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THE INFLUENCE OF WEATHER, GEOGRAPHY, AND HABITAT ON MIGRATING RAPTORS ON CAPE MAY PENINSULA[1]

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Abstract. For many shorebirds and passerines, stopovers in areas of concentrated resources increase survival during migration. For raptors, physical factors have generally been considered to be the chief influence on migratory behavior, and few studies have collected quantitative data on the use of resting and foraging habitat during migration. Our object was to survey three different habitats along a 30-km section of the Cape May peninsula. We measured abundance, flight altitude, and flight direction of eight species of migrating raptors to evaluate the influence of habitat and physical factors, including wind speed, wind direction, and location, on migratory behavior. Physical factors such as wind speed and direction were weakly related to bird density and altitude. Although interactions among physical factors were significant, they were not consistent with predictions based on bird mass or wing-aspect ratio. Habitat type was significantly associated with most species' altitude and density. Birds generally occurred in higher densities and at lower altitudes above habitats similar to those used in breeding or wintering seasons. We suggest that the strong habitat association is due to the need for suitable foraging sites. Many migratory raptors are able to prey upon migratory birds, insects, and fish that also concentrate at the end of the Cape May peninsula or in waters offshore. Most of the raptors observed in Cape May are immature and inexperienced, and the concentration of similarly immature and inexperienced prey may prove to be a critical factor in successful migration along the Atlantic Coast.

Key words: Migration; raptors; stopover; habitat; Cape May; prey.

INTRODUCTION

Most studies of avian migration have focused on wind, tide, and other abiotic factors as the key features influencing migration, even though the availability of foraging, resting, and roosting habitat is crucial to survival during this season (Gauthreaux 1982, Greenberg 1987, Ketterson and Nolan 1982, Moore and Kerlinger 1987). Recent studies of shorebirds and passerines have documented the importance of food availability and competition in important stopover or staging areas during migration (Rappole and Warner 1976, Keast 1980, Schneider and Harrington 1981, Cherry 1982, Burger 1984, Myers and McCaffrey 1984, Terrill and Ohmart 1984, Bairlain 1985, Hutto 1985, Biebach et al. 1986, Burger 1986, Greenberg 1987, Moore and Kerlinger 1987, Dunn et al. 1988). These studies indicate that food availability and migrant condition are major determinants of whether birds stop along migration routes or migrate non-stop. The availability of food in migratory stopover areas has been recognized recently as being crucial to survival of several bird populations (Burger 1986, Myers et al. 1987).

Despite the importance of stopover areas to survival, few data are available on the factors affecting bird distribution and habitat use within stopover areas (Burger 1986, Kerlinger 1989, Safriel and Lavee 1988). Studies of raptors, in particular, have focused on migratory routes, phenology, flight characteristics, and methods of orientation and navigation (Kerlinger 1989).

We examined habitat use by migrating hawks as well as wind, altitude, and distance from a water crossover point. We surveyed raptors in three habitat types along a 30-km length of the Cape May, New Jersey peninsula to evaluate the importance of habitat to birds migrating on the

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peninsula. We investigated how birds are distributed on the peninsula during migration, including determining which species concentrate in staging areas and the primary factors affecting bird distribution.

The Cape May peninsula has the largest and most diverse migratory flights of raptors in North America (Kerlinger 1989). Each year as many as 80,000 individuals of 15 species fly past the point of the peninsula. Considerable work has been completed on the effect of weather factors on the direction, altitude, and visibility of the Cape May birds (Kerlinger 1984, Kerlinger and Gauthreaux 1984) and on locations of breeding or wintering areas from banding returns (Bildstein et al. 1984, Clark 1985a, 1985b). Holthuijzen et al. (1982) conducted a telemetry survey of Sharp-shinned Hawks (*Accipiter striatus*) but restricted surveillance to less than a few km from the point.

The study of birds only at the end of the peninsula may distort understanding of the ecological relationship between migrating raptors and habitat. Counts from single locations place a greater emphasis on the abiotic factors affecting flight while minimizing the effects of variations in habitat and other biotic factors. Over the last few decades the forest and field habitat of the Cape May raptor concentration area has been reduced and segmented into discrete patches by development. It is important to understand how migrants use these fragmented habitats to identify habitat critical to the protection of species diversity and numbers. Thus, one of our objectives was to document habitat use over a relatively wide area (0–30 km from Cape May Point).

In this paper we test the following null hypotheses concerning raptor migration: (1) There are no differences in the numbers of birds concentrating at Cape May Point compared to areas away from the point. (2) There are no differences in the influence of weather factors on numbers or altitude of birds on Cape May Point compared to a control site 30 km away from the point. (3) There are no differences in the influence of habitat type on density or altitude of hawks at any point on the peninsula.

METHODS

The Cape May peninsula at the southern tip of New Jersey, is 18 km north of Delaware, across the Delaware Bay. The peninsula is 30 km long, extending from the town of Sea Isle City on the Atlantic Ocean (latitude 39°9′45″ longitude 74°41′30″) and Dennisville (latitude 39°11′45″ longitude 74°49′30″) on the Delaware Bay shore to Cape May Point (latitude 38°55′0″ longitude 74°56′15″). The peninsula is about 10 km wide at the northernmost point and includes habitats ranging from densely populated ocean resort beaches to sparsely populated oak-pine (*Quercus-Pinus*) forests.

