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Magnitude and Seasonal Timing of Northern Harrier (*Circus cyaneus*) Migration at Hawk Mountain Sanctuary, Pennsylvania, 1936-1999

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Introduction

Northern Harriers (Circus cyaneus) are found throughout much of North America and Eurasia (Cramp and Simmons 1980). Typically, Northern Harriers migrate individually (Beske 1982, Kerlinger 1989), and usually across a broad front (MacWhirter and Bildstein 1996). In North America, harriers are long-distance migrants that generally depart from their breeding grounds in Alaska, Canada, and the northern continental United States in late August-early September (Watson 1977). Even so, the timing of departure from the breeding grounds is not particularly well quantified (MacWhirter and Bildstein 1996), and their migration, overall, is not well studied.

The aim of this study was to determine whether the magnitude or the timing of Northern Harrier migration has changed at Hawk Mountain Sanctuary, Pennsylvania between 1936 and 1999 and, if so, which factors were involved in the change.

Methods

The autumn migration of raptors has been recorded at Hawk Mountain Sanctuary each year since 1934, except for three years (1943-1945) during World War II. The resulting migration-count database is the longest and most complete record of raptor migration in the world (Bednarz et al. 1990, Bildstein 1998). In recent decades counts have been made daily from the Sanctuary's North Lookout between 15 August and 15 December, except during periods of foul weather (for additional details on the study area and data collection see Allen et al. [1996]). We used Hawk Mountain Sanctuary counts of migrating Northern Harriers from 1936 through 1999 to estimate changes in magnitude and timing of the harrier migration at this Appalachian ridge-top site. (Data from 1934 and 1935 were deleted because of relatively low count efforts in those two years.)

We attempted to control for the effect of count effort by restricting the analysis to the period of 15 September-7 November, during which effort was approximately the same each year. Prior to 1966, counts were recorded by day. Beginning in 1966, counts were recorded by hour. Hourly counts made prior to 0800 h and after 1800 h were excluded from our analysis because observations usually were not conducted during those hours prior to 1966. Count effort at the North Lookout was substantially lower in 1967-1977 than in periods 1936-1966 and 1978-1999. Therefore, we conducted our analyses both with and without data from 1967-1977.

Count data were converted to mean annual passage rates by dividing the total number of birds sighted each year by the total number of hours of observation during that year. Annual median date of passage of the autumn flight was defined as the day on which at least 50% of the annual flight had passed. Tests were conducted for long term trends in annual passage rate and in annual median date of the flight. We also investigated if the timing of migration was related to the magnitude of each year's flight. For each of the tests we created four competing models: intercept alone; intercept and year; intercept, year and year2; and intercept, year, year2, and year3. Including year, year2, and year3 in our models allowed us to test both for linear and nonlinear long term trends. For each test, the best model was selected based on Akaike's Information Criteria, adjusted for small sample size (Burnham and Anderson 1998).

Statistical analyses were performed using simple linear regression and multiple regression, and the SAS statistical program (SAS Institute 1990). We also tested for a correlation between annual passage rate and median date of passage using partial correlation.

Results

Earliest and latest dates of Northern Harrier southbound migration at Hawk Mountain were 1 August 1996 and 24 January 1999, respectively. Mean date (+ standard deviation) of passage for 50% of the annual flight is day-of-year 280 (13 October in non-leap years) + 6.2 days. Mean rate of passage peaked at 0.50 + 0.09 individuals per hour in the last half of October, when the chance of seeing at least one individual per day is 86% + 5.3.

When analyzing all years, (i.e. 1936-1999), we detected a third-order trend in annual passage rate (Figure 1 top, Table 1). Passage rates, which were low during the 1930s, increased during the 1940s, 1950s, 1960s, and 1970s, and then decreased during the 1980s and 1990s. Highest rates of passage occurred in the late 1970s and early 1980s. The highest annual passage rate was 0.73 birds per hour in 1970; the lowest annual passage rate was 0.16 birds per hour in 1996.

The best model of annual passage rate versus annual median date of passage was quadratic but not significant (Figure 1 bottom, Table 1). Even so, the median date of harrier passage was approximately two days earlier in the 1970s (mean day-of-year passage = 281.6, N = 10) than in other decades combined (mean day-of-year passage = 283.6, N = 54), and 4.4 days earlier than in the first five and last five years of observation combined (i.e. 1936-1940 and 1995-1999) (mean day-of-year passage = 285, N = 10). We did not detect a significant correlation between annual passage rate and annual median date of the autumnal flight (Table 1).

We obtained similar results with and without including data from 1967-1977.

Table 1. Models for rate of passage versus year, day of year versus year, and rate of passage versus day of year. The best model was selected based on Akaike's Information Criteria (Burnham and Anderson 1998). Models considered best are identified with **.

