ECOLOGY AND CONSERVATION OF MIGRATORY RAPTORS

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ABSTRACT OF THE DISSERTATION

Stopover Ecology of Migratory Raptors

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When confronting a barrier to migration, birds often stop over in suitable habitat to maintain or improve body condition. Many researchers have documented the importance of migratory stopovers for many species of migratory shorebird and passerine birds. Few studies are available on the stopover ecology of migratory raptors. I studied the stopover ecology of 15 species of migratory raptors on the Cape May peninsula, an important stopover for birds about to cross Delaware Bay. In a study of eight raptor species on the entire Cape May peninsula, I found two species concentrating in the lower ten km portion of the peninsula. Birds were most abundant in or flew lowest over habitats similar to those used in breeding and wintering areas. I then attached radio-transmitters to 16 Sharp-shinned Hawks. Eight birds left the area (mean stay=1.1 days), and eight stayed until their transmitter stopped (mean stay =4.1 days). Home range size averaged 2,380 ha. with core areas of less than 300 ha. The two groups differed only in weight, with lighter birds staying until their transmitter stopped. Heavier birds crossed the bay in lower wind speeds and higher visibility than when birds migrated over land. If weather conditions were unsuitable the birds altered their pathway to cross the bay elsewhere or stopped migrating. Birds selected

different habitats for each major behavior. They hunted in shorter forests with open canopies and roosted in taller forest with closed canopies. I conclude that the major influence on birds attempting to cross the bay is physical condition modified by weather. Habitat is important because physical condition or weather influence birds to stay in the area and the availability of habitat is declining. In my final study I surveyed all species in the lower ten km of the peninsula and found that seven of nine species selected forest, field, or marsh habitats, and eight species avoided developed areas. I conclude that the destruction of habitat on the peninsula, especially the lower peninsula is creating a long term and irreversible impact on migratory birds.

PREFACE

A migratory stopover is defined as "an area with the combination of resources (like food, cover and water) and environmental conditions (temperature, precipitation, presence and absence of predators and competitors) that promotes occupancy by individuals of a given species in migratory passage" (Morrison et al. 1992). Migration is a time of exceptional demands on an individual bird and yet little is known of the habitat needs in general, and in particular at migratory stopovers. Perhaps in consequence the importance of stopovers has been overlooked in the development of conservation strategy (Moore et al. 1996)

The Cape May peninsula was first recognized as important to migratory raptors by the market hunters of the late 1800's (Dunne 1988). Published accounts of the migratory flights of passerines, woodcock and hawks in the scientific literature started in the early 1900s has continued until recently with papers on migratory owls, and neotropical migrant birds. The Cape May stopover is recognized as one of the most important bird stopovers in the United States and among the most important in the world (Kerlinger 1989, 1996). Abundance estimates are unavailable for most species except raptors, which number as many as 80,000 individuals of 15 different species in a three month (autumn) period.

Much of the recent literature on raptors has dealt with the influence of weather and geography as the cause of this large concentration. At first researchers assumed that birds drifted to the Atlantic coast on prevailing northwest winds, and the birds hesitated or stopped when faced with the 18 km Delaware Bay crossing (Allen and Peterson 1937, Mueller and Berger 1966). But later work suggested that birds corrected for drift, but descended in altitude on reaching the Delaware Bay coast, thus presenting the appearance of concentration (Murray 1964, 1969, Kerlinger and Gauthreaux 1984).

In these studies, no author tried to determine the role of biotic factors such as the availability of habitat, or the condition of birds when they approached the area. The peninsula is rich in prey for a number of different species: migrating passerines are prey for Sharp-shinned Hawks, Cooper's Hawks, Northern Harriers, Merlins, Northern Goshawks, Peregrine Falcons and other bird eaters, fish are abundant for Ospreys, even insects for kestrels. Moreover, nearly all the birds coming to the stopover are immature, unlike those using inland migration routes (Clark 1985 a,b, Gustafson 1985, Krohn 1977, Bildstein et al. 1986). Young birds are necessarily less experienced and more vulnerable, and a large number of them in the relatively small area of a stopover can result in competition that grows more intense with the ever-diminishing area of habitats in the lower portion of the peninsula (Niles et al. 1996). Finally, several species of hawks can be prey for larger hawks, making the risk of predation motivation for secure resting and roosting habitat. Little is known of these biotic factors and their influence relative to more generally studied abiotic factors such as wind and geography.

The relative influence of abiotic and biotic factor is the focus of Chapter One of my thesis. The focus is raptors, but because of the close connection with passerines, my work addresses the area as a stopover for most species. My work begins with a study on the relative influence of abiotic factors (geography, wind direction and speed) with biotic factors (species differences and habitat use). I surveyed all raptor species but focused on Sharp-shinned Hawks, Ospreys, Northern Harriers and several buteo species (Red-tailed Hawk, Red-shouldered Hawk and Broad-winged Hawk).

The next two chapters of my thesis deal with a radio-telemetry study of Sharp-shinned Hawks conducted in 1989 and 1990. Chapter Two focuses on home range and movement of birds within the stopover, and the routes taken to leave it. This study presents data on the relationship of bird condition, length of stay and the cost/benefit relationship of strategies for continuing migration. The third chapter concentrates on behavior and habitat use. In it I focus on the habitats selected for hunting, perching and migrating, and the changes birds made with experience.

In the final chapter I once again concentrate on all species in the stopover but narrow the area of study to the lower ten km of the peninsula. In the first chapter I found several species concentrated in this area, and in the telemetry work I found individual Sharp-shinned Hawks in the area, hunting and resting for days while waiting for good weather to cross. Thus the habitat within the lower ten km area may be critical for protecting the long-term integrity of the stopover for raptors. In this chapter I present data on raptor distribution and habitat use, once again examining habitat selection, but for all eight raptor species observed.

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My dissertation is dedicated to my family, Joseph, Daniel, William and Kathleen.

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CHAPTER ONE: THE INFLUENCE OF WEATHER, GEOGRAPHY, AND HABITAT ON MIGRATING RAPTORS ON CAPE MAY PENINSULA

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 1987, 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, Bairlien 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 body 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,

raptors, in particular, have focused on migratory routes, phenology, flight characteristics, and methods of orientation and navigation (see Kerlinger 1989 for a summary).

I examined habitat use by migrating hawks as well as wind, altitude, and distance from a water crossover point. I surveyed raptors in three habitat types (forest, field, and marsh) along a 30-km length of the Cape May Peninsula, New Jersey, to evaluate the importance of habitat to birds migrating on the peninsula. I 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,b). 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 the objectives was to document habitat use over a relatively wide area, (0-30 km from Cape May Point).

In this paper I 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.

I classified habitats on the peninsula into six categories using 1986, 1" = 400' aerial photographs (Fig. 1). I 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. I 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. I 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 h and 13:00 h 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 I 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 observers watched for birds at each point for 30 min. Observers were trained to estimate distance by setting reference points at 100 m intervals at all survey points with a Rangematic rangefinder. Observers also measured the height of stands of vegetation with an clinometer or tape to enable estimation of 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, the 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 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, I summarized the results of each survey and compared summaries. To evaluate the influence of these factors on flight altitude, I compared physical-factor data measured for individual birds (i.e., unsummarized data). I used the F-test for homogeneity of variances (Wilks-Shapiro test). I 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, I also combined data into three geographical groups. Surveys on the 30-, 20-, and 10-km intervals were reclassified into two groups, 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). I used these categories to test the effect of geographical position, wind speed, and wind direction on density and altitude. I 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, I 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, I 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.

I 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).

I included the Sharp-shinned Hawk, Osprey (Pandion haliaetus), Northern Harrier (Circus cyaneus), and Turkey Vulture (Cathartes aura) in the 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, I conducted 140 surveys at 24 points and counted 596 birds; in 1986, I 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 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. 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 Northern 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 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 Northern 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. Sharp-shinned Hawks flew highest in NE and SW winds and lowest in SE and 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, I compared Sharp-shinned Hawks with 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-shinneds flying north. The direction of all other species was also significantly related to position but not as strongly ($X^2 = 10.8$, $P < .05$). 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, Bairlein 1985, Biebach 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 en-route migratory habitat use or body 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 body condition and length of stay (Bildstein 1984, Clark 1985a,b). 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,b) studying Sharp-shinned Hawks and by Krohn et al. (1977) on the basis of their observations on 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 at Cape May 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 weather conditions, would cause birds not to cross, 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 this study, I surveyed birds throughout a migratory stopover area in the three main habitats. This enabled me 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

My data suggests 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 this 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 my observations that wind condition does not affect bird concentrations at Cape May Point.

Murray (1964) suggested bird concentrations at Cape May in northwest winds are a result of birds descending in altitude thus making them easier to observe. In this study, wind direction or speed did not affect the altitude of Ospreys, Northern Harriers, and Turkey Vultures, even though Ospreys were found in greater numbers at the point. Sharp-shinned Hawks flew lower in northwest winds but they also flew low in southeast winds. Moreover, buteos, the only other hawks whose altitude was significantly affected by winds (wind speed), 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 the 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. I 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, I calculated the density of birds I 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. I 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

I 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. My 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. I 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 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

I 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 this 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.

I 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 ten 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,b). 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 unpublished 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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Table 1. Number of individuals of each species observed on Cape May Peninsula in surveys, autumn 1984 and 1986.

Species	Total Number	Mean Altitude ± S.E.
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	

Table 2. Mean ± SE birds/survey on Cape MayPeninsula 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 P=0.10	F=12.00 P=0.0001	F=31.80 P=0.0001	F=0.34 P=0.71	F=1.40
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 P=0.51	F=0.02 P=0.88	F=2.47 P=0.06	F= 1.53 P= 0.21	F= 0.84 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 P=0.49	F=0.02 P=0.86	F=0.42 P=0.52	F=0.09 P=0.76	F=0.23 P=0.63

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 ± S.E.) according to location on the peninsula, wind direction, and wind speed, from surveys conducted on Cape May Peninsula in 1984 and 1986.

	N	Northern Harrier	N	Osprey	N	Sharp-shinned	N	Turkey Vulture	N	Total Buteos
LOCATION										
Atlantic Coast	19	63 ± 19.6	13	87 ± 24.0	42	66 ± 11.9	22	53 ± 9.9	33	109 ± 14.0
Delaware Bay	43	30 ± 6.0	26	64 ± 10.0	80	83 ± 9.2	56	74 ± 8.1	18	56 ± 14.1
Point	17	71 ± 20.2	48	62 ± 7.1	501	64 ± 3.3	21	120 ± 23.5	24	123 ± 15.9
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	13	38 ± 17.2	27	78 ± 11.4	218	74 ± 5.8	15	114 ± 21.2	18	75 ± 17.4
NW	20	47 ± 12.2	20	49 ± 10.0	207	46 ± 4.4	48	58 ± 7.1	37	121 ± 13.0
SE	23	39 ± 10.4	22	61 ± 11.5	70	45 ± 6.4	13	112 ± 30.9	14	83 ± 24.8
SW	23	60 ± 18.3	18	75 ± 15.4	128	99 ± 6.6	23	82 ± 15.4	17	94 ± 21.4
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	37	54 ± 10.8	49	61 ± 7.4	295	55 ± 4.4	52	74 ± 8.0	43	135 ± 12.6
> 6.7 m/sec	42	41 ± 10.1	38	74 ± 10.1	328	77 ± 4.1	47	85 ± 12.8	43	64 ± 10.3
F, P		F=0.76, P=0.39		F=0.04, P=0.85		F=100.45,		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	N	Marsh	N	Field	N	Forest	F	P	DF
Northern Harrier	(59)	40 ± 7.9	(13)	46 ± 10.9	(7)	109 ± 41.0	1.75	0.18	2,76
Osprey	(54)	70 ± 7.5	(23)	56 ± 9.8	(10)	74 ± 26.4	0.87	0.42	2,84
Sharp-shinned Hawk	(189)	86 ± 6.0	(232)	52 ± 4.4	(202)	65 ± 5.3	30.3	0.0001	2,620
Turkey Vulture	(37)	86 ± 10.3	(50)	77 ± 9.3	(12)	66 ± 36.0	3.08	0.05	2,96
Total Buteos	(36)	68 ± 17.8	(36)	153 ± 12.2	(14)	43 ± 8.6	8.38	0.001	2,83

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.

		Distance from Point			
SPECIES		Point - 10 km	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	O	5.093	1.787	17.2	0.001
SPECIES	E	1.383	0.553		

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 Habitat	Source	Habitat Preference in Cape May (Significance level)	
			Highest Numbers	Lowest Altitude
Broad-winged Hawk	Forest	Matray 1974	Forest (0.05)	Forest/Marsh (0.01)
Cooper's Hawk	Forest	Reynolds et al. 1984	Forest (0.01)	
Northern Harrier	Field/Marsh	Hamerstrom & Kopeny 1981	Forest/Marsh (0.01)	
Osprey	Marsh/Forest	Poole 1989		
Red-tailed Hawk	Field/Forest	Janes 1984 Bildstein 1987	Forest (0.01)	Forest/Marsh (0.05)
Sharp-shinned Hawk	Forest	Reynolds et al. 1984	Forest (0.01)	Field/Forest (0.001)

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

Hectares Available by Distance from Cape May Point

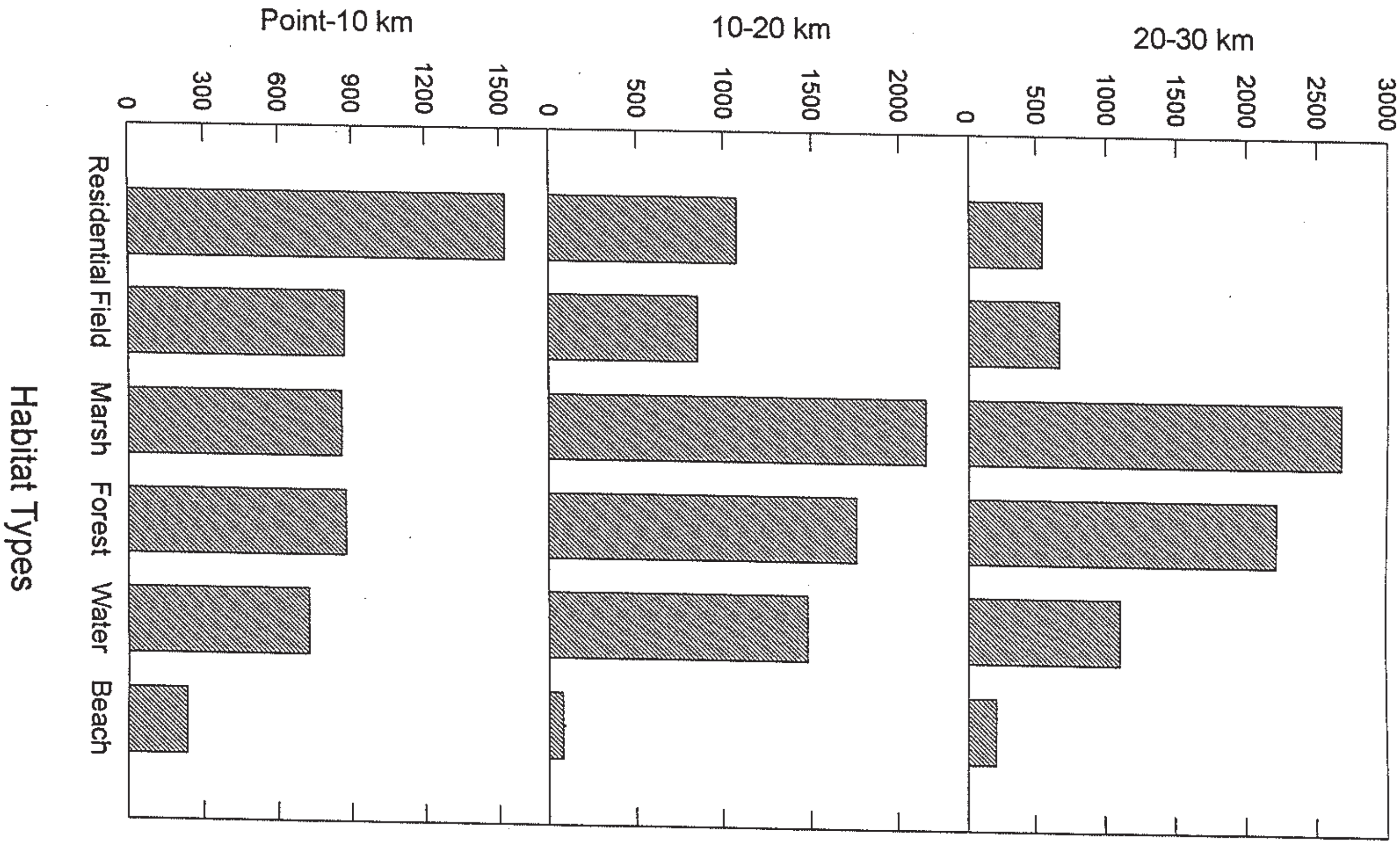
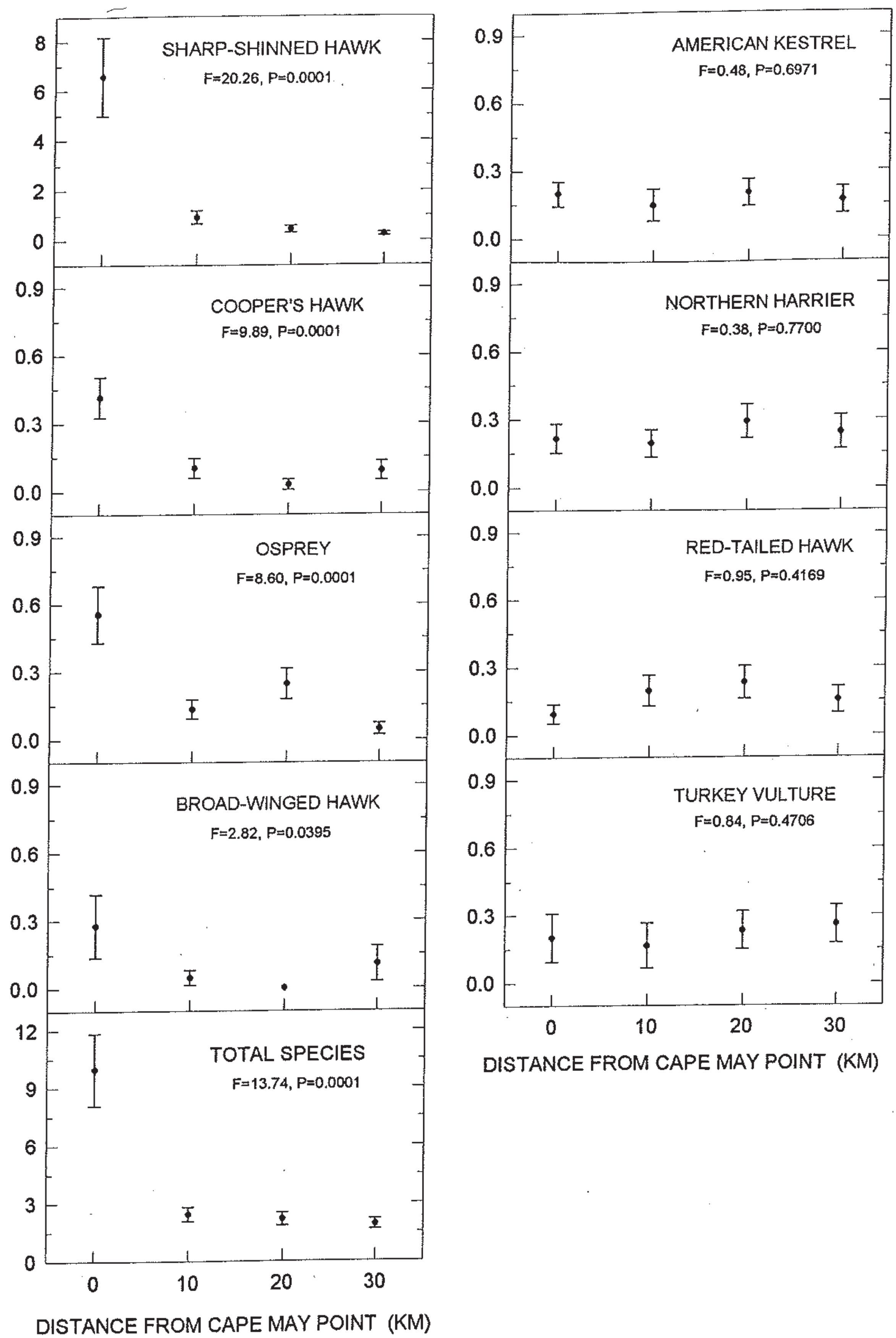


Figure 2. The number of birds/survey ± SE at each 10 km interval on Cape May Peninsula in 1984 and 1986. F and P values from a one-way ANOVA are given in each graph.


SHARP-SHINNED HAWK
F=20.26, P=0.0001
COOPER'S HAWK
F=9.89, P=0.0001
OSPREY
F=8.60, P=0.0001
BROAD-WINGED HAWK
F=2.82, P=0.0395
TOTAL SPECIES
F=13.74, P=0.0001
AMERICAN KESTREL
F=0.48, P=0.6971
NORTHERN HARRIER
F=0.38, P=0.7700
RED-TAILED HAWK
F=0.95, P=0.4169
TURKEY VULTURE
F=0.84, P=0.4706
DISTANCE FROM CAPE MAY POINT (KM)
DISTANCE FROM CAPE MAY POINT (KM)

CHAPTER TWO: HOME RANGE AND MIGRATORY PATHWAYS OF SHARP-SHINNED HAWKS AT A MIGRATORY STOPOVER

INTRODUCTION

Habitat selection and behavior of birds at migratory stopovers is an important aspect of migration (Myers et al. 1987, Moore et al. 1993). Birds stop over to rebuild lost fat reserves so they can continue their migratory journey or successfully compete with conspecifics on arrival at breeding or wintering areas (Greenberg 1982, Myers and McCaffrey 1984). Many different factors influence stopover behavior in both shorebirds and passerines, including prey availability, competition, weather, predation, body condition and amount of fat reserves (Rappole and Warner 1976, Cherry 1982, Biebach et al. 1986, Dunn et al. 1988, Moore et al. 1990, Winker et al. 1992). Most stopover studies examine long distance migrants and much of this work has involved developing a model that predicts the length of stay and the overall importance of stopovers in species survival (Biebach et al. 1986, Moore and Kerlinger 1987, Dunn et al. 1988, Alerstram and Lindstrom 1990, Lyons and Haig 1995). Birds must minimize the time they spend in a stopover to take advantage of early arrival at wintering or breeding grounds (Alerstram and Lindstrom 1990). Thus a bird at a stopover must balance the need to minimize time while building its condition to an optimal point, subject to all the factors that can influence the rate of weight gain (Alerstram and Lindstrom 1990). These factors include competition, prey availability, habitat availability and quality, condition on arrival and condition while at the stopover (Biebach et al. 1986, Moore and Kerlinger 1987, Safriel and Lavee 1988, Moore and Yong 1991, Skagen and Knopf 1994, Lyons and Haig 1995).

Most stopover studies are based on observations of many individuals over short time periods with band-recapture or mark-resighting studies. These methods of assessing bird requirements bias the observer's understanding because they are limited to the most obvious behaviors (Altman 1974), and provide little understanding of the variation in behavior of individuals, which some researchers believe integral to understanding those factors influencing the use of stopover habitats (Biebach et al. 1986, Safriel and Lavee 1988, Lyons and Haig 1995).

Recently, attention has focused on studying fewer individuals for a longer period of time and the results often contrast sharply with previous studies. Safriel and Lavee (1988) found that the relationship of weight or condition to the length of stay was less significant than previously suspected for birds in an oasis stopover in the Sinai, because of the many variables that influenced stay, including competition and food availability. Similarly, Lyons and Haig (1995) studying shorebirds through an intensive marking and resighting study in a spring stopover in South Carolina, rejected the hypothesis that the length of stay is directly linked to body condition. They reasoned that the decision to stop or stay is complicated by a number of factors including date of arrival, condition, prey availability, and competition. Skagen and Knopf (1994) found through a telemetry study of shorebirds staging at a mid-continental stopover area that birds moved out of the study area in a variety of conditions that made it difficult to determine any predictable influence.

The concentration on the role of fat reserves and weight in migratory shorebirds and passerines contrasts sharply with studies detailing the factors influencing behavior in migratory hawks. Most literature on the migration of raptors centers on the role of morphology and the influence of abiotic factors like wind and barriers to migration (see Kerlinger 1989 for a review). In his book on flight strategies, Kerlinger (1989) pointed out the lack of research on the role of biotic factors in migration strategy; factors such as habitat use, competition, and the condition of birds in migratory stopovers or concentration areas. Even after an exhaustive literature review he could not determine if raptors are influenced by the same factors as shorebirds and passerines (Kerlinger 1989:114).

Raptors differ in several respects from shorebirds and passerines. Raptors migrate during the day, often relying on soaring or gliding flight, thus decreasing the need to develop fat reserves (Kerlinger 1992:115). But fat reserves have been found in some species during migration and may be significant factor influencing migration (Blem 1980, Geller and Temple 1983, Clark 1985a). Smith et al. (1986) suggested raptors use fat reserves to fly non-stop to wintering or breeding areas. New evidence from radio telemetry studies suggests the opposite: that migrating raptors make use of en-route resources

(Grubb et al. 1994, Niles et al. 1996, Bildstein pers. comm.). Grubb et al. (1994) found bald eagles spending nearly half of their time hunting and resting in migratory stopovers. Niles et al. (1996) found the most plausible explanation for four species of raptors concentrating at an Atlantic coast stopover was the use of habitat for foraging and resting before making a 18 km water crossing.

