A COMPARISION STUDY OF MIGRATORY RAPTOR DISTRIBUTION AND HABITAT USE AT THE CAPE MAY PENINSULA STOPVER

by

Cristina A. Frank

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ABSTRACT OF THE THESIS

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Stopover habitats must provide sufficient resources for migratory birds to rest and refuel before negotiating ecological barriers and continuing migration. The pressure of finding suitable habitat intensifies when migrants encounter stopovers that have been degraded by human activities. There is limited documentation of how migrants respond to altered landscapes. This comparison study evaluated potential relationships between changes in habitat use and distribution of migratory raptors and changes in the landscape at Cape May Peninsula, New Jersey by replicating point count surveys originally conducted in the late 1980s. This valuable coastal stopover provides resources for fall migrants as they prepare to cross the 18km-wide Delaware Bay. Habitat loss and degradation has occurred throughout the Cape May Peninsula with the greatest losses occurring in the lower 10km. Migratory raptors concentrated near their crossing point in the lower 10km in all survey years, however in 2002, there was a significant decline in the number of raptors observed in this region of the peninsula. Raptors were more evenly distributed throughout northern regions of the study area suggesting that migrants are extending their search for suitable stopover habitat into areas of the peninsula where availability is greater. Coupled with accelerated habitat loss within the concentration area between the survey periods, our data suggest that raptors are responding to the degraded landscape by exhibiting greater variation in habitat use, weaker relationships with specific habitat types, spending more time using habitat and are utilizing portions of the peninsula outside of the traditional concentration area. These results identify the need for conservation and protection of priority stopover areas and a diversity of habitats throughout the entire Cape May stopover, including the expansion of regulatory protection for habitats as far north as 20km from the lower 10km concentration area of the peninsula. This study also suggests that habitat at both the local and landscape levels influence habitat use

and distribution at Cape May Peninsula.

Acknowledgements

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My thesis is dedicated to my grammy, Florence Ruth MacNeill, who taught me the importance of strength and determination through all of life's chapters.

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INTRODUCTION

The arrival of many migrants to overwintering and breeding sites and the physical condition in which they arrive relies heavily on the selection of favorable stopover habitat encountered while en route (Moore and Kerlinger 1987, Myers et al. 1987, Moore et al. 1993, Niles et al. 1996). Moore and Aborn (2000) define a stopover site as “any place where a migratory bird pauses for some length of time between migratory flights.” During migration “pauses,” birds use habitat for resting, roosting and foraging (Greenberg 1987, Moore and Kerlinger 1987, Niles et al. 1996, Moore and Aborn 2000). Recent studies of avian migration have identified patterns of habitat use at stopover sites (Greenberg 1987, Moore and Kerlinger 1987, Niles et al. 1996, Moore and Aborn 2000, Petit 2000). Evidence suggests that these patterns evolve as migrants select among habitats with environmental components crucial to improving body condition (Niles et al. 1996, Moore and Aborn 2000, Petit 2000, Simons et al. 2000). The ecological challenges and energetic demands experienced by a migrant en route will ultimately influence habitat selection (Rappole and Warner 1976, Blem 1980, Moore 1991, Simons et al. 2000). These problems intensify when a migrant is forced to confront an ecological barrier such as a mountain range, urban, arid or agricultural landscape or a large water body (Barrow et al. 2000). Habitats adjacent to ecological barriers have been recognized as critical stopovers for migrants that concentrate there before making the energetically demanding cross (Sprunt 1975, Moore et al. 1993, Barrow et al. 2000). It is also within these habitats that migrants are further challenged by the effects of a rapidly growing human population. The response of migrants to increasingly degraded landscapes encountered en route is as understudied as its subsequent effects on their survival throughout migration (Parker 1994). An understanding of migrants’ preferences for stopover habitat and the factors affecting the selection process, therefore, must be considered when developing conservation strategies and regulations for migratory birds. Despite the documented value of stopover areas to migrants, little is known of the biotic factors affecting bird distribution and habitat use within stopovers. In particular, studies of raptors have focused primarily on abiotic factors such as weather, migratory routes and methods of orientation and navigation (Kerlinger 1989).

In the late 1980s Niles et al (1996) conducted two studies that examined the distribution and influence of abiotic (weather and geography) and biotic (habitat use) factors on migratory raptors at the Cape May, New Jersey stopover (Figure 1). Niles et al. (1996) surveyed raptors throughout the fall migrations of 1984 and 1986 to address the relative influence of geography, wind direction, speed and habitat. This study found several species of raptors concentrating in the lower 10km of Cape May Peninsula. Radio-telemetry work conducted by Niles et al. (1996) further indicated that migrating Sharp-shinned Hawks (*Accipiter striatus)* were hunting and resting for several days while waiting for good weather to cross the Delaware Bay. To investigate raptor distribution, habitat use and selection within the concentration area, Niles et al. (1996) conducted a second set of surveys in 1988 that narrowed the study area to the lower 10km of the peninsula. Niles et al (1996) found raptors distributed throughout the concentration area using a variety of habitats and avoiding developed land. This work led to the development of a comprehensive critical areas map that identified and provided regulatory protection for migratory raptor stopover habitat within the lower 10km of Cape May Peninsula.

Development and subsequent habitat degradation and destruction throughout Cape May Peninsula have since continued at impressive rates. Between 1984 and 2001, development throughout Cape May County increased by 28% and emergent wetland, cultivated/grassland and forested habitats decreased by 2%, 30% and 3% respectively (Lathrop 2004). Within the lower 10km of the peninsula, residential development increased by 20% (Figure 2) and emergent wetland, cultivated/grassland and forested habitats decreased by 5%, 26% and 2% respectively. Development between 10 and 20km from Cape May Point increased by 26%.

Understanding how migrants respond to the degraded landscape is essential to identifying, protecting and conserving critical stopover habitat. During the fall migration of 2002, we replicated the surveys originally conducted by Niles et al. (1996) in 1984 and 1986 to investigate the influences of observed changes in the landscape on migratory raptor distribution and habitat use at this valuable stopover site. We adopted the protocol used by Niles et al. (1996) to survey raptors throughout the entire peninsula. Land cover changes between 1984 and 2001 on Cape May Peninsula, New Jersey were also quantified and compared with the point count data. Using three years of point count data and the GIS analysis of the land cover types in Cape May Peninsula, the following questions assessing changes in migratory raptor habitat associations and distribution were addressed: 1) Has the landscape of Cape May Peninsula changed between the survey periods? 2) Are migrating raptors distributed differently between survey periods? 3) Have the relationships between raptors and land cover types changed?

METHODS

The study area consists of the entire Cape May Peninsula located at the southern tip of New Jersey (Figure 1). The peninsula is bordered on the west by the Delaware Bay and on the east by the Atlantic Ocean. From its southern tip (38 57' lat., 74 53' long.), the peninsula extends approximately 60km north along the Atlantic coast and approximately 40km north on along the Delaware Bay coast. The peninsula is about 10km wide at its northernmost point and includes a wide range of habitats. Lathrop (2004) reported that upland forest (18%), emergent marsh (23%), palustrine wetland (21%) and cultivated/grassland (6%) habitats comprised 68% of Cape May County's habitat in 2001. Residential development (18%), open water (8%), bare land (1%) and beach (5%) accounted for the remaining area. The northern end of the peninsula includes the pitch pine (*Pinus rigida*) dominated forests of the New Jersey Pine Barrens. Upland areas are vegetated with white oak (Quercus alba)-pitch pine forests interspersed with fields of red cedar (*Juniperus virginiana*) and other successional species. A large portion of the peninsula is comprised of tidal emergent wetlands and freshwater wetlands. The majority of tidal areas are salt marshes dominated by *Spartina alterniflora* and *Spartina patens*. Freshwater wetlands include red maple (*Acer rubrum*), black gum (*Nyssa sylavtica*) and Atlantic white cedar (*Chamaecyparis thyoides*).

We replicated the methods of (Niles et al. 1996) which included point count surveys of migratory raptors conducted at 24 points located within 10km increments of distance from Cape May Point in forest, field and marsh habitats All points were located within one kilometer of four east-west UTM lines. The first line was located one kilometer from the southern tip of the peninsula with each subsequent line 10 kilometers north of the last. These lines were then divided into a Delaware Bay and Atlantic Ocean side and three survey points, one in each of three randomly selected areas of habitat including marsh, field and forest, were placed on either side for each of the four UTM lines. Forested sites had to allow views in all directions of at least 10km. Each observer surveyed six of 24 points for 30 minutes each. All observers, points and starting times were staggered to avoid observer and temporal biases. To account for the smaller viewing area at forested survey locations, densities were calculated using a 150m radius (7.1 hectares) (Niles et al. 1996). Densities for marsh and field habitats were calculated using a 300m radius (28.3 hectares).

For all surveys, skilled observers identified up to 15 species of raptors, noting their flight direction, distance, altitude and behavior. Eight behaviors were recorded including perching, hovering, milling, kettling (circling to gain altitude), direct high flight, direct low flight, interaction with a conspecific and interaction with another species. Observers also indicated if the birds were hunting. Flight direction was summarized by combining directions into southbound (S, SW, SE, W) and northbound (N, NE, NW, E) trajectories. For analyses, summarized flight direction data and observed behaviors were used to define three behavior categories. Migratory behavior includes observations of raptors flying south at ≥30m, non-migrating behavior includes raptors flying north at ≥30m and habitat-using behaviors includes raptors flying, milling or hovering in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors.

Prior to the survey period, observers were trained to estimate distance and altitude with a Rangematic rangefinder. Observers also used reference points of known distances and heights established at each survey location to assist with estimating bird height and distance. Wind direction, wind speed and temperature were also collected during the survey period from National Oceanographic and Atmospheric Administration (NOAA) taken at the Cape May County Airport. All surveys were conducted between 08:00 and 13:00 hours.

To investigate the influences of land cover changes on migratory birds within the Cape May Peninsula stopover, land cover types and land cover changes were quantified for Cape May Peninsula using a 1984 Level 3 Land Cover Classification and a 2001 Level 1 Landsat 7 ETM+ Satellite Image Land Cover Classification of New Jersey (Lathrop 2004). The 1984 classification was created by the Grant F. Walton Center for Remote Sensing and Spatial Analysis (CRSSA) from a composite data set of September and November Normalized Difference Vegetation Index (NDVI), Landsat Thematic Mapper Band 5 and wetland and housing data layers (Hasse and Lathrop 2001). The 2001 Landstat satellite image land cover classification was generated by CRSSA as an update to a 1995 land cover classification. The update utilized various standard change detection/mapping techniques and the 1994/1995 Landstat TM imagery data as a baseline (Lathrop 2004). The land cover mapping was completed at the most generalized level, Level I, with 8 classes: Developed (4 classes of developed: 1) High Intensity (>75% impervious surface (IS)), 2) Medium intensity (50-75% IS), 3) Low intensity (<50% IS) wooded, 4) Low intensity un-wooded, Cultivated/Grassland, Upland Forest, Barren, Marine/Estuarine Unconsolidated Shoreline, Estuarine Emergent Wetland/Marsh, Palustrine Wetland and Water. For the purposes of this research, the 1984 Land Cover Classification was generalized to a Level 1 Classification and the four developed classes were merged into one class. Land cover changes were calculated for each of the four 10km interval of the study area (Figure 2).

All data were analyzed using JMP 7.0 (SAS 2007) and the Statistical Analysis System (SAS) for Windows 9.1 (SAS 2003). The results of each survey were summarized and used for reporting the mean number and mean altitude of observed raptors (Table 1). Relative abundance (mean number of individuals per survey) and density data (summarized by all surveys conducted in each habitat type) was employed in all within year analyses. Within year analyses included ANOVAs to test the influence of location by 10km interval and ANOVAs of distribution among the three habitat types surveyed. Relative abundance and density data was further summarized over all surveys conducted at each point to account for the variation in the number of surveys between years. These data were used within ANOVA to test for differences in distribution and habitat use between years. Unsummarized frequency and behavior data was used to evaluate variations in raptor behavior throughout the survey periods. The Brown and Forsythe's Variant of the Levine's Test, the F-test for homogeneity of variances (Wilks-Shapiro test) and the studentized residual test were applied to the data to test for model assumptions. To meet the normality assumptions of statistical tests, the data were log-transformed (Oehlert 2000). The sequential Bonferroni technique was employed to adjust for the large number of tests included in all groups of analyses (Holm 1979, Rice 1989). This nonparametric method corrects for the group-wide type-I error rate by adjusting the significance level with the number of tests (Rice 1989). For this study, significance is reported with an asterisk at the 5% level which has been adjusted using the sequential Bonferroni technique.

Analyses of behavior and habitat use (Figure 5 and Figure 6) examining all species as a group excluded Black Vultures and Turkey Vultures. This allowed interpretation of the results without the effects of the two species which occurred at significantly higher frequencies during surveys conducted in 2002

(Table 1). Analyses of individual species included those that occurred most frequently throughout survey years: Cooper's Hawk *(Accipiter cooperii*), Northern Harrier (*Circus cyaneus*), Osprey (*Pandion haliaetus*), Sharp-shinned Hawk, Red-tailed Hawk (*Buteo jamaicensis*) and Turkey Vulture (*Cathartes aura*).

RESULTS

Land Cover Changes

Land cover totals between 1984 and 2001 revealed habitat loss throughout the study area with the greatest percent loss (16%) occurring at the southern most tip of the peninsula (Figure 2). Increases in developed land occurred throughout all zones of the study area with the greatest increases occurring in the northern regions. Cultivated/grassland habitat declined most dramatically throughout the entire peninsula with 26% loss within the lower 10km, 35.3% loss between 10 and 20km from Cape May Point, 28.7 % loss between 20 and 30km from the Point and 28.9% loss between 30 and 40km from the Point. Upland forest experienced the greatest declines within 20 and 30km from the Point (6.5%) and approximately 5.2% of emergent wetland habitat was lost within the lower 10km.

Distribution and Abundance

Fifteen species of raptors were observed during surveys conducted during the fall of 1984, 1986 and 2002. Analysis was confined to the six most abundant species observed during each survey year: Cooper’s Hawk, Northern Harrier, Osprey, Red-tailed Hawk, Sharp-shinned Hawk and Turkey Vulture (Table 1, Figure 3). In 1984, 470 raptors were observed over 135 surveys. In 1986, 513 raptors were observed over 116 surveys and in 2002, 1,021 raptors were observed over 330 surveys. Notable changes in counts between the survey years included a sharp decline in Sharp-shinned Hawks and increases in Turkey Vultures and Black Vultures.

Generally, the total number of birds observed increased with decreasing distance to the crossing point located at the southern most tip of the peninsula (Figure 4). In 1984 and 1986, the concentration of raptors within the lower 10km was primarily from an increase in the number of Sharp-shinned Hawks observed at the point. Of the birds observed in the lower 10km in 2002, 40% were Turkey Vultures and 30% were Sharp-shinned Hawks. Taken together, birds were distributed evenly in all zones north of the lower 10km in 2002. A similar pattern was observed in 1986. This trend was less pronounced when

Turkey Vultures were removed from the analysis. Northern Harriers and Turkey Vultures were evenly distributed throughout the peninsula during 1984 and 1986. In 2002, Northern Harriers concentrated 30-40km from the crossing point and Turkey Vultures concentrated near the point but were evenly distributed throughout northern zones. Red-tailed Hawks showed no preference for location in 2002. Cooper's Hawk and Sharp-shinned Hawks were observed in significantly greater numbers within the lower 10km of Cape May Peninsula during all study years. In 2002, however, Cooper's Hawks were observed more frequently in northern zones than in previous years.

Behavior

The frequency of behaviors varied among species and year (Figure 5). In 1984 and 1986, raptors were observed exhibiting habitat use behaviors more often than migrating or non-migrating behaviors during all survey years. In 2002, fewer birds were exhibiting habitat using behaviors than in previous years and there was greater variation in behavior overall. Taken together, approximately 54% of raptors were using habitat 1984, 86% in 1986 and 46% in 2002 (Figure 5 and Appendix A, Table 2 and Table 3). In 2002, only 19% of raptors were observed exhibiting habitat using behaviors in the lower 10km as compared with 30% and 65% in 1984 and 1986 respectively (Appendix A, Table 2). Raptors displaying using behaviors were relatively evenly distributed across the three 10km zones north of the lower 10km in 1986 and 2002 but showed greater concentration in the 10-20km zone in 2002. Northern Harriers demonstrated using behaviors most frequently in all zones of all survey years. Northern Harriers and Red-tailed Hawks showed the least variation between survey periods.

Habitat Association

Higher raptor densities were observed in grassland habitats followed by forested habitats in all survey years (Figure 6). The occurrence of raptors in grassland habitats increased with each subsequent survey year. Most species were observed in greater densities in habitats that resemble those used during the breeding season. Cooper's Hawks, Red-tailed Hawks and Sharp-shinned Hawks occurred in greater densities at forested survey locations during all survey years. Northern Harriers were observed more frequently in marsh habitat. Turkey Vultures were evenly distributed among the three habitat types in 1984 and 1986 but concentrated in forested habitats in 2002. Ospreys demonstrated variability between habitats each year with some degree of preference for marsh and forested habitats in 1984 and 2002.

DISCUSSION

Hedenstrom and Alerstam (1998) estimate that 90% of the migration period is spent at successive stopover sites where birds rest and rebuild protein and energy stores. Distribution, habitat use and behavior at stopovers result from a complex interaction of factors encountered throughout migration and within stopovers (Moore and Aborn 2000, Jenni and Schaub 2003). Weather, topography, time program, time of day, body condition and the available stopover habitat influence a migrant's decision to land at a stopover. Within a stopover, migrants are further influenced by predation, competition, habitat availability and habitat quality (Moore and Aborn 2000). Energy demands at stopovers can be double that experienced during migration as migrating individuals search an unfamiliar landscape for much needed foraging and roosting habitats (Hedenstrom and Alerstam 1998, Moore and Aborn 2000, Wikelski et al. 2003). These challenges escalate at stopovers where anthropogenic changes in the landscape are prevalent. The Cape May Peninsula, for example, is a stopover immediately adjacent to the 18km-wide Delaware Bay that hosts countless migrants every fall in a landscape degraded by rapid development.

Migratory raptors at the Cape May stopover are faced with the additional challenge of making an energetically demanding water crossing. Many raptor species readily make water crossings, including Ospreys, Merlins, Northern Harriers and Peregrine Falcons (Kerlinger et al. 1985), but must employ primarily powered flight in the absence of thermals over water. Sharp-shinned Hawks, Coopers Hawks, American Kestrels, Northern Goshawks, Vultures and many species of Buteos are reluctant to negotiate water crossings in adverse weather conditions. Many species fly back inland to utilize the resources of the peninsula as they wait for favorable weather to cross or follow the bayshore coast north in search of a narrower crossing (Allen and Peterson 1936, Kerlinger 1989, Niles et al. 1996). Primarily composed of juveniles, inexperienced and less efficient migratory raptors at the Cape May stopover are likely to be easily affected by local habitat changes and prey availability (Kerlinger 1989). They therefore must forage during migration. Raptors at this coastal stopover benefit from large numbers of similarly aged juvenile passerine and shorebird migrants (Kerlinger 1989). Though not well studied, fat deposition in migratory raptors faced with a water crossing has been documented. Clark (1985a, 1985b) readily observed fat deposition in Sharp-shinned Hawks, Cooper's Hawks, American Kestrels and Merlins at Cape May Point (Kerlinger 1989).

This research investigated the distribution, habitat use and behavior of raptors within Cape May Peninsula in an effort to accelerate our understanding of migration behavior in response to a changing landscape. Point count surveys originally conducted in the late 1980s and repeated in 2002, allowed examination of changes in distribution and habitat use throughout the peninsula. Unlike most studies of migrating birds, the influence of weather was not considered in our analyses. It was assumed that weather, namely wind direction and speed, played a significant role in the distribution and behavior of migratory raptors at this stopover but its effects are well documented.

Species Abundance

Overall counts of migratory raptors observed in the late 1980s and in 2002 revealed declining population trends in a number of species (Table 1, Figure 3). Declines in American Kestrel and Sharp-shinned Hawks numbers were observed throughout the peninsula with the greatest declines occurring in the lower 10km (Table 1, Figure 3, Figure 4). Both species show little variation in habitat use during the breeding season and may therefore be responding to a loss of grassland and forested habitats within the study area (Woltmann 2001). Approximately 26% of the grassland habitat within the lower 20km was lost between 1984 and 2001 (Figure 2). Viverette et al. (1996) attributed a reported decrease in migrating Sharp-shinned Hawks at traditional raptor-migration watch sites along Atlantic Coast to migratory short-stopping. Increases in counts of Black Vultures, Turkey Vultures and Cooper's Hawks were observed between the survey periods. These species have demonstrated variability in habitat use throughout the breeding season and have adapted fairly well to the urban landscape (Woltmann 2001). Preferable weather conditions, migration tendency and the prevalence of marsh habitat throughout Cape May Peninsula likely explain the lack of variation in counts of Northern Harriers, Osprey, Peregrine Falcons and Merlins.

Distribution

Similar to previous study years, raptors were observed throughout the peninsula but concentrated near the crossing point at Cape May Point (Figure 4). This was most consistent for Sharp-shinned Hawks and Cooper's Hawks. All species, however, were distributed more evenly throughout the northern portions of the peninsula in 2002. Cooper's Hawks, Turkey Vultures and Osprey utilized all portions of the peninsula evenly whereas less than 50% of Red-tailed Hawks, Northern Harriers and Turkey Vultures were observed within the lower 10km concentration area. This data suggests that raptors extended their distribution further north of the crossing point, perhaps deterred from using the lower peninsula by decreased habitat availability and quality resulting from the largely suburban landscape currently characterizing the lower 10km (Figure 2).

Geographic changes in patterns of migration have been detected in other studies. Many are linked to environmental changes from humans (Kerlinger 1989). Merlins breeding on Canadian Great Plains have changed their migratory behavior by shortening their migration to follow prey species. Their prey species have shifted distribution in response to granaries and exotic plant species associated with human activity. Niles et al. (1996) suggested that the need to hunt, rest or roost and consequently the need for suitable habitat affects distribution at Cape May Peninsula. Our data support this theory. As our data suggest, distribution of migratory raptors is not fixed. There can be tremendous temporal and spatial variation in distribution and habitat use between years due to weather and habitat suggesting the need for conservation of a variety of sites within stopovers to allow for variation between seasons.

Habitat Association

Raptors were most abundant in habitats that they are associated with during the breeding season but overall were distributed among forest, field and marsh habitats (Figure 6). In 2002, more raptors favored grassland habitats regardless of the considerable decrease in grassland/agriculture land cover types observed throughout the peninsula. This suggests that more raptors may be forced to concentrate in smaller, fewer habitat areas where competition between birds is greater. Red-tailed Hawks, Turkey Vultures and Cooper's Hawks demonstrated the greatest variability among habitats suggesting that these species may be capable of adapting to the changing landscape. Cooper's Hawks and to a lesser degree, Sharp-shinned Hawks, have been documented using woodlots within residential areas for roosting and foraging (Woltmann 2001). During the breeding season, Woltmann (2001) reported extensive use of densely vegetated habitat patches within residential areas by Cooper's Hawks.

In general, most species are more variable in their use of habitat during migration than during the breeding season. Variation can also occur as migrants are forced to utilize available habitats rather than preferred habitats. We suggest that raptors may be more variable in habitat use at the Cape May stopover, primarily within the lower 10km, due to the reduction in habitat availability and quality of those habitats that remain. Variation in habitat use can occur between migration seasons, years and location (Petit 2000).