We classified habitats on the peninsula into six categories using 1986 1″ = 400′ aerial photographs (Fig. 1). We established survey points within 1 km of four east-west lines 10 km apart. The first line was within one km from the southern end of the peninsula at Universal Transverse Mercator (UTM) line 4312. The second line (10 km) was located at UTM 4322, the third (20 km) at UTM 4332, and the fourth at UTM 4342, 30 km from the southern end of the peninsula. We divided each line into a Delaware Bay and Atlantic Ocean side, then randomly located survey sites for three of the six classified habitats: marsh, forest, and field. We restricted the choice of survey sites in two ways: (1) sites had to be more than 300 m from a road, and (2) forested sites had to have unrestricted views of at least 100 m in all directions and a canopy that allowed a partial view of the sky.

All points were surveyed for hawks between 08:00 hr and 13:00 hr two times per week for eight weeks from 15 September to 7 November in 1984 and 1986. Two observers surveyed all habitats in one day for both Atlantic and Delaware Bay points. In 1986 we randomly chose a new set of points and conducted the project in the same way. Start locations and observers were staggered so that all points were surveyed at different times of day by different observers to avoid observer bias and influences of time on the data.

In both years we watched for birds at each point for 30 minutes. Observers were trained to estimate distance by setting reference points at 100 m intervals at all survey points with a Rangematic rangefinder. We also measured the height of stands of vegetation with a clinometer or tape to enable the observer to estimate vegetation height under each bird sighting. Whenever a bird was sighted, observers recorded the distance of the first sighting and the closest sighting of each bird, time, species, direction of flight (or track), altitude of the bird at 10 m intervals at its closest track, and the type of flight. Wind direction, wind speed, and ambient temperature were obtained from National Oceanographic and Atmospheric

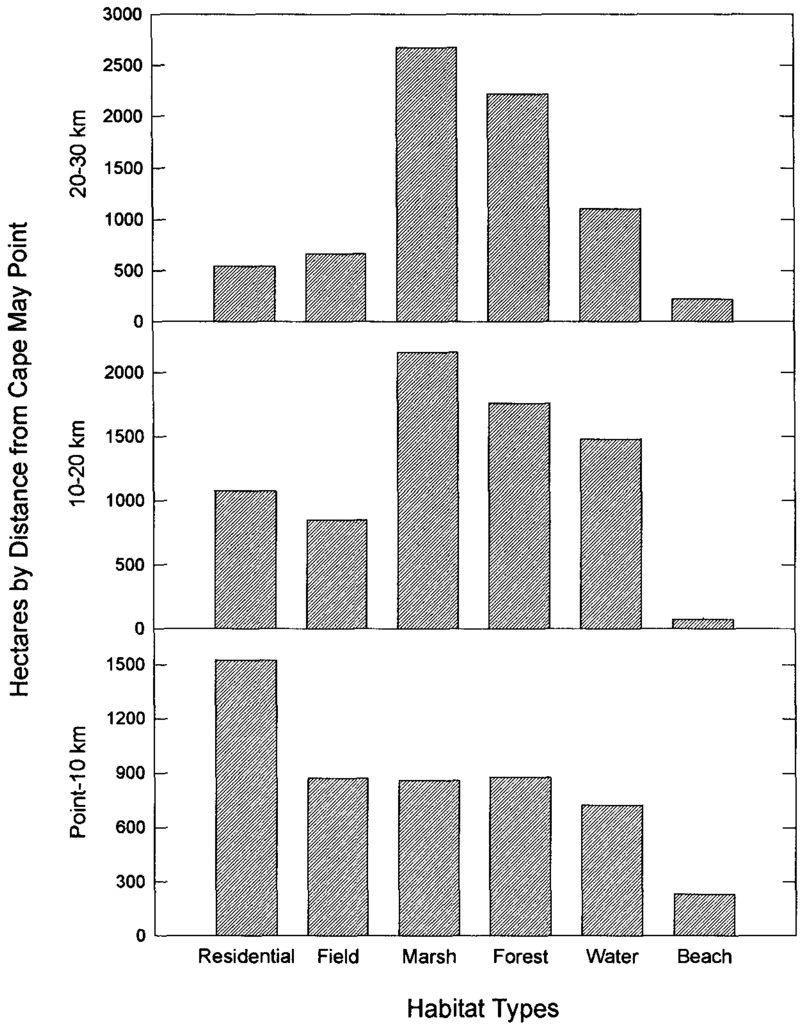

FIGURE 1. Area (ha) of habitats on Cape May peninsula from Cape May Point to 30 km north of the point.

Administration (NOAA) summaries taken at the Cape May County Airport, which is within 20 km of all points. Wind direction was classified into four categories: NW, NE, SE, and SW. Wind speed (highest gust speed) was classified into two categories: ≤ 6.7 m/sec and >6.7 m/sec.

