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AUTUMN RAPTOR MIGRATION

THROUGH THE FLORIDA KEYS

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To: Dean Arthur W. Herriott
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This thesis, written by Cindy Beth Brashear, and entitled Autumn Raptor Migration Through the Florida Keys, having been approved in respect to style and intellectual content, is referred to you for judgement.

We have read this thesis and recommend that it be approved.

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I dedicate this thesis to Robert Goehmann without whose love and support this would not have been possible and to my parents (Don and Judy) for instilling in me a love of and curiosity about nature.

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ABSTRACT OF THE THESIS

AUTUMN RAPTOR MIGRATION THROUGH THE FLORIDA KEYS

by

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Professor Philip K. Stoddard, Major Professor

This study documents the 1996 and 1997 autumn migration seasons at Grassy Key for 16 species of raptors (hawks, eagles, and falcons). My results indicate the Florida Keys are a major raptor migration flyway (over 26,000 sightings). I identified factors influencing watch-site location in the Keys. Northbound flights must be included to avoid inflating southbound counts. By removing the "season effect" (natural rise, peak, and wane of raptor numbers during migration), I demonstrate wind has little consistent effect on raptor counts in the Keys. I further demonstrate we do not see more raptors on cold front days than on non-cold front days. However, cold fronts following tropical storms (as in 1996) increase the number of raptors observed for most species. I conducted a nightly roosting survey on Boot Key resulting in near or over 3,000 raptor sightings per season and present a model to predict aerial counts from roosting counts.

TABLE OF CONTENTS

PAGE

CHAPTER

LIST OF TABLES **PAGE**

LIST OF FIGURES **PAGE**

LIST OF FIGURES cont. **PAGE**

CHAPTER 1

Introduction to raptor migration.

This thesis documents the first two full-season autumn raptor migration counts in the Florida Keys.

Many raptors of the order Falconiformes including hawks, eagles, and falcons migrate annually between breeding and wintering grounds. Historically, raptors were considered pests and hunted by humans (Brown and Amadon 1968). Raptors were especially vulnerable to hunting as they passed in large numbers along migration corridors. Modern threats to raptors include loss of habitat, loss of critical resources, continued hunting by humans, and chemical poisoning by environmental contaminants such as organochlorines (Bildstein and Zallas 1995). Although many countries are committed to legal protection and conservation of raptors, local laws may not be enforced. Information needed to identify threats to raptor populations includes raptor life history, abundance, distribution, habitat use, and other ecological factors (Bildstein and Zallas 1995). This study focuses on North American migrant raptors whose habitat includes breeding grounds (northern hemisphere), wintering grounds (mostly southern hemisphere), and the migration corridor. Identification of major migratory routes and protection of critical resources along the routes is essential to successful conservation of existing raptor populations.

Bird migration was one of the first natural phenomena to attract the attention of man (Brown and Amadon 1968) while raptor migration has been documented as early as the Bible in the Book of Job (39:26) : "Doth the hawk fly by the wisdom and stretch her wings to the south?". Aristotle's belief that the seasonal appearance and disappearance of birds was due to hibernation persisted until the early nineteenth century (Milne 1958).

Annual migration is now known to occur in many bird species. Dingle (1980) defines migration as "a specialized behavior, especially evolved for the displacement of an individual in space". Bird migration has more generally been described as "a massive shift of birds twice each year between regular breeding and wintering ranges" (Newton 1979). Two modern theories of bird migration origin are commonly mentioned and may have occurred simultaneously (Lincoln 1979). The "Northern Ancestral Home Theory" suggests advancing glacial ice fields pushed migrants south and, as ice caps receded, the birds returned north to breed. More accepted is the "Southern Ancestral Home Theory" that all migratory birds originated in the tropics and the young sought new territories as populations increased. Regardless of historical origins, many breeding bird populations in the northern hemisphere now migrate when changing environmental conditions affect chances of survival or successful reproduction (Haugh 1972). Most migrant species breed in the northern hemisphere and overwinter in the southern while a few breed in the southern hemisphere and overwinter in the northern. "Differential migration" denotes differences in timing of migration within a species by age, sex, and geographic distribution (Gauthreaux 1978, 1982, Ketterson and Nolan 1983).

Most raptor species breeding in north temperate latitudes are tropical migrants although seasonal migration patterns may vary. Autumn migration can begin from

August to January and spring migration from January to June (Cade 1960). Photoperiod length followed by weather changes seem to control the onset of migration in some raptors but the time of onset may also have evolved in relation to the distance to be traveled (Haugh 1972, 1986). During their journey, raptors may follow passerine and shorebird migration to ensure abundant food supply (Haugh 1972, Kerlinger 1989). Hawks may be considered complete migrants (migration by more than 90% of a species) or partial migrants (migration by some members of a species). Differential migration of raptors is more prevalent among partial migrants (Kerlinger 1989). Species from extreme northern latitudes may migrate sooner than those from lower latitudes (Geller and Temple 1983) and northern breeding individuals may migrate sooner than southern counterparts (Herbert and Herbert 1965). In autumn, adults of most species migrate later than juveniles (Haugh 1972) and may winter north of juveniles (Kelringer 1989). Differential migration by sex is common, with females often preceding males (Kerlinger 1989).

In North America, raptors migrate from as far north as the tundra regions and continue as far south as Argentina, South America (Clark and Wheeler 1987) (Fig. 1.1). Monitoring raptor populations at breeding grounds is difficult and expensive because most species are secretive or breed in remote or inaccessible areas (Fuller and Mosher 1987). Information about raptor populations is gathered primarily from migration watch-sites and banding stations but satellite telemetry has more recently provided information of migration routes. (S. Ambrose, U.S. Fish and Wildlife Service, unpubl. data; K. Meyer, Avian Research and Conservation Institute, unpubl.

data; W. Seeger, Edgewood Research, Development, and Engineering Center, pers. commun.).

Hawk migration watch-sites are located where geographic and topographic features concentrate migrating raptors (Fig. 1.2). Well-known watch-sites in eastern North America such as Hawk Mountain, Pennsylvania (inland) and Cape May Point, New Jersey (coastal) document thousands of raptors each autumn (Dunne and Sutton 1986, Titus and Fuller 1990). Hawk Mountain was the first official hawk-watch to prevent the annual killing of hundreds of migrant hawks and eagles flying down the Kittatiny Ridge (Broun 1948).

Hawk Mountain migration records date to 1934 (Bildstein and Zallas 1995). Cape May's consistent season-long count began in 1976 (Dunne and Clark 1977) although records were kept as early as 1936 (Allen and Peterson 1936). Qualitative analyses of long-term data from watch-sites show species population trends as decreases or increases over time. Results are used as indicators of change in populations and instrumental in raptor management and policy decisions (Titus and Fuller 1990). When compared to alternate raptor management methods, migration count data are useful in detecting long-term trends (Hussell 1985, Titus et al. 1989, 1990, Titus and Fuller 1990). However, the effectiveness and quality of raptor watch-site results have been questioned. Weaknesses perceived include lack of standardized data collection over years, variation in observer ability and fatigue, a bias toward low-flying migrants resulting in potential for a high proportion of uncounted birds, impact of high single-day totals on overall counts, and weather effects (Hussell 1981, Kochenberger and

Dunne 1985, Sattler and Bart 1985, Kerlinger 1989, Bednarz et al. 1990, Allen et al. 1996). Various strategies address these criticisms of migration counts. Example strategies include standardized data collection at most individual sites and among sites following Hawk Migration Association of North America guidelines (Bildstein and Zallas 1995) and radar used to document raptors at altitudes too high for ground-based observers to detect (Richardson 1975, Able et al. 1982, Kerlinger and Gauthreaux 1984, 1985, Alerstam 1987).

Raptors feed at the top of many food chains and, thus, serve as sensitive indicators of broad changes in the ecosystem (Bildstein and Zallas 1995, Newton 1979). Decline in annual migration counts of several species of raptors at traditional long-term watch-sites in eastern North America, most notably Tundra Peregrine Falcons (*Falco peregrinus tundrius)* and Ospreys (*Pandion haliaeetus)*, confirmed the widespread infiltration of pesticides such as DDT into global ecosystems (Carson 1962, Hickey 1969, Newton 1979, Bildstein and Zallas 1995). Migration counts also show rebounds in populations after DDT was banned. Identifying negative trends are crucial to biologists working for the continued success of species and ecosystems. Following a successful reintroduction program, the Peregrine Falcon was removed from the U.S. Fish and Wildlife Service endangered species list in 1994 but is still listed as "threatened". More recent migration count data from Cape May suggest a decrease in American Kestrels (Dunne and Sutton 1986). Decreases in migrating Sharp-shinned Hawks (*Accipiter striatus)* and a decline in their reproductive success in eastern North

America were recently identified at long-term raptor monitoring stations; the cause of these declines have not yet been identified (Kerlinger 1993, Viverette et al. 1996).

There are no major raptor migration watch-sites (over 10,000 sightings per season) in the eastern United States south of Assateague Island, Virginia. Because many raptor species hesitate to cross water barriers and the lack of data collection in the southeastern United States and Caribbean, the majority of raptors migrating to the southern hemisphere are believed to fly south through Mexico taking advantage of the landbridge to South America. A relatively new watch-site in Vera Cruz, Mexico documents over 4 million raptors each autumn (Ernest Ruelas Inzunza, Pronatura, pers. commun.). Raptors have been seen in the Florida Keys during migration but no prior attempt has been made to conduct a full autumn census.

The Florida Keys are an island chain approximately 170 kilometers (km) long extending southwest from the tip of the Florida peninsula (Fig. 1.3). Haugh (1986) suggested the Florida Keys as a worthwhile site to establish a raptor migration monitoring station. Since 1989, annual October one-day counts of migrating raptors in the Keys have been conducted indicating large numbers of raptors passing through the Keys (W. Hoffman, National Audubon Society, pers. commun.). I conducted a pilot study of autumn raptor migration through the Florida Keys in 1995. My 1995 results (Appendix 1) demonstrate the Keys may be an important autumn migratory raptor route with over 11,000 sightings, a Peregrine Falcon count second only to Cape May, and the highest one-day Peregrine Falcon total in the United States.

Commercial development along the migratory flyway can result in extensive loss of habitat for prey species and roosts of raptors (Bent 1937, Kerlinger 1989, Niles 1996). The Keys exhibit most types of southern Florida ecosystems including mangrove forests, wetlands, pinelands, beaches, nearshore regions, and hardwood hammocks (Ripple and Keogh 1995) - all of which have been significantly diminished by development. Further reduction of foraging and roosting habitat could adversely affect raptor migration and the migration of other bird species.

This study was conducted to provide better understanding of the role of Florida, the Keys, and the Caribbean in raptor migration. Determining the volume of raptors migrating through the Keys will afford knowledge to spot long-term trends of populations, potential threats to species and ecosystems, and provide evidence of the need to preserve critical resources along the Florida Keys flyway.

This study documents the 1996 and 1997 autumn census and flight direction of migrant raptors through the Florida Keys (Chapter 2), weather effects on migration (Chapter 3), and a raptor roosting survey performed on Boot Key (Chapter 4).

CHAPTER 2

Census and flight direction of autumn migrant raptors through the Florida Keys - 1996, 1997.

INTRODUCTION

Raptor migration watch-sites are usually situated along natural corridors on the migratory flyway where concentrations of raptors occur (Murray 1964, Mueller and Berger 1967, Bildstein and Zallas 1995). These concentrations are generally attributed to topography and/or weather and may occur at mountain ridges, passes, narrow coastal plains, isthmuses, and peninsulas (Haugh 1972). Mountain ridges generate updrafts for soaring species while coastal watch-sites are usually located on barrier islands or peninsulas which act to funnel migrants. Well-known hawk watch-sites in eastern North America such as Hawk Mountain, Pennsylvania (inland ridge) and Cape May Observatory, New Jersey (coastal) document thousands of raptors each autumn (Dunne and Sutton 1986, Titus and Fuller 1990). Watch-sites with over 10,000 annual raptor sightings are generally considered to be along major migratory flyways and offer an economical and efficient method for studying a widespread and sometimes secretive raptor population (Fuller and Mosher 1990). More traditional long-term monitoring methods such as nesting surveys can be difficult, labor intensive, and expensive (Fuller and Mosher 1987, Titus and Fuller 1990).

Raptor species can be categorized as complete (90% of the population migrates annually) or partial migrants, by winter destination, and by distance willing to travel over water (Table 2.1). Many raptors will not cross bodies of water greater than 25 (km) and only 14 of 133 species are known to cross over 100 km (Kerlinger 1989). The landbridge through Texas, Mexico, and Central America is considered the primary route for North American migrants, probably due to their reluctance to migrate over water (Lack 1954, Haugh,1972, Heintzelman 1975, Macrae 1985, pers. observ.). Few raptors en route to wintering grounds in Central or South America would be expected to migrate through the Florida Keys because of the 144 km water crossing from Key West to Cuba, the nearest Caribbean island to the south.

The tendency for some raptor species to avoid water crossings may be due to flight strategy. Flight strategy of raptors includes physiological, morphological, and behavioral characteristics that may have been shaped by natural selection (Alerstam 1981). Hawks are considered diurnal but night flights by some species have been reported (Russell 1991). Raptors employ two basic styles of flight - gliding and powered flight. Gliding raptors hold wings outstretched with no flapping, using air currents to keep aloft and updrafts to gain altitude (Kerlinger 1989). Gliding requires less energy than powered flight. Soaring flight is gliding in circles and some species have anatomical adaptations to "lock" the wings in place to further save energy (Kuroda 1961). During powered flight, the wings move up and down to give thrust (Gill 1990). The airspeed thus gained maintains lift. Raptors are generally larger than other birds and expend more energy during powered flight.

Morphological adaptations to flight include wing span, wing area, tail area, mass, wing loading, aspect ratio, and slotting on wingtips (Kerlinger 1989). All of these characteristics may play a major role in whether a raptor relies more on soaring or powered flight. There are eight main raptor body shapes including buteo, vulture, accipiter, Osprey, kite, Northern Harrier (*Circus cyaneus*), and falcon shapes (Clark and Wheeler 1987) (Fig 2.1). Buteos and vultures possessing long broad wings are most often observed in soaring flight during migration (pers. observ.). Accipiters possess short rounded wings with longer tails and seem to use powered flight more than buteos and vultures. However, accipiters are seen soaring in thermals more often than the remaining body shapes which possess longer narrower wings and tails. Ospreys and kites use both powered and soaring flight during migration while falcons and Northern Harriers generally use powered flight but are occasionally seen soaring in thermals.

Soaring species save energy by using thermal convection for lift. Thermals form as the Earth's surface heats and columns of warm air rise. These columns of rising air form infrequently over water because water has high albedo, evaporation takes place in water, and more heat is required to raise the temperature of water than land (Woodcock 1975, Kerlinger 1989, Winsberg 1990). Thus, water crossings can be barriers to migration of soaring species. Species seen in the Keys that do not generally rely on thermals and are known to cross water barriers over 100 km include the Peregrine Falcon, Merlin (*F. columbaris*), Osprey, and Northern Harrier. Flocking behavior is common among soaring species and may assist raptors in finding thermals and prey (Kerlinger 1989). Raptors that rely on powered flight generally do not flock but may be seen in temporary chance aggregations due to topographical features or meteorological conditions (Griffin 1964, pers. observ.)

Raptors hesitating to cross water at the end of peninsulas may mill about the area and can hinder accurate counts. After passing a watch-site, migrant raptors encountering water crossings sometimes turn around to fly in the direction opposite to normal migration, a behavior termed "reverse migration" (Mueller and Berger 1969, Richardson 1972, Harmata 1984, Akesson et al. 1996). However, true autumn raptor reverse migration implies a southbound individual flies part of the journey south then returns north to overwinter in nesting grounds (Raveling 1976). Possible reasons for true reverse migration in birds include inadequate fat reserves for the journey (Akesson et al. 1996) and social isolation (Raveling 1976). A better term for migrant raptors changing direction may be "reverse movements" (Richardson 1972) or "reverse-flights" because the end of the journey is unknown (unless tracking devices are used). We cannot assume birds observed turning north are returning to nesting grounds for they may turn south again to continue the migration. Reverse-flights during raptor migration may be due to foraging, hesitation to cross water, or the raptors may be local inhabitants or wintering birds (Dunne and Clark 1977, pers. observ. 1996). Raptors that hesitate to cross water may be waiting for optimal weather conditions or may be searching for an alternate route.

Reverse-flights are seldom seen at inland watch sites but occur frequently at coastal sites. If potential northbound routes are not visible to observers at a peninsular watch-site, raptors may be undetected when turning around. Repeat counts at Cape May have been documented by second sightings of birds with distinct plumage and by retraps of birds banded in the season (Dunne and Clark 1977). These birds were not detected as they flew north. In a migrant raptor stopover habitat study at Cape May Point, large numbers of Sharp-shinned Hawks and other raptors were reported flying north, suggesting the birds fly south, round the point, and return northward up the bayshore (Niles 1996). Kerlinger and Gauthreaux (1984) suggest the large number of migrants counted at Cape May with westerly winds may be due to multiple counting of raptors which have turned back inland after encountering water. The evidence suggests that reverse-flights are frequently undetected and double-counting occurs to an unknown extent.

I expected fewer migrating raptors in the Keys than at other major United States watch-sites because of the 144 km crossing over the Florida Straits; however, I counted comparable numbers of some species during my study. The Peregrine Falcon total was near to or higher than Cape May which traditionally has the highest count. Satellite telemetry indicates migrant Peregrine Falcons from as far northeast as Greenland and as far northwest as Alaska pass through the Florida Keys and Caribbean islands on the way to South America in the fall (S. Ambrose, U.S. Fish and Wildlife Service, unpubl. data; W. Seeger, Edgewood Research, Development, and Engineering Center, pers. commun.). Although the Tundra Peregrine Falcon was removed from the U. S. Fish and Wildlife Service endangered species list in 1994, it is still Federally listed as threatened. The Florida Keys may provide important information on future Peregrine Falcon and other at-risk species trends if long-term studies are performed.

In addition to reporting the daily and season species totals of the 1996 and 1997 census of autumn raptor migrants through the Florida Keys, I show that : (1) the Florida Keys are a major raptor migratory flyway, (2) comparable or greater numbers of Peregrine Falcons are seen migrating through the Keys than seen at other watch-sites in the United States, (3) reverse-flights are more easily detected on Grassy Key than elsewhere, and (4) reverse-flight migrants, if unaccounted for, may greatly inflate migrant raptor counts.

METHODS

The Florida Keys are an island chain approximately 170 km long extending southwest from the tip of the Florida peninsula (Fig. 2.2). My watch-site is a privately owned area on Grassy Key, approximately halfway down the island chain and 92 km northeast of Key West (Fig. 2.3). The watch-site is approximately 100 meters (m) wide and located at 24°45.8 N latitude and 80°56.85 W longitude. Passing raptors and their flight direction are easily noted because the site is narrow and few foraging or roosting raptors are seen. The site is not directly before or after a water crossing which reduces milling that may hinder accurate counts.

I stationed observers on both sides of the key to ensure complete coverage over both the Atlantic Ocean and Gulf of Mexico shorelines and shallows. Skies were monitored for migrating raptors from 1 September to 15 November 1996 (75 days / 618 hours) and 5 August to 14 November 1997 (102 days / 909 hours). The census began earlier in 1997 to document migration of Swallow-tailed Kites (*Elanoides forficatus)* and Ospreys. Complete coverage was maintained 7 days a week and at least 8 hours a day from 0900 to 1700 hours EDT. Coverage continued past 1700 hours if migrants were still observed moving south. On a few anticipated high volume days, the count began earlier. Rain occasionally halted observation. Six observers were on-site with 2 to 6 observers on duty each hour. The intense sun, heat, and humidity in the Keys make long-term viewing difficult. To reduce effects of observer fatigue which has been cited as a concern to accurate migration counts (Sattler and Bart 1985), the maximum time an observer was on duty with no rest was 3 hours.

I used binoculars and spotting scopes to identify migrant raptors. Every hour, each raptor seen passing the watch-site was recorded and identified to genus, species, age, and sex when possible. I noted flight direction as "southbound" down the Keys or "northbound" up the Keys (reverse-flights). Data were recorded following most guidelines of the Hawk Migration Association of North America (HMANA); thus, our collected data is standardized for both years and with most watch-sites in North America. Because quick identification of small falcons was sometimes difficult, I include an "Unidentified falcon not Peregrine" category to report sightings that were either American Kestrels (*F. sparverius*) or Merlins.

Statistical comparison of the 2 seasons to spot population trends are not presented. Various methods have been used to detect population trends but are most reliably performed on multi-year data sets (Bednarz et al. 1990, Titus and Fuller 1990, Allen et al. 1996, Hatfield et al. 1996). Long-term migration counts can be informative for large geographical areas but are not likely to be useful in detecting short-term trends (Titus and Fuller 1990). In addition, the presence of El Nino in 1997 affected normal weather patterns and may have affected migration patterns and numbers. But, if counts are continued in the future, the site should yield valuable long-term population data. Differential migration results are not included because age and sex were not consistently recorded.

