habitat to that in others. This habitat yielded both different proportions of the various species involved and a different aspect of migratory behavior.

LOGISTICS

Matinicus Rock has a U.S. Coast Guard Light Station on it. Thus it was necessary to get the Coast Guard's approval before using the island for this study. Also, the Nat'l Audubon Soc. under the guidance of Steve Kress, uses the island as a research station throughout the summer while studying the seabirds nesting there. Thus it was also necessary to get approval from Nat'l Audubon. Once that was done, the next step was to gather food and equipment. Equipment included such things as paper, writing instruments, cameras, film, dissecting tools,

alcohol and salt for preserving specimens, binoculars, and clothing for all weather. I brought enough food with me for two months. The final logistical problem was actually getting on the island, which proved to be very frustrating. I was originally planning to go out on Thursday, September 2. The Coast Guard in Rockland (where the boat leaves from) told me to call on Sept. 1 and check to see if the weather was looking favorable. In bad weather, it is hopeless to try to land at Matinicus. When I called on Sept. 1, I was told that the boat had just left and another would not leave till the 9th. On the ninth I went to Rockland early, to be sure to not miss the boat. The winds picked up as the boat was preparing to leave, so the trip was postponed till Friday. Luckily, the Coast Guard personnel waiting to go out on the rock offered me a place to sleep for the night. On Friday, September 10, I finally made it to Matinicus (in this paper, "Matinicus"=Matinicus Rock).

STUDY AREA(S)

Matinicus Rock (43°47'N, 68°51'W) is a thirty-five acre treeless island twenty-one miles from the closest mainland, and seventeen miles due south of Vinal Haven Island. Clustered at the southwest end of the island are the buildings of a U.S. Coast Guard Light Station (see Figure six). Although much of the island is exposed rock, there is a good deal of vegetation. The tallest of this, however, is barely more than six feet tall (rushes and cattails). Most of the vegetation is under eighteen inches tall. There are many small to large permanent "puddles" scattered over the island. On the southeast side, the island drops down steeply to the water, while on the northwest side it slopes down to a "beach" made up of wave worn rocks up to a foot in diameter. There is a high ridge running the length of the island along the sea side, and smaller ridges running across the island. In several areas there are "boulder piles"-- areas with large boulders strewn about.

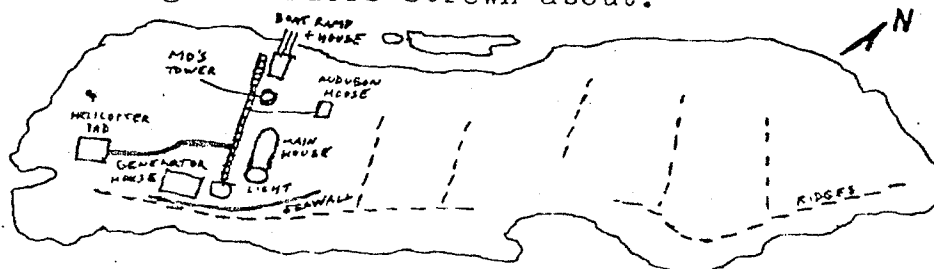


Figure 6. Rough map of Matinicus Rock.

Mount Desert Rock (MDR), where Steve Mullane and Ann Rivers gathered hawk data, is slightly farther from mainland. It is much smaller than Matinicus, covering only four acres, and also has less vegetation. Although there are several islands within five to ten miles of Matinicus, there are none within ten miles of MDR.

Green's Island, where John Drury gathered hawk data, is very different from both Matinicus and MDR. First, it is less than half as far from mainland, and, second, it is not as barren, having a good cover of trees. It lies off the southwest corner of Vinylhaven Is.

Beech Mountain can, for all practical purposes, be considered a mountain on mainland, though it is located on Mount Desert Island. It is probably the best spot on MDI for observing hawk migration. Figure seven is a map showing all four of these sites.

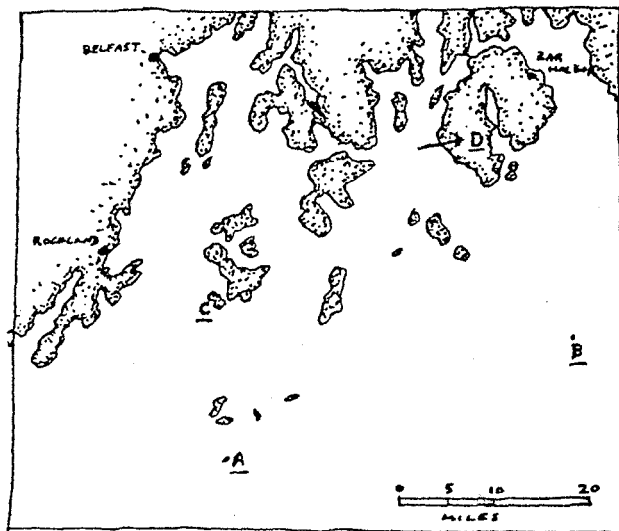


Figure 7. A map showing the location of A) Matinicus Rock, B) Mount Desert Rock, C) Green's Island, and D) Beech Mountain.

METHODS

Evidence of migration is obtained in two ways:

- (1) by directly observing birds in flight and
- (2) by noting the fluctuations in numbers and species in an area.

-Mueller and Berger, 1961

I utilized both of the above methods in my study. Both methods were used in counting hawks, and the second was used

The data sheet has 24 blank spaces across the top for writing in time periods, and lists all the hawks, with their various plumages, down the left side. There is a space in the top left corner for the date. Figure eight shows a section of a sample data sheet. I used fifteen minute time intervals, which worked well. Each hawk was marked off using a slash (/) or a dotted slash (/.). The dotted slash was used to represent a hunting/resting hawk. This is a hawk that 1) caught some sort of prey on or over the island, 2) attempted to, or 3) perched on the island. The purpose of this distinction is to separate those birds that only pass by the island from those that use the island in some manner. If a large number of birds flew over in any one time period, the number could be used on the data sheet instead of slash marks (see Figure 8A). Circled slash marks represent birds that appear to be flying together in a group.

Figure 8. Example of a data sheet. A=daily sheet, B=totals sheet.

After finishing my formal observations for a day (usually one to five hours), I would skip a column and use the next two columns for daily totals (see Fig. 8A). The first daily total is the total seen during formal observation time. The second is that plus "incidental" observations of hawks. Incidental observations are those hawks seen while I was doing anything but formal observations. Finally, on each daily sheet, I would skip two more columns and put in a running total of all hawks seen to date.

Another way these data sheets are useful is for keeping daily totals (see Figure 8B). On this sheet (or sheets) the dates and hours spent observing are written across the top in place of times. Then the daily totals are written in. Incidental observations are put in parentheses.

The blank paper on the clipboard is used for other observations, comments, notes, and a "directional diagram." This is a diagram showing the direction taken by all hawks approaching and leaving the island, except those chasing prey.

At the end of each a journal entry was made, covering all subjects, relying on the data sheet, notes sheet, and memory. My journal for the 47 days I was on Matinicus is over 90 pages long. Additional notebooks were used for recording all dead birds found and weather data. The weather data taken include sky condition, precipitation, visibility, wind direction, wind speed, air temperature, and barometric pressure. These were all taken from the Coast Guard weather report sheets, which are filled in at three-hour intervals around the clock. The light station on Matinicus has complete weather monitoring gear.

Formal observations were made either from Mo's Tower, a 45 foot abandoned lighthouse tower with an open platform on top, or from a high point mid-island. On Mo's Tower I usually kept a spotting scope set up. Although Mo's Tower offers a much higher vantage point, it is placed too close to the southwestern end of the island, making it difficult to spot small hawks at the far end. So the majority of my observations were made from a high spot in the center of the island.

I confined most of my formal observation time between 0900 and 1230. Even when I wasn't formally observing, I was

constantly watching for hawks. It is very unlikely that I could have missed many hawks.

My data were analyzed using either the College Of the Atlantic's Digital PDP11 or a Sinclair ZX81 home computer. The programs I used were either taken from Poole and Borchers (1977) or were written myself, using Campbell (1974) as a statistical reference. Listings of the programs that I wrote are included in Appendix D. The statistical tests used are described below, as they are mentioned.

RESULTS

Hawks

I spent a total of 47 days on Matinicus, from 11 Sep to 28 Oct, 1982. During that time I saw 320 total hawks of seven species, putting 51.5 hours of formal observation time. The average number of hawks per hour was 6.2, and the average per day was 6.8. However, if only those days from 11 Sep to 12 Oct are considered the hourly average is 6.3 and the daily average is 9.8.

The solid line in Figure nine is a plot of the total hawks seen on each day. The mean date of migration was 23 Sep, with a standard deviation of 7.9 days. The peak day of migration was 19 Sep, with 39 hawks. It can be seen from Figure nine that migration was already under way when I arrived. In the six days between 16 Sep and 21 Sep 128 hawks passed Matinicus. This represents forty percent of the total hawks in only 12.7 percent of the time. The dotted line in Figure nine is a plot of five-day moving averages of the number of hawks. Five-day averages tend to eliminate effects of weather, etc. and show more the true seasonal timing of migration. Here the mean date is 24 Sep, with a standard deviation of 7.2 days. It can be seen that both plots in Figure nine have two peaks, one nearly two weeks later than the other. This second peak is partially due to the later migrating peregrine falcons (see Seasonal Timing of Migration, below). Figure ten shows the same two plots as in Figure nine, but considering all hawks except peregrines. Note that the mean date of migration in both hawks per day and five-day moving averages is a day earlier, and the standard deviations are slightly less with peregrines removed. Figure eleven shows the two five-day moving averages (with and without

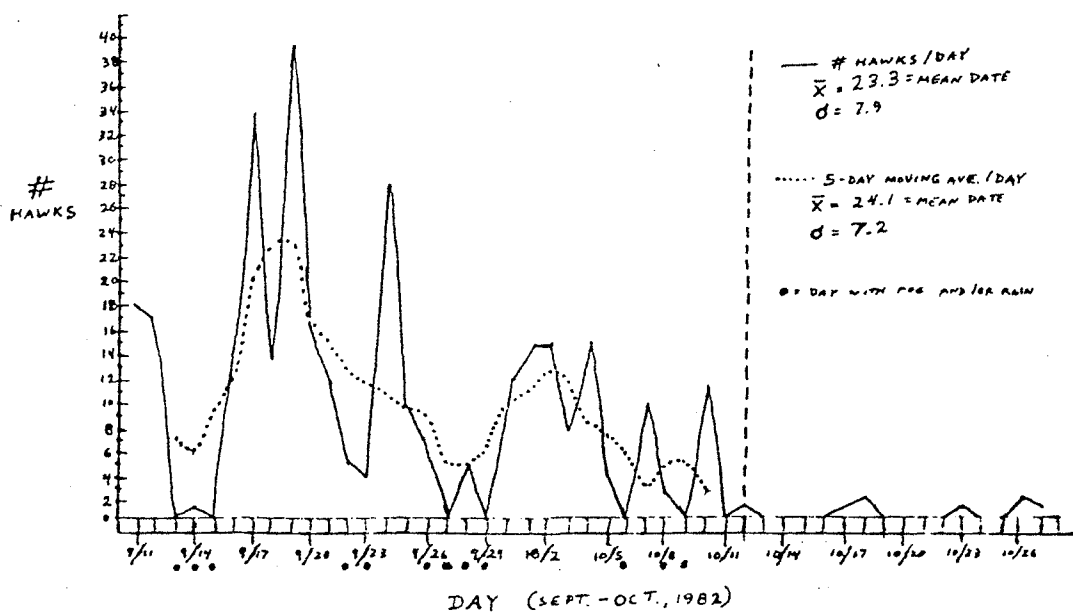


Figure 9. Total hawks per day.