This study provides evidence that warrants the conservation of a variety of habitat types and sizes including even small patches of forested and shrub-scrub habitat interspersed within residential areas.

Behavior

Many studies have suggested that certain behaviors observed during flight may serve to facilitate the location of suitable stopover habitat (Jenni and Schaub 2003). The degree to which habitat availability and other factors influencing bird migration is still uncertain, especially for raptors. Our data suggest that habitat use behaviors and migratory behaviors vary with species, location and season.

Conservation Implications

As the quality of stopover habitats decline, predation pressure, competition, time spent looking for suitable resting and feeding habitat increases. Searching for suitable habitat is costly and birds may instead decide to depart in poor condition (Jenni-Eiermann and Jenni 2003). These factors ultimately affect body-condition, timing of migration, survival rates, timing of breeding and reproductive success. This is especially important at a stopover dominated by young inexperienced birds (Kerlinger et al. 1985). This research demonstrates that habitat use and distribution within the Cape May Peninsula stopover is variable among years, species and location suggesting that conservation of a matrix of critical habitats both within the lower 10km concentration area and areas further north will benefit all species of migrants. Identification and protection of stopover habitat within this region is essential given its adjacency to an ecological barrier, the consistency of use by migrants and the certainty of extensive anthropogenic changes in the landscape. Continued research needs to evaluate conservation and land protection efforts to improve understanding of stopover ecology and to guide appropriate conservation and management strategies.

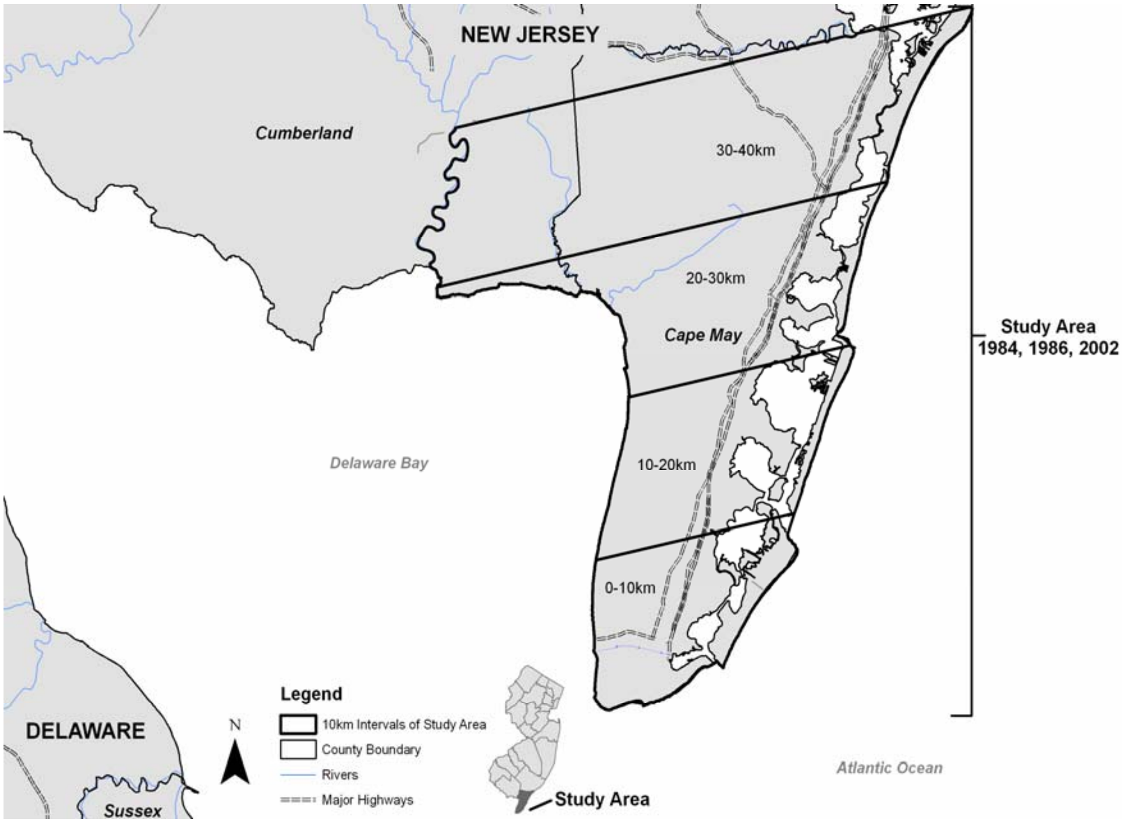

Figure 1. Map of study area located in Cape May Peninsula, New Jersey. In 1984, 1986 and 2002, point count surveys of migratory raptors were conducted at 24 points located within 10km increments of distance from Cape May Point in marsh, field and forest habitats. All points were located within one kilometer of four east-west UTM lines. These lines were then divided into a Delaware Bay and Atlantic Ocean side and three survey points, one in each of three randomly selected areas of habitat including marsh, field and forest, were placed on either side for each of the four UTM lines.

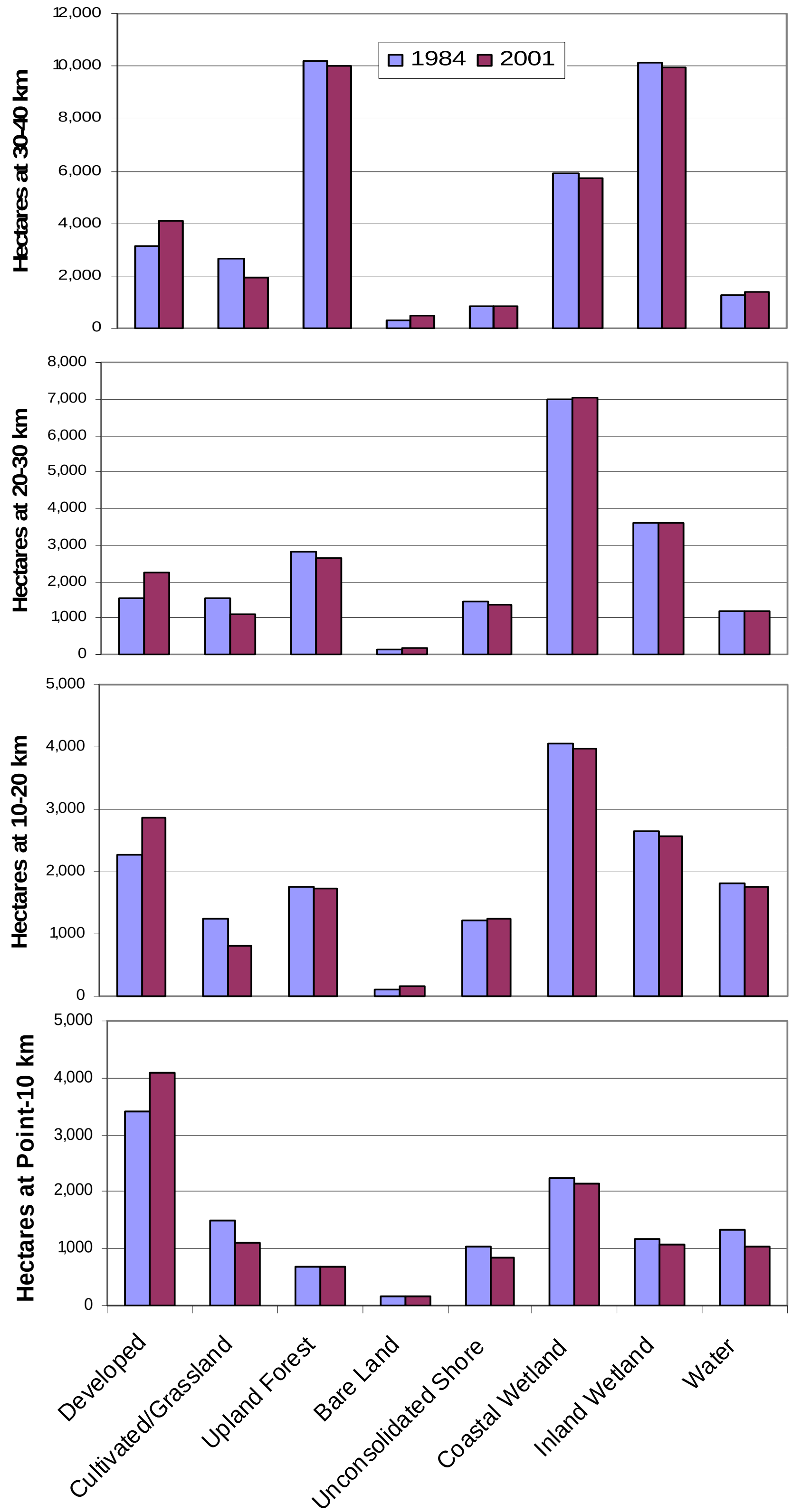

Figure 2. A comparison of the hectares of land cover classes present in 1984 and 2001 in each of four 10km intervals of Cape May Peninsula, New Jersey (Lathrop 2004).

Table 1. Total number of individuals of each species observed on Cape May Peninsula in surveys conducted during the fall of 1984, 1986 and 2002. Mean number of individuals per survey and mean altitude for each species is also reported.

SPECIES	Abundance			Mean Birds/Survey +/- S.E.			Mean Altitude +/- S.E.		
	1984	1986	2002	1984 *n=135*	1986 *n=116*	2002 *n=330*	1984	1986	2002
American Kestral (*Falco sparverius*)	15	29	19	0.11 +/- 0.032	0.25 +/- 0.035	0.06 +/- 0.021	20 +/- 6.3	11 +/- 2.2	34 +/- 13.1
Bald Eagle (*Haliaeetus leucocephalus*)	1	0	10	0.01 +/- 0.012	-	0.03 +/- 0.007	76 +/- 24.6	-	56 +/- 18.0
Black Vulture (*Coragyps atratus*)	2	2	57	0.01 +/- 0.055	0.02 +/- 0.060	0.17 +/- 0.035	50 +/- 17.4	11 +/- 8.3	28 +/- 76.0
Broad-winged Hawk (*Buteo platypterus*)	20	7	1	0.16 +/- 0.039	0.06 +/- 0.042	0.00 +/- 0.025	58 +/- 5.5	64 +/- 4.4	200 +/- 57.1
Cooper's Hawk (*Accipiter cooperii*)	22	19	100	0.16 +/- 0.057	0.17 +/- 0.062	0.30 +/- 0.037	45 +/- 5.2	14 +/- 2.7	56 +/- 5.7
Merlin (*Falco columbarius*)	7	10	18	0.05 +/- 0.023	0.09 +/- 0.025	0.05 +/- 0.015	13 +/- 9.3	16 +/- 4.2	31 +/- 13.4
Northern Goshawk *(Accipiter gentilis)*	5	0	2	0.04 +/- 0.009	-	0.01 +/- 0.006	46 +/- 11.0	-	53 +/- 40.3
Northern Harrier (*Circus cyaneus*)	34	18	53	0.25 +/- 0.048	0.16 +/- 0.052	0.16 +/- 0.030	20 +/- 4.2	12 +/- 2.8	12 +/- 7.8
Osprey (*Pandion haliaetus*)	14	46	46	0.10 +/- 0.045	0.40 +/- 0.049	0.14 +/- 0.029	35 +/- 6.6	24 +/- 1.7	39 +/- 8.4
Peregrine Falcon (*Falco peregrinus*)	4	8	4	0.03 +/- 0.019	0.07 +/- 0.020	0.01 +/- 0.012	30 +/- 12.3	18 +/- 4.2	42 +/- 28.5
Rough-legged Hawk (*Buteo lagopus*)	2	2	1	0.01 +/- 0.008	0.02 +/- 0.009	0.00 +/- 0.005	61 +/- 17.4	14 +/- 8.3	8 +/- 57.1
Red-shouldered Hawk (*Buteo lineatus*)	1	3	3	0.01 +/- 0.011	0.03 +/- 0.012	0.01 +/- 0.007	11 +/- 24.6	14 +/- 6.8	88 +/- 32.9
Red-tailed Hawk (*Buteo jamaicensis*)	19	24	92	0.14 +/- 0.055	0.21 +/- 0.059	0.28 +/- 0.035	35 +/- 5.6	31 +/- 2.4	49 +/- 5.9
Sharp-shinned Hawk (*Accipiter striatus*)	300	313	204	2.22 +/- 0.467	2.70 +/- 0.503	0.62 +/- 0.298	39 +/- 1.4	14 +/- 0.7	49 +/- 4.0
Turkey Vulture (*Cathartes aura*)	24	32	411	0.18 +/- 0.245	0.28 +/- 0.264	1.25 +/- 0.157	34 +/- 5.0	34 +/- 2.1	68 +/- 2.8
TOTAL	470	513	1021	3.49 +/- 0.615	4.42 +/- 0.663	3.09 +/- 0.393	37 +/- 2.1	17 +/- 2.0	53 +/- 1.4

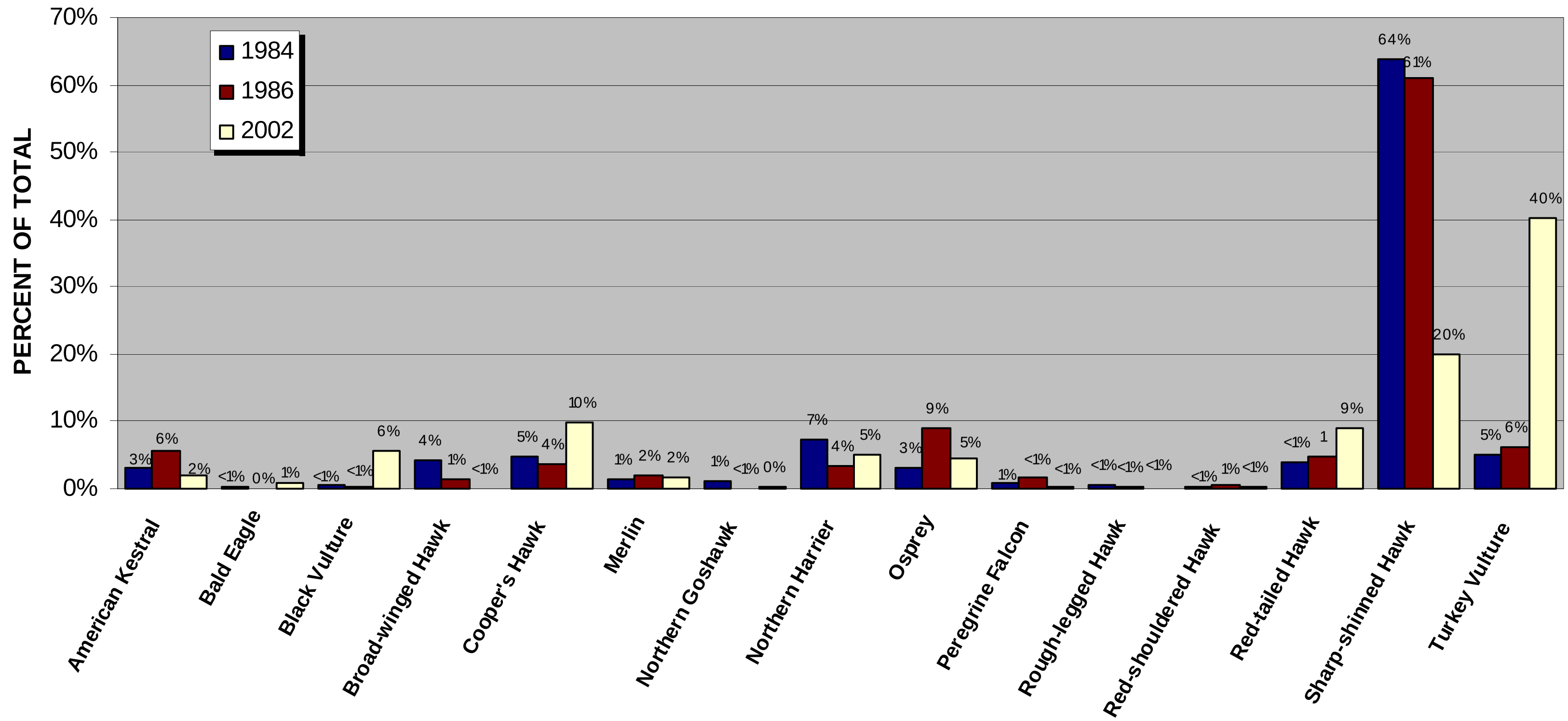

Figure 3. Percent of individuals of each species observed on Cape May Peninsula, New Jersey in surveys conducted in the fall of 1984, 1986 and 2002.

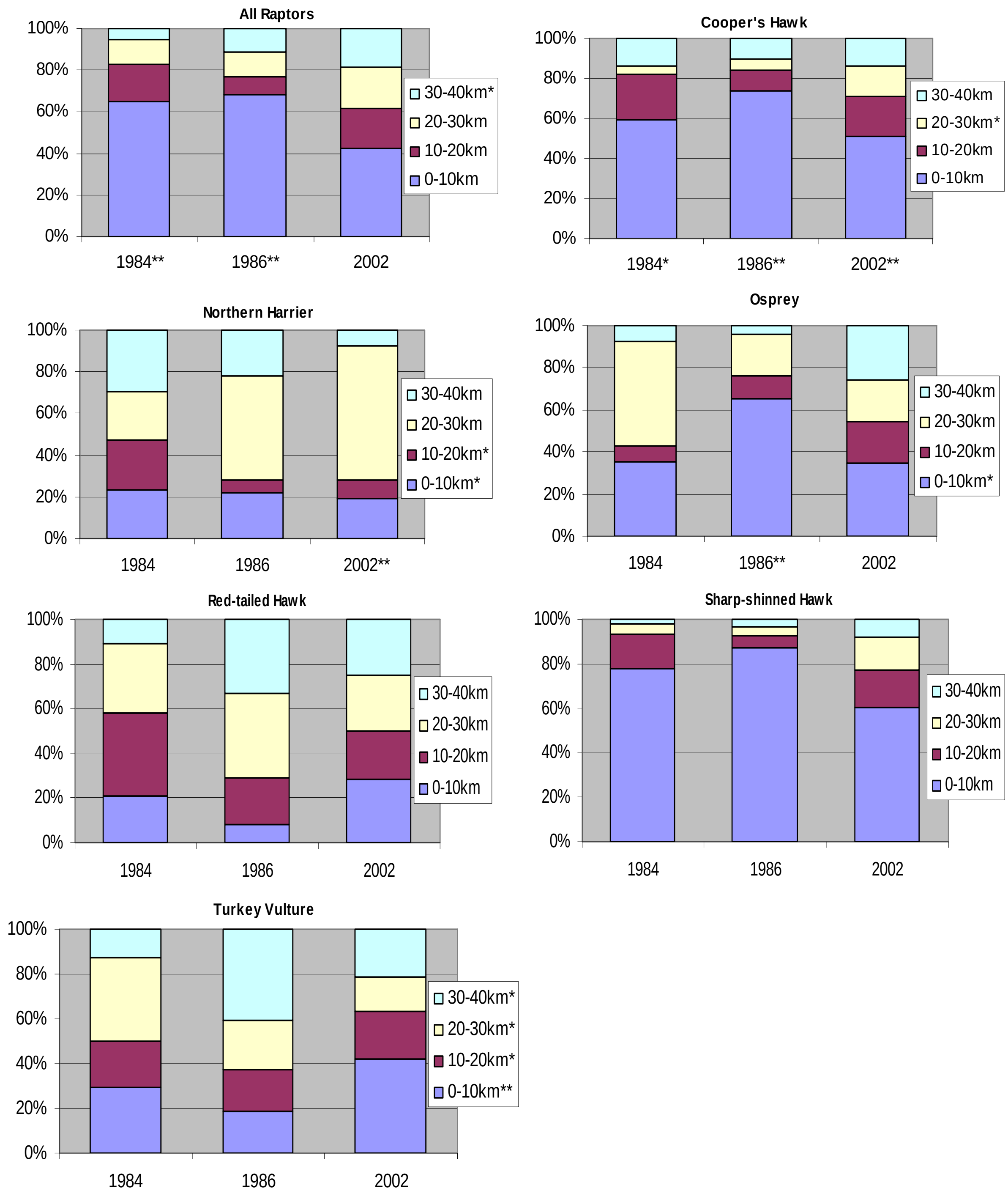

Figure 4. For each survey year, the percent of raptors observed is reported for each 10km increment of Cape May Peninsula. Significant results from an ANOVA of relative abundance observed within each year against the four increments of distance from Cape May Point are reported with an asterisk next to the survey year. Significant results from an ANOVA of relative abundance, averaged over all surveys at each point, by km across years are reported with an asterisk next to the 10km interval in the legend. Significance is reported at the 5% level with “*” which has been adjusted using the sequential Bonferroni technique. See Appendix A, Table 1 for additional results.

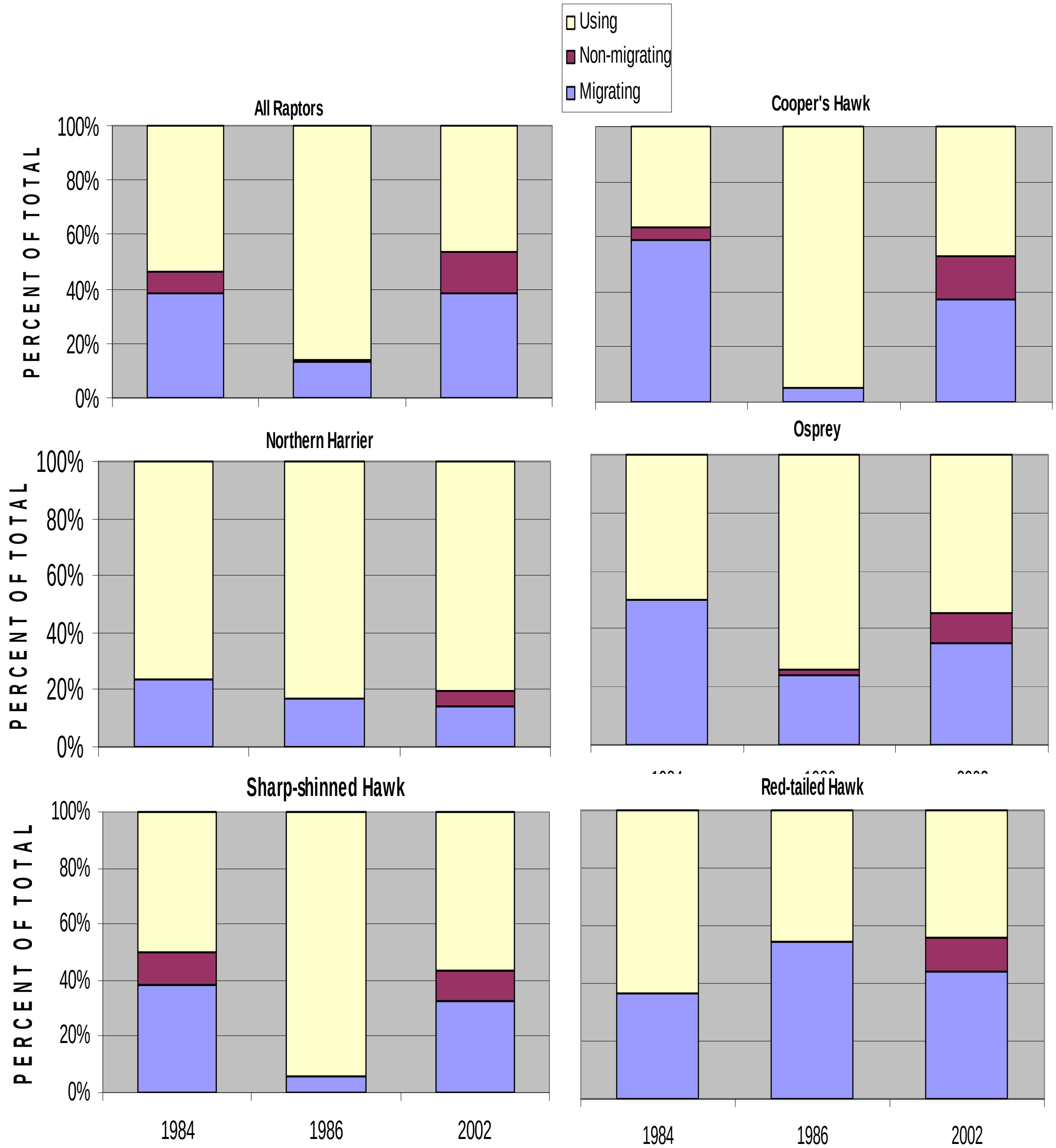

Figure 5. For each survey year, the percent of raptors exhibiting migrating, non-migrating and using behaviors is reported. Migration behavior includes observations of raptors flying south at ≥30m, non-migrating behavior includes raptors flying north at ≥30m, and habitat-using behaviors includes raptors flying in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors. See Appendix A, Table 2 and Table 3 for additional results.