Seasonal raptor migration results by species include southbound, northbound, "net", and "gross" totals. The net total is the southbound minus the northbound count, representing the minimum estimated number of raptors that attempted the flight south through the middle Keys and remained south of the watch-site. The gross total is the southbound plus the northbound count, representing the total number of sightings and providing evidence of the extent to which the migrant raptors use the Keys flyway.

RESULTS

I observed 20,034 southbound migrants in 1996 and 20,732 in 1997 (Tables 2.2 and 2.3). I cannot assume southbound sightings do not include double-counts because of the 6,399 & 6,740 northbound sightings or reverse-flights. Individuals observed heading north could have continued north or turned south again. If reverse-flights are not included, the number observed actually migrating south past the Grassy Key site is inflated by as much as 32% & 33%. Thus, the net totals of 13,635 in 1996 and 13,992 in 1997 are the more reliable estimates of the minimum number of raptors that reached the middle Keys and remained south. These individuals could have continued the journey to winter in the southern Keys, the Caribbean islands, or South America. The number observed that actually attempted the flight south probably falls between the net and southbound totals. Turkey Vultures continuously fly up and down the local area and Broad-winged Hawk observations vary from year to year at most sites. If these 2 species are discounted, the most abundant sightings by species are the same for both 1996 and 1997 net and gross totals. Descending order for both years by net totals are Sharp-shinned Hawk, Osprey, Peregrine Falcon, and American Kestrel while gross ranks are Sharp-shinned Hawk, American Kestrel, Osprey, and Peregrine Falcon.

Comparing by genus, more falcons were observed followed by accipiter and buteo totals in both 1996 net and gross and in 1997 net results (Table 2.4). Gross totals for 1997 show a slight increase in the number of accipiters versus falcons. Comparing representative soaring species to more powerful flyers passing through the Keys, soaring species hesitated more at water crossings (pers. observ.) and were over 3 times more likely to make reverse-flights (Table 2.5). Daily migration counts include southbound and northbound migration totals (Appendix 2). Daily southbound, northbound, and net cumulative totals show similarities and differences within and among years (Figs. 2.4 - 2.18). The daily passage rate is expressed by Julian date and the final day indicates the totals for the season. Red-tailed Hawk (*B. jamaicensus*) cumulative totals are not shown due to low numbers of sightings.

Southbound dates of first sighting, date of 10% passage, peak number, and peak date for each species are shown for both 1996 and 1997 (Table 2.6). These results reveal interesting annual trends and comparisons among the two years. For 1996 and 1997, I considered a species to have arrived earlier in one year than the other if the date of first sighting was 7 or more days earlier in one of the years. If a species arrived less than 7 days apart between the 2 years, I considered them as arriving at the same approximate time.

Turkey Vultures, Ospreys, Bald Eagles, Swallow-tailed Kites, Red-tailed Hawks, and American Kestrels are not included in discussions of dates of first sighting because they arrived in August of 1997. Within species, Mississippi Kites, Northern Harriers, Merlins, and Peregrine Falcons arrived at approximately the same time in both years while Sharp-shinned Hawks, Red-shouldered Hawks, Broad-winged Hawks, Short-tailed Hawks, and Swainson's Hawks arrived earlier in 1997.

For dates of 10% passage, Sharp-shinned Hawks, Cooper's Hawks, Northern Harriers, Broad-winged Hawks, and American Kestrels arrived earlier in 1997. None of the raptor species compared arrived early in 1996. The first ten percent of Turkey Vultures, Red-shouldered Hawks, Short-tailed Hawks, Swainson's Hawks, Merlins, and Peregrine Falcons passed within 7 days of each other between the 2 years. Ospreys, Bald Eagles, and Swallow-tailed Kites are not included due to the numbers of August sightings while Mississippi Kites and Red-tailed Hawks are not included because of low counts.

Peak dates for Broad-winged Hawks, Short-tailed Hawks, Swainson's Hawks, Merlins, and Peregrine Falcons were earlier in 1997. Ospreys, Northern Harriers, and Cooper's Hawks arrived at approximately the same time while Sharp-shinned Hawk and American Kestrel peaks were on the same date for both years. Bald Eagles, Swallow-tailed Kites, Mississippi Kites, and Red-tailed Hawks are not included due to August peaks or low numbers of sightings. Turkey Vultures are not included because the high southbound peak date resulted from continuous passage back and forth across the watch-site.

DISCUSSION

My results showed large numbers of both southbound and northbound raptors. If reverse-flights are not included, the number of individuals passing through the Keys would be inflated by as much as 33%. Reverse-flights were common among soaring species which hesitate to cross water barriers. Reverse-flights by migrants capable of extended powered flight such as Peregrine Falcons and Ospreys were probably foraging flights or flights over the area while waiting for more favorable weather conditions. I compared my findings with known evidence of winter destinations and water crossing behavior.

Short-tailed Hawks (*B. brachyurus)* breed in central Florida and migrate to the southern part of the peninsula and the Keys in winter. The number of Short-tailed Hawks residing in Florida is approximately 500 (Millsap et al. 1996). My count of approximately 25 Short-tailed Hawks suggest most do not migrate as far south as the middle Keys. Some Bald Eagles are winter migrants with Florida at the southern limit of their range. They are known to cross water barriers of only 25-100 km. The few Bald Eagles sighted during the migration season in the Keys may be local birds. However, I saw more southbound than northbound eagles indicating some individuals may be migrants.

American Kestrels and Sharp-shinned Hawks may migrate south as far as Central America but are not known to cross water barriers over 25 km. However, a few migrants winter in the Bahamas and Cuba (Bond 1993). Many American Kestrels and Sharp-shinned Hawks migrating through Florida probably winter in the southern United States north of my Grassy Key site which accounts for the 19% & 21% American Kestrel reverse-flights, part of the 52% & 31% "Unidentified falcon not Peregrine", 35% & 22% of Sharp-shinned Hawk, and part of the 21% & 28% "Unidentified accipiter" reverse-flights.

Cooper's Hawks (*A. cooperii*), Red-tailed Hawks, and Red-shouldered Hawks (*B. lineatus*) migrate as far south as Mexico and southern Florida and are not known to cross water barriers over 25 km. This hesitation to cross water accounts for low sightings of the 2 buteo species, the 16% Cooper's Hawk reverse-flights, and part of the 17% "Unidentified accipiter" reverse-flights.

Mississippi Kites (*Ictina mississippiensis*), Swallow-tailed Kites, Swainson's Hawks (*B. swainsonii*), and Ospreys are complete migrants with over 90% of the populations wintering south of northern breeding grounds and many south of the United States. Some Ospreys winter in southern Florida and a small number of Swainson's Hawks winter in southern Florida and Texas. Because Ospreys are residents in the Keys and because of their documented ability to cross water over 100 km, I believe most northbound Ospreys seen were local or foraging birds. Swainson's Hawks breed in the western United States and are not known to cross water barriers greater than 25 km. The few observed in southern Florida are presumably lost and probably winter in the Keys and southern Florida. The unusual 1996 negative net count of Swainson's Hawks (-72) reveals more northbound than southbound flights indicating they somehow passed by unseen during their flight south - perhaps too high or too far off-shore to be detected or perhaps they were among the 74 southbound "Unidentified buteo" sightings.

The onset of migration for Swallow-tailed Kites and Mississippi Kites occurs in late July, earlier than most raptor species. No northbound kite flights were observed in 1996 and only 2 in 1997. Mississippi Kites are not known to cross water barriers which may account for the low numbers seen in the Keys (23 & 12). The majority of Mississippi Kites probably migrate south along the Gulf coast through Texas. Satellite telemetry of a small number of migrating Swallow-tailed Kites leaving breeding grounds in southern Florida shows they take a southern route from the west coast of the peninsula near Naples, over the Florida Strait to Cuba, the Yucatan, and through Central America to South America (K. Meyer, unpubl. data). Swallow-tailed Kites have rarely been observed migrating in flocks after leaving breeding grounds (K. Meyer, pers. commun.). Nonetheless, in 1997 we observed flocks of 63, 49, 42, 17, 10, and individuals passing through the Keys for a total of 264 between 5 August and 2 October. Most flocks were seen at hours when cumulonimbus clouds threatening rain were passing over the site and seemed to be forcing the kites down. My findings show the Keys are a migratory flyway for Swallow-tailed Kites and many more kites may be passing through the Keys earlier in the season and at altitudes difficult to detect without radar.

Turkey Vultures, Broad-winged Hawks, Merlins, Peregrine Falcons, and Northern Harriers winter from the southern United States to South America. Turkey Vultures and Broad-winged Hawks rely on thermals for soaring and are not known to cross water barriers over 25 km. This behavior may account for the high percentage of northbound individuals. My findings indicate 72% & 53% of Turkey Vulture flights in the Keys were northbound. Because Turkey Vultures made numerous trips back and forth along the coast resulting in the highest gross sightings, I believe most remained in the Keys and are better revealed in the final net counts (1,012 / 2,905). The 23% & 44% Broad-winged Hawk reverse-flights were probably due to avoidance of water crossings, searching for stronger thermals, or weather conditions not conducive to southbound migration. Merlins are known to cross water barriers over 100 km, thus, the 30% & 21% Merlin northbound sightings may have been due to a mix of wintering and foraging birds. The low percentage of northbound Peregrine Falcons (8% & 6%) and Northern Harriers (9% & 12%) corroborates other studies showing these species do not hesitate to cross wide expanses of water.

Smith (1980) suspects Broad-winged Hawks cross the Caribbean even though they are known to hesitate at water crossings. Flocks have been seen in Trinidad (Rowlett 1980) and other Caribbean islands (ffrench 1980). Kerlinger (1989) suggests the evidence of Broad-winged Hawks crossing the Caribbean is not convincing. However, I do not believe the large numbers of Broad-winged Hawks, Sharp-shinned Hawks, and American Kestrels shown by the net counts could be supported by the limited Keys habitat south of our watch-site. I suggest many individuals of these species undertake the Caribbean crossing.

Comparisons by genus were as expected with accipiters and buteos more likely to make reverse-flights than falcons. The higher percentage of northbound flights by soaring buteos and accipiters is probably due to the lack of thermals forming over water. Although buteos generally rely more on thermal soaring than do accipiters, I observed more accipiters in reverse-flight. Because of their greater flocking tendency, perhaps buteos were more willing to attempt the Caribbean crossing in flocks. Alternatively, more northbound Broad-winged Hawks may have been undetected if flying in thermals at high altitudes.

Visual counts may give a minimum estimate of the number of birds migrating but are especially useful in determining species composition and relative numbers by species (Newton 1979). I also believe visual counts are useful in determining timing of species passage. Dates of passage at Grassy Key show some similarities and may serve as guidelines for further research. Weather may have played a large role in similarities and disparities in passage dates between the 2 years (see Chapter 3); similar findings may or may not be found in future years.

Numbers of raptors passing through the Florida Keys surpassed my expectations and indicate the Grassy Key watch site is located along a major migratory raptor flyway (over 10,000 sightings). Based on previous findings, I believed numbers would be lower due to water crossings. The 1996 net raptor total for the Keys (13,635) surpasses total numbers seen at Hawk Mountain (11,790) mainly due to the dearth of Broad-winged Hawk sightings at Hawk Mountain that year (Goodrich 1996). The 1997 Hawk Mountain Broad-winged Hawk counts were closer to the average in

1997 (Keith Bildstein, Hawk Mountain Sanctuary, pers. commun.) and the number of total raptors exceeded Grassy Key's net flights by 5,937. Grassy Key had lower numbers of Broad-winged Hawk flights in 1997 than in 1996. Variability in annual counts of this species are common and probably due to weather patterns directing the raptors along alternate migration routes. The Grassy Key Peregrine Falcon totals near or surpass those seen at Cape May for both years. The highest daily Peregrine Falcon count was greater at Grassy Key with 377 & 341 compared to 206 & 291 at Cape May (V. Elia, Cape May Bird Observatory, pers. commun.). Cape May reported 1,503 Peregrine Falcons in 1996 and 1,791 in 1997. My totals show 1,303 net and 1,533 gross Peregrine Falcons in 1996 and 1,505 net and 1,689 gross in 1997. My net counts remove as many reverse-flights as possible, probably making double-counts less frequent in the Keys than at other watch-sites. Thus, more Peregrine Falcons may actually migrate through the Keys than past other watch-sites.

The northeastern watch-sites are closer to migrant nesting grounds and may reveal population trends in eastern ecosystems. Because Peregrine Falcons from as far west as Alaska pass through the Keys, long-term counts in the Keys may show more geographically widespread trends for this species. Further evidence indicating Peregrine Falcons from origins other than the Atlantic flyway, is the timing of the Cape May Peregrine Falcon counts in relation to Grassy Key. I would expect the Grassy Key peak to occur a few days after the peak at a site so far to the north. In 1996, Cape May's peak Peregrine Falcon flight occurred 8 days before Grassy Key's - 1 October and 9 October respectively. However, in 1997, Cape May's peak flight occurred 4 days after Grassy Key's - 7 October and 3 October respectively (V. Elia, Cape May Bird Observatory, pers. commun.). The disparity in peak dates for 1997 may be due to weather conditions conducive to raptor observation or may further point to a higher portion of the Grassy Key Peregrine Falcon flight arriving from various migratory routes and perhaps from more western breeding areas.

I do not know whether we see other migrant species from western areas apart from the approximately 100 Swainson's Hawks each year. Further satellite telemetry studies and future capture and banding of raptors in the Keys may reveal more species with western origins.

Two main hypotheses are generally discussed of why there may be large numbers of raptor sightings at water crossings. One hypothesis is that raptors drift with prevailing northwesterly winds to ridges and the Atlantic coast (Allen and Peterson 1936, Mueller and Berger 1967). Alternatively, species that usually migrate at high altitudes over a broad front may descend in the presence of northwest winds to avoid being pushed over water such as the Atlantic Ocean (Murray 1964, 1969, Kerlinger and Gauthreaux 1984). A counting bias may exist if birds are seen at low altitudes only under certain conditions. If either of the above hypotheses are correct, the Keys should reflect more raptors at observable altitudes in most wind directions because the birds have been funneled into the area and are surrounded by water. Perhaps I see a greater percentage of actual birds passing through the Keys than usually seen at watch-sites without the aid of radar.

Alternatively, I see high altitude flocks and individuals descending with increased cumulonimbus cloud formation. Thus, the lack of land on either side (or one side as at Atlantic coastal sites) may not be a deterrent to high altitude flights and may not result in a counting bias. In addition, raptors may not be descending to avoid being pushed over the water but are avoiding potential thunderstorm activity.

Because of the unique topography at Grassy Key allowing flight direction to easily be observed, I believe my counts are more accurate than at many coastal sites. The topography of the Florida Keys with unskirtable water crossings is different than encountered elsewhere along North American migration routes. Upon reaching the Keys, southbound raptors unwilling to cross water must winter in the United States or attempt an alternate route through Mexico. Sixteen km down the Keys from my site is the southern end of Marathon, Florida and the beginning of the longest (11.2 km) unskirtable stretch of open water within continental North America (the Great Lakes are large water crossings but are skirtable). I have observed hundreds of raptors hesitating and turning around at this 11.2 km water crossing in the Keys. Southbound raptors reaching Key West must either attempt the approximately 144 km crossing to Cuba, winter in Key West, or turn around. The presence of unskirtable water crossings in the Keys may result in more reverse-flights at Grassy Key than at other sites and the topography is conducive to detecting reverse-flights. However, to lessen repeat sightings and avoid inflating counts, other peninsular migration watch-sites should attempt to estimate the amount of reverse-flights by locating potential areas of reversal.

Because of reverse-flights, migratory raptors use the habitat in the Keys to a greater extent than if they passed directly through on their way south and may use the Keys as a stopover point for longer periods of time. In addition to counting raptors, watch-sites with a high percentage of reverse-flights should perform studies of potential stopover points and critical resources.

MANAGEMENT RECOMMENDATIONS

My migrant raptor counts at Grassy Key indicate the Florida Keys are a major migration route. I believe the location of a long-term raptor migration site is crucial to successful monitoring in the Keys. Before and after choosing the Grassy Key site, I surveyed many areas to determine site feasibility. I conclude that a site directly before a water crossing is undesirable because of the tendency to multiple-count milling raptors. A site directly after a water crossing is undesirable because the raptors seem to spread over a broad front when crossing and, thus, are more likely to remain undetected. My site is located 4 km after and 16 km before a water crossing. A site should be narrow to allow sightings across the entire key. If the area is narrow but both sides of the key cannot be seen (as at my Grassy Key site), monitoring stations should be posted on each side of the key to spot raptors and constant communication should be maintained to prevent double-counting. If the area is wide, the ability to see over all vegetation and buildings is crucial to spot passing raptors and is especially important if the area is surrounded by favorable roosting or foraging habitat. If roosting habitat is present, surveys performed each evening and the following morning should be compared to prevent double-counting. In addition, if there are several small keys over the adjacent ocean or gulf area, the possibility of raptors moving in a broader front may increase and hinder counts. There are numerous small keys extending from Florida Bay (southwestern tip of Florida) down to the northern tip of Long Key (the major key before Grassy Key). Migrants traveling down the west coast or central part of Florida could island-hop through these small keys and never be spotted at a site along the major chain of the northern Keys. Because of this potential alternate route, a site located north of Long Key would probably yield fewer sightings.

Migrant raptors reaching Florida may head south over the ocean at any point from southern Florida and would be difficult to monitor. However, I believe the majority of raptors continue their journey south through the Keys. My sightings of hundreds of raptors turning around at the 11.2 km water crossing indicate some raptors may not attempt crossing the perceived barrier. If a site were located south of Marathon, many raptors that traveled through most of the Keys may not be counted. Thus, I believe a site between the northern tip of Long Key and the 11.2 km water crossing would reveal a greater sample of the migrant population. In addition, the site would be better situated to identify southbound and reverse-flight raptors and, thus, to determine the extent the Keys flyway and resources are being used. Therefore, the best scenario for a long-term monitoring site of raptor migration in the Keys would be a narrow area with little vegetation, located between Long Key and the 11.2 km water crossing, not directly before or after a water crossing, and with no adjacent keys over the ocean or gulf.

Long-term raptor monitoring in the Florida Keys should be established. I have shown the Keys are a major migratory flyway. There are comparable or more Peregrine Falcon counts than at any other site in the United States and the Peregrine Falcons arrive from across the North American continent and Greenland. Long-term monitoring would provide information to be used in conjunction with other sites to determine population trends, potential problems in breeding-ground ecosystems, and may point to potential problems in ecosystems along the migration route. Banding studies (including blood analysis) should be implemented to increase knowledge of geographic origin and health of raptors. Telemetry and fixed radar studies would extend knowledge of the numbers of raptors flying at high altitudes, raptor behavior at water crossings, potential stopover areas, and potential final destinations. Of more local import, studies of the critical resources of migrant raptors through the Keys should be performed. Identification of roost and prey requirements will provide further impetus to protect an already overdeveloped area with limited resources.

CHAPTER 3

Season, wind, and cold front effects on autumn raptor migration through the Florida Keys - 1996, 1997.

INTRODUCTION

The number and timing of migrant raptors observed at a migration watch-site may be affected by the date of onset of migration, proximity of the watch site to breeding grounds, how often the raptors stop to feed and rest, prey availability, topographical barriers, weather conditions encountered en-route, and local weather conditions. Northeastern United States hawk watch-sites are closer to breeding grounds, thus, peak dates of passage would be expected to occur earlier in the autumn season than at southeastern sites. In addition, the further away from point of origin in both time and space, the less likely may be an association between weather conditions and numbers of some raptor species (Haugh 1972). Thus, after beginning migration, raptors may continue to push south regardless of weather conditions.

Local weather conditions that may influence raptor migration include wind direction, wind speed, cloudcover, (which prevents thermal formation), and precipitation (Kerlinger 1989). On a more continental scale, cold fronts may influence raptor migration. In autumn, the northeastern United States experiences northwesterly winds following the passage of cold fronts, conditions that may persist from one to three days. High numbers of migrating raptors are often seen at northeastern watch-sites following cold front passage (Trowbridge 1895, 1902, Stone 1922, Allen and

Peterson 1936, Mueller and Berger 1961, Haugh 1972, Alerstam 1990, Hall et al. 1992, Allen et al. 1996). West to northwest winds following cold fronts have been cited as a possible catalyst in raptor migration, pushing raptors toward topographical features such as the Appalachian Mountain ridge and the Atlantic coast (Alan and Peterson 1936, Mueller and Berger 1967, Haugh 1972, Able 1973, Alerstam 1990). Some investigators refute the idea that cold front passage enhances migration, suggesting instead that raptors are only more easily seen at coastal sites with west winds when descending from high altitudes to avoid being pushed over water (Murray 1964, Millsap and Zook 1983, Kerlinger and Gauthreaux 1984). If true, this phenomenon could result in a counting bias dependent on wind direction. Quantitative analyses, however, refute the contention that weather conditions create bias in migration counts. A study of cold front passage (day of cold front and 3 days following) on numbers of raptors migrating past Hawk Mountain shows cold fronts enhance fall migration rather than making birds more visible (Allen et al. 1996). Studies such as this restore faith in the validity and usefulness of traditional migration counts.