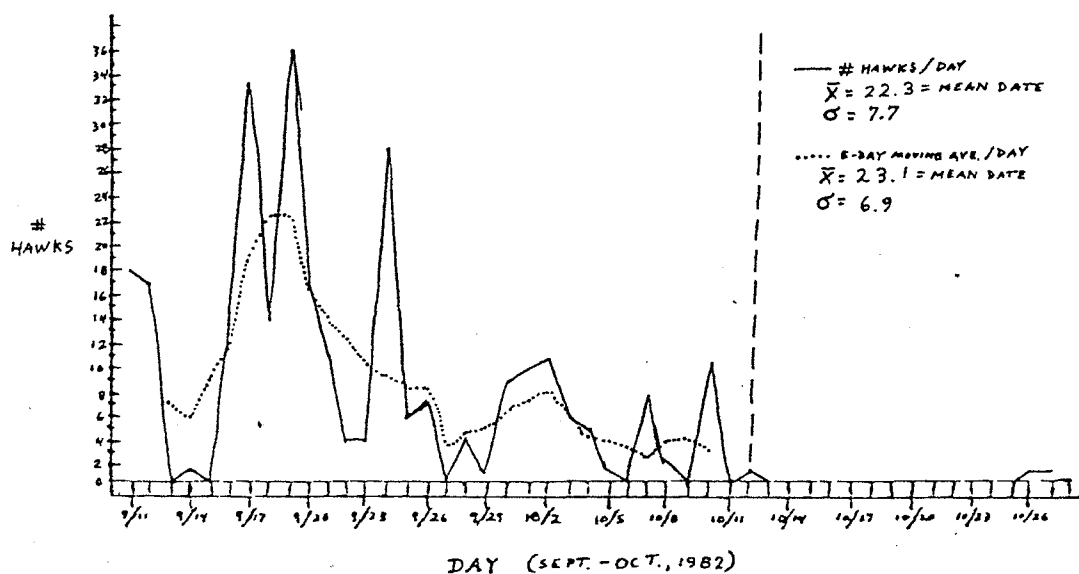


Figure 10. Total hawks per day without peregrines.

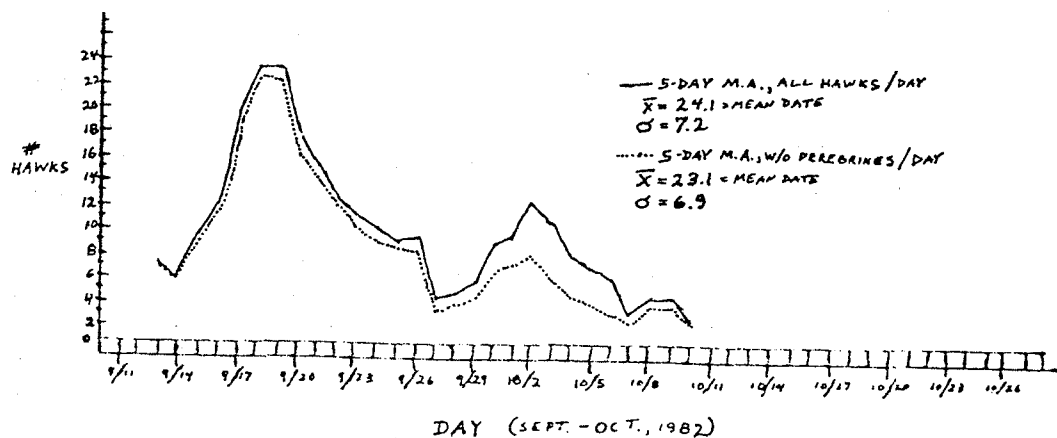


Figure 11. Five-day moving averages, with and without peregrines.

peregrines) plotted together. Notice that the main effect of removing peregrines is to lower the second peak. Also note, however, that this second peak isn't eliminated, just reduced.

I had access to data from a total of four sites. At Matinicus, Green's, and MDR, the data were either collected myself or I was given access to it by those who collected it. The data from Beech Mountain were taken from Currie and MacRae (1980). I have two years of hawk data from MDR. "MDR1" is the data from the fall of 1982 only, whereas "MDR11" is the compiled data from the falls of 1982 and 1981. Figure twelve represents a compilation of all of the data from the three island sites. Since all sites are fairly close, the timing of migration at each site should be similar. Note that the mean date of migration (22.1) is nearly identical to that on Matinicus without peregrines (22.3), and the graph still has a double-peaked shape.

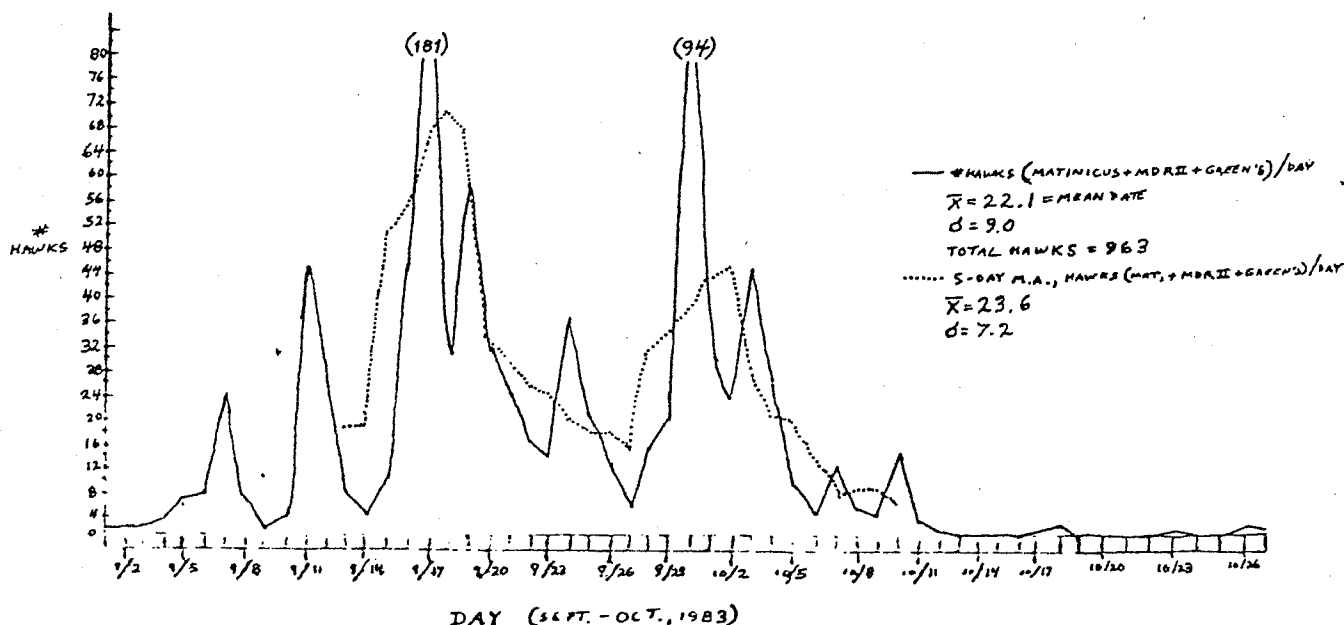


Figure 12. Total hawks per day, all island sites combined.

Weather and migration. Weather variables have often been related to hawk migration. The effects of different weather variables have usually been looked at independently, though Nisbet and Drury (1968) published a paper on the effects of weather on migration using multivariate statistics. Due to the small size of my samples, I cannot use such statistical tests, so I will analyze each variable individually. It is important to remember during the following discussion that, as Nisbet and Drury (1968) say, "references to 'significant'

variables are made in the this statistically descriptive sense only, and do not necessarily imply cause-and-effect relationships." In other words, just because (for instance) the association of migration with westerly winds is statistically significant, it cannot be stated as a fact that westerly winds cause heavy migration at Matinicus.

Mueller and Berger (1961) state that weather conditions at the point of departure are important in their relationship to migration, but, unfortunately, birds are rarely seen departing. Matinicus provides a unique opportunity to see birds departing for migration, since many spend one or several days on the island. Unfortunately, results at this time are unclear, and will have to await the compilation of more years of data.

In analyzing the effects of most weather variables on migration I have used nonparametric statistics (Haugh, 1972; Campbell, 1974). These tests include the Mann-Whitney U-test for two samples and the Kruskal-Wallis Test for more than two samples. In both of these tests there is no need to assume that the data being analyzed are normally distributed, which cannot be assumed for hawk migration and weather variables. The Mann-Whitney U-test is only able to give significance at a single level (.05), but this is sufficient for the following.

Precipitation/visibility seemed to be the only weather variable that was able to nearly stop diurnal migration. Lack (1960) states that "All authorities have agreed that migration is favored by clear weather, while fog, mist, and rain are unfavorable, and though statistical evidence is in most cases lacking, this conclusion can be accepted." With a few exceptions Mueller and Berger (1961) and Haugh and Cade (1966) agree that rain generally stops migration. Evans and Lathbury (1973) found that rain did not stop the migration of black kites, although it did stop that of buzzards (buteos). They also state that heavy fog grounds migrants.