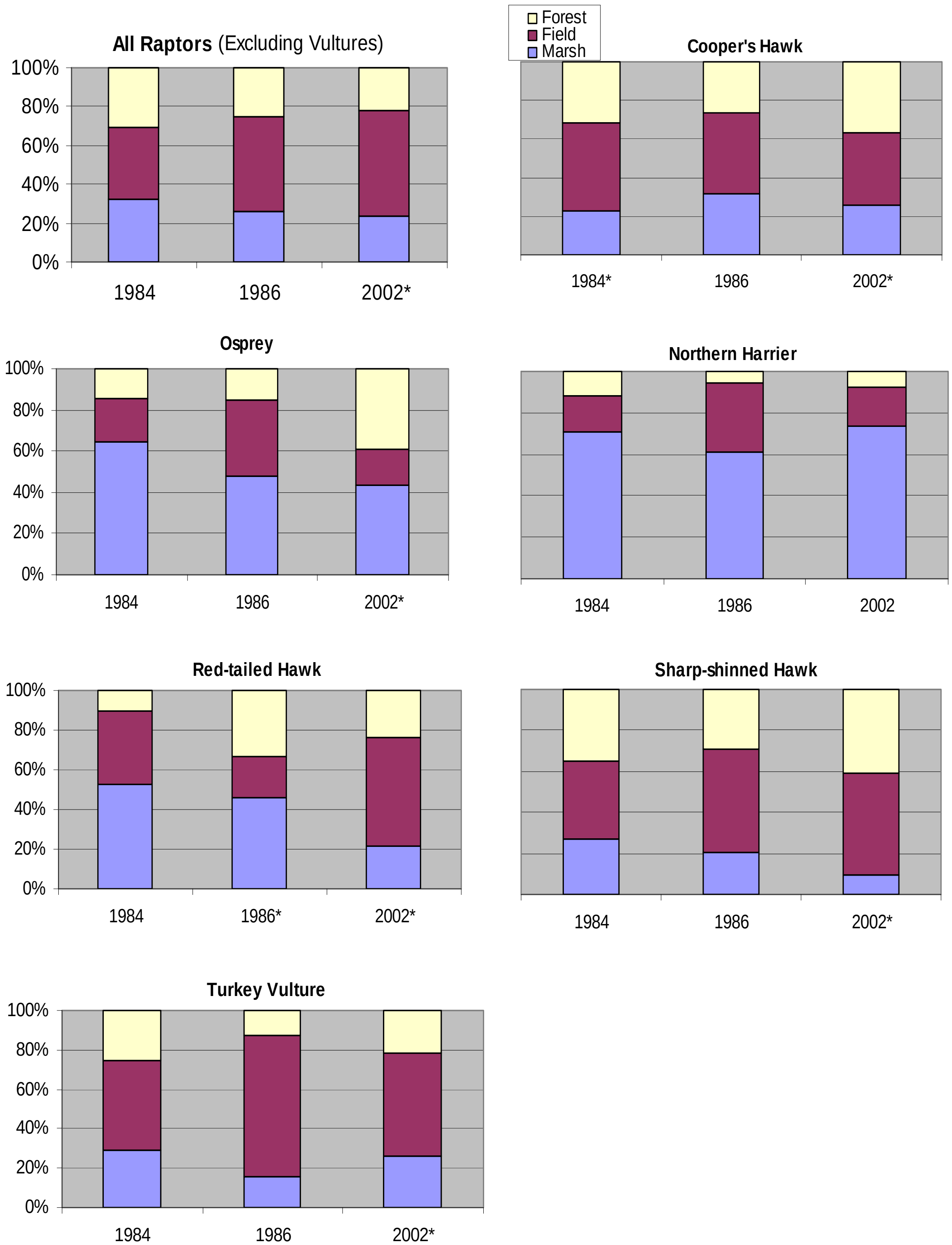

Figure 6. For each survey year, the percent of raptors observed in marsh, field and forested habitats is reported. Significant results from an ANOVA of mean density observed each year against habitat type are reported next to the survey year. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique. See Appendix A, Table 4 for additional results.

Chapter Two: Distribution and Habitat Associations of Migratory Raptors in the Cape May Stopover, New Jersey

INTRODUCTION

The Cape May Peninsula is a well-recognized, critical stopover site for fall migrants, including migratory waterfowl, shorebirds, raptors, woodcocks and neotropical migrants (Allen and Peterson 1936, Stone 1965, Krohn et al. 1977, Wiedner and Kerlinger 1990, Wiedner et al. 1992, McCann et al. 1993, Niles 1996). A migratory stopover is "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" (Morrision et al. 1992). During migration stopovers, it is essential for birds to replenish fat reserves, rest and locate cover from predators and harsh weather conditions (Biebach et al. 1986, Barlein 1987, Greenberg 1987, Moore and Kerlinger 1987, Winker et al. 1992, Moore et al. 1993, Niles et al. 1996, Moore and Aborn 2000). The ability of migrants to fulfill these requirements affects success throughout migration and at wintering grounds, and influences productivity during the breeding season (Moore and Kerlinger 1987, Myers et al. 1987, Moore et al. 1993). The ecological challenges and energetic demands experienced by migrants en route ultimately influence habitat selection (Rappole and Warner 1976, Blem 1980, Moore 1991, Simons et al. 2000). These challenges, including weather conditions, the risk of mortality from predation and other threats, the availability of resources at stopovers and body condition, intensify when a migrant is forced to confront an ecological barrier such as urban, arid, or agricultural landscape, a mountain range or a large water body (Alerstam 1981, Kerlinger 1989, Alerstram and Lindsrom 1990, Loria and Moore 1990, Barrow et al. 2000, Moore and Aborn 2000, Schaub and Jenni 2001, Berthold et al. 2003). Habitats adjacent to ecological barriers have been recognized as critical stopovers for migrants that concentrate there prior to making the energetically demanding flight (Sprunt 1975, Moore et al. 1993, Barrow et al. 2000). The response of migrants to increasingly degraded landscapes encountered en route is as understudied as its subsequent effects on their survival throughout migration (Parker 1994). An understanding of migrants' preferences for stopover habitat and the factors affecting the selection process, therefore, must be considered when developing conservation strategies and regulations for migratory birds.

Despite the documented value of stopover areas to migrants, little is known of the biotic factors affecting bird distribution and habitat use within stopovers. In particular, studies of raptors have focused primarily on abiotic factors such as weather, migratory routes and methods of orientation and navigation (Kerlinger 1989). Point count surveys of migratory raptors at the Cape May stopover were conducted to evaluate how habitat and geography influences habitat use and distribution throughout the peninsula. Bordered by the Delaware Bay on the west and the Atlantic Ocean on the east, the Cape May Peninsula offers areas of concentrated resources for fall, south-bound migrants waiting for favorable weather to cross the 18km-wide bay (Wiedner and Kerlinger 1990, Wiedner et al. 1992, McCann et al. 1993, Niles et al. 1996). The peninsula is rich in prey for a number of different raptor species, including migrating passerines for Sharp-shinned hawks (*Accipiter striatus*), Cooper's Hawks (*Accipiter cooperii*), Northern Harriers (*Circus cyaneus*), Northern Goshawks (*Accipiter gentiles*), Peregrine Falcons *(Falco peregrinus*); fish for Ospreys (*Pandion haliaetus)*; and insects for American Kestrels (*Falco sparverius*). Migrants also find resting and roosting sites offered by scrub and forested habitats that characterize the peninsula (McCann et al. 1993). The quality and quantity of these and other habitats within the region, however, are in decline due to increases in development. Between 1984 and 2001, residential development on the lower 20km of the peninsula increased by 23% (Appendix C, Table 1). Between 1972 and 1995, development destroyed over 40% of forest, shrub-scrub and field habitats (Niles 1996). It is important to understand how migrants use the degraded landscape to identify habitat critical to the protection of species' health.

Surveys conducted by Niles et al. (1996) during the fall migrations of 1984, 1986 demonstrated that migratory raptors were associated with habitat throughout the Cape May stopover but concentrated near their crossing point at the southern tip of the peninsula. To investigate raptor distribution, habitat use and habitat selection within the concentration area, Niles et al. (1996) conducted additional surveys in 1988 that narrowed the study area to the lower 10km of the peninsula (i.e. the concentration area). Niles et al. (1996) found raptors distributed throughout the concentration area using a variety of habitats and avoiding developed land. This work led to the development of a comprehensive critical areas map that identified and provided regulatory protection for migratory raptor stopover habitat within the lower 10km of Cape May Peninsula. In 2002, we adopted the protocol used by Niles et al. (1996) in 1984 and 1986 to assess changes in raptor distribution and habitat use between the survey periods (Frank et al. 2007). In contrast to previous years, this research indicated a reduced concentration of raptors within the concentration area and an even distribution throughout the northern portions of the peninsula. To better understand current raptor distribution and habitat use in areas north of the concentration area, we employed the protocol used by Niles et al. (1996) in 1988 but expanded the study area to the lower 20km of the peninsula. This allowed the identification of additional critical stopover habitat areas within Cape May Peninsula and for the examination of changes in raptor distribution and habitat use within the concentration area between survey periods.

Using data collected from point count surveys and a GIS analysis of the land cover types in Cape May Peninsula, the following questions concerning migratory raptor habitat associations and distribution were addressed: 1) Are birds distributed evenly throughout the lower 20km of Cape May Peninsula? 2) Is there a relationship between birds and land cover types? 3) Is there a relationship between birds and land cover types at different scales? 4) Are birds distributed differently within the lower 10km concentration area of Cape May Peninsula?

METHODS

The study area consists of the entire Cape May Peninsula located at the southern tip of New Jersey (Figure 1). The peninsula is bordered on the west by the Delaware Bay and on the east by the Atlantic Ocean. From its southern tip (38 57' lat., 74 53' long.), the peninsula extends approximately 60km north along the Atlantic coast and approximately 40km north on along the Delaware Bay coast. The peninsula is about 10km wide at its northernmost point and includes a wide range of habitats. Lathrop (2004) reported that upland forest (18%), emergent marsh (23%), palustrine wetland (21%) and cultivated/grassland (6%) habitats comprised 68% of Cape May County's habitat in 2001. Residential development (18%), open water (8%), bare land (1%) and beach (5%) accounted for the remaining area. The northern end of the peninsula includes the pitch pine (*Pinus rigida*) dominated forests of the New Jersey Pine Barrens. Upland areas are vegetated with white oak (*Quercus alba*)-pitch pine forests interspersed with fields of red cedar (*Juniperus virginiana*) and other successional species. A large portion of the peninsula is comprised of tidal emergent wetlands and freshwater wetlands. The majority of tidal areas are salt marshes dominated by *Spartina alterniflora* and *S. patens*. Freshwater wetlands include red maple (*Acer rubrum*), black gum (*Nyssa sylavtica*) and Atlantic white cedar (*Chamaecyparis thyoides*).

In 2003, we modified the protocol used by Niles et al. (1996) in 1988 to investigate raptor distribution and habitat use within the lower 20km of Cape May Peninsula (Figure 1). During the fall of 1988 and 2003, surveys were conducted at points located throughout the lower portion of Cape May Peninsula. In 1988, the study area encompassed only the lower 10km of the peninsula and was divided into one km^2 blocks based on a Universal Transverse Mercator (UTM) grid. Survey points were randomly located within each one km^2 block (Niles 1996). In 2003, the study area was expanded to the lower 20km of Cape May Peninsula. Survey points were randomly located within every other one km^2 block of every other one km row of a UTM grid overlaying the lower 20km. In 1988, 50 points were surveyed in the lower 10km and 64 points (35 in the lower ten km) were surveyed in the lower 20km in 2003. Between year comparisons of distribution from south to north (SNCOORD) and west to east (WECOORD) UTM grid lines used only those data collected from within UTM lines that were surveyed both years. This data was also used for between year comparison of land cover associations and behaviors within the concentration area. All points were surveyed between 08:00 and 13:00 hours twice a week for eight weeks between September and November. All points were surveyed within one day to reduce weather variation among survey days. Points were organized into routes and surveyed by one of 11 observers for 30 minutes. All observers, points and starting times were staggered to avoid observer and temporal biases.

Surveys employed skilled observers to identify several species of raptors, noting their flight direction, distance, altitude and behavior. Eight behavior categories were used including perching, hovering, milling, kettling (circling to gain altitude), direct high flight, direct low flight, interaction with a conspecific and interaction with another species. Observers also indicated if the birds were hunting. Prior to the survey period, observers were trained to estimate distance and altitude with a Rangematic rangefinder. Observers also used reference points of known distances and heights established at each survey location to assist with estimating bird height and distance. Wind direction, wind speed and temperature were also collected during the survey period from National Oceanographic and Atmospheric Administration (NOAA) taken at the Cape May County Airport. Flight direction was summarized by combining directions into southbound (S, SW, SE, W) and northbound (N, NE, NW, E). For analyses, summarized flight direction data and observed behaviors were used to define three behavior categories. Migratory behavior includes observations of raptors flying south at ≥30m, non-migrating behavior includes raptors flying north at ≥30m and habitat-using behaviors includes raptors flying, milling or hovering in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors.

To investigate the influences of land cover on migratory raptors, land cover types were quantified on Cape May Peninsula using a 2001 Level 1 Landsat 7 ETM+ Satellite Image Land Cover Classification of New Jersey. We compared the quantity and location of each land cover type with summaries of point count data. The 2001 Landstat satellite image land cover classification was generated by the Rutgers University Center for Remote Sensing and Spatial Analysis (CRSSA) as an update to a 1995 land cover classification. The update utilized various standard change detection/mapping techniques and the 1994/1995 Landstat TM imagery data as a baseline (Lathrop 2004). The land cover mapping was completed at the most generalized level, Level I, with 8 classes: Developed (4 classes of developed: 1) High Intensity (>75% impervious surface (IS)), 2) Medium intensity (50-75% IS), 3) Low intensity (<50% IS) wooded, 4) Low intensity un-wooded, Cultivated/Grassland, Upland Forest, Barren, Marine/Estuarine Unconsolidated Shoreline, Estuarine Emergent Wetland/Marsh, Palustrine Wetland and Water. For the purposes of this analysis, the four developed classes were merged into one class. Land cover types were further summarized into three categories: Developed, Undeveloped A (includes cultivated/grassland, upland forest, estuarine emergent wetland and palustrine weland) and Undeveloped B (includes only cultivated/grassland, upland forest and palustrine weland). Estuarine emergent wetland (marsh) was eliminated from the Undeveloped B category to allow analysis of the relationships to land cover types without the effects of this extensive habitat type. This information was used to tally the amount of each land cover type within a 300m (28.3ha), 600m (113.1ha) and 900m radius (254.47ha) of each survey location. The area of each land cover type was converted to a proportion of the total area at each spatial scale interval to test the relationship between bird abundance and land cover type.

All analyses were conducted with all species grouped and with individual species considered separately. Analyses examining all species taken together excluded Black Vultures and Turkey Vultures. This allowed interpretation of the results without the effects of these two species, which occurred at significantly higher frequencies during surveys conducted in 2003 (Table 1). All data were analyzed using

JMP 7.0(SAS 2007) and the Statistical Analysis System for Windows 9.1 (SAS 2003). Relative abundance and density data summarized by survey was employed in all within year analyses that did not test against specific survey location/point characteristics (i.e. proportion of habitat at a survey location). To account for the variation in the number of surveys at each point, data were summarized over all surveys at each point. The summarized data were used to evaluate the influence of location (by UTM) within Cape May Peninsula on total abundance of raptors and to examine the relationship between total abundance and land cover types at three different scales. These data were used in a t-test to evaluate overall trends in relative abundance and in ANOVAs to test the influence of location by UTM grid line for 1988 and 2003. The Brown and Forsythe's Variant of the Levine's Test, the F-test for homogeneity of variances (Wilks-Shapiro test) and the studentized residual test were applied to the data to test for model assumptions. To meet the normality assumptions of statistical tests, the summarized data were log-transformed (Oehlert 2000). Rather than transforming both the abundance and land cover data, the Spearman's rank correlation coefficient (*R*), a nonparametric measure of correlation, was calculated to describe the relationship between abundance and the proportion of each land cover type. This method converts the variables to ranks and applies a linear regression to the ranked data (Lehman et al. 2005). Because of the large area of emergent marsh throughout the peninsula, analyses included a land cover category that excluded this habitat type.

The sequential Bonferroni technique was employed to adjust for the large number of tests included in all groups of analyses (Holm 1979, Rice 1989). This nonparametric method corrects for the group-wide type-I error rate by adjusting the significance level with the number of tests (Rice 1989). For this study, significance is reported with an asterisk at the 5% level which has been adjusted using the sequential Bonferroni technique.

RESULTS

Lower 20km Surveys

In 2003, observers collected data from 846 surveys at 64 points and counted 2,221 individual raptors representing 15 species. Turkey Vulture (*Cathartes aura*), Sharp-shinned Hawk (*Accipiter striatus)*, Northern Harrier (*Circus cyaneus*), Cooper's Hawk (*Accipiter cooperii*), Osprey (*Pandion haliaetus)* and Red-tailed Hawk (*Buteo jamaicensis*) were the most abundant (Table 1, Figure 2).

Distribution

Overall, raptors were not evenly distributed throughout the lower 20km of Cape May Peninsula (Figure 3). Birds concentrated in the western and southern portions of the study area. All species, analyzed together and individually, were not distributed evenly from west to east (WECOORD) (Figure 1, Appendix B, Table 1). Northern Harriers occurred most often in the western portion of the peninsula while all other species were observed in greater numbers in the eastern portion. Northern Harriers and Ospreys were evenly distributed from north to south (SNCOORD) (Appendix B, Table 2). Cooper's Hawks, Red-tailed Hawks, Sharp-shinned Hawks and Turkey Vultures occurred most often in the southern region of the peninsula.

Land Cover Association

The direction of the relationship between raptor abundance and each land cover type was similar for all species analyzed as a group and for individual species (Table 2, Table 3 and Table 4). The strength and significance of the relationship, however, varied by species. All birds analyzed together demonstrated a negative correlation with increasing area of developed land and a positive relationship with increasing area of habitat. These relationships were not significant at any of the three spatial intervals of measurement (300, 600, 900m radius) for developed land and undeveloped land A (all habitat types included). A significant positive relationship was observed between raptors and the undeveloped land B (excluding emergent marsh and water) category at only the smallest spatial scale (300m).

Each species analyzed individually generally demonstrated a negative relationship with developed land at all scales of measurement (Table 3). Correlation was significantly negative for Northern Harriers at the largest spatial scale (900m). Sharp-shinned Hawks and Cooper's Hawks demonstrated a weak positive correlation with developed land at the three spatial intervals. Highly significant positive correlations with the area of undeveloped land B (excluding emergent wetland, bare land, water and developed land) was observed at all spatial intervals for all species except Ospreys and Northern Harriers (Table 4). Ospreys exhibited a minimal relationship with habitat and Northern Harriers exhibited a strong negative relationship because emergent marsh was eliminated from this analysis.

Cooper's Hawks, Northern Harriers, Red-tailed Hawks, Sharp-shinned Hawks and Turkey Vultures demonstrated strong positive relationships with the habitats that they preferred during the breeding season (Table 5). Positive correlations with field and forested habitat were significant for Sharp-shinned Hawks and Turkey Vultures at most spatial scales. Additional significant relationships were observed for Northern Harriers and marsh habitat at all spatial scales and for Red-tailed Hawks and field habitat at 600m and 900m. Weak correlation was observed between Ospreys and their preferred habitats.

Lower 10km Comparison (1988 and 2003)

Of the 14 species counted in 1988 and 2003, Cooper's Hawks, Northern Harriers, Osprey, Red-tailed Hawks, Sharp-shinned Hawks and Turkey Vultures were observed most frequently during both years (Table 6, Figure 4). Most analyses were thus limited to these species. In 1988, 1,857 raptors were observed over 468 surveys. In 2003, 1,564 raptors were observed over 478 surveys.

Changes in abundance observed between 1988 and 2003 were compared with changes in abundance between the same years recorded at the Cape May Hawk Watch located at Cape May Point, New Jersey (Table 7). Declines in counts of Merlins, Ospreys, Red-tailed Hawks and Sharp-shinned Hawks were detected by both studies. Increases in counts of Bald Eagles, Black Vultures, Cooper's Hawks, Peregrine Falcons and Turkey Vultures were also detected by both studies. Although trends of Broad-winged Hawks, Red-shouldered Hawks and Swainson's Hawks disagreed between studies, this can be explained by the survey locations for each study. Buteos are known to cross the Delaware Bay in high numbers from Cape May Point. The difference in abundance trends for American Kestrel detected by each study may be explained by observer bias or may indicate that fewer kestrels are stopping over due to the extensive decline in grassland/agricultural habitat at Cape May Peninsula.

Distribution

Overall, the number of raptors observed per survey within the lower 10km of Cape May Peninsula decreased between the survey years of 1988 and 2003 (Table 6, Table 7 and Figure 5). In 1988 and 2003, raptors were distributed throughout the lower 10km of the Cape May Peninsula with greater frequency to the south and west, near their crossing point, in both years (Figure 5). This pattern of distribution was more pronounced in 2003 with declines observed to the west and the northwest of the study area (Figure 5). In 2003, raptors concentrated immediately adjacent to the crossing point but decreased rapidly in number within a short distance of Cape May Point. Although more raptors were recorded in the southern and western portions of the study area in 2003, there was no significant difference between years among south to north or west to east UTM lines when all species were analyzed together (Appendix B, Table 3).

Land Cover Association

The direction of the relationship between raptor abundance and each land cover type was similar for all species, taken together, and for individual species across years (Table 8, Table 9 and Table 10). At all three intervals of measurement (300, 600, 900m radius), raptors were positively associated with undeveloped land and negatively associated with developed land (Table 8). Stronger, significant relationships were observed in 1988 at all spatial scales of undeveloped A and undeveloped B categories and no significant relationships were observed in 2003.