In this study I followed twenty-four Sharp-shinned Hawks at a coastal stopover area in Cape May County, New Jersey. The Cape May Peninsula has long been known as a concentration area of hawks, passerines, woodcock, and several species of Odonates and Lepidoptera in fall migration (Allen and Peterson 1935, Krohn et al. 1977, Wiedner et al. 1992). I captured birds at several sites located 20-40 km north of the peninsula point to examine their behavior before and after they reached the 18.3 km wide Delaware Bay crossing. Because these hawks were migrating, I followed them continuously from dawn to dusk. In this paper I discuss the movement and home range characteristics of these birds and the tactics they used to overcome abiotic and biotic impediments to migration.

Few data exist on the en-route migratory behavior of migratory raptors; thus it is necessary to start with a presentation of the data on home range and core areas within home ranges of radio-tracked birds. I demonstrate the repeated use of specific ranges within the stopover area, and compare birds that spent varying amounts of time in the stopover area. I present the different patterns of flight path and stopover behaviors and relate them to physical condition of the birds and the weather conditions the birds encountered. Finally, I present a model describing the cost-benefit relationship of factors influencing stopover behavior.

METHODS

The study area included the entire Cape May peninsula from its southern terminus at the junction of Delaware Bay and the Atlantic Ocean (38° 57' lat., 74° 53' long.) to its northern edge approximately 60 km north along the Atlantic Ocean (39° 22' lat., 74° 24' long.) and west approximately 40 km along the Delaware Bay coast (39° 14' lat., 75° 10' long.). Forests and marsh and field habitats comprised 66% of the peninsula's habitat (25 %, 29%,12%, respectively). The remaining area included residential development 16%, open water (15%) and beach (3%). The most northern part of the study area included the southernmost extension of pitch pine (Pinus rigida) dominated forests of the New Jersey Pine Barrens. The upland areas were composed mostly of white oak (Quercus alba)-pitch pine forests interspersed with succeeding fields of red cedar (Juniperus virginiana) and other early successional species. A considerable portion of the area was wetland, both tidal emergent wetlands (30%) and freshwater wetlands (30%). Tidal areas were typical salt marsh habitats dominated by Spartina alterniflora and S. patens. The freshwater areas were mostly forested with red maple (Acer rubrum) and black gum (Nyssa sylvatica), interspersed with areas of Atlantic white cedar (Chamaecyparis thyoides).

I captured Sharp-shinned Hawks in three locations. In 1988 I obtained two birds trapped at banding stations at the point of the peninsula, and released the transmittered birds approximately 50 km north of the point capture site as a pilot study. In 1989 I captured 11 hawks at the northern end of the peninsula, 27 mi (43 km) from Cape May Point, in a field adjacent to Atlantic coast marsh. In 1990 I captured five hawks on the western side of the peninsula, 15 km from the point, in a field adjacent to Delaware Bay marsh.

Birds were trapped from mid-September to early November using mist nets and lure birds as described in Clark (1985b). I trapped two birds each day. Birds were outfitted with tail-mounted transmitters weighing less than 2 g (2 cm x 1 cm x .8 cm), with a 24 cm whip antenna, attached to the central two tail feathers with a small plastic electrical tie and glue (model LS-3. Merlin , L.L. Electronics, Mahomet, Illinois)(Kenward 1978). The transmitters were functional for up to 12 days with an average life of four days. The range of the transmitter varied considerably with the activity of the birds and the height of the tracker. I received a good signal from a perched bird for just over 1 km, and from a flying bird for up to 5 km. Flying birds could be lost when they perched, so trackers usually stayed within 1 km of moving birds.

To minimize the impact of transmitter weight I used only female Sharp-shinned Hawks. Females ranged in weight from 150 g to 210 g and transmitters ranged from 1.9% and 2.6% of body weight, far below the 5% generally considered the critical threshold for avoiding impacts from weight (Cochran

1980, Gessamen and Nagy 1988). However, transmitters were mounted on the central two retrices (Kenward 1978), thus avoiding the impact associated with backpack harnesses (Gessamen and Nagy 1988, Hiraldo et al. 1994). I used only immature birds because they account for over 95% of the birds that migrate through the peninsula, and adults migrate through the peninsula for much shorter periods of time (Clark 1985b). After weighing each bird I measured tarsus length, wing chord, and culmen length. Birds in 1989 and 1990 were processed within 30 minutes of capture and released at the point of capture. In 1988 birds were processed and transported north before release.

I tracked birds continuously from the time they were released until they left the area of the peninsula (33%) or the transmitter stopped (66%). Teams of two people began tracking birds at dawn and stayed with them until dusk or whenever the birds roosted. I fixed a bird's location by taking multiple fixes (>2) within 100 m-200m depending on the habitat. Locations were recorded on aerial photographs printed with the NJ state plane coordinate system grid of 1000 ft (304 m). Using mylar overlays with 100 ft (30 m) grids, the tracker located birds to within 100 ft (30 m) or within a habitat patch if smaller than 30 m. Flying birds were tracked from moving vehicles so locations were not as accurate. Trackers recorded the location of each bird on each move. If a bird moved continuously, then locations were taken a minimum of once every five minutes.

At all times trackers assigned one of three behaviors to birds with transmitters: flying, perching, or fly-stopping (flying from one perch to another).

These behaviors were determined through variations in signal direction and strength (Holthuijzen et al. 1982, Kenward 1980). Fly-stopping behavior, where birds will repeatedly alternate flying with short perches, has been described as the primary method of hunting for accipiter species (Marquiss and Newton 1981, Rosenfeld and Bielefeldt 1993).

I analyzed locations using multinuclear polygons obtained by clustering in RANGES IV home range analysis software (Kenward 1990). This method provided the best estimate of multiple core areas of home range without estimated or smoothed boundaries that can include areas not actually visited by the bird. Smoothed boundaries are appropriate to tracking data that represent a sample of the animal's activity area, but since I tracked continuously estimation was unnecessary. Tracked birds, however, did use areas for several days at a time, and clustering points helped define those areas and provided useful statistics enabling comparison between birds and years. Using RANGES IV, I estimated the home range area, cluster area, number of clusters and three other descriptive statistics. The "partial area" is the total area of all clusters divided by a polygon drawn around all clusters. This is a measure of patchiness from 0-1, with low values indicating greater patchiness. "S-fixes index" estimates diversity in fix distribution, and "S-area index" estimates diversity in cluster area. A high S-fix index indicates that the number of fixes varies widely within clusters, and a high S-area index indicates that clusters vary in size.

For analysis I grouped birds into those that left the area and those that stayed. Birds that left were defined as those that either moved south off the peninsula, moved north to cross the bay, or moved further north where the bay narrows to a river. All of these birds left within one full day of release. The decision to characterize a bird as staying was confounded by transmitters that stopped shortly after release. If a transmitter stopped within one day, I could not be sure the bird left the area or stayed after the transmitter stopped, so they were omitted in comparisons of birds that stayed or left. Thus only birds whose transmitters operated for more than two full days (two mornings after the day of capture) were included as birds that stayed in the study area.

All tests were done with Kruskal-Wallis one way analysis of variance, with year and outcome (stayed or left the area) as class variables (Zar 1988, SAS Inst. 1989). Results of hypothesis tests were considered statistically significant for P values ≤ 0.05.

All hawk locations were entered on the ARC/INFO Geographic Information System (GIS), and three dimensional plots were generated with the amount of time a bird spent in a location as the third (Z) dimension. A smaller two dimensional map accompanies each larger map giving all locations and the general direction of movement.

RESULTS

General Characteristics

Preliminary Telemetry Trials. I followed 26 Sharp-shinned Hawks over a three year period from 1988 through 1990 (include 8 birds that were dropped from the analysis). In preparation for the main project I took two birds from the Cape May Raptor Project banding station to a release point approximately 60 km north along the Atlantic Ocean coast. Both birds left the release site the day after release, one leaving the peninsula that day, the second stopping at Cape May for four days and then crossing the bay at mid-day of the sixth day after release. Bird #1 left the release site by 10:00 hr. and moved quickly down the Atlantic coast. I followed the bird in trucks but lost her at 12:00 heading south. I later found the signal of the bird out over Delaware Bay at about 13:00 hr.

After bird #2 left the release site at 13:30 hr. of the second day, it flew directly to the point by 16:02. It spent the next four days in an area 3 km from Cape May Point. The bird was observed at times during the day but was mostly out of sight. I developed a method of locating the bird using bearings taken in at least two locations. Most often I precisely located the bird (within 10 m) by repeating bearings from at least four directions. The site was composed of scrub oak (_Quercus ilicifolia_), choke cherry (_Prunus virginiana_) and bayberry (_Myrica pensylvanica_), <10m in height with occasional open patches of _Andropogon sp._ and small bayberry. This bird rested most of the day and occasionally flew and stopped, apparently hunting the abundant small passerines in the area. At 09:00 on the sixth day the bird left the site and moved slowly to a point 1 km north of Cape May Point, and crossed the bay by 12:00 hr.

These two birds were not included in the analysis of movement but were used in developing this approach to following migrating birds. I found high-drain transmitters improved signal range up to 10 km when tracking above the treeline, and still preserved the 3% or less transmitter weight proportion. Unfortunately high drain transmitters also reduced transmitter life to about five days, but I considered this trade-off suitable for birds on migration.

Main Study. In 1989 I followed 14 birds for 940 daylight hours and in 1990, 10 birds for 339 daylight hours. Of the 24 birds, 8 birds left the study area by either crossing the Delaware Bay or by moving north up the Delaware Bay coast and crossing at a narrower point. All of these birds left the area within two days of release (Table 1) and all started moving from the release site the morning after release.

The remaining 16 hawks stayed in the study area until the transmitters ran down. Unfortunately, 7 transmitters either failed shortly after release or the birds left and I could not definitely determine their departure. With these 7 birds, 3 in 1989 and 4 in 1990, signals ceased within 24 hours of release; for most I was not able to locate the signal the morning after release.

Of the remaining 9 birds, I tracked 8 into the third day after release; the remaining bird's transmitter died in the second day after release. These 8 birds were grouped as birds that remained in the area for two reasons. First, they stayed into the second day while the birds that definitely left did so in the second day after release. Second, I had definitely determined transmitter failure as the cause of signal loss. Of these birds, 2 stayed two days (three days after release), 2 for three days, 2 for four days, 1 for five days and 1 for nine days. Hereafter I consider only the hawks followed in 1989 and 1990.

Home Range and Movement Characteristics

The average weight of all birds was 174.5 g (S.E.=4.70, Table 1). Weights varied from 154 g to 219 g, with a relatively even distribution: five birds weighed more than 180 g, five birds less than 170 g. In general, I tracked birds an average of 2.9 days, ranging from less than one day to over 9 days. Of the time birds were tracked, 15% was spent moving, accounting for nearly 35% of the fixes (mapped locations). The average distance of movements that were not fly/stop (hunting) was 4,267.3 feet (1293 m). The mean home range was 2380.5 ha (S.E.=85.8). From the cluster analysis, core areas or areas accounting for 95% of all fixes, were 296.78 ha. The ratio of core area to home range was 19%, the S-fix index was 2.76, and the S-areas index was 1.27 (Table 1).

Differences between capture sites. Capture/release sites changed between 1989 and 1990, making the comparison of hawk locations problematic for the two years. Nevertheless, no differences were found between the two years and those capture sites with respect to most variables: 1) The proportion of birds staying and leaving was not significantly different between the two sites (Chi square=1.067, df=1, P=0.30), 2) The weights of birds caught on the Atlantic and Delaware Bay coasts (167.7 and 183.0 g, respectively) also were not significantly different (Kruskal-Wallis Z=.08; Table 1). Of all movement variables, only the proportion of time spent moving was significantly different between years, with birds captured in 1989 (on the Atlantic coast) spending more time moving than those caught in 1989 (on the Delaware Bay coast) (Kruskal-Wallis $\underline{Z}$=0.01). All home range variables were the same between birds caught in different study areas and years (Table 1).

Differences between hawks that stayed or left the area. Birds that stayed were significantly lighter than birds that left, 168.0 g versus 185.7 g, respectively (Kruskal-Wallis $\underline{Z}$=0.05; Table 2). The total time birds were followed was significantly different between these two groups (Kruskal-Wallis $\underline{Z}$=0.001). Birds that left the study area did so within one day of release, while the birds that stayed were tracked an average of 4 days until the transmitter ran down. Other than length of stay, there were no differences in the movement or home range characteristics between birds that left or stayed (Table 2).

Approaches to the Water Crossing

Birds that left. Birds left the study area in two ways: by crossing the Delaware Bay through Cape May, and BY crossing the bay 40 to 100 km to the northwest where the bay narrows to 15 km. (Table 3). Each pattern will be discussed below.

1. Cape May and Across the Bay.

Six birds left the peninsula through Cape May and across Delaware Bay, four leaving within 24 hours of capture. This included one of the 1988 birds that was not included in the movement and home range analysis (Figures 1a-e and

Table 3). Four birds flew south along the Atlantic Coast of the peninsula and one south along the Delaware Bay coast. Three of the birds used the Atlantic side of the peninsula to reach the point, while one used the Delaware Bay side of the peninsula. Two birds used both sides before reaching the peninsula.

A related approach was to fly to Cape May, stay for a period of time and then cross the bay. This approach was followed by one of the two birds tracked in 1988 and one bird from 1989 (Fig. 2 a, b). The one in 1988 stayed in the Cape May area for just over four days; the bird in 1989 stayed for two days. Both birds encountered adverse weather on arriving at the point.

2. Northwest along Delaware Bayshore and Across the Bay.

The second pattern was to fly north from the release site and cross the bay at a more northern point. Three birds took this route, all from the Delaware Bay release site (Fig. 3 a, b, c). Two crossed after a two-day flight north on the bayshore, crossing approximately 40 km northwest of the release site at a point where the bay crossing is 14.4 km and narrows quickly to less than a few km. A third bird flew south almost to Cape May then turned north and crossed the bay at the top of the peninsula. Interestingly, this crossing was almost three times greater (around 49 km) than crossing from Cape May. On average, the birds that made a northern crossing stayed in the area less than two days. All three birds encountered either winds of moderate to high speeds or from westerly directions. When they moved they stopped repeatedly so that the ratio of time spent moving/time spent stopped was only slightly less than the average for the entire group. Two of these birds were the heaviest of all transmittered birds.

Birds that stayed. Birds that stayed exhibited two approaches: moving to and staying at Cape May or staying north of Cape May.

1. Cape May and Stay.

Three birds flew to Cape May and did not cross in the period in which I was tracking them. This approach may be the same as the previous approach, with the difference being the outcome (see below). Two of the 3 birds flew to Cape May and stayed until the transmitter ran down which took about four days (Figure 4a, b). One of these moved down the Atlantic Coast from the release site to Cape May, the other down the bay coast. The latter bird, after reaching Cape May, moved once a day for 3 days from a woodlot 10 km north of the point, to the point, then returned to the woodlot. A third bird stayed for 2 days at the point then moved to a location approximately 40 km north, where the transmitter expired (Fig 4c). Two birds encountered westerly winds of moderate or high speeds.

2. Move North and Stay.

A second pattern was to move north from the release site and stay. Two birds did this, one on each side of the peninsula (Figure 5a, b). The first stopped in an area about 45 km north of the point, and the second nearly 100 km from the point. One bird did not have any days without poor visibility, westerly winds or moderate to high speed winds during the time it was tracked. On average these birds spent a little more than 4 days in the area.

A variant of the preceding pattern was to not move from the release area. Three birds did this but 2 were tracked for just over 2 days before the transmitters failed. The third bird was followed for over 9 days, spending all of its time within a 5 km range (Figure 6). Within this range, however, it spent most of its time in a small core area of 369 ha.

The estimated length of stay for these hawks can be considered a minimum because of eventual loss of transmitter power. With birds that stayed, tracking ended when the transmitters failed; for birds that left, the time they were in the peninsula area before capture is not known.

Weather and the Decision to Leave

The 8 birds that left the peninsula did so under the same environmental conditions. All birds left in good visibility (19 km [12 mi] or better), winds less than 16 kph (10 mph) and in the absence of westerly or southwesterly winds (Table 4). Temperatures ranged from 1-20°C (33-68°F) and barometric pressure from 29.7 to 30.4. The strongest winds in which birds left were from the northeast; the weakest were from the south.

Weather and the Decision to Stay

Of the 8 birds that did not leave the study area, 4 stayed even though their stay included days of high visibility and winds less than 16 kph from the northwest, north, northeast, east or south (Table 5). The remaining 4 birds did not have good flight conditions, 3 because of poor visibility or high winds. Of the 3 birds that flew to Cape May and stayed, 2 did not experience days of high visibility, or low or following winds while I tracked them.

DISCUSSION

Stopover Ecology of Sharp-Shinned Hawks

Because of age related differences in foraging and other survival skills, the fate of immature birds during migration is uncertain for most migratory species (Gauthreaux 1982, Burger 1988) and understanding their stopover ecology is a significant aspect of their overall survival (Ketterson and Nolan 1982, Moore et al. 1993). Moore et al. (1993) suggested that the study of birds at a migratory stopover may provide a window to the difficulties encountered throughout migration, and that the most difficult problems are manifest at ecological barriers such as water crossings, deserts and mountains.

In this study I examined individual immature Sharp-shinned Hawks confronting a migratory barrier (18 km of open water) in a prey-rich stopover. I followed birds continuously from morning roost to evening roost and thus consider the characterization of the factors influencing these birds as comprehensive. Moreover, I was able to observe birds while they made the choice to wait or proceed across the migratory barrier.

In this study, about half of the birds I radio-tracked left the Cape May peninsula area, presumably continuing their southward migration. The other half stayed in the study area for three to nine days. The only differences between birds that left and stayed was their weight, heavier birds left the area sooner. The birds that departed did so within a narrow range of weather conditions that were relatively infrequent during the fall migratory period. The data suggests body condition is a factor influencing migration and stopover ecology, in ways similar to migratory shorebirds and passerines.

Body condition has not been shown previously to be a significant influence on the behavior of migrating raptors (Kerlinger 1989). Much of the literature on the stopover ecology of Sharp-shinned Hawks has been dominated by a discussion on the role of wind and barriers to migration. Kerlinger and Gauthreaux (1984) substantiated a hypothesis proposed by Murray (1964, 1969) that concentrations at the Cape May stopover were a result of birds either descending in altitude to facilitate the Delaware Bay water crossing, thus making them more visible, or birds were turning northward, resulting in double counting. Kerlinger and Gauthreaux (1984) argued against Mueller and Berger (1967) and others who assumed the large concentrations were a result of birds drifting to the coast.

This question of whether birds drift or descend in altitude while following a broad front is important to my assertion that the choices hawks make at stopover areas take into account both biotic and abiotic influences. Kerlinger and Gauthreaux (1984) based their argument on a comparison of radar and visual observations taken at the point of the Cape May peninsula and a location approximately 40 km north and approximately 15 km inland from the coast. In the northern site, they found raptors flying at higher altitudes than birds at the point and altering headings to correct for westerly winds that would cause drift to the east. They assumed however that the birds had not already drifted to the coast and had altered heading to stay inland.

Our study area included Kerlinger and Gauthreaux's (1984) northern site, as well as the point, and I found birds were already reacting to the Atlantic Coast and in some cases the Delaware Bay crossing. Based on my results, the birds at their northern study site, could have been (1) returning from the point and making new attempts at crossing; (2) stopping to replenish depleted resources; (3) flying inland after reaching the Atlantic Coast or (4) about to face the Delaware Bay for the first time. These alternatives were not accounted for by Kerlinger and Gauthreaux (1984), thus the birds could have drifted to the coast.

Likewise, the descent in altitude describe by Murray (1964) can be explained in other ways suggested by the data. In this study hawks left , as well as hawks that stayed, spent time at the point, some for up to four days. The point area is dense with passerine prey (Wiedner et al 1992, McCann et al. 1993), and I observed Sharp-shinned Hawks regularly hunting in the area. Moreover, other hawk species concentrate at the point, some preying on Sharp-shinned Hawks, thus making proximity to cover a priority for the sharp-shinneds. Low flying behaviors such as hunting, evading predators, or seeking shelter, over periods lasting several days, could easily explain the reduction in altitude observed by Kerlinger and Gauthreaux (1984). Moreover Niles et al. (1996) did not find a consistent change in altitude in eight species of raptors including Sharp-shinned Hawks, visually surveyed at points located 40 to 0 km from the Delaware Bay crossing.

Murray (1964) and Kerlinger and Gauthreaux (1984) did not address the higher proportion of immature (hatching year) raptors at Cape May as compared to most inland migration concentration areas. For example, observers at Hawk Mountain along the Appalachian Mountains report that as much as 50% of the sharp-shinned flight consists of adults (L. Goodrich pers. comm.). In contrast, over 90% of the sharp-shinned flight at Cape May are immatures (Clark 1985a). This disparity in immature/adult ratio occurs for a variety of species including other raptors species (Bildstein et al. 1984, Clark 1985b), passerines (Gustafson 1986) and woodcock (Krohn et al. 1977).

One possible explanation for this coastal concentration of immatures is that they do not correct for prevailing northwesterly winds and drift to the coast. In contrast adults do correct their headings and stay inland. An age-related difference in migration orientation can be supported in several ways. Drost (1938) moved over 200 European Sparrowhawks east of their European migratory pathway. From 36 recoveries he reported adults corrected for the move while immatures remained east of their normal pathway. Perdick (1958) repeated the experiment with adult and immature European starlings (Sternus vulgaris) and reported similar results.

Further evidence of an age-related difference comes from recoveries of birds banded at Cape May. More than 50% of the birds banded as immatures in Cape May are recaptured or recovered in inland banding stations as adults (W. Clark, unpubl. data). Moreover, of the few adults that are recaptured, all are recaptured at inland banding stations. In contrast, few birds banded at inland banding stations are recaptured at Cape May Banding station (K. Bildstein, pers. comm.).

The reasons Sharp-shinned Hawks correct for drift as adults can only be speculated. Many researchers however, point to the difficulty of water crossings and increased chance of energy depletion, predation, competition, and mortality (see Kerlinger 1989:244-268 and Moore et al. 1993 for a review). The mid-Atlantic coast includes two major water crossings, Delaware Bay and Chesapeake Bay, as well as a number of smaller bays and sounds.

The costs of coastal migration influence not only drifted immatures but also those birds coming from northeastern breeding areas (New England and Canada) and travel along the coast. The diverse origins of birds coming to the Delaware Bay water barrier result in a wide range of body condition. I suggest this range in condition of mostly immature birds is the primary influence on migratory behavior in the Cape May stopover, but it is complicated by biotic and abiotic influences unique to each individual at the time it arrives.

Home Range Characteristics

Kerlinger (1984) described the choices hawks face when confronting a barrier to migration, such as the Delaware Bay, as a complicated balance of crossing sometimes with great risk, or going around the barrier at great energetic cost. The hawks in this study took both approaches as well as a third, staying until the weather and their body condition were right. Four of the eight that crossed Delaware Bay stayed for periods up to four days, and eight others remained at least until the transmitter expired (4-9 days). Although four birds of this group may not have had the proper weather conditions for leaving the peninsula (good visibility and moderate wind speed from any direction except the west), the remaining four stayed despite good weather conditions. The birds that stayed hunted and rested as they would in wintering or breeding areas (Niles et al., in prep.).

Instrumented Sharp-shinned Hawks did not use the habitats of the peninsula randomly. They used specific areas within the general area they occupied, and repeatedly returned to the same areas to hunt and roost. Moreover, there was no significant difference between the ranges of birds that stayed or left, suggesting that all birds used habitat on the peninsula similarly, regardless of whether they waited for good weather or attempted to re-build or maintain body resources.

The home ranges that resulted from peninsula habitat use were similar to those reported in other studies of similar-size raptors during the breeding period.

The average total home range size was 2380.5 ha, with a core area of 95% from all observations (excluding long movements) of about 300 ha. Marquiss and Newton (1981) reported similar home ranges using a maximum polygon method for breeding European kestrels (Falco tinnunculus), similar in body size to Sharp-shinned Hawks. They found that territories ranged from 10 to 3500 ha due to variations in habitat quality and the restriction of movement caused by breeding behavior. Average territories in productive habitat were from 100 to 500 ha., wintering ranges were much larger (Marquiss and Newton 1981).

I anticipated that a migratory home range should be very large, as birds are unfamiliar with the area and are not restricted to a nest or the care of young. The abundant prey on the peninsula (because it is also a stopover for passerines) may be a key reason for the relatively small size of the ranges. A second reason for the small home range size may the amount of time birds were in the area; the longer a bird remains the larger the area it might use. For example, bird number 8905 stayed nine days, longer than any other bird, and it had the largest core area of 1125 ha.

Other researchers have reported home ranges or territories in migrating passerines and shorebirds (Rappole and Warner 1976, Myers et al. 1979), but usually in relation to competition and resource depletion (Greenberg 1982, Moore and Yong 1991, Schneider and Harrington 1981). Competition was not apparent in this study as I observed competitive interactions in only one home range, even though I followed birds continuously. Furthermore, if core areas were selected in response to competition for prey I would expect to see more core area use close to mainland-marsh edges where passerines occurred in higher densities (Wiedner et al. 1992, McCann et al. 1993). This was not the case; core areas were spread throughout the peninsula and in areas north and west of the peninsula.

A more likely reason for home ranges is the advantage of familiar hunting areas and safe resting and roosting sites. The birds in this study not used the same general area but frequently returned to the same patches of forests to hunt and to previously used sites to roost. Experience in unknown areas would be important to all birds in migration but especially for immature birds who are often inexperienced at hunting and avoiding predators (Newton 1979).