Weather during the autumn raptor migration season in the Florida Keys is different than encountered in the temperate northeastern United States. Weather systems in Autumn arrive later in the Keys than in more northern regions and include fewer and less extreme cold fronts (Newton 1979). Cold fronts rapidly lose their strength as they progress through Florida because of the tropical climate and peninsular weather effects (Winsberg 1990). The arrival of Autumn in Florida has been defined as the first week in which the average daily temperature drops below 15.6 degrees Celsius (Winsberg 1990). From 1957 to 1986, half of the two-day cool air spells in southern Florida occurred from 1 November to 17 November, over a week later than in northern Florida. Thus, cold air masses are less liable to penetrate into southern parts of the state. In addition, cold fronts often move off-shore in Florida before reaching the Keys. However, I show that southern Florida does experience some cold front effects and migrant raptor numbers seem to increase in conjunction with cold front passage.

The contrast between wet and dry seasons is notable in the tropics where hawks find favorable wintering conditions during the dry season (Brown and Amadon 1968). Raptors may winter in the Keys because, although the Florida climate is known as humid subtropics, the area south of Miami (including the Keys) has mean temperatures and a seasonal rainfall regime that classify it as tropical (Winsberg 1990).

Winds affect numbers of raptors visible to ground-based observers by increasing or decreasing the number of birds flying (Newton 1979). Winds also determine, in part, whether migrants pass over watch-sites or over other areas. In southern Florida, prevailing southeast winds in the summer and early fall originate in the Bermuda-Azores High in the Atlantic (Winsberg 1990). Tropical storm formation in the Atlantic is usually prevalent during late Summer and Autumn. Tropical storms that move over the eastern United Sates may temporarily delay migration at points north of the Keys until weather conditions are more favorable. During the twentieth century through 1989, most Florida hurricanes arrived in September and October. Analysis of tropical storms and hurricanes striking the state between 1884 and 1984 reveal that the Pensacola area, the Keys, and Dade County have the highest probability of experiencing a storm (Winsberg 1990) .

In the early stage of the autumn migration season, small numbers of raptors begin passing watch-sites (pers. observ.). As the season progresses, daily numbers of raptors increase, peak, and subsequently decrease. I term this rise, peak, and wane of migrating raptors the "season effect". Little has been published on how this season effect may mask the extent to which weather conditions influence raptor migration. Weather conditions affecting hourly Red-tailed Hawk migration at Hawk Mountain were analyzed with the autumn study period categorized into early, mid and late season (Maransky et al. 1997). The Hawk Mountain study focused on changing weather patterns within the season but did not address the total season effect of the migrating raptor population. Removing the season effect may lead to better understanding of weather effects on raptor migration.

I present the dates of passage and associated wind and cold front data for 13 species of raptors migrating through the Florida Keys on their way to southern wintering grounds. I test the hypothesis that the number of raptors observed on a given day is associated with the passage of a cold front. I also present a model of the season effect, based on nonparametric Loess regression, to test the hypothesis that following winds increase the number of migrant raptors independently of the season effect.

METHODS

Data collection methods are the same as described in Chapter 2 except as noted below. Local weather conditions were recorded hourly from an on-site electronic weather monitor. The anemometer and wind vane were located approximately 10 m above ground level. I recorded hourly wind direction to the nearest 45 degrees and wind speed in units of meters/second. I converted hourly wind direction and speed to daily mean vectors. Cold front and tropical storm passage were noted daily from the television Weather Channel and newspaper. Because cold fronts may stall and subsequently move off-shore in Florida before reaching the Grassy Key watch-site, I recorded cold fronts moving off-shore in northern and central Florida above $27^{0}14$ N latitude, as having passed through the Keys 1 day later. Cold fronts passing off-shore in southern Florida below $27^{0}14$ N latitude, were recorded as having passed through the Keys on the same day.

Graphs depicting daily southbound and northbound raptor counts with associated winds and cold fronts show patterns of migrant passage at Grassy Key (Figs. 3.1 to 3.11). Most graphs are plotted on a log scale to better compare counts on the majority of days with low numbers of passing raptors.

Cold Front Passage

To determine whether more raptors are seen on cold front days than non-cold front days, I performed paired-sample t-tests between cold fronts and numbers of passing raptors. For the t-test, the "cold front day" category is the sum of the species number on a cold front day plus the number on the following day and the "non-cold front day" category is the sum of the species number the day before the cold front plus the number on the second day following a cold front (i.e., the sum of species numbers seen on either side of the "cold front day" total). Thus, I avoid including the season effect in the paired-sample t-tests by viewing a cold front as an event rather than comparing raptor counts seen on all cold front days to all other days across the entire season. The paired-sample t-tests showed no differences in raptor numbers on cold front days compared to other days. Chi square tests on numbers of raptors on cold front days (including the following day) and on other days in October resulted in significant associations for all species on cold front days in 1996. Chi square tests were also significant for all species in 1997 except for Ospreys, Cooper's Hawks, and Merlins. Although X^2 tests did not take the season effect into account, the discrepancy between the X^2 tests and paired-sample t-tests warranted further investigation of cold front effects on raptor migration. To compare years, I calculated the expected number of raptors on cold front days in October for each year by multiplying the percent of days with cold fronts (including the following day) by numbers of raptors observed on those days. Species examined include the Turkey Vulture, Osprey, Northern Harrier, Sharp-shinned Hawk, Cooper's Hawk, Broad-winged Hawk, American Kestrel, Merlin, and Peregrine Falcon. Other species are not discussed due to low numbers of sightings. Because Turkey Vultures and Broad-winged Hawks are flocking species, the movement of individuals may not be independent. Therefore, I also analyzed cold front passage of these 2 species using numbers of flocks as my dependent variable.

Wind

I tested the hypothesis of a relationship between migrant raptor passage and local winds. I transformed the count data to remove the season effect, $[x - y] / y = z$. The daily numbers of select species of raptors were log transformed, x. I filtered the log-transformed data via Loess regression using a weighted running average with a 15 or 21 element weighting array, (y). I examined graphs of each species using both the 15 and 21 element arrays and chose the array which best smoothed daily fluctuations. The output was a curve that tracked smoothly the trends in daily counts but was insensitive to daily highs and lows (example Fig. 3.12). The weighting coefficients for the 15 element weighting array were

0.034, 0.044, 0.054, 0.064, 0.074,
0.084, 0.094, 0.104, 0.094, 0.084,
0.074, 0.064, 0.054, 0.044, 0.034.

The weighting coefficients for the 21 element weighting array were

0.045, 0.046, 0.047, 0.048, 0.049, 0.050, 0.051,
0.052, 0.053, 0.054, 0.055, 0.054, 0.053, 0.052,
0.051, 0.050, 0.049, 0.048, 0.047, 0.046, 0.045.

To remove the season effect, I subtracted the filtered array from the log-transformed data and scaled the sum by the reciprocal of the filtered array (example, Figs. 3.13 and 3.14). Dates examined for each species begin on the first two consecutive days of sightings and conclude on the day of last sighting. Filtering data reduced the number of days by 14 or 20 depending on length of the filter.

In the season effect study, daily mean vector wind directions were categorized into "following" winds (from 292.5 to 360 and 0 to 112.4 degrees - WNW to ESE) designated by the unit vector +1 or "opposing" winds (from 112.5 to 292.4 degrees - ESE to WNW) designated by the unit vector -1 (Fig. 3.15). A wind direction unit vector when scaled by the magnitude of the mean wind vector for each day results in a continuous variable hereafter referred to as the "wind variable". Combining wind speed and wind direction affords greater understanding of wind effects; for example, strong following winds may affect raptors differently than weak following winds. To detect wind effects on numbers of southbound raptors passing Grassy Key, I used Spearman rank correlation statistical tests between wind variable and scaled raptor residual using SPSS 7.5 computer software. A positive correlation signifies an increase in number of birds as following wind speeds increase in velocity. Species examined are the same as in the cold front analysis. In the statistical results reported below, one can obtain a cumulative alpha level of 0.05 for 9 comparisons by considering as significant individual probabilities less than 0.005.

RESULTS

Cold Front Passage

In both 1996 and 1997, I found no evidence suggesting more raptors are seen on cold front days than on non-cold front days for all species (according to paired-sample t-tests, $P > 0.005$). However, numbers of raptors observed on cold front days (including the following day) in October are similar for both years in some species and different in others (Table 3.1). Five cold fronts passed during October 1996 (32% of days) and 4 cold fronts in 1997 (26% of days). A more useful approach to determine if cold fronts increase the volume of raptors passing through the Keys (or affect the number observed) may be to compare the ratio of observed raptor numbers on cold front days to expected numbers of birds. For example, the number of Broad-winged Hawks seen on cold front days in 1996 was not statistically different from chance (paired-sample t-test, $P > 0.005$) but actual numbers observed in October were over 150% more than expected. I determined any ratio of observed-to-expected higher than 1.50 as "biologically" significant (50% more than expected). Thus, in 1996 all species seen on cold front days were significantly high except for Turkey Vultures, Ospreys, and Cooper's Hawks. Observed numbers of Sharp-shinned Hawks, Broad-winged Hawks (individuals and flocks), American Kestrels, and Peregrine Falcons were over twice the expected number in 1996. In comparison, in 1997 the only species that was 50% higher than expected on cold front days was the Sharp-shinned Hawk.

In 1996, daily peak number for all species except Turkey Vultures occurred on or the day after cold front passage (Figs. 3.1 - 3.11). In 1997, Northern Harrier, Sharp-shinned Hawk, American Kestrel, and Merlin peak counts occurred on or the day after a cold front. The second highest 1997 daily count for Ospreys and Peregrine Falcons occurred on or 1 day after a cold front. Turkey Vultures, Cooper's Hawks, and Broad-winged Hawks did not have any of the 3 highest daily totals on or the day after cold front passage in 1997.

Wind

In general, local daily winds had little consistent effect on numbers of raptors seen flying south over Grassy Key. The effect of the wind variable (speed of following or opposing wind) on numbers of migrants with and without the season effect was different for many species within years, and different for most species between years (Table 3.2). Removal of the season effect left only a few significant species-wind correlations and those were not significant both years for most species. Northern Harriers are the only species with positive correlations (at the 0.05 level) consistent for both years after the season effect is removed. Thus, increasing following wind speeds may increase the number of Northern Harriers observed although the correlation was not significant when considering the multiple-comparison significance level, $P < 0.005$. American Kestrels show opposite significant correlations with wind, positive in 1996 and negative in 1997. Thus, independent of frontal systems, local winds do not seem to affect raptors migrating through the Keys except, perhaps, Northern Harriers.

DISCUSSION

Cold Front Passage

Although paired-sample t-tests did not reveal more raptors seen on cold front days, the ratio of observed-to-expected numbers of raptors passing with cold fronts exhibit markedly different results in 1996 and 1997. Effects of cold fronts on most species in 1996 were biologically significant (over 50% more than expected) in contrast to 1997 when cold fronts had little measurable effect. I believe the discrepancy between the 2 years may be the dearth of tropical storms in 1997 due to the cyclic weather pattern, El Nino.

On 7 October 1996, Tropical Storm Josephine moved northeast from the Gulf of Mexico across the Gulf states and northern Florida. Winds and rain associated with Josephine continued to affect the southeastern United States, including Florida, on 8 October. A fast-moving cold front passed through the southeastern United States and Florida on the night of 8 October bringing much improved weather on the 9th. The peak southbound counts for Peregrine Falcons (377) and Merlins (46) occurred on 9 October 1996.

On 16 October 1996, Tropical Storm Lili approached Cuba from the southwest. On the night of the 16th, Lili was upgraded to hurricane status producing high winds and storm surges in southern Florida and the Keys. On the 17th, Lili passed through the Florida Straits, narrowly missing the Keys, and continued across the Atlantic to the Bahamas on the 18th. On the 19th, Lili had moved farther into the Atlantic and a cold front passed through the Keys. The peak day for Northern Harriers (72), Sharp-shinned Hawks (1,221), Cooper's Hawks (54), American Kestrels (896), and overall raptors (3,865) occurred on 19 October.

I believe Tropical Storm Josephine delayed large numbers of raptors to the north prior to 9 October. An unprecedented netting success of warblers in Miami also occurred on 9 October (P. K. Stoddard, Florida International University, pers. commun.). Hurricane Lili, while not passing directly over Florida and the Keys, probably delayed raptors who were sensitive to changes in barometric pressure and high winds. The subsequent cold fronts following the storms resulted in favorable migration weather conditions and high peak counts of migrating raptors on Grassy Key. The ratios of observed-to-expected numbers of migrant raptors in 1997 probably show the effect of cold fronts while the 1996 ratios show effects of cold fronts in conjunction with tropical storms. Thus, in the Florida Keys, cold fronts alone (1997) have little effect on numbers of migrant raptors except for Sharp-shinned Hawks while cold fronts in conjunction with tropical storms (1996) seem to increase migration of most species. At the very least, cold fronts following tropical storms increase the number of sightings of raptors in the Keys.

Turkey Vultures, Ospreys, and Cooper's Hawks do not seem to be affected by cold fronts with, or without, tropical storms. Of particular interest are the results of Turkey Vultures and Turkey Vulture flocks in 1996 with ratios of 0.80 and 1.76, respectively. Reducing the number of Turkey Vultures by considering flocks instead of individuals as the independent unit of analysis, doubles the significance of cold front effects for this species. Observations of flocks of migrating raptors have been reported but flocking behavior is rarely studied (Kerlinger 1989). Kerlinger and Gauthreaux (1985) studied flocks of Broad-winged Hawk migrants in southern Texas. They reported flocking behavior such as length of takeoff, space between individuals soaring in thermals, number of hours flown per day, and wind effects on individuals as they landed and took off. Other raptor migration sites studying effects of weather on migration may benefit by considering flocks as individuals.

My statistical findings that cold fronts alone do not affect migration of most species do not necessarily conflict with results from watch-sites in the northeastern United States such as Hawk Mountain (Allen et al. 1996). The discrepancy between my results at Grassy Key and Hawk Mountain are probably due to topography and geography. Northeastern watch-sites are closer to breeding grounds and experience stronger cold fronts and fewer tropical storm effects than do Florida and the Keys.

Because large numbers of hawks in Central America use tropical storms during their passage, Smith (1980) speculates that large numbers of Broad-winged Hawks may use updrafts associated with tropical storms to cross the Gulf of Mexico. Although I have observed raptors climbing to great heights in front of convective storms, I have not observed an increase in numbers of raptors during tropical storms. However, raptors already over the ocean may use tropical storm updrafts to enhance migration or raptors may be flying in these updrafts at high altitudes. Regardless, based on my analysis of tropical storms and cold fronts, I think it likely that tropical storms serve more to delay, than enhance, migration.

Comparing the raptor and cold front passage graphs, the season effect may also influence numbers of raptors seen on cold front days (Figs. 3.1 - 3.11). Although peak days may have occurred in conjunction with cold front passage, a steady increase is often seen leading up to a cold front. This increase in raptor numbers before a cold front is especially notable in 1996 for Merlins and Peregrine Falcons and in 1997 for Ospreys, Northern Harriers, Sharp-shinned Hawks, American Kestrels, and Peregrine Falcons. A possible explanation is that the season effect is building and the counts leading up to a cold front are coinciding with the season effect. Alternatively, raptors may be overtaking a weak cold front somewhere north of the Keys (especially if a front stalled to the north). Raptors overtaking cold fronts to the north may also account for peak numbers of Ospreys and Peregrine Falcons occurring 1-2 days before cold front passage at Grassy Key in 1997. Another factor that should always be considered when conducting traditional raptor migration watch-site counts, is that birds throughout the season may have flown at altitudes too high to detect without radar (Kerlinger 1984).

Future counts at Grassy Key during normal years with tropical storm formation and in El Nino years will provide interesting comparisons to my findings.

Wind

Correlations of raptor numbers and the wind variable were influenced by the season effect. The relationship of the wind variable and number of raptors with the season effect removed was disparate between the two years indicating winds may have very little to do with timing of raptor migration through the Keys (i.e. a significant correlation may be due to chance alone). In addition, Northern Harrier correlations were not significant at the significance level for multiple comparisons, $P < 0.005$. Thus, I tentatively accept the null hypothesis that no relationship exists between increasing following winds and raptor counts at Grassy Key.

Haugh (1972) suggests that the further away from the initial departure point in both time and space, the less likely will be an association between weather conditions and numbers of Broad-winged Hawks. The Florida Keys are far from most migrant raptor breeding grounds, thus weather may play a lesser role in migration strategy. In addition, if migrant raptors descend with winds that may push them over large bodies of water (Murray 1964, Millsap and Zook 1983, Kerlinger and Gauthreaux 1984), then I probably see a proportionately greater number of migrants passing over the Keys than seen passing over other watch-sites. Thus, wind may not make a great difference in whether a raptor will migrate through the Keys on a given day.

A long-term study in the Florida Keys would better reveal associations between observed raptor numbers and weather conditions especially if radar was used in conjunction with ground observation. I suggest further exploration to determine if the season effect will influence conclusions drawn between weather and raptor counts on long-term data sets at other hawk-watch sites.

CHAPTER 4

A roosting survey of autumn migrant raptors at Boot Key, Florida - 1996, 1997.

INTRODUCTION

The Florida Keys serve as a major autumn migratory flyway for over 13,000 raptors, representing 16 species (Chapter 2). The total volume of raptors using the Keys flyway in autumn is somewhere over 26,000 including both southbound and northbound birds. Northbound raptors include those migrants avoiding water crossings, foraging, awaiting more favorable weather conditions, and those wintering in the Keys.

Falconiformes are mainly diurnal, resting at night. Because roosting, foraging, and resting habitat is crucial to raptor survival during migration, stopover areas and critical resources of raptors along migratory flyways need to be identified (Niles et al. 1996). Energy costs for raptors may be greater during migration along coastal sites because of an increased need for powered flight to avoid being pushed over the ocean (Kerlinger et al. 1985). The Florida Keys are surrounded by ocean, thus, foraging and resting habitat for raptors may be especially important in the Keys.

Food availability during migration is crucial to the survival of several bird populations (Burger 1986, Myers et al. 1987). However, where competing avian predators concentrate and experience a shortage of prey, foraging individuals often suffer a decline in food intake rate through disturbance of prey, antagonistic encounters, displacement, and avoidance (Goss-Custard 1980). Because many raptors feed primarily on birds, both prey and predators may be at risk if the prey base is depleted by habitat loss. Foraging habitat may be especially important to immature migrant raptors that are less efficient at capturing prey (Niles et al. 1996). In general, first-time migrants of most species face a 50% mortality rate during migration, mainly due to inexperience (Kerlinger 1989). Decreasing flyway resources could result in even higher mortality.

The Florida Keys have been identified as an "area of critical state concern" because of the high number of rare and endangered species and natural communities present (Crawford 1975, Calleson et al. 1994). The Keys are more accessible to the public than are 2 other ecologically important American archipelagoes (Hawaiian and the Aleutian Islands). The Keys have undergone two main periods of deforestation (Bancroft et al. 1992). The first period was conversion of forest into agricultural land in the late 1800's and the second was clearing for human settlement and tourism in the early 1900's. Commercial development and clearing continue today. Peregrine Falcons and Ospreys are often seen roosting on radio towers along the Keys, but most raptors of all species rely on vegetation for roosting and foraging. Forest fragmentation has reduced the population and distribution of four forest-breeding birds in the upper Keys (Bancroft et al. 1992). Further reduction of foraging and roosting habitat could have adverse effects on raptor migration and survival of all migrant bird species in the Keys.

In 1995, I conducted pilot studies of raptors roosting at and flying over Boot Key. Because Boot Key is located directly before an 11.2 km water crossing and has abundant roosting and foraging habitat, many raptors circle the island. Thus, accurate aerial counts are difficult to obtain at Boot Key because excessive milling increases the chance of multiple counting. However, roosting counts were relatively simple to perform and, I believe, provide a valid estimate of the number of raptors roosting on Boot Key. I also observed raptors foraging on Boot Key.

In this study, I report 1996 and 1997 results from a nightly raptor roosting survey on Boot Key during the autumn migration season, comparisons of Boot Key roosting results with numbers of raptors flying past Grassy Key, and I present a simple regression model to predict aerial counts at Grassy Key from roosting counts at Boot Key.

METHODS

Boot Key is located directly south of Marathon, Florida, approximately halfway down the island chain - 48 miles northeast of Key West and 16 km south of Grassy Key (Fig. 4.1). Boot Key lies directly before an 11.2 km water crossing, the longest encountered in North America that cannot be skirted by land. Boot Key is approximately 3.2 km^2 in area, privately owned, and one of the few relatively undeveloped keys remaining along the major island chain (only one small permanent structure on the island). Habitats include coastal, mangrove, wetland, and a few hammock regions which, according to The Nature Conservancy's 1996 Preservation 2000 Annual Report, provide critical nesting and feeding areas for many migratory birds in the Keys. A drawbridge connects Boot Key to Marathon and a 2.5 km paved road crosses the key. Vegetation along the road edge consists mainly of the exotic species, Australian Pine (*Casurina equisetifolia*).