The strength and significance of these relationships varied among species and years. Most species demonstrated a negative relationship with developed land at all scales of measurement (Table 9) and a positive relationship with undeveloped land B (excluding emergent wetland, bare land and developed) during both years (Table 10). In general, each species demonstrated stronger relationships with land cover types at all spatial scales in 1988. Correlation with developed land was significantly negative for Northern Harriers and Osprey at all scales only in 1988 (Table 9). A significant positive relationship with undeveloped land at all scales of measurement was demonstrated by Red-tailed Hawks, Sharp-shinned Hawks and Turkey Vultures during both survey years (Table 10). Ospreys exhibited weaker positive relationships with undeveloped land in 2003 and Cooper's Hawks exhibited weaker positive relationships in 1988. Northern Harriers were negatively associated with undeveloped land due to the exclusion of emergent marsh from the analysis. Overall, negative relationships with developed land were stronger in 1988 and positive relationships with undeveloped land were stronger in 2003. Exceptions include weak positive relationships with developed land exhibited by Sharp-shinned Hawks and Cooper's Hawks in 2003.

<u>Behavior</u>

Approximately half of all raptors observed during 1988 and 2003 were migrating, a third exhibited habitat-using behaviors and a fifth exhibited non-migrating behaviors (Figure 6). When vultures were removed from the tally, about 50% raptors in 2003 were using habitat compared to 37% in 1988 (Appendix

B, Table 4). All species were observed using habitat more often in 2003 than in 1988. This was most apparent for Cooper's Hawks (1988: 32%, 2003: 49%) and Sharp-shinned Hawks (1988: 28%, 2003: 47%).

DISCUSSION

During fall migration, migratory raptors flying south through Cape May Peninsula must decide whether to stopover or continue migration as they approach the Delaware Bay (Kerlinger et al. 1985, Niles et al. 1996). In adverse weather conditions, it is likely that many individuals, who at this time of year are likely to be juveniles, will utilize the habitats throughout Cape May Peninsula to rest and refuel before continuing migration (Kerlinger 1989, Niles et al. 1996). Anthropogenic changes in the landscape at this and other coastal stopovers introduce additional challenges to migrants arriving in an unfamiliar landscape to compete with other migrants for suitable habitat. Energy demands at stopovers can be double that experienced during migration as migrants search an unfamiliar landscape for much needed foraging and roosting habitats (Hedenstrom and Alerstam 1998, Meyer et al. 2000, Wikelski et al. 2003) . Energy demands will increase dramatically for migrants arriving in degraded landscapes as exploration is costly (Jenni-Eiermann and Jenni 1999). In areas of poor habitat quality, migrants experience greater energetic costs as they spend more time searching for suitable habitat, select less optimal habitat (Simons et al. 2000), or opt to continue migrating (Rappole and Warner 1976, Terrill 1988). Results from previous studies conducted at the Cape May Stopover (Frank et al. 2007), suggest that migratory raptors are moving further north from their preferred crossing point in search of increased habitat availability and quality. Results from surveys conducted in 1988 and 2003 provide additional evidence to support this theory. We suggest that upon confronting adverse weather conditions at Cape May Point, raptors, requiring increased fat stores before crossing barriers, have adjusted their distribution to correspond with areas where suitable habitat remains. In addition, raptors have demonstrated increased variation in habitat preferences as a result of the decline in availability and quality of habitat, particularly within the concentration area. As overall counts observed in 2003 suggest (Table 6 and Table 7), many raptors, including American Kestrels, may opt to continue migration without stopping due to the altered landscape.

Conservation Implications

Habitat loss and increases in development throughout the peninsula has and will continue to affect the availability and quality of migratory stopover habitat on Cape May Peninsula and other coastal stopovers. Evidence suggests that without suitable habitat, migrants will be forced to confront the challenges associated with migration in poor body condition. This study supports several conservation recommendations already offered by authors of similar studies examining stopover ecology. Moore (2000) suggests conservation of a network of sites along migration routes. The spatial distribution of suitable stopover sites at the landscape level is an important aspect of migration that has received scant attention (Jenni and Schaub 2003). Identification and protection of high-priority habitats within stopovers is equally important as many species utilize the same areas during stopover (Moore and Aborn 2000). Conservation and protection of a diversity of habitat types, sizes and locations within stopovers should also be considered. This allows variation in habitat use and distribution of migrants within seasons and years. Sites should be structurally heterogeneous and provide a diversity of food and water resources.

Future research should incorporate analysis of available land cover data at a higher level of detail to address more specific habitat types. A more comprehensive analysis of how habitat is dispersed throughout a stopover site will also benefit our understanding of stopover behaviors. Moore et al. (1995) and Moore and Simons (1992) suggest that the effects of fragmentation, including changes in patch size, isolation and structure, could negatively impact migrants by increasing predation, competition, and energetic costs by forcing birds to move through poor habitats. Continued research of habitat use and behaviors during migration are necessary to develop and contribute to the successful management and conservation of migratory birds. Our understanding of en route behaviors, especially those at valuable stopover sites, dictates the effectiveness of conservation strategies throughout the length of migratory route.

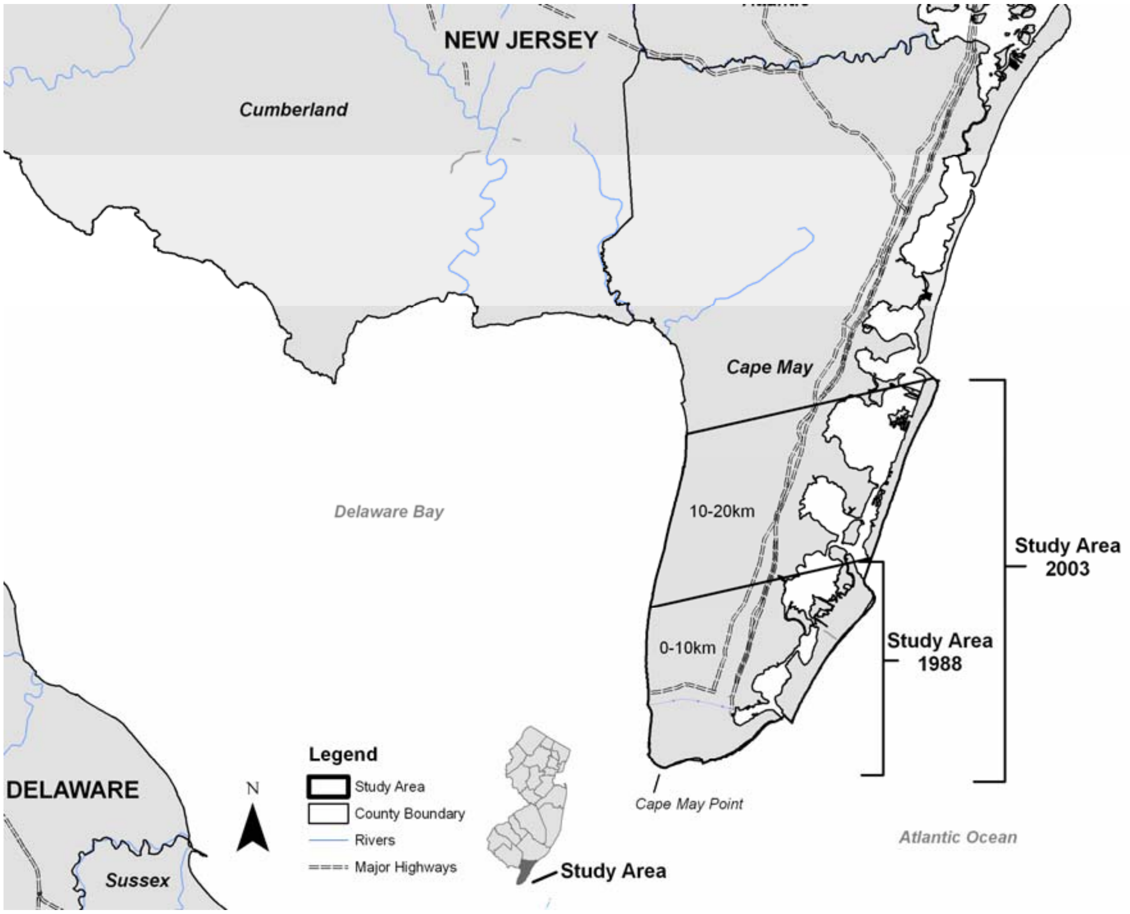

Figure 1. Map of study areas. In 1988, surveys were located in the lower 10km (0-10km) of Cape May Peninsula, New Jersey. In 2003, surveys were located in the lower 20km (0-20km).

Table 1. Number of individuals of each species observed in the lower 20km of Cape May Peninsula, New Jersey in surveys conducted in the fall of 2003.

SPECIES	**Total Number of Individuals**	**Mean Birds/Survey +/- S.E.**	**Mean Altitude +/- S.E.**
American Kestrel (*Falco sparverius*)	27	0.03 +/- 0.009	31 +/- 10.4
Bald Eagle (*Haliaeetus leucocephalus*)	16	0.02 +/- 0.006	47 +/- 7.6
Black Vulture (*Coragyps atratus*)	99	0.12 +/- 0.029	75 +/- 4.8
Broad-winged Hawk (*Buteo platypterus*)	21	0.02 +/- 0.011	78 +/- 9.8
Cooper's Hawk (*Accipiter cooperii*)	173	0.20 +/- 0.031	66 +/- 5.7
Merlin (*Falco columbarius*)	40	0.05 +/- 0.009	28 +/- 4.4
Northern Harrier (*Circus cyaneus*)	180	0.21 +/- 0.021	24 +/- 2.8
Osprey (*Pandion haliaetus*)	101	0.12 +/- 0.014	72 +/- 7.0
Peregrine Falcon (*Falco peregrinus*)	46	0.05 +/- 0.009	45 +/- 8.3
Red-shouldered Hawk (*Buteo lineatus*)	7	0.01 +/- 0.005	143 +/- 12.8
Red-tailed Hawk (*Buteo jamaicensis*)	97	0.11 +/- 0.016	67 +/- 7.2
Sharp-shinned Hawk (*Accipiter striatus*)	343	0.41 +/- 0.073	71 +/- 4.4
Swainson's Hawk (*Buteo swainsoni*)	2	0.00 +/- 0.002	80 +/- 20.0
Turkey Vulture (*Cathartes aura*)	1069	1.26 +/- 0.155	89 +/- 2.7
TOTAL	2221	2.63 +/- 0.258	44 +/- 2.0

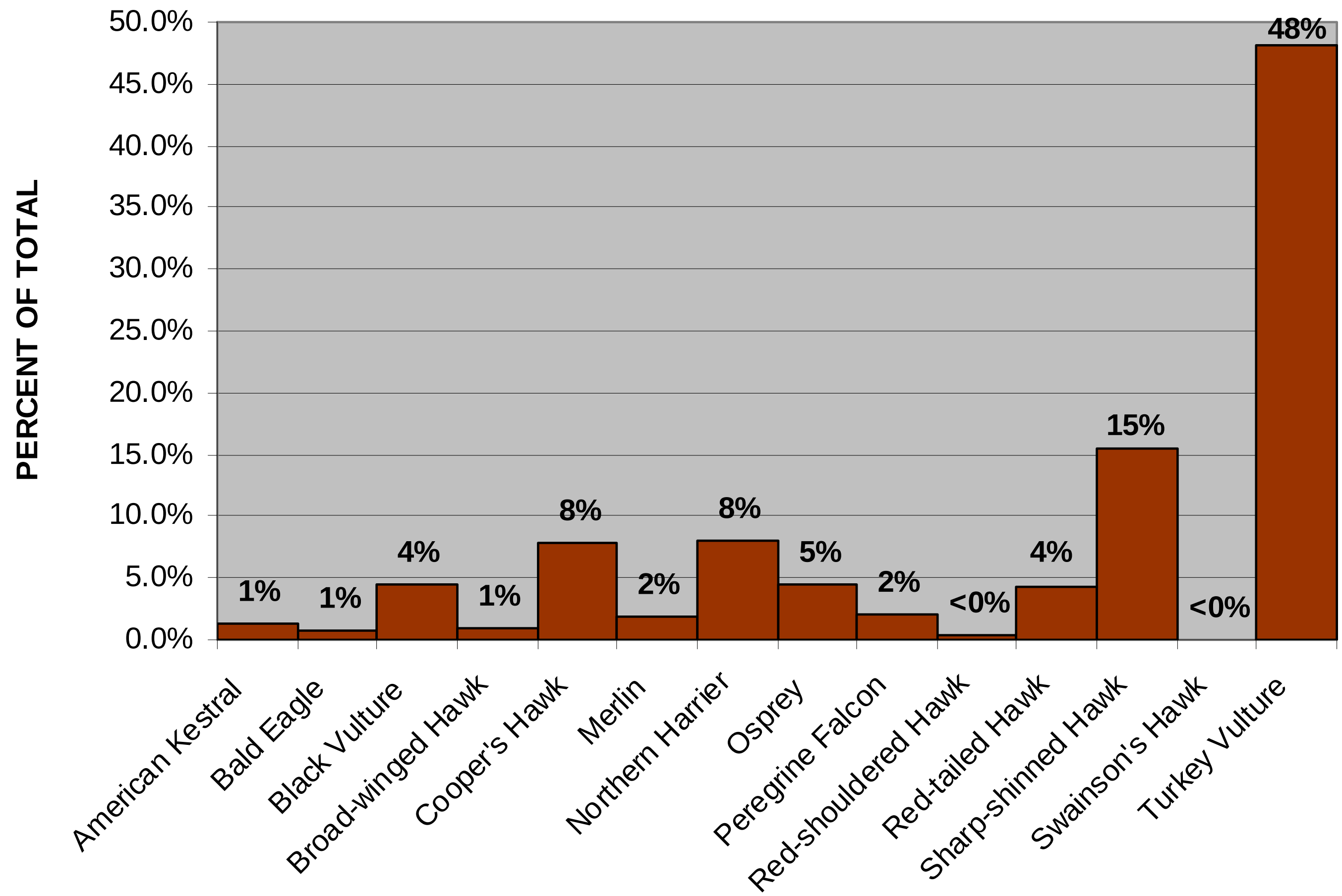

Figure 2. Percent of individuals of each species observed on Cape May Peninsula, New Jersey in surveys conducted in the fall of 2003.

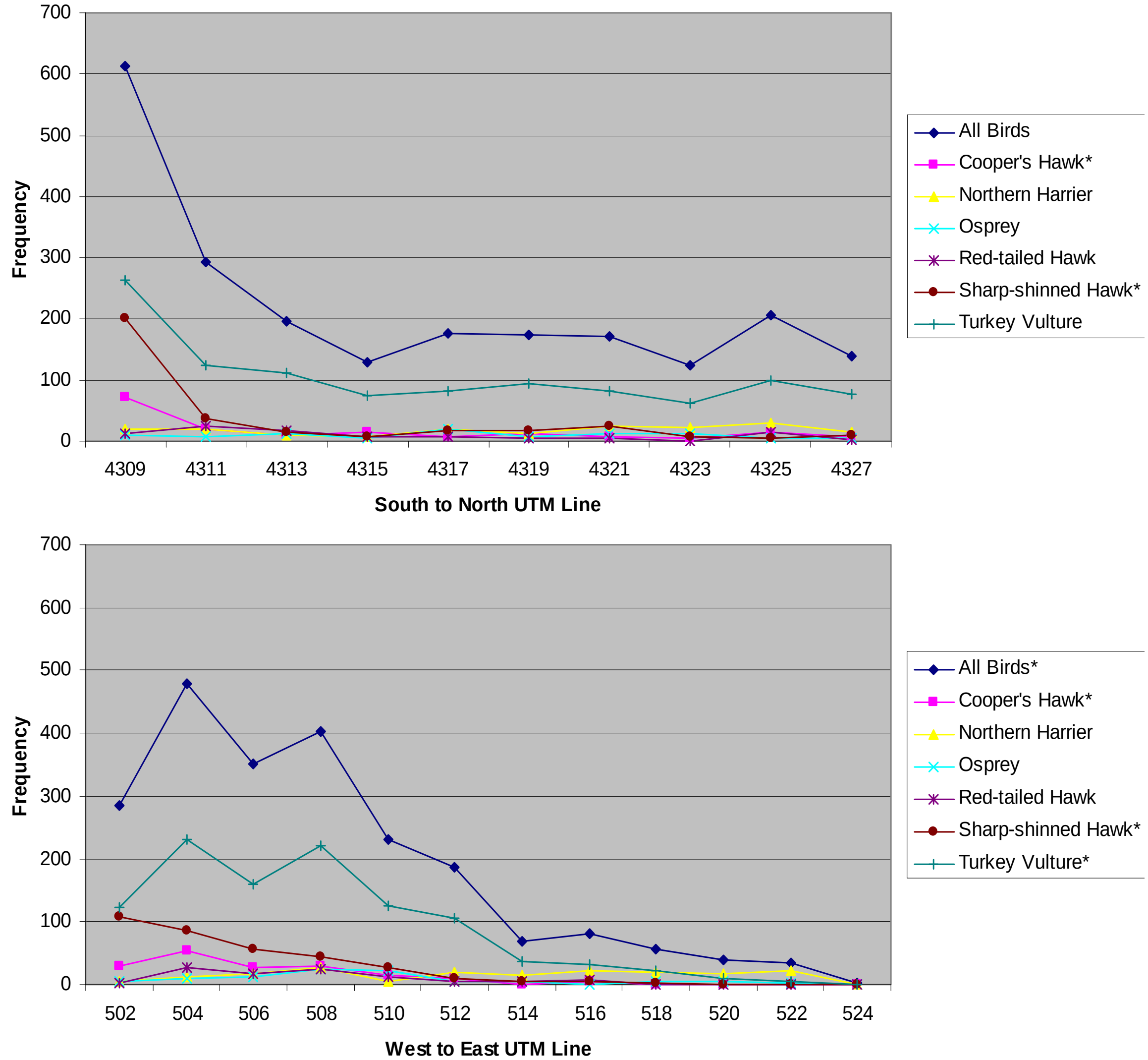

Figure 3. Frequency of individual raptors at each UTM grid line. “*” indicates significance at the 5% level which has been adjusted using the sequential Bonferroni technique. See Appendix B, Table 1 and Table 2 for additional results.

Table 2. Analysis of mean number of individual raptors per survey by the proportion of land cover types measured at three different spatial intervals of 300m (28.3 ha), 600m (113.1 ha) and 900m (254.47 ha) radius around each point. Spearman's rank correlation coefficient (*R)* and corresponding P value are reported.

LAND COVER TYPE	**SCALE OF LAND COVER MEASURED AT SURVEY LOCATION** (radius in meters)					
	300		**600**		**900**	
	R	**P**	***R***	**P**	***R***	**P**
Undeveloped A (all habitat types)	0.094	0.461	0.214	0.089	0.166	0.189
Undeveloped B (all habitat types except emergent marsh and water)	0.448	<0.001*	0.100	0.433	0.069	0.587
Developed	-0.079	0.532	-0.150	0.237	-0.169	0.182

Table 3. Analysis of mean number of individual raptors per survey observed at each point by the proportion of developed land measured at three different spatial intervals of 300m (28.3 ha), 600m (113.1 ha) and 900m (254.47 ha) radius. Spearman's rank correlation coefficient (*R*) and corresponding P value are reported. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

SPECIES	Scale of Habitat	Spearman *R*	P
All Species	300	-0.079	0.532
	600	-0.024	0.850
	900	-0.023	0.859
Cooper's Hawk	300	0.233	0.064
	600	0.263	0.036
	900	0.231	0.066
Northern Harrier	300	-0.369	0.003
	600	-0.382	0.002
	900	-0.404	0.001*
Osprey	300	-0.168	0.184
	600	-0.133	0.296
	900	-0.171	0.177
Red-tailed Hawk	300	-0.121	0.341
	600	-0.061	0.632
	900	-0.045	0.724
Sharp-shinned Hawk	300	0.247	0.049
	600	0.297	0.017
	900	0.269	0.031
Turkey Vulture	300	-0.002	0.989
	600	0.053	0.677
	900	0.060	0.638

Table 4. Analysis of mean number of individual raptors per survey observed at each point by the proportion of undeveloped land B (excluding emergent wetland, bare land and developed) measured at three scales of 300m (28.3 ha), 600m (113.1 ha) and 900m (254.47 ha) radius. Spearman's rank correlation coefficient (*R*) and corresponding P value are reported. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

SPECIES	**Scale (m)**	***R***	**P**
All Species	300	0.448	<0.001*
	600	0.473	<0.001*
	900	0.465	<0.001*
Cooper's Hawk	300	0.322	0.009*
	600	0.375	0.002*
	900	0.388	0.002*
Northern Harrier	300	-0.455	<0.001*
	600	-0.494	<0.001*
	900	-0.528	<0.001*
Osprey	300	0.060	0.639
	600	0.087	0.494
	900	0.055	0.664
Red-tailed Hawk	300	0.373	0.002*
	600	0.433	<0.001*
	900	0.438	<0.001*
Sharp-shinned Hawk	300	0.434	<0.001*
	600	0.447	<0.001*
	900	0.466	<0.001*
Turkey Vulture	300	0.626	<0.001*
	600	0.670	<0.001*
	900	0.666	<0.001*

Table 5. Analysis of mean number of individual raptors per survey observed at each point by the proportion of the preferred habitat(s) of each species measured at three spatial intervals of 300m (28.3 ha), 600m (113.1 ha) and 900m (254.47 ha) radius. Spearman's rank correlation coefficient (*R*) and corresponding P value are reported. The source column provides the citation that was referenced for each species' preferred habitat during the breeding season. The habitat type column indicates the habitat types used in the analyses to determine species' preferences for habitat. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

SPECIES	**Breeding Habitat**	**Source**	**Habitat Type**	**SCALE OF HABITAT MEASURED AT SURVEY LOCATION** (radius in meters)					
				300		**600**		**900**	
				Spearman ρ	**P**	**Spearman ρ**	**P**	**Spearman ρ**	**P**
Cooper's Hawk	Forest	Reynolds et al. 1984	Field	0.331	0.007	0.402	0.001*	0.501	>0.001*
			Forest	0.260	0.037	0.316	0.011	0.325	0.009
Osprey	Marsh/Forest	Poole 1989	Marsh	0.082	0.522	0.125	0.324	0.190	0.132
			Forest	-0.075	0.555	-0.084	0.507	-0.042	0.740
Northern Harrier	Field/Marsh	Hamerstrom & Kopeny 1981	Field	-0.354	0.004	-0.337	0.006	-0.297	0.017
			Marsh	0.716	>0.001*	0.765	>0.001*	0.773	>0.001*
Red-tailed Hawk	Field/Forest	Janes 1984, Bildstein 1987	Field	0.332	0.007	0.415	>0.001*	0.452	>0.001*
			Forest	0.322	0.009	0.336	0.007	0.373	0.002
Sharp-shinned Hawk	Forest	Reynolds et al. 1984	Field	0.421	>0.001*	0.493	>0.001*	0.487	>0.001*
			Forest	0.350	0.004	0.412	>0.001*	0.365	0.003
Turkey Vulture	Forest	Brown 1976	Field	0.450	>0.001*	0.559	>0.001*	0.613	>0.001*
			Forest	0.366	0.002*	0.525	>0.001*	0.567	>0.001*

Table 6. A comparison of total raptor abundance and mean altitude of each species observed in the lower 10km of Cape May Peninsula, New Jersey in surveys conducted in the fall of 1988 and 2003. Given are t and P values of an analysis of the number of birds per survey between years. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