A few potential problems with this correlation at Matinicus must be kept in mind. First, the observer's efforts and effectiveness on such days is much reduced, which could lead to misleading counts. Also, it seems obvious that birds flying in heavy fog would have to pass very close to the island just

to see it. Thus birds could be flying by, but missing Martinique. On the other hand, hawks that were on the island when the fog rolled in remained on the island until it lifted. This supports the idea that rain and fog exert a strong influence on migratory behavior.

In Figure nine, the days with extended periods of fog and/or rain have been marked. It can be seen that, up to 10 Oct the days of very little to no migration are the same as those with fog/rain. After 10 Oct there are many clear days without hawks, but this apparently represents the gradual ending of the migratory season.

For the period between 11 Sep and 10 Oct a Mann-Whitney U-test was performed to compare days with fog and/or rain to those without. The mean number of hawks with fog/rain was 3.57, while that without was 16.75. This difference was significant at the .05 level. The same days were then divided into three categories; fog, rain, and neither. Using the Kruskal-Wallis procedure, the difference was significant at the .001 level ($H=16.485$).

Since rain/fog correlated so well with days of extremely low migration, these days were excluded from the analysis of the effects of other variables. Also, the period from 11 Sep to 10 Oct was used in the rest of the analyses of weather variables, since it is likely that, after 10 Oct, the gradual ending of the migratory season would have an effect.

Dean and Amadon (1968) state that the largest flights of hawks occur after bad weather breaks. This is because the hawks are held up by extended periods of bad weather and, when it breaks, they move "en masse." This certainly appears to be evident in Figure nine (page 46), since all of the major peaks come after periods of bad weather.

The effects of wind direction on hawk migration have been studied more than those of any other weather variable. There is some question as to whether wind direction affects the number of hawks moving or the concentrations of birds at certain points. Lack (1960) says that "wind direction influences the direction but not necessarily the volume of migration (though wind direction may influence the volume passing within visual

range of a particular place)." This relates back to the theory of wind drift discussed earlier. The correlations between wind direction and migration found by Mueller and Berger (1961;1967), Haugh and Cade (1966), Allen and Peterson (1936), and Ferguson and Ferguson (1922) would all seem to support the wind drift/leading line hypothesis. In all of the above cases, the wind direction most strongly correlated with large migrations was one that would tend to drift hawks toward the coastline or shoreline involved (Atlantic Ocean and westerly winds for Allen and Peterson (1936) and Ferguson and Ferguson (1922); western shore of Lake Michigan and westerly winds for Mueller and Berger (1961;1967); and the southern shore of Lake Ontario and southerly winds for Haugh and Cade (1966)).

Haugh (1972) associated fall migration with northerly and/or westerly winds, and spring migration with southerly winds. It should be noted that this could also explain all of the correlations mentioned above.

For my data on wind direction, I divided the compass into the eight standard points and compared hawks per day for each. Mann-Whitney U-tests showed that the difference between flights on all days with a northerly wind component (9 days) and those on days with a southerly wind component (4 days) was not statistically significant. However, the difference in the movements on westerly winds (7 days) and easterly winds (9 days) was significant at the .05 level. The mean number of hawks per day on westerly winds was 23, while that on easterly winds was 11.4. This would seem to support the theory of wind drift. Other comparisons showed no significant differences.

Figure thirteen shows the effects of both wind direction

and velocity on hawk migration. It is based on a similar figure used by Mueller and Berger (1967). Very little can be deduced from this figure. Additional years of data may reveal a pattern.

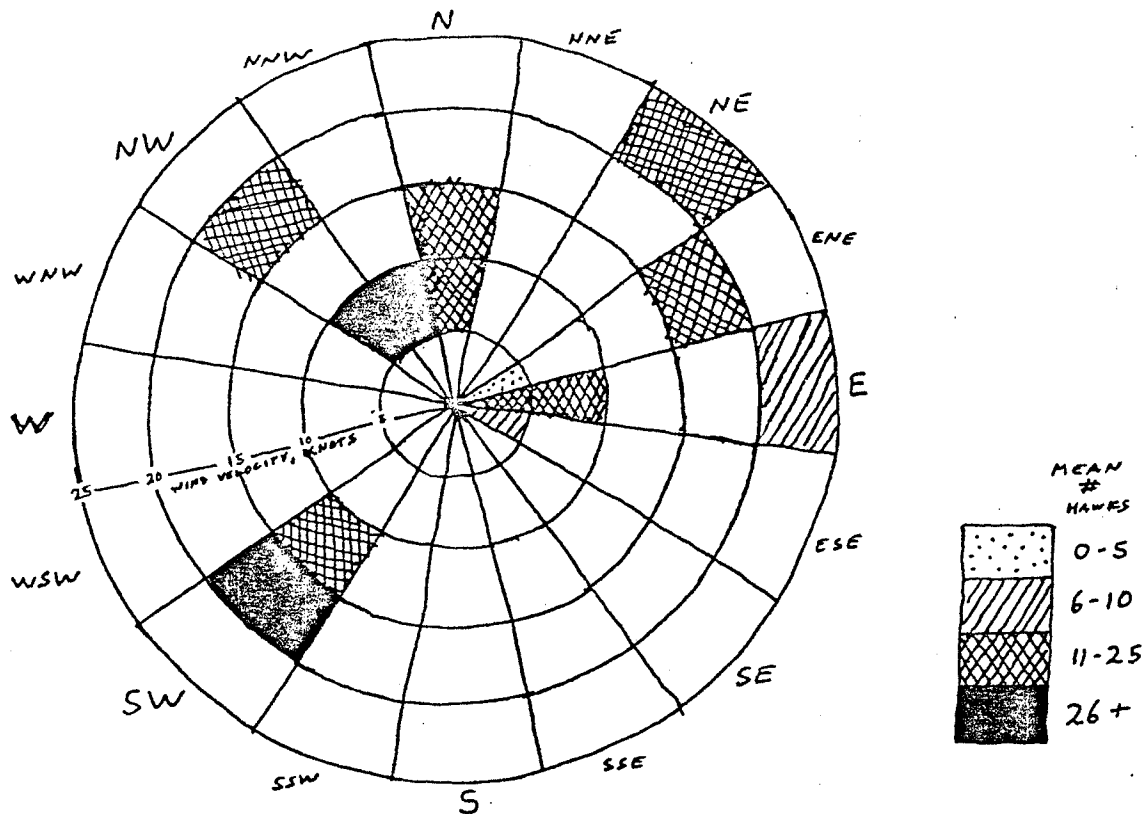


Figure 13. The effects of wind direction and velocity on the hawk migrations at Matinicus. The radial lines enclose 22.5° increments of wind directions. The concentric circles enclose five knot increments in wind speed. The intensity of shading indicates the mean number of hawks associated with each combination of direction and velocity.

Barometric pressure has often been correlated with hawk migration. Haugh (1974) and Baggs, et al (1950) agree that migration is strongly associated with low pressure areas. Since I did not record the passage of lows and highs I have no information to add here. However, I did record the pressure every three hours, and I can thus compare hawk movements with general rising or falling barometric trends.

Haugh (1972) and Mueller and Berger (1961) have associated fall flights with a rising barometer, while Haugh (1972) and Haugh and Gade (1966) have associated spring flights with a

falling barometer. I analyzed my data by looking at trends over the 24 hours preceding each day's migration (the 1030 barometer reading) and dividing the days into two groups according to whether the barometer was rising (9 days) or falling (7 days). A Mann-Whitney U-test showed no significant differences in the numbers of hawks associated with each group.

Note that although pressure changes have been correlated with migration by others, a direct causal relationship cannot be assumed, because

There is no sensory mechanism known by which a bird could determine absolute pressure, and there is no evidence that birds can detect the slight changes in barometric pressure that occur in nature over a period of a few hours. (Mueller and Berger, 1961).

They go on to say that a bird flying from the ground to a tall tree top would be subjected to a pressure change of greater magnitude than would usually occur in nature in an interval as short as an hour.

Decreasing temperature in the fall (Haugh, 1972; Mueller and Berger, 1967) and increasing temperature in the spring (Haugh, 1972; Haugh and Cade, 1966) have been found to correlate well with large migrations of hawks. Although Mueller and Berger (1961) found that hawk flights usually occurred after a drop in temperature, they decided that the correlations were not of sufficient magnitude to show a strong relationship between temperature change and migration. My own data showed no significant correlation between changing temperature and migration.

Both Haugh and Cade (1966) and Mueller and Berger (1967) found some correlation between sky conditions and migration, in that more hawks migrated on clear skies. However, my data showed no significant correlation. This may be because a large percentage of the hawks involved in both of the above studies were buteos, which depend on thermals during migration, which form more readily on sunny days. Most of the hawks at Matinicus were falcons, which do not depend on soaring flight.

Daily timing of migration. "A puzzling aspect of the September flights is the invariable appearance of the bulk of a day's migrants between nine and eleven A.M." (Brown, 1935).

Mueller and Berger (1973) and Haugh and Gade (1966) found that there was a general mid-morning peak of hawk numbers. They further found an early morning peak for accipiters, a late morning peak for buteos and an early afternoon peak for falcons. In Europe, Berman and Galea (1974) found an afternoon peak for all species. The flights on Matinicus peak in mid-morning, as shown in Figure fourteen. I spent 51.5 total hours observing, of which there were no hawks in 30.5.

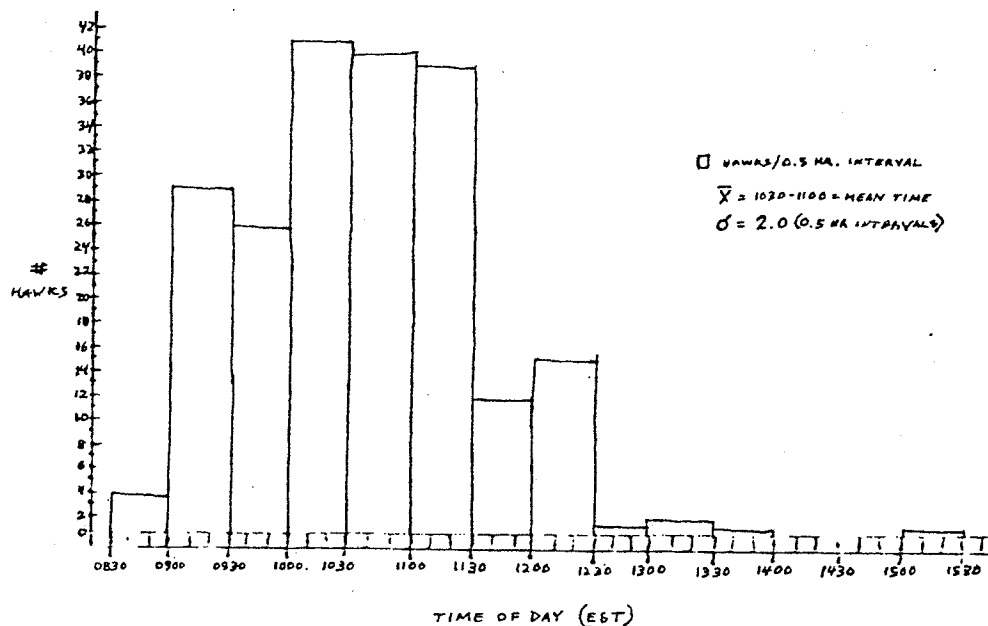


Figure 14. The daily timing of hawk flights.