I conducted a roosting survey on Boot Key from 15 September - 15 November 1996 and 5 August - 13 November 1997. I counted raptors during road surveys from a vehicle every evening approximately 1 hour before sunset and, again, approximately 2 hours after sunrise the following morning. Secretive raptor species, such as buteos, are difficult to detect from a road survey. Once weather conditions become favorable for thermal formation in the morning, these secretive species begin soaring in thermals to gain altitude. Thus, the morning survey includes a survey conducted from the Boot Key drawbridge to detect soaring raptors. To avoid double-counts, I used the higher count for each species (evening or following morning total) for the nightly roosting total.

I performed comparative evening and morning roosting surveys for 2 days at Long Key State Recreation Area (north of Boot Key) and at Bahia Honda State Park (south of the 11.2 km water crossing). Both sites yielded very few observations of roosting raptors.

I compare Boot Key roosting raptor totals to Grassy Key "net" aerial totals to show end-of-season comparisons (Table 4.1). The net count is the number of southbound minus northbound raptors at Grassy Key and is the best season estimate indicating the number of raptors that passed Grassy Key and remained south of the site. The "gross" aerial count is the total number of sightings (southbund plus northbound) and is the best indicator of the volume of migrants using the Keys flyway. For daily comparisons of the total number of raptors observed, I examine southbound and gross totals at Grassy Key and compare them to Boot Key roosting totals using Spearman rank correlations (SPSS statistical software).

For individual species, I present Pearson r^2 values to indicate daily variability between roosting counts and the southbound, northbound, and net aerial counts at Grassy Key for 1996 (Table 4.2). I used linear equations based on 1996 data to predict 1997 aerial counts at Grassy Key from roosting counts at Boot Key (Table 4.3). The 1996 aerial count data type (south, north, or net) with the higher r^2 value is the most reliable predictor of 1997 aerial counts. In the accompanying figure, I included southbound predictions for all species, northbound predictions for Merlins, and net predictions for Broad-winged Hawks and American Kestrels. I did not include northbound and net predictions for other species because the difference in r^2 between the 3 flight direction categories was less than 0.01. I also did not include Cooper's Hawks in the prediction analysis because I saw too few on Boot Key to make a meaningful estimate.

RESULTS

I observed 2,923 raptors on Boot Key in 1996 and 3,477 in 1997 (Table 4.1). The most abundant species in 1996 in descending order were

American Kestrels

Turkey Vultures

Broad-winged Hawks

Ospreys

Peregrine Falcons

Sharp-shinned Hawks.

The most abundant species in 1997 were the same as in 1996 except for greater numbers of Turkey Vultures than American Kestrels and more Sharp-shinned Hawks than Peregrine Falcons. Comparing roosting to net flight results, 21% & 25% of the total number of raptors observed flying at Grassy Key were roosting at Boot Key.

By genus, I observed almost twice as many roosting falcons as buteos and over 5 times more buteos than accipiters (Table 4.2). I believe many more accipiters roosted on Boot Key but were not observed. Accipiters are secretive and, thus, few would be counted on the road survey. In addition, accipiters may have left Boot Key before the morning survey because they do not rely on thermals. Up to 31% of falcons, 29% of buteos, and 9% of accipiters in the Grassy Key net results were observed roosting on Boot Key.

Daily fluctuations between the total number of raptors observed roosting at Boot Key and southbound and gross numbers flying past Grassy Key in both years (southbound: Figs. 4.2 and 4.3) were southbound 1996, $r_s = 0.66$ gross 1996, $r_s = 0.71$

southbound 1997, $r_s = 0.80$ gross 1997, $r_s = 0.80$

($P < 0.001$ for all comparisons).

For individual species, values of r^2 for southbound Grassy Key aerial versus Boot Key roosting counts were higher than northbound and net for most species examined (Table 4.3). The exceptions were northbound r^2 values for Merlins and net r^2 values for Broad-winged Hawks and American Kestrels. For many species, predictions of southbound aerial counts at Grassy Key in 1997 are very close to the observed aerial counts especially for Sharp-shinned Hawks and the 3 falcon species. Predictions for northbound Merlins and net Broad-winged Hawks are not as close to observed flights as the southbound predictions. However, the respective northbound and net r^2 values are greater, thus, the predictions for northbound Merlins and Broad-winged Hawks are, presumably, more reliable.

In addition to roosting observations in both my extensive 1995 Boot Key pilot study and this study, I observed several Peregrine Falcons, Merlins, American Kestrels, Bald Eagles, and Ospreys feeding at Boot Key. Sharp-shinned Hawks, Cooper's Hawks, and Northern Harriers were observed in behavior probably associated with foraging (such as flying low over trees around the key), although feeding was not observed directly.

DISCUSSION

Migrant raptors are using Boot Key as a major stopover area to rest and feed on their way south. In contrast, Long Key to the north and Bahia Honda to the south do not appear to be major stopover areas for migrant raptors. Fewer raptors may roost at Bahia Honda because the site is located after the 11.2 km water crossing. Raptors that roost before the crossing to replenish energy reserves may pass over Bahia Honda the following day.

High numbers of raptors counted at Boot Key are probably due to a combination of 2 factors. First, Boot Key is one of the few remaining undeveloped areas in the Keys. Boot Key's mangrove forests and hardwood hammocks are suitable habitat both for raptor prey and roosts. The surrounding area is the highly developed city of Marathon. Second, Boot Key is located directly before the longest water crossing (11.2 km) the migrants encounter before the crossing from the Keys to Cuba. Many raptors, especially soaring species, hesitate to cross water barriers because of a lack of thermal formation over water. In 1995, I observed a flock of over 300 Broad-winged Hawks reach the water crossing after Boot Key, mill about for approximately 1 hour, and subsequently head north back up the Keys. Weather conditions seemed to be conducive to southbound migration but the flock did not continue south over the water. I have also observed large flocks of Turkey Vultures return up the Keys rather than cross this water barrier. I believe the large number of soaring species on Boot Key is partially due to this hesitancy to cross water, especially, if the migrants arrive late in the afternoon.

Falcons are easily observed roosting in Australian Pine and are the most abundant migrants observed on Boot Key. High numbers of American Kestrels may be due to their reluctance to cross water. However, over 200 Peregrine Falcons roosted on Boot Key each season even though this species crosses water readily. Peregrine Falcons may stop at Boot Key because it is relatively undisturbed and harbors abundant prey (birds) including migrant waterfowl, passerines, and shorebirds (pers. observ.).

Daily fluctuations of the total number of raptors at Boot Key were similar both to southbound and gross aerial counts at Grassy Key. The gross total equals southbound plus northbound counts, thus, northbound sightings at Grassy Key had little effect on the correlation between daily counts of the total number of raptors roosting at Boot Key and those flying over Grassy Key.

My roosting survey was much more efficient in time involved, personnel required, and cost than the aerial survey. My predictions of 1997 aerial counts from roosting counts are similar in many species to the observed aerial counts. These predictions are based on equations garnered from one season (1996). If a longer-term survey is initiated, perhaps roosting counts at Boot Key may be reliably used to estimate numbers of raptors passing through the Keys and reveal insight into raptor behavior before water crossings.

The Boot Key roost / Grassy Key aerial predictions revealed several interesting questions crucial to understanding the relationship between roosting and aerial counts Behavioral factors such as the number of birds turning around at the 11.2 km water crossing but not roosting on Boot Key, the number of raptors roosting on Boot Key for more than 1 night, and the use of the critical resources at Boot Key need to be addressed. Regardless of whether Boot Key is included in a long-term survey, a better description of raptor behavior before the 11.2 km water crossing (directly after Boot Key) may lead to better understanding of reasons for northbound flights observed in an aerial census.

MANAGEMENT RECOMMENDATIONS

The large numbers of raptors counted at Boot Key reveal the need for raptor stopover areas in the Keys. Because of the abundance of migrant raptors through the Florida Keys and their presumed (but undocumented) need to rest and feed, further studies of critical resources should be performed. If habitat is found to be critical, the narrow belt of land in the Keys and the surrounding ecosystem should be preserved. More information may lead to identification of possible threats to migrant raptors and Keys ecosystems.

The following are suggestions for conducting a roosting survey at Boot Key. Australian Pine lining the road on Boot Key are an exotic species but do not seem to be encroaching on the mangrove and hardwood hammock areas of this key. The majority of falcons observed on Boot Key roost in the pines, thus, for management purposes, I would suggest leaving these trees intact along the roadside. The roosting surveys I performed along the road did not overly disturb Merlins and Peregrine Falcons. American Kestrels may fly as a vehicle approaches but can be kept track of with careful observation. Stopping the vehicle will usually result in American Kestrels flying, thus, I suggest slow constant movement. Other species fly among the trees further away from the roadside and are not disturbed by the road survey. The morning spotting scope survey of soaring birds from the Boot Key Bridge does not disturb raptors. The surveys require approximately 1 hour in the evening (approximately 1 hour before dusk) and 1 hour in the morning (at approximately 0900 hrs). The same person would preferably conduct both the evening and morning survey. On high volume days, 2 people would be preferable for the evening road survey, a driver and the observer. By comparison, aerial surveys on Grassy Key required 2-6 people, working for at least 8 hours a day.

A tower on Boot Key would be useful both for conducting roosting surveys and for identifying reverse-flight raptor behavior before a water crossing. If raptor are trapped for banding farther up the Keys island chain, low cost short-duration radio transmitters could be fitted on some raptors and their behavior monitored at Boot Key.

I suggest Boot Key be preserved as a critical wildlife area in the Keys - mainly as a major migrant raptor stopover area. Currently, Boot Key is privately owned but the public has free access. The owner has petitioned to build on Boot Key but has thus far been denied, probably because of the abundance of mangrove trees on the island. Historically, a county garbage dump was located on Boot Key and, unfortunately, illegal dumping continues today. Further disturbances on Boot Key include off-road vehicles on trails through hammock areas, herbicides sprayed on roadside vegetation, and pesticides used for mosquito control. I have observed "mosquito control" trucks on Boot Key spraying roadsides lined with hundreds of American Kestrels roosting in trees and on power lines.

In addition to serving as a raptor stopover area, Boot Key also harbors important endemic species. The endangered White-crowned Pigeon (*Columba leucocephala*) roosts and forages on Boot Key. Ospreys and, occasionally, Bald Eagles are found on the key throughout the year. Boot Key is also an important habitat for various plant species. An island of hardwood hammock within the mangroves on the central eastern part of the key, contains at-risk and significant plant species (W. Hoffman, The National Audubon Society, pers. commun.). The key is one of the few areas before the 11.2 km water crossing with Silver Palms (*Thrinax morrisii*) and Thatch Palms (*Thrinax radiata)*. At-risk plant species include the Pearl Berry (*Vallesia antillana*), Bird Pepper *(Capsicum annuum*), and the Gulf Gray Twig (*Schoepfa chrysophylloides*).

If preserved and managed correctly, Boot Key could be of ecological, scientific, and educational benefit to local inhabitants and tourists. With appropriate advertisement directed at bird-watching enthusiasts, a preserved Boot Key could bring significant funds into the local economy. At the same time, Boot Key would serve as haven to many species, especially to migrant raptors on their way to southern wintering grounds.

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TABLES

Table 2.1. Migrant raptor species known to pass through the Florida Keys categorized as complete or partial migrants (from Kerlinger 1989), by southern winter destination (Clark and Wheeler 1985; K. Meyer, Avian Research and Conservation Institute, unpubl. data), and by distance willing to travel over water (km) (from Kerlinger 1989, K. Meyer unpubl. data).

Species	Partial/ Complete	Wintering grounds	Water crossing distance (km)
Turkey Vulture (*Cathartes aurus*)	Partial	South America/US	< 25
Osprey (*Pandion haliaeetus*)	Complete	South America	>100
Bald Eagle (*Haliaeetus leucocephalus*)	Partial	US	25-100
Northern Harrier (*Circus cyaneus*)	Partial	South America/US	< 25
Sharp-shinned Hawk (*Accipiter striatus*)	Partial	Southern US/Central America	< 25
Cooper's Hawk (*A. cooperii*)	Partial	Mexico/Southern Florida	>100
Swallow-tailed Kite (*Elanoides forficatus*)	Complete	South America	0
Mississippi Kite (*Ictina mississippiensis*)	Complete	South America	>100
Red-shouldered Hawk (*Buteo lineatus*)	Partial	Mexico/Southern Florida	< 25
Broad-winged Hawk (*B. platypterus*)	Complete	South America/US	< 25
Short-tailed Hawk (*B. brachyurus*)	Partial	Southern Florida	0
Swainson's Hawk (*B. swainsoni*)	Complete	South America	< 25
Red-tailed Hawk (*B. jamaicensus*)	Partial	Mexico/Southern Florida	< 25
American Kestrel (*Falco sparverius*)	Partial	Southern US/Central America	< 25
Merlin (*F. columbaris*)	Partial	South America/US	>100
Peregrine Falcon (*F. peregrinus*)	Partial	South America/US	>100

Table 2.2. Autumn 1996 migrant raptor census (01 September - 15 November) of 16 species observed passing Grassy Key, Florida.

Species	South[a]	North[b]	Net[c]	Gross[d]	% North[e]
Turkey Vulture	3,624	2,612	1,012	6,236	72%
Osprey	1,824	245	1,579	2,069	13%
Bald Eagle	29	10	19	39	34%
Northern Harrier	577	52	525	629	9%
Sharp-shinned Hawk	3,037	1,065	1,972	4,102	35%
Cooper's Hawk	311	59	252	370	19%
Unidentified accipiter	867	179	688	1,046	21%
Swallow-tailed Kite	23	0	23	23	0%
Mississippi Kite	28	0	28	28	0%
Red-shouldered Hawk	21	1	20	22	5%
Broad-winged Hawk	3,660	837	2,823	4,497	23%
Short-tailed Hawk	27	11	16	38	41%
Swainson's Hawk	140	210	-70	350	150%
Red-tailed Hawk	3	0	3	3	0%
Unidentified buteo	74	18	56	92	24%
American Kestrel	2,159	421	1,738	2,580	19%
Merlin	532	157	375	689	30%
Unidentified falcon not Peregrine	310	160	150	470	52%
Peregrine Falcon	1,418	115	1,303	1,533	8%
Unidentified falcon	254	69	185	323	27%
Unidentified raptor	1,116	178	938	1,294	16%
Total	20,034	6,399	13,635	26,433	32%

[a] South is southbound.

[b] North is northbound

[c] Net is southbound minus northbound.

[d] Gross is southbound plus northbound.

[e] % North is the ratio of northbound to southbound sightings.

Table 2.3. Autumn 1997 migrant raptor census (05 August - 14 November) of 16 species observed passing Grassy Key, Florida.

Species	South[a]	North[b]	Net[c]	Gross[d]	% North[e]
Turkey Vulture	6,155	3,250	2,905	9,405	53%
Osprey	1,969	380	1,589	2,349	19%
Bald Eagle	29	5	24	34	17%
Northern Harrier	465	54	411	519	12%
Sharp-shinned Hawk	4,055	901	3,154	4,956	22%
Cooper's Hawk	188	22	166	210	12%
Unidentified accipiter	194	54	140	248	28%
Swallow-tailed Kite	262	2	260	264	1%
Mississippi Kite	12	0	12	12	0%
Red-shouldered Hawk	39	20	19	59	51%
Broad-winged Hawk	2,640	1,172	1,468	3,812	44%
Short-tailed Hawk	23	5	18	28	22%
Swainson's Hawk	103	28	75	131	27%
Red-tailed Hawk	3	11	-8	14	367%
Unidentified buteo	48	31	17	79	65%
American Kestrel	1,594	337	1,257	1,931	21%
Merlin	429	90	339	519	21%
Unidentified falcon not Peregrine	677	211	466	888	31%
Peregrine Falcon	1,597	92	1,505	1,689	6%
Unidentified falcon	86	23	63	109	27%
Unidentified raptor	164	52	112	216	32%
Total	20,732	6,740	13,992	27,472	33%
Total omitting August	20,193	6,671	13,552	26,864	33%

[a] South is southbound.

[b] North is northbound.

[c] Net is southbound minus northbound.

[d] Gross is southbound plus northbound.

[e] % North is ratio of northbound to southbound sightings.

Table 2.4. Autumn 1996 (01 September - 15 November) and 1997 (05 August - 14 November) migrant raptor census by genus observed passing Grassy Key, Florida.

Genus	1996/1997 South[a]	1996/1997 North[b]	1996/1997 Net[c]	1996/1997 Gross[d]	1996/1997 % North[e]
Total Accipiters	4,215/4,437	1,303/ 977	2,912/3,460	5,518/5,414	31%/22%
Total Buteos	3,925/2,856	1,077/1,267	2,848/1,589	5,002/4,123	27%/44%
Total Falcons	4,673/4,383	922/ 753	3,751/3,630	5,595/5,136	20%/17%
Total Falcons - possible Peregrine	1,672/1,683	184/ 115	1,488/1,568	1,856/1,798	11%/ 7%

[a] South is southbound.

[b] North is northbound

[c] Net is southbound minus northbound.

[d] Gross is southbound plus northbound.

[e] % North is ratio of northbound to southbound sightings.

Table 2.5. Autumn 1996 and 1997 percent northbound migrant raptor totals for representative soaring species and powered flight species observed passing Grassy Key, Florida.

Representative species	1996 % Northbound	1997 % Northbound
Soaring[a]	32%	50%
Powered flight[b]	8%	7%

[a]Soaring species include all buteos and Turkey Vultures.

[b]Powered flight species include Peregrine Falcons and Northern Harriers.

Table 2.6. Southbound migrant raptor dates of passage through the Florida Keys in 1996/1997 for the first sighting, after 10% passage, daily peak number, and peak date.

Species	1st Sighting	10% Passage	Peak #	Peak Date
Turkey Vulture	04Sep / 05Aug	20Oct / 22Oct	646 / 1,506	31Oct / 09Nov
Osprey	01Sep / 05Aug	06Sep / 22Aug	111 / 183	24Sep / 29Sep
Bald Eagle	06Sep / 05Aug	16Sep / 5Aug	3 / 3	17Sep / 05Aug
Northern Harrier	02Sep / 05Sep	19Sep / 30Sep	72 / 53	19Oct / 20Oct
Sharp-shinned Hawk	05Sep / 16Sep	11Oct / 03Oct	1,221 / 1,405	19Oct / 19Oct
Cooper's Hawk	13Sep / 02Sep	14Oct / 02Oct	54 / 29	19Oct / 21Oct
Swallow-tailed Kite	01Sep / 05Aug	01Sep / 05Aug	3 / 74	01Sep / 05Aug
Mississippi Kite	05Sep / 02Sep	05Sep / 02Sep	12 / 5	10Sep / 02Oct
Red-shouldered Hawk	18Sep / 03Oct	10Oct / 10Oct	4 / 10	11Sep / 22Oct
Broad-winged Hawk	03Sep / 12Sep	09Oct / 22Sep	1,036 / 643	20Oct / 02Oct
Short-tailed Hawk	17Sep / 02Oct	16Oct / 20Oct	5 / 9	31Oct / 22Oct
Swainson's Hawk	03Oct / 17Oct	20Oct / 22Oct	25 / 38	30Oct / 09Oct
Red-tailed Hawk	12Nov / 09Aug	13Nov / 09Aug	2 / 1	12Nov / 09Aug
American Kestrel	10Sep / 24Aug	10Oct / 02Oct	896 / 346	19Oct / 19Oct
Merlin	06Sep / 07Sep	21Sep / 24Sep	46 / 103	09Oct / 30Sep
Peregrine Falcon	13Sep / 15Sep	29Sep / 28Sep	377 / 341	09Oct / 03Oct

Table 3.1. Raptor totals seen on all days and cold front days passing Grassy Key, Florida from 1 - 31 Oct 1996 and 1997. Cold front totals include day of cold front passage plus the following day. Five cold fronts passed in Oct 1996 = 32% of the total number of days. Four cold fronts passed in Oct 1997 = 26% of the total number of days.

	Total raptors	Raptors with cold front	Expected with cold front	Ratio of observed to expected
	1996 / 1997	1996 / 1997	1996 / 1997	1996 / 1997
Turkey Vulture	1,772 / 2,605	452 / 402	567 / 677	0.80 / 0.59
Turkey Vulture flock	326 / 362	184 / 126	104 / 94	1.76 / 1.34
Osprey	666 / 566	289 / 158	213 / 147	1.36 / 1.07
Northern Harrier	361 / 298	182 / 107	115 / 78	1.58 / 1.38
Sharp-shinned Hawk	2,344 / 3,682	1,705 / 1,574	750 / 957	2.27 / 1.64
Cooper's Hawk	252 / 140	115 / 25	81 / 36	1.43/ 0.69
Broad-winged Hawk	3,138 / 2,152	2,523 / 402	1,004 / 560	2.51 / 0.72
Broad-winged Hawk flock	819 / 720	577 / 224	262 / 187	2.20 / 1.20
American Kestrel	2,035 / 1,222	1460 / 464	651 / 318	2.24 / 1.46
Merlin	395 / 173	206 / 36	126 / 81	1.63 / 0.80
Peregrine Falcon	1,206 / 1,122	793 / 256	386 / 292	2.05 / 0.88

Table 3.2. Wind variable (wind speed and whether following or opposing wind) on numbers of migrant raptors observed passing Grassy Key, Florida, 1996 using the Spearman rank correlation (1-tailed test).