SPECIES	1988			2003			t	P
	Total Number	Mean Birds/Survey +/- S.E.	Mean Altitude +/- S.E.	Total Number	Mean Birds/Survey +/- S.E.	Mean Altitude +/- S.E.		
American Kestral	366	0.78 +/- 0.078	38 +/- 3.2	16	0.03 +/- 0.010	36 +/- 21.3	-12.62	<0.0001*
Bald Eagle	3	0.01 +/- 0.004	55 +/- 35.7	5	0.01 +/- 0.006	76 +/- 38.1	0.30	0.764
Black Vulture	0	-	-	68	0.14 +/- 0.047	83 +/- 10.3	4.39	<0.0001*
Broad-winged Hawk	28	0.06 +/- 0.015	89 +/- 11.7	17	0.04 +/- 0.019	87 +/- 20.7	-2.10	0.036*
Cooper's Hawk	87	0.19 +/- 0.027	88 +/- 6.6	139	0.29 +/- 0.052	69 +/- 7.2	1.16	0.247
Merlin	53	0.11 +/- 0.018	40 +/- 8.5	27	0.06 +/- 0.012	28 +/- 16.4	-2.67	0.008*
Northern Harrier	74	0.16 +/- 0.020	40 +/- 7.2	88	0.18 +/- 0.027	34 +/- 9.1	0.03	0.975
Osprey	175	0.37 +/- 0.036	81 +/- 4.7	65	0.14 +/- 0.020	74 +/- 10.6	-6.07	<0.0001*
Peregrin Falcon	13	0.03 +/- 0.008	73 +/- 17.2	29	0.06 +/- 0.013	40 +/- 15.8	2.32	0.021*
Red-shouldered Hawk	23	0.05 +/- 0.016	142 +/- 12.9	7	0.01 +/- 0.008	143 +/- 32.2	-2.25	0.015*
Red-tailed Hawk	94	0.20 +/- 0.044	103 +/- 6.4	74	0.16 +/- 0.027	80 +/- 9.9	-0.95	0.344
Sharp-shinned Hawk	605	1.29 +/- 0.121	78 +/- 2.5	293	0.62 +/- 0.125	77 +/- 5.0	-7.45	<0.0001*
Swainson's Hawk	0	-	-	2	0.00 +/- 0.003	80 +/- 60.2	1.40	0.161
Turkey Vulture	336	0.72 +/- 0.125	115 +/- 3.4	734	1.57 +/- 0.265	110 +/- 3.1	4.45	<0.0001*
TOTAL	1857	3.97 +/- 0.266	77 +/ 1.6	1564	3.31 +/- 0.445	88 +/- 2.2	-4.95	<0.0001*

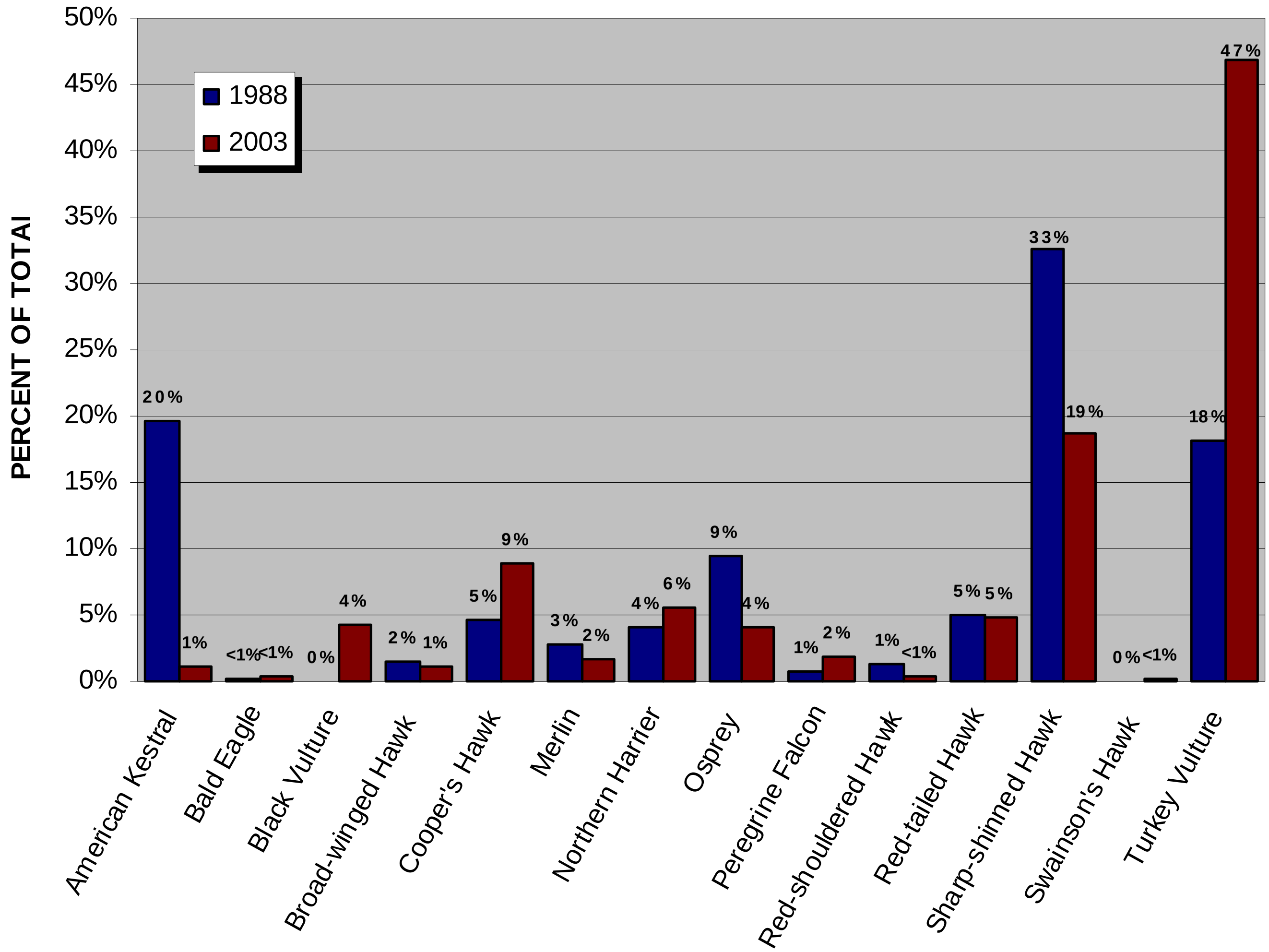

Figure 4. Percent of individuals of each species observed on Cape May Peninsula, New Jersey in surveys conducted in the fall of 1988 and 2003.

Table 7. A comparison of changes in relative abundance of raptors detected in this study and recorded at the Cape May Hawk Watch located at Cape May Point, New Jersey over two fall seasons, 1988 and 2003.

SPECIES	**Change in Abundance (%) 1988 to 2003**	
	This Study	Cape May Hawk Watch
American Kestrel	-95.6	0.1
Bald Eagle	66.7	394.4
Black Vulture	n/a	1415.4
Broad-winged Hawk	-39.3	29.7
Cooper's Hawk	59.8	69.2
Merlin	-49.1	-3.8
Northern Harrier	18.9	-4.8
Osprey	-62.9	-30.0
Peregrin Falcon	123.1	202.1
Red-shouldered Hawk	-69.6	33.6
Red-tailed Hawk	-21.3	-45.2
Sharp-shinned Hawk	-51.6	-1.2
Swainson's Hawk	n/a	33.3
Turkey Vulture	118.5	50.8
TOTAL	-15.8	3.3

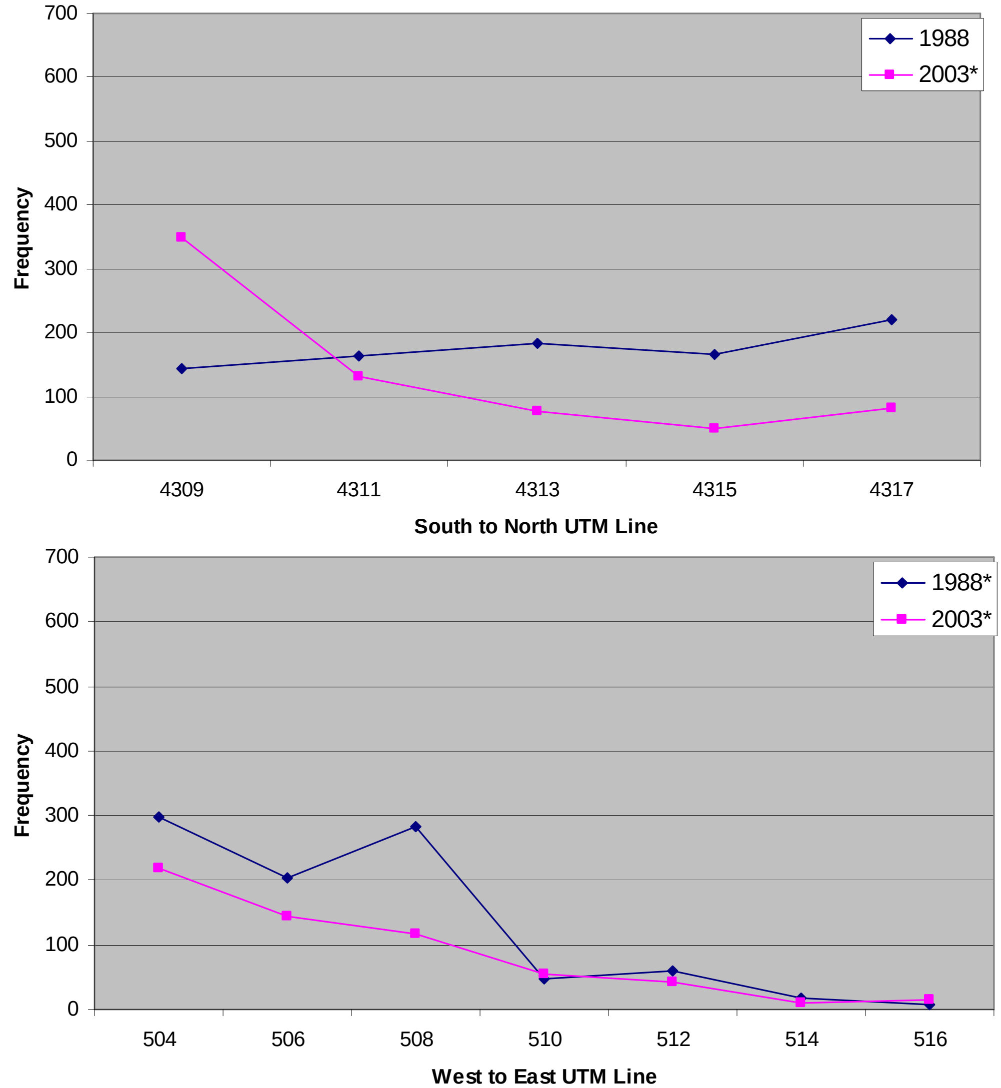

Figure 5. Frequency of individual raptors per survey, excluding Turkey and Black Vultures, observed within south to north (SNCOORD) and west to east (WECOORD) UTM grid lines located in the lower 10km of Cape May Peninsula, New Jersey. "*" indicates significance at the 5% level which has been adjusted using the sequential Bonferroni technique. See Appendix B, Table 3 for additional results.

Table 8. Analysis of mean number of individual raptors per survey observed at each point by the proportion of land cover types measured at three different spatial intervals of 300m (28.3 ha), 600m (113.1 ha) and 900m (254.47 ha) radius. Black and Turkey Vultures were eliminated from the analysis. Spearman's rank correlation coefficient (*R)* and corresponding P value are reported. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

LAND COVER TYPE	Scale (m)	1988		2003	
		R	**P**	***R***	**P**
Undeveloped (all habitat types)	300	0.565	<0.0001*	0.367	0.030
	600	0.545	<0.0001*	0.334	0.050
	900	0.539	<0.0001*	0.228	0.188
Undeveloped (all habitat types except marsh)	300	0.581	<0.0001*	0.383	0.023
	600	0.543	<0.0001*	0.373	0.027
	900	0.553	<0.0001*	0.293	0.087
Developed	300	-0.192	0.182	-0.181	0.298
	600	-0.187	0.194	-0.137	0.433
	900	-0.110	<0.0001*	-0.156	0.370

Table 9. Analysis of mean number of individual raptors per survey observed at each point by the proportion of developed land measured at three different spatial intervals of 300m (28.3 ha), 600m (113.1 ha) and 900m (254.47 ha) radius. Spearman's rank correlation coefficient (*R*) and corresponding P value are reported. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

SPECIES	**Scale (m)**	**1988**		**2003**	
		R	**P**	***R***	**P**
Cooper's Hawk	300	0.00	1.000	0.12	0.495
	600	-0.01	0.944	0.10	0.583
	900	0.04	0.763	0.02	0.923
Northern Harrier	300	-0.45	0.001*	-0.35	0.038
	600	-0.49	<0.001*	-0.30	0.076
	900	-0.48	0.001*	-0.31	0.073
Osprey	300	-0.40	0.004*	-0.35	0.038
	600	-0.42	0.002*	-0.24	0.156
	900	-0.39	0.005	-0.25	0.143
Red-tailed Hawk	300	-0.30	0.032	-0.31	0.070
	600	-0.29	0.043	-0.28	0.106
	900	-0.21	0.152	-0.30	0.081
Sharp-shinned Hawk	300	-0.03	0.819	0.05	0.763
	600	-0.03	0.856	0.10	0.563
	900	0.06	0.685	0.02	0.890
Turkey Vulture	300	-0.04	0.772	-0.05	0.786
	600	-0.03	0.845	-0.04	0.841
	900	0.04	0.792	-0.06	0.749

Table 10. Analysis of mean number of individual raptors per survey observed at each point by the proportion of habitat (excluding emergent wetland, bare land and developed) measured at three spatial intervals of 300m (28.3 ha), 600m (113.1 ha) and 900m (254.47 ha) radius. Spearman's rank correlation coefficient (*R*) and corresponding P value are reported. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

SPECIES	**Scale (m)**	**1988**		**2003**	
		R	**P**	***R***	**P**
Cooper's Hawk	300	0.35	0.014	0.46	0.005
	600	0.30	0.033	0.44	0.008
	900	0.31	0.027	0.38	0.022
Northern Harrier	300	-0.08	0.587	-0.29	0.085
	600	-0.21	0.141	-0.34	0.045
	900	-0.22	0.118	-0.31	0.070
Osprey	300	0.42	0.002*	0.29	0.095
	600	0.40	0.004	0.36	0.035
	900	0.37	0.008	0.26	0.124
Red-tailed Hawk	300	0.62	<0.001*	0.60	<0.001*
	600	0.53	<0.001*	0.63	<0.001*
	900	0.57	<0.001*	0.59	<0.001*
Sharp-shinned Hawk	300	0.52	<0.001*	0.50	0.002*
	600	0.57	<0.001*	0.52	0.001*
	900	0.59	<0.001*	0.44	0.009
Turkey Vulture	300	0.48	<0.001*	0.62	<0.001*
	600	0.56	<0.001*	0.70	<0.001*
	900	0.57	<0.001*	0.68	<0.001*

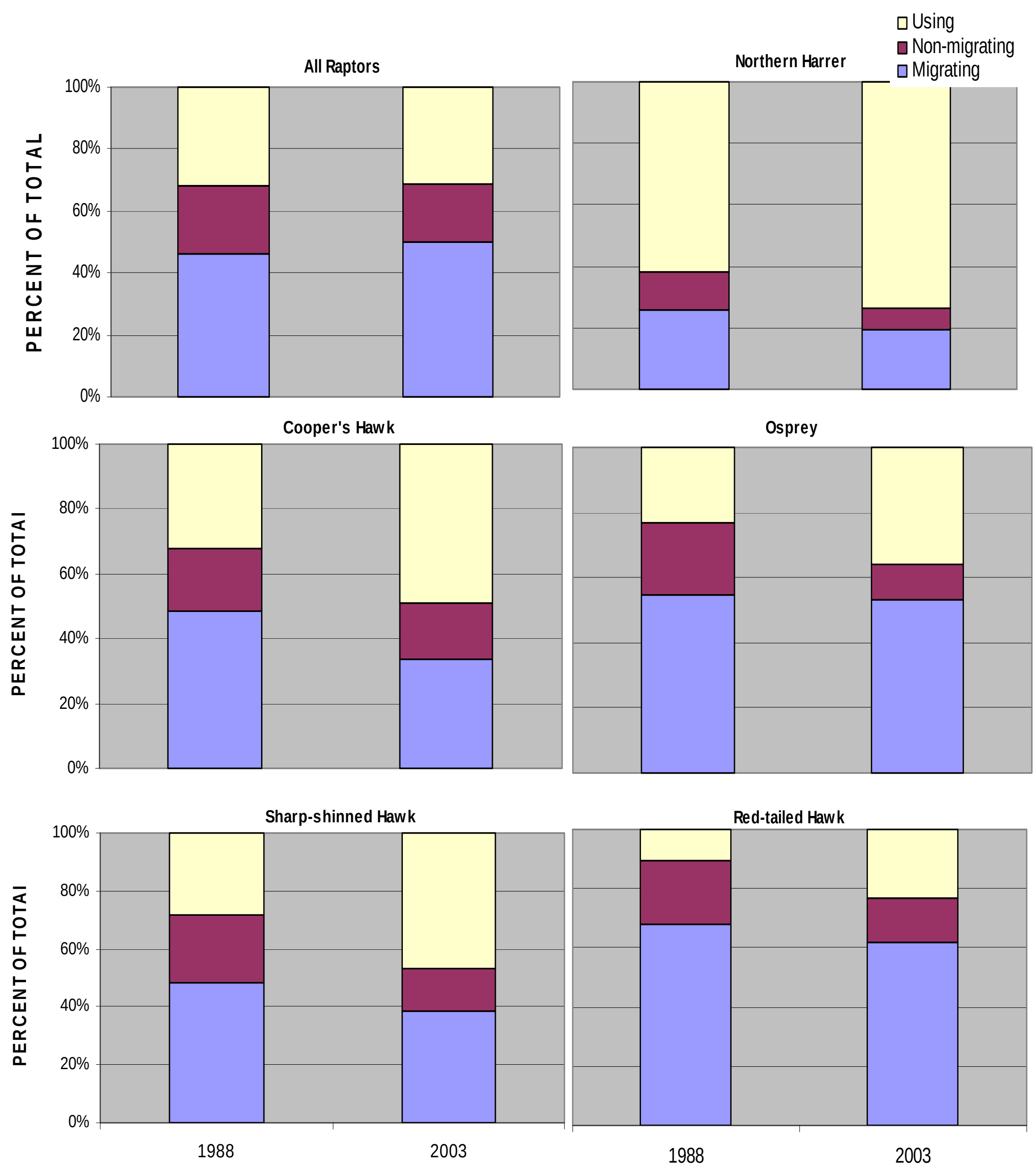

Figure 6. For each survey year, the percent of raptors exhibiting migrating, non-migrating and using behaviors is reported for each species. Migration behavior includes observations of raptors flying south at ≥30m, non-migrating behavior includes raptors flying north at ≥30m, and habitat-using behaviors includes raptors flying in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors. See Appendix B, Table 4 for additional results.

Chapter Three: Conservation Implications for Migratory Raptor Habitat in the Cape May Stopover, New Jersey

INTRODUCTION

State, national and international conservation initiatives have recently begun to direct research and protection efforts on migratory stopover areas. However, comprehensive conservation strategies for the protection of migratory birds are lacking primarily due to significant gaps in our understanding of how migrants move through the landscape encountered at stopovers and more importantly, how they respond to and are ultimately impacted by degraded landscapes (Petit 2000). The identification of priority areas within stopovers and strategies for their protection must be accelerated to compete with the rapid rate of anthropogenic expansion in landscape. This is especially so for migratory stopovers associated with ecological barriers that are often fragmented by development (Sprunt 1975, Moore et al. 1993, Barrow et al. 2000). The Cape May Peninsula, New Jersey is a well-recognized, critical stopover site for fall migrants that gather here prior to making the energetically demanding flight over the18km-wide Delaware Bay (Allen and Peterson 1936, Stone 1965, Krohn et al. 1977, Wiedner and Kerlinger 1990, Wiedner et al. 1992, McCann et al. 1993, Niles 1996). Identification and protection of stopover habitat within this region is essential given its adjacency to an ecological barrier, the consistency of use by migrants, the predominance of inexperienced, young birds and the extensive anthropogenic changes in the landscape.

In the late 1980s, Niles et al (1996) conducted two studies that examined the distribution and influence of abiotic (weather and geography) and biotic (habitat use) factors on migratory raptors at the Cape May, New Jersey stopover. This research documented the concentration of several species of raptors throughout a variety of habitats in the lower 10km of Cape May Peninsula. Radio-telemetry work conducted by Niles et al. (1996) further indicated that migrating Sharp-shinned Hawks (*Accipiter striatus)* were hunting and resting for several days while waiting for good weather to cross the Delaware Bay. This work led to the development of a comprehensive critical areas map that identified and provided regulatory protection for migratory raptor stopover habitat within the lower 10km of Cape May Peninsula. In 2002 and 2003, we adopted the protocol used by Niles et al. (1996) to investigate the influences of changes in the landscape on migratory bird distribution and habitat use to identify additional critical stopover habitat areas at this valuable stopover site. Results of these comparison studies indicated notable habitat loss throughout the peninsula, a significant expansion of migratory raptor distribution north of the lower 10km and identified the need to revise current regulatory protections to address changes in the landscape. Using five years of point count data and GIS analyses of land cover types and distribution of migratory raptors in Cape May Peninsula, we will contribute to current conservation and planning efforts of migratory stopover habitat in the region by: 1) identifying the critical migratory stopover habitat in the Cape May Peninsula and; 2) identifying conservation and protection strategies for stopover habitat at the Cape May stopover.

METHODS

The study area consists of the entire Cape May Peninsula located at the southern tip of New Jersey (Figure 1). The peninsula is bordered on the west by the Delaware Bay and on the east by the Atlantic Ocean. From its southern tip (38 57' lat., 74 53' long.), the peninsula extends approximately 60km north along the Atlantic coast and approximately 40km north on along the Delaware Bay coast. The peninsula is about 10km wide at its northernmost point and includes a wide range of habitats. In 2002 and 2003, we replicated two studies of migratory raptors, conducted by Niles et al. (1996) in the 1980s, to investigate the influences of changes in the landscape on migratory bird distribution and habitat use at the Cape May stopover. In 2002, we replicated the survey protocol used by Niles et al. (1996) throughout the fall migrations of 1984 and 1986. In 2003, we modified the protocol used by Niles et al. (1996) in 1988 to investigate raptor distribution, habitat use and habitat selection within the lower 20 km of Cape May Peninsula.

During the fall of 1988 and 2003, surveys were conducted at points located within the lower portion of Cape May Peninsula. In 1988, the study area encompassed the lower 10km of the peninsula and was divided into one km^2 blocks based on UTM coordinates and survey points were randomly located within each one km^2 block (Niles et al. 1988). In 2003, survey points were randomly located within every other one km^2 block of every other one km row of a Universal Transverse Mercator (UTM) grid overlaying the lower 20km of Cape May Peninsula. In 1988, 50 points were surveyed in the lower 10 km and 64 points (35 in the lower 10 km) were surveyed in the lower 20 km in 2003. All points were surveyed between 08:00 and 13:00 hours twice a week for eight weeks between September and November. All points were surveyed within one day to reduce weather variation among survey days. Points were organized into routes and surveyed by one of 11 observers for 30 minutes. All observers, points and starting times were staggered to avoid observer and temporal biases. Between year comparisons of relative abundance data collected in 1988 and 2003 within the lower 10km were used to compose Figure 3.