Seasonal timing of migration. Figures 9, 10, 11, and 12 (pages 46 and 47) relate to the seasonal timing of all migrant hawks. The migration of hawks at Matinicus in 1982 appeared to be centered around 22 or 23 Sep. However, the mean date of migration at MDR in 1982 was 26 Sep. Figure fifteen represents the movements at both Matinicus and MDR. Both graphs show the same double peak. But at MDR the second peak was larger, whereas at Matinicus the first was larger.

Hofslund (1966) found that the seasonal migration times of all species were fairly close, whereas Titus and Mosher (1982) and Haugh (1972) found that there were differences between the species. Figures sixteen and seventeen are the graphs of the migrations of the four main species seen at Matinicus. The movements

of sharpies, merlins, and kestrels were all centered around 21 to 23 Sep, while that of peregrines was centered around 3 Oct. Using a test of the difference of means with unequal variances (similar to a t-test; see Campbell, 1974), the difference between the timing of peregrines and that of all other species was statistically significant at the .001 level.

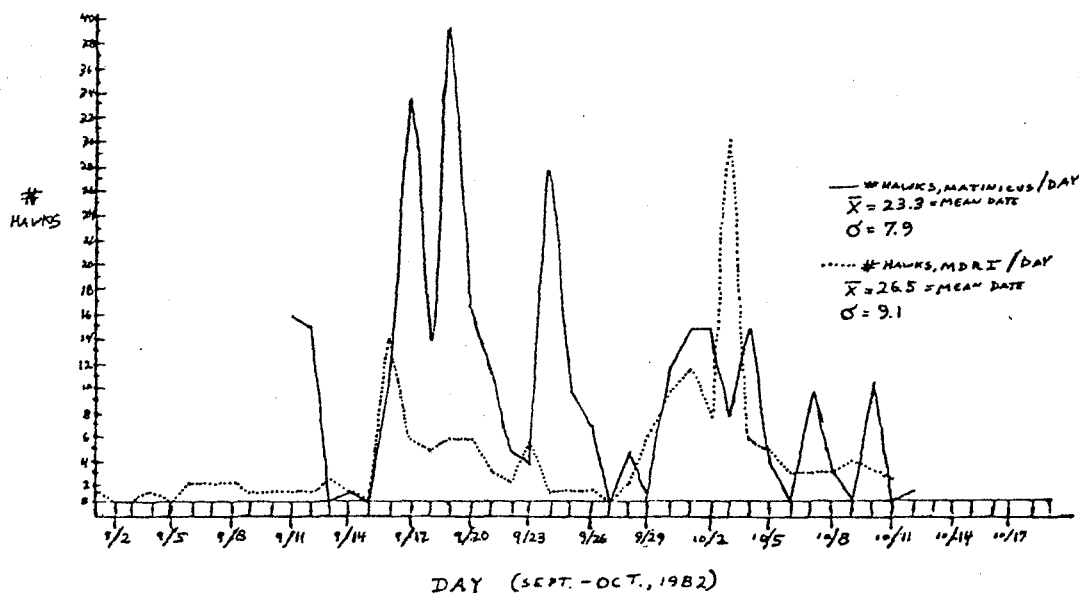


Figure 15. The migrations at Matinicus and MDRI.

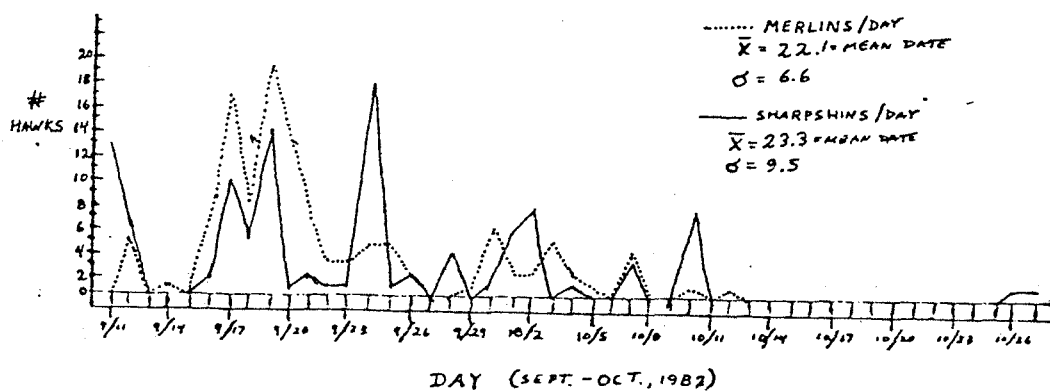


Figure 16. Sharp-shins and merlins at Matinicus.

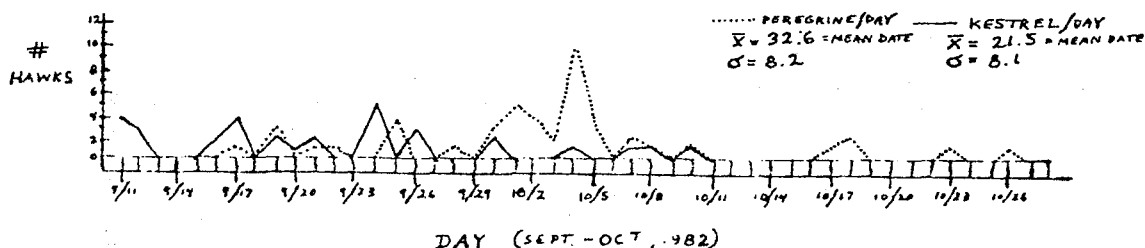


Figure 17. Kestrels and peregrines at Matinicus.

Seasonal timing of migration has also been related to maturity. Among the peregrines passing Matinicus in 1982, the mean date of migration for adults was 28 Sep, while that of immatures was 4 Oct. However, due to the large standard deviations and small number of adults, this difference is not statistically significant. Berry (1971) found that adult peregrines made up a much larger percentage of the total in the first half of the season (27%) than in the second half (3%).

Differences in the migrant populations at various sites.

It became obvious during my time on Matinicus that the composition of the hawk migrants was very different from that at other sites. Peregrine falcons, for instance, made up 14.5 percent of the total, whereas on Beech Mt. they make up only 0.5 percent of the total. Table 1 lists the percentage of each species seen at four different sites. A chi-square test was done on the differences in the percentages of each species seen at Matinicus, Green's, and Beech Mt. The difference was significant at the .001 level ($\chi^2=114.984$, d.f.=24).

TABLE 1
% of all species at all sites.

Species	Matinicus	MDRII	Green's	Beech
Goshawk	0.3	-	0.3	0.2
Sharp-shin	33.8	22.3	60.6	68.3
Cooper's	-	-	-	0.1
Peregrine	14.5	16.3	0.6	0.5
Merlin	36.9	31.7	2.4	2.0
Kestrel	9.8	22.7	28.4	17.3
Osprey	1.2	5.0	**	2.7
Harrier	3.4	2.0	6.5	4.9
Red-tailed	-	-	0.6	1.6
Broad-winged	-	-	0.3	2.1
Red-shouldered	-	-	0.3	-
Rough-legged	-	-	-	0.1
Bald eagle	-	-	-	0.2

** - No data on ospreys was gathered at Green's.

Basically this difference can be explained by looking at the migrating behavior and physiology of each species and the nature of each observation site. The four observation sites can be divided into three different classes. Beech Mt., as has

been mentioned, can be considered a mountain on the mainland. This first class will be called "coastal mountains." Green's Island represents the second class, consisting of wooded inner islands. The terms "wooded" and "inner" are both important in determining the composition of the migrants, as shall be seen. "Inner" is used in comparison with the remaining sites, since Green's is only about half as far from mainland as Matinicus and MDR. The class of site represented by Green's will be called "inner islands." The final class, called "outer islands" is represented by both Matinicus Rock and Mount Desert Rock. The only major differences between these two sites are their relative sizes and extent of isolation from other islands (see Figure seven, page 42).

If all of these sites are thought as part of leading lines, then Mueller and Berger (1967) would say that hawks could be attracted to such sites either because they are lines between favorable and unfavorable habitat, or because they provide conditions that make migrating easier.

Beech Mt. is very likely used for both reasons. Being on the coast, it can easily be seen as a line between favorable and unfavorable habitat. Also, it appears to provide conditions favorable for soaring flight, probably in the form of deflection currents, though thermals may also be present. Inner islands may also be attractive to hawks for several reasons. First, the fact that they are land amid water provides hawks with a place to rest. Also, songbirds stop on such islands during migration and would provide a food supply for hawks that feed on migration. The same two things can be said for outer islands. The differentiating factors between the two are their relative distances from mainland, and the difference in vegetation. Table two summarizes the characteristics of each site class.

TABLE 2
Characteristics of site classes.

Site class	Distance from Mainland	Soaring Cond.	Tree Cov.	Food
Coastal Mountains	-	Yes	Yes	Yes
Inner Islands	0-10 miles	No	Yes	Yes
Outer Islands	15-25 miles	No	No	Yes

TABLE 3
Characteristics of hawk groups.

Hawk group	Wing Loading	Wing Slotting	Preferred Habitat	Feed During Mig.
Falcons	High	None	Open	Yes
Accipiters	Med.	Med.	Wooded	Yes
Buteos	Low	High	Open/wooded	No(?)