	Number of days 1996	With season effect 1996	Without season effect 1996	Number of days 1997	With season effect 1997	Without season effect 1997
		r_s	r_s		r_s	r_s
Turkey Vulture	19	0.155	0.376*	33	-0.289*	-0.001
Osprey	62	0.032	-0.102	81	-0.197*	-0.320**
Northern Harrier	55	0.516**	0.487*	51	0.378**	0.242*
Sharp-shinned Hawk	47	0.384**	-0.171	38	-0.223	-0.183
Cooper's Hawk	31	0.240	-0.233	40	0.318*	0.280*
Broad-winged Hawk	46	0.503**	-0.423**	39	0.264*	0.281*
American Kestrel	41	0.620**	0.563**	39	-0.279*	-0.484**
Merlin	47	0.175	0.265*	35	-0.122	0.022
Peregrine Falcon	50	-0.037	-0.090	42	0.093	-0.288*

Table 4.1. Raptors observed roosting at Boot Key and net totals of raptors flying past Grassy Key, Florida, 15 Sep - 15 Nov 1996 and 5 Aug - 14 Nov 1997. "Net" is southbound minus northbound counts and "R/F" refers to the ratio of roosting to flight totals.

	1996			1997		
Species	Roost Total	Flight Total	Ratio R/F	Roost Total	Flight Total	Ratio R/F
Turkey Vulture	617	1,012	0.61	1,265	2,905	0.44
Osprey	231	1,579	0.15	363	1,589	0.23
Bald Eagle	3	19	0.16	4	24	0.17
Northern Harrier	54	525	0.10	29	411	0.07
Sharp-shinned Hawk	109	1,972	0.06	277	3,154	0.09
Cooper's Hawk	4	252	0.02	5	166	0.03
Unidentified accipiter	39	688	0.06	24	140	0.17
Swallow-tailed Kite	2	23	0.09	9	260	0.03
Mississippi Kite	2	28	0.07	0	12	0.00
Red-shouldered Hawk	2	20	0.10	3	19	0.16
Broad-winged Hawk	478	2,823	0.17	422	1,468	0.29
Short-tailed Hawk	4	16	0.25	6	18	0.33
Swainson's Hawk	49	-70	-0.70	11	75	0.15
Red-tailed Hawk	0	3	0.00	0	-8	0.00
Unidentified buteo	92	56	1.64	15	17	0.88
American Kestrel	733	1,738	0.42	611	1,257	0.49
Merlin	112	375	0.30	67	339	0.20
Unidentified falcon not Peregrine	64	150	0.43	127	466	0.27
Peregrine Falcon	206	1,303	0.16	202	1,505	0.13
Unidentified falcon	51	185	0.28	18	63	0.29
Unidentified raptor	71	938	0.08	19	112	0.17
Total	2,923	13,635	0.21	3,477	13,992	0.25

Table 4.2. Genus totals of migrant raptors observed roosting at Boot Key and net totals flying past Grassy Key, Florida, 15 Sep - 15 Nov 1996 and 5 Aug - 13 Nov 1997. "Net" is southbound minus northbound counts and "R/F" refers to the ratio of roosting to flight totals.

	1996			1997		
Genus	Roost Total	Flight Total	Ratio R/F	Roost Total	Flight Total	Ratio R/F
Accipiters	152	2,912	0.05	306	3,460	0.09
Buteos	625	2,848	0.22	457	1,589	0.29
Falcons	1,166	3,751	0.31	1,025	3,630	0.28

Table. 4.3. Boot Key (roost) versus Grassy Key (aerial) r^2 values indicating daily variability for 1996.

Species	r^2 South	r^2 North	r^2 Net
Turkey Vulture	0.19	0.00	0.09
Osprey	0.10	0.04	0.10
Northern Harrier	0.13	0.01	0.00
Sharp-shinned Hawk	0.11	0.00	0.01
Broad-winged Hawk	0.00	0.00	0.53
American Kestrel	0.21	0.07	0.37
Merlin	0.14	0.35	0.09
Peregrine Falcon	0.67	0.06	0.65

Table 4.4. Predicted aerial southbound counts for the 1997 season at Grassy Key (based on 1997 Boot Key roost counts) compared to actual Grassy Key aerial counts. The prediction is based on a linear equation from 1996 Boot Key roost counts and Grassy Key aerial counts. Predictions for Grassy Key aerial raptor flight directions include "S" (southbound), "N" (northbound), and "S - N" (net).

Species	Direction	1997 Predicted	1997 Aerial	Ratio P/A
Turkey Vulture	S	3,998	6,131	0.65
Osprey	S	1,189	1,496	0.79
Northern Harrier	S	529	447	1.18
Sharp-shinned Hawk	S	3,943	4,055	0.97
Broad-winged Hawk	S	3,382	2,635	1.28
Broad-winged Hawk	S-N	3,121	2,109	1.48
American Kestrel	S	1,672	1,590	1.05
American Kestrel	S-N	1,331	1,290	1.03
Merlin	S	421	422	1.00
Merlin	N	98	89	1.10
Peregrine Falcon	S	1,368	1,597	0.86

FIGURES

Fig. 1.1. Autumn raptor migration routes from northern breeding grounds in North America to southern wintering grounds as far south as South America. The solid line indicates routes taken through the southeastern United States and the Caribbean islands. The dashed line indicates routes taken via the landbridge through Texas, Mexico, and Central America.

Fig. 1.2. Map of United States and Central America showing major hawk-watch sites with over 10,000 annual sightings (from Kerlinger 1989).

1. Balboa, Panama
2. Point Diablo, CA
3. Goshutes, NV
4. Rio Grande Valley National Wildlife Refuge, TX
5. Corpus Christi, TX
6. Hawk Ridge, Duluth, MN
7. Whitefish Point, MI
8. Cedar Grove, WI
9. Hawk Cliff, Ontario
10. Derby Hill, NY
11. Hawk Mountain, PA
12. Cape May Point. NJ
13. Mount Wachussett, MA
14. Mount Tom, MA
15. Hook Mountain, NY
16. Raccoon Ridge, NJ
17. Bake Oven Knob, PA
18. Veracruz, Mexico
19. Assateague, VA

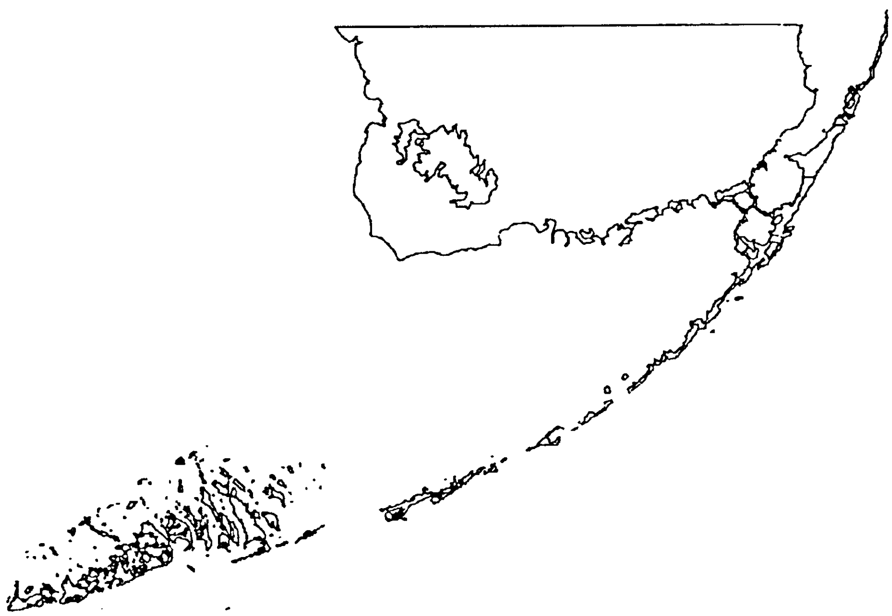


Fig. 1.3. Map of southern Florida and the Florida Keys.

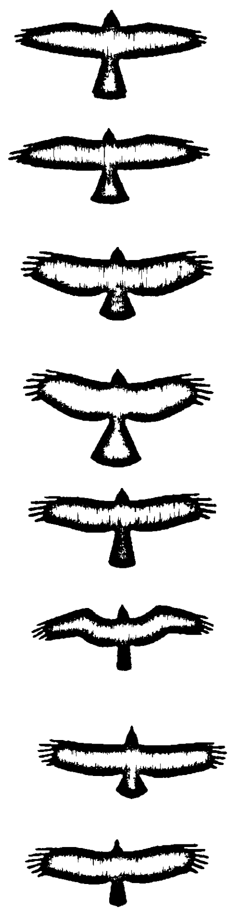


Fig. 2.1. Silhouettes showing the 8 main raptor body shapes. From top to bottom: falcon, kite, buteo, accipiter, Northern Harrier, Osprey, Eagle, and Turkey Vulture (From Clark and Wheeler 1987).

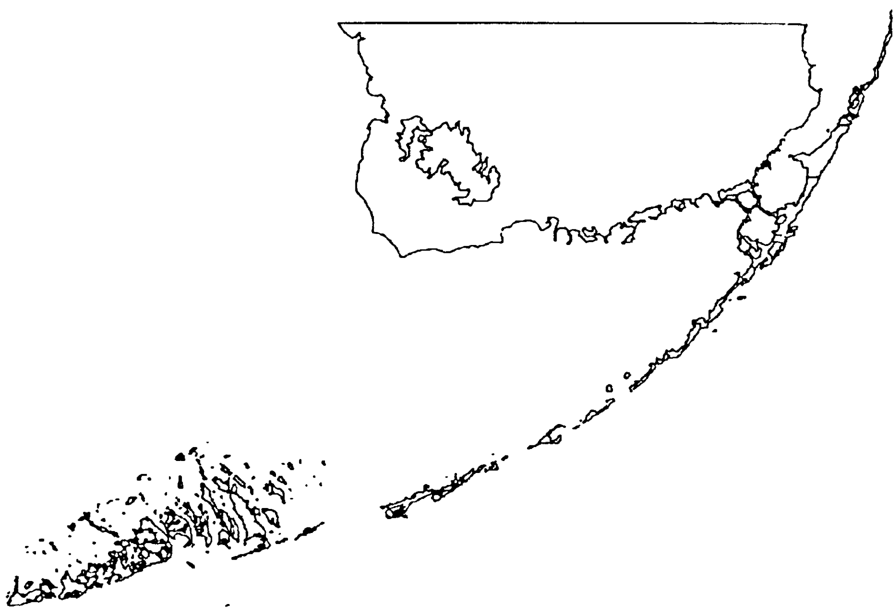


Fig. 2.2. Map of southern Florida and the Florida Keys.

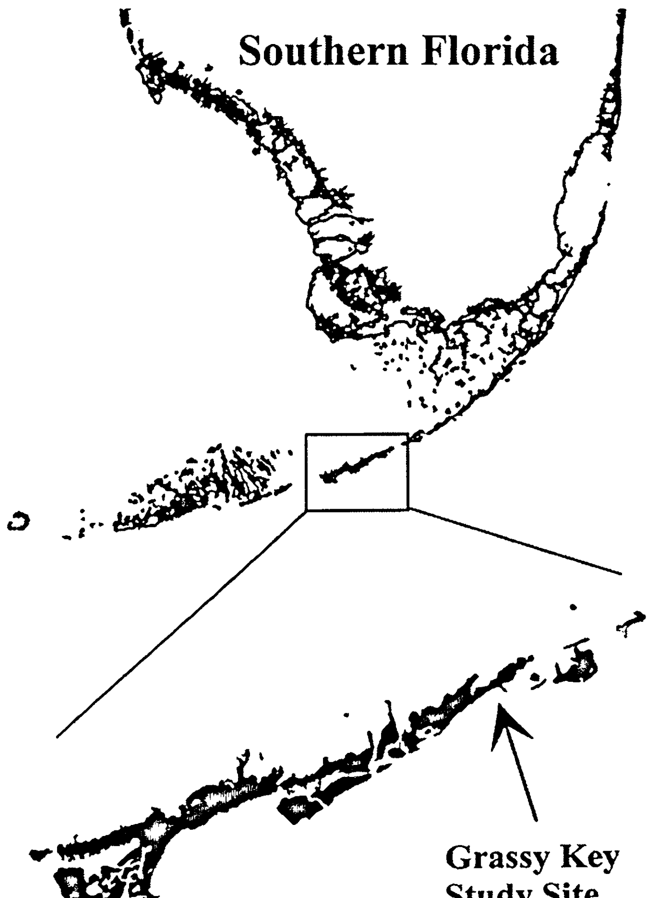
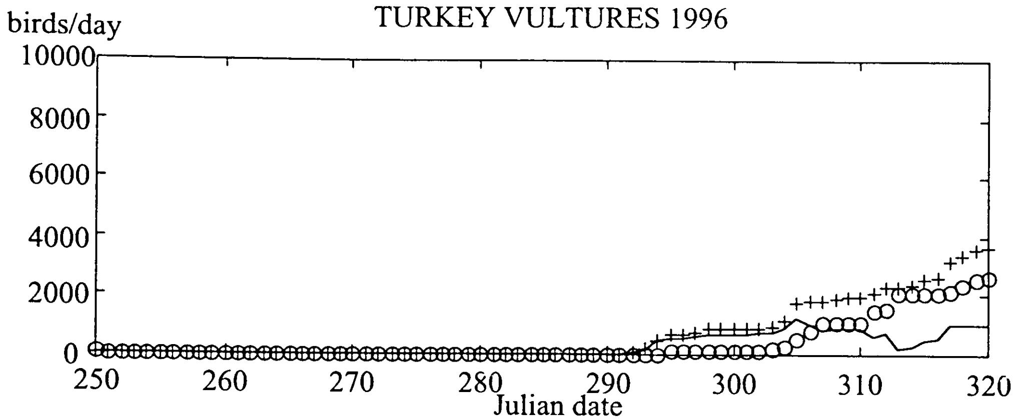


Fig. 2.3. The Florida Keys indicating the Grassy Key raptor migration study site.



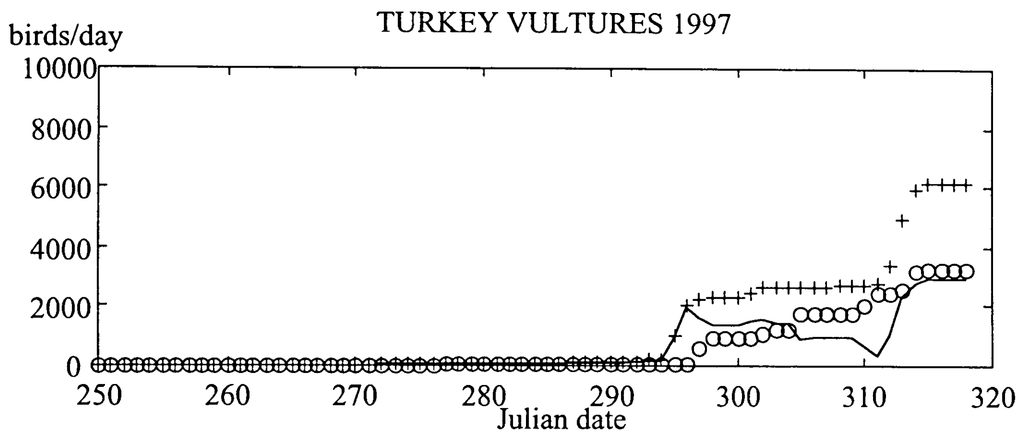


Fig. 2.4. Cumulative totals of migrant Turkey Vultures by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 31 Oct (305) 1996 and 09 Nov (313) 1997.

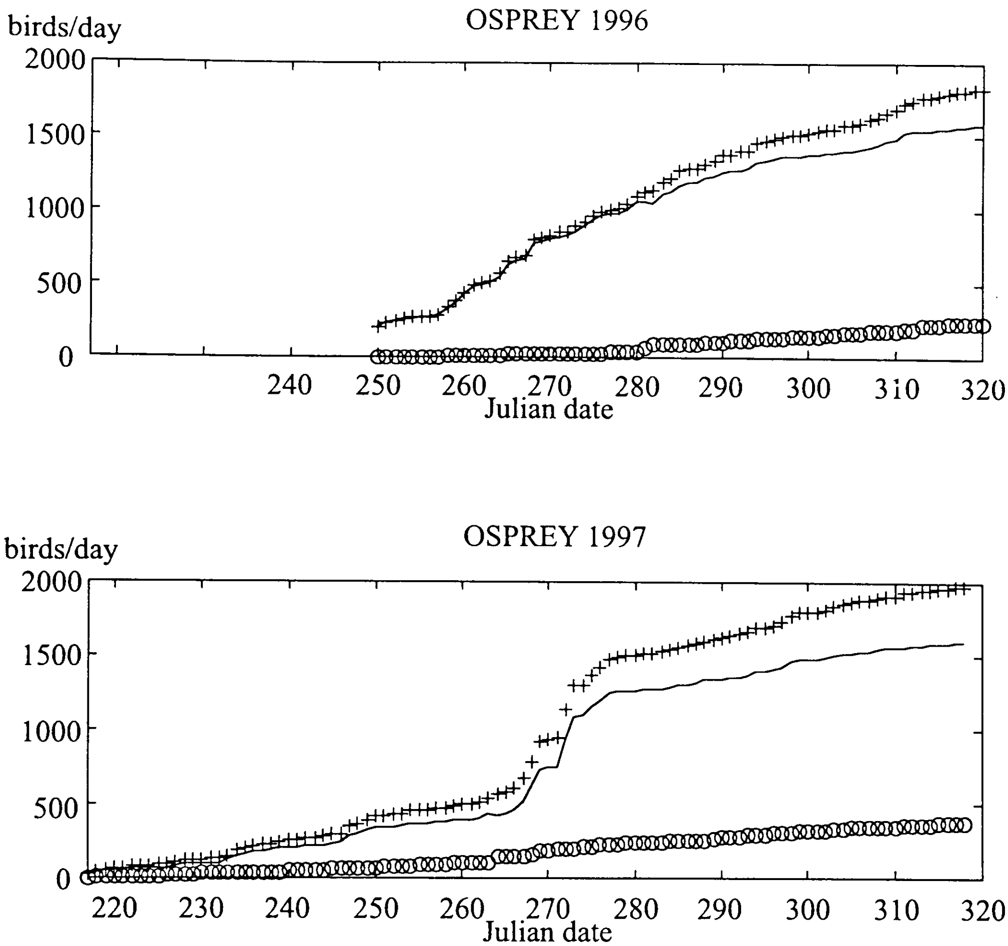
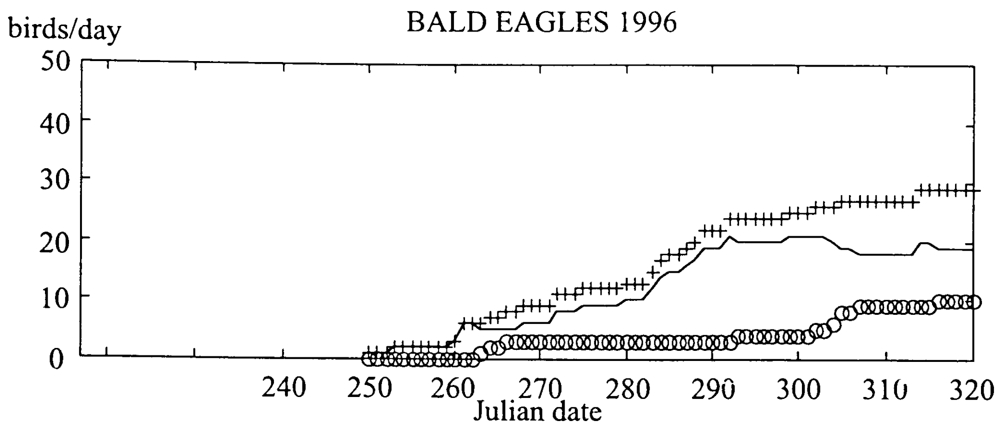


Fig. 2.5. Cumulative totals of migrant Ospreys by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 24 Sep (268) 1996 and 29 Sep (272) 1997.