All data were analyzed using PC Statistical Analysis System (PC-SAS; SAS Institute 1985). To evaluate the influence of wind, position, and habitat on survey counts, we summarized the results of each survey and compared summaries. To evaluate the influence of these factors on flight altitude, we compared physical factor data measured for individual birds (i.e., unsummarized data). We used the F-test for homogeneity of variances, Wilks-Shapiro test. We log-transformed the summarized data and bird altitudes to meet normality assumptions of statistical tests (Zar 1988).

Our original design was to classify surveys into 10-km intervals for both sides of the peninsula, then determine effects of weather and location on the number and altitude of observed birds. Because far fewer birds were seen in the three intervals north of the point than at the point, however, we also combined data into three geographical groups. Surveys on the 30-, 20-, and 10-km intervals were reclassified into two groups,

TABLE 1. Number of individuals of each species observed on Cape May peninsula in surveys, autumn 1984 and 1986.

Species	Total number	Mean altitude ± SE
American Kestrel (*Falco sparverius*)	45	50 ± 7.1
Broad-winged Hawk (*Buteo platypterus*)	31	187 ± 15.3
Cooper's Hawk (*Accipiter cooperii*)	46	112 ± 12.3
Northern Harrier (*Circus cyaneus*)	79	58 ± 7.9
Osprey (*Pandion haliaetus*)	87	87 ± 6.6
Red-tailed Hawk (*Buteo jamaicensis*)	55	105 ± 9.0
Sharp-shinned Hawk (*Accipiter striatus*)	623	95 ± 3.0
Turkey Vulture (*Cathartes aura*)	99	114 ± 7.7
Other species (< 14 of each observed)	46	—
TOTAL	1,111	

one representing all surveys conducted on the Delaware Bay (western) side of the peninsula, and a second including all surveys conducted on the Atlantic Ocean (eastern) side of the peninsula. The third group included all surveys conducted in the lowest interval at the point of the peninsula (0–10 km). We used these categories to test the effect of geographical position, wind speed, and wind direction on density and altitude. We used a three-way ANOVA to test the influence of each factor separately and in association with one (two-level interaction) or two (three-level interaction) other factors (Zar 1988).

The comparison of habitat types was compromised by the much smaller viewing area in forest survey points. To account for this, we calculated densities for each point using an area of 24 ha (300-m radius) for field and marsh survey sites and a 10-ha area (150-m radius) for forest sites. For the comparison of altitudes, we subtracted the height of vegetation from the altitude of the birds to eliminate the effect of vegetation height in the comparison of habitats. Data were then analyzed using habitat and position on the peninsula (using point, Delaware Bay, and Atlantic Coast classifications) in a two-way ANOVA.

We summarized the direction-of-flight data by combining directions into southbound (S, SW, SE, W), northbound (N, NE, NW, E), and perching categories. Chi-square analysis was used for contingency tables (Zar 1988).

We included the Sharp-shinned Hawk, Osprey (*Pandion haliaetus*), Northern Harrier (*Circus cyaneus*), and Turkey Vulture (*Cathartes aura*) in our analyses, and combined Red-tailed Hawk (*Buteo jamaicensis*), Broad-winged Hawk (*Buteo platypterus*), and Red-shouldered Hawk (*Buteo lineatus*) because of the low number of individuals of these species sighted.

RESULTS

SPECIES ABUNDANCE

In 1984 we conducted 140 surveys at 24 points and counted 596 birds; in 1986 we conducted 123 surveys at 24 points and counted 515 birds. Of the 15 species counted, Sharp-shinned Hawks were the most abundant and Bald Eagles (*Haliaeetus leucocephalus*) the least abundant (Table 1).

Location on the Peninsula, wind speed and wind direction. When data were analyzed using the original survey design, based on north to south geographical intervals, the total number of birds observed migrating through the peninsula increased significantly to the south (i.e., toward the point) (Fig. 2). The increase, from 1.9 birds/survey 30 km north of the point to 9.9 birds/survey at the point, appeared to result primarily from an increased number of Sharp-shinned Hawks at the point. Most of the increase occurred in the lower 10 km. Nearest the point Sharp-shinned Hawks increased from 0.4 birds/survey at the 30-km line to 6.6 birds/survey at the point. Although Sharp-shinned Hawks were the most numerous hawk seen in the entire peninsula, they comprised a much greater proportion of the birds seen at the point, accounting for 66% of the birds at the point but only 38%, 21%, and 12% of birds at the 10-, 20- and 30-km lines. Numbers of Northern Harriers, Turkey Vultures and buteo species observed did not change significantly toward the point. There was no significant difference between Atlantic and Delaware Bay sides