Now that the characteristics of the sites have been discussed, the characteristics of the birds must be discussed to see why different types are attracted to different sites (Table three summarizes these). Three different groups of hawks will be considered; falcons, accipiters, and buteos. The extent to which each group makes use of soaring has been discussed. In general, birds with lighter wing loading and slotted wing tips are able to soar best. The extent of wingtip slotting can be seen from Figure one (page 12). Poole (1938) published a paper on weights and wing areas in North American Birds. The following figures are from this paper. In looking at wing loading, I have compared individuals from each group that are in the same weight class. For instance, in the 1200 to 1400 weight class, the wing loading of female peregrines, representing the falcons, is 0.91 g/cm^2 . That of female goshawks (accipiters) is 0.68 g/cm^2 , and that of female red-tails (buteos) is 0.57 g/cm^2 . Thus the falcons have the highest wing loading, the accipiters are in the middle, and buteos have the lowest. This relationship apparently holds within any one weight class (I also checked the 700-900 gram class and the 130-180 gram class). These measurements agree with general comments made earlier concerning the degree to which these different groups make use of soaring flight; buteos using it the most, falcons the least, and accipiters somewhere in between. However, Brown and Amadon (1968) mention that even species which seldom soar will do so under favorable conditions. As can be seen from Table two, soaring birds would be most attracted to Beech Mt., and in fact, the percentage of buteos at Beech Mt. is higher than at any other site (see Table four). However, this percentage (4.0) is still much lower than that at a place such as Hawk

Mountain, Ia. (see Table six).

TABLE 4
Percentages of hawk groups at site types.

Hawk group	% of total @ Outer Is.	% of total @ Inner Is.	% of total @ Coastal Mt.
Falcons	65.8	31.4	19.8
Accipiters	28.5	60.9	68.6
Buteos	-	1.2	4.0

Difference is statistically significant at .001 level.

The fairly low percentage of buteos at Beech Mt. probably relates to the unwillingness of the birds to cross water. Many writers have observed that soaring hawks are almost totally unwilling to cross expanses of water. Similarly, species with basically flapping flight cross water most readily (Brown and Amadon, 1968). Since falcons make the most use of flapping flight, they should be the most willing to cross water, with accipiters in between. Haugh (1972) notes that "unlike most hawks, the peregrine seems not averse to flying over water during migration."

Referring to Figure seven (page 42), it can be seen that Beech Mt. is effectively on a peninsula, surrounded by large bays to the east and west. This may be the factor that limits the number of buteos at Beech. Similarly, the willingness of falcons to cross water may contribute to their high numbers at the outer island sites.

The preferred habitat of each group may also influence the numbers seen at each site. This seems especially important in distinguishing between outer and inner island sites. As can be seen from Table four, the percentages of both falcons and accipiters at these two site types are very different. The accipiters are basically forest birds, while falcons are birds of open country, and this may account for the differences seen.

Feeding behavior during migration may also be an important factor. Although songbirds are present at all sites, they are most vulnerable at the outer island sites, due to the lack of cover (see discussion on vulnerability of prey, page 8). Thus those species that feed most during migration would be attracted

to the outer islands for this reason.

Newton (1979) says that soaring hawk species may fast on migration. Leahy (1982) agrees with this, stating that soaring migrants seldom feed en route. This would probably mean that soaring hawks put on weight before migration, and draw on fat reserves during migration. Newton (1979) has suggested that this habit may even have adaptive value, since fasting would lead to reduced weight, which would lead to reduced wing loading, which would reduce the bird's energy expenditure, since soaring would be easier.

Many researchers report that falcons and accipiters feed during migration. My own research shows that 71.3% of the hawks seen during my formal observations stopped to hunt/rest on the island (see METHODS, page 42-43 for a definition of hunting/resting hawks). This is in sharp contrast to Beech Mt., where very few birds are seen hunting.

So, given that both accipiters and falcons feed on migration, they should be most attracted to the outer island sites. For falcons this is true. However, the percentage of accipiters at the outer islands is the lowest out of the three sites (see Table four). It should be remembered that accipiters are forest hawks, and they utilize soaring to some extent. They probably are able to hunt as effectively in wooded areas as in the open. Thus, they make up a higher percent of the total at Green's, where they can hunt and stay with their preferred habitat, and an even higher percentage at Beech, where they can hunt, stay with their preferred habitat, and utilize updrafts.

Table four is a comparison between the three sites. Using a chi-square test, the differences in the compositions of the migrants at each site is statistically significant at the .001 level ($\chi^2=51.2954$, D.F.=4).

Since MDR is 1) much smaller than Matinicus and B) more isolated, I have to question my grouping of them as one site type. Table five is a comparison between MDR11 and Matinicus. There is no statistically significant difference between the two, which seems to support my grouping of them.

Although I am comparing three classes of sites, there are probably others. Hawk Mountain (Haugh, 1972), for instance, would not fit into any of my classes, so this would be a separate class ("inland mountains"). Here the hawks do not

have to cross water to get to the site from any direction (unlike Beech Mt.) so there is a much higher percentage of buteos. Table six is a comparison between Beech Mt. and Hawk Mt., and the difference is statistically significant at the .001 level ($X^2=110.864$, D.F.=2).

TABLE 5
Percentages of hawk groups at two sites.

Hawk group	% of total @ Matinicus	% of total @ MDRII
Falcons	61.2	70.7
Accipiters	34.1	22.3
Buteos	-	-

TABLE 6
Percentages of hawk groups at two sites.

Hawk group	% of total @ Beech Mt.	% of total @ Hawk Mt.
Falcons	19.8	2.3
Accipiters	68.6	16.5
Buteos	4.0	76.4

"Open ocean" could be considered another class. Kerlinger, Cherry, and Powers relate their observations at sea. Table seven is a comparison between the hawks seen at the outer islands and the open sea. The difference between the two for falcons and accipiters is not statistically significant. However, much higher percentages of ospreys are seen over the open sea. This is probably because ospreys can feed over the open sea (Rogers and Leatherwood, 1981), and only have to come to land to rest. Also, their preferred habitat is coastlines, so they are very accustomed to flying over water. Table eight is the same comparison as Table seven, with ospreys added. Now the difference is statistically significant, at the .001 level ($X^2=26.1216$, D.F.=2). Figure eighteen shows the percentage of different species at different sites.

TABLE 7
Percentages of hawk groups at two sites.

Hawk group	% of total @ Outer Is.	% of total @ Open Sea
Falcons	65.8	62.0
Accipiters	28.5	14.7
Buteos	-	-

TABLE 8
Same as Table 7, with ospreys.

Hawk group	% of total @ Outer Is.	% of total @ Open Sea
Falcons	65.8	62.0
Accipiters	28.5	14.7
Buteos	-	-
Ospreys	1.2	25.3

-17-

Age ratios. Stone (1937), in speaking of Cape May, N.J., said, "The great majority of the migrating hawks are birds of the year, and it is only occasionally that we see an adult." For most species, this statement would apply at Matinicus as well. The only hawks that I attempted to determine the age of were sharp-shins, harriers, and peregrines. Of these, only peregrines showed a "normal" age ratio. Of those that I was able to age (93.6% of the total), 22.7% were adults and 77.3% were immatures. This is equal to approximately one adult for every four young. Ward and Berry (1972) report 18% adult peregrines at Assateague Island, MD. over 12 years of data. This is comparable to my own total of 22.7% adults.

The age ratios of sharp-shins and harriers were very different. The eleven harriers I saw were all immatures, and of the sharp-shins that I was able to safely age (74.6% of the total), 96.3 percent were immature, and only 3.7 percent were adults (four birds out of 110). This is less than one adult for every 20 young.

If Berger's (1964) statement that individual birds probably follow the same route year after year is accepted, and we can assume that this high percentage of young on Matinicus in 1982 is similar to other years, then there are two possible explanations for this age ratio. Either 1) the adult bird's don't migrate much, or 2) the young birds seen are not surviving till adult age (or, in other words, they are "experiencing negative selection"). Since Haugh (1972) and others have reported no unusually high percentages of immatures (ie-the adults do migrate), the latter must be the case if Berger's statement is accepted. However, Mueller and Berger (1967) state that the path pursued by a bird varies considerably from year to year. Brown and Amadon (1968) go a step farther in saying that, in some species, age groups migrate in separate flight lines. Newton (1979) explains this by saying that juveniles may be more likely to be drifted by the wind, thus creating artificially large concentrations of juveniles. This would seem to explain the strange age ratios seen at Matinicus Rock.

Feeding behavior. I have 38 chases (successful or not) mentioned in my journal where the prey species was identified.

of these, 23 were successful. The prey species can be divided into three different size categories; small (warblers to sparrows), medium (thrush-sized), and large (flickers, doves). Among all three small hawks (sharpies, merlins and kestrels) 100% of the prey captured was in the small category, though I saw both a merlin and a sharpshin make an unsuccessful attempt at a medium sized bird. Small prey items composed 45.5% of the successful hunts of peregrines, and medium and large prey made up 36.4% and 18.1%, respectively. No hawk was observed chasing, capturing or eating anything other than a bird. Ferguson and Ferguson (1922) list insects as comprising over 60% of the stomach contents of merlins migrating past Fisher's Island, N.Y. Although dragonflies, butterflies and other insects were present on Matinicus, I never observed a merlin attempting to feed on an insect. This may have more to do with ease of observation than actual prey selection, or easily obtainable birds.

Rogers and Leatherwood (1981) report seeing a peregrine feeding on leach's storm petrels at sea. I found one "kill site" of a leach's petrel, in which everything but the legs and wings had been eaten. I have no way of knowing what species of hawk ate the petrel, or that it wasn't another predator (ie- gull).

Pithers (1965) reports seeing a European kestrel taking a bird missed by a peregrine. I witnessed the reverse of this situation, in which a peregrine took a bird that a merlin was having trouble catching. I quote from my journal; "A MERL (merlin) was chasing a warbler and a PEFA (peregrine) grabbed it out of the air. It appeared to be holding it by only one foot or wing. It dropped it, but caught it again before it hit the ground." This was just one example of the remarkable speed and agility of the peregrine.

Haugh (1972) says that migrating hawks will rob each other of prey. Although I never saw a hawk attempt to steal from another after the kill, I saw several cases of hawks competing for the same food, such as that described above between a peregrine and a merlin. I also twice observed two merlins chasing the same bird. In the first instance, both hawks made repeated stoops at a flying songbird, alternating with each other. Neither hawk managed to catch the bird, as both finally gave up. The second instance was similar, except that the bird was

caught. It appeared to be struck by both birds simultaneously, though one may have struck it slightly earlier. Neither bird released the prey, and the two merlins tumbled to the ground, both still holding the songbird. After hitting the ground, one flew away with the prey, the other without. Peregrines were also often seen competing. When one peregrine chased a bird out over the water and began stooping at it, others would join in, alternately stooping at the songbird till one caught it. I never saw peregrines "fight" for prey the way the two merlins did, but I saw two immature peregrines harass and beg from an adult that had captured a flicker. I have no way of knowing, of course, if the three birds were an actual family group. All three perched on a single eight-foot long rock, and the two young birds called till the adult bird finished eating. It made no move to share its prey with the young birds, but neither did it chase them away. The feeding behavior of individual species will be discussed below, under species accounts.