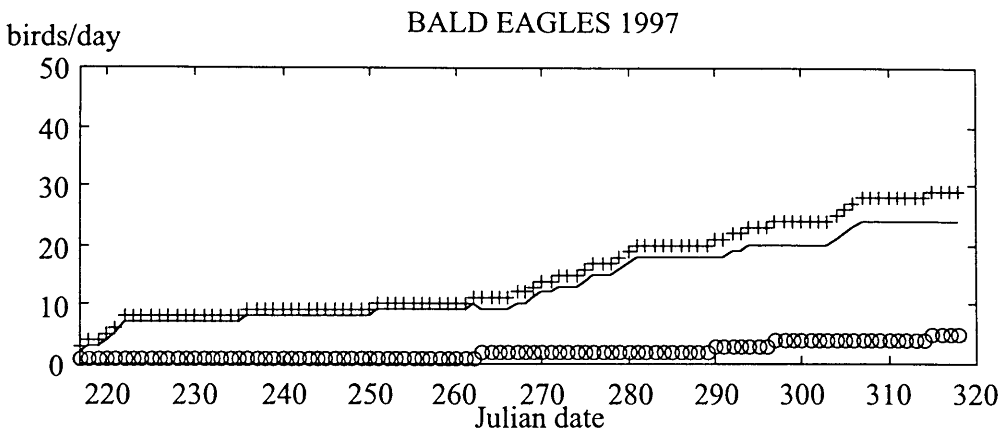
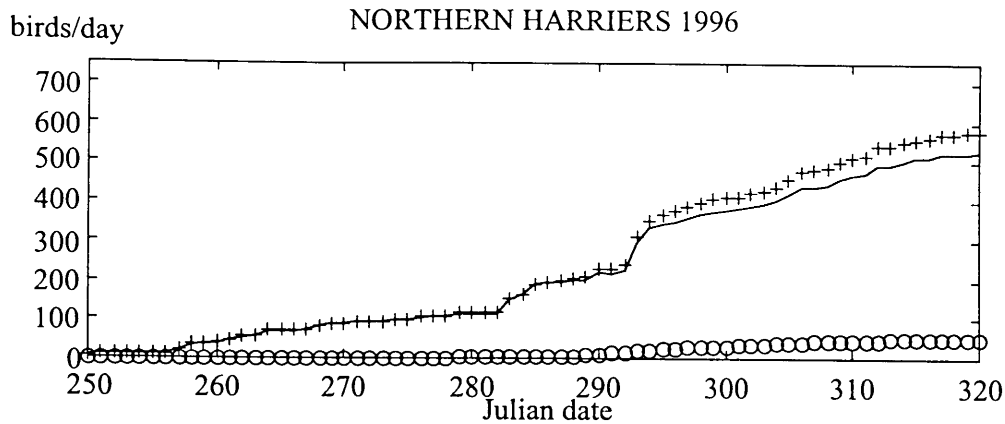


Fig. 2.6. Cumulative totals of migrant Bald Eagles by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 17 Sep (261) 1996 and 05 Aug (217) 1997.



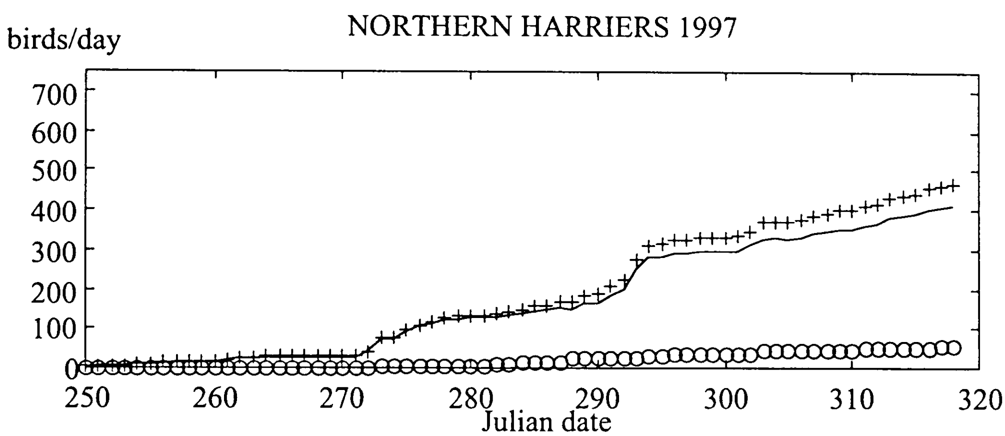
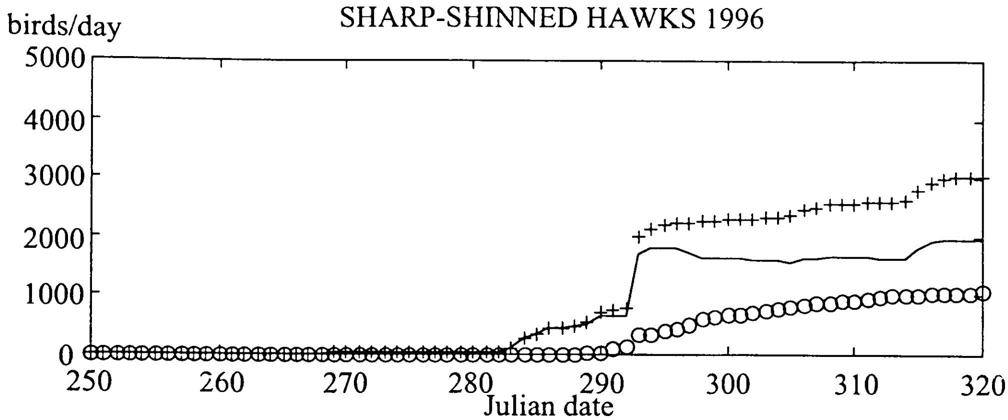


Fig. 2.7. Cumulative totals of migrant Northern Harriers by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 19 Oct (293) 1996 and 20 Oct (293) 1997.



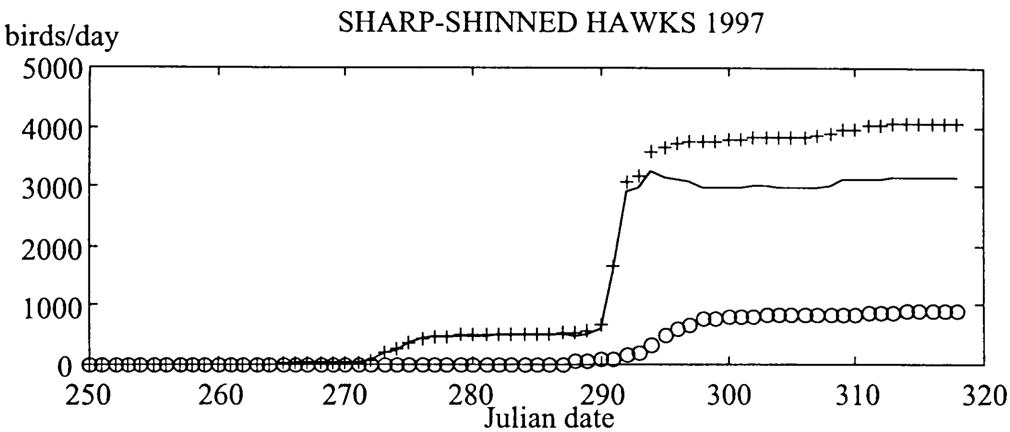
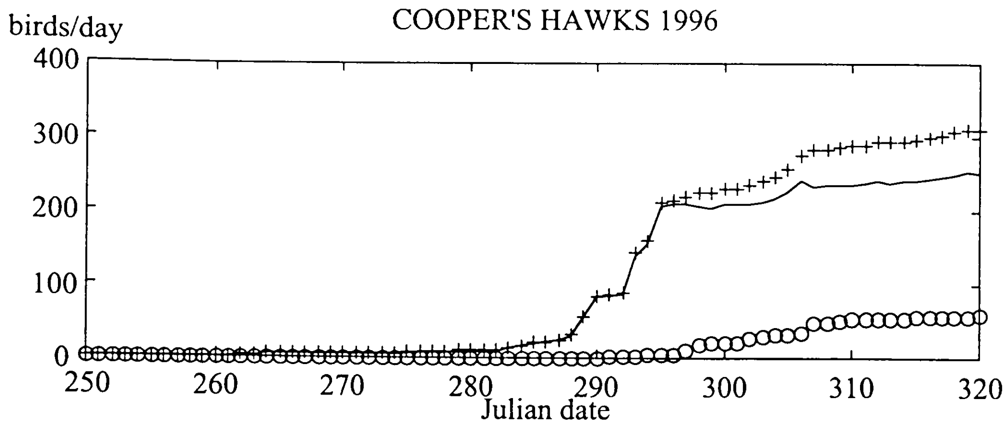


Fig. 2.8. Cumulative totals of migrant Sharp-shinned Hawks by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 19 Oct (293) 1996 and 19 Oct (292) 1997.



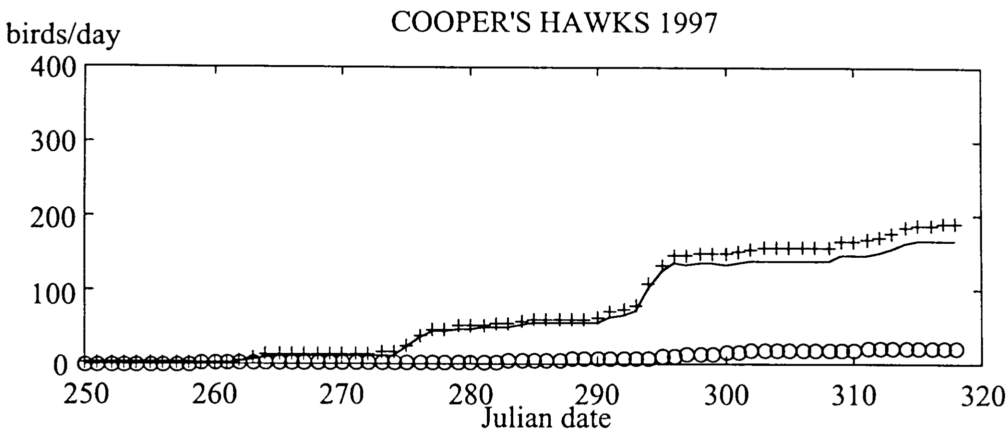
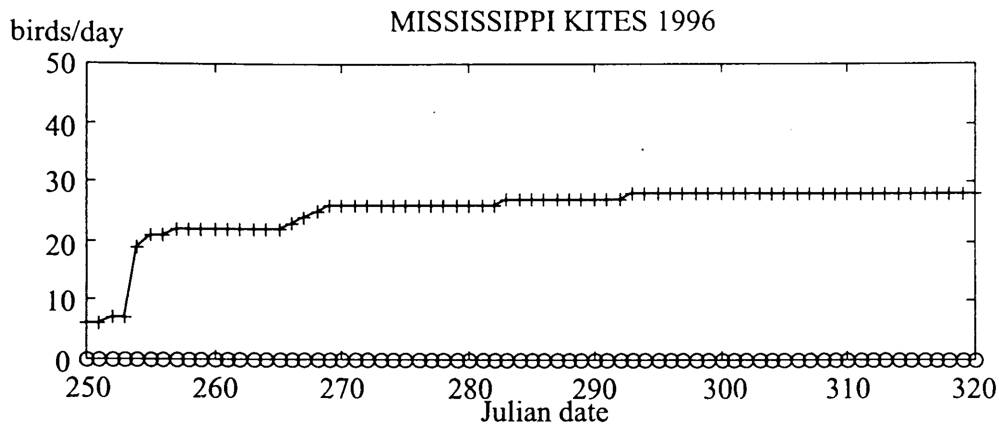


Fig. 2.9. Cumulative totals of migrant Cooper's Hawks by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 19 Oct (293) 1996 and 21 Oct (294) 1997.



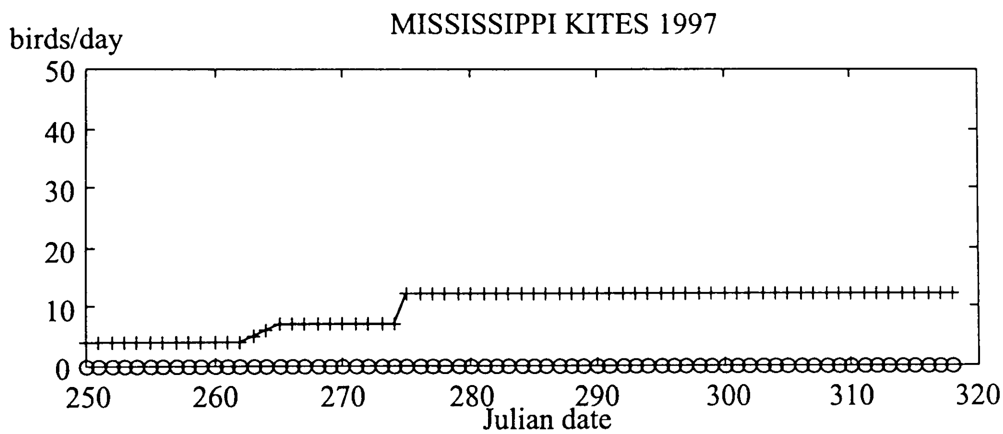
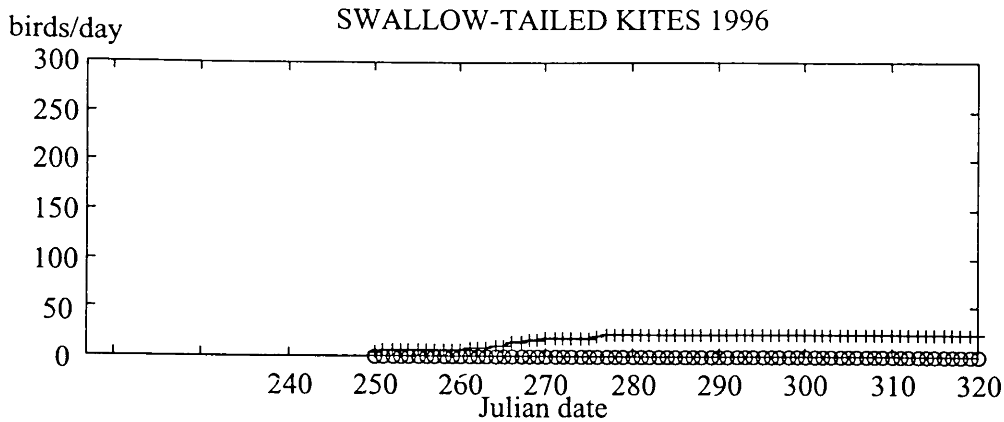


Fig. 2.7. Cumulative totals of migrant Mississippi Kites by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 10 Sep (254) 1996 and 02 Oct (275) 1997.



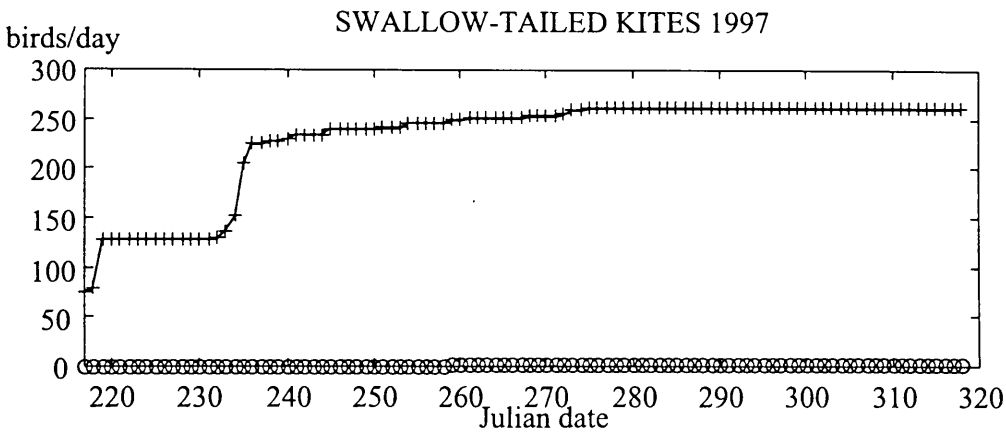
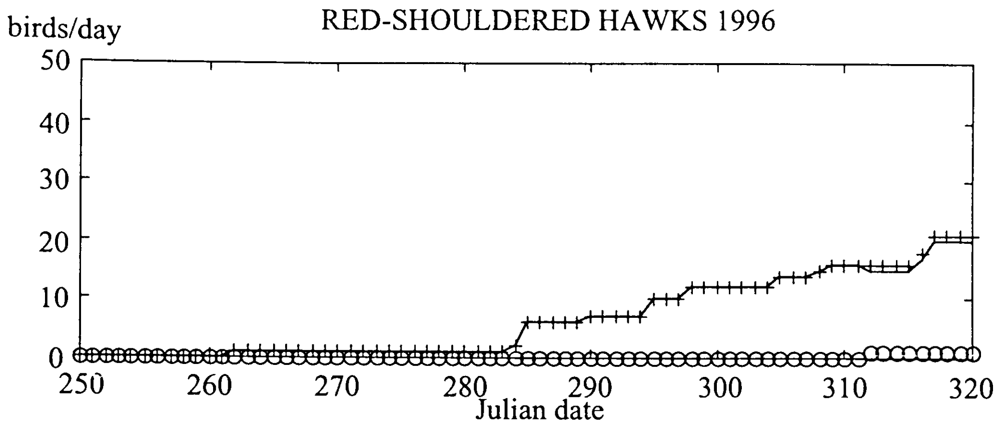


Fig. 2.11. Cumulative totals of migrant Swallow-tailed Kites by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 01 Sep (245) 1996 and 05 Aug (217) 1997.



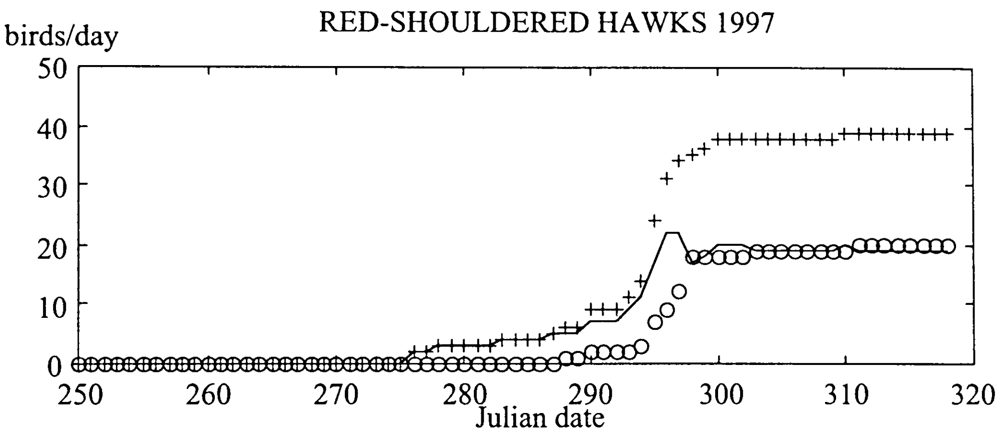
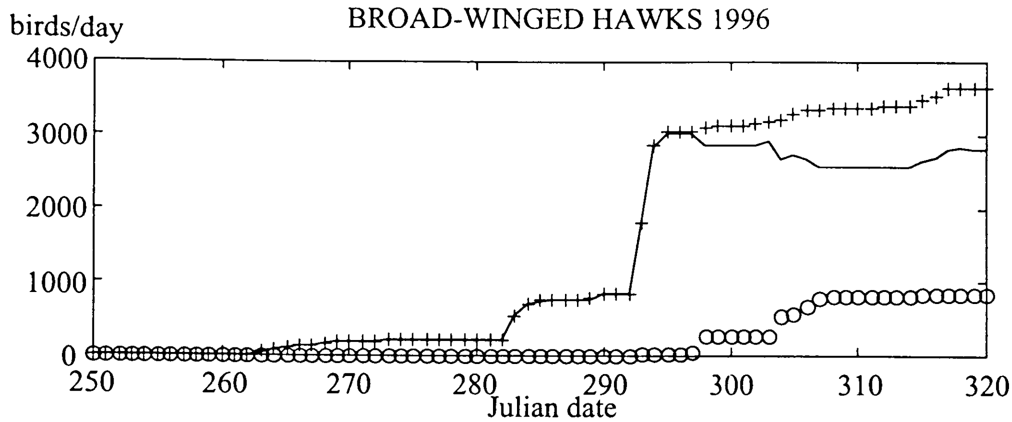


Fig. 2.12. Cumulative totals of migrant Red-shouldered Hawks by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 11 Sep (255) 1996 and 22 Oct (295) 1997.



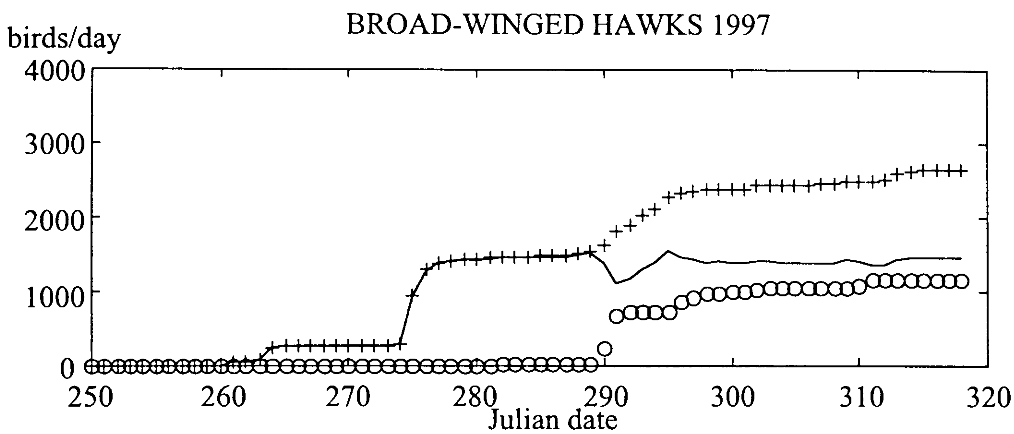


Fig. 2.13. Cumulative totals of migrant Broad-winged Hawks by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 20 Oct (294) 1996 and 02 Oct (275) 1997.