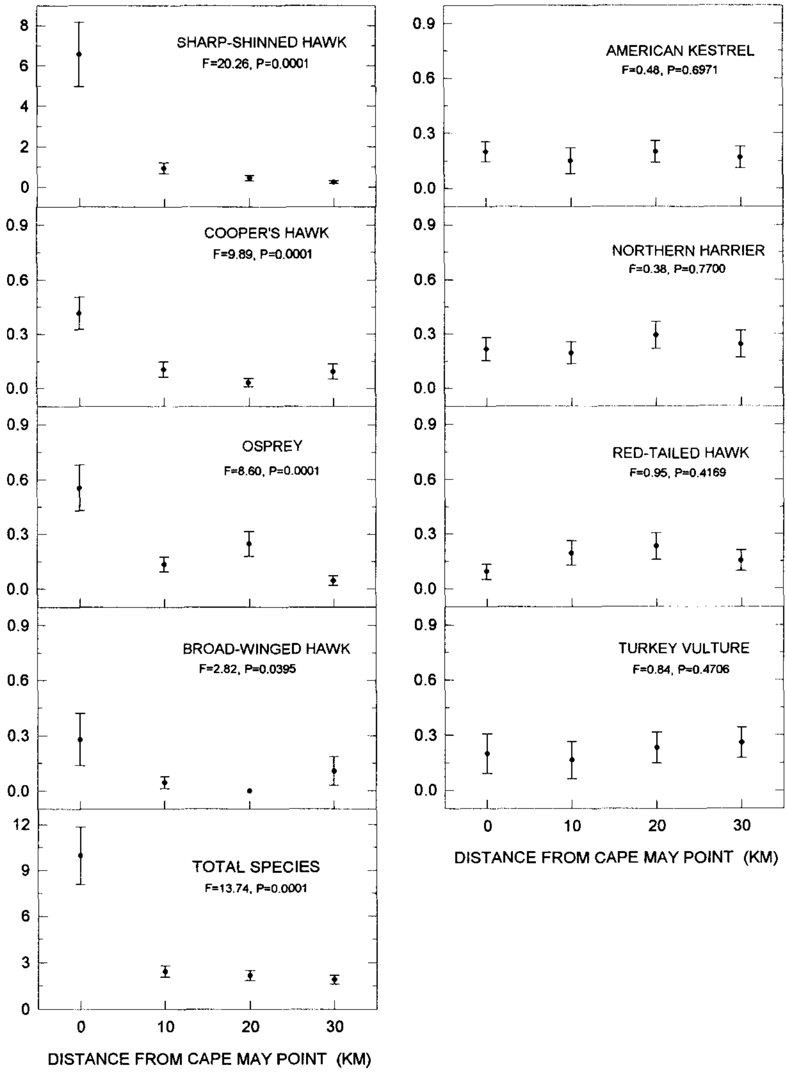

FIGURE 2. The number of birds/survey ± SE at each 10 km interval on Cape May peninsula in 1984 and 1986. F and *P* values from a one-way ANOVA are given in each graph.

of the peninsula (Table 2, Duncan's Multiple Range test, $P > 0.05$). Wind speed and direction were not significantly associated with the number of birds (Table 2).

Habitat. There were significant differences in the number of birds counted in marsh, field, and forest habitats for Sharp-shinned Hawks, Northern Harriers and buteo species (Table 3). Sharp-shinned and buteo species flew over forests more often than over fields and marshes. Harriers flew over marshes more than forests and fields. For all species combined, more birds were counted over forest habitats. The effect of habitat strongly depended on location on the peninsula. Interactions of these two factors were significant for four species.

ALTITUDE

Location. On average, the eight most common species flew at different altitudes. Kestrels (*Falco sparverius*) and harriers flew the lowest at 50 and 58 m above the vegetation, respectively, and Broad-winged Hawks the highest at 187 m (Table 1). Turkey Vultures, Red-tailed Hawks, Cooper's

TABLE 2. Mean ± SE birds/survey on Cape May peninsula by location (Atlantic Coast, Delaware Bay, point), wind direction and wind speed, from surveys during fall 1984 and 1986.

	n	Northern Harrier	Osprey	Sharp-shinned Hawk	Turkey Vulture	Total buteos
Location						
Atlantic Coast	96	0.15 ± 0.042	0.08 ± 0.028	0.42 ± 0.091	0.19 ± 0.070	0.34 ± 0.089
Delaware Bay Coast	101	0.33 ± 0.068	0.20 ± 0.049	0.66 ± 0.187	0.25 ± 0.078	0.18 ± 0.052
Point	65	0.22 ± 0.064	0.55 ± 0.126	6.55 ± 1.597	0.20 ± 0.108	0.37 ± 0.145
F, P		$F = 2.38$	$F = 12.00$	$F = 31.80$	$F = 0.34$	$F = 1.40$
df = 2, 44		$P = 0.10$	$P = 0.0001$	$P = 0.0001$	$P = 0.71$	$P = 0.25$
Wind direction						
NE	68	0.22 ± 0.072	0.27 ± 0.090	2.66 ± 0.804	0.12 ± 0.065	0.24 ± 0.079
NW	82	0.22 ± 0.058	0.28 ± 0.082	2.87 ± 1.116	0.39 ± 0.122	0.42 ± 0.130
SE	49	0.31 ± 0.078	0.14 ± 0.058	0.31 ± 0.124	0.06 ± 0.035	0.23 ± 0.074
SW	64	0.22 ± 0.072	0.25 ± 0.063	1.59 ± 0.570	0.20 ± 0.084	0.22 ± 0.090
F, P		$F = 0.77$	$F = 0.02$	$F = 2.47$	$F = 1.53$	$F = 0.84$
df = 2, 238		$P = 0.51$	$P = 0.88$	$P = 0.06$	$P = 0.21$	$P = 0.47$
Windspeed						
≤6.7 m/sec	139	0.25 ± 0.045	0.25 ± 0.055	1.75 ± 0.568	0.24 ± 0.074	0.30 ± 0.083
>6.7 m/sec	124	0.23 ± 0.052	0.23 ± 0.056	2.34 ± 0.658	0.19 ± 0.057	0.28 ± 0.061
F, P		$F = 0.47$	$F = 0.02$	$F = 0.42$	$F = 0.09$	$F = 0.23$
df = 1, 238		$P = 0.49$	$P = 0.86$	$P = 0.52$	$P = 0.76$	$P = 0.63$