	Model	Adj-r^2	P-value	AICc
Rate of passage versus Year	**Year year^{2}year^3	0.21	0.001	-261.26
	Yearyear^2	0.14	0.004	-257.35
	Year	0.06	0.03	-253.16
	Intercept	0.00		-250.33
Day of year versus year	**Year year^2	0.04	0.11	213.32
	Intercept	0.00		213.52
	Year	-0.00	0.32	214.72
	Yearyear^{2}year^3	0.03	0.22	215.67
Rate of passage versus day of year	**Intercept	0.00		-250.30
	Year	-0.01	0.42	-248.78
	Yearyear^2	0.01	0.36	-247.96
	Year year^{2}year^3	-0.01	0.49	-246.01

Discussion

The results of our study suggest that the timing of Northern harrier migration has not changed significantly during the 64 years from 1936 through 1999. Even so, during the 1970s passage rate of harriers was higher than in other years, and in the same decade the timing of migration averaged two days earlier than in other decades combined.

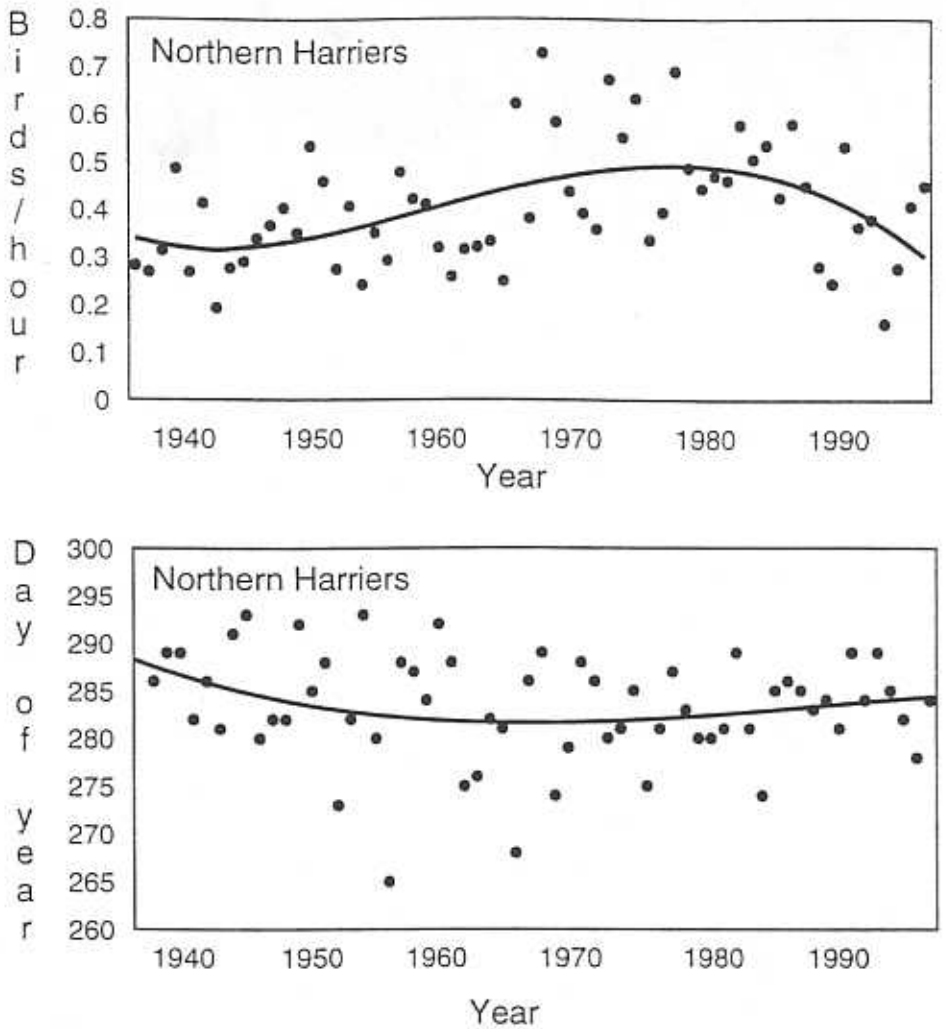

Figure 1. *Top:* Annual rates of passage of Northern Harriers at Hawk Mountain Sanctuary, PA, 1936-1999. *Bottom:* Annaul median dates of autumn passage of Northern Harriers at Hawk Mountain Sanctuary, PA, 1936-1999. (Note: in non-leap year 270 = 27 September; day of year 280 = 6 October, and day of year 290 = 16 October.)