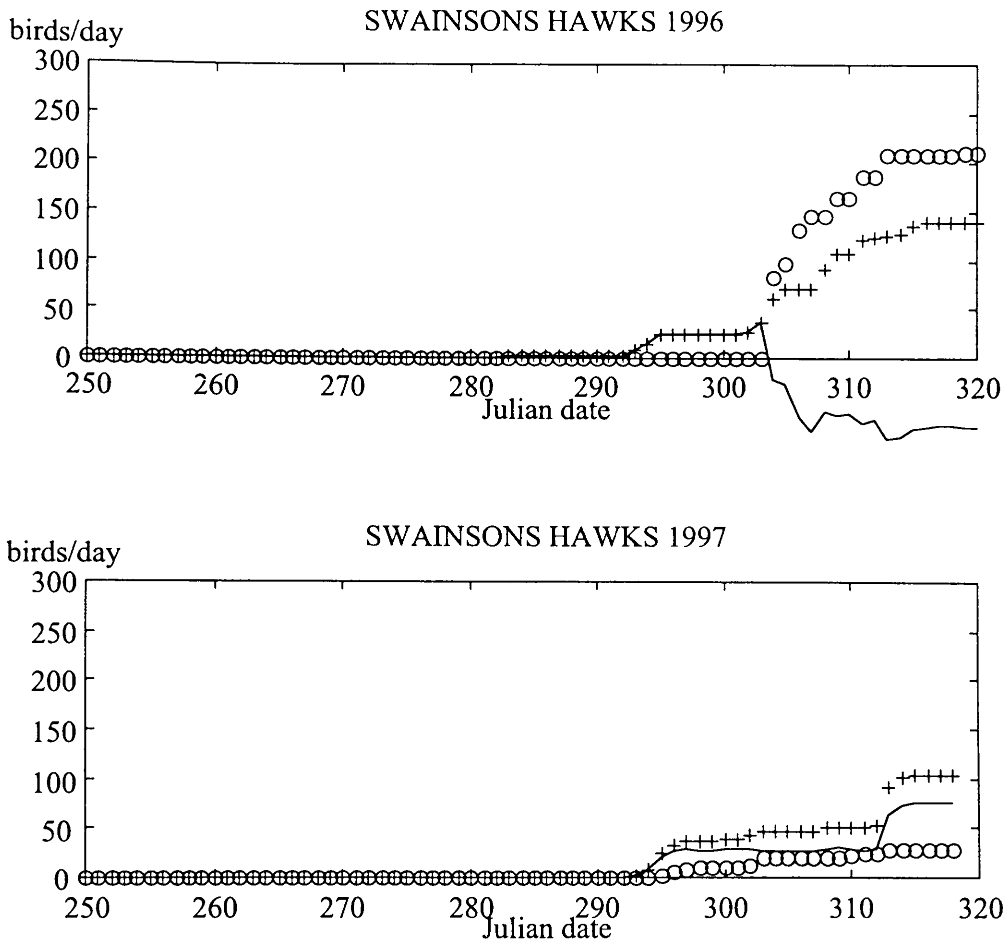


Fig. 2.14. Cumulative totals of migrant Swainson's Hawks by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. The net total for 1996 is below the x axis because more northbound than southbound raptors were seen. Southbound peak dates are 30 Oct (304) 1996 and 09 Oct (282) 1997.

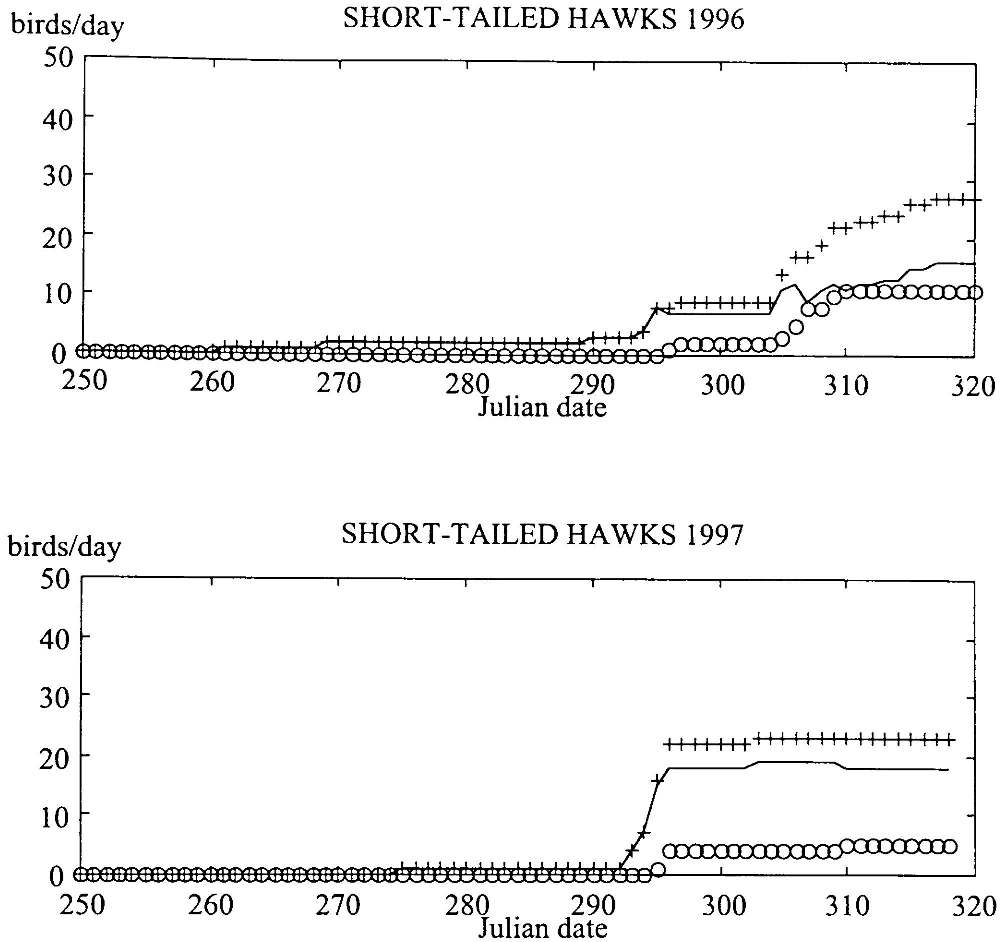
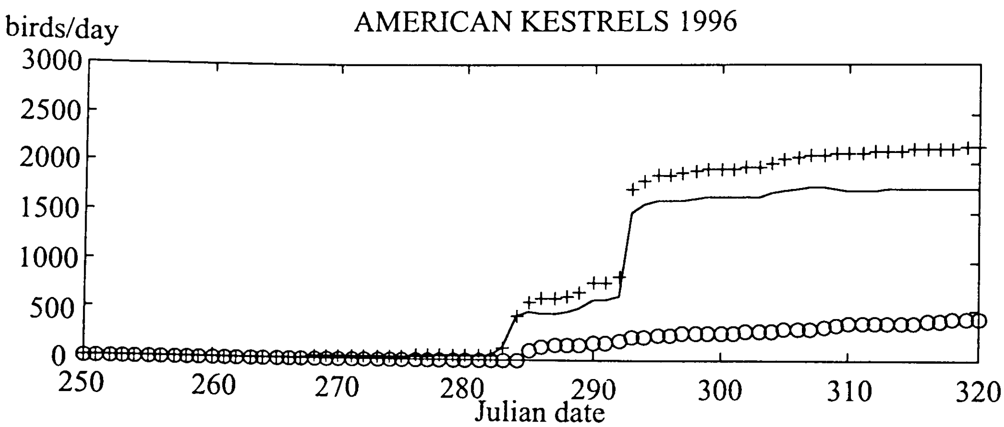


Fig. 2.15. Cumulative totals of migrant Short-tailed Hawks by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 31 Oct (305) 1996 and 22 Oct (295) 1997.



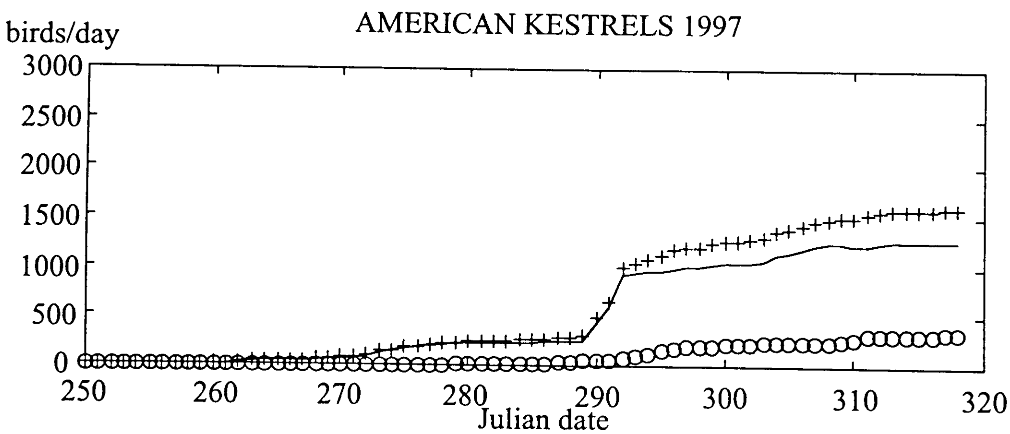
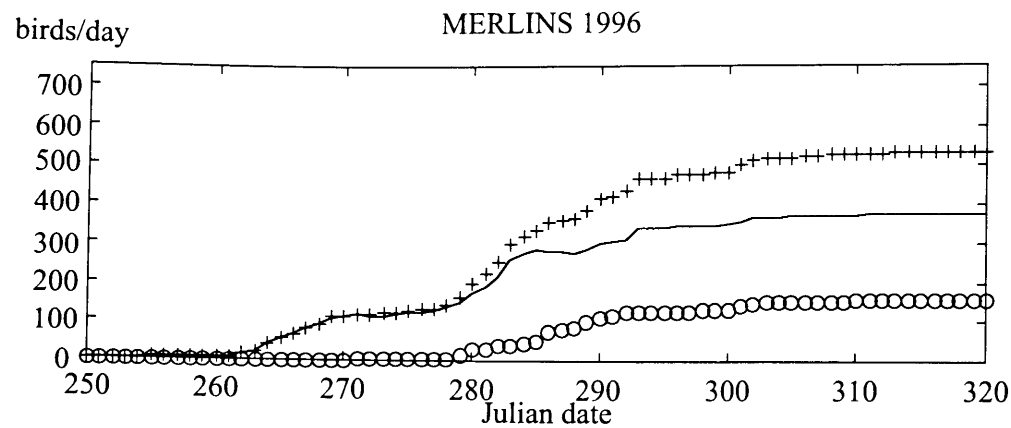


Fig. 2.16. Cumulative totals of migrant American Kestrels by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 19 Oct (293) 1996 and 19 Oct (292) 1997.



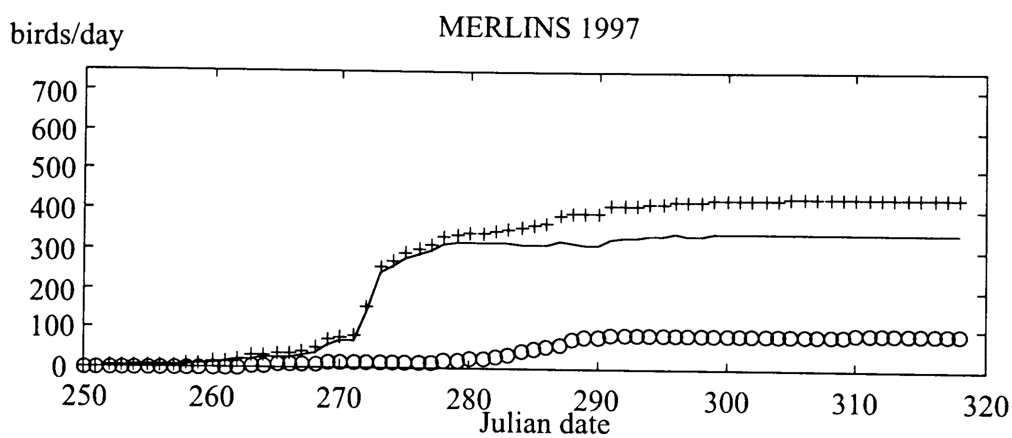


Fig. 2.17. Cumulative totals of migrant Merlins by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 09 Oct (283) 1996 and 30 Sep (273) 1997.

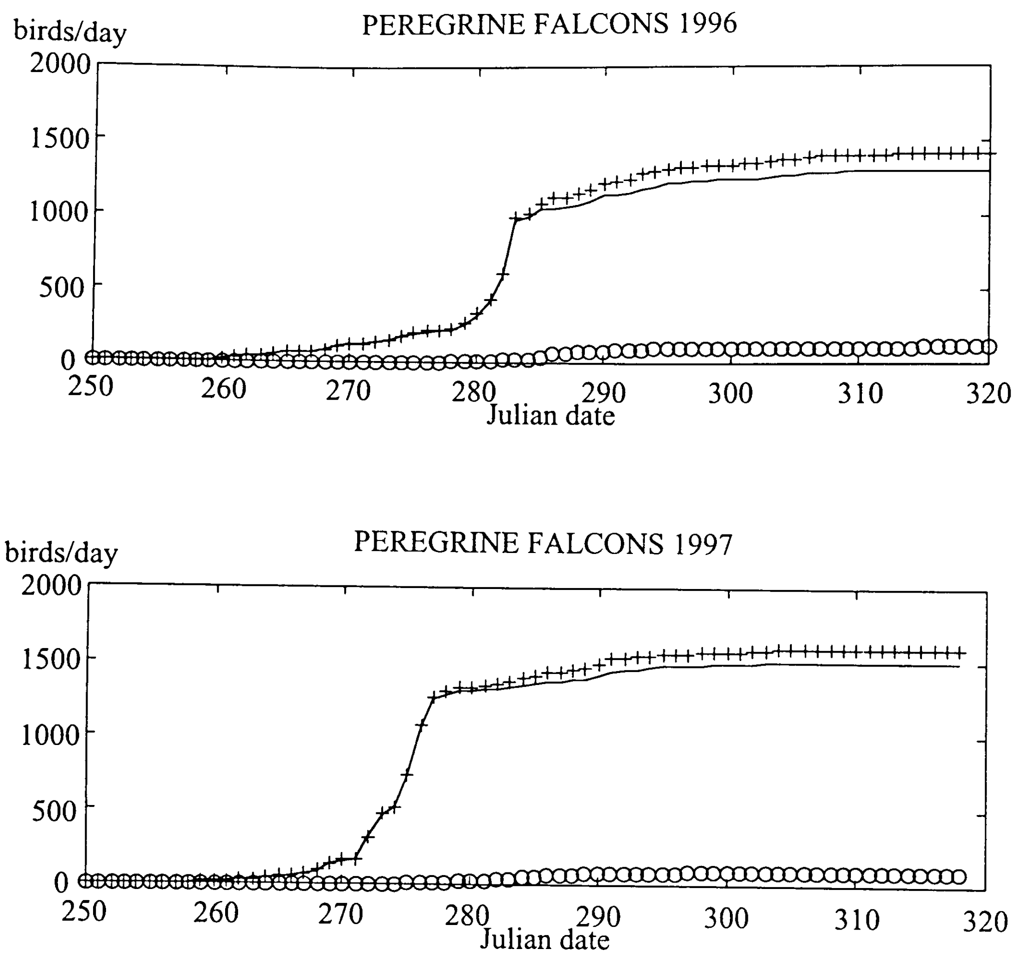


Fig. 2.18. Cumulative totals of migrant Peregrine Falcons by Julian date observed passing Grassy Key, Florida. Cumulative totals cover the periods from 01 Sep (245) - 15 Nov (320) 1996 and 05 Aug (217) - 14 Nov (318) 1997. "+" is southbound, "O" is northbound, and the solid line is the "net" total where net equals southbound minus northbound counts. The final day indicates the season total. Southbound peak dates are 09 Oct (283) 1996 and 03 Oct (276) 1997.

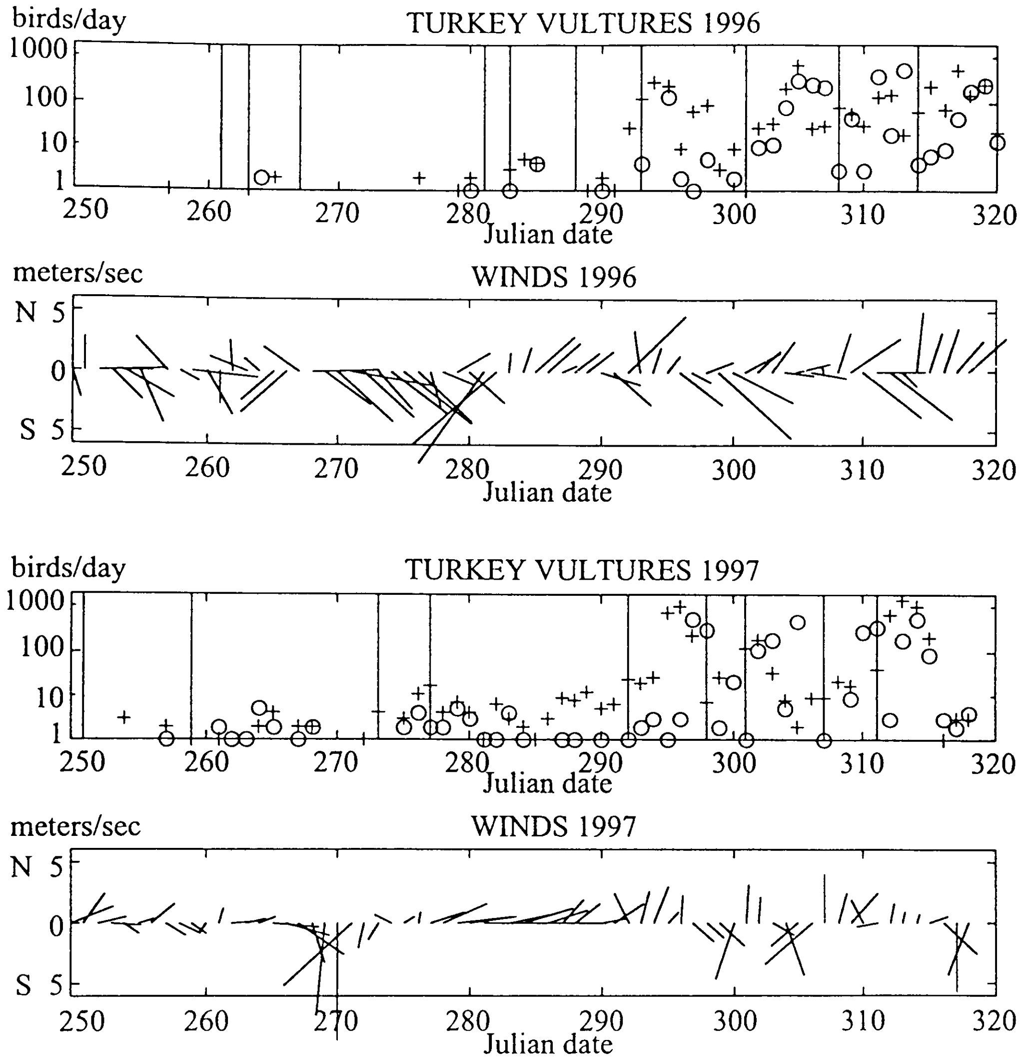


Fig. 3.1. Daily totals of migrant Turkey Vultures by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 31 Oct (305) 1996 and 09 Nov (313) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