Hawks, Sharp-shinned Hawks, and Ospreys flew at roughly the same altitude (87 m–114 m). Sharp-shinned Hawks, buteo species and Turkey Vultures flew at different altitudes on different areas of the peninsula but in no significant pattern (Table 4). Ospreys and harriers did not change altitude significantly regardless of their position relative to the point.

Wind direction and speed. Wind direction was significantly associated with altitudes of Sharp-shinned Hawks only (Table 4). Sharp-shinned Hawks flew highest in NE and SW winds and lowest in SE and NW winds. Turkey Vultures flew highest in NE and lowest in NW winds.

A significant relationship was evident between wind speed and flight altitudes of Sharp-shinned Hawks, and buteo species (Table 4). Under high wind conditions, buteos were observed at lower altitudes, whereas Sharp-shinned Hawks were observed at higher altitudes.

Habitat. The altitudes of birds over marsh, field, and forest habitats were significantly different for Sharp-shinned Hawks, Northern Harriers and buteo species (Table 5). Sharp-shinned Hawks flew lowest over field and forest, buteos flew lowest over forest, and harriers over marshes and fields. When all species were combined there was no significant relationship between habitat type and altitude.

DIRECTION OF FLIGHT

To maintain suitable samples for the comparison of number of birds perched or flying north or south we compared Sharp-shinned Hawks with

TABLE 3. Mean ± SE density/survey in marsh, field and forest habitats on Cape May Peninsula, 1984 and 1986. *F* ratio and *P* values from two way ANOVA of habitat against position on the peninsula are followed by significance of the habitat-position interactions. Significance is as follows: $P > 0.05$ (NS) $P < 0.05$ (+) $P < 0.01$ (++) (df = 2, 260).

Species	Marsh $n = 84$	Field $n = 90$	Forest $n = 92$	*F*	*P*	Habitat/position interaction
Northern Harrier	0.02 ± 0.004	0.01 ± 0.002	0.01 ± 0.005	4.67	0.01	+
Osprey	0.02 ± 0.004	0.01 ± 0.002	0.02 ± 0.007	1.02	0.35	+
Sharp-shinned Hawk	0.08 ± 0.031	0.10 ± 0.037	0.32 ± 0.101	4.81	0.01	++
Turkey Vulture	0.01 ± 0.003	0.02 ± 0.005	0.02 ± 0.007	1.04	0.36	+
Total buteos	0.01 ± 0.002	0.01 ± 0.003	0.02 ± 0.010	3.34	0.04	NS

TABLE 4. Real height (m) of raptors (mean ± SE) according to location on the peninsula, wind direction and wind speed, from surveys conducted on Cape May peninsula in 1984 and 1986.

	Northern Harrier	*n*	Osprey	*n*	Sharp-shinned Hawk	*n*	Turkey Vulture	*n*	Total Buteos	*n*
Location										
Atlantic Coast	63 ± 19.6	19	87 ± 24.0	13	66 ± 11.9	42	53 ± 9.9	22	109 ± 14.0	33
Delaware Bay	30 ± 6.0	43	64 ± 10.0	26	83 ± 9.2	80	74 ± 8.1	56	56 ± 14.1	18
Point	71 ± 20.2	17	62 ± 7.1	48	64 ± 3.3	501	120 ± 23.5	21	123 ± 15.9	24
F, P	$F = 1.92$, $P = 0.15$		$F = 0.15$, $P = 0.86$		$F = 2.88$, $P = 0.05$		$F = 3.11$, $P = 0.05$		$F = 4.99$, $P = 0.01$	
df	2, 59		2, 66		2,600		2, 80		2, 63	
Wind direction										
NE	38 ± 17.2	13	78 ± 11.4	27	74 ± 5.8	218	114 ± 21.2	15	75 ± 17.4	18
NW	47 ± 12.2	20	49 ± 10.0	20	46 ± 4.4	207	58 ± 7.1	48	121 ± 13.0	37
SE	39 ± 10.4	23	61 ± 11.5	22	45 ± 6.4	70	112 ± 30.9	13	83 ± 24.8	14
SW	60 ± 18.3	23	75 ± 15.4	18	99 ± 6.6	128	82 ± 15.4	23	94 ± 21.4	17
F, P	$F = 0.26$, $P = 0.86$		$F = 1.13$, $P = 0.34$		$F = 5.40$, $P = 0.001$		$F = 1.90$, $P = 0.13$		$F = 1.47$, $P = 0.23$	
df	3, 59		3, 66		3,600		3, 80		3, 60	
Windspeed										
≤6.7 m/sec	54 ± 10.8	37	61 ± 7.4	49	55 ± 4.4	295	74 ± 8.0	52	135 ± 12.6	43
>6.7 m/sec	41 ± 10.1	42	74 ± 10.1	38	77 ± 4.1	328	85 ± 12.8	47	64 ± 10.3	43
F, P	$F = 0.76$, $P = 0.39$		$F = 0.04$, $P = 0.85$		$F = 100.45$, $P = 0.0001$		$F = 1.25$, $P = 0.27$		$F = 8.60$, $P = 0.005$	
df	1, 59		1, 66		1, 600		1, 80		1, 63	