In 1984, 1986 (Niles et al. 1996) and 2002, point count surveys of migratory raptors were conducted at 24 points located within 10km increments of distance from Cape May Point in forest, field, and marsh habitats All points were located within one kilometer of four east-west UTM lines. The first line was located one kilometer from the southern tip of the peninsula with each subsequent line 10 kilometers north of the last. These lines were then divided into a Delaware Bay and Atlantic Ocean side and three survey points, one in each of three randomly selected areas of habitat including marsh, field and forest, were placed on either side for each of the four UTM lines. Forested sites had to allow views in all directions of at least 100m. Each observer surveyed six of 24 points for 30 minutes each. All observers, points and starting times were staggered to avoid observer and temporal biases. For all surveys, skilled observers identified up to 15 species of raptors, noting their flight direction, distance, altitude and behavior. Eight behaviors were used including perching, hovering, milling, kettling (circling to gain altitude), direct high flight, direct low flight, interaction with a conspecific and interaction with another species. Observers also indicated if the birds were hunting. Flight direction was summarized by combining directions into southbound (S, SW, SE, W) and northbound (N, NE, NW, E). For analyses, summarized flight direction data and observed behaviors were used to define three behavior categories. Migratory behavior includes observations of raptors flying south at $\geq$30m, non-migrating behavior includes raptors flying north at $\geq$30m and habitat-using behaviors includes raptors flying, milling or hovering in any direction $\leq$30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors.

Prior to the survey period, observers were trained to estimate distance and altitude with a Rangematic rangefinder. Observers also used reference points of known distances and heights established at each survey location to assist with estimating bird height and distance. Wind direction, wind speed and temperature were also collected during the survey period from National Oceanographic and Atmospheric Administration (NOAA) taken at the Cape May County Airport. All surveys were conducted between 08:00 and 13:00 hours.

To investigate the influences of land cover changes on migratory birds within the Cape May Peninsula stopover, land cover types and land cover changes were quantified for Cape May Peninsula using a 1984 Level 3 Land Cover Classification and a 2001 Level 1 Landsat 7 ETM+ Satellite Image Land Cover Classification of New Jersey (Lathrop 2004). The 1984 classification was created by the Rutgers University Center for Remote Sensing and Spatial Analysis (CRSSA) from a composite data set of September and November NDVI (Normalized Difference Vegetation Index), Landstat Thematic Mapper Band 5 and wetland and housing data layers (Hasse and Lathrop 2001). The 2001 Landstat satellite image land cover classification was generated by CRSSA as an update to a 1995 land cover classification. The update utilized various standard change detection/mapping techniques and the 1994/1995 Landstat TM imagery data as a baseline (Lathrop 2004). The land cover mapping was completed at the most generalized level, Level I, with 8 classes: Developed (4 classes of developed: 1) High Intensity (>75% impervious surface (IS)), 2) Medium intensity (50-75% IS), 3) Low intensity (<50% IS) wooded, 4) Low intensity un-wooded, Cultivated/Grassland, Upland Forest, Barren, Marine/Estuarine Unconsolidated Shoreline, Estuarine Emergent Wetland/Marsh, Palustrine Wetland and Water. For the purposes of this research, the 1984 Land Cover Classification was generalized to a Level 1 Classification and the four developed classes were merged into one class. Estuarine emergent wetland (marsh) was eliminated from Figures 3, 4 and 5 due to the extensive protection regulations that have ultimately safeguarded this habitat type.

The results of each survey were summarized and used for reporting the mean number and mean altitude of observed raptors. The summarized abundance and altitude data collected in 1988 and 2003 for all species was used to display the spatial distribution of differences in raptor abundance through the creation of surface maps (Figures 3, Figure 4 and Figure 5). The surface maps were obtained by interpolation of the data from each point using ArcMap 9.2 software (ESRI 2006). This tool uses known values to estimate a value where there is no measurement available. The inverse distance weighting (IDW) method, used here, is the simplest method of interpolation but provides a valuable qualitative display of the data (Sauer et al. 1995). The IDW method estimates unknown measurements as weighted averages over the known measurement at neighboring points (Longley et al. 2003) and assigns these values to the appropriate pixels of the resulting raster image. The resulting images for each year were subtracted using the minus tool in ArcMap 9 (ESRI 2006). This tool subtracts the values of corresponding pixels to produce a difference image (Figure3).

RESULTS

Land Cover Classification

Estuarine emergent wetland dominates the eastern portion of the 40km Cape May Peninsula and portions of the western bayshore region (23.6%) (Figure 1) (Lathrop 2004). Palustrine wetland (21.5%) and upland forest (18.6%) characterize a central corridor that spans the length of the peninsula. Grassland/cultivated areas (6.1%) are dispersed throughout the peninsula in fragmented patches. Developed areas comprise about 16.6% of the peninsula with the densest development occurring on the barrier islands, along the southwestern bayshore and near the tip of the peninsula (Lathrop 2004). Developed areas also occur throughout the formerly contiguous forested portions of the central corridor (Figure 1 and Figure 2).

Land cover totals between 1984 and 2001 revealed habitat loss throughout the study area with the greatest percent loss (16.3%) occurring at the southern most tip of the peninsula (Figure 2, Appendix C, Table 1). Cultivated/grassland habitat declined most dramatically throughout the entire peninsula with 26% loss within the lower 10km, 35.3% loss between 10 and 20km from Cape May Point, 28.7 % loss between 20 and 30km from the Point and 28.9% loss between 30 and 40km from the Point. Upland forest experienced the greatest declines within 20 and 30km from the Point (6.5%) and approximately 5.2% of emergent wetland habitat was lost within the lower 10km. Increases in developed land occurred throughout the study area with the greatest increases occurring throughout the central corridor. Development within the lower 10km increased from 29.5% in 1984 to 36.7% in 2001. Overall, there was a loss of approximately 3,100 ha of habitat throughout the study area (Figure 2, Appendix C, Table 1).

Distribution in the Lower 10km

Overall, the number of raptors observed per survey within the lower 10km of Cape May Peninsula decreased between the survey years of 1988 and 2003 (Figure 3). Greater declines were observed to the west and within the central corridor of the study area. The largest declines were observed in the developed areas within the central corridor of the peninsula and along the bayshore. Little to no change in abundance of raptors occurred in the eastern and southeastern portions of the lower 10km.

Distribution in the Lower 20km

Raptors were not evenly distributed throughout the lower 20km of Cape May Peninsula. Raptor abundance increased with decreasing distance to the crossing point located at the southern most tip of the peninsula (Figure 4). Birds concentrated in the southern and central portions of the study area and generally avoided heavily developed areas.

The mean height of birds varied with geographic location on the peninsula (Figure 5). Generally, birds flew higher as they approached the crossing point at the southern-most tip of the peninsula and over developed areas. Birds flew lowest over the eastern and northwestern portions of the peninsula. These areas are dominated by marsh habitat to the east and a matrix of forested, palustrine wetland, marsh and field habitats to the northwest.

Behavior

Migratory raptors exhibited habitat using behaviors with different frequency depending on species observed, location and survey year (Figure 6). All observations taken together, approximately 54% of raptors were exhibiting habitat-using behaviors in 1984, 86% in 1986 and 46% in 2002 (Appendix A, Table 3). In 2002, only 19% of all raptors were observed exhibiting habitat using behaviors in the lower 10km as compared with 30% and 65% in 1984 and 1986 respectively (Appendix A, Table 2). When Black and Turkey Vultures are removed from the analysis and analysis is limited to habitat-using observations, a northward shift in the distribution of raptors throughout the peninsula in 2002 is apparent (Figure 6). In 2002, only 33% of birds using habitat were observed displaying habitat using behaviors in the lower 10km of Cape May Peninsula and demonstrated much greater concentration in the 10-20, 20-30 and 30-40km zones. When analyzed individually, most species demonstrated greater concentrations in northern areas of the peninsula in 2002 than in 1986 but resembled distributions observed in 1984. Similarities in distribution between 1984 and 2002 could be the result of similar weather conditions including wind pattern. Greater concentrations of Cooper's Hawks, Ospreys and Turkey Vultures observed in forest, field and marsh habitats in the lower 10km in 2002 may also be explained by the reduced availability of suitable habitat. More raptors may be forced to concentrate in the same areas of habitat due to reduced availability.

DISCUSSION

Many studies have identified the Cape May Peninsula as critical stopover site for fall migrants, including migratory waterfowl, shorebirds, raptors, woodcocks and neotropical migrants (Allen and Peterson 1936, Stone 1965, Krohn et al. 1977, Wiedner and Kerlinger 1990, Wiedner et al. 1992, McCann et al. 1993, Niles 1996). Studies conducted by Niles et al. (1996) in 1984 and 1986 found the greatest concentration of raptors in the lower 10km of the peninsula. Supplemental studies conducted by Niles et al. (1996) in 1988 did not find any additional north-south concentration of raptors within the 10km concentration area. Frank et al. (2007) used identical techniques to study raptors in the Cape May Peninsula in 2002 and 2003 to determine if habitat loss influenced raptor distribution and habitat use. Our research indicates that overall raptor abundance and habitat use in the lower 10km decreased (Figure 3 and Figure 6) and that raptors were no longer distributed evenly throughout the lower 10km (Figure 3). A map of the distribution of raptors throughout the lower 20km indicates a concentration of raptors northward from the lower 10km through the fragmented habitats of the central corridor (Figure 4). Raptors were also observed flying at lower altitudes over the forested wetland and upland forest habitats of the central corridor within 10-20km from Cape May Point (Figure 5). We suggest that many migrants extended their search for suitable stopover habitat in 2002 into northern areas of the peninsula where habitat availability is greater (Figure 1, Figure 2 and Figure 6). Our data also strongly suggest that migratory raptors are variable in their distribution and habitat use throughout the Cape May Peninsula.

<u>Conservation Recommendations</u>

Despite declines in available habitat in Cape May Peninsula, the area remains one of the country's most significant stopovers for migratory birds. As a result of this research, we have identified several key sites within the Cape May stopover and suggest a number of regulatory and conservation strategies to prioritize and protect habitats for migratory birds.

Identification of Priority Sites

The identification of high-priority sites and habitat types within a stopover is more appropriate than focusing on individual species (Winker et al. 1992, McCann et al. 1993, Swanson et al. 2003, Mehlman et al. 2005). This is because migratory birds often utilize similar critical areas at stopovers and understanding of species-specific requirements en route is inadequate (Moore 2000). Interpolation of abundance data from our studies showed concentrations of raptors over specific areas of grassland/cultivated, forested wetland and upland forest habitat. These areas include Indian Trail Swamp, Villas Wildlife Management Area (WMA), Higbee Beach WMA, Cape May County Park South, Cape May National Wildlife Refuge (NWR), Fishing Creek Marsh and forested wetland and upland forest habitats along Fulling Mill Road and the western bayshore between Del Haven and Goshen. Many of these sites have been identified as priority sites by conservation programs including New Jersey Audubon Society's Important Bird and Birding Areas (NJAS' IBBA) Program and by the NJ Department of Environmental Protection's Office of Natural Lands Management (ONLM) Natural Heritage Program. Natural Heritage Priority Sites identify critically important areas in NJ that represent some of the best remaining habitat for rare species and rare ecological communities in the state. The IBBA Program identifies and conserves Important Bird Areas (IBAs), areas throughout NJ that provide essential habitat for breeding, wintering and migrating birds throughout the state IBAs, heritage priority sites and other priority habitats should be considered top priorities for conservation and preservation of biological diversity in NJ.

Conservation Strategies

This study supports several conservation recommendations already offered by authors of similar studies examining stopover ecology. Moore (2000) suggests conservation of a network of sites along migration routes. The spatial distribution of suitable stopover sites at the landscape level is an important aspect of migration that has received little attention (Jenni and Schaub 2003). This research demonstrates that habitat use and distribution within the Cape May Peninsula stopover is variable among years, species and location suggesting that conservation of a matrix of critical habitats both within the lower 10km concentration area and areas further north will benefit all species of migrants. Conservation and protection of a diversity of habitat types, sizes and locations within stopovers should also be considered. This allows variation in habitat use and distribution of migrants within seasons and years (Sprunt 1975, Winker et al. 1992, Bibby 2003). Creating and maintaining edge habitats within even small urban woodlots have been shown to benefit migratory birds (Rodewald and Matthews 2005). Small areas of upland forest, coastal scrub, hedgerows and filter strips within urban landscapes are also of conservation value to migrants (Winker et al. 1992, McCann et al. 1993, Swanson et al. 2003). Our surveys recorded migratory raptors in small habitat areas near development (Figure 4 and Figure 5). Large contiguous forests should also be maintained as they offer a diversity of habitats not available in smaller woodlots and provide stopover habitat for forest species (Winker et al. 1992, McCann et al. 1993, Swanson et al. 2003) Sites should be structurally heterogeneous (ie. shrub/scrub) and provide a diversity of food and water resources.

Outreach and education will facilitate successful implementation of conservation strategies. New Jersey's Wildlife Action Plan (WAP) identifies the development of educational materials for public and private landowners about the importance of the Atlantic Flyway and its migratory stopover sites as a specific conservation action (NJDEP 2007). Outreach to private landowners should encourage habitat restoration projects that leverage funding from any one of several habitat incentive programs including the United States Fish and Wildlife Service's Partners for Fish and Wildlife, the United States Department of Agriculture's Conservation Reserve and Conservation Reserve Enhancement Programs and the New Jersey Department of Environmental Protection's Landowner Incentive Program.

Protection Regulation

Gaps in protection of stopover habitat have been identified in current regulatory protections for habitats occurring in the Cape May stopover. Some protection is afforded to habitats in Cape May Peninsula through the Freshwater Wetlands Act, Coastal Area Facilities Review Act and the New Jersey Department of Environmental Protection Agency's Landscape Project. Currently, all forest and grassland patches in the lower 10km of the Cape May Peninsula and all forest patches in the Coastal Landscape Region are considered critical areas by the Landscape Project due to the importance of these habitats to migrating birds. Our data strongly suggest that designation of critical areas for migrating birds should be expanded to include habitats within the lower 20km and preferably as far north as the lower 30km of Cape May Peninsula.

Research

Future research should incorporate analysis of available land cover data at a higher level of detail to address more specific habitat types. A more comprehensive analysis of how habitat is dispersed throughout the landscape will also benefit our understanding of stopover behaviors. Moore et al. (1995) and Moore and Simons (1992) suggest that the effects of fragmentation, including changes in patch size, isolation, and structure, could negatively impact migrants by increasing predation, competition and energetic costs by forcing birds to move through poor habitats. Continued research of habitat use and behaviors during migration are necessary to develop and contribute to the successful management and conservation of migratory bird habitat. As New Jersey's WAP prescribes, surveys of migratory raptors at the Cape May Stopover should be repeated at least every five years (NJDEP 2007). This will allow a better assessment of migratory raptor distribution and habitat use within the changing landscape of Cape May Peninsula, New Jersey.

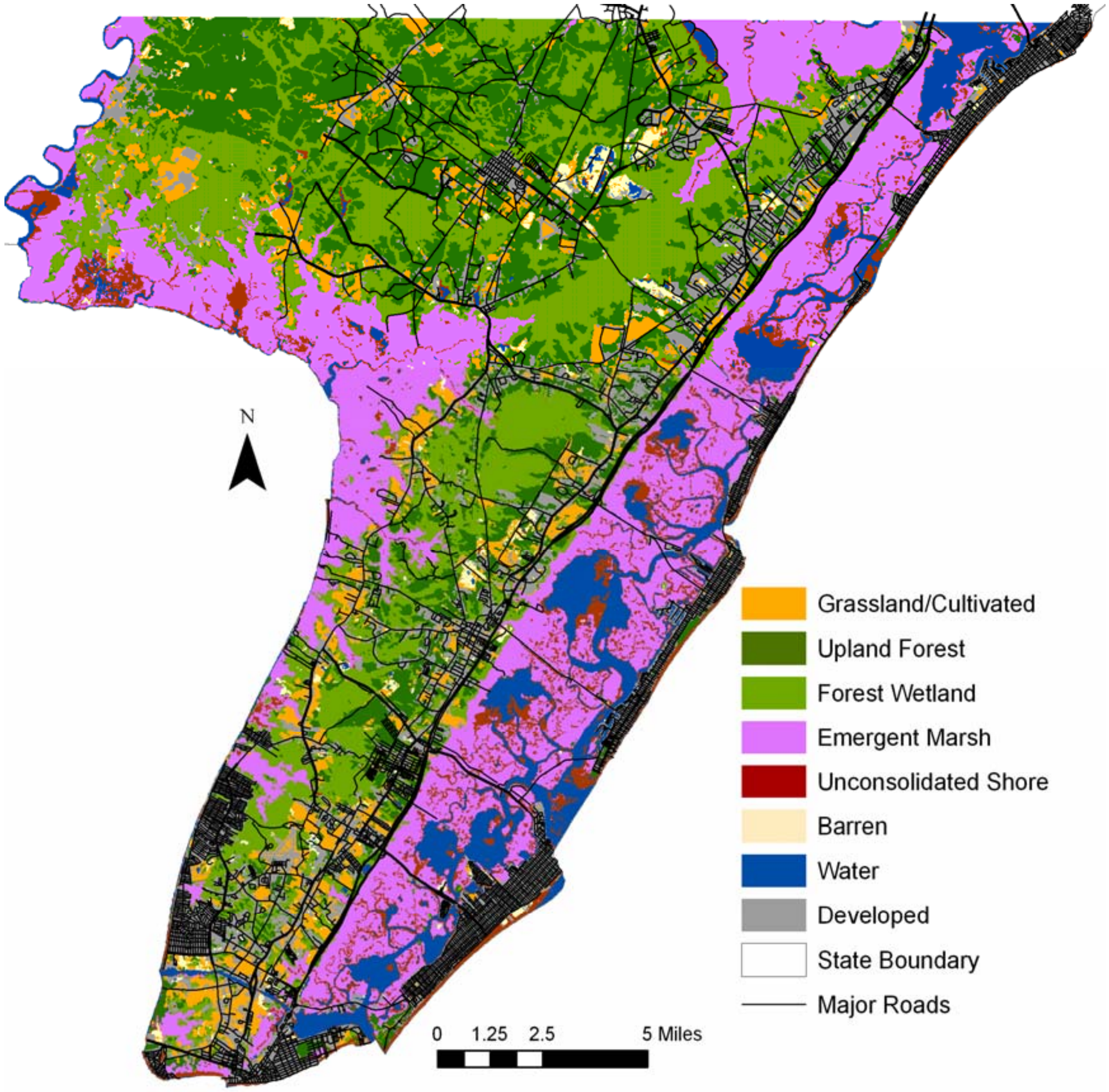

Figure 1. Land use/land cover of Cape May Peninsula, New Jersey, 0-40km from Cape May Point in 2001 (Lathrop 2004). See Appendix C, Table 1 for calculations of changes in land use/land cover types.

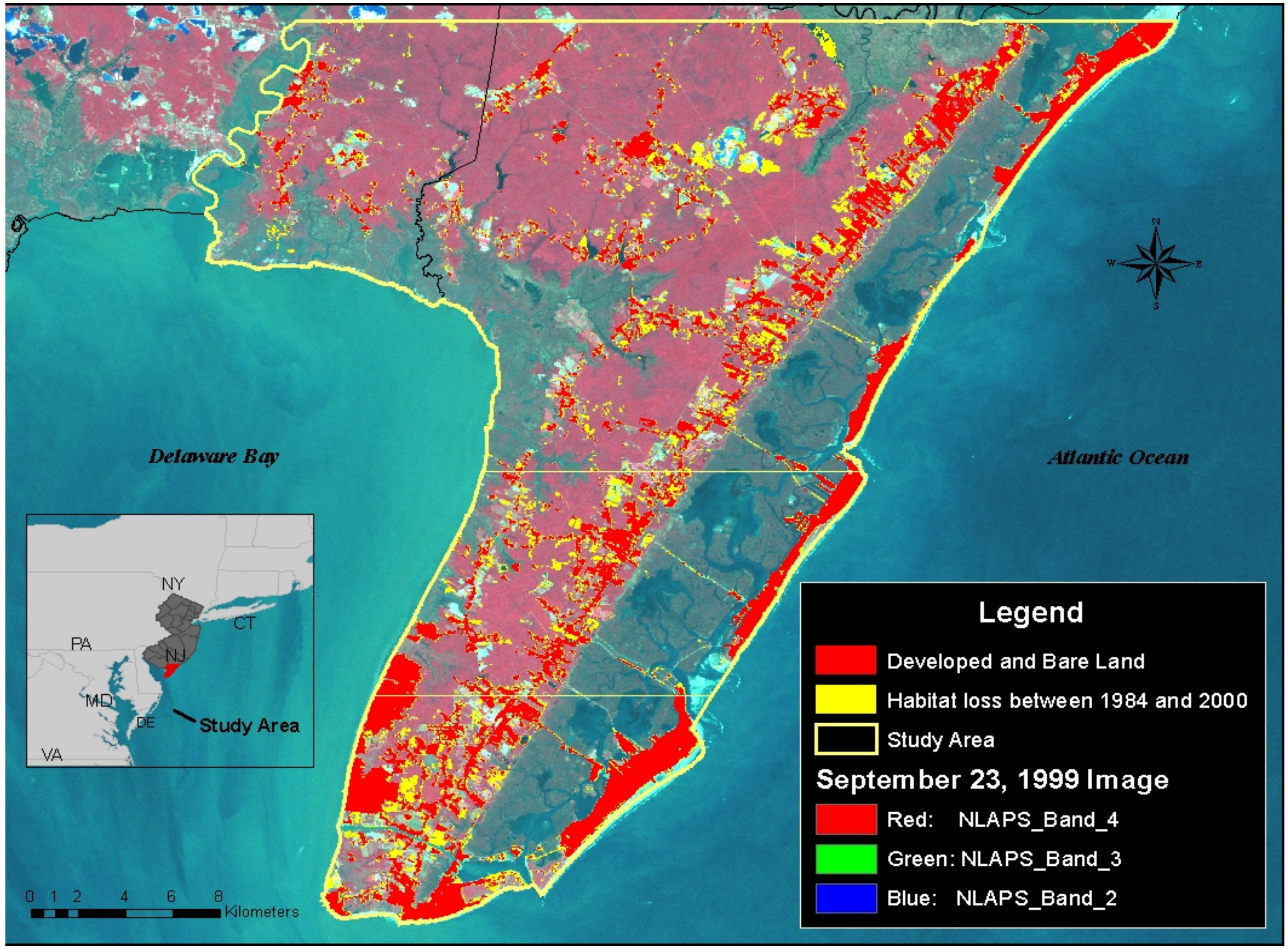

Figure 2. Map of Cape May Peninsula, New Jersey, 0-40km from Cape May Point, displaying developed and bare land in red and habitat loss between 1984 and 2001 in yellow (Lathrop 2004). See Appendix C, Table 1 for calculations of changes in land use/land cover types.