The three smaller hawks constantly harassed flickers, although I never saw any of them actually strike one. Flickers would often roost along the top of Mo's Tower, and one kestrel in particular seemed to enjoy flying around the edge of the tower, scaring all the flickers into flight. In my journal I wrote that, "I seriously think that they do it just for fun. And I think that the reason they choose COFL'S (flickers) for this game is the way they scream. At any rate, it looks like a fun game for the hawks, and probably less fun for the flickers." Allen and Peterson (1936) say that, "Although one of the commonest sights during the Hawk flights is a screaming Flicker with a little Sharp-shin in hot pursuit, there was not a trace of a flicker in any of the stomachs examined. It seems as if they just enjoy hearing the Flickers squeal."

Species accounts.

Merlins. Merlins were the most common hawk on Matinicus (120=36.9%), though they weren't far ahead of sharp-shins (110). Their mean date of migration was 22 Sep (see Figure sixteen, page 54). Their high-number day was 19 Sep, when 19 merlins passed Matinicus. This is the same date as the highest total hawk day (39 hawks). Merlins not only comprise a much higher

percentage of the total migrants at Matinicus compared to Beech Mt. (Table one, page 55), they also are higher in actual numbers (120 vs. 33). They are a strongly outer island oriented migrant.

Kudebeck (1951) describes the hunting methods of merlins well. He says "often the birds remain very low, the falcon stoops again and again in rapid succession, attacking from short distances at a few metres up to approximately 20 to 50 metres. At times the falcon appears to be flying up and down like a shuttle..." This last sentence in his description is especially well put. In my journal, I put it like this; "they don't try to follow the twists and turns of their prey. Instead they get above the prey and repeatedly swoop down at it pendulum-like." On another day, I wrote, "the bottom of each pendulum-swing was where the bird was--or close, anyway. The little bird managed to avoid the MERL about 4 or 5 times. Then on one of the swings, the two met perfectly."

The mistake of a small bird being chased by a merlin is to try to out-fly it. Merlins are extremely fast and agile in flight. Hunting merlins generally fly up and down the island while looking for prey. They sometimes make passes at birds in the vegetation, but I only saw one take a perched bird. This bird was sitting on a railing about three feet off the ground. A merlin came in very low, skimming the ground, and then rose sharply and plucked the bird off its perch from behind. All other birds were taken in flight.

Sharp-shins. Sharp-shins were the second most numerous hawk species (110 birds=33.8%). Their mean date of migration was 23 Sep (Figure 16, page 54), the same as that for all hawks. Their high-number day was 24 Sep, with 18 sharp-shins. Although they comprise a fairly high percentage of the hawks at Matinicus, it is a much lower percentage than that at either inner islands or coastal mountains (see Table one, page 55). The total number of sharp-shins could be seen on a single good day at Beech Mt. They are oriented toward both coastal mountains and inner islands during migration. There was an extremely high percentage of immature birds (96.3%) on Matinicus.

Sharpies use a different hunting method than merlins. They usually fly low over the ground while hunting, and often take

their prey in the vegetation or just as it takes off. They were never seen to stoop repeatedly as merlins will do, and usually gave up on their prey if they didn't strike it on the first attempt. When they did extend their chase, they followed the twists and turns of their prey in a very agile manner. They made no effort to get above their prey, as merlins did.

A second hunting method they often use is to make a sudden dash at nearby prey from a perch. This is probably closer to the hunting technique they use in their usual forest habitats.

Sharp-shins also differed sharply in their choice of feeding site after obtaining prey. Merlins usually seek a high exposed spot to eat (ie- top of a large boulder). Sharpshins, however, usually stay in the vegetation where they made the kill or fly to a well hidden spot, often combining the shelter of rocks and vegetation. Merlins seem intent on their prey while feeding and can usually be approached quite closely; whereas sharp-shins remain more alert and fly at any approach.

Peregrine Falcons. The high percentage (14.5) of peregrines on Matinicus helped to make my time there extremely enjoyable. "There is perhaps no more marvelous spectacle in nature than that of a peregrine falcon..." (Grossman and Hamlet, 1964). Their percentage and numbers on Matinicus were much higher than those at either of the other sites (Table 1, page 55). In fact, the number of peregrines at Matinicus is higher than that seen at such well-known sites as Hawk Mt., Pa. Broun (1939) reports seeing 24 peregrines out of 17,024 hawks in 1938. More recently, Haugh (1972) reports 21 peregrines out of 24,720 hawks in 1968. There is a "normal" percentage of adults and immatures. Peregrines seem to be strongly oriented to outer island sites during migration through Maine. The mean date of migration for peregrines was 3 Oct (see Fig. seventeen, page 54), and the highest number day was 4 Oct, with 10 peregrines. Their mean date of migration is significantly later than that for all species, indicating that peregrines may migrate slightly later than the other species.

Since the peregrine is an endangered species, it would be worthwhile to understand its migration routes better. Enderson (1965) states that many peregrines, presumed to be 'arctic' birds, migrate to Central and South America to winter. His labelling of the migrants as 'arctic' birds would seem logical, since there are almost no peregrines in eastern North America that aren't

- 2 -

arctic. White (1968) called these arctic peregrines a separate sub-species, *F.p. tundrius*. He described them as having very narrow malar stripes and a conspicuous white forehead band. The birds I saw fit this description, though there is much individual variation. White (1968) also says that peregrine migration is of the "leapfrog" type, where the populations nesting farthest north move farthest south. He goes on to say that "The bulk of the migrants appearing along the Atlantic seaboard appear to be from the tundrius population."

Accepting that the peregrines seen on Matinicus are tundra-inhabiting birds, the question that remains relates to the route they use to get from the arctic to their wintering grounds. Shor (1970) has proposed a route based on banding recoveries. He says that the source of the birds seen along the Atlantic coast is western Greenland. The birds head southward down the Hudson Bay and James Bay and then across Quebec to the Atlantic (see Figure nineteen), where they pass such places as coastal Maine, Cape May Point and Assateague Island. They then go on down or off the Atlantic coast to South America, wintering in Uruguay or Argentina.

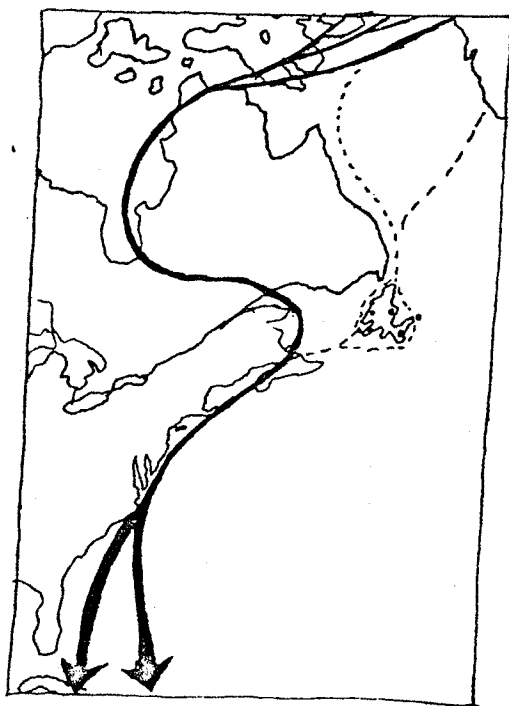


Figure 19. Proposed migration routes of Peregrine Falcons.

- 1 -

This route may explain the migration of peregrines from western Greenland, but there are some problems. First, it seems likely that peregrines migrating south past the Great Lakes (Haugh, 1972) would have come from James Bay, where fair numbers of peregrines are seen in the fall (Leslie Leo, personal communication). Second, this would make the trip unnecessarily long for birds in extreme southwestern and southern Greenland. The dotted line in Figure nineteen would seem to represent a more sensible route for these birds. To prove this, data would be needed from the Labrador Coast and Newfoundland.

Burrows (1981) reports yearly sightings of peregrines at six locations in Newfoundland. These are represented by the dots on Figure nineteen. Tufts (1978) also mentions that peregrines are seen in Nova Scotia during migration. Since no numerical data are available, no conclusions can be drawn from these reports, except that peregrines are present along both coasts of Newfoundland in the fall.

Rudebeck (1951) describes the hunting method used by peregrines as "the famous stoop, the peregrine striking obliquely from above with an enormous speed at birds in flight." In regards to the number of stoops, he says, "very often it will stoop only once, irrespective of the result, but now and then it will make another attempt or even go on stooping five or ten times, and in rare cases it will repeat its attempts 50 times or even more." Most of the peregrines that I watched hunting made relatively short stoops, and repeated them until it caught the bird. Peregrines usually seemed to try to drive their prey upward and/or over the water. Brown and Amadon (1968) say that if a falcon finds a particularly good food supply during migration that it may stop for a few days. This could explain the fact that some peregrines spent several days on the island in good weather.

American kestrel. Kestrels comprised 9.8 percent of the total numbers, with 32 birds. They are seen at slightly higher percentages at Beech, and much higher at Green's (see Table one, page 55). The high percentage of males seen (66.7) may simply mean that females, with their less brilliant colors, were more often identified as unknowns. In fact, if all of the females

and unknowns are considered one group, then males make up 56.2% of the total, a much more "normal" figure. The mean date of migration for kestrels was 21 Sep, and the highest number day was 24 Sep, with five (see Figure 17, page 54). Kestrels, unlike other falcons, seem to be oriented more toward inner islands. This may be because birds are usually not their main prey.

Kestrels feed on Matinicus in the same manner as elsewhere, hovering over a bird before taking it on the ground or dropping on it from a perch. I never saw a kestrel catch a bird in flight.

Northern harrier. Harriers made up 3.4 percent of the total. The eleven harriers seen were scattered fairly uniformly from 11 Sep to 3 Oct. Single birds were seen on all days except 17 Sep, when two were seen. All harriers seen were immature birds.

Only one harrier was seen to capture prey, although others were apparently hunting. Harriers quartered the island close to the ground, and the one that was seen capturing prey dropped on it in the vegetation (a warbler).