TABLE 5. Mean ± SE real height (m) of birds observed in three habitats on Cape May Peninsula, 1984 and 1986.

Species	Marsh	*n*	Field	*n*	Forest	*n*	*F*	*P*	df
Northern Harrier	40 ± 7.9	(59)	46 ± 10.9	(13)	109 ± 41.0	(7)	1.75	0.18	2, 76
Osprey	70 ± 7.5	(54)	56 ± 9.8	(23)	74 ± 26.4	(10)	0.87	0.42	2, 84
Sharp-shinned Hawk	86 ± 6.0	(189)	52 ± 4.4	(232)	65 ± 5.3	(202)	30.3	0.0001	2, 620
Turkey Vulture	86 ± 10.3	(37)	77 ± 9.3	(50)	66 ± 36.0	(12)	3.08	0.05	2, 96
Total buteos	68 ± 17.8	(36)	153 ± 12.2	(36)	43 ± 8.6	(14)	8.38	0.001	2, 83

all other species combined. The direction of flight of Sharp-shinned Hawks was significantly associated with the position of the birds on the peninsula ($x^2 = 40.7$, $P < .001$). Of the 623 Sharp-shinned Hawk sightings, 32% were flying north; but of those sighted on the bayshore, 60% were flying north. Birds on the bayshore and at the point accounted for over 95% of all the Sharp-shinned Hawks flying north. The direction of all other species was also significantly related to position but not as strongly ($\chi^2 = 10.8$, $P < .05$). About 28% of the birds along the Delaware bayshore were flying north, and birds on the bayshore and at the point accounted for 77% of the birds flying north. Few Sharp-shinneds perched (12%) while many more of the other species were perched (39%). Ospreys were found perched more than any other species, particularly at the point, where over 45% of the birds seen were perched.

DISCUSSION

ABIOTIC AND BIOTIC FACTORS AFFECTING MIGRATING RAPTORS

Stopover or staging behavior has been documented in passerine and shorebird migrants. Many authors have reported a significant relationship between fat deposition and length of stay that is complicated by competitors, food availability, date, and weather (Rappole and Warner 1976, Cherry 1982, Morrison 1984, Bairlain 1985, Beibach et al. 1986, Moore and Kerlinger 1987, Dunn et al. 1988, Moore and Simons 1992, Moore et al. 1993, Safriel and Lavee 1988, Skagen and Knopf 1994). Generally, however, stopover habitats are important because they can influence energy needs, vulnerability to predators, and exposure to environmental stress (Moore et al. 1993).

Unlike shorebirds and passerines, there is little quantitative evidence concerning whether migrating raptors pause to improve their body condition before continuing migration. Most literature on raptors in migration has dealt with numbers and movements, with little work evaluating enroute migratory habitat use or condition, even though several major concentrations of raptors have been observed (see Kerlinger 1989 for a review).

Holthuijzen et al. (1982) radio-tracked Sharp-shinned Hawks and found birds remaining in the Cape May Point area for up to four days. This length of stay may have been underestimated, however, because birds were not tracked outside of fixed receiver locations close to the point. Other telemetry studies indicate that at least some raptors stop over in times of bad weather or to replenish depleted energy reserves (Kerlinger 1989).

Several authors have published banding results on raptors on migration, however, none have dealt with condition and length of stay (Bildstein et al. 1984; Clark 1985a, 1985b). Measuring changes in condition during a short migratory stopover may be impossible for many raptor species because the drastic fluctuation of weight caused by consumption of relatively large prey makes it very difficult to standardize weights for a comparison between captures (C. Schultz, pers. comm.). Perhaps due to this and other difficulties of studying raptor condition during migration, raptor behavior and biological needs at stopovers have not been considered factors influencing the abundance of hawks at wide water crossings.