Bildstein et al. (1984) found that in autumn, juvenile Northern Harriers migrate before adults, and it is possible that the larger harrier flights reported in the 1970s at Hawk Mountain Sanctuary represent flights in years in which reproductive output was high, and in which the relative ratios of juvenile-to-adult harriers was higher than in other years. The difficulty in distinguishing between adult female and juvenile harriers of both sexes limits our ability to gather information on the age classes of individuals migrating past Hawk Mountain each autumn. Nevertheless, the relatively high counts of Northern harriers at Hawk Mountain Sanctuary during the 1970s (figure 1 top) immediately follow the cessation of several decades of widespread use of DDT, a pesticide suspected of substantially reducing reproductive success in the species (Hammerstrom 1969). Therefore, it seems reasonable to suggest that the high harrier counts in the 1970s were made up of relatively high numbers of young harriers.

Another possible explanation for coincidental shifts in the timing and magnitude of the harrier flight is that both reflect a geographic shift in the principal breeding grounds of harriers to the north, as a result of DDT's greater impacts on harrier populations in more southerly portions of their breeding ranges where the pesticide was more heavily used. Northern populations of raptors often migrate earlier than more southern populations.

On the other hand, two years with extremely early median dates of passage, 265 (22 September) in 1957, and 268 (25 September) in 1967, may reflect years with especially low rates of reproductive success in which adults that failed to nest, or who failed to fledge any young, migrated particularly early.

We found that the magnitude of the harrier flight at Hawk Mountain Sanctuary has decreased since 1970. Even so, the average passage rate of 0.34 + 0.12 birds per hour in 1995-1999, is about the same as the 0.33 + 0.09 birds per hour reported in 1936-1940.

According to Hammerstrom (1986), the sizes of at least some North American breeding populations of Northern Harriers are strongly related to the abundance of their main prey, meadow voles (Microtus pennsylvanicus). Fluctuations in migration counts at Hawk Mountain Sanctuary, however, cannot be explained by coincidental or lagging predator-prey cycle fluctuations, as the periodicity of meadow vole cycles is typically 3 to 4 years.

Northern Harrier populations declined in the northeastern United States in the latter half of the 20th Century (Serrentino 1992). Some researchers have suggested that the decline is probably due to loss of breeding habitat. In particular, changes in agricultural techniques and the reforestation of farmlands appear to have had an important impact on the abundance of this species directly, or indirectly by affecting the density of their prey, as well as availability of safe nesting sites (MacWhirter and Bildstein 1996). Long term counts of raptor migrants at Hawk Mountain Sanctuary, and other long term count sites, including Bake Oven Knob, Pennsylvania (Heintzelman 1979), offer the promise of low-cost, long term population monitoring for Northern Harriers and other species of North American raptors (Zalles and Bildstein 2000).

Acknowledgments

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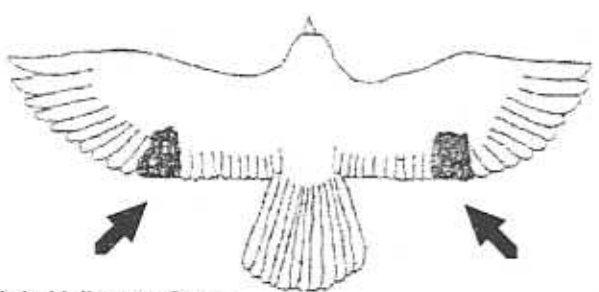
Red-tailed Hawk Migration Study Continues

Beginning in September, 2000, banders from Little Gap Raptor Research Group began color marking Red-tailed Hawks for a study of migration patterns and behavior of individuals of this species. The research project is a joint effort between the Wildlife Information Center, Hawk Mountain Sanctuary, and Little Gap Raptor Research. We hope to answer a number of questions about Red-tailed Hawk migration including: 1) are early autumn birds migrating, dispersing, or are they local birds moving up and down the ridge; 2) how much affinity do Red-tails have to the Kittatinny during their migration; 3) where do Red-tails we see at Kittatinny watch sites spend the winter; and 4) what is the source of the Red-tails we see along the Kittatinny (where do they breed).

Throughout the autumn of 2000, banders at Little Gap (25 km north of Allentown, PA and 18 km up ridge from our Bake Oven Knob watch site) color marked 90 Red-tailed Hawks. As of 22 December nine sightings have been reported, including only one at Bake Oven Knob. Six of the sightings were from Kittatinny watch sites, one was from a site just north of the Kittatinny, and two were from sites well south of the ridge. Sightings ranged from as much as 400 km (250 miles) to the south and 130 km (80 miles) west of the Little Gap banding station where the birds were marked.

As the color markings should remain on the birds throughout the winter and perhaps into spring, we are asking observers to continue looking for these color marked birds and to report all sightings to the Wildlife Center at P.O. Box 198, Slatington, PA 18080, 610-760-8889, or at *wildlife@fast.net*. All sightings are very valuable including those with only partial information requested below. Thanks to all who reported sightings.



Pink, Yellow or Green dye on Secondaries

Please report the following (if known)

Your name, address, phone, email
Date of sighting
Time of day
Location of sighting (state, county, locality)
Age of bird
Dye color
Behavior of bird when observed