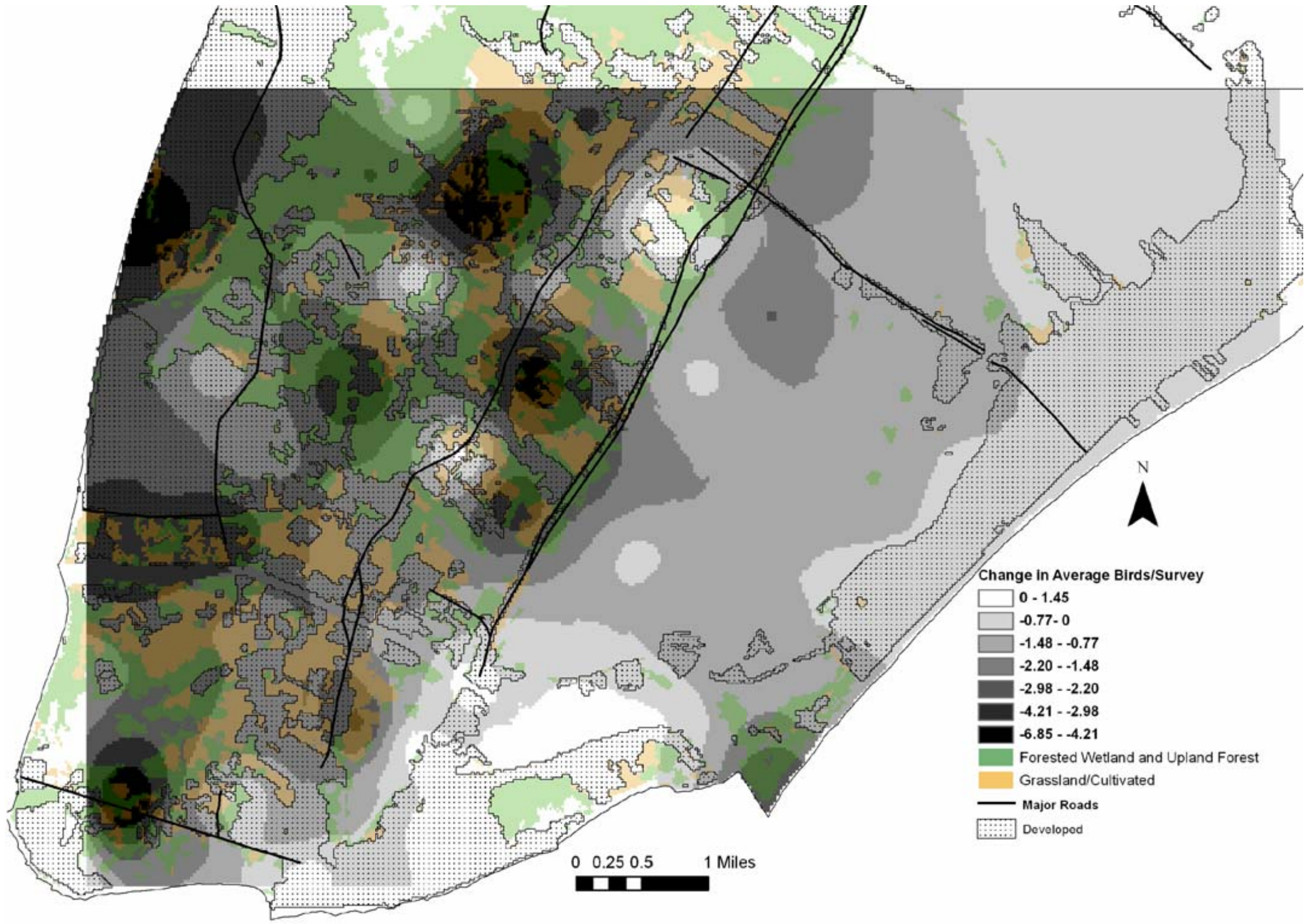

Figure 3. Difference in mean number of raptors per survey observed between the fall survey periods of 1988 and 2003 on Cape May Peninsula, New Jersey. This map was obtained by interpolation of count data collected at each survey site. Darker shades indicate the greatest declines in abundance. Developed areas, forested wetland, upland forest and grassland/cultivated land cover types are also shown.

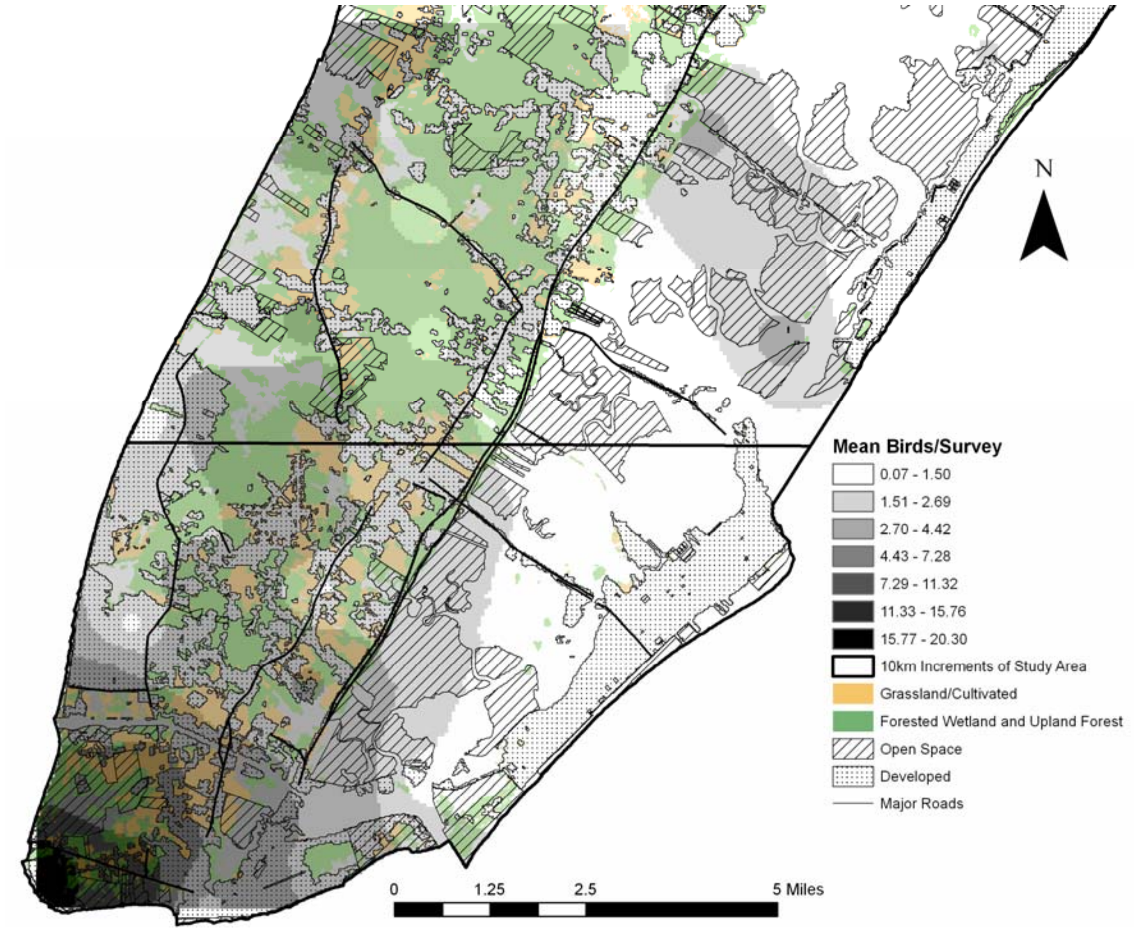

Figure 4. Mean number of raptors per survey observed on Cape May Peninsula, New Jersey throughout the fall of 2003 displayed with developed areas, open space, forested wetland, upland forest and grassland/cultivated. This map was obtained by interpolation of the count data collected at each survey site (n=64). Increasing abundance is indicated with darker shading.

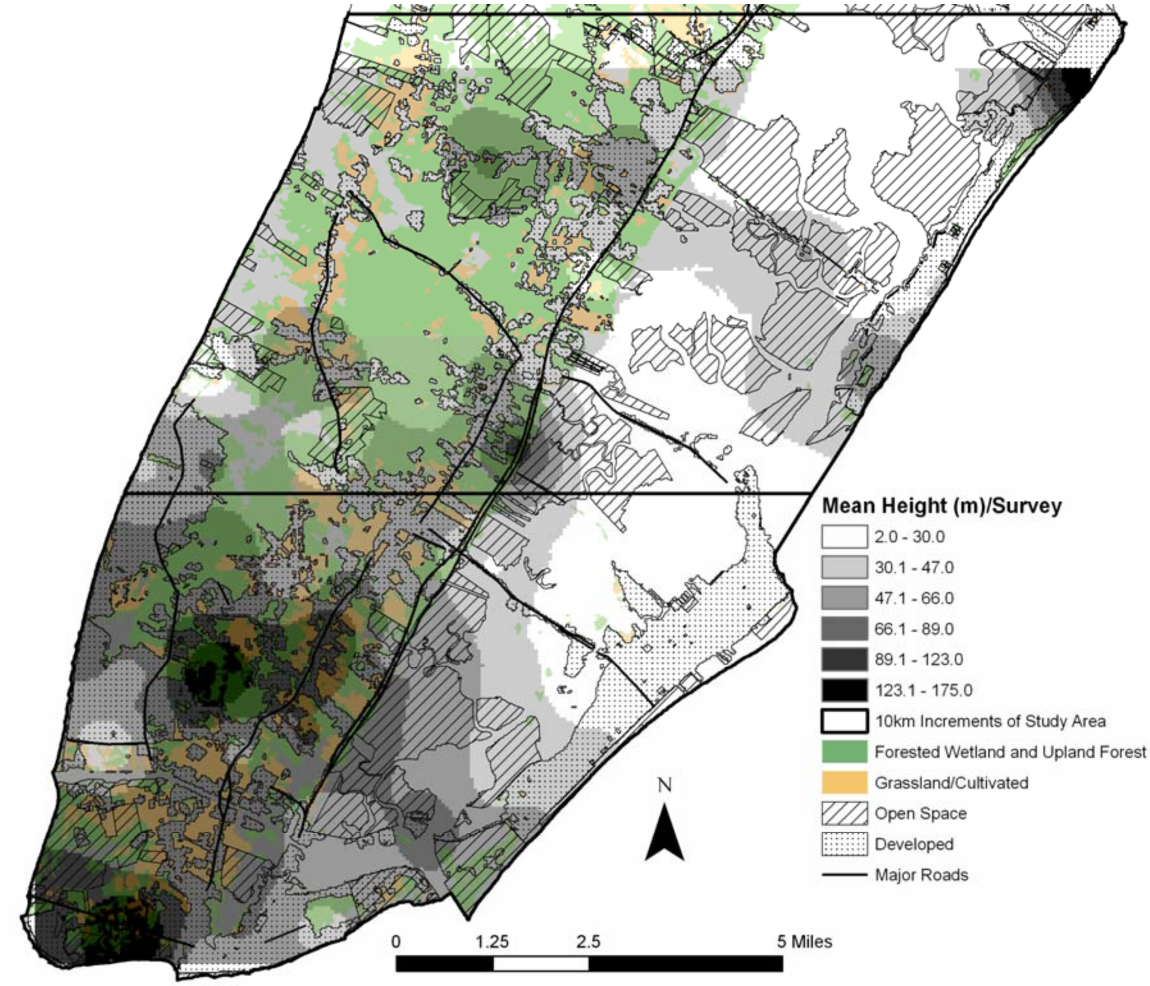

Figure 5. Mean height (m) of raptors observed on Cape May Peninsula, New Jersey throughout the fall of 2003 displayed with developed areas, open space, forested wetland, upland forest and grassland/cultivated. This map was obtained by interpolation of height data collected during each observation at each survey location. Increasing heights are displayed in darker shades.

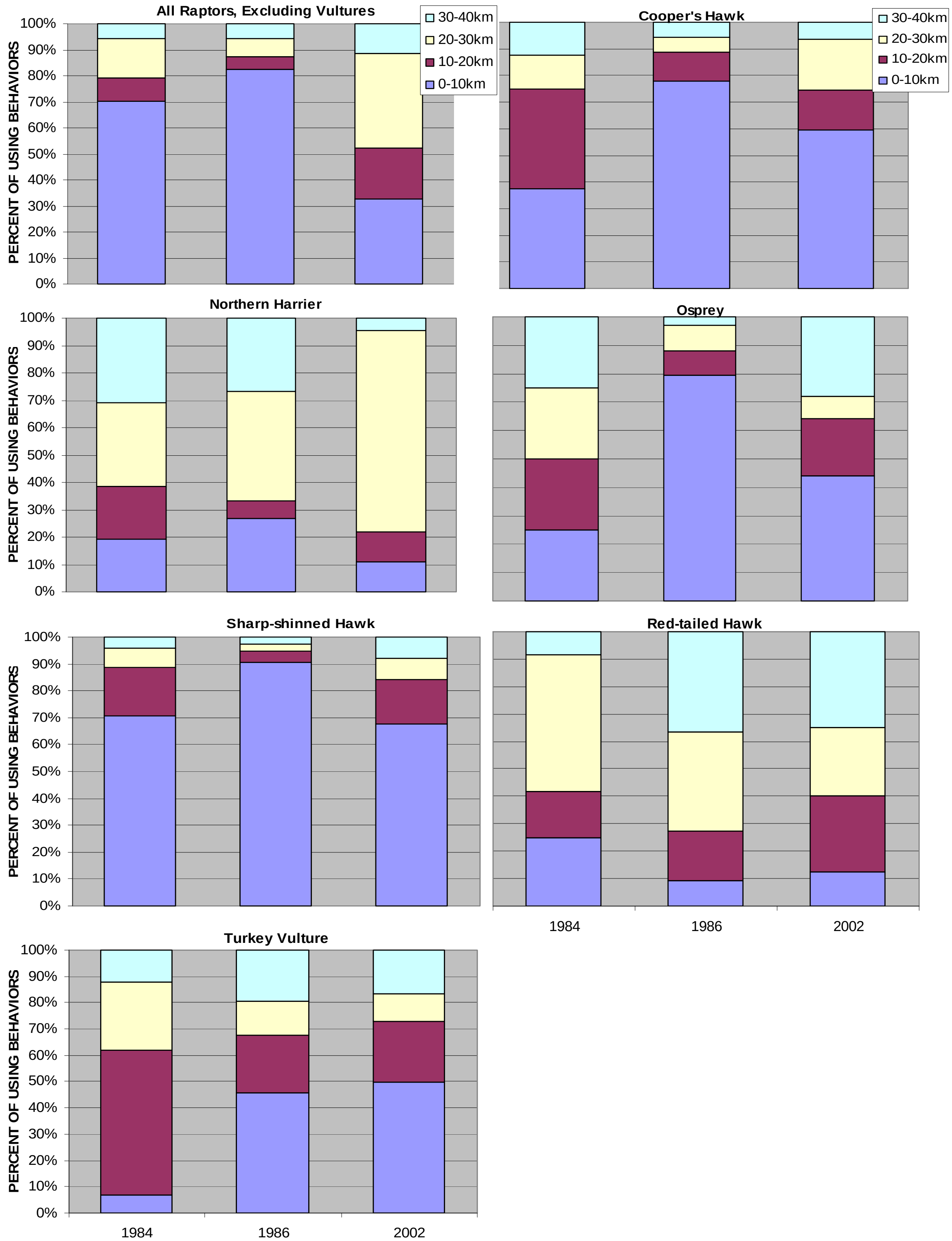

Figure 6. For each survey year, the percent of raptors exhibiting habitat-using behaviors is reported for each 10km zone of Cape May Peninsula, New Jersey. Habitat-using behaviors includes raptors flying in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors. See Appendix B, Table 2 and Table 3 for additional results.

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APPENDIX A:
SUPPLEMENTAL TABLES AND FIGURES FOR

CHAPTER ONE:
A TEMPORAL COMPARISON OF
RAPTOR DISTRIBTION AND
HABITAT USE DURING FALL MIGRATION AT
CAPE MAY PENINSULA, NEW JERSEY

Table 1. For each survey year, the mean number of individual raptors per survey is reported for each 10 km increment of Cape May Peninsula. F ratios and P values are reported from an ANOVA of relative abundance observed each year against the four increments of distance from Cape May Point. Also reported are F ratios and P values from an ANOVA of relative abundance, averaged over all surveys at each point, observed within the four 10 km increments against all years. Significance is reported at the 5% level which has been adjusted using the sequential Bonferroni technique.

		DISTANCE FROM CAPE MAY POINT									
		0-10 km		10-20 km		20-30 km		30-40 km			
SPECIES	YEAR	N	Mean Birds +/- S.E.	N	Mean Birds +/- S.E.	N	Mean Birds +/- S.E.	N	Mean Birds +/- S.E.	F	P
Cooper's Hawk	1984	13	0.36 +/- 0.161	5	0.15 +/- 0.105	1	0.03 +/- 0.062	3	0.09 +/- 0.082	3.33	0.022*
	1986	14	0.45 +/- 0.173	2	0.07 +/- 0.115	1	0.03 +/- 0.064	2	0.07 +/- 0.092	6.23	0.001*
	2002	51	0.61 +/- 0.105	20	0.24 +/- 0.067	15	0.19 +/- 0.039	14	0.17 +/- 0.052	5.70	0.001*
F, P			F=0.30, P=0.744		F=1.14, P=0.346		F=7.37, P=0.006*		F=0.67, P=0.529		
Northern Harrier	1984	8	0.22 +/- 0.073	8	0.24 +/- 0.057	8	0.26 +/- 0.152	10	0.29 +/- 0.074	0.05	0.987
	1986	4	0.13 +/- 0.079	1	0.04 +/- 0.063	9	0.31 +/- 0.158	4	0.15 +/- 0.083	2.04	0.112
	2002	10	0.12 +/- 0.048	5	0.06 +/- 0.036	34	0.44 +/- 0.096	4	0.05 +/- 0.047	8.20	<0.0001*
F, P			F=3.74, P=0.048*		F=3.83, P=0.045*		F=1.45, P=0.267		F=2.42, P=0.123		
Osprey	1984	5	0.14 +/- 0.116	1	0.03 +/- 0.059	7	0.23 +/- 0.090	1	0.03 +/- 0.063	2.42	0.069
	1986	30	0.97 +/- 0.125	5	0.18 +/- 0.065	9	0.31 +/- 0.093	2	0.07 +/- 0.071	9.13	<0.0001*
	2002	16	0.19 +/- 0.076	9	0.11 +/- 0.038	9	0.12 +/- 0.056	12	0.14 +/- 0.040	0.93	0.425
F, P			F=9.18, P=0.002*		F=0.92, P=0.420		F=0.41, P=0.673		F=1.36, P=0.287		
Red-tailed Hawk	1984	4	0.11 +/- 0.106	7	0.21 +/- 0.106	6	0.19 +/- 0.127	2	0.06 +/- 0.100	0.72	0.543
	1986	2	0.06 +/- 0.114	5	0.18 +/- 0.117	9	0.31 +/- 0.131	8	0.30 +/- 0.112	1.24	0.300
	2002	26	0.31 +/- 0.069	20	0.24 +/- 0.068	23	0.29 +/- 0.080	23	0.27 +/- 0.064	0.14	0.935
F, P			F=1.59, P=0.236		F=0.21, P=0.815		F=0.70, P=0.512		F=1.96, P=0.176		
Sharp-shinned Hawk	1984	233	6.47 +/- 1.614	46	1.35 +/- 0.269	14	0.45 +/- 0.181	7	0.21 +/- 0.103	10.00	<0.0001*
	1986	273	8.81 +/- 1.739	16	0.57 +/- 0.297	14	0.48 +/- 0.187	10	0.36 +/- 0.113	10.45	<0.0001*
	2002	123	1.46 +/- 1.056	35	0.42 +/- 0.171	29	0.37 +/- 0.114	17	0.20 +/- 0.066	5.73	<0.001*
F, P			F=2.39, P=0.126		F=3.24, P=0.068		F=0.14, P=0.871		F=0.33, P=0.725		
Turkey Vulture	1984	7	0.19 +/- 0.802	5	0.15 +/- 0.338	9	0.29 +/- 0.243	3	0.09 +/- 0.277	0.56	0.640
	1986	6	0.19 +/- 0.864	6	0.21 +/- 0.372	7	0.24 +/- 0.251	13	0.46 +/- 0.305	1.78	0.156
	2002	172	2.05 +/- 0.525	87	1.04 +/- 0.215	65	0.83 +/- 0.153	87	1.04 +/- 0.176	0.53	0.664
F, P			F=13.36, P=<0.001*		F=6.87, P=0.008*		F=5.99, P=0.012*		F=5.13, P=0.020*		
TOTAL	1984	304	8.44 +/- 2.056	86	2.56 +/- 0.545	54	1.74 +/- 0.492	26	0.76 +/- 0.410	6.96	<0.001*
	1986	349	11.26 +/- 2.215	46	1.64 +/- 0.601	61	2.10 +/- 0.509	57	2.04 +/- 0.452	5.80	0.001*
	2002	432	5.14 +/- 1.346	199	2.37 +/- 0.347	204	2.62 +/- 0.310	186	2.21 +/- 0.261	2.62	0.051
F, P			F=0.32, P=0.734		F=2.86, P=0.089		F=0.80, P=0.468		F=4.20, P=0.036*		
TOTAL, No Vultures	1984	297	8.25 +/- 1.827	81	2.35 +/- 0.349	45	1.45 +/- 0.37167	23	0.68 +/- 0.2368	7.62	<0.0001*
	1986	343	11.06 +/- 1.968	40	1.36 +/- 0.384	54	1.86 +/- 0.38427	44	1.57 +/- 0.261	7.73	<0.0001*
	2002	346	2.93 +/- 1.196	55	1.18 +/- 0.222	131	1.68 +/- 0.23431	77	0.92 +/- 0.1507	4.62	0.004*
F, P			F=1.61, P=0.233		F=4.84, P=0.024*		F=0.02, P=0.980		F=1.64, P=0.228		

Table 2. For each survey year, the number of individual raptors and percent of raptors exhibiting migrating, non-migrating and using behaviors is reported for each 10 km increment of Cape May Peninsula. Migration behavior includes observations of raptors flying south at ≥30m, non-migrating behavior includes raptors flying north at ≥30m, and habitat-using behaviors includes raptors flying in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors.