There are two theories concerning raptor concentration at coastal water crossings. Allen and Peterson (1936), in one of the first published accounts of the raptor concentrations at Cape May, proposed that birds drift with the prevailing northwest winds to the Atlantic coast and concentrate there because they are unwilling to make the 18 km Delaware Bay water crossing. This "drift" hypothesis was later supported by Mueller and Berger (1967a, 1967b) on Sharp-shinned Hawks and by Krohn et al. (1977) on the basis of their observations on American Woodcock (*Scolopax minor*) at Cape May. Another theory developed by Murray (1964, 1969) and supported by Kerlinger (1984), Kerlinger and Gauthreaux (1984), and Clark (1985b), proposed that birds concentrate there because they migrate in "broad fronts" and decrease altitude upon reaching water crossings. Murray (1969) acknowledged the "diversion line" effect of the Delaware Bay coast, which in some conditions would prevent birds from crossing, and Kerlinger (1984) noted that drift is possible above some threshold wind speed. It is important to note, however, that in all these discussions on concentration, the interaction of birds and habitat was not addressed. Kerlinger (1989:254) suggested birds may concentrate because of the large numbers of avian prey that also concentrate at water crossings.

In our study we surveyed birds throughout a migratory stopover area in the three main habitats. This enabled us to characterize bird distribution and abundance in relation to abiotic factors such as wind and geographic position, and with biotic factors such as habitat type.

INFLUENCE OF WIND ON ABUNDANCE AND ALTITUDE

Our data suggest that physical factors have only a partial influence on the number of raptors at the water crossing. If physical factors (wind speed and direction) were the sole determinants of whether birds fly or pause, then morphological differences such as weight or wing-aspect ratio should predict the species most likely to concentrate in stopover areas. Low-mass species with low wing-aspect ratios should have a more difficult time crossing water bodies than heavier species with high aspect ratios (Kerlinger 1985). But in our study the two species that were observed in greater numbers close to the point of the Cape May peninsula had very dissimilar morphology. Sharp-shinned Hawks are small with low wing-aspect ratios, whereas Ospreys are large with high aspect ratios. In addition, the species that did not concentrate also ranged from high to low aspect ratios and mass. In general, morphological characteristics did not predict the species most likely to concentrate at the point thus supporting our observations that wind condition does not affect bird concentrations at Cape May Point.

Murray (1964) suggested bird concentrations at Cape May in NW winds are a result of birds descending in altitude and thus becoming easier to observe. In our study, wind direction or speed did not affect the altitude of Ospreys, Northern Harriers, and Turkey Vultures even though Ospreys were found in higher numbers at the point. Sharp-shinned Hawks flew lower in northwest winds but they also flew low in southeast winds and their numbers did not vary significantly. Moreover buteos, the only other hawks whose altitude was significantly affected by winds, flew higher at the point. Northern Harriers flew at a significantly lower altitude at the point but did not occur in greater numbers there. Thus our data do not support descent in altitude as an explanation for the concentration of birds at the Delaware Bay water crossing, particularly in northwest winds.

INFLUENCE OF DECREASING LAND AREA

Another explanation for the concentration of raptors at Cape May Point is the gradual reduction in land area caused by the converging Atlantic and Delaware Bay coastlines. We discarded this possibility for two reasons. First, a concentration due to space limitation should affect all species, but not all species concentrated at the point. Second, we calculated the density of birds we would expect to see at point habitats based on density of birds observed 30 km north of the point and the total amount of habitat available at each interval. We found that the observed densities were far higher than would be expected if the coast were simply funneling birds onto the point (Table 6).

INFLUENCE OF HABITAT

We believe the concentration of species at the point cannot be explained as an effect of weather factors taken singly or in combination, or simply as a result of the geography of the peninsula. Our data suggest that birds are not simply flying over the peninsula, adjusting altitude depending on the weather or only holding over in adverse weather conditions. We believe that some of the migratory raptors observed on the peninsula use habitats for feeding and resting in ways similar to what has been reported for migratory passerines and shorebirds.

Of the raptors in the present study, about half were observed perching or not flying south, indicating behavior other than migration, such as foraging and resting. A primary cause for the concentration of Ospreys at Cape May point was the large number of birds using the habitat for

TABLE 6. The expected (E) densities of concentrating species (birds/ha) at three intervals based on the observed (0) densities at 20–30 km above the point. Observed and expected densities for marsh, field, and forest habitats were calculated separately to correct for uneven changes in the two peninsula areas.

Species		Distance from point: Point–10 km	Distance from point: 10–20 km	x^2	*P*
Cooper's Hawk	O	0.197	0.060	8.3	0.01
	E	0.050	0.023		
Osprey	O	0.337	0.047	12.6	0.001
	E	0.083	0.017		
Sharp-shinned Hawk	O	3.890	1.233	12.6	0.001
	E	1.113	0.350		
TOTAL ALL SPECIES	O	5.093	1.787	17.2	0.001
	E	1.383	0.553		

perching, which accounted for nearly half of all Ospreys seen in that area. The large number of Sharp-shinned Hawks flying north at the point and on the Delaware Bay shore suggests that birds fly south, round the point and head northward up the bayshore. Although some birds continued migrating up the bay to cross at a narrower point, many were observed flying close to or within woodlands. To some extent the local habitat use pattern seemed to be true for all hawk species examined.