Other hawks. Two other hawk species were seen. Four ospreys were seen. Three of these simply flew by, and one was seen hunting. This one caught two fish about an hour apart and spent time after catching each one sitting on a Coast Guard buoy offshore eating.

A single large (female?) immature goshawk was seen. It perched low, rather than on the highest spots available (where peregrines and merlins perch). It was chased by a peregrine twice. For all practical purposes, goshawks can be considered accidental at Matinicus.

Other Birds

At least 114 species of birds were seen at Matinicus Rock from 11 Sep to 28 Oct, 1982. At least one other species of Empidonax flycatcher was seen, and a possible orange-crowned warbler specimen (a tower-kill) awaits positive identification. Appendix C lists all species seen. Some of the more interesting observations of non-falconiform birds are described below.

On 16 Sep, at 3:45 A.M., I stepped out on the porch to check on the number of tower kills (see "Tower Kills", below) and a greater shearwater came crawling through the grass and went under the porch. Since it was still there at daybreak, I picked it up and checked it for wounds and photographed it. It was unable to take off from land, so I took it down to the water and set it on a large rock. It jumped, barely clearing the water before flying away. It appeared to be a healthy bird, and flew away normally.

At four different times, leach's storm petrels flew through open doors into the main house and were taken back outside. One dead one was found next to the tower, presumably a tower kill. The remains of another were found that had apparently been eaten by either a hawk or a gull. Petrel burrows can be found on the island wherever there is sufficient soil.

On 8 Oct a tightly packed group of nine great blue herons was seen on a rock near the water. Both blue-winged teals and black ducks were seen several times in the "puddles" on the island. Huge flocks of common eiders were usually present around the island. One flock that I attempted to count through a spotting scope contained about 1,100 birds.

A dead sora was found on 20 Sep. It presumably hit the tower. Unexpected shorebirds included white-rumped sandpipers, a whimbrel, a common snipe, and a woodcock.

A single adult puffin was seen on 11 Sep. My journal says, "At 1335 I came around a boulder and found myself face-to-face with a PUFFIN!...It was more surprised than me, and it flopped down into a burrow (Audubon # XXIII)." I took two photos of it as it left the island an hour later. Both are over-exposed, but there appears to be a yellow color band on its right leg.

On 24 Sep an immature red-headed woodpecker was seen and photographed. On 21 Sep a northern wheatear was observed and

photographed. On 11 Sep, a yellow-headed blackbird was seen throughout the day. My journal says: "Two sharpshins scared up a bird that, at a quick glance, looked like a ♀ yellow-headed blackbird." I later was able to get better looks at it and photograph it. On 25 Sep a dickcissel was found dead, of no apparent cause.

Songbirds

My data on songbirds is not detailed enough to attempt to correlate their movements with weather conditions (see Lack, 1960; Nisbet and Drury, 1968). Warblers were generally more abundant early in the study period and fringillids later. Yellow-rumped warblers and palm warblers were present after other warblers were no longer seen.

From my notes, I was able to separate forty days into three general categories of relative songbird abundance. Then the number of hawks seen on each of these days was determined, in an attempt to correlate hawk movement with changing numbers of prey. A Kruskal-Wallis test showed no statistical significance of the difference in hawk numbers in each of the three categories. A Mann-Whitney U-test on the difference between the number of hawks on high and low songbird abundance also showed no statistical significance.

Migratory Insects

Griffin (1964) discusses the migration of monarch butterflies, and Allen and Peterson (1936) mention seeing both monarchs and dragonflies at Cape May, N.J. I kept a count of monarchs and dragonflies seen, and came up with eighteen and six, respectively, though I wasn't putting much effort into spotting them.

Mammals

Harbor seals were seen daily throughout the seven-week period. There were usually between thirty and forty in sight. Two young seals were found dead. No grey seals were seen. Four bats (unidentified species) were seen flying during the

day. A mummified star-nosed mole was found about mid-island (seemingly too high for waves to have left it there. My journal says, "How did it get there?? Could there be a population of them here? Seems doubtful." The most likely explanation seems to be that it was left there by a predator or scavenger.

The only cetaceans seen were white-sided dolphins. A group of at least 250 was seen on 13 Oct, headed approximately southwest. They came very close to the island, and many leapt clear of the water.

Tower Kills

My notes for 16 Sep say "4:30 am-- the fog is gone and with its passing migration has come. And with migration, light house kills have come. That's mostly why I'm awake. With birds crashing into my bedroom window every few minutes, I couldn't sleep...There's a pile of 14 dead passerines on the porch-- almost all warblers-- and the final toll will certainly be higher." The final toll was, in fact, 51 birds, 44 of which were warblers. The largest was a flicker. Although this was the worst night for tower kills, it was not the only one. There were thirteen nights with tower kills, resulting in a total of 74 dead birds.

The conditions that bring about these kills and exactly how they affect the birds involved are unclear to me. Leahy (1982) says that the birds are attracted to lights of certain tall structures and get disoriented by them. Crawford (1981) associated tower kills in Florida with north winds and cloud cover. He said that clouds affect the birds in two ways. First, birds fly at lower altitudes under overcast, and, second, light is refracted by a greater number of minute moisture droplets, disorienting the birds. He says that fog or precipitation are not necessary, as long as the sky is overcast. Laskey (1960) also correlated tower kills with northerly winds and overcast skies, and Ogden (1960) found overcast skies to be important.

Crawford (1981) relates an additional thought regarding why birds hit towers. He says, "birds enter the illuminated area of a tower and are reluctant to leave; they mill around

and many are killed by hitting the tower, guy wires, or other birds."

Checking my own weather data, I found the following conditions on the night of September 15-16. First, it had been solidly foggy since late on the night of 12 Sep. The fog finally broke between 10:30 p.m. on the 15th and 1:30 a.m. on the 16th. The tower kills started around 11:30 p.m., 15 Sep (about the time the fog broke?). The winds were steadily from east-northeast, at around 20 knots. After the fog broke, it remained overcast.

The only other night with more than two tower kills was October 8-9, when 8 were found. This was, again, a cloudy night with east-northeasterly winds at around 20 knots. However, there was also a thick fog throughout the night.

It was obvious that birds were hitting lit areas. These included the lighthouse light, lit windows in the main house, and two areas lit with floodlights; a bright red outside door on the main house, and a white wall on the boathouse. All birds were hitting the southwest side of the buildings (ie- they were flying into the wind). When I stood on the porch to observe, birds would often fly into me. Since I could clearly see the birds as much as ten feet away, they should have been able to see me and the red door that many of them hit.

Importance of the Island for Migrants

The outer islands, collectively, are probably extremely important sites for migrating falcons. They provide both a food supply and a place to rest. Accipiters are much less dependent on these islands, since they can capture food easily among trees. Islands such as Wooden Ball and Seal are probably even more important, since they are similar in habitat and much larger.

DISCUSSION/SUMMARY

In my 47 days on Matinicus Rock, I saw 320 hawks of seven species. The mean hawks per observer hour was 6.21, although this is affected somewhat by a fifteen day period from 13 Oct to 27 Oct when almost no hawks went by (7 total). The mean date of migration was 23 Sep, with a standard deviation

of 7.9 days.

The only climatic variables that correlated well with the amount of visible hawk migration were precipitation and wind direction. On rainy and/or foggy days there was no migration. On days with a westerly component to the wind there were more hawks than on those with easterly components (difference statistically significant at .05 level). This may indicate that wind drift is an important factor in the migration of hawks at Matinicus Rock, perhaps especially so in respect to sharpshins and kestrels, which migrate over inner islands and coastal mountains in higher percentages of the total. This is also consistent with the idea that juveniles may be more strongly affected by wind drift than adults (Newton, 1979), since 96.3 percent of the sharpshins seen were immature birds, excluding those birds that were not aged. Other meteorological variables, such as barometric pressure, temperature, and sky conditions showed no statistically significant relationship to the hawk movements. This lack of correlation may be explainable by the idea that falcons, which comprise the majority of the migrants at Matinicus Rock, are less dependent on weather conditions during migration than other types of hawks.

The daily movements of hawks were heaviest during mid- to late morning. The mean time of migration was 10:30 to 11:00 AM, with a standard deviation of one hour. Thus most of the migrants were seen passing Matinicus Rock between 9:30 and noon. This time period is also where most of the formal observation time occurred, but since I was constantly watching for hawks, whether during formal observation time or not, I feel that this represents the actual daily timing of the movements.

The seasonal timing of the movements of sharpshins, kestrels, and merlins was the same. However, peregrines showed a significantly (.001) later mean (Oct. 3). Looking only at peregrines, the mean date of migration for adults was 28 Sept, while that for immature birds was 4 Oct. Due to large standard deviations, however, this difference was not statistically significant. This situation may become clearer as the data base grows.

The observation sites from which I had access to data can be classified into three types; outer islands, inner islands, and coastal mountains. There are significant differences in the composition of the migrants at each site type. Falcons were strongly

oriented toward the outer islands. Accipiters were oriented toward the coastal mountain sites, though many pass inner islands as well. Buteos were absent from outer islands, and occurred in the highest percentages at the coastal mountain site. These differences can be explained by both the characteristics of the sites involved and those of the various hawk groups (see text). The age ratio of the peregrines observed could be considered typical. However, unusually high percentages of juvenile sharpshins and harriers were observed.

Much feeding behavior was observed. The small hawks (sharpshins, merlins and kestrels) were never seen to take anything but small (warbler, sparrow) sized prey, although a few unsuccessful chases of medium (thrush)-sized prey were noted. Peregrines took a high percentage of small prey items (45.5%). This is probably an indication of the relative vulnerability of this size class, since vulnerability is affected by relative numbers of prey species (Brown and Amadon, 1968), and small birds were by far the most numerous. In other words, the peregrines were simply feeding on what was most abundant. The percentage of each class taken decreased from small to medium to large.

No prey items other than birds were seen being chased, captured or eaten but birds, although insects such as dragonflies were fairly common. Again, this may be a reflection of the relative abundances of large insects and birds, or it may relate to the observer's ease of detecting insects as compared to that of detecting birds.

Both inter- and intra-specific competition for food was observed. In inter-specific cases, peregrines were successful over all others. All three smaller hawks were commonly seen chasing flickers, which produced loud screams upon being chased. None of these hawks were seen actually striking a flicker. This behavior was interpreted as "play."

Differences in the feeding behavior of the various hawk species was discussed. These differences relate to the physiology and habitat preferences of each species. The possible migration routes of peregrines was discussed. The peregrines seen at Matinicus Rock are most likely all "arctic" peregrines.