In contrast, however, the influence of competition may have been obscured because I had difficulty visually observing the birds much of the time I followed them, particularly when they were moving. In the few competitive encounters I did observe, birds moved and stopped in a pattern similar to that when hunting, but the moves were more frequent and covered a smaller area. Perhaps home ranges set close to the point were not obviously defended because of the hawk's risk of being captured by larger hawks during overt territorial behavior.

Water Crossing and Weather Conditions

Visibility and wind were significant factors influencing the decision to make the water crossing. All birds left when visibility was equal to or greater than 19 km (12 mi), allowing clear sight of the other side of Delaware Bay at a low altitude. Other researchers have pointed to visibility as a potential factor in the decision to make a water crossing, but without presenting visibility thresholds when crossing would commence (Kerlinger 1989:256-259). My data suggest birds were reluctant to cross unless visibility was nearly unrestricted (12 miles or more).

Crossing the bay only on moderate winds and avoiding west or southwest winds clearly indicated birds' reluctance to fly in any significant adverse wind. Flying on moderate winds from the northeast, northwest or north is consistent with the advantage of a following wind. Flying on moderate winds from the southeast or south, while not flying on westerly or southwesterly winds of any speed indicated a clear avoidance of the danger of being blown out over the open ocean. Avoiding wind speeds of over 16 kph (10 mph), even for following winds, may be a result of the Sharp-shinned Hawk's small size, thresholds for larger hawks may be higher. Similar results were reported by Kerlinger (1989:260).

The data suggest that crossing an 18 km water body requires significant judgment before a bird will act. The three conditions (high visibility, low wind speed, and wind direction from other than the west), occurred on average only once every four days, and often for only a short time each day, from mid-

September to early November in the two years of this study (N=92 days). Days with six hours or more of favorable conditions occurred only once every five days. On occasion periods of nine days or more would pass without the right conditions for crossing. Moreover, suitable conditions often changed to adverse within a three hour period. This required birds to constantly monitor the weather, be ready to cross when the time arrived, and respond to changing conditions at any time. This assessment of weather conditions was evident in bird number 8914. It flew to the point of the peninsula and remained in a wooded wetland for several days while a haze restricted visibility to less that two miles. While there, it not only went on foraging flights which were low and often inside the forest, but it also soared higher than 100 m over the forest several times each day. It would circle for a short period then return to the forest from which it flew. Eventually the bird left the area going north and crossed the bay the next day at a point where the crossing was less than 10 km. By the time it crossed, however, conditions had changed to high visibility and moderate winds from directions other than west.

A Model

Based on this study, the approach a raptor takes to the Delaware Bay crossing depends first on physical condition, then on weather conditions. The relatively specific weather conditions during which birds left the area suggest the importance of weather. But the lower weight of birds that stayed implies the importance of physical condition. That half the birds that stayed did so even though they experienced suitable weather conditions for crossing suggests the priority of physical condition.

Our data therefore indicates a hierarchy to a bird's decision-making as it confronts the Delaware Bay water crossing. The choice to stay or leave does not appear to be discrete event, but more a process that starts when a hawk arrives in the area and ends when that hawk is on its way to the next water crossing or ecological barrier. This subjective evaluation of factors influencing a decision to stay or leave has been found in several recent studies of shorebird and passerine stopover ecology. Skagen and Knopf (1994) and Lyons and Haig (1995), working on shorebirds, could not develop a clear relationship between length of stay and the amount of fat deposited while at the stopover. Bairlain (1985) and later Safriel and Lavee (1988), working on passerines at desert oases, and Moore and Yong (1992) working on passerines on the Gulf Coast, also rejected simple models based on fat deposition as the primary determinant of stopover behavior, in favor of models involving a decision-making process that involves constantly changing factors.

In Table 6 I present a conceptual model of the relative significance of abiotic and biotic factors influencing a bird crossing the Delaware Bay. I include competition although I observed only a few conspecific competitive interactions. Competition was difficult to observe or interpret from the telemetry data but I assume it to be more frequent than observed. Prey availability is included in the "future condition" factor and predation in the "risk factor." In general, I assume competition, prey availability and the risk of predation are greatest at the point and decline significantly as one travels north.

I can derive four basic patterns from the approaches described earlier. The first, migrating through Cape May, minimizes the time spent migrating more than any other pattern, and according to Alerstam and Lindstrom (1990) may be the most effective pattern for birds setting up winter territories. However, it is also the pattern with the greatest risk of injury or death from being blown out over the ocean or being attacked by other raptors or by gulls. If a bird continues to fly when it reaches the peninsula, it would have little time to judge all the weather conditions and would be less aware of the possibility for conditions to change. Also, the bird has lost energy by flying to the peninsula. Overall, this is the pattern with the greatest benefit from a time minimization perspective but also carries the greatest risk. Because fatigue is the greatest threat, this pattern is best taken by birds in top condition, as it can lead to unpredictable losses in energy and body condition.

The second approach, flying north and crossing, also satisfies the need to minimize time although to a lesser degree than the first. It also significantly decreases the risk of being blown out over the ocean or being preyed on by other raptors. It does, however, cost the most in energy and future condition as the trip north can be against the prevailing northwest winds and may require nearly 140 km of flying as opposed to less than 20 km. This alternative is most likely undertaken by birds in at least moderate or good condition, and is likely a result of the combination of good physical condition with unsuitable crossing weather.

The third alternative, waiting at the point to cross, can increase the time to reach the wintering area. But because the bird is at the point of the peninsula, this alternative also provides the bird with dense prey and so it can significantly improve future condition. The bird reduces the risk of crossing because the bird can wait for the right moment to cross. Nevertheless, there is the risk of predation by other raptors during the time it remains in the point. Birds would experience competition for both prey and cover, that could grow intense if weather conditions remain suitable for migration but not for crossing. The point has a much lower proportion of woodland, the preferred habitat of Sharp-shinned Hawks, than more northern parts of the peninsula (Niles et al., in prep.). This pattern best minimizes the risk of crossing because birds gain in body condition while at the point where weather conditions can be judged accurately .

The fourth pattern is to fly to the peninsula and stay. A bird could stay because it is exhausted, or it wintering in the area of the peninsula. The peninsula is dense with passerine prey particularly within 3 km of the coast (McCann et al. 1993) and would be a very suitable area to restore lost resources. This pattern will, however, significantly increase the time to a wintering area and would have some risk from other raptors migrating through the area.

Of the four patterns, the third, flying to the point and waiting, is likely to provide the most benefit. This approach requires more time than flying straight through, but minimizes the danger from adverse weather and reduces energy needs while generally improving physical condition. The large concentration of hawks at Cape May substantiates this pattern as the most effective way of dealing with the many factors influencing migration at this barrier to migration.

Our data indicates a stopover in Cape May not only balances losses while in the area but may regulate the overall condition of immature Sharp-shinned Hawks in migration in a large portion of the eastern flyway. As discussed earlier, only immatures drift to the coast, encounter water crossings and thus face much greater risks than those following inland routes (Table 7). The greatest risk is the Delaware Bay water crossing, but a similar crossing confronts them at the Chesapeake Bay approximately 150 km to the south. Accompanying these increased risks is an extremely dense concentration of prey that also drifts to each stopover. Moreover, passerine prey may arrive in the same depleted condition as many Sharp-shinned Hawks. Murray and Jehl (1964) found passerines in generally poor condition at a coastal site 100 km north of Cape May. The combination of the abundance and condition of passerines would provide foraging opportunities for bird-eating hawks likely unequaled anywhere along the Atlantic coastal flyway.

I have developed a model to characterizing the influence of the stopover on migrating Sharp-shinned hawks (Fig. 7). If birds arrive in good condition and the weather is good they will continue. If they arrive in good condition and the weather is bad they can wait and maintain condition. If they arrive in moderate or poor condition they could continue or wait and improve until either the weather is right or their condition is right. In each case the birds leave in good condition.

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Table 1. Weight, tracking time, movement and home range characteristics among migrating Sharp-shinned Hawks tracked using radio-telemetry in 1989 and 1990.

Year	1989		1990		
	N=11 Mean	SE	N=6 Mean	SE	P value
Weight (g)	168.0	3.70	185.7	9.80	0.08
Time (days)	3.18	0.85	1.67	0.34	0.18
Time Moving/Total Time	0.19	0.04	0.69	0.01	0.02
Movement Fixes/ Total Fixes	0.37	0.05	0.32	0.06	0.26
Mean Distance (m)	4004.50	1379.6	4672.7	1212.5	0.50
Area (ha)	2656.60	797.50	1920.2	1338.20	0.36
Cluster (ha)	258.60	82.50	360.4	192.90	0.90
Cluster (total area)	0.87	0.03	0.357	0.15	0.14
S-FIX	2.75	0.36	2.79	0.59	0.71
S-AREA	1.19	0.09	1.14	0.20	0.53

Table 2. Weight, days tracked, movement and home range comparisons of migrating Sharp-shinned Hawks that stayed within or left the Cape May peninsula during radio-tracking. Study years 1989 and 1990 are combined.

Hawk Outcome	Stayed on peninsula		Left the peninsula		
	N=8 Mean	SE	N=8 Mean	SE	P value
Weight (g)	165.1	4.55	184.0	6.95	0.05
Time tracked (days)	4 .0	0.89	1.13	0.29	0.01
Time Moving/Total Time	0.18	0.04	0.11	0.03	0.18
Movement Fix/Total Fix	0.37	0.03	0.33	0.07	0.85
Mean Distance (m)	3661.80	571.63	4891.30	1853.80	0.70
Area (ha)	2596.4	985.1	2099.9	1001.8	0.62
Cluster (ha)	314.2	130.1	274.3	113.7	0.96
Cluster/total area	0.10	0.03	0.31	0.14	0.46
S-Fix	2.87	0.37	2.60	0.53	0.44
S-Area	1.35	0.13	1.15	0.12	0.07

Table 3. Destination and outcome of radio-tracked Sharp-shinned Hawks as they approached the Delaware Bay water crossing at Cape May, New Jersey.

DESTINATION /OUTCOME	Bird No.	Duration of tracking (days)	Mean Duration (days and hours)
Cape May and Cross	8802	1.00	1 d 0 hr
	8910	1.10	
	8911	0.23	
	9006	0.22	
	8908	1.10	
North along Bay and Cross	9002	2.15	1 d 15 hr
	9005	1.20	
	9009	2.30	
Cape May, stay and Cross	8914	2.20	3 d 20 hr
	8801	5.20	
Cape May, Stay	9001	3.20	4 d 2 hr
	8903	5.20	
	8906	4.00	
North then Stay	8909	4.11	4 d 2 hr
	8901	4.20	
Stay	8905	9.20	9 d 2 hr

Table 4. Weather conditions at the time Sharp-shinned Hawks crossed Delaware Bay on migration south; hawks tracked using radio-telemetry in fall, 1989 and 1990.

Bird No.	Outcome	Last Date Tracked	Visibility in km (mi.)	Wind Direction	Wind Speed in kph (mph)	Barom. Pressure	Temp. °C (°F)
8908	Cape May and Cross	23 Oct.	19 (12)	SE	11 (7)	30.4	19 (66)
8910	Cape May and Cross	23 Oct.	19 (12)	SE	11 (7)	30.4	19 (66)
8911	Cape May and Cross	23 Oct.	19 (12)	NW	13 (8)	30.4	15 (59)
8914	Cape May, stay, and Cross	10 Nov.	19 (12)	S	5 (3)	29.7	1 (34)
9002	North and Cross	29 Oct.	19 (12)	NW	16 (10)	30.1	4 (39)
9005	North and Cross	25 Oct.	19 (12)	NE	16 (10)	29.7	15 (60)
9006	Cape May and Cross	25 Oct.	19 (12)	NE	16 (10)	29.7	16 (61)
9009	North and Cross	3 Oct.	19 (12)	S	13 (8)	30.2	20 (68)

Table 5. Weather conditions during the time Sharp-shinned Hawks stayed on Cape May peninsula prior to making the Delaware Bay water crossing or leaving the area of the peninsula. Hawks tracked using radio-telemetry during fall, 1989 and 1990.

Bird No.	Outcome	Good Migration Days Available?	Adverse conditions
8901	North and Stay	Yes	None
8903	Cape May and Stay	No	Low visibility or high winds
8904	Stay, with uncertain outcome	Yes	None
8905	Stay	Yes	None
8906	Cape May and Stay	No	Low visibility or westerly winds
8909	North and Stay	No	High winds or westerly winds
8913	Stay, with uncertain outcome	No	Low visibility, high winds or westerly winds
9001	Cape May and Stay	Yes	None

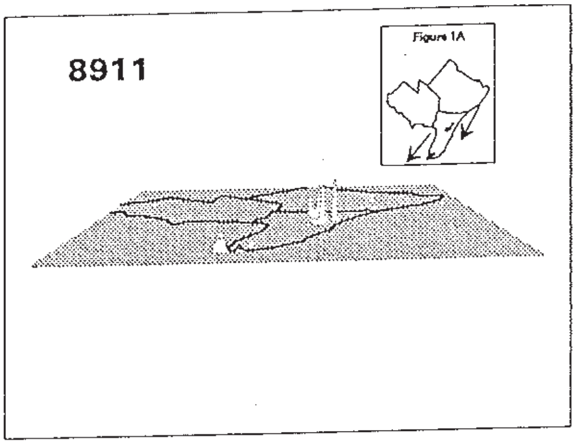
Table 6. A model describing the relationship of the factors that influence a migrating Sharp-shinned Hawk's decision to make the Delaware Bay water crossing or stay on Cape May peninsula.

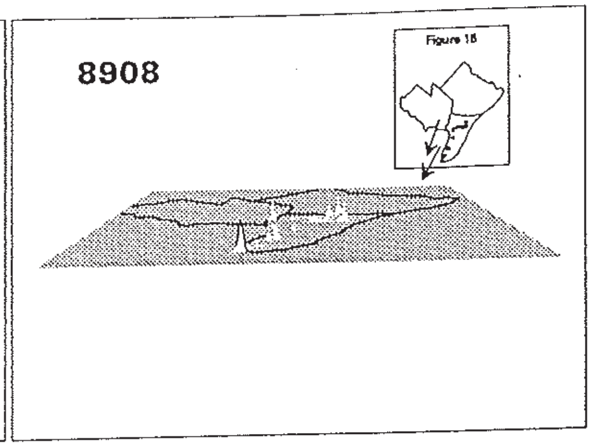
Body Condition	GOOD	GOOD-MED	MED-POOR	POOR
Approach	CAPE MAY AND CROSS	CAPE MAY, THEN FLY NORTH AND CROSS	CAPE MAY THEN STAY; EVENTUALLY CROSS	APPROACH THEN STAY; EVENTUALLY CROSS
Weather Conditions:				
Visibility	19 km (12 mi)	<19 OR	<19 OR	NS
Wind Speed	≤16 km (10 mi)	>10 OR	>10 OR	NS
Wind Direction	NOT W or SW	W or SW	W or SW	NS
Considerations:				
Time until arrival at wintering area	↓↓	↓	↑	↑↑
Energy consumption	↑	↑↑	↔	↓↓
Risk	↑	↑	↓	↓↓
Future Condition	↓ OR ↔	↓	↑↑	↑↑

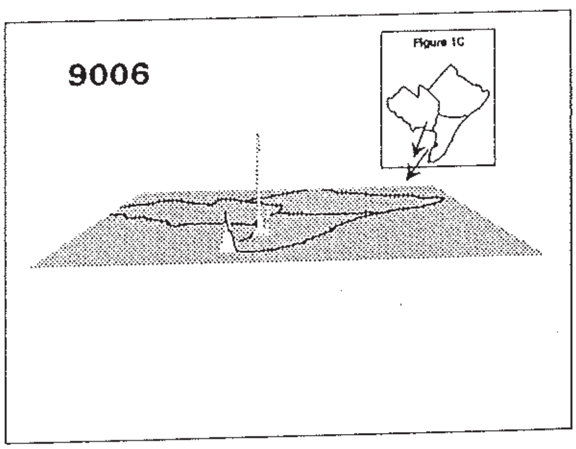
Table 7. A comparison of the factors influencing survival of migratory Sharp-shinned Hawks in inland and coastal pathways.

pathway	influence of weather	chance of predation	competition	prey availability	speed of migration
inland	low	moderate	moderate	moderate	fast
coastal	moderate	low	low	high	moderate
stopover	severe	severe	severe	very high	slow

Figure 1a-e. Three dimensional graph of the locations of sharp-shinned hawks that flew south to Cape May then crossed the Delaware Bay. The Z axis represents the total time spent at each location.


8911
Figure 1A


8908
Figure 1B


9006
Figure 1C

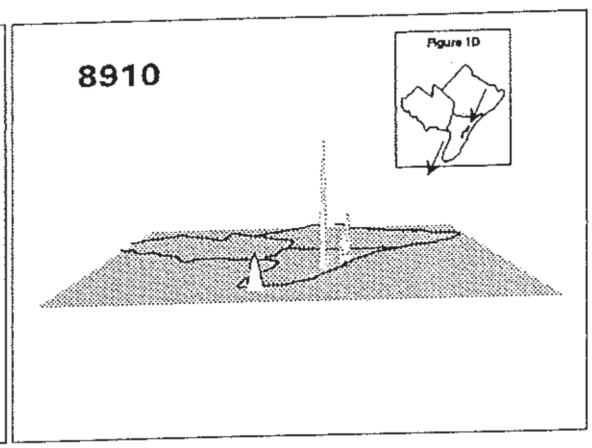
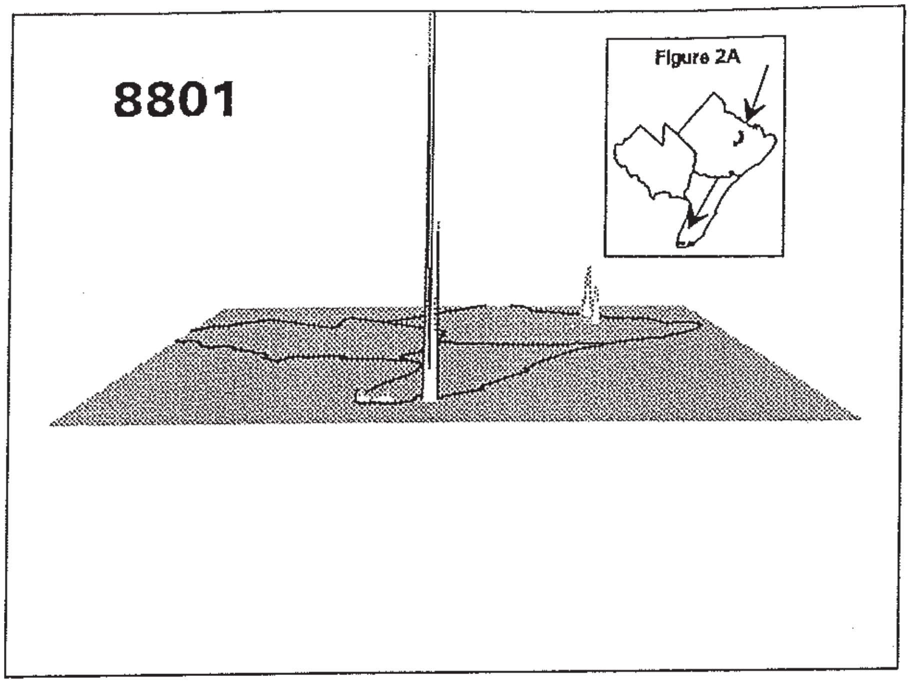

8910
Figure 1D

Figure 2 a,b. Three dimensional graph of the locations of sharp-shinned hawks that flew south to Cape May, stayed in the area and then crossed the Delaware Bay. The Z axis represents the total time spent at each location.


8801
Figure 2A

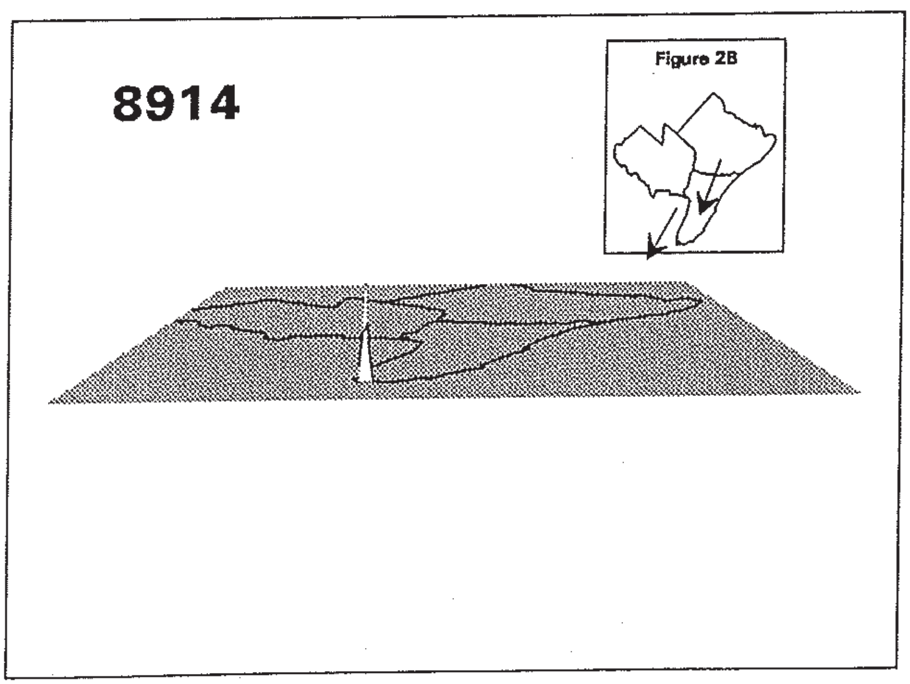
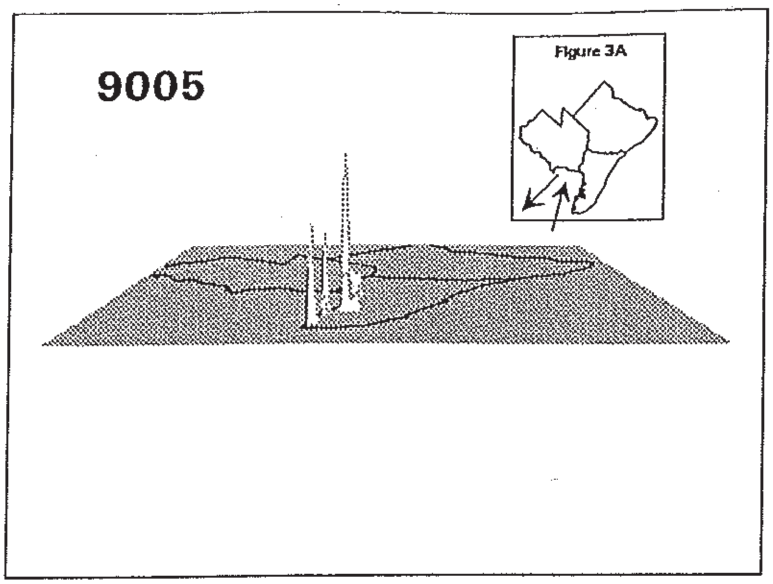
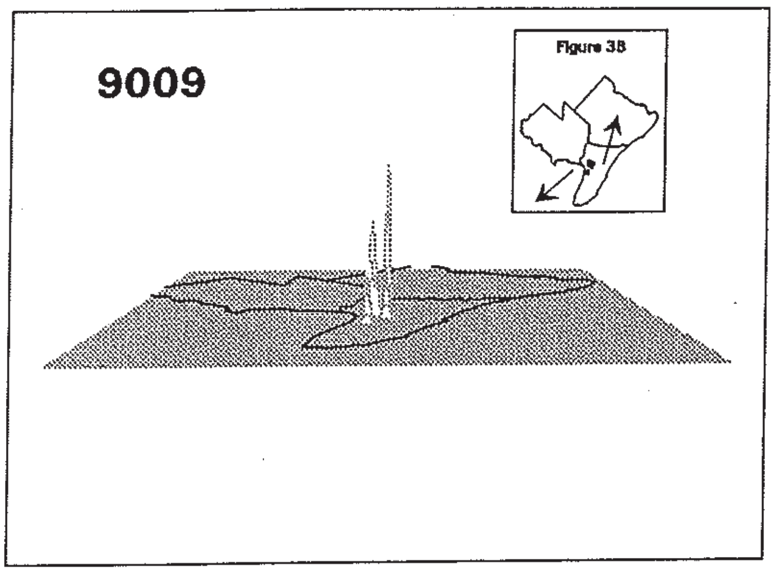

8914
Figure 2B

Figure 3 a-c. Three dimensional graph of the locations of sharp-shinned hawks that flew north on the Cape May peninsula and then crossed the Delaware Bay. The Z axis represents the total time spent at each location.