HABITAT REQUIREMENTS

We suggest that the need to hunt, rest or roost and consequently the need for appropriate habitats, affects the distribution of raptors at Cape May Point. First, if birds were flying without regard to habitat, they should occur in similar densities above all habitats. In this study, densities of birds in each habitat were significantly different for five of the eight species.

Second, species were most numerous in the habitats they would normally select at breeding or wintering sites (Table 7). For example, Sharp-shinned Hawks often breed in dense, forested habitat and hunt forest birds and mammals (Reynolds et al. 1982), and Sharp-shinneds were most numerous above forested habitats of the peninsula. Northern Harriers are usually found in open fields and wetlands and prefer wetlands in wintering areas (Preston 1990), and they were most numerous in marsh habitats. Red-tailed Hawks, the most numerous buteo species, winter in field and forested habitats, often preferring fields with scattered woodlands for perch hunting (Bildstein 1987, Preston 1990). Red-tailed Hawks in our study were most numerous above forested habitats, which in the lower peninsula often occur in isolated woodlots surrounded by fields or marshes.

Third, many species flew lowest over the habitats where they would normally forage: buteos over forests, harriers over marshes, kestrels over fields, and Sharp-shinned Hawks and Cooper's Hawks over forests and fields. In general, the species that concentrated at Cape May Point were most dense and flew lowest over the habitats they use in wintering and breeding areas.

TABLE 7. Breeding habitats and habitats used by migrating raptors at Cape May 1984 and 1986 for species with significant differences in habitat.

Species	Breeding/ wintering habitat	Source	Habitat preference in Cape May (significance level): Highest numbers	Habitat preference in Cape May (significance level): Lowest altitude
Broad-winged Hawk	forest	Matray 1974		forest (0.01)
Cooper's Hawk	forest	Reynolds et al. 1982	forest (0.01)	
American Kestrel	field	Mills 1976		
Northern Harrier	field/marsh	Hamerstrom & Kopeny 1981	marsh (0.01)	marsh (0.05)
Osprey	marsh/forest	Poole 1989		
Red-tailed Hawk	field/forest	Bildstein 1987, Preston 1990	forest (0.01)	marsh (0.05)
Sharp-shinned Hawk	forest	Reynolds et al. 1982	forest (0.01)	field (0.001)

We propose that habitat selection for foraging is a major force influencing the stopover of raptors in the Cape May peninsula. The two species that concentrate at the point of the peninsula can take advantage of very concentrated prey. Sharp-shinned Hawks can prey on passerine migrants which concentrate in the Cape May coastal zone (McCann et al. 1993). Ospreys forage extensively on the shallow water shelf along the Delaware Bay shore. In the fall, Delaware Bay estuarine fish populations are at their highest and are generally moving past the point to oceanic wintering locations (T. McCloy, pers. comm.). Northern Harriers could benefit from increased availability of avian prey at the point but they are limited by the decreased availability of appropriate foraging habitat (marsh and field) within 10 km of the point.

HABITAT AND THE PROTECTION OF MIGRATING RAPTORS

There are two reasons why the availability of resting and foraging habitat is important to birds migrating through Cape May. First, energy costs increase along coasts because prevailing winds from the northwest cause eastward drift over the ocean unless birds compensate with powered flight (Kerlinger et al. 1985), and because birds encounter water crossings where there is no thermal activity and they must use powered flight exclusively. That raptor migration ceases during high winds or in poor visibility conditions at water crossings is evidence of the difficulty (Cochran 1975, Kerlinger and Gauthreaux 1984, Kerlinger 1985).

The second reason why suitable habitat is so important is the predominance of immature birds in the Cape May migration (Bildstein et al. 1984; Clark 1985a, 1985b). Up to 95% of all captured raptors at Cape May banding stations are immature, a ratio far higher than those estimated at most breeding locations (Newton 1979). This high proportion is probably not a result of trap bias because the proportion of immature birds is much lower at other banding locations using similar capture methods (Heintzelman 1986). Moreover, mist-netted passerines and hunter-killed woodcock at Cape May are also mostly immature (Krohn et al. 1977, Gustafson 1986).

For immature raptors flying down the coast, suitable habitat to rest and feed may be important to overall survival during migration, which can be the period of greatest mortality (Schmutz and Fyfe 1987). Immature raptors are less efficient at capturing prey (Bildstein et al. 1984, Fischer 1985, Toland 1986) and may find the large concentration of mostly immature prey in places like Cape May an easy way to restore depleted energy.

An unintended result of the emphasis on abiotic influences in most research on migrating raptors is that conservation agencies and government regulators have placed a low priority on land protection in concentration areas. Development on Cape May peninsula between 1973 and 1986 has resulted in a loss of nearly 30% of all suitable upland and freshwater wetland habitat (Niles, unpub. data). The remaining habitat has become increasingly fragmented and often degraded by human disturbance. Destruction and degradation may force birds to move through key areas sooner than they would if habitats were available. This may significantly decrease the survival of all migrating raptors but particularly immatures which comprise a major portion of the migratory flight.

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