		DISTANCE FROM CAPE MAY POINT																															
		0-10 km								10-20 km								20-30 km								30-40 km							
		Total		M		NM		U		Total		M		NM		U		Total		M		NM		U		Total		M		NM		U	
SPECIES	YEAR	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Cooper's Hawk	1984	13	59	9	41	1	5	3	14	5	23	2	9	0	0	3	14	1	5	0	0	0	0	1	5	3	14	2	9	0	0	1	5
	1986	14	74	0	0	0	0	14	74	2	11	0	0	0	0	2	11	1	5	0	0	0	0	1	5	2	11	1	5	0	0	1	5
	2002	51	51	17	17	6	6	28	28	20	20	11	11	2	2	7	7	15	15	2	2	4	4	9	9	14	14	7	7	4	4	3	3
Northern Harrier	1984	8	24	3	9	0	0	5	15	8	24	3	9	0	0	5	15	8	24	0	0	0	0	8	24	10	29	2	6	0	0	8	24
	1986	4	22	0	0	0	0	4	22	1	6	0	0	0	0	1	6	9	50	3	17	0	0	6	33	4	22	0	0	0	0	4	22
	2002	10	18	5	9	0	0	5	9	5	9	0	0	0	0	5	9	36	63	1	2	1	2	34	60	6	11	2	4	2	4	2	4
Osprey	1984	5	63	4	50	0	0	1	13	1	13	0	0	0	0	1	13	1	13	0	0	0	0	1	13	1	13	0	0	0	0	1	13
	1986	30	65	3	7	0	0	27	59	5	11	2	4	0	0	3	7	9	20	5	11	1	2	3	7	2	4	1	2	0	0	1	2
	2002	16	35	4	9	1	2	11	24	9	20	3	7	1	2	5	11	9	20	5	11	2	4	2	4	12	26	4	9	1	2	7	15
Red-tailed Hawk	1984	4	21	1	5	0	0	3	16	7	37	5	26	0	0	2	11	6	32	0	0	0	0	6	32	2	11	1	5	0	0	1	5
	1986	2	8	1	4	0	0	1	4	5	21	3	13	0	0	2	8	9	38	5	21	0	0	4	17	8	33	4	17	0	0	4	17
	2002	25	27	19	21	1	1	5	5	20	22	6	7	3	3	11	12	23	25	7	8	6	7	10	11	23	25	8	9	1	1	14	15
Sharp-shinned Hawk	1984	233	78	100	33	26	9	107	36	46	15	12	4	7	2	27	9	14	5	2	1	1	0	11	4	7	2	1	0	0	0	6	2
	1986	273	86	2	1	1	0	270	85	16	5	4	1	0	0	12	4	14	4	6	2	0	0	8	3	14	4	6	2	0	0	8	3
	2002	121	60	37	18	7	3	77	38	35	17	13	6	3	1	19	9	29	14	11	5	9	4	9	4	17	8	5	2	3	1	9	4
Turkey Vulture	1984	7	8	3	3	0	0	4	4	51	56	12	13	7	8	32	35	23	25	7	8	1	1	15	16	10	11	3	3	0	0	7	8
	1986	45	41	6	5	1	1	38	34	22	20	4	4	0	0	18	16	21	19	10	9	0	0	11	10	23	21	7	6	0	0	16	14
	2002	293	48	147	24	26	4	120	20	122	20	33	5	33	5	56	9	94	15	41	7	28	5	25	4	104	17	36	6	28	5	40	7
TOTAL	1984	304	65	137	29	28	6	139	30	86	18	28	6	7	1	51	11	54	11	9	2	1	0	44	9	26	6	8	2	0	0	18	4
	1986	347	68	14	3	1	0	332	65	46	9	9	2	0	0	37	7	61	12	23	5	2	0	36	7	57	11	21	4	0	0	36	7
	2002	429	42	203	20	36	4	190	19	199	20	56	6	40	4	103	10	204	20	66	6	43	4	95	9	186	18	68	7	36	4	82	8

Table 3. For each survey year, the number of individual raptors and percent of raptors exhibiting migrating, non-migrating and using behaviors is reported for each species. Migration behavior includes observations of raptors flying south at ≥30m, non-migrating behavior includes raptors flying north at ≥30m, and habitat-using behaviors includes raptors flying in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors.

	MIGRATING						NON-MIGRATING						USING					
	1984		1986		2002		1984		1986		2002		1984		1986		2002	
SPECIES	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%
Cooper's Hawk	13	59	1	5	37	37	1	5	0	0	16	16	8	36	18	95	47	47
Northern Harrier	8	24	3	17	8	14	0	0	0	0	3	5	26	76	15	83	46	81
Osprey	4	50	11	24	16	35	0	0	1	2	5	11	4	50	34	74	25	54
Red-tailed Hawk	7	37	13	54	40	44	0	0	0	0	11	12	12	63	11	46	40	44
Sharp-shinned Hawk	115	38	18	6	66	33	34	11	1	0	22	11	151	50	298	94	114	56
Turkey Vulture	25	27	27	24	257	42	8	9	1	1	115	19	58	64	83	75	241	39
TOTAL	182	39	67	13	393	39	36	8	3	1	155	15	252	54	441	86	470	46

Table 4. For each survey year, the mean density of raptors per survey is reported for each marsh, field and forested habitat. F ratios and P values are reported from an ANOVA of mean density over all surveys observed each year against habitat type. Also reported are F ratios and P values from an ANOVA of mean density, averaged over all surveys at each point (to account for differences in survey effort among years), observed in marsh, field and forest habitats against all years. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

		HABITAT TYPE							
		MARSH		FIELD		FOREST			
SPECIES	YEAR	N	Mean Density +/- S.E.	N	Mean Density +/- S.E.	N	Mean Density +/- S.E.	F	P
Cooper's Hawk	1984	5	0.00 +/- 0.006	10	0.01 +/- 0.006	7	0.03 +/- 0.007	3.41	0.036*
	1986	6	0.01 +/- 0.006	8	0.01 +/- 0.006	5	0.02 +/- 0.006	1.05	0.354
	2002	26	0.01 +/- 0.007	37	0.01 +/- 0.007	37	0.04 +/- 0.007	7.70	0.001*
F, P			F=4.86, P=0.018*		F=2.51, P=0.105		F=4.04, P=0.033*		
Northern Harrier	1984	24	0.02 +/- 0.005	6	0.00 +/- 0.005	4	0.01 +/- 0.006	1.50	0.226
	1986	11	0.01 +/- 0.003	6	0.01 +/- 0.003	1	0.00 +/- 0.003	1.76	0.177
	2002	39	0.01 +/- 0.003	10	0.00 +/- 0.003	4	0.01 +/- 0.003	4.43	0.013*
F, P			F=3.24, P=0.060		F=1.11, P=0.347		F=1.05, P=0.369		
Osprey	1984	9	0.01 +/- 0.004	3	0.00 +/- 0.004	2	0.01 +/- 0.004	0.36	0.697
	1986	22	0.02 +/- 0.008	17	0.02 +/- 0.007	7	0.02 +/- 0.007	0.33	0.717
	2002	20	0.01 +/- 0.004	8	0.00 +/- 0.004	18	0.02 +/- 0.004	8.87	<0.001*
F, P			F=0.83, P=0.451		F=2.75, P=0.087		F=2.29, P=0.126		
Red-tailed Hawk	1984	10	0.01 +/- 0.003	7	0.01 +/- 0.003	2	0.01 +/- 0.004	0.04	0.957
	1986	11	0.01 +/- 0.007	5	0.00 +/- 0.007	8	0.03 +/- 0.007	3.26	0.042*
	2002	20	0.01 +/- 0.005	50	0.02 +/- 0.005	22	0.03 +/- 0.005	4.72	0.010*
F, P			F=0.97, P=0.396		F=11.03, P=0.0001*		F=8.59, P=0.002*		
Sharp-shinned Hawk	1984	81	0.05 +/- 0.076	113	0.09 +/- 0.083	106	0.39 +/- 0.089	5.66	0.004*
	1986	64	0.06 +/- 0.101	158	0.14 +/- 0.096	91	0.32 +/- 0.096	2.19	0.117
	2002	19	0.01 +/- 0.020	102	0.03 +/- 0.020	83	0.11 +/- 0.020	11.41	<0.0001*
F, P			F=0.52, P=0.602		F=0.18, P=0.839		F=0.29, P=0.751*		
Turkey Vulture	1984	7	0.00 +/- 0.007	11	0.01 +/- 0.007	6	0.02 +/- 0.008	1.29	0.278
	1986	5	0.00 +/- 0.007	23	0.02 +/- 0.006	4	0.01 +/- 0.006	1.40	0.250
	2002	106	0.03 +/- 0.019	215	0.07 +/- 0.019	90	0.12 +/- 0.019	5.02	0.007*
F, P			F=14.75, P=<0.0001*		F=21.89, P=<0.0001*		F=80.18, P=<0.0001*		
TOTAL	1984	151	0.10 +/- 0.083	177	0.14 +/- 0.091	142	0.53 +/- 0.098	5.62	0.005*
	1986	132	0.13 +/- 0.112	257	0.23 +/- 0.106	124	0.44 +/- 0.106	1.97	0.144
	2002	260	0.08 +/- 0.037	467	0.15 +/- 0.037	294	0.38 +/- 0.037	7.23	0.001*
F, P			F=3.07, P=0.068		F=3.98, P=0.034*		F=5.14, P=0.015*		

APPENDIX B:
SUPPLEMENTAL TABLES AND FIGURES FOR

CHAPTER TWO:
DISTRIBUTION AND HABITAT ASSOCIATIONS OF
MIGRATORY RAPTORS IN THE
CAPE MAY STOPOVER, NEW JERSEY

Table 1. Mean number of individual raptors per survey observed at each south to north UTM grid line of the lower 20km of Cape May Peninsula, New Jersey in 2003. Given are F and P values for each species. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

NSCOORD		ALL BIRDS		COOPER'S HAWK		NORTHERN HARRIER		OSPREY		RED-TAILED HAWK		SHARP-SHINNED HAWK		TURKEY VULTURE	
UTM	# Surveys	Count	Mean Birds/Survey +/- S.E.	Count	Mean Birds/Survey +/- S.E.	Count	Mean Birds/Survey +/- S.E.	Count	Mean Birds/Survey +/- S.E.	Count	Mean Birds/Survey +/- S.E.	Count	Mean Birds/Survey +/- S.E.	Count	Mean Birds/Survey +/- S.E.
4309	56	612	10.93 +/- 0.959	73	1.30 +/- 0.114	20	0.36 +/- 0.080	11	0.20 +/- 0.056	13	0.23 +/- 0.062	201	3.59 +/- 0.260	262	4.68 +/- 0.593
4311	70	294	4.20 +/- 0.858	21	0.30 +/- 0.102	19	0.27 +/- 0.072	8	0.11 +/- 0.050	24	0.34 +/- 0.056	36	0.51 +/- 0.232	123	1.76 +/- 0.531
4313	69	195	2.83 +/- 0.864	10	0.14 +/- 0.103	11	0.16 +/- 0.072	12	0.17 +/- 0.050	18	0.26 +/- 0.056	15	0.22 +/- 0.234	112	1.62 +/- 0.535
4315	82	128	1.56 +/- 0.792	16	0.20 +/- 0.094	7	0.09 +/- 0.066	5	0.06 +/- 0.046	7	0.09 +/- 0.051	8	0.10 +/- 0.215	75	0.91 +/- 0.490
4317	110	176	1.60 +/- 0.684	7	0.06 +/- 0.081	19	0.17 +/- 0.057	21	0.19 +/- 0.040	8	0.07 +/- 0.044	17	0.15 +/- 0.185	81	0.74 +/- 0.423
4319	90	175	1.96 +/- 0.756	12	0.13 +/- 0.090	12	0.13 +/- 0.063	8	0.09 +/- 0.044	4	0.04 +/- 0.049	18	0.20 +/- 0.205	94	1.04 +/- 0.468
4321	97	172	1.77 +/- 0.729	7	0.07 +/- 0.087	25	0.26 +/- 0.061	13	0.13 +/- 0.042	4	0.04 +/- 0.047	25	0.26 +/- 0.197	81	0.84 +/- 0.451
4323	84	125	1.49 +/- 0.783	4	0.05 +/- 0.093	22	0.26 +/- 0.065	13	0.15 +/- 0.045	1	0.01 +/- 0.051	7	0.08 +/- 0.212	63	0.75 +/- 0.484
4325	98	205	2.09 +/- 0.725	15	0.15 +/- 0.086	29	0.30 +/- 0.061	6	0.06 +/- 0.042	15	0.15 +/- 0.047	5	0.05 +/- 0.196	100	1.02 +/- 0.449
4327	90	139	1.54 +/- 0.756	8	0.09 +/- 0.090	16	0.18+/- 0.063	4	0.04 +/- 0.044	3	0.03 +/- 0.049	11	0.12 +/- 0.205	78	0.87 +/- 0.468
		F	2.805	**F**	6.339	**F**	0.607	**F**	0.854	**F**	2.072	**F**	14.683	**F**	1.433
		P	0.0089*	**P**	<0.0001*	**P**	0.7853	**P**	0.5705	**P**	0.0485*	**P**	<0.0001*	**P**	0.1977

Table 2. Mean number of individual raptors per survey at each west to east UTM grid line of the lower 20km of Cape May Peninsula, New Jersey in 2003. Given are F and P values for each species. Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

EWCOOR		**ALL BIRDS**		**COOPER'S HAWK**		**NORTHERN HARRIER**		**OSPREY**		**RED-TAILED HAWK**		**SHARP-SHINNED HAWK**		**TURKEY VULTURE**	
UTM	**# Surveys**	**Count**	**Mean Birds/Survey +/- S.E.**	**Count**	**Mean Birds/Survey +/- S.E.**	**Count**	**Mean Birds/Survey +/- S.E.**	**Count**	**Mean Birds/Survey +/- S.E.**	**Count**	**Mean Birds/Survey +/ S.E.**	**Count**	**Mean Birds/Survey +/- S.E.**	**Count**	**Mean Birds/Survey +/- S.E.**
502	14	284	20.29 +/- 1.880	30	2.14 +/- 0.227	6	0.43 +/- 0.156	6	0.43 +/- 0.110	2	0.14 +/- 0.125	109	7.79 +/- 0.500	122	8.71 +/- 1.169
504	84	479	5.67 +/- 0.767	55	0.65 +/- 0.093	12	0.15 +/- 0.064	10	0.12 +/- 0.045	26	0.31+/- 0.051	86	1.02 +/- 0.204	232	2.81 +/- 0.477
506	96	352	3.61 +/- 0.718	28	0.29 +/- 0.087	16	0.17 +/- 0.059	13	0.14 +/- 0.042	16	0.17 +/- 0.048	57	0.59 +/- 0.191	159	1.61 +/- 0.447
508	124	404	3.26 +/- 0.632	29	0.23 +/- 0.076	26	0.21 +/- 0.052	24	0.19 +/- 0.037	25	0.20 +/- 0.042	43	0.35 +/- 0.168	220	1.77 +/- 0.393
510	110	231	2.11 +/- 0.671	14	0.13 +/- 0.081	5	0.05 +/- 0.056	23	0.21 +/- 0.039	12	0.11 +/- 0.045	26	0.24 +/- 0.178	126	1.15 +/- 0.417
512	112	186	1.66 +/- 0.665	11	0.10 +/- 0.080	20	0.18 +/- 0.055	6	0.05 +/- 0.039	5	0.04 +/- 0.044	10	0.09 +/- 0.177	105	0.94 +/- 0.413
514	104	70	0.67 +/- 0.690	1	0.01 +/- 0.083	14	0.13 +/- 0.057	5	0.05 +/- 0.040	4	0.04 +/- 0.046	5	0.05 +/- 0.183	36	0.35 +/- 0.429
516	76	82	1.08 +/- 0.807	4	0.05 +/- 0.097	21	0.28 +/- 0.067	1	0.01 +/- 0.047	7	0.09 +/- 0.054	4	0.05 +/- 0.215	32	0.42 +/- 0.502
518	41	57	1.39 +/- 1.098	0	0	20	0.49 +/- 0.091	6	0.15 +/- 0.064	0	0	2	0.05 +/- 0.292	22	0.54 +/- 0.683
520	43	40	0.93 +/- 1.073	1	0.02 +/- 0.129	17	0.40 +/- 0.089	5	0.12 +/- 0.063	0	0	0	0	10	0.23 +/- 0.667
522	28	34	1.21 +/- 1.329	0	0	23	0.82 +/- 0.110	2	0.07 +/- 0.078	0	0	0	0	5	0.18 +/- 0.870
524	14	2	0.14 +/- 1.880	0	0	0	0	0	0	0	0	1	0.07 +/- 0.500	0	0
		F	7.177	**F**	7.256	**F**	2.024	**F**	1.929	**F**	1.365	**F**	9.941	**F**	5.422
		P	<0.0001*	**P**	<0.0001*	**P**	0.0446*	**P**	0.0566	**P**	0.2178	**P**	<0.0001*	**P**	<0.0001*

Table 3. Total abundance and mean number of individual raptors per survey, excluding Turkey Vultures and Black Vultures, observed within south to north (SNCOORD) and west to east (WECOORD) UTM grid lines located in the lower 10km of Cape May Peninsula, New Jersey. F ratios and P values are reported from ANOVAs of mean raptors per survey observed at each year against each UTM line. Also reported are t and P values from an analysis of mean raptors per survey, averaged over all surveys at each point (to account for differences in survey effort among years), observed within each UTM grid line against year. . Significance is reported at the 5% level with "*" which has been adjusted using the sequential Bonferroni technique.

SNCOORD	**Count**		**Mean Birds/Survey +/- S.E.**		**t**	**p**
	1988	**2003**	**1988**	**2003**		
4309	143	350	4.61 +/- 0.820	6.25 +/- 0.538	0.57	0.601
4311	164	132	3.35 +/- 0.652	1.89 +/- 0.481	-1.08	0.314
4313	183	77	3.33 +/- 0.615	1.12 +/- 0.484	-1.82	0.103
4315	166	50	2.91 +/- 0.604	0.61 +/- 0.444	-2.87	0.018
4317	220	82	3.93 +/- 0.610	0.75 +/- 0.384	-2.56	0.038
		F	2.26	18.49		
		P	0.018	<0.0001*		
WECOORD	**Count**		**Mean Birds/Survey +/- S.E.**		**t**	**p**
	1988	**2003**	**1988**	**2003**		
504	298	219	5.96 +/- 0.600	2.62 +/- 0.432	-2.35	0.044
506	204	143	4.00 +/- 0.594	1.73 +/- 0.438	-3.84	0.006
508	282	116	4.48 +/- 0.535	1.41 +/- 0.438	-3.26	0.009
510	46	54	1.31 +/- 0.717	1.02 +/- 0.539	-0.72	0.500
512	59	43	2.11 +/- 0.802	0.77 +/- 0.529	-3.33	0.024
514	17	9	1.06 +/- 1.061	0.18 +/- 0.566	-1.42	0.359
516	8	16	0.47 +/- 1.029	0.38 +/- 0.611	-0.94	0.442
		F	9.04	13.52		
		P	<0.0001*	<0.0001*		

Table 4. For each survey year, the total number of individual raptors and percent of raptors exhibiting migrating, non-migrating and using behaviors is reported for each species. Migration behavior includes observations of raptors flying south at ≥30m, non-migrating behavior includes raptors flying north at ≥30m, and habitat-using behaviors includes raptors flying in any direction ≤30m and raptors interacting with other individuals or exhibiting perching or hunting behaviors.

	TOTAL		MIGRATING				NON-MIGRATING				USING			
			1988		2003		1988		2003		1988		2003	
SPECIES	1988	2003	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%
Cooper's Hawk	87	139	42	48.3	47	33.8	17	19.5	24	17.3	28	32.2	68	48.9
Northern Harrier	73	88	19	26.0	17	19.3	9	12.3	6	6.8	45	61.6	65	73.9
Osprey	173	64	95	54.9	34	53.1	38	22.0	7	10.9	40	23.1	23	35.9
Red-tailed Hawk	94	73	64	68.1	45	61.6	20	21.3	11	15.1	10	10.6	17	23.3
Sharp-shinned Hawk	605	294	291	48.1	114	38.8	143	23.6	43	14.6	171	28.3	137	46.6
Turkey Vulture	331	744	204	61.6	456	61.3	103	31.1	172	23.1	24	7.3	116	15.6
TOTAL	1848	1574	857	46.4	785	49.9	399	21.6	299	19.0	592	32.0	490	31.1
TOTAL (No Vultures)	1517	830	653	43.0	329	39.6	296	19.5	127	15.3	568	37.4	374	45.1

APPENDIX C:
SUPPLEMENTAL TABLES AND FIGURES FOR

CHAPTER THREE:
CONSERVATION IMPLICATIONS FOR
MIGRATORY RAPTORS HABITAT
IN THE
CAPE MAY STOPOVER, NEW JERSEY

Table 1. Land cover changes calculated for the 40km Cape May Peninsula, New Jersey using Level I Land Cover Classifications from 1984 and 2001 (Lathrop 2004). Measurements are reported in hectares for each 10km increment from Cape May Point.

0-10KM FROM CAPE MAY POINT

GRIDCODE	LANDCOVER *11,517 total hectares*	1984	2001	CHANGE	% CHANGE
110	Developed	3,400	4,090	690	20.3%
120	Cultivated/Grassland	1,505	1,113	-392	-26.0%
140	Upland Forest	672	684	12	1.8%
160	Barren	159	173	14	8.8%
200	Marine/Estuarine, Unconsolidated Shoreline	1,047	849	-198	-18.9%
210	Estuarine Emergent Wetland	2,252	2,135	-117	-5.2%
240	Palustrine Wetland	1,154	1,068	-86	-7.5%
250	Water	1,329	1,046	-283	-21.3%
	Total Habitat (120, 140, 210, 240)	5,583	5,000	-583	-11.7%
	Total Habitat (excluding 210)	3,331	2,865	-466	-16.3%

10-20KM FRM CAPE MAY POINT

GRIDCODE	LANDCOVER *15,139 total hectares*	1984	2001	CHANGE	% CHANGE
110	Developed	2,269	2,867	598	26.4%
120	Cultivated/Grassland	1,253	811	-442	-35.3%
140	Upland Forest	1,758	1,742	-16	-0.9%
160	Barren	115	166	51	44.3%
200	Marine/Estuarine, Unconsolidated Shoreline	1,226	1,244	18	1.5%
210	Estuarine Emergent Wetland	4,042	3,967	-75	-1.9%
240	Palustrine Wetland	2,658	2,577	-81	-3.0%
250	Water	1,817	1,764	-53	-2.9%
	Total Habitat (120, 140, 210, 240)	9,711	9,097	-614	-6.7%
	Total Habitat (excluding 210)	5,669	5,130	-539	-10.5%

Table 1 continued. Land cover changes calculated for the 40km Cape May Peninsula, New Jersey using Level I Land Cover Classifications from 1984 and 2001 (Lathrop 2004). Measurements are reported in hectares for each 10km increment from Cape May Point.

20-30KM FRM CAPE MAY POINT

GRIDCODE	LANDCOVER *19,288 total hectares*	1984	2001	CHANGE	% CHANGE
110	Developed	1,555	2,231	676	43.5%
120	Cultivated/Grassland	1,530	1,091	-439	-28.7%
140	Upland Forest	2,820	2,638	-182	-6.5%
160	Barren	144	167	23	16.0%
200	Marine/Estuarine, Unconsolidated Shoreline	1,438	1,356	-82	-5.7%
210	Estuarine Emergent Wetland	6,996	7,026	30	0.4%
240	Palustrine Wetland	3,599	3,593	-6	-0.2%
250	Water	1,205	1,185	-20	-1.7%
	Total Habitat (120, 140, 210, 240)	14,945	14,348	-597	-4.2%
	Total Habitat (excluding 210)	7,949	7,322	-627	-8.6%

30-40KM FRM CAPE MAY POINT

GRIDCODE	LANDCOVER *34,465 total hectares*	1984	2001	CHANGE	% CHANGE
110	Developed	3,106	4,103	997	32.1%
120	Cultivated/Grassland	2,680	1,906	-774	-28.9%
140	Upland Forest	10,210	10,031	-179	-1.8%
160	Barren	318	511	193	60.7%
200	Marine/Estuarine, Unconsolidated Shoreline	826	829	3	0.4%
210	Estuarine Emergent Wetland	5,890	5,745	-145	-2.5%
240	Palustrine Wetland	10,142	9,979	-163	-1.6%
250	Water	1,294	1,362	68	5.3%
	Total Habitat (120, 140, 210, 240)	28,922	27,661	-1,261	-4.6%
	Total Habitat (excluding 210)	23,032	21,916	-1,116	-5.1%