9005
Figure 3A


9009
Figure 3B

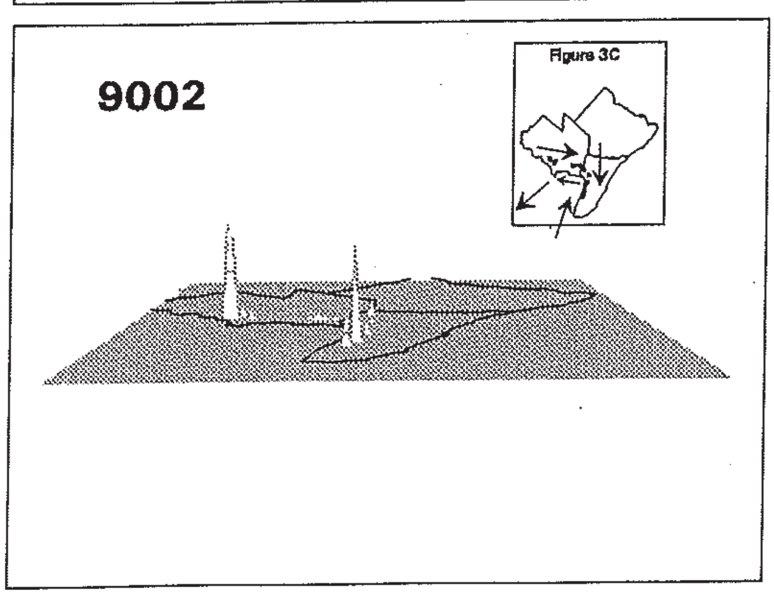
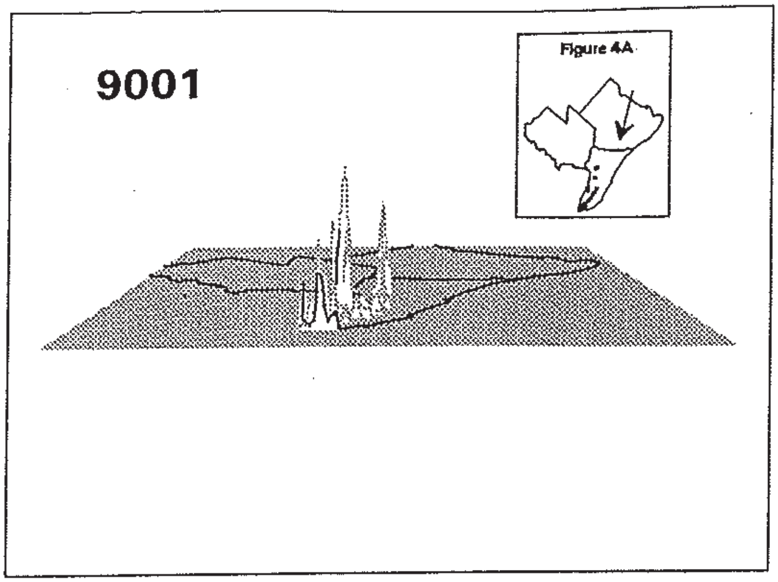
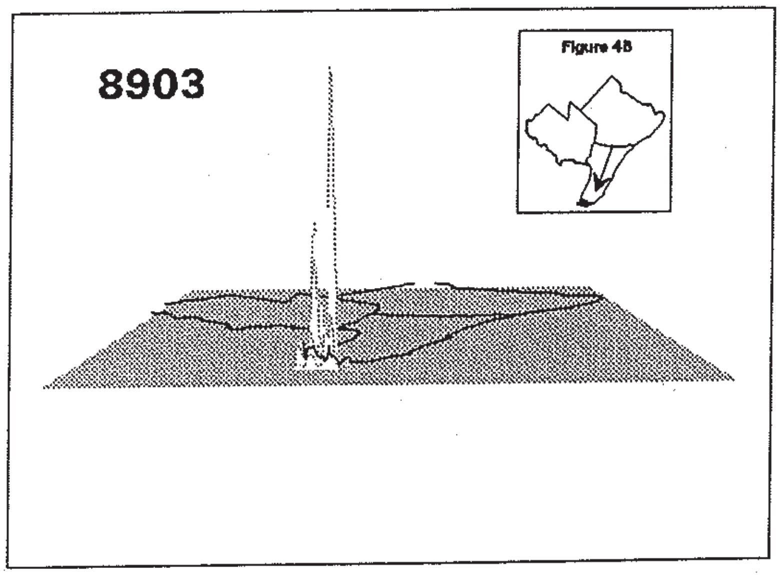

9002
Figure 3C

Figure 4a-c. Three dimensional graph of the locations of sharp-shinned hawks that flew south to Cape May and stayed until the transmitter ran down. 8906 flew to Cape May, stayed for two days, then moved north approximately 40 km remained until the transmitter ran down. The Z axis represents the total time spent at each location.


9001
Figure 4A


8903
Figure 4B

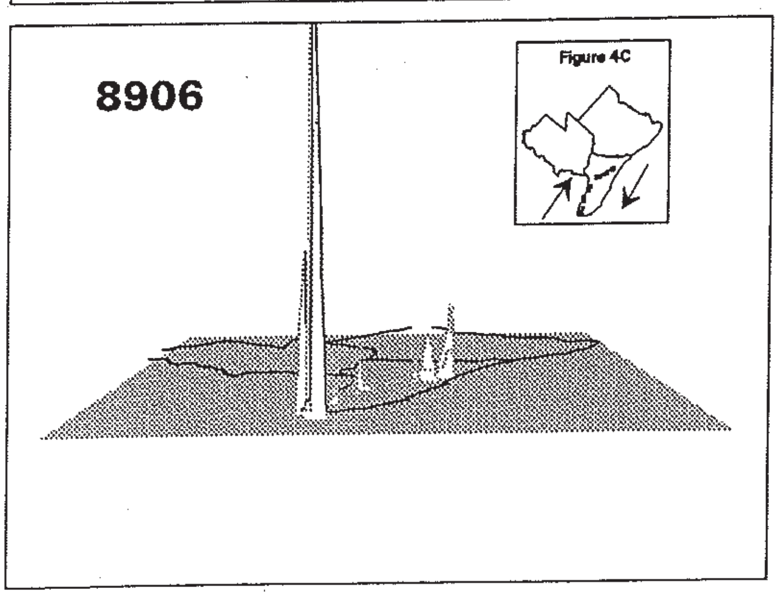

8906
Figure 4C

Figure 5 a,b. Three dimensional graph of the locations of sharp-shinned hawks that flew north and stayed in the northern peninsula until the transmitter ran down. The Z axis represents the total time spent at the location.

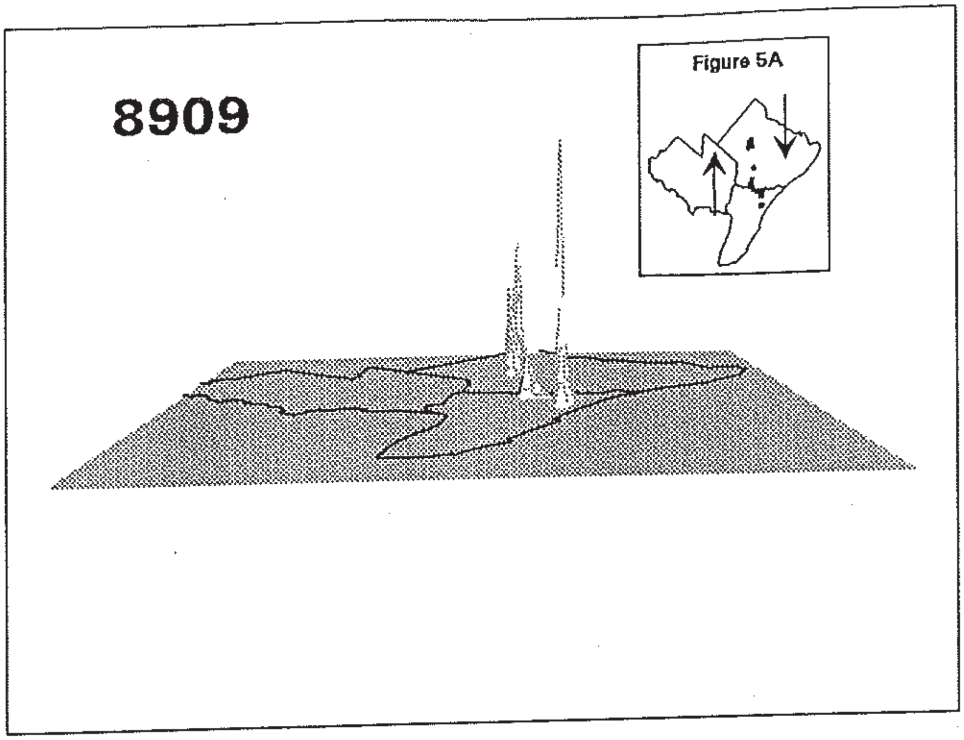


Figure 5A
8909

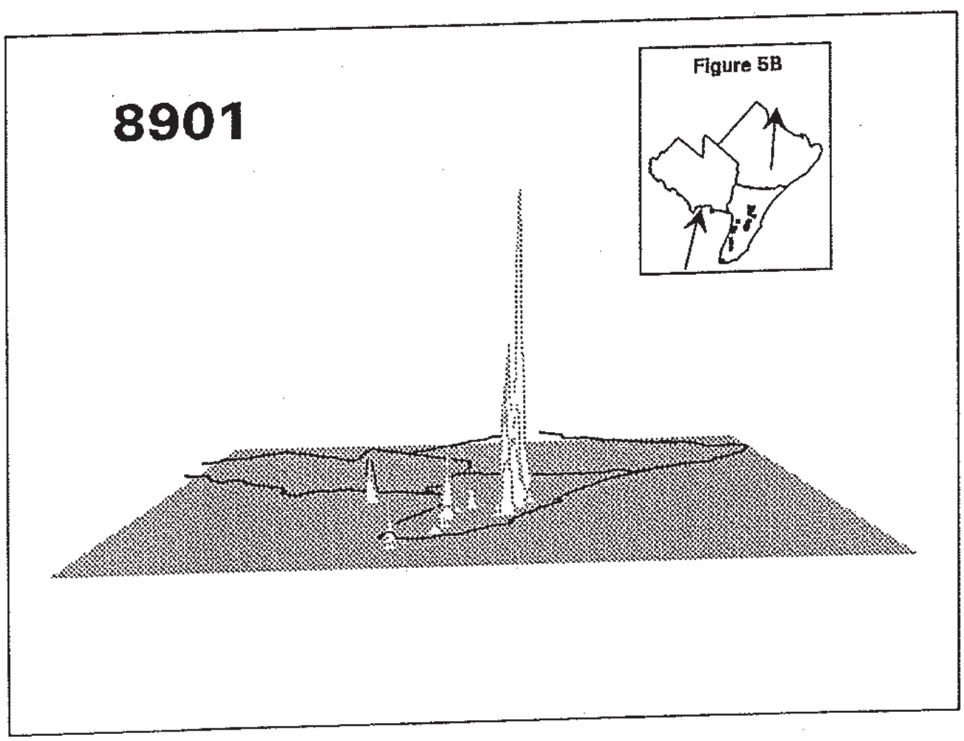


Figure 5B
8901

Figure 6. Three dimensional graph of the locations of a sharp-shinned hawk that stayed in the northern peninsula until the transmitter ran down. The Z axis represents the total time spent at the location.

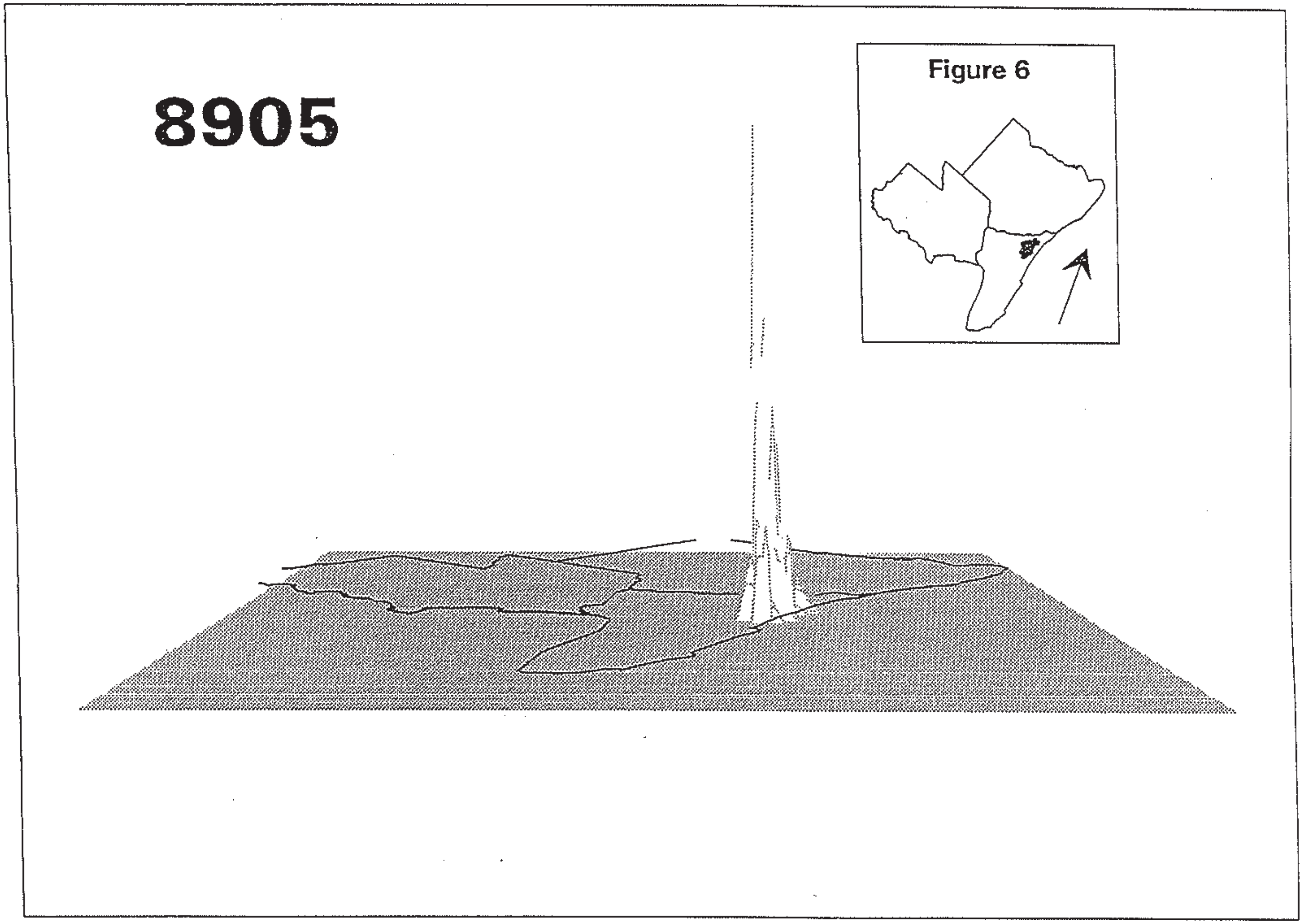
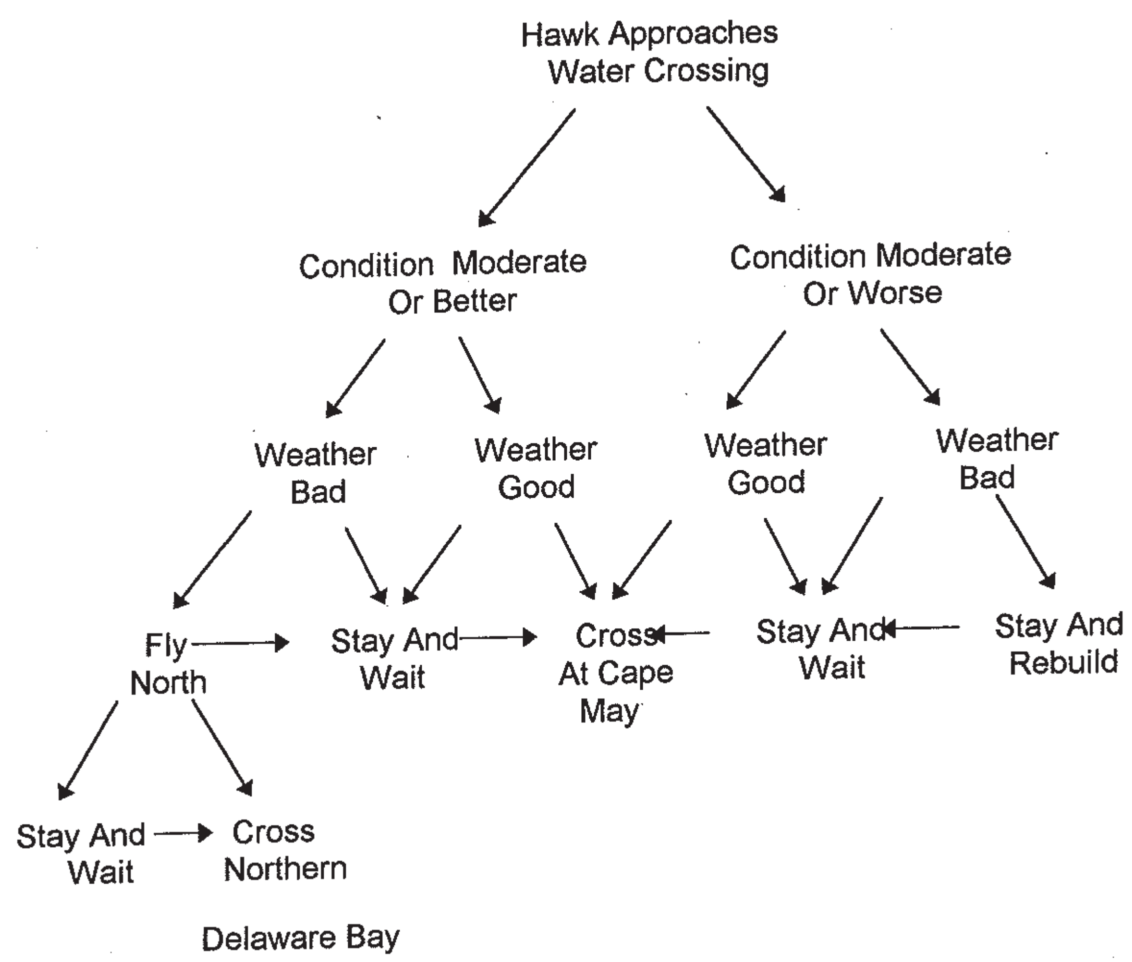

8905
Figure 6

Figure 7. A decision model for sharp-shinned hawks as they approach the Delaware Bay crossing at Cape May. Good weather includes those conditions suitable for crossing given in Table 7. All choices were defined in text.


Hawk Approaches Water Crossing
Condition Moderate Or Better
Condition Moderate Or Worse
Weather Bad
Weather Good
Weather Good
Weather Bad
Fly North
Stay And Wait
Cross At Cape May
Stay And Wait
Stay And Rebuild
Stay And Wait
Cross Northern
Delaware Bay

CHAPTER THREE: BEHAVIOR AND HABITAT SELECTION OF MIGRATORY SHARP-SHINNED HAWKS AT A COASTAL STOPOVER.

INTRODUCTION

Migrating birds follow a hierarchical method of selecting habitats (Hutto 1985, Moore et al. 1993). At broad geographic scales, birds follow pathways that may have been determined evolutionarily by both extrinsic factors (weather and geography) and intrinsic factors (food availability and predation). In contrast to the ultimate causation of pathways, habitat selection is proximally determined by an en-route assessment of a habitat's intrinsic value through either previous experience or exploratory behavior (Hutto 1985). One consequence of this hierarchical model is that migratory birds are restricted to habitats within the pathway regardless of their overall intrinsic value because seeking more valuable habitats outside the pathway increases risk and the time needed to reach the bird's wintering area (Gauthreaux 1982, Hutto 1985, Moore et al. 1993). Thus the habitats used by birds in migration may only be the best available within the pathway.

Because these pathways are selected through generations of migrating birds, this model of habitat selection in migration suggests that pathways are constant throughout a bird's life and, unlike habitat selection, is not the product of en-route assessment. I found (Chapter Two) that Sharp-shinned Hawks confronting a geographic barrier (18 km of water) to migration changed their pathway depending on weather and their condition. Birds generally followed four strategies to confront the barrier: 1) Birds in higher weight categories crossed using two different pathways depending on the weather. 2) Birds in lower weight categories did not cross and spent an average of 4 days in this prey-rich stopover, either near the point or further north. Thus the pathway was a result of a decision making process that varied in response to proximate extrinsic and intrinsic factors. Moreover, some birds that fly the hazardous coastal pathway as immature birds, follow more inland routes in subsequent years (W. Clark, unpublished data). I concluded in Chapter Two that perhaps only migration direction is programmed and all other aspects of migration are a result of decision making based on proximate factors while en route.

In this paper I describe the behavior of birds while in the Cape May stopover area, and examine the relative influence of time, weather, strategy and the availability of habitat. I will test the hypothesis that habitat selection, at the pathway, habitat and micro-habitat level, is a result of a bird's assessment of both extrinsic (weather and location) and intrinsic factors (food availability, competition, predation). This paper follows from Chapter Two, which focused on home range, movement and strategy of Sharp-shinned Hawks.

One additional goal is to define the critical stopover habitats for this species. The peninsula is one of the most important migratory bird stopovers in the continental United States (Kerlinger 1989, Niles et al. 1996), but it is also one of the most important resort areas on the Atlantic Coast, and development is causing major decline in available habitats. This loss from development is estimated to be as much as 50% for some habitats between 1972 and 1991(Niles unpubl. data). Thus my second hypothesis is that changes in habitat are limiting habitat selection, and may be a threat to the ability of this species to negotiate the Delaware Bay crossing.

I test these hypotheses using behavior and habitat data collected while following 24 Sharp-shinned Hawks migrating through the Cape May peninsula. In this study birds were followed birds from dawn to dusk to enable observers to resume tracking the following day, and to characterize the movement of birds and the strategy they chose when confronting the Delaware Bay crossing (see also Chapter Two). Tracking also allowed observers to characterize bird behavior in broad categories through variations in signal strength, direction, and regularity. Thus I could assess the influences of changing abiotic and biotic factors on their behavior.

METHODS

Our study area included the entire Cape May peninsula from its southern terminus at the junction of Delaware Bay and the Atlantic Ocean (38° 57' N, 74° 53' W) northward approximately 60 km along the Atlantic Ocean (39° 22 N, 74° 24' W) and to the west approximately 40 km along Delaware Bay coast (39° 14'

N, 75° 10' W) (Fig.1) Forests and marsh and field habitats comprised 66% of the peninsula's habitat (25%, 29%, 12%, respectively). The remaining area included residential development (16%), open water (15%) and beach (3%). The proportion of habitat changed within ten km of the point of the peninsula. Forest, marsh and field decreased from 77% of the total area 10-30 km from the point, to 51% at the point, while residential development increased from 8% to 30% (Fig 2). The most northern part of the study area included the southern most extension of pitch pine (Pinus rigida)-dominated habitats of the New Jersey Pine Barrens. The upland areas were composed mostly of white oak (Quercus alba)-pitch pine forests interspersed with late successional fields of red cedar (Juniperus virginiana) and other early successional habitats. Tidal wetlands areas were typical salt marsh habitats dominated by Spartina alterniflora and Spartina patens. The freshwater wetlands were mostly forested with red maple (Acer rubrum) and black gum (Nyssa sylvatica), interspersed with areas of Atlantic white cedar (Chamaecyparis thyoides).

I captured birds in three locations. In 1988, for the pilot study, I obtained birds trapped at banding stations located at the point of the peninsula and released them approximately 50 km north of the point. In 1989, I captured birds 43 km from the point, in a field adjacent to the Atlantic Coast marsh. In 1990, I moved the trapping location to the western side of the peninsula, 15 km from the point, in a field adjacent to the Delaware Bay marsh. The two northern peninsula trap sites accounted for all the birds in the 1989 and 1990.

Birds were trapped from mid-September to early November using mist nets and lure birds as described in Clark (1985b). I trapped two birds each day. Birds were outfitted with tail-mounted transmitters weighing less than 2 g (2 cm x 1 cm x .8 cm), with a 24 cm whip antenna, attached to the central two tail feathers with a small plastic electrical tie and glue (model LS-3. Merlin , L. L. Electronics, Mahomet, Illinois)(Kenward 1978). The transmitters were functional for up to 12 days with an average life of four days. The range of the transmitter varied considerably with the activity of the birds and the height of the tracker. I received a good signal from a perched bird for just over 1 km, and from a flying bird for up to 5 km. Flying birds could be lost when they perched, so trackers usually stayed within 1 km of moving birds.

To minimize the impact of transmitter weight I used only female Sharp-shinned Hawks. Females ranged in weight from 150 g to 210 g and transmitters ranged from 1.9% and 2.6% of body weight, far below the 5% generally considered the critical threshold for avoiding impacts from weight (Cochran 1980, Gessamen and Nagy 1988). However, transmitters were mounted on the central two retrices (Kenward 1978), thus avoiding the impact associated with backpack harnesses (Gessamen and Nagy 1988, Hiraldo et al. 1994). I used only immature birds because they account for over 95% of the birds that migrate through the peninsula, and adults migrate through the peninsula for much shorter periods of time (Clark 1985b). After weighing each bird I measured tarsus length, wing chord, and culmen length. Birds in 1989 and 1990 were processed within 30 minutes of capture and released at the point of capture. In 1988 birds were processed and transported north before release.

I tracked birds continuously from the time they were released until they left the area of the peninsula (33%) or the transmitter stopped (66%). Teams of two people began tracking birds at dawn and stayed with them until dusk or whenever the birds roosted. I fixed a bird's location by taking multiple fixes (>2) within 100 m-200m depending on the habitat. Locations were recorded on aerial photographs printed with the NJ state plane coordinate system grid of 1000 ft (304 m). Using mylar overlays with 100 ft (30 m) grids, the tracker located birds to within 100 ft (30 m) or within a habitat patch if smaller than 30 m. Flying birds were tracked from moving vehicles so locations were not as accurate. Trackers recorded the location of each bird on each move. If a bird moved continuously, then locations were taken a minimum of once every five minutes.

BEHAVIOR

I delineated five categories of behavior: hunting, flying, perching, migrating and roosting, through variations in signal direction and strength (Kenward 1980, Holthuijzen et al. 1982). Birds were considered hunting when they alternated flying and perching behavior. This fly and stop behavior has been reported as the chief method of hunting for Sharp-shinned Hawks and other congeners such as the European Sparrowhawk (Marquiss and Newton 1981, Joy 1990). Birds were considered flying when they took longer flights (over one minute) or flights that were not part of the fly and stop pattern characteristic of hunting. These flights all took place within an area of concentrated use, in which birds spent most of their time (Chapter Two). Flights between use areas or out of the study area were judged migratory flights. Perching was defined as stopping not linked to fly-stopping, and roosting was the last stop the day. I was able to verify behaviors 20% of the time through visual sightings of instrumented birds.