The most notable non-falconiform species seen include a red-headed woodpecker, a dickcissel, a yellow-headed blackbird,

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and a northern wheatear. The phenomenon of tower kills was discussed and deserves more study.

EDUCATIONAL VALUE OF PROJECT

This project was undoubtedly one of the most successful learning experiences of my career. I learned much concerning field work, literature research, data analysis, and presentation of my research; as well as about the migration of hawks in coastal Maine. This project has led to many ideas for future work, and hopefully will become an ongoing study. Aside from the educational value of the project, the field work was one of the most enjoyable experiences of my life.

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Steve Kress helped in logistics and obtained permission for me to use the Audubon House on Matinicus Rock. Steve Mullane and Joe Van Oss, who had both been on Matinicus, gave me some idea of what to expect. Butch Rommel spent long hours brainstorming

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LIST OF ALL BIRDS SEEN ON MATINICUS ROCK, 11 Sept. to 27 Oct, 1962
(TOTAL=116)

- *SORA
- COMMON LOON
- *GREATER SHEARWATER
- LEACH'S STORM PETREL
- NORTHERN GANNET
- DOUBLE-CRESTED CORMORANT
- GREATER CORMORANT
- GREAT BLUE HERON
- CANADA GOOSE
- COMMON EIDER
- BLUE-WINGED TEAL
- BLACK DUCK
- SURF SCOTER
- WHITE-WINGED SCOTER
- SHARP-SHINNED HAWK
- *GOSHAWK
- NORTHERN HARRIER
- OSPREY
- AMERICAN KESTREL
- MERLIN
- PEREGRINE FALCON
- SEMIPALMATED PLOVER
- SEMIPALMATED SANDPIPER
- WHIMBREL
- SPOTTED SANDPIPER
- RUDDY TURNSTONE
- *COMMON SNIFE
- WHITE-RUMPED SANDPIPER
- RED KNOT
- *AMERICAN WOODCOCK
- GREATER BLACK-BACKED GULL
- HERRING GULL
- *ATLANTIC PUFFIN
- BLACK GUILLEMOT
- MORNING DOVE
- *YELLOW-BILLED CUCKOO
- RUBY-THROATED HUMMINGBIRD
- BELTED KINGFISHER
- YELLOW-BELLIED SAPSUCKER
- COMMON FLICKER
- *RED-HEADED WOODPECKER
- YELLOW-BELLIED FLYCATCHER
- (EMPIDONAX FLYCATCHERS-Unidentified species)
- EASTERN WOOD PEEWEE
- EASTERN PHOEBE
- *BARN SWALLOW
- AMERICAN CROW
- NORTHERN RAVEN
- RED-BREASTED NUTHATCH
- BROWN CREEPER
- MARSH WREN
- WINTER WREN
- GRAY CATBIRD
- BROWN THRASHER
- AMERICAN ROBIN
- SWAINSON'S THRUSH
- HERMIT THRUSH

Continued...

VEERY
 *NORTHERN WHEATEAR
 RUBY-CROWNED KINGLET
 GOLDEN-CROWNED KINGLET
 HORNED LARK
 WATER FLIT
 CEDAR WAXWING
 EUROPEAN STARLING
 RED-EYED VIREO
 *PHILADELPHIA VIREO
 BLACK AND WHITE WARBLER
 TENNESSEE WARBLER
 NORTHERN PARULA
 YELLOW WARBLER
 MAGNOLIA WARBLER
 CAPE MAY WARBLER
 BLACK-THROATED BLUE WARBLER
 YELLOW-RUMPED WARBLER
 BLACK-THROATED GREEN WARBLER
 BLACKBURNIAN WARBLER
 CHESTNUT-SIDED WARBLER
 BAY-BREASTED WARBLER
 BLACKPOLL WARBLER
 OVENBIRD
 NORTHERN WATERTHRUSH
 MOURNING WARBLER
 COMMON YELLOWTHROAT
 YELLOW-BREASTED CHAT
 WILSON'S WARBLER
 CANADA WARBLER
 AMERICAN REDSTART
 PALM WARBLER
 *(ORANGE-CROWNED WARBLER- "tower kill"- positive ID still needed)
 BOBOLINK
 *YELLOW-HEADED BLACKBIRD
 NORTHERN ORIOLE
 COMMON GRACKLE
 RUSTY BLACKBIRD
 BROWN-HEADED COWBIRD
 EASTERN MEADOWLARK
 RED-WINGED BLACKBIRD
 SCARLET TANAGER
 ROSE-BREASTED GROSBEEK
 PURPLE FINCH
 AMERICAN GOLDFINCH
 SAVANNAH SPARROW
 NORTHERN JUNCO
 WHITE-CROWNED SPARROW
 WHITE-THROATED SPARROW
 LINCOLN'S SPARROW
 SWAMP SPARROW
 SONG SPARROW
 TREE SPARROW
 FIELD SPARROW
 DICKCISSEL
 CHIPPING SPARROW
 SNOW BUNTING
 RUFOUS-SIDED TOWHEE
 FOX SPARROW

(*-Denotes that a single
 bird of this species
 was seen)

used two different computers for analyzing such of my data. When possible, I used a Sinclair ZX81 home computer. For more complex programs, I used a Digital PDP11. The programs for 1) Mann-Whitney U-tests, 2) mean, variance, and standard deviation, and 3) Chi-square Tests were taken from Foote and Borchers (1977). The following three programs were written for this project, using Campbell (1974) as a statistical reference.

Program 1- Five Day Moving Averages.

This program is used for determining five-day moving averages. The data entered into this program must be in the form of the number of occurrences on each of a series of dates. The dates used must be numbered consecutively. For instance, my data covered the period from 11 Sept. to 10 Oct. The dates in Oct. had to be changed to run consecutively with those in Sept., so, since Sept. has 30 days, 1 Oct. was called "31", 2 Oct. was called "32", etc. The start date is not important, so the dates in Sept. remained unchanged.

Since this program determines five-day averages around a certain date, the first day for which a five-day average can be given is the third observation day. When the computer asks "FIRST DAY FOR WHICH YOU WANT 5-DAY M.A.'S=?", the third day of observation must be entered.

```

10 PRINT "5-DAY MOVING AVERAGES"
12 LET Y=0
13 DIM X(90)
20 PRINT
30 PRINT "FIRST DAY FOR WHICH YOU WANT 5-DAY M.A.'S=";
35 INPUT M
40 PRINT "LAST DAY FOR WHICH YOU WANT 5-DAY M.A.'S=";
45 INPUT N
50 FOR I=M-2 TO N+2
55 LET Y=Y+1
60 PRINT "  DAY ";I;"=";
70 INPUT X(I)
80 IF Y(5) THEN 120
90 LET A=X(I)+X(I-1)+X(I-2)+X(I-3)+X(I-4)
100 PRINT "5-DAY AVERAGE (AROUND DAY";I-2;"")=";A/5
120 NEXT I
130 END

```

Program 2- Kruskal-Wallis Test.

This program performs the Kruskal-Wallis Test. This is a test for the significance of the difference of more than two population medians. To simplify this program greatly, it was written in such a way that it asks for the ranks of the items in a sample, rather than the ranks themselves. Ranking is a simple procedure. First, the data are divided into groups, according to the sample they belong in. For instance, when I compared the numbers of hawks moving on days with high, medium, and low songbird abundance, I would separate my data into three lists; high songbird abundance, medium, and low. In each list

would be the number of hawks occurring on each day with the proper associated level of songbird abundance. Next, all of the data (numbers of hawks) from all three lists must be placed in ascending order. Finally, the data are ranked. This involves assigning a number to each datum, reflecting its order in the ascending list. For example, the lowest number of hawks from all three lists is given rank 1, the second lowest, rank 2, etc. In the case of ties (ie- two days with the same number of hawks), all the items involved in the tie are given the average of the ranks corresponding to their positions in the single ascending list. If, for instance, I had two days with 6 hawks, and these days occupied positions seven and eight in the ascending list, both would be assigned rank 7.5. Once these ranks are all assigned, they are substituted for the data in the separate lists (ie- those of numbers of hawks on days with various levels of songbird abundance).

The computer will ask for the number of samples (3 in the above example) and the size of each sample (the total number of items in the appropriate list). Then it will ask for the ranks of the items in each sample. Finally, it will print out an "H" value. The significance level of the difference between the populations is found by using a table of Chi-squared values using one less than the number of samples as the degrees of freedom.

```

10 PRINT "KRUSKAL-WALLIS TEST"
20 PRINT
25 LET B=0
26 LET R(I)=0
27 LET X=0
30 DIM X(20),Y(20)
35 PRINT "NUMBER OF SAMPLES=";
36 INPUT Z
40 FOR I=1 TO Z
50 PRINT "SAMPLE ":I
60 PRINT "  SIZE=";
70 INPUT N(I)
80 FOR J=1 TO N(I)
90 PRINT "    RANK":J:"=";
100 INPUT Y(J)
120 R(I)=R(I)+Y(J)
130 NEXT J
140 LET S(I)=R(I)*2/N(I)
160 LET X=X+S(I)
170 B=B+N(I)
180 NEXT I
190 LET H=(12/(B*(B+1)))*X-3*(B+1)
200 PRINT "H=";H
210 END

```

Program 5- Fisher-Behrens Test.

This is a test for the significance of the difference between two means, used when the two samples involved have unequal variances. The mean, variance, and size of each sample must be calculated first. The result will be a "D" value and a "Theta" value. These are equal to the "d" values and " θ " values, respectively, as used in Campbell (1974). These values are used in a table (A14 in Campbell, 1974) to determine significance of the difference between the means.

```
10 PRINT "TODDMUV-TEST OF DIF. OF MEANS W/UNEQUAL VARIANCES"
20 PRINT
30 PRINT "SAMPLE 1"
40 PRINT "  MEAN=";
50 INPUT A
60 PRINT "  VARIANCE=";
70 INPUT B
80 PRINT "  SIZE=";
90 INPUT N
100 PRINT
110 PRINT "SAMPLE 2"
120 PRINT "  MEAN=";
130 INPUT C
140 PRINT "  VARIANCE=";
150 INPUT E
160 PRINT "  SIZE=";
170 INPUT M
180 D=(A-C)/SOR(B/N+E/M)
190 T=SOR((B/N)/(E/M))
199 PRINT
200 PRINT "D=";D
210 Z=ATN(T)
215 Z=(Z*180)/PI
220 PRINT "THETA=";Z
230 END
```