I used NOAA weather readings taken at Atlantic City International Airport every three hours, including temperature, wind speed and direction, barometric pressure and visibility. I summed the amount of time spent in a behavior for each three hour period, and used single factor ANOVAS to compare the mean amount of time and the mean length of each behavior/3hr period with time period, visibility, wind speed and wind direction, as well as a bird's location and approach. Wind speed was converted to two categories, 0-16 kph and >16 kpm, based on a threshold wind speed for making the Delaware Bay crossing as given in Chapter Two. Visibility was converted to two categories below and above or equal to 12 miles which was also the threshold for birds that crossed the bay in the methodology in Chapter Two. I also plotted the total amount of time and the number of times birds migrated against visibility. I used the F-test for homogeneity of variances, and the data met normality assumptions without transformation (Zar 1988). Our data was taken continuously, so to meet the independence assumption of the regression model I only compared separate behaviors to the factors listed above and not against each other. All data were analyzed using PC Statistical Analysis System (PC-SAS; SAS Institute 1989).

HABITAT USE

I characterized the habitats of tracked birds with a six level hierarchical classification system. It included general habitat type (forest, herbaceous, agricultural, developed, etc.), vegetation form (needleleaf, broadleaf, mixed, forest plantation, herbaceous, mixed herbaceous, hayfield rowcrop, orchard or agriculture, suburban-urban or developed), wetland or upland, canopy closure (closed as >75% cover, open as 50-75% cover, sparse as <50% cover), dominant canopy species, and overstory height (high >15m, medium 10-15m, low <10m) and shrub cover (heavy >50%, light <50%). Classifications were determined subjectively for the patch where the bird was located, and changed each time a bird moved to a new patch. Classifications were not made when a bird could not be assigned to a patch, or when the bird was moving large distances.

Available habitat was determined from random sampling peninsula habitats in 5 km blocks. In each block I randomly chose 20 points and used the same evaluation procedure for describing habitats used while following birds. I limited sampling to forest and herbaceous areas within 300 m from a road. I used chi-square and Bonferoni Z tests to test for differences between available and selected habitats, and to separate levels within habitats (Neu et al. 1974, PC-SAS; SAS Institute 1989).

RESULTS

TIME PERIOD

Birds spent nearly equal amounts of time perching and hunting (42% and 36%, respectively). Flying, including both long flights within the home range and migration flights, accounted for about 20% of their time, 5% of that in migration (Table 1). Each perching behavior lasted an average of 47 minutes (S.E.= 3.9 minutes) and an average hunt lasted about 34 minutes (S.E.= 3.0 minutes). Average within-range flights lasted about ten minutes. Migrating movements lasted about 46 minutes on average (S.E.= 13.2) .

The time of day significantly affected the amount of time spent perching ($F=4.36$, $df=4$, $P<0.01$), hunting ($F=4.31$, $df=4$, $P<0.01$), and flying ($F=2.32$, $df=4$, $P<0.05$) (Table 1). The proportion of time spent hunting varied from 42% in mid-morning to 31% in the early afternoon. Time spent perching ranged from 46% in the early afternoon to 33% in mid-morning. Flying behavior, which may have included both competitive interaction, predator escape and prey searches, ranged from 20% of their time in mid-morning to 12% in early morning. With the exception of the mid-morning and early afternoon, hunting and perching remained relatively constant throughout the day. Birds did not significantly alter the amount of time spent migrating during the day; the proportion of time ranged from 4% to 7% of each time period.

WEATHER

Weather affected migrating and flying behaviors. Birds spent less time migrating in low visibility ($F=4.14$ $df=1$ $P<.05$), ranging from 7% of their time in 19.3 km (12 mi) to unlimited visibility to 2% in less than 19.3 km visibility (Table 2). Although birds attempted to migrate at low visibility, 99% of the migrating time of all birds occurred in visibility greater than 9.7 (6 miles). Visibility did not affect other behaviors significantly. Wind direction affected flying behavior, especially when winds were from the east, south and west ($F=3.30$, $df=8$, $P<0.05$). Wind direction did not significantly affect perching or hunting behavior, but when I combined all wind directions into two categories, winds from the west and all other directions combined, direction did affect migrating behavior. Birds spent a greater proportion of their time migrating when winds were generally from the west ($F=3.72$, $df=1$, $P<0.05$). Wind speed did not significantly affect any behavior, including migration. No weather conditions influenced the amount of time birds spent perching. Some weather conditions significantly affected the average time of behaviors, but not in a consistent fashion.

LOCATION

The location of a bird with respect to the Delaware Bay crossing affected only the amount of time spent hunting (Table 3). Birds within ten km of the point spent over 55% of their time hunting, while those elsewhere on the peninsula spent 37% ($F=5.87$, $df=1$, $P<0.05$).

HABITAT

Comparison to random points- all behaviors combined

The birds chose habitats in different proportion to habitats available (Fig. 3). Birds used forest 98% of the time, and scrub-shrub 2% of the time, compared to 92% and 8% available. Selected forests were mostly mixed (deciduous-coniferous) with closed or moderately closed canopies of medium to tall height. While over 60% of available forest on the peninsula is broadleaf and 36% mixed, birds spent 64% of their time in mixed forest and 35% in broadleaf forest. Less than 1% of their locations were in pine forests. Half of the of the available forests had open canopies, while 30% were sparse and 20% closed canopy; birds spent 80% of their time in closed and open forests and less than 17% in sparse canopies. Birds preferred forest with closed canopies over other types (Bonferoni test $P<0.05$). Almost 60% of the peninsula forest is dominated by oak or maple, and 38% by transitional species such as sweet gum, cherry or locust. Less than 5% is red or Atlantic white cedar dominated. Birds, however, chose cedar in much higher proportion to its availability, and transitional in lower proportion than what was available (Bonferoni test $P<0.05$). Most of the peninsula forest is medium to low height (54% and 34% respectively), while Sharp-shinned Hawks chose much taller forest with 41% tall forest and only 6%

in short forest (Bonferoni test $P<0.05$). Finally, 89% of the forest used by birds had well developed understories, higher than the 68% of the available forest with similar understories.

Habitat comparisons for individual behaviors

Birds chose habitats with very specific features for each behavior. While flying, birds chose forests with many of the same characteristics described above except with more closed canopies (Bonferoni test $P<0.05$) (Fig. 4). The dominant species in selected forests occurred in the same proportions as what was available.

While hunting, birds chose forests that were shorter than those available, with over 30% of the locations in forest dominated by red cedar as compared to 4% available (Bonferoni test $P<0.05$). Canopy closure was not significant. Bird use in transitional forest was much lower at 11% as compared to 38% available (Bonferoni test $P<0.05$). The average height of hunted forest shifted, with 72% of all locations in the medium height category and only 23% in the tall category. Understory cover was not significant.

Birds preferred to perch in mixed forest with closed canopies of oak or maple species in the same proportion as what was available with two exceptions. The forests they chose for perching were mostly taller than those available, with well developed understories (Bonferoni test $P<0.05$).

For roosting, birds used forest at the opposite successional extreme as the forest preferred for hunting. These forests had the tallest trees, with over 51% of all locations occurring in the tallest category (Bonferoni test $P<0.05$). They used forest with much less transitional species and understory coverage was not significantly different than what was available. Roosting forests were the most closed of all the habitats chosen for each behavior with nearly 60% of all locations in the closed canopy category (Bonferoni test $P<0.05$).

STRATEGY AND HABITAT

Whether a bird stayed or left the peninsula had little effect on behavior. It only affected flying behavior; birds that stayed in the area spent more time flying than birds that left the area ($F=4.16$, $df=3$, $P<0.001$).

Staying or leaving altered a bird's choice of habitat in two behaviors and two habitat variables: dominant species and forest height. Birds that stayed, hunted and perched in forests that were of moderate height with a significantly higher proportion of red cedar and transitional species (Bonferoni test $P<0.05$) (Fig. 5). The proportion of locations in cedar dominated forest was 26% and 30% for hunting and perching, respectively, as compared to only 4% available. The birds that left used cedar forests in closer proportion to their availability (8% and 0%, respectively). The birds that stayed used medium forest in much higher proportion than was available for both behaviors, but those that left used much taller forest, with nearly 77% of all locations of perched birds in tall forest sites (Bonferoni test $P<0.05$).

DISCUSSION

TIME SPENT MIGRATING

The Sharp-shinned Hawks in this study spent most of their time perching and hunting regardless of weather conditions, and spent very little time migrating regardless of whether they were staying or leaving. My method may have underestimated the time spent migrating because I followed them only within the stopover. But I followed 4 birds nearly 100 km up the Delaware Bayshore and they spent less than 10% of their time migrating. Cochran (1972) followed one sharp-shinned hawk in migration and it averaged 150 km/day and five hours of migration/day. The bird migrated four of the 11 days it took to get to its wintering area. Grubb et al. (1994) followed a single bald eagle from Canada to Arizona and found it spent less than 40% of the time migrating.

The large proportion of time spent hunting may be a reflection of the birds being in the area of Cape May. In the only comparable study, Holthuijzen et al. (1982) found Sharp-shinned Hawks hunted 39% of their time while in the Cape May stopover. Rosenfield and Bielefeldt (1993) reported Cooper's Hawks, a congener of the Sharp-shinned Hawk, spent approximately 20% of their time hunting during the breeding period. Masman et al. (1988) found European

Kestrels spent no more than 20% of their time hunting. My birds may spend more time hunting because they are in migration, where foraging is the primary activity (Moore et al. 1993) and in an area dense with mostly immature passerine prey (Gustafson 1986, McCann et al. 1993).

A DAILY PATTERN OF BEHAVIOR

Time of day was the primary factor influencing behavior of Sharp-shinned Hawks during migration. It influenced perching, hunting and, indirectly, roosting behavior (birds roosted at nearly the same time every day). Although hunting and perching took place throughout the day, they were related and often fell into a pattern in which birds would hunt at least twice a day-once in the morning and once in the afternoon.

The hunt and rest patterns of the day were most often punctuated by flights in which the birds moved long distances but stayed within a restricted home range. These flights could occur throughout the day, but were most prominent in the morning. There could have been several causes for these flights. The most likely was a method of scanning for prey that would end with the short fly and perch behavior more characteristic of hunting (Marquiss and Newton 1981). But I also observed birds evading other hawk species, and on several occasions conducting antagonistic interactions with conspecifics. For example, one bird that remained on the peninsula for 9 days when its transmitter ran down, stayed within a home range of about 300 ha. On one occasion in the late afternoon it flew almost randomly from one end of its range to another for nearly an hour. When I was able to observe the bird, it was accompanied by a second Sharp-shinned Hawk, and they were displacing each other from successive perches. This territorial interaction ended when both birds flew to evening roosting sites.

INFLUENCE OF WEATHER

Although weather had a limited effect on perching and hunting, it significantly influenced the proportion of time spent migrating. Visibility greater than 19.3 km (12 mi.) and westerly winds increased migratory activity, although wind speed had no significant effect. The influence of visibility and westerly winds have already been reported by a number of authors studying hawks in Cape May and at other hawk concentration areas (see Kerlinger 1989 for a review, Hall et al. 1993).

I previously found birds crossing the Delaware Bay under specific weather conditions that were different from the conditions in which I observed birds migrating over land (Table 4 and Chapter Two). This comparison suggests two conclusions. First, birds are less cautious when flying over land where they can avoid adverse conditions, high winds or opposing direction by flying close to or within the forest canopy. They can also change directions, perch, or hunt. Over water they have few options beyond an energetically expensive flight to the other side or to return. Several researchers have observed birds drifting out towards open ocean and certain oblivion (Kerlinger 1989). Although this alone would justify caution, birds also face unpredictable weather that can change to unfavorable conditions in a short time period. In Chapter Two I reported suitable weather for crossing occurred during less than 30% of the migratory period, but these conditions often lasted less than three hours.

Our second conclusion is that the more restrictive weather conditions necessary for crossing is the major reason for the concentration of Sharp-shinned Hawks at Cape May (Allen and Peterson 1936, Dunne and Clark 1977, Niles et al. 1996). This conclusion can be substantiated in at least two ways. First westerly winds at any speed are the best winds for sighting hawks at Cape May Point (Allen and Peterson 1936) but are adverse for crossing the bay (Chapter Two). Secondly, several of the instrumented birds in the study flew to the point , did not cross, and either stayed or continued migrating north up the bay. For example, two birds from this study were released together, approximately 15 km north of the point. The first left the release site with favorable weather conditions and crossed before 0900 hours. The second hunted at the release site, then left after the wind had changed in direction and speed (westerly > 16 km). It flew to the point, did not cross and eventually flew north along the Delaware Bayshore.

INFLUENCE OF HABITAT AVAILABILITY

Habitat in any migratory stopover must meet the energetic requirements of the migrant and provide refuge from predators and from environmental stress (Moore et al. 1993). In Cape May, over 95% of the migrant birds are immature (Dunne and Clark 1977, Bildstein et al. 1984, Clark 1985a,b), so failure to meet those needs has a much higher probability of death for migrants (Ketterson and Nolan 1982, Moore et al. 1993). Moreover, this stopover lies before a formidable barrier to migration, which also magnifies the problems with which the bird must cope (Moore et al. 1993).

Thus habitat in the Cape May peninsula must have a number of very important qualities. Foremost it must provide food, adequate refuge from avian predators, shelter while adverse weather prevents crossing Delaware Bay, and it must be spacious enough to support thousands of competitors in densities far exceeding any breeding or wintering areas. The habitat on the Cape May peninsula appears to meet many of these needs.

The typical habitat for Sharp-shinned Hawks on Cape May is tall, mature mixed-species forests with mostly closed canopies and well developed understories. This differs from the typical habitat on the peninsula which was shorter and more open with a less developed understory and less pine. It is similar to structure and composition of nesting habitat describe by Joy (1990) and similar in structure as described by Reynolds et al. (1982).

But the study demonstrates birds used a wide range of forested habitat depending on behavior. For hunting, birds selected forests that were shorter and more open, with a well developed understory and more transitional species like cedar, cherry and sweetgum. This habitat was more likely to be a regenerating field in mid-stage, or a cedar dominated wetlands. The key feature was the presence of cedar, particularly upland red cedar. McCann et al. (1993) found this habitat to be one of the most significant for migratory passerines on the Cape, thus providing or abundant prey. I had often observed Sharp-shinned Hawks flying in the small open spaces of red cedar patches, flushing prey into flight and following in pursuit.

Perching most often took place in tall, closed canopies mixed with evergreen species of cedar and pine. These forests afforded birds maximum visibility for prey while still providing shelter from adverse weather and to some extent, avian predators. Flying behaviors were in similar forests.

Roosting took place in forests at the opposite extreme of those used for hunting and in forest more typical of nesting habitat. Roosting forest were taller, more closed and included more pine than those selected for other behaviors perhaps giving roosting birds a better view for avian and ground predators, and easy escape if necessary (Joy 1990). The pine were most likely the actual roosting trees. I observed birds perching in deciduous trees until sunset, when birds flew into a pine within the forest stand to roost.

Generally Sharp-shinned Hawks did not used developed areas within the study area and nearly all the observations were in forest. There were no observations in grassland areas and only a few in scrub-shrub habitats, which is consistent with data from breeding areas (Reynolds et al. 1982, Joy 1990). There were few locations in urban or residential areas, which constitute a significant area in the lower Cape (Table 1). It appears that presence of humans and the predators associated with them may be important negative features keeping most birds out of most residential areas including those with overstories and scrub landscaping.

THE IMPACT OF HABITAT CHANGE

This study substantiates the importance of habitat for Sharp-shinned Hawks in migration (Niles et al. 1996). It is unlikely that any specific habitats are critical to the birds' survival because they can range freely and use a wide range of habitats for each behavior. However, they may be influenced by the total area of habitat, especially in the lower 10 km.

It is possible that the area of habitat is already limiting. Counts of Sharp-shinned Hawks done at Cape May have fallen in the last ten years from a high of over 30,000 birds to a low of less than 10,000 birds (Kerlinger 1993). Although the change could be related to many factors, it occurred as nearly 50% of all forest habitat was lost to residential development (Niles unpubl. data). I found little use of residential areas and must assume that the loss of forest constitutes a negative impact. The severity of that impact is difficult to determine because its effect would be mostly indirect: increased predation, increased mortality from premature and risky crossings of the bay, increased competition and higher energy expenditures. None of these impacts can be measured easily and would mostly go undistinguished from the many other impacts that would contribute to an overall decline in the species. I conclude that the loss of habitat may be a serious threat to the migratory stopover in Cape May.

MIGRATORY PATHWAY AND HABITAT CHOICE

Sharp-shinned Hawks that reached the study area appeared to continuously assess the extrinsic and intrinsic factors influencing their behavior. Extrinsic factors such as weather and location affected migratory behavior which led birds to develop a strategy to the bay crossing which then influenced behavior and habitat selection. For example, when a bird faces adverse crossing conditions and stops close to the point, it can respond quickly to changes in weather. It could also access a great amount of prey, possibly improving its condition, motivating it to move on . Or it could face a large number of competitors and avian predators motivating it to move further north. Whether it stays or moves north may also depend on changes in physical condition, weather conditions and the availability of migratory prey. Innate programming would lack the plasticity necessary for the unpredictable conditions encountered in migration (Kerlinger 1989:323).

Our data also suggests that the assessment of habitat is proximally determined. For example, the birds that eventually crossed the Delaware Bay used habitats similar to both what was generally available and to their typical breeding habitats. Those that stayed used habitats that were not typical and would provide the most prey and the best shelter from predation. For Sharp-shinned Hawks the benefits of these habitats would be apparent. The exploratory assessment of habitat has been demonstrated in a number of species in nonbreeding migratory birds as evidence of proximal causation (see Hutto 1985 for a review).

ACKNOWLEDGMENTS

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Table 1. The proportion of time transmittered Sharp-shinned Hawks spent in each of four behaviors during the day. The day is divided into five time periods

		Flying		Perching		Hunting		Migrating	
Time Period	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Dawn-0800	29	0.12	0.03	0.45	0.06	0.37	0.06	0.06	0.04
0801-1100	31	0.20	0.05	0.32	0.06	0.42	0.07	0.06	0.03
1101-1400	34	0.16	0.04	0.46	0.07	0.31	0.06	0.07	0.03
1401-1700	29	0.14	0.05	0.43	0.07	0.39	0.07	0.04	0.03
1701-Dusk	13	0.16	0.09	0.40	0.13	0.36	0.13	0.08	0.08
All Periods	136	0.16	0.02	0.41	0.03	0.37	0.03	0.06	0.02

Table 2. The proportion of time transmittered Sharp-shinned Hawks spent in each of four behaviors as affected by visibility, wind speed, wind direction and barometric pressure.

		Flying		Perching		Hunting		Migrating	
	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Visibility									
0-9.7 km	37	0.12	0.04	0.51	0.06	0.34	0.06	0.03	0.03
9.7-unltd	99	0.17	0.03	0.38	0.04	0.38	0.04	0.07	0.02
Wind Speed									
0-16 kph	82	0.17	0.03	0.46	0.04	0.31	0.04	0.05	0.02
>16 kph	54	0.13	0.03	0.34	0.05	0.45	0.05	0.07	0.03
Wind Direction									
No Wind	16	0.06	0.04	0.44	0.10	0.50	0.10	0.00	0.00
N	6	0.13	0.05	0.43	0.15	0.44	0.16	0.00	0.00
NE	13	0.29	0.10	0.24	0.10	0.39	0.12	0.07	0.07
E	11	0.26	0.07	0.41	0.09	0.32	0.10	0.00	0.00
SE	17	0.33	0.09	0.38	0.09	0.29	0.08	0.00	0.00
S	45	0.13	0.03	0.52	0.05	0.33	0.05	0.02	0.02
SW	32	0.19	0.05	0.35	0.06	0.37	0.06	0.09	0.03
W	36	0.16	0.04	0.36	0.06	0.40	0.07	0.09	0.04
NW	50	0.12	0.03	0.43	0.05	0.42	0.05	0.03	0.02
Not West	108	0.18	0.03	0.44	0.04	0.36	0.03	0.02	0.01
Westerly	118	0.15	0.02	0.39	0.03	0.40	0.03	0.06	0.02

Table 3. The proportion of time transmittered Sharp-shinned Hawks spent in each of four behaviors in two location categories: Point includes all bird locations that were within 10 km of Cape May Point.

		Flying		Perching		Hunting		Migrating	
Location	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Mainland	208	0.17	0.02	0.41	0.02	0.37	0.02	0.05	0.01
Point	18	0.07	0.03	0.37	0.10	0.55	0.10	0.01	0.01

Table 4. A comparison of the weather conditions that increase migration over land with those necessary for a water-crossing for Sharp-shinned Hawks.

	Wind speed	Wind direction	Visibility
Water crossing	<16 kph	Not Westerly	≥ 19 km
Over land	Not Significant	Westerly	> 9.7 km

Figure 1. The area where migratory Sharp-shinned Hawks were tracked in the Cape May peninsula and Delaware Bay region.

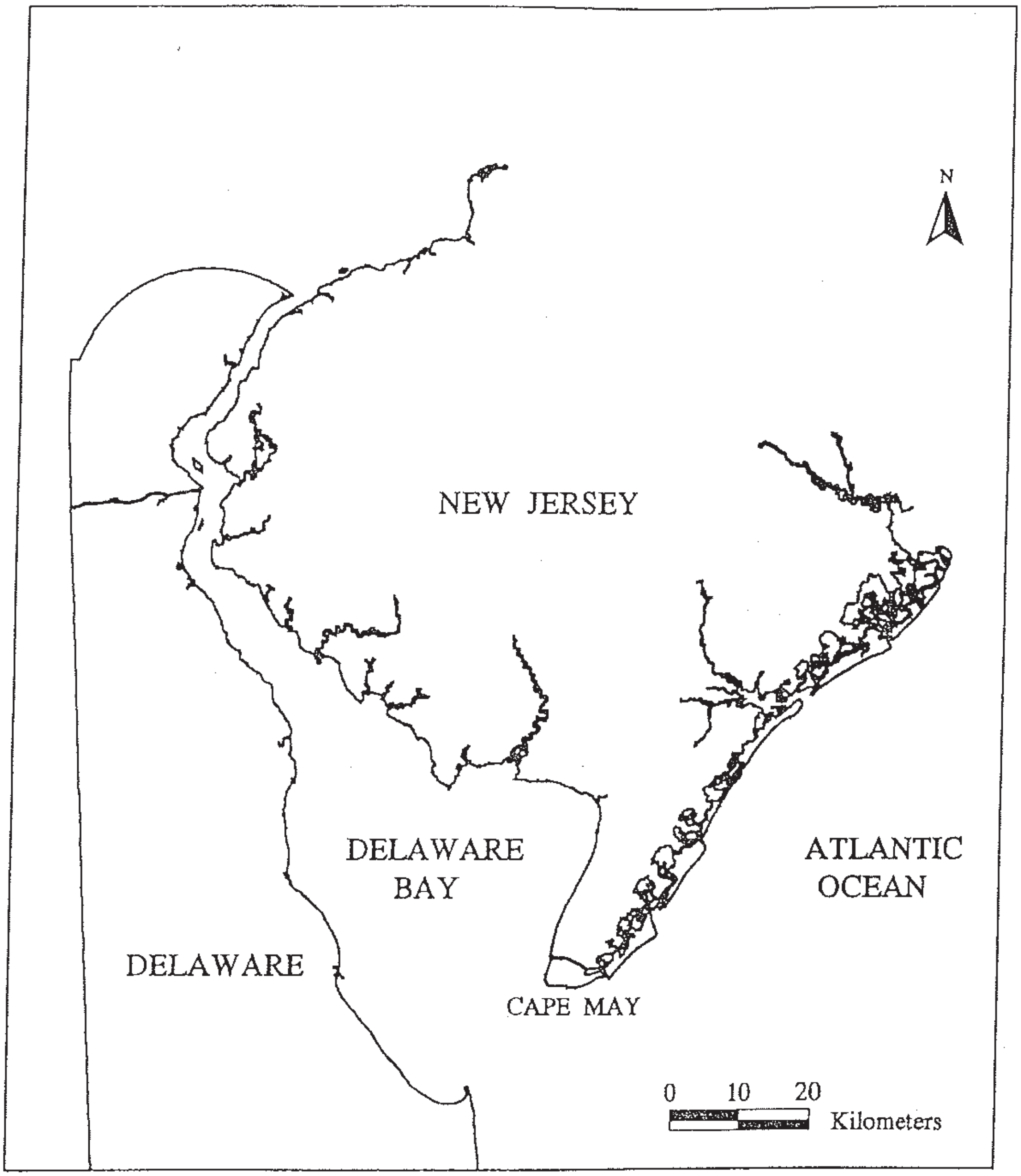

N
NEW JERSEY
DELAWARE
BAY
ATLANTIC
OCEAN
DELAWARE
CAPE MAY
0 10 20
Kilometers

Figure 2. The proportion of six habitat types in two areas of the Cape May peninsula, from the point of the peninsula to ten km north, and from 10 km north of the point to 30 km north of the point.

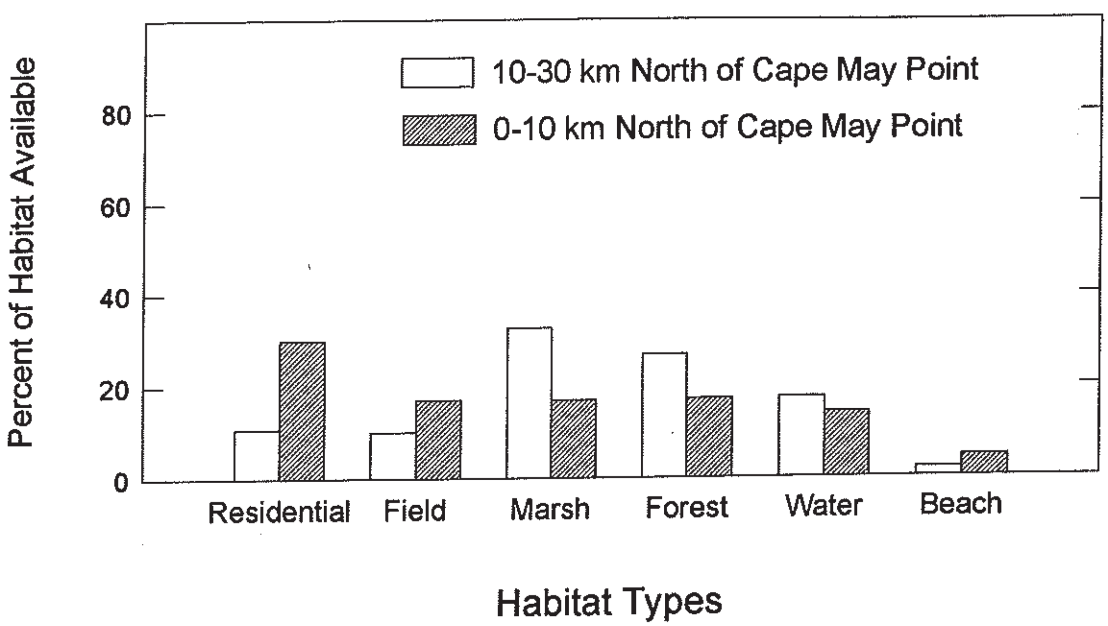
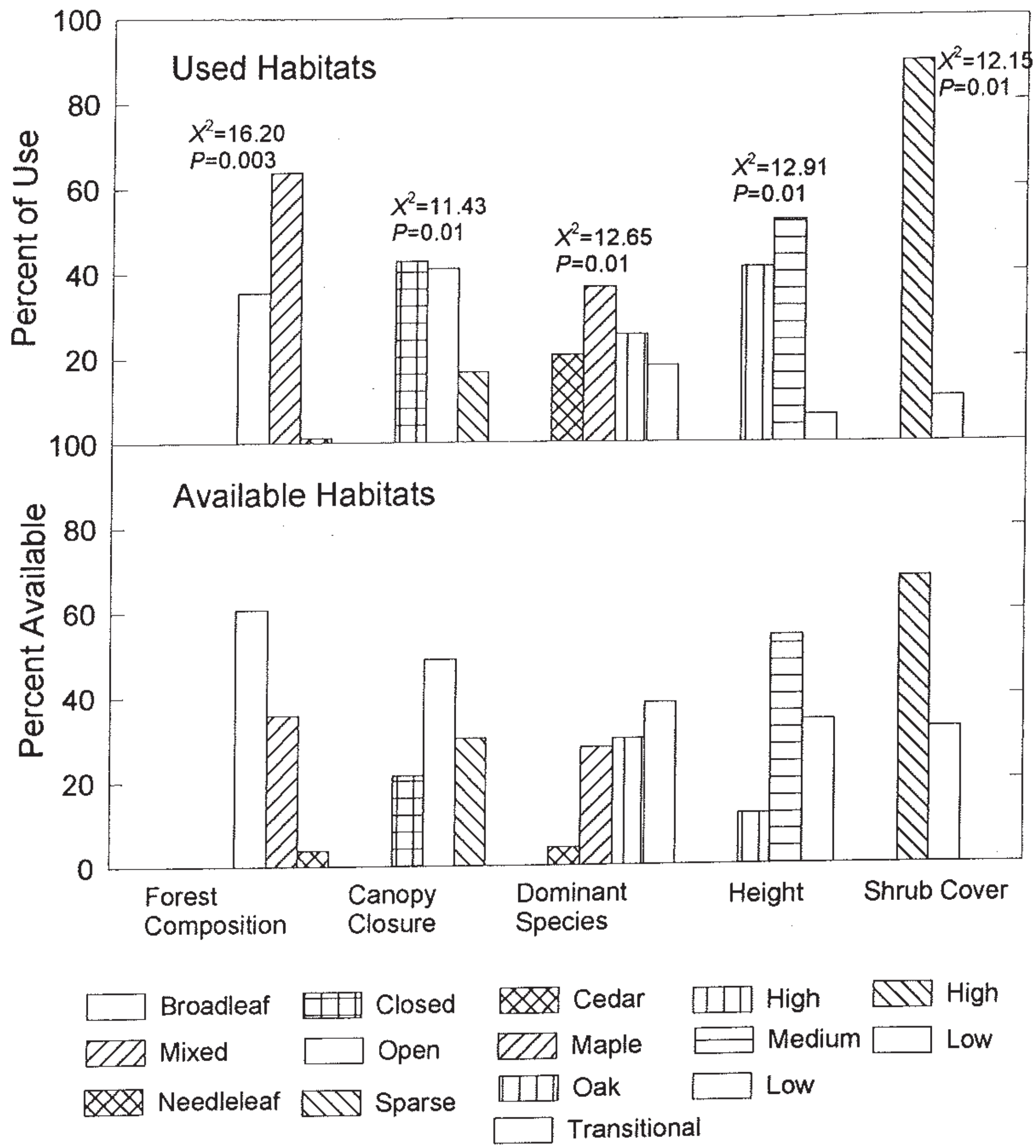
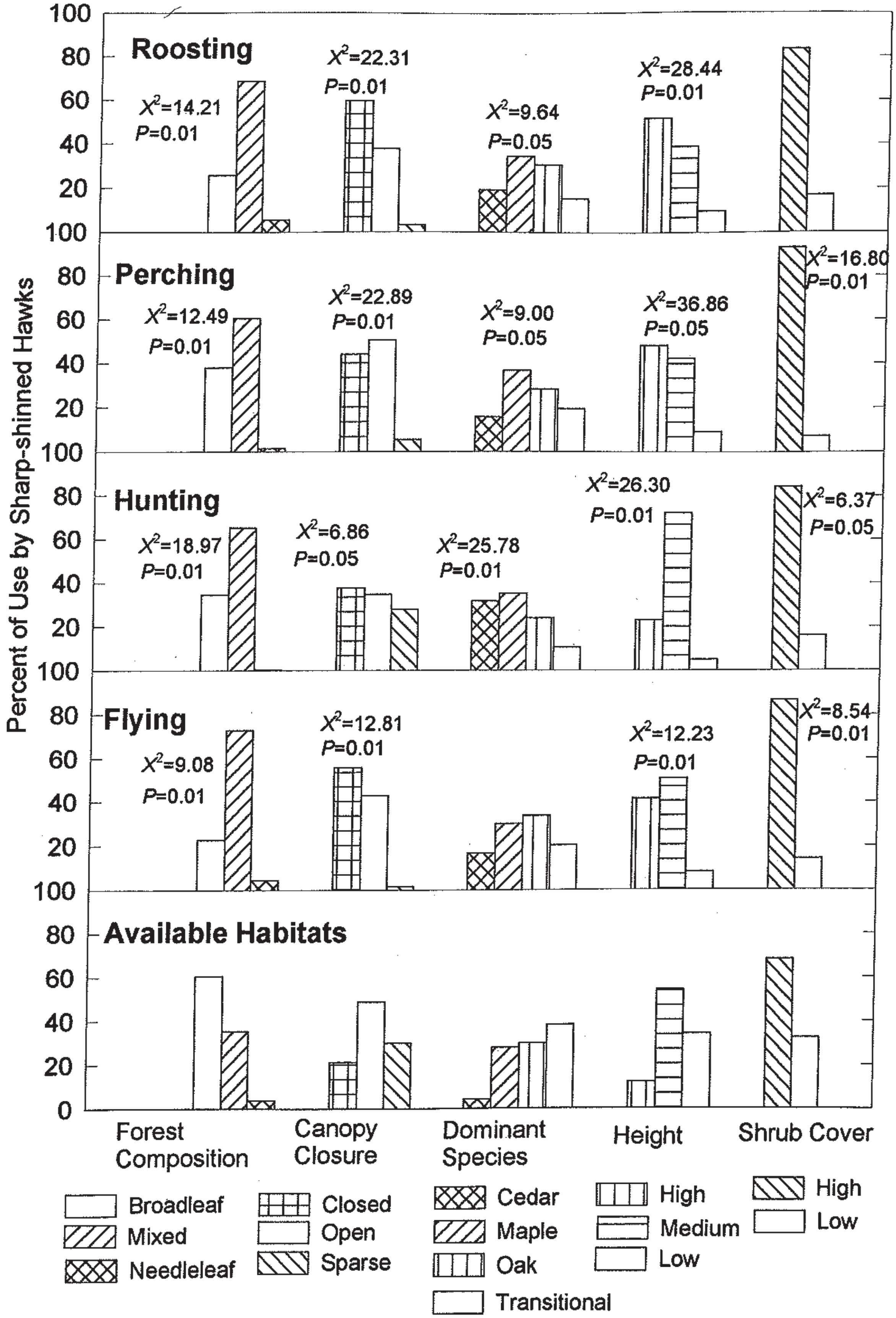

Percent of Habitat Available
80
60
40
20
0
10-30 km North of Cape May Point
0-10 km North of Cape May Point
Residential
Field
Marsh
Forest
Water
Beach
Habitat Types

Figure 3. A comparison of habitats available on the Cape May peninsula with those used by transmittered Sharp-shinned Hawks tracked in 1989 and 1990. Available habitats are represented by randomly placed points.



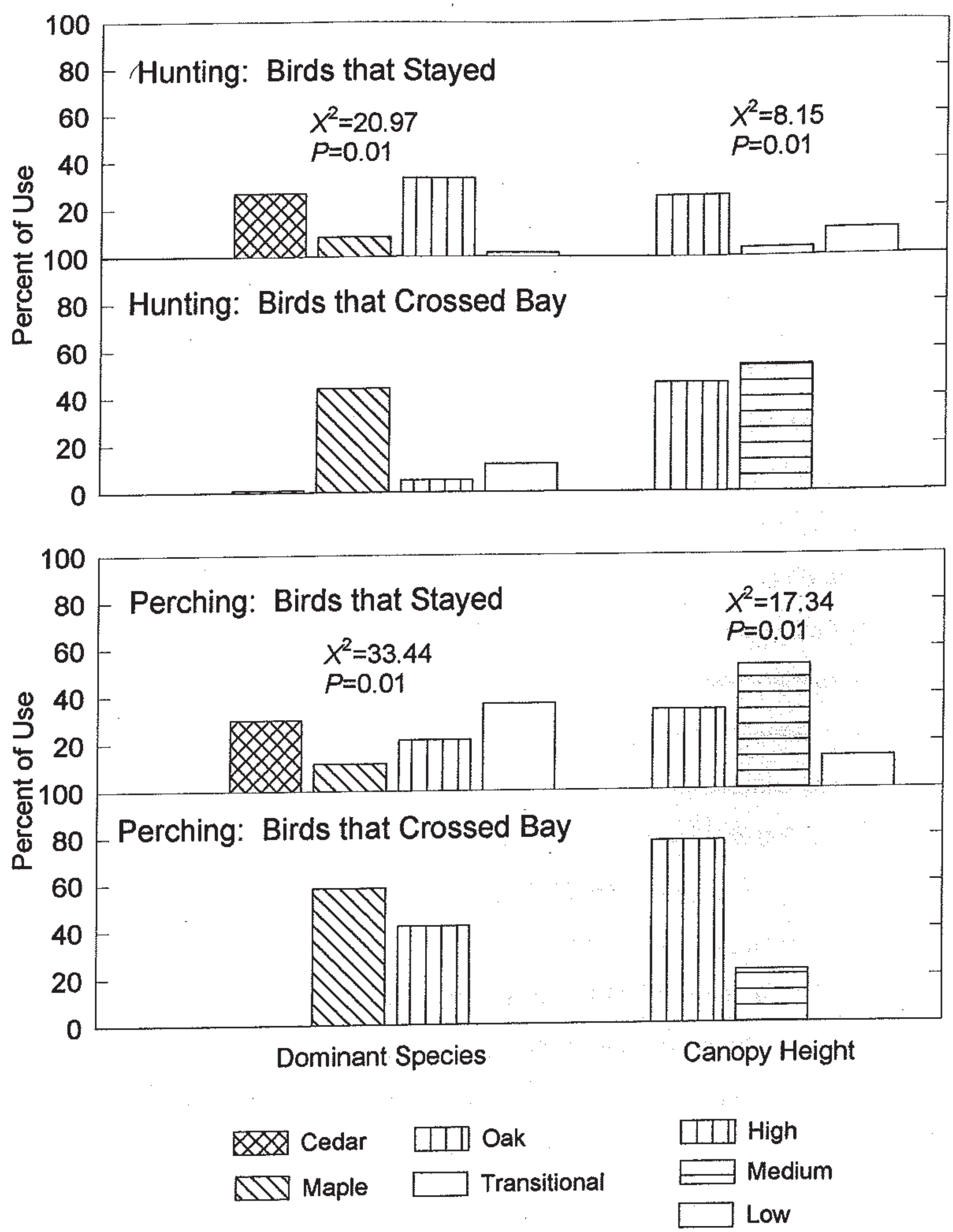
100
80
60
40
20
Percent of Use
Used Habitats
X^2=16.20
P=0.003
X^2=11.43
P=0.01
X^2=12.65
P=0.01
X^2=12.91
P=0.01
X^2=12.15
P=0.01
100
80
60
40
20
0
Percent Available
Available Habitats
Forest Composition
Canopy Closure
Dominant Species
Height
Shrub Cover
Broadleaf
Mixed
Needleleaf
Closed
Open
Sparse
Cedar
Maple
Oak
Transitional
High
Medium
Low
High
Low

Fig. 4. A comparison of habitats available on the Cape May Peninsula with those used by transmittered Sharp-shinned Hawks tracked in 1989 and 1990 in each of four behaviors: flying, hunting, perching, and roosting. Available habitats are represented by randomly placed points.



Percent of Use by Sharp-shinned Hawks
Roosting
X²=14.21 P=0.01
X²=22.31 P=0.01
X²=9.64 P=0.05
X²=28.44 P=0.01
Perching
X²=12.49 P=0.01
X²=22.89 P=0.01
X²=9.00 P=0.05
X²=36.86 P=0.05
X²=16.80 P=0.01
Hunting
X²=18.97 P=0.01
X²=6.86 P=0.05
X²=25.78 P=0.01
X²=26.30 P=0.01
X²=6.37 P=0.05
Flying
X²=9.08 P=0.01
X²=12.81 P=0.01
X²=12.23 P=0.01
X²=8.54 P=0.01
Available Habitats
0
20
40
60
80
100
Forest Composition
Canopy Closure
Dominant Species
Height
Shrub Cover
Broadleaf
Mixed
Needleleaf
Closed
Open
Sparse
Cedar
Maple
Oak
Transitional
High
Medium
Low
High
Low

Fig. 5. A comparison of habitats available on the Cape May Peninsula with those used by transmittered Sharp-shinned Hawks tracked in 1989 and 1990 following two different strategies: staying within the peninsula or leaving the area by crossing Delaware Bay. Only two behaviors are compared: hunting and perching. Available habitats are represented by randomly placed points.


Hunting: Birds that Stayed
X²=20.97
P=0.01
X²=8.15
P=0.01
Hunting: Birds that Crossed Bay
Perching: Birds that Stayed
X²=33.44
P=0.01
X²=17.34
P=0.01
Perching: Birds that Crossed Bay
Percent of Use
Percent of Use
0
20
40
60
80
100
Dominant Species
Canopy Height
Cedar
Maple
Oak
Transitional
High
Medium
Low

CHAPTER FOUR: DISTRIBUTION, HABITAT USE AND CONSERVATION OF MIGRATORY RAPTORS IN THE CAPE MAY STOPOVER

INTRODUCTION

Migratory birds must balance the need to reach wintering areas with the energetic requirements of transport while they adjust to unfamiliar habitats, avoid predation, compete with both migrants and residents, and avoid dangerous weather (Alerstram and Lindstrom 1990, Moore et al. 1993). These costs magnify at ecological barriers like large water crossings, where birds often wait for suitable weather or to improve their body condition (Rappole and Warner 1976, Moore and Kerlinger 1987). The suitability of habitat for foraging, resting, escaping predators and roosting often determines the extent to which birds can improve their condition and resume migration, and ultimately reach wintering or breeding grounds (Moore et al. 1993). The importance of habitat has been well reported for migratory passerines and shorebirds but has only been recently reported for raptors (Niles et al. 1996).

The Cape May peninsula is an important east coast stopover for passerines woodcock and raptors (Mabey et al. 1992, Krohn et al. 1977, Dunne and Clark 1977). Niles et al. (1996) found that most of the eight raptors migrating through the peninsula used habitats similar to those used during the breeding and wintering period. In Chapter Two I found that Sharp-shinned Hawks (Accipiter striatus), the most abundant hawk in the stopover, followed several pathways to continue migration. Those that did not leave quickly, stayed an average of four days. The primary difference between birds that stayed and left was weight; heavier birds left sooner. A bird's choice to leave or stay was interrelated with a number of important factors, most prominently weather conditions. Birds would make the water crossing only in a narrow range of conditions that occurred less than a third of the time.

The peninsula provides an abundant resource for bird-eating raptors that concentrate because of the similarly dense population of passerine species (Weidner et al. 1992, Mabey et al. 1993). This relationship of predator and prey is significant not only because it occurs at an ecological barrier (18 km water crossing), but also because nearly all the birds coming through Cape May are immature (Dunne and Clark 1977, Bildstein et al. 1984, Clark 1985a, b), the age group that suffers the greatest losses during migration (Ketterson and Nolan 1982).

The conservation of habitats for migratory raptors can have an important influence on the population ecology of raptors in the eastern migratory pathway. Niles et al. (1996) studied the distribution of eight raptor species throughout the 40 km peninsula and found at least three of eight species concentrated in the lower ten km. In this paper I present information on the distribution, habitat and behavior of nine species of raptors in the lower ten km portion of the peninsula. I address the following questions: 1) Are birds distributed evenly in the lower ten km area; 2) does the relationship between birds and habitat, found throughout the peninsula, persist in the lower ten km area where bird density is greatest; 3) how do birds behave within the stopover area; and 4) what are the components of a plan for the long-term protection of habitat, given the diverse needs of the species in the area.

METHODS

The Cape May peninsula forms the southern end of New Jersey in the mid-Atlantic region. Cape May Point is located at the southernmost extension of the peninsula. Delaware Bay separates southern New Jersey from Delaware to the south. My study area included the lower ten km of the 40 km Cape May peninsula, from the town of Wildwood on the Atlantic Ocean (39° 9' 45" N, 74° 41' 30" W) and Green Creek (39° 11' 45" N, 74° 49' 30" W) on the Delaware Bay shore, to Cape May Point (38° 55' 0" N, 74° 56' 15" W). The lower ten km of the peninsula is about ten km wide at the northernmost point and includes habitats ranging from densely populated ocean resort beaches to sparsely populated oak-pine (Quercus Pinus) forests. Habitat types ranged from upland interspersed with freshwater and tidal wetlands in the western half, and tidal salt marsh and urban barrier islands in the eastern half.

The area was divided into one km blocks based on universal transverse Mercator (UTM) coordinates, and I randomly located one survey point within every other block for a total of 50 points. I surveyed all points for hawks within one day, to reduce variation among days in weather conditions, and I surveyed twice weekly for eight weeks. Points were organized along five north-south survey lines and five observers surveyed birds. To eliminate bias due to different observers and time of day, each observer surveyed a different route each day, and each route was started at a different point each day.

Observers surveyed each point for 30 minutes. They were trained to estimate distance by setting reference points at 100 m intervals with a Rangematic rangefinder at all survey points. Observers also measured the height of stands of vegetation with a clinometer or tape as reference to estimate vegetation height at each bird sighting. Whenever a bird was sighted, observers recorded the distance to the bird at first sighting and at closest sighting of each bird, time, species, direction of flight (or track), and altitude of the bird (in ten m intervals). I recorded species, direction of flight, altitude, activity and behavior in eight categories, including flying <30 m high, flying above 30 m, kettling (circling with other hawks to gain altitude), milling (flying low and varying direction), hovering, perching, and hunting (chasing or catching prey). Milling, hovering, perching and hunting were classified as "using habitat" behaviors for analyses. Southbound kettling and direct flights were classified as migrating.

From black and white aerials photographs (1985; 1:400 scale), I classified all habitats within a 400 m radius of each survey point into forest, field, marsh, developed area and open water categories. As all 50 points were randomly located, these habitat descriptions were used to represent the study area. I measured the linear distance of forest edge, or the border between marsh and forest and field and forest. I also measured the internal area of forest, 100 m from any edge, as core forest. The area of each habitat was converted to a percentage of the total area. To determine habitat use by raptors, I compared the proportion of habitat at points where birds were seen to the proportion of habitat available in the study area.

All data were analyzed using PC Statistical Analysis System (PC-SAS; SAS Institute, Inc. 1985). To evaluate the influence of geographic position on counts within the ten km area, I summarized the results of each survey and compared summaries. I used the F-test for homogeneity of variances and Wilks-Shapiro test, then log-transformed the summarized data to meet normality assumptions of statistical tests (Zar 1988). The distribution of observed birds is presented in a three-dimensional graph with the x axis as the east-west UTM coordinate, the y axis as the north-south coordinate and the z axis as the number of observed birds for all surveys combined. The outermost points roughly define the Cape May peninsula as viewed from the southwest. I used the unsummarized data to determine the extent of habitat selection. The proportions of each habitat were compiled into categories, as follows. I used three categories for forest, marsh, water and development, corresponding to 1-33%, 34-66% and 67-100%. Because of the much smaller available area of field and core forest habitats, I used categories of 0-25%, 26-50% and greater than 50%. I used chi square to test for differences between available and selected habitats, and to separate levels within habitats (PC-SAS; SAS Institute, Inc. 1985).

RESULTS

I observed 15 raptor species during my study, but I limited analyses to the nine most abundant species: Sharp-shinned Hawk, Cooper's Hawk (Accipiter cooperii), American Kestrel (Falco sparverius), buteo species (including Red-shouldered Hawk [Buteo lineatus], Red-tailed Hawk [Buteo jamaicensis] and Broad-winged Hawk [Buteo platypterus]), Northern Harrier (Circus cyaneus), Osprey (Pandion haliaetus), and Turkey vulture (Cathartes aura). I grouped buteo species because of low sample size and the similarity in migratory flight characteristics and food habits (Erlich et al. 1988). I sighted 1,734 individuals of all species and 1,670 individuals of the nine most abundant species. The most sighted birds were Sharp-shinned Hawks (552, or 31%) followed by kestrel (337, or 20%), Turkey Vulture (290, or 17%) and Osprey (161, or 10%) (Table 1). All three buteo species totaled less than 8% and Northern Harriers and Cooper's Hawks less than 5% each.

Distribution

All species except the kestrel were evenly distributed from north to south. Sharp-shinned Hawks and Northern Harriers were not evenly distributed east to west (Figs. 1-8). Kestrels were clustered in the upper and lower three km of the 10 km study area with few in the central three km ($F=2.52$, $df=8$, $P<0.05$) (Fig 3). Sharp-shinned Hawks occurred most often in the western and central portion of the peninsula corresponding to the mainland ($F=2.74$, $df=14$, $P<0.001$)(Fig 6), and Northern Harriers occurred in the eastern portion corresponding to the Atlantic coastal marsh ($F=3.81$, $df=14$, $P<0.001$) (Fig 4). Taken together, hawks were distributed throughout the peninsula, but the fewest birds were on the barrier islands to the east, and most used the mainland portion of the study area (Fig. 8).

Habitat Use

The use of habitat differed by species. As the area of forest and field increased within survey sites, so did the number of buteo species and Sharp-shinned Hawks (Table 1). An increasing area of core forest (forest with an internal buffer of 100m) significantly increased the numbers of six species, Sharp-shinned Hawk, American Kestrel, Turkey Vulture and the three buteo species. The area of marsh was associated significantly with only Northern Harriers. The amount of edge habitat was positively related to the numbers of four species: kestrels, Ospreys, sharp-shinneds and Turkey Vultures. All but Northern Harrier and Osprey were negatively associated with the area of water within a survey area. Finally, developed area was associated with significantly fewer birds of all species except Northern Harriers.

Behavior

I was able to assign behaviors to 1,734 sightings of the fifteen species observed in my study and 1,617 of the nine species used in my analysis. Nearly half of all sightings occurred between 1100 and 1300 hours, 13% in the early morning and 39% in the late afternoon (Table 2). Time of day did not affect all behaviors in the same way (Chi square=56.79, $df=4$, $P<0.001$). The highest proportion of migrating behavior took place in the morning and decreased as the day progressed. Northbound flights and using behaviors increased as the day progressed. Behavior also varied significantly by species (Chi square=252.2, $df=12$, $P<0.001$). Typical migrating behavior, kettling and high direct flights, varied by species with Turkey Vultures, buteos and Ospreys the highest (41%, 37%, 25%, respectively), and Cooper's Hawks, kestrels and harriers the lowest (22%, 22%,12%, respectively) (Table 3). Most species were seen flying north about a third of the time, but ranged from a high of 43% for vultures and 9% for harriers.

The most prominent behavior of observed raptors varied with species. With the exception of kestrels, most birds were seen flying (Table 4). Of all sightings, buteos were most often seen milling or in kettles at altitudes greater than 30 m. Vultures, buteos and Cooper's Hawks were most often seen flying north at various altitudes. Perching, hovering or milling at low altitudes accounted for nearly 57% of kestrel sightings. Sixty percent of the Northern Harrier sightings were either hovering or low attitude milling. Kestrels and Northern Harriers were the species least frequently seen flying north. Ospreys were most often (29%) seen milling at low altitudes (mostly over water) and flying north (27%). Sharp-shinned Hawks were seen nearly equally in all behavior categories except for northbound flights. I saw kestrels and sharp-shinneds interacting with conspecifics and other species more often than all other species. Turkey Vultures were most often observed in kettling or northbound flights.

DISCUSSION

Distribution in the Lower Ten km Area

Generally my surveys found no evidence of a consistent increase in birds on approaching the lower portion of the 10 km study area. Niles et al. (1996) used identical techniques to study raptors in the entire peninsula from 40 km north of the point to the point, including the 10 km area of this study. They found that the number of raptors was highest in the 10 km area and lowest in the area 40 km from the point, largely because of the greater numbers of four species (Sharp-shinned Hawks, Broad-winged Hawks, Ospreys and Cooper's Hawks). In this study I found no additional north-south concentration of raptors within the 10 km area.

The significant east-west variation in numbers of Sharp-shinned Hawks and Northern Harriers is apparently a result of the stratification of habitat on the peninsula. Most of the western and central peninsula is upland with scattered estuarine and lacustrine wetlands. Approximately 4.8 km of coastal marsh separates the mainland from the barrier islands, which are almost entirely developed. The species found most often in tidal marsh areas of the study area, Northern Harriers and Ospreys, are normally associated with marsh habitats (Poole 1989, Preston 1990). I conclude it is the lack of habitat that prevents much use of barrier islands, because the few patches of dune woodland habitat that exist were used heavily, especially by bird eating raptors like Merlins, sharp-shinneds and Cooper's Hawks, possibly because of the great numbers of migratory passerines in those patches (Mabey et al. 1992, Chapter Three).

Habitat and Migratory Birds

Habitat use by migratory raptors in the lower peninsula observed in this study is consistent with use found throughout the peninsula by Niles et al. (1996). Sharp-shinned Hawks used forests, Red-tailed Hawks used fields and forests, and Northern Harriers used marsh just as they do in breeding and wintering periods (Reynolds et al. 1982, Bildstein 1987, Preston 1990, Joy 1990). Moreover, I found core forest was important to a diverse group of species, including species that did not select forests without a 100m buffer. The diverse habitat use of these species indicates forest is used for predator escape, resting, and roosting, as well as foraging. I suggest this relationship with forest and core forest is strong for all species because it was significant despite the bias in my survey method. Observers stood in open fields, marsh, or sparsely forested habitats to allow clear viewing. I did not survey the interior areas of closed canopy forests so my method would tend to overestimate birds using marsh, fields and edges, and underestimate those using forest. Consistent with this bias, perhaps, edge habitats were significant for four species, not only because edge provides both suitable prey and perches, but because birds are more visible at edges.

The most consistent habitat relationship was that birds avoided developed areas. The numbers of eight species declined with increasing area of development, which supports the conclusion that habitat of nearly any type is valuable as long as it is not developed. Moreover, my data suggest for several reasons that habitat quality depends, in part, on its proximity to development. First, over half of the species in this study used core forest, which is the habitat most affected by the proximity of development. Second, many of the residential areas I surveyed included overstories of mature oak and pine and were landscaped with shrub cover, yet few birds were counted. Thus, I conclude that birds avoided these areas, perhaps because of the presence of people, pets, vehicles and the ground predators of a suburban landscape that often pervade surrounding undeveloped habitats.

Although my study highlights the wide variety of habitats necessary for the diverse population of migratory raptors migrating through the lower ten km area, it also over-simplifies each species' real habitat needs. For example, Niles et al. (1996) found Sharp-shinned Hawks in migration used mature forest typical of the breeding season, in addition to most other successional stages of forest for hunting, perching and roosting. Each species is likely to use a similar variety of habitats not demonstrated in this study. Thus in the lower ten km area nearly all major habitat types and the many variations of structure in those habitats will have value to some part of the migratory population.

Migratory Behavior

When birds migrate to the lower Cape May peninsula they do one of three things. They may cross Delaware Bay and continue south through Delaware; they may fly northwest along the bayshore to a better crossing if weather is adverse; or they may stop at Cape May and wait for better weather or to improve their body condition (Niles et al. 1996). In this study I observed migrating hawks foraging, resting and roosting, as well as competing with conspecifics. Because observers were positioned in open areas or open canopy forests, my method was biased against observation of birds either perched or moving within forest areas. Nearly one third of the birds seen were heading north, suggesting they were searching for a suitable crossing point, or simply milling to locate prey, escape from predators, or locate suitable habitat for perching or roosting. Although it is beyond this study to relate behaviors to habitat, I can assume that each species will require habitat in which to forage, perch, escape predators, and roost. The habitat needs of the 15 species of raptors observed in this study would cover nearly all successional stages of upland and wetland habitat on the peninsula.

THE CONSERVATION OF THE LOWER TEN KM AREA

The lower ten km of the Cape May peninsula is rapidly developing with residential housing. Development has caused the loss of over 30% of both upland and wetland habitats since 1972 (Fig 2.). This development is significant because the area was already the most densely populated area of the peninsula excluding the barrier islands. If current development pressure continues it is likely to have a significant long-term negative and irreversible impact on the quality of the peninsula as a stopover for raptors, passerines and woodcock (Scolopax minor). Niles et al. (In prep.) estimate that significant changes in quality could cause both direct and indirect impacts to the long-term survival of migrant raptors.

In contrast there have been significant conservation actions initiated to protect the lower Cape May peninsula, involving several state agencies, USFWS, the Nature Conservancy and several state conservation groups. The lower ten km area has been designated an area of exceptional resource value by the New Jersey Department of Environmental Protection (Torok 1995), which provides complete protection of wetland areas as well as a 50 m upland buffer. Moreover, the entire area lies within the state coastal zone protection area, requiring large developments to mitigate damage to both upland and wetland habitats. Part of the ten km area is high in the state's priority for land acquisition under a new bond act passed in 1996, and within the land acquisition area of the USFWS's Cape May National Wildlife Refuge. The entire peninsula is part of the Nature Conservancy's Bioreserve Program. Finally, a large portion of the area around Cape May Point has already been purchased and managed for migratory birds by several state agencies, including the New Jersey Division of Fish, Game and Wildlife.

The difficulty is that current protection is not guided by a single plan that engages the strengths of each of these disparate protection programs. Current efforts are largely fragmented into at least 11 different federal, state and non-governmental organizations (NGOs). In the remainder of this paper I recommend actions that would better organize protection based on the data presented in this paper and in other papers on raptor distribution and habitat use (Niles et al. 1996, Chapters Two and Three) and data collected by Cape May Bird Observatory. The latter source suggested declines in at least one species, Sharp-shinned Hawk, that may be a result of habitat loss in the lower peninsula (Kerlinger 1993, Chapter Three).

I also include the protection of passerine migrants in these actions. The needs of these species are as diverse as raptors, so a common strategy is feasible, and the loss of habitat in a migratory stopover can negatively impact migratory passerine survival (Moore et al. 1993). Moreover, preliminary habitat protection recommendations suggested by Maybe et al. (1992) for the middle Atlantic coast and Rich et al. (1994) for New Jersey are consistent with the needs of raptor species.

My recommended actions assume the following: 1) All areas of habitat are being used by migrant raptors and the passerines on which many depend, so protection efforts should include all habitats; 2) the chief restriction to avian use is development or the actual destruction of habitat; 3) proximity of a habitat to development makes it less suitable to migrant hawks; 4) the current area of habitats used by avian species is the minimum necessary to avoid significant negative and long-term impacts to the migratory raptor population in the area; 5) to be successful, protection must be consistent with the needs of the communities affected by protection.

Recommendations

1. Develop a comprehensive critical areas map. Based on my study, a map of all key habitats should be produced and distributed to all agencies that plan development or acquire land in the lower ten km area. Because development on the southern peninsula is guided by two regulatory programs that protect all wetlands, the map should include all wetlands and a 50 m buffer as required by current regulation. Large wooded areas with internal buffers of greater than 100m should be distinguished from other wooded areas. The map should include all public lands and lands owned or managed by conservation groups. All existing development should be mapped as well as areas that have the greatest potential for development as estimated by zoning regulations. A draft version of the map should be reviewed by area biologists and naturalists to refine boundaries based on personal experience.

A comprehensive map of habitats is a prerequisite for protection in any migratory stopover threatened with development. A map will not only guide conservation groups to the areas that need protection, but will also guide developers and land planners to areas where development may have the least impact. Communities have an economic interest in protecting the migration, since large migratory flights attract birders that use local businesses during their visits, thereby influencing the local economy (Kerlinger 1995).

2. Focus land protection activities. A working group, including representatives of each conservation agency should be organized to develop a coordinated land protection strategy. Priorities should be based on the critical areas mapping, the likelihood of regulatory protection, and the acceptability of acquisition. Considerable local opposition to public ownership often exists because of the possibility of uncontrolled illicit activities and the tax exempt status conferred on public land. But other methods of protection are feasible, such the purchase of development rights, conservation easements and cooperative agreements that would not conflict with the needs of adjacent and nearby landowners. All techniques should be included in the strategy. The group should create a map of lands that cannot be protected, for use by a planning group composed of local planners and developers covered in action 3.

An active working group representing all the significant conservation groups is necessary for several reasons: 1) It is key to coordinating activities such as land acquisition and management; 2) a group can share experience and develop solutions to problems encountered by individual members; 3) the group's meetings provide the interested public access to the activities of each group.

3. **Mitigate the impact of unavoidable development.** Using mapping developed by the land acquisition group, a second working group should develop protection using existing state and federal land use regulations. Layered maps of critical areas, acquired land, and land currently protected by land use regulations will suggest the location of areas that cannot be protected. With a prior understanding of these areas, conservation agency representatives, land use regulators, local land use planners and developers can develop a strategy to mitigate the impacts of development or to move it to less destructive locations. For example, tax relief can be granted to developers of low density housing if they concentrate it into smaller areas and protect the remaining land. Once key areas are identified, private conservation groups can develop cooperative agreements with land development companies to produce housing with minimal impact.

Many stopover areas are not covered by restrictive land use regulations and this action may not apply. However, most areas include one or more community planning boards that can respond to a critical area designation. The goal of this working group is not to stop development but to assist land use planners in making land use decisions with the least negative impact to the migration.

4. Provide diverse habitats with minimum management. Habitat management depends on the species in need of protection, but in stopover areas like Cape May, management must be aimed at a large group of species with needs that encompass nearly all habitats. Thus, management should produce an array of habitats balanced by the practical restrictions imposed by resources. The overall objective of management should be to maintain existing habitats through minimal change. Fields should be restored on a schedule that would allow succession from naturally regenerated herbaceous species, but prevent woody species from establishing and thus prevent future plowing or harrowing (5-7 years in Cape May). Forests should remain unmanaged. Their many uses by migrating birds and small area as a proportion of the entire lower peninsula makes every patch valuable, and the larger the patch the more valuable it becomes. While forests may not be critical in all stopovers, they probably are in most East coast areas like Cape May, Cape Charles in Virginia, and along the shore of lake Ontario in New York (Maybe et al. 1992, C. Agar, pers. comm.).

Some experimental cutting, however, could help provide scrub-shrub habitat, which is also highly valued (Niles et al. 1996) but occurs in very small amounts, is naturally ephemeral and nearly impossible to maintain through cost-effective management. Small openings of approximately one to three hectares, cut 25% at a time every five years will provide an array of different age habitats from early field to scrub-shrub and early successional forest. This would impact breeding species, especially those most affected by forest fragmentation. But large areas of contiguous forest exist north of the lower portion of the peninsula (Rich et al. 1995), so I conclude migratory species take priority on the peninsula. A management working group composed of both wildland and parks managers should form to review land management for such conflicts. They should also coordinate activities that could influence another area, and provide input to the land acquisition working group.

5. Encourage recreation while minimizing impact. The land that is purchased should be managed not only to protect migrant birds but to encourage recreation associated with them. The economy of Cape May peninsula is essentially based on tourism, and recreation associated with wildlands can play an important role in extending the traditional summer tourist season into the spring and fall. Weidner and Kerlinger (1990) estimated that birders alone spent nearly six million dollars annually while visiting the lower peninsula. But it is important to manage recreation, otherwise disturbance impacts are likely. In a study on human disturbance on raptors, Burger et al. (1996) found unrestricted use of fields on one public land property in the lower ten km led to significant declines in raptor use. Areas can be managed to encourage appropriate use through the construction of trails, viewing areas and interpretive displays. Distributing small parking lots, restricting use to trails and educating birders on the impacts of disturbance can help alleviate impacts. The distribution of users should be done with the cooperation of surrounding landowners, who are generally reluctant to see their land open to public use.

6. Monitor both birds and people. The survey of raptors in the lower ten km area is the only way to test if land protection efforts are sufficient. The long-standing raptor count conducted by NJ Audubon at Cape May Point is useful to determine changes in the numbers of birds passing though the point. It is, however, subject to many influences that cannot be accounted for easily in a rigorous analysis, such as significant changes in yearly weather patterns and changing observers. But the survey has been conducted for almost 20 years, making it an invaluable index. Similar surveys done in other locations in weather conditions suitable for migrating but unsuitable for crossing (winds>19 kph (15 mph), visibility $\geq$16 km (10 mi), west or northwest)(Chapter Two) would help characterize the migratory population over a larger area and serve as a good indicator of habitat use. It is also important to establish a count of the number of people engaged in bird related recreation for two reasons: 1) to determine density and distribution of people to identify potential impacts and initiate action to avoid them, and 2) to provide the community with an estimate of the economic value of bird related tourism. Such an estimate with multipliers can provide a realistic and convincing argument for protection.

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Table 1. Habitats selected by 9 species of migrant raptors in the lower 10 km of Cape May peninsula in 1988. Given are Chi square and P values and the direction of the habitat relationship. Core forest is forest with an internal buffer of 100m.

Habitat	2df	Buteo species	Cooper's Hawk	American Kestrel	Northern Harrier	Osprey	Sharp-shinned	Turkey Vulture
Forest	ChiSquare	13.96					12.04	11.28
	P	0.001↑					0.002 ↑	0.004↑
Field	ChiSquare	13.43					5.07	
	P	0.001↑					0.08↑	
Marsh	ChiSquare				2.96			
	P				0.09↑			
Core	ChiSquare	14.29					11.37	5.93
Forest	P	0.001↑					0.001↑	0.05↑
Edge	ChiSquare			4.55		3.45	7.53	18.84
	P			0.03↑		0.06↑	0.006↑	0.001↑
Water	ChiSquare	7.74	5.98	6.11			16.65	13.16
	P	0.021↓	0.05↓	0.05↓			0.001↓	0.001↓
Develop	ChiSquare	22.58		6.57		4.74	28.62	30.07
-ment	P	0.001↓		0.03↓		0.09↓	0.001 ↓	0.001↓

Table 2. The frequency of three categories of behavior of all species combined in each of three time periods, morning, mid-day and afternoon, as surveyed in the lower 10 km of Cape May peninsula in 1988. Migration behavior includes flying south at $\geq$30 m and kettling at any altitude; non-migration behavior includes flying north at any altitude; using behavior includes all other flying, perching, hunting and any intra- or interspecies interactions.

Behavior (n=1734)	Morning 800-1100	%	Mid-day 1101-1400	%	Late Afternoon 1401-1700	%	TOTAL	%
Migrating	93	42	250	30	124	18	467	27
Non-migrating	46	21	220	26	217	32	483	28
Using	81	37	364	44	339	50	784	45
Total by Time Period (% of Total)	220	(13)	834	(48)	680	(39)	1734	(100)

Table 3. The frequency of three categories of behavior of nine migratory species surveyed in the lower ten km of Cape May Peninsula in 1988. Migration behavior includes flying south at ≥30 m and kettling at any altitude, non-migratory behavior includes flying north at any altitude, and habitat-using behavior includes other types of flying, and perching hunting and any intra- or interspecific interactions.

Behavior	Buteo species	%	Cooper's Hawk	%	American Kestrel	%	Northern Harrier	%	Osprey	%	Sharp-shinned	%	Turkey Vulture	%
Migrating	48	37	17	22	64	19	8	12	40	25	138	25	118	41
Non-migrating	51	39	25	33	31	9	9	13	43	27	161	29	125	43
Habitat-using	32	24	35	45	242	72	52	75	78	48	253	46	47	1
Total	131		77		337		69		161		552		290	

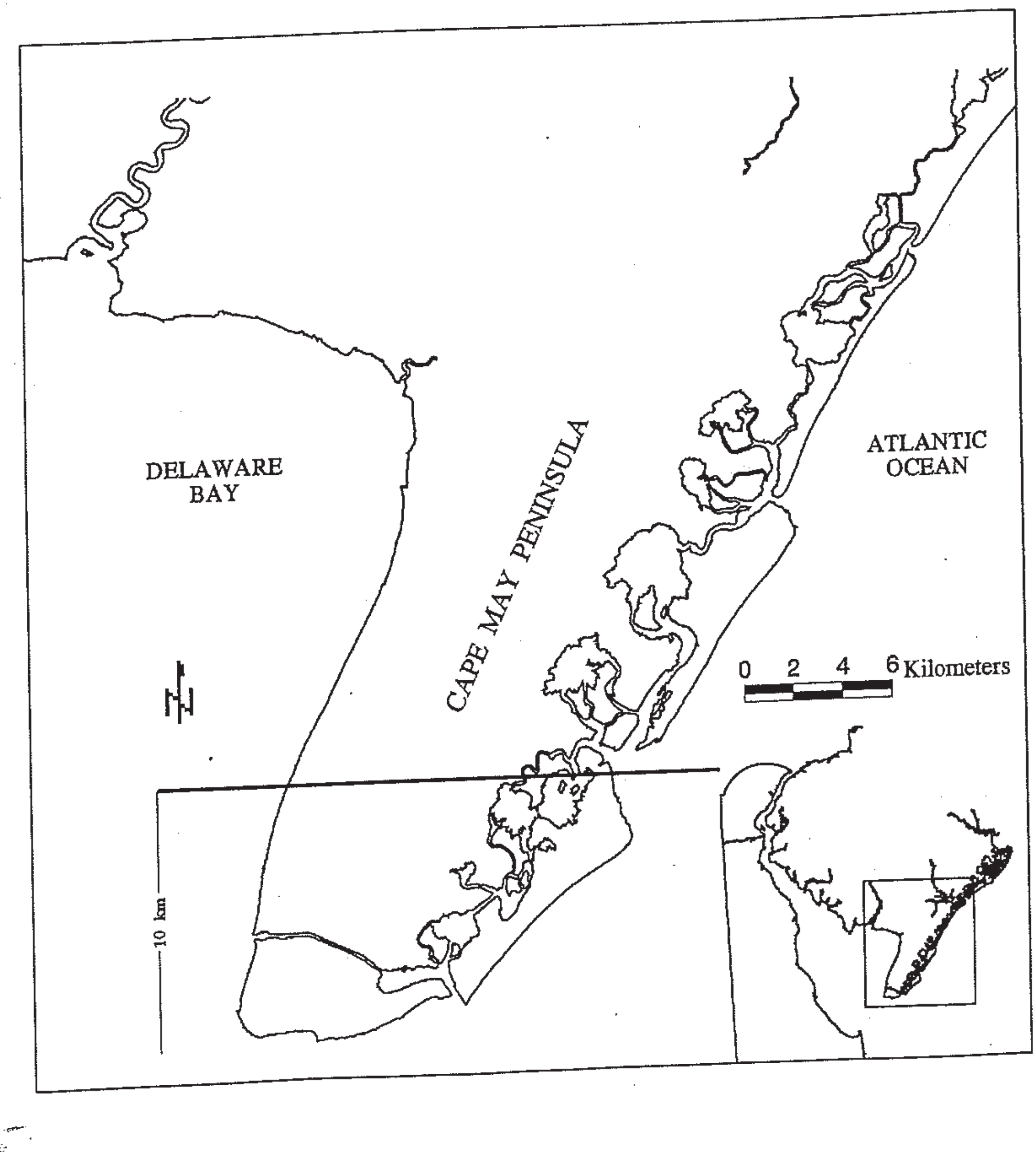
Table 4. Frequency of behavior of nine species of migrating raptors in the lower ten km of the Cape May Peninsula, from surveys in 1988.

Behavior	Buteo species	%	Cooper's Hawk	%	American Kestrel	%	Northern Harrier	%	Osprey	%	Sharp-shinned	%	Turkey Vulture	%
Perching	2	1.5	1	1.3	66	19.6	0	0	3	1.9	3	0.5	0	
Hovering	7	5.3	8	10.4	87	25.8	16	23.2	8	5.0	55	10.0	3	1.0
Milling<30m	7	5.3	12	15.6	36	10.7	26	37.7	14	8.7	50	9.1	12	4.1
Milling>30m	16	12.2	7	9.1	18	5.3	7	10.1	47	29.2	82	14.9	26	9.0
Kettling	44	33.6	11	14.3	18	5.3	3	4.3	15	9.3	61	11.1	72	24.8
Direct>30m	4	3.1	6	7.8	46	13.6	5	7.2	25	15.5	77	13.9	46	15.9
Direct<30m	0	0	6	7.8	29	8.6	3	4.3	5	3.1	55	10.0	6	2.1
Interact	0	0	1	1.3	6	1.8	0	0	1	0.6	8	1.4	0	0
Northbound	51	38.9	25	32.5	31	9.2	9	13.0	43	26.7	161	29.2	125	43.1
N=1617	131		77		337		69		161		552		290	

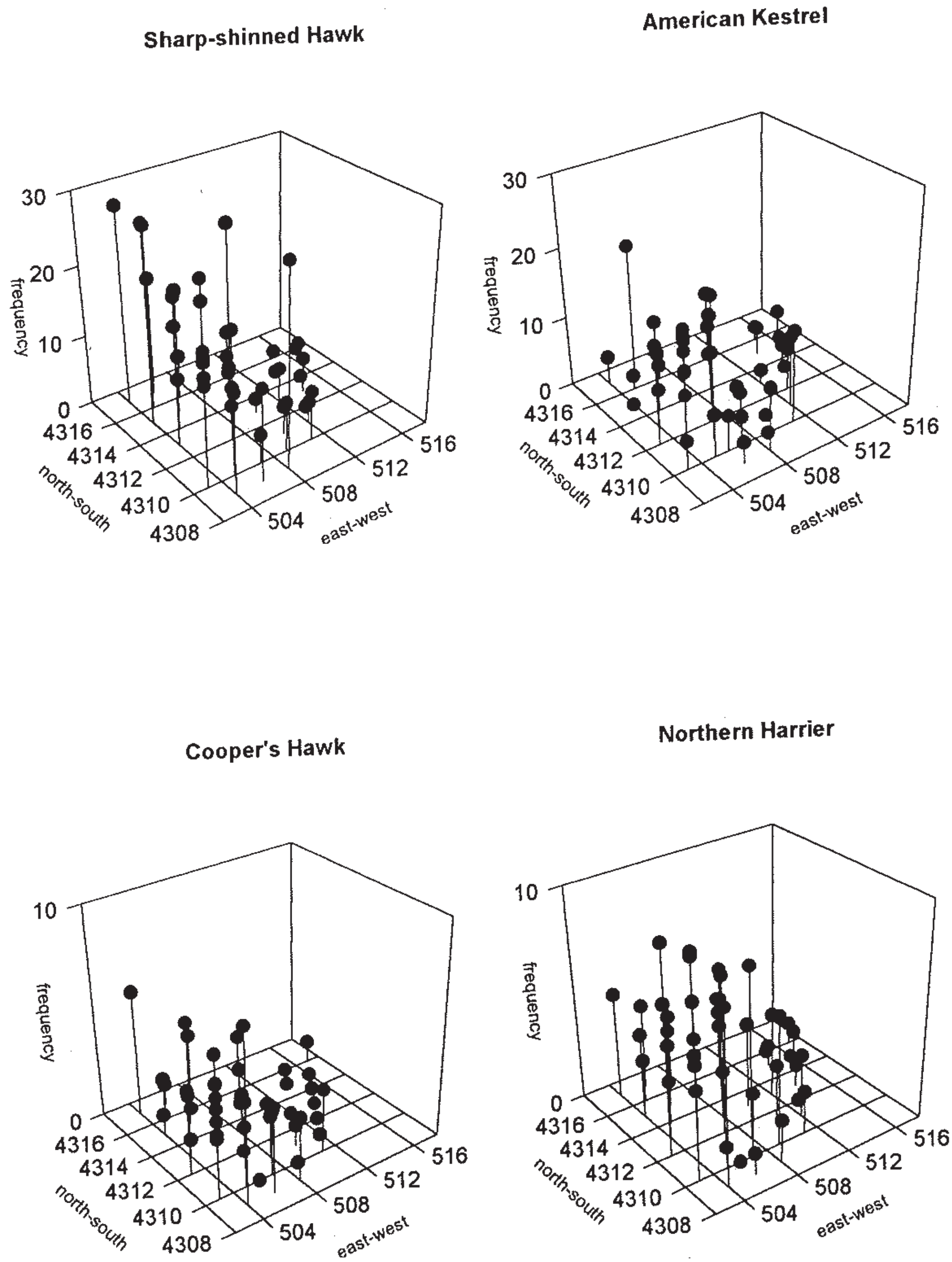
Table 5 . Habitats selected by 9 species of migrating raptors seen within the lower ten km of the Cape May peninsula in 1988. Given are Chi square value, p values and the direction of the habitat relationship. Core forest includes forest with an internal buffer of 100m.

Habitat	2df	Buteo species	Cooper's Hawk	American Kestrel	Northern Harrier	Osprey	Sharp-shinned	Turkey Vulture
Forest	ChiSquare	13.96					12.04	11.28
	P	0.001↑					0.002 ↑	0.004↑
Field	ChiSquare	13.43					5.07	
	P	0.001↑					0.08↑	
Marsh	ChiSquare				2.96			
	P				0.09↑			
Core Forest	ChiSquare	14.29					11.37	5.93
	P	0.001↑					0.001↑	0.05↑
Edge	ChiSquare			4.55		3.45	7.53	18.84
	P			0.03↑		0.06↑	0.006↑	0.001↑
Water	ChiSquare	7.74	5.98	6.11			16.65	13.16
	P	0.021↓	0.05↓	0.05↓			0.001↓	0.001↓
Development	ChiSquare	22.58		6.57		4.74	28.62	30.07
	P	0.001↓		0.03↓		0.09↓	0.001 ↓	0.001↓

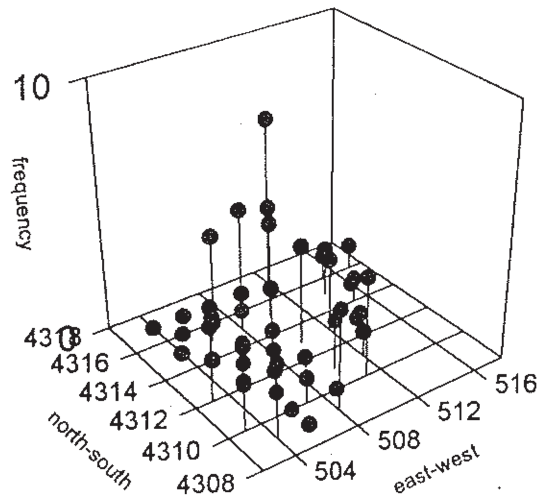
Fig. 1. The location of the study are in the lower 10 km of the Cape May Peninsula.


DELAWARE
BAY
CAPE MAY PENINSULA
ATLANTIC
OCEAN
0 2 4 6 Kilometers
10 km

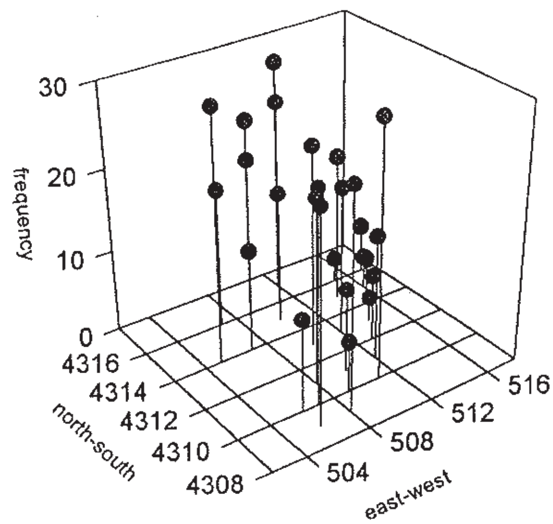
Figs. 2-9. Distribution and frequency of birds observed at each site surveyed in the lower ten km area of the Cape May peninsula in 1988. The x axis is the east-west UTM coordinate, the y axis is the north-south coordinate and the z axis is the number of observed birds for all surveys combined. The survey points roughly define the lower ten km area of the peninsula as viewed from the southwest.


Sharp-shinned Hawk
American Kestrel
Cooper's Hawk
Northern Harrier
frequency
north-south
east-west
0
10
20
30
4316
4314
4312
4310
4308
504
508
512
516

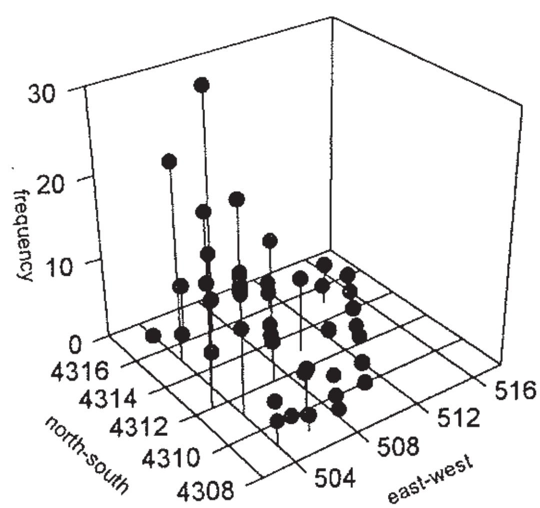
Osprey



Buteo Species



Turkey Vulture



All Species

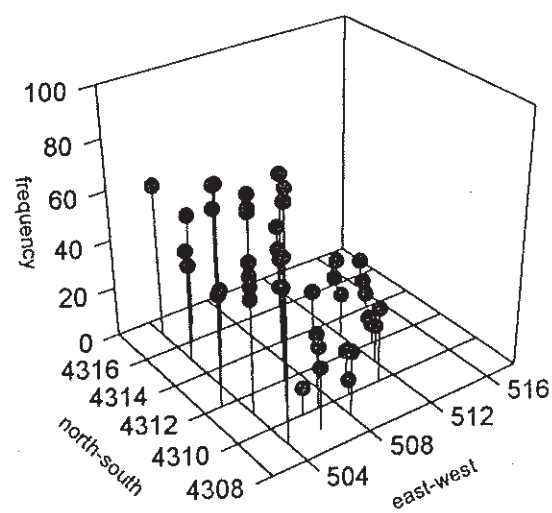
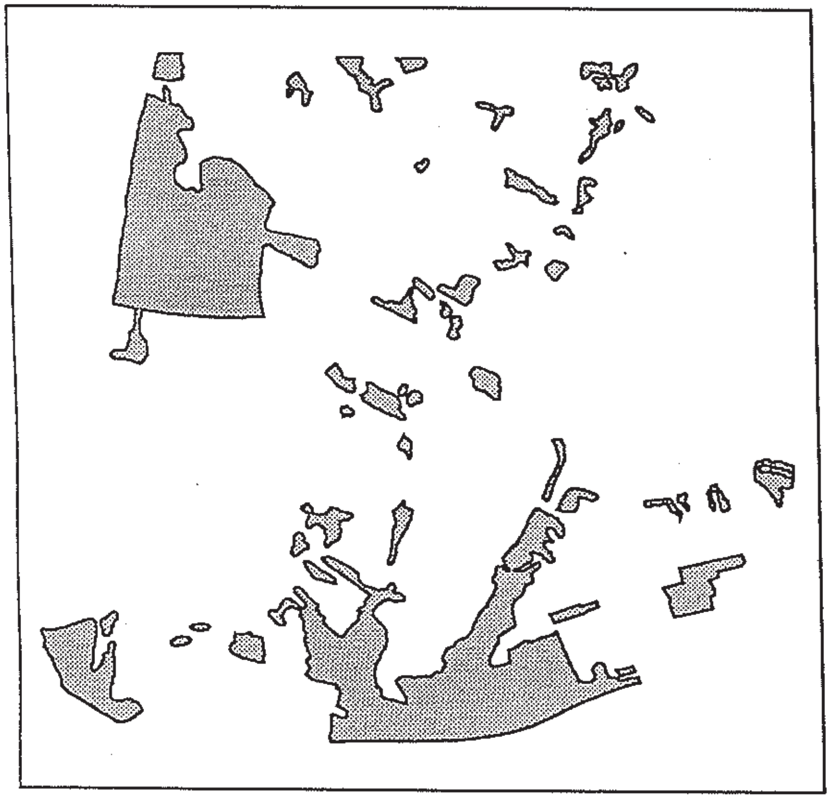
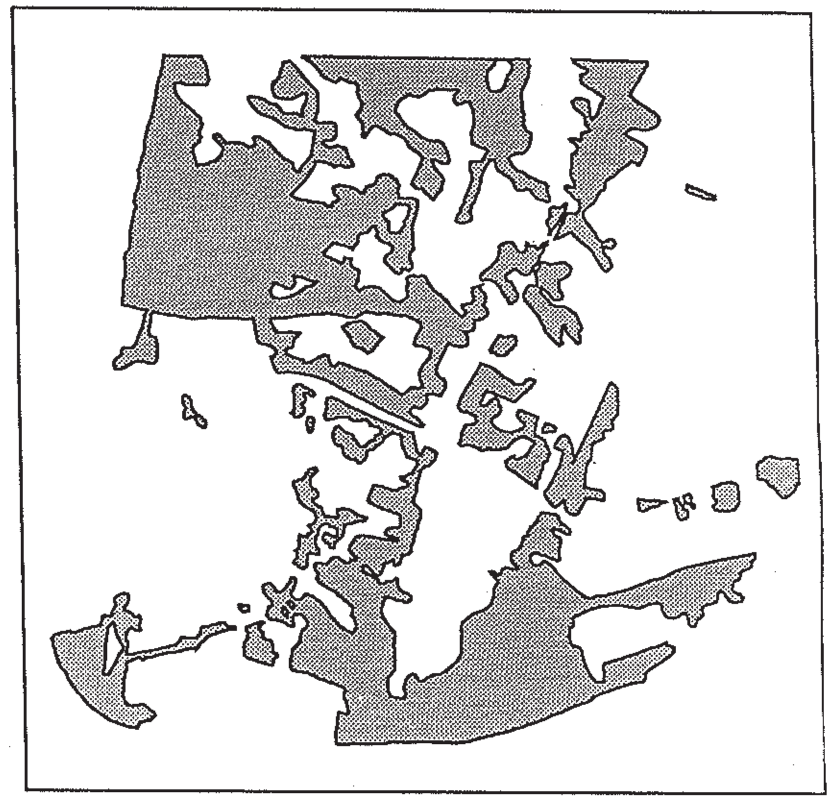


Fig. 10. The change in area of residential development between 1972 and 1992 in the lower 10 km of the Cape May Peninsula. Shaded areas represent residential development.



Cape May Point
Urban Areas 1972



Cape May Point
Urban Areas 1992

BIBLIOGRAPHY

Alerstram, T. and A. Lindstrom. 1990. Optimal bird migration: the relative importance of time, energy and safety. Pages 331 -351 in: E. Gwinner, ed., Bird Migration: The Physiology and Ecophysiology.

Allen R. P., and R. T. Peterson. 1936. The hawk migration at Cape May Point. Auk 53:393-404.

Bairlain, F. 1985. Body weight and fat deposition of palearctic passerine migrants in Central Sahara. Oecologia (Berlin) 66:141-146.

Biebach, H., W. Friedrich, and G. Heine. 1986. Interaction of body mass, fat foraging and stopover period in trans-Saharan migrating passerines. Oecologia (Berlin) 69:370-379.

Bildstein, K. L., W. S. Clark, D. L. Evans, M. Field, L. Soucy, and E. Henckel. 1984. Sex and age differences in fall migration of Northern Harriers. J. Field Ornith. 55:143-150.

Bildstein, K. L. 1987. Behavioral ecology of Red-tailed Hawks (Buteo jamaicensis), Northern Harriers (Circus cyaneus), and American Kestrels (Falco sparverius) in South Central Ohio. Ohio Biol. Survey 18:1-53.

Blem, C. 1980. The energetics of migration. In Animal Migration, orientation, and navigation, ed. S. A. Gauthreaux, Jr., pp.175-224. New York:Academic Press.

Burger, J. 1984. Abiotic factors affecting migrant shorebirds, p. 1-72. In J. Burger and B. L. Olla [eds.], Behavior of marine animals, vol. 6: Shorebirds: migration and foraging behavior. Plenum Press, New York.

Burger, J. 1986. The effect of human activity on shorebirds in two coastal bays in Northeastern U.S. Envir. Conserv. 13:123-130.

Burger J. 1988. Effects of age on foraging in birds. Acta XIX Congressus Internationalis Ornithologica. Vol I. Ed. H. Oullet. Univ. Of Ottawa Press.

Burger, J., M. Gochfeld, and L. J. Niles. 1995. Ecotourism and birds in coastal New Jersey: contrasting responses of birds, tourists, and managers. Environmental Conservation 22: 56-65.

Cherry, J. D. 1982. Fat deposition and length of stopover of migrant white-crowned sparrows. Auk 99:725-732.

Clark, W. S. 1985a. Migration of the merlin along the coast of New Jersey. Raptor Res. 19:85-93.

Clark, W. S. 1985b. The migration of Sharp-shinned Hawks at Cape May Point: banding recovery results, p. 137-148. In M. Harwood [ed.], Proc. of the Fourth Hawk Migration Conf. Hawk Migration Assoc. of North America. Medford, Massachusetts.

Cochran, W.W. 1972. A few days of fall migration of a Sharp-shinned Hawk. Hawk Chalk 11:39-44.

Cochran, W. W. 1975. Following a migrating peregrine from Wisconsin to Mexico. Hawk Chalk 14:28-37.

Cochran, W. W. 1980. Wildlife telemetry, p. 57-520. In: S. D. Schemnitz [ed.], Wildlife Management Techniques Manual. The Wildlife Society, Washington, DC.

Drost, R. 1938. Uber den Einfloss von Verfrachtungen zur Herbstzugzeit auf den Sperber Accipiter nisus (L.) Proc Int. Ornithol. Congr. 9:502-521.

Dunn, P. O., T. A. May, M. A. McCollough, and M. A. Howe. 1988. Length of stay and fat content of migrant Semipalmated Sandpipers in eastern Maine. Condor 90:824-835.

Dunne, P.J. and W.S. Clark . 1977. Fall hawk movement at Cape May Point, NJ.-1976. Rec. NJ. Birds 3:114-124.

Erlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The birder's handbook: a field guide to the natural history of North American birds. Simon and Schuster, New York.

Fischer, D. L. 1985. Piracy behavior of wintering bald eagles. Condor 87:246-251.

Gauthreaux, S. A., Jr. 1982. The ecology and evolution of avian migration systems, p. 93-167. In D. S. Farner and J. R. King [eds.], Avian Biology Vol. 6. Academic Press, New York.

Geller, G. A. and S. A. Temple. 1983. Seasonal trends in body condition of juvenile Red-tailed Hawks during autumn migration. Wilson Bull. 95:492-495.

Gessamen, J. A. and K. A. Nagy. 1988. Transmitter loads affect the flight speed and metabolism of homing pigeons. The Condor 90:662-668.

Greenberg, R. 1982. Competition in migrant birds in the nonbreeding season, p. 281-307. In R. F. Johnston [ed.], Current Ornithology, Vol. 5. Plenum Press, New York.

Greenberg, R. 1987. Competition in migrant birds in the nonbreeding season, p. 281-307. In R. F. Johnston [ed.], Current Ornithology, Vol. 5. Plenum Press, New York.

Grubb, T.G., W.W. Bowermann and P.H. Howey. 1994. Tracking local and seasonal movements of wintering Bald Eagles (Haliaeetus leucocephalus) from Arizona and Michigan with Satellite Telemetry. In: Raptor Conservation Today. Meyburg, B.U. and R. D. Chancellor, eds. WWGRB\The Pica Press.

Gustafson, M. 1986. Fall passerine banding project. Peregrine Observer 8(1):7-9.

Hall L.S., A.M. Fish and M.L.Morrison. 1993. The Influence of weather on hawk movements in coastal Northern California. Wilson Bull. 104(3):447-461.

Hamerstrom, F. N., and M. Kopeny. 1981. Harrier nest site vegetation. Raptor Res. 15:86-88.

Heintzelman, D. S. 1986. The migrations of hawks. Indiana University Press, Bloomington, Indiana.

Hiraldo, F., J. A. Donazar, and J. J. Negro. 1994. Effects of tail-mounted radio-tags on adult lesser kestrels. J. Field Ornithology 65(4):466-471.

Holthuijzen, A. M. A., L. Oosterhuis, and M. R. Fuller. 1982. Habitat use of migrating immature female Sharp-shinned Hawks (Accipiter striatus) at Cape May Point, New Jersey, U.S.A., p. 1-18. In R. D. Chancellor [ed.], Proc. of the World Conference on Birds of Prey, Thessaloniki, Greece, April 26-29, 1982. Internat. Council for Bird Preserv.

Hutto, R. L. 1985. Habitat selection by nonbreeding, migratory land birds, p. 455-473. In M. L. Cody [ed.], Habitat selection in birds. Academic Press, New York.

Janes, S. W. 1984. Influences of territory composition and interspecific competition on Red-tailed Hawk reproductive success. Ecology 65:862-870.

Joy, S.M. 1990. Feeding ecology of Sharp-shinned Hawks and nest site characteristics of accipiters in Colorado. M.Sc. thesis. Colorado State Univ., Fort Collins, CO.

Keast, A. 1980. Migratory parulidae: what can species co-occurrence in the North reveal about ecological plasticity and wintering patterns?, p. 457-476. In K. A. Morton, ed. Migrant birds in the neotropics. Smithsonian, Washington, DC.

Kenward, R. E. 1978. Radio transmitters tail mounted on hawks. Ornis Scandinavica 9:220-223.

Kenward, R. E. 1990. Ranges IV. Software for analysing animal location data. Institute of Terrestrial Ecology, Wareham, UK.

Kerlinger, P. 1984. Flight behavior of Sharp-shinned Hawks during migration. 2. Over water. Anim. Behav. 32:1029-1034.

Kerlinger, P., and S. A. Gauthreaux, Jr. 1984. Flight behavior of Sharp-shinned Hawks during migration. 1. Over land. Anim. Behav. 32:1021-1028.

Kerlinger, P. 1985. Water-crossing behavior of raptors during migration. Wilson Bull. 97:109-113.

Kerlinger, P., V. P. Bingman, and K. P. Able. 1985. Comparative flight behavior of migrating hawks studies with tracking radar during autumn in central New York. Can. J. Zool. 63:755-761.

Kerlinger, P. 1989. Flight strategies of migrating hawks. University of Chicago Press, Chicago, Illinois.

Kerlinger P. 1993. Sharp-shinned hawk populations in a free fall. Peregrine Observer 15:1-2.

Ketterson E. D., and V. Nolan. 1982. The role of migration and winter mortality in the life history of a temperate-zone migrant, the Dark-eyed Junco, as determined from demographic analysis of winter populations. Auk 99:243-259.

Krohn, W. B., J. C. Rieffenberger, and F. Ferrigno. 1977. Fall migration of woodcock at Cape May, New Jersey. J. Wildl. Manage. 41:104-111.

Lyons, J. E., and S. M. Haig. 1995. Fat content and stopover ecology of spring migrant semipalmated sandpipers in South Carolina. The Condor 97:427437.

Mabey, S. E., J. McCann, L. J. Niles, C. Bartlett, and P. Kerlinger. 1992. Neotropical migratory songbird regional coastal corridor study. Final Report. National Oceanic and Atmospheric Administration.

Marquiss, M. and I. Newton. 1981. A radio-tracking study of the ranging behaviour and dispersion of European sparrowhawks (Accipiter nisus). J. Anim. Ecol. 51:111-133.

Masman, D., and M. Klaassen. 1987. Energy expenditure during free flight in trained and free-living European Kestrels (Falco tinnunculus). Auk 104: 603-616.

Matray, P. F. 1974. Broad-winged Hawk nesting and ecology. Auk 91:307-324.

McCann, J. M., S. E. Mabey, L. J. Niles, C. Bartlett, P. Kerlinger. 1993. A regional study of coastal migratory stopover habitat for Neotropical migrant songbirds: land management implications. Trans. N. A. Wildl. and Natural Resour. Conf. 58:398-407.

Mills, G. S. 1976. American kestrel sex ratios and habitat separation. Auk 93:740-748.

Moore F., and P. Kerlinger. 1987. Stopover and fat deposition by North American wood warblers (Parulinae) following spring migration over the Gulf of Mexico. Oecologia (Berlin) 74:47-54.

Moore, F.R., P. Kerlinger and T. R. Simons. 1990. Stopover on a Gulf coast barrier island by spring trans-Gulf migrants . Wilson Bull. 102: 487-500.

Moore F.R. and W. Yong. 1991. Evidence of food-based competition among passerine migrants during stopover. Behav. Ecol. Sociobiol.28:85-90.

Moore, F. R., and T. R. Simons. 1992. Habitat suitability and stopover ecology of neotropical landbird migrants, p. 345-355. In J. M. Hagan and D. W. Johnston, eds., Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, DC.

Moore, F. R., S. A. Gauthreaux, Jr., P. Kerlinger, and T. R. Simons. 1993. Stopover habitat: Management implications and guidelines, p. 58-69. In D. Finch and P. Stangel. (eds), Status and management of neotropical migratory birds. USDA Forest Serv. General Technical Rep. RM-229.

Morrison, R. I. G. 1984. Migration systems of some New World shorebirds, p. 125-202. In J. Burger and B. L. Olla [eds.], Behavior of marine animals, Vol. 6: Shorebirds: migration and foraging behavior. Plenum Press, New York.

Mueller, H. C., and D. D. Berger. 1967a. Fall migration of Sharp-shinned Hawks. Wilson Bull. 79:397-414.

Mueller, H. C., and D. D. Berger. 1967b. Wind drift, leading lines, and diurnal migrations. Wilson Bull. 79:50-63.

Murray, B. G., Jr. 1969. Sharp-shinned Hawk migration in the northeastern United States. Wilson Bull. 81:119-120.

Murray, B. G., Jr. 1964. A review of Sharp-shinned Hawk migration along the northeastern coast of the United States. Wilson Bull. 76:257-264.

Murray, B.G. Jr., and J.R. Jehl Jr. 1964. Weights of autumn migrants from coastal New Jersey. Bird Banding 35:253-263.

Myers, J. P., P. G. Connors, and F. A. Pitelka. 1979. Territoriality in non-breeding shorebirds. Studies in Avian Biol. 2:231-246.

Myers, J. P., and B. McCaffrey. 1984. Paracas revisited: do shorebirds compete on their wintering grounds? Auk 101:197-199.

Myers, J. P., R. I. G. Morrison, P. Z. Antas, B. A. Harrington, T. E. Lovejoy, M. Sallaberry, S. E. Senner, and A. Tarak. 1987. Conservation strategy for migratory species. Amer. Scientist 75:19-26.

Neu C.W., C.R.Byers, J.M. Peek. 1974. A technique for analysis of utilization-availability data. J.Wildl. Mange.38(3):541-545.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD.

Niles, L. J., J. Burger, and K. E. Clark. 1996. The influence of weather, geography and habitat on migrating raptors on Cape May Peninsula. Condor 98:383-395.

Page, G., and D. F. Whitaker. 1975. Raptor predation on wintering shorebirds. Condor 77:73-83.

Perdeck, A. C. 1958. Two types of orientation in migrating starling, Sturnus vulgaris L., and chaffinches, Fringilla coelebs L., as revealed by displacement experiments. Ardea 46:1-37.

Poole, A. F. 1989. Ospreys: a natural and unnatural history. Cambridge University Press, Cambridge, England.

Preston, C. R. 1990. Distribution of raptor foraging in relation to prey biomass and habitat structure. Condor 92:107-112.

Rappole, J. H., and D. W. Warner. 1976. Relationships between behavior, physiology, and weather in avian transects at a migration stopover site. Oecologia 26:193-212.

Reynolds, R. T., G. Meslow, and H. M. Wight. 1982. Nesting habitat of coexisting accipiters in Oregon. J. Wildl. Manage. 46:124-138.

Rich, A. C., D. S. Dobkin, and L. J. Niles. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conserv. Biol. 8:1109-1121.

Rosenfield, R. N., and J. Bielefeldt. 1993. Cooper's Hawk. In: A. Poole and F. Gill [eds.], The Birds of North America, No. 75. Philadelphia Academy of Natural Science.

Safriel, U. N., and D. Lavee. 1988. Weight changes of cross-desert migrants - do energetic considerations alone determine the length of stopover? Oecologia (Berlin) 76:611-619.

SAS Institute. 1985. SAS/STAT Guide for personal computers. Version 6 edition. SAS Institute, Inc. Cary, NC.

SAS Institute. 1989. SAS/STAT Guide for personal computers. Version 6 edition. SAS Institute, Inc. Cary, NC.

Schmutz J. K., and R. W. Fyfe. 1987. Migration and mortality of Alberta Ferruginous Hawks. Condor 89:169-174.

Schneider, D. C., and B. A. Harrington. 1981. Timing of shorebird migration in relation to prey depletion. Auk 98:801-811.

Skagen, S. K., and F. L. Knopf. 1994. Residency patterns of migrating sandpipers at a midcontinental stopover. Condor 96:949-958.

Smith, N.G., D.L. Goldstein, and G.A. Bartholomew.1986. Is long-distance migration possible for soaring hawks using only stored fat? Auk 103:607-611.

Terrill, S., and R. D. Ohmart. 1984. Facultative extension of fall migration of Yellow-rumped Warblers (Dendroica coronata). Auk 101:427-438.

Toland, B. 1986. Hunting success of some Missouri raptors. Wilson Bull. 8:116-125.

Torok, L. 1995. Protocols for the establishment of exceptional resource value wetlands pursuant to the Freshwater Welands Protection Act (NJSA 13:9B-1 et. Seq.) based on documentaition of state or federal endangered or threatened species. NJ Dept. Of Environ. Protection. 152 p.

Weidner, D. S., and P. Kerlinger. 1990. Economics of birding: a national survey of active birders. American Birds 44: 209-213.

Wiedner D.S., P. Kerlinger, D.A. Sibley, P. Holt, J. Hough,and R. Crossley. 1992. Visible morning flights of neotropical landbird migrants at Cape May, New Jersey. Auk 109:500-510.

Winker, K., D. KW. Warner, and A. R. Weisbrod. 1992. Migration of woodland birds at a fragmented inland stopover site. Wilson Bull. 104(4):580-598.

Zar, J. H. 1988. Biostatistical analysis. Second edition. Prentice Hall, Englewood Cliffs, NJ.

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