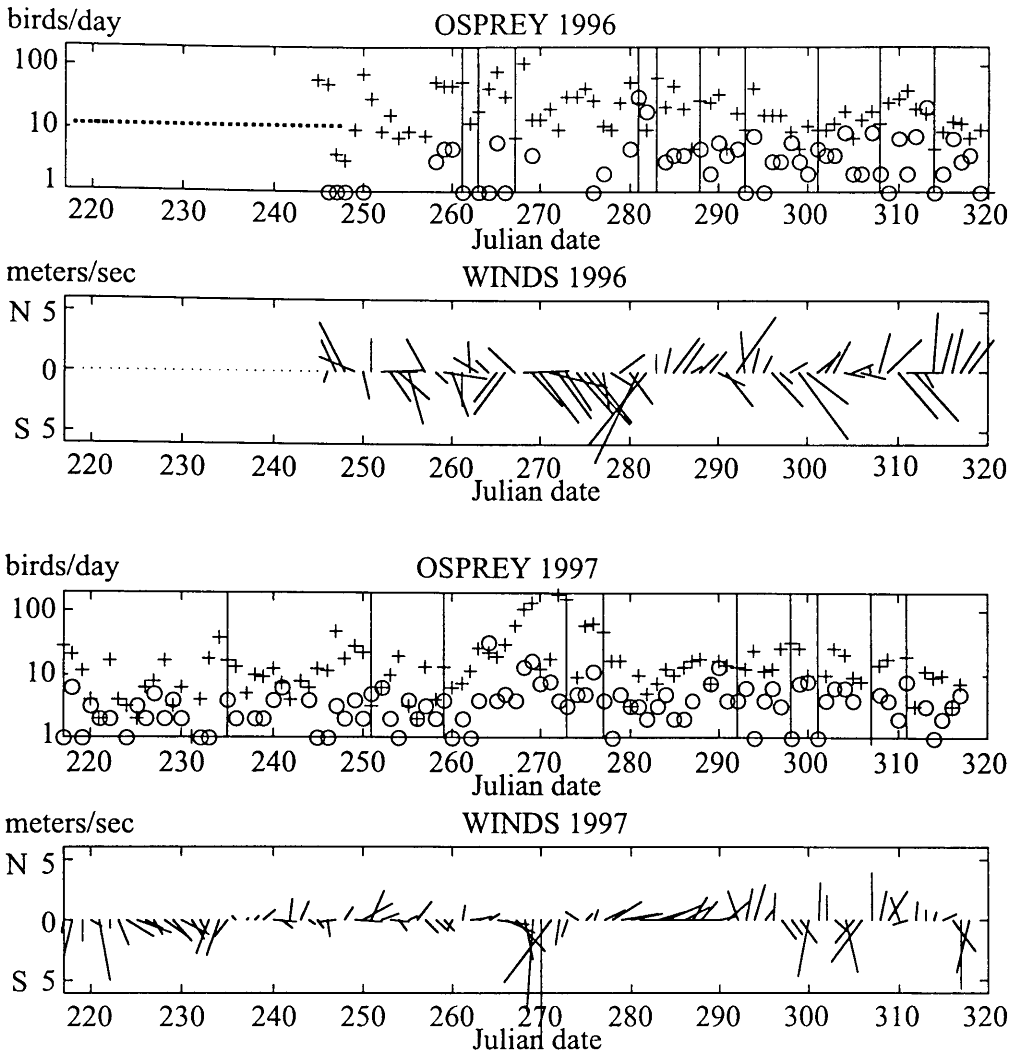


Fig. 3.2. Daily totals of migrant Ospreys by Julian date observed passing Grassy Key, Florida from 01 Sep (245) - 15 Nov (320) 1996 and from 05 Aug (217) - 14 Nov (318) 1997. Southbound peak dates are24 Sep (268) 1996 and 29 Sep (272) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

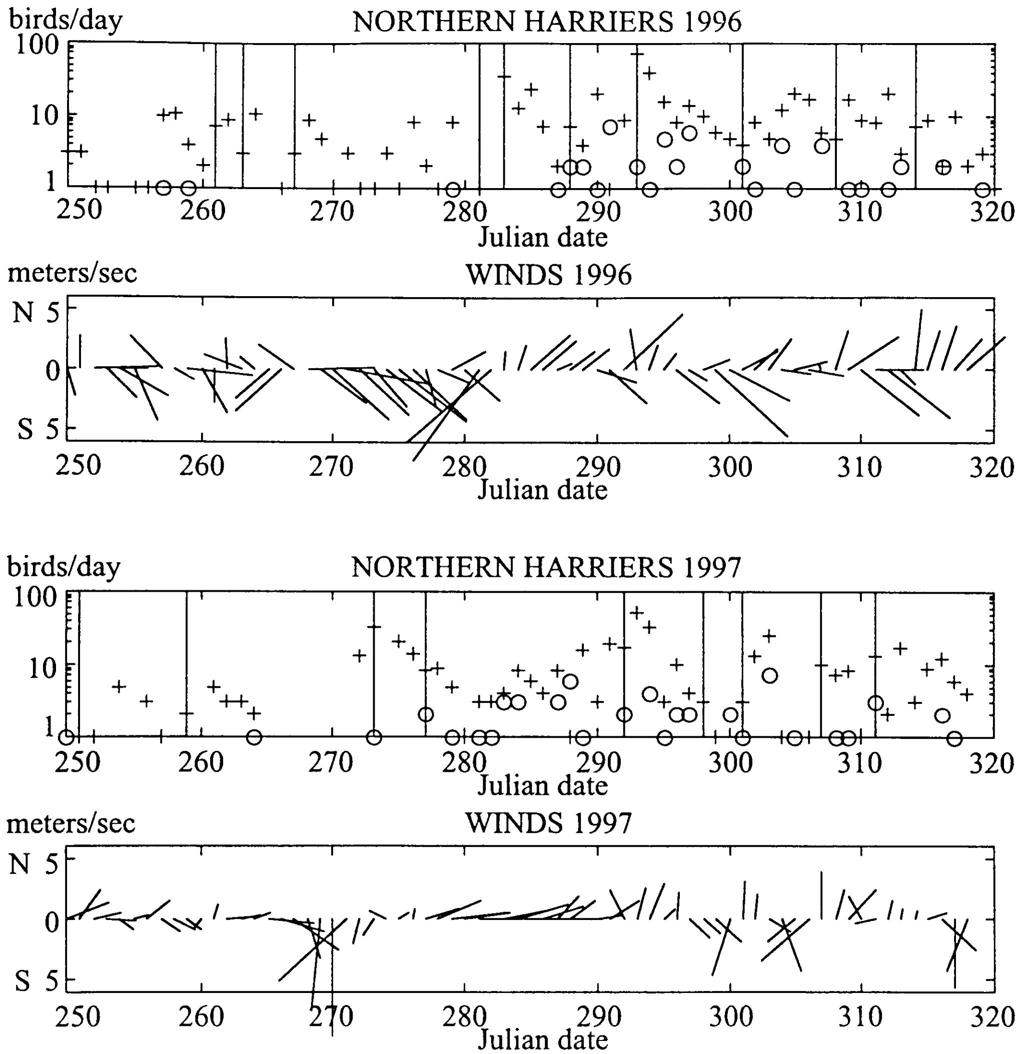


Fig. 3.3. Daily totals of migrant Northern Harriers by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 19 Oct (293) 1996 and 20 Oct (293) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

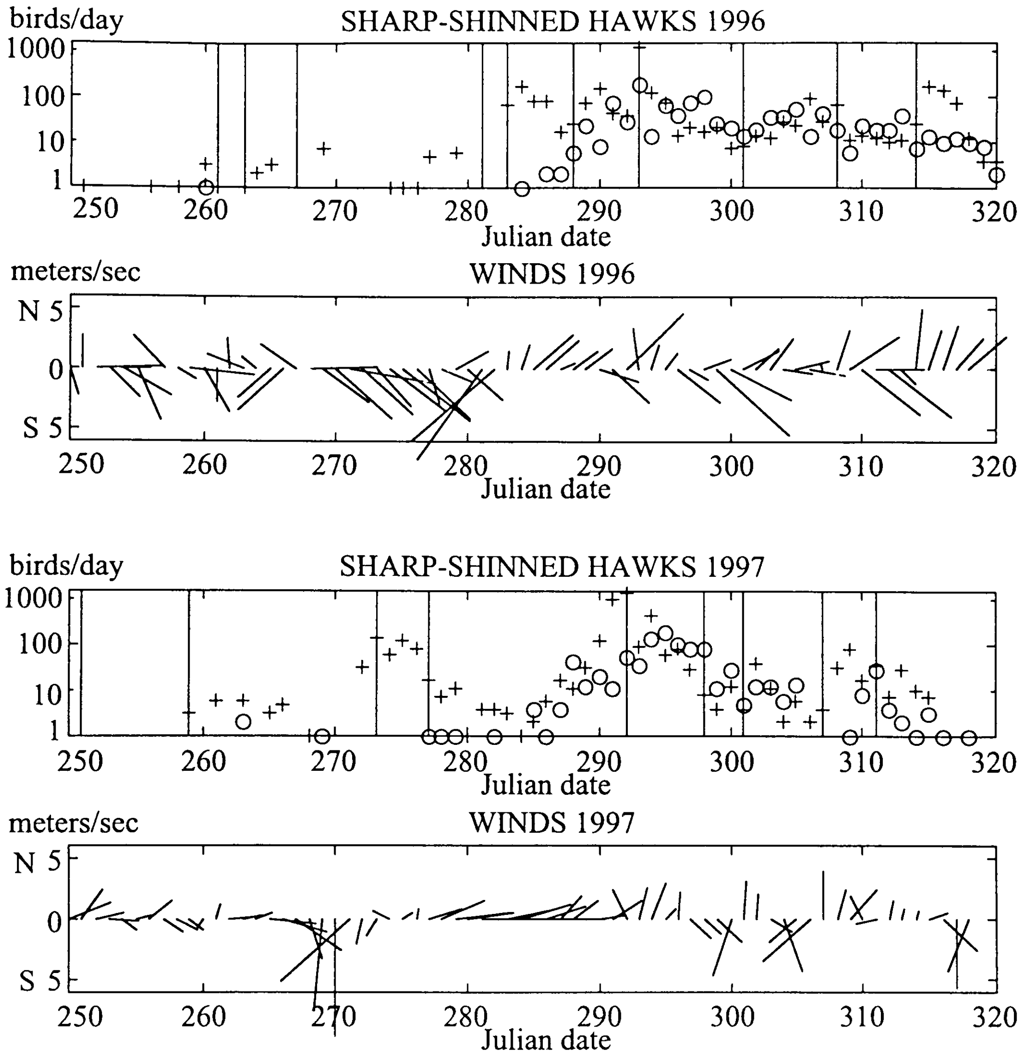


Fig. 3.4. Daily totals of migrant Sharp-shinned Hawks by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 19 Oct (293) 1996 and 19 Oct (292) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

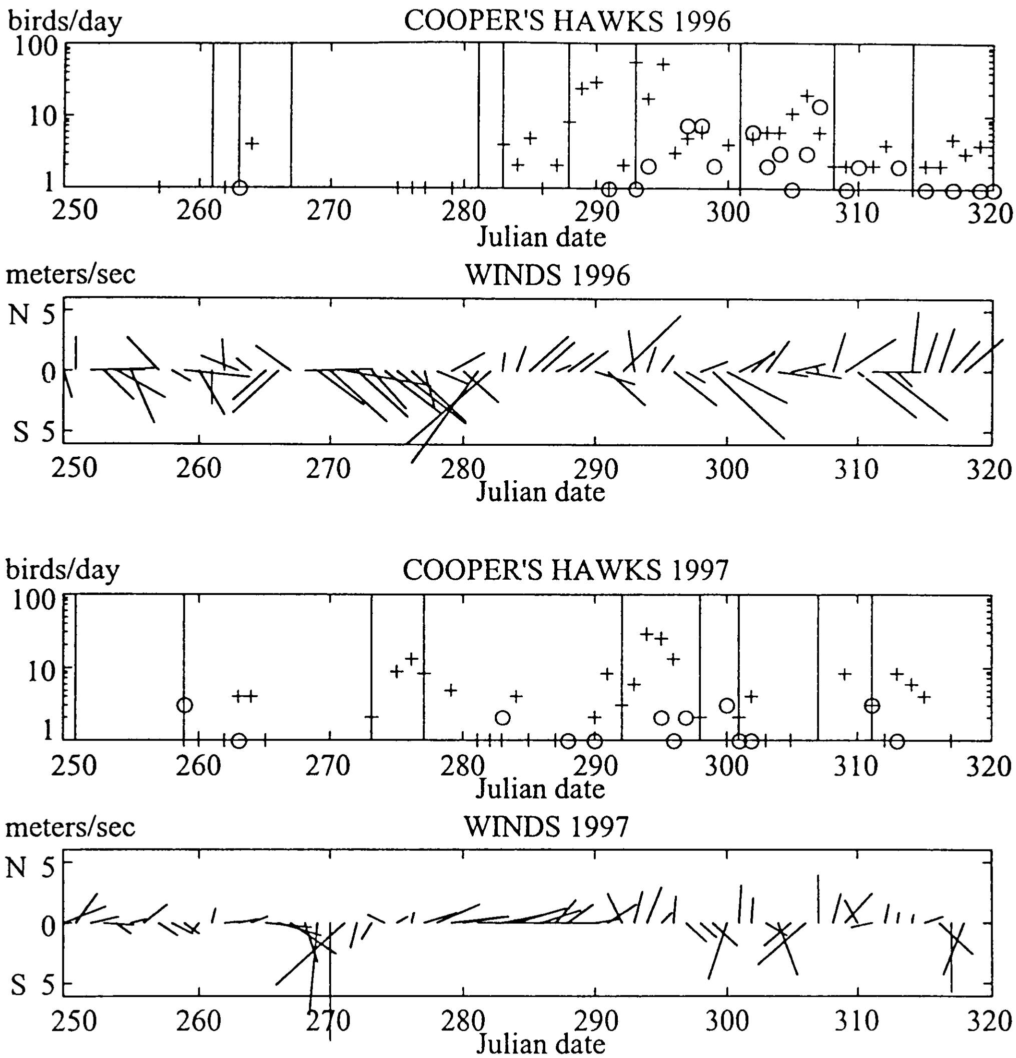


Fig. 3.5. Daily totals of migrant Cooper's Hawks by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 19 Oct (293) 1996 and 21 Oct (294) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

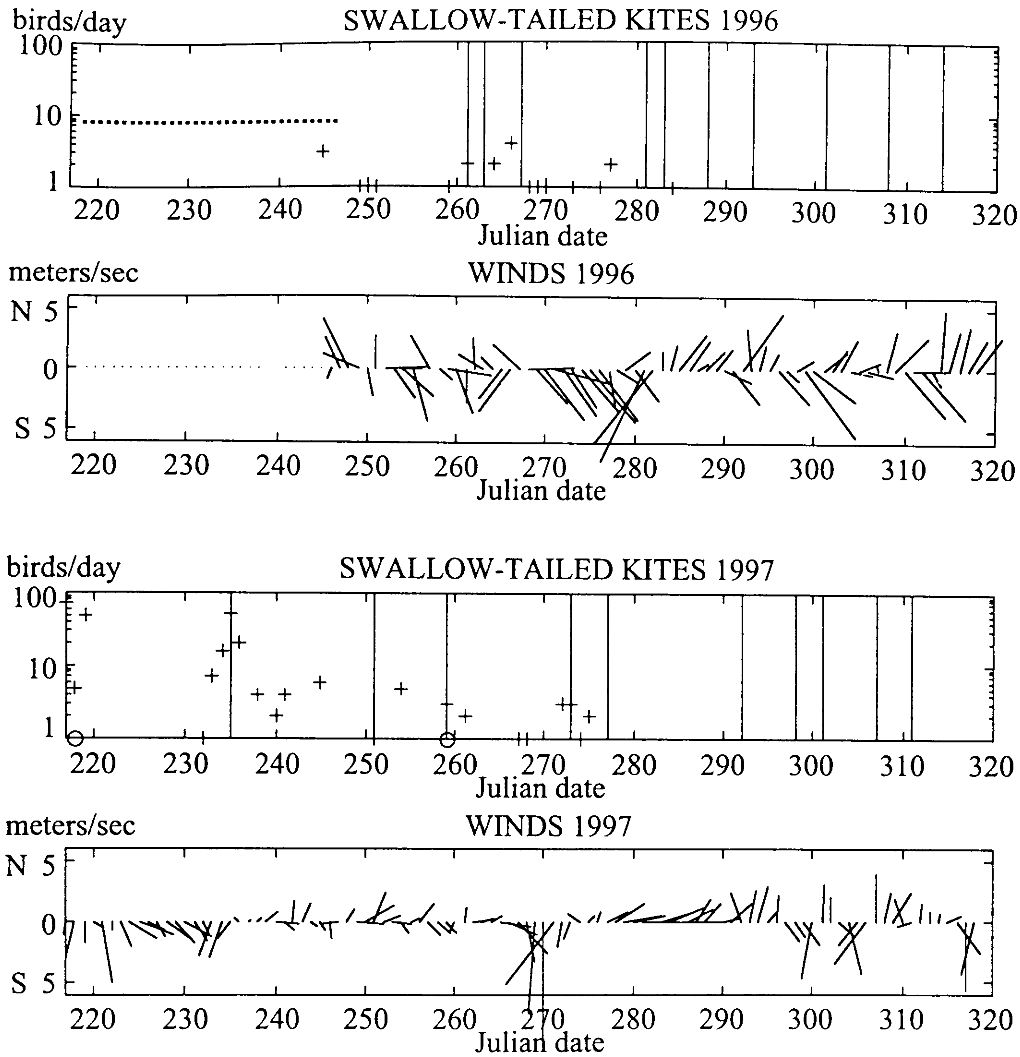


Fig. 3.6. Daily totals of migrant Swallow-tailed Kites by Julian date observed passing Grassy Key, Florida from 01 Sep (245) - 15 Nov (320) 1996 and from 05 Aug (217) - 14 Nov (318) 1997. Southbound peak dates are 01 Sep (245) 1996 and 05 Aug (217) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

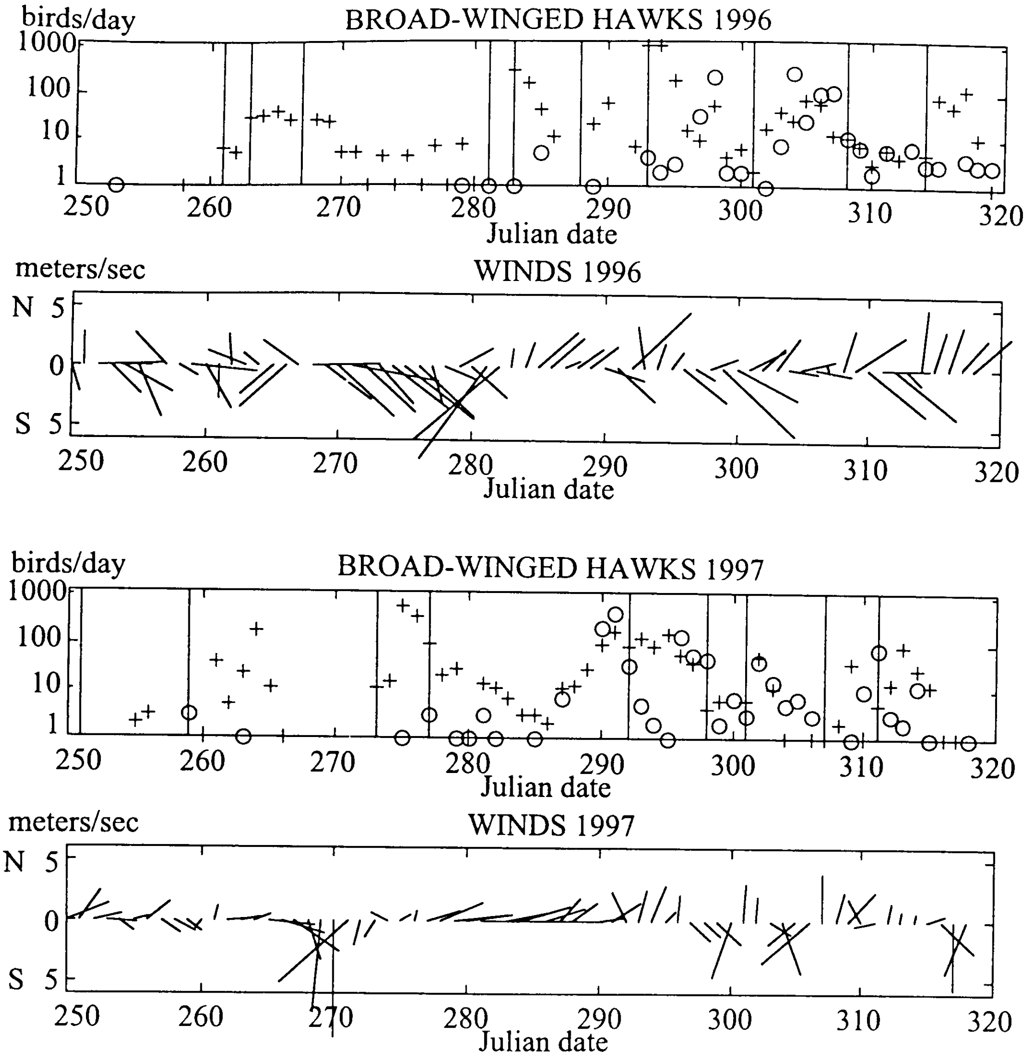


Fig. 3.7. Daily totals of migrant Broad-winged Hawks by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 20 Oct (294) 1996 and 02 Oct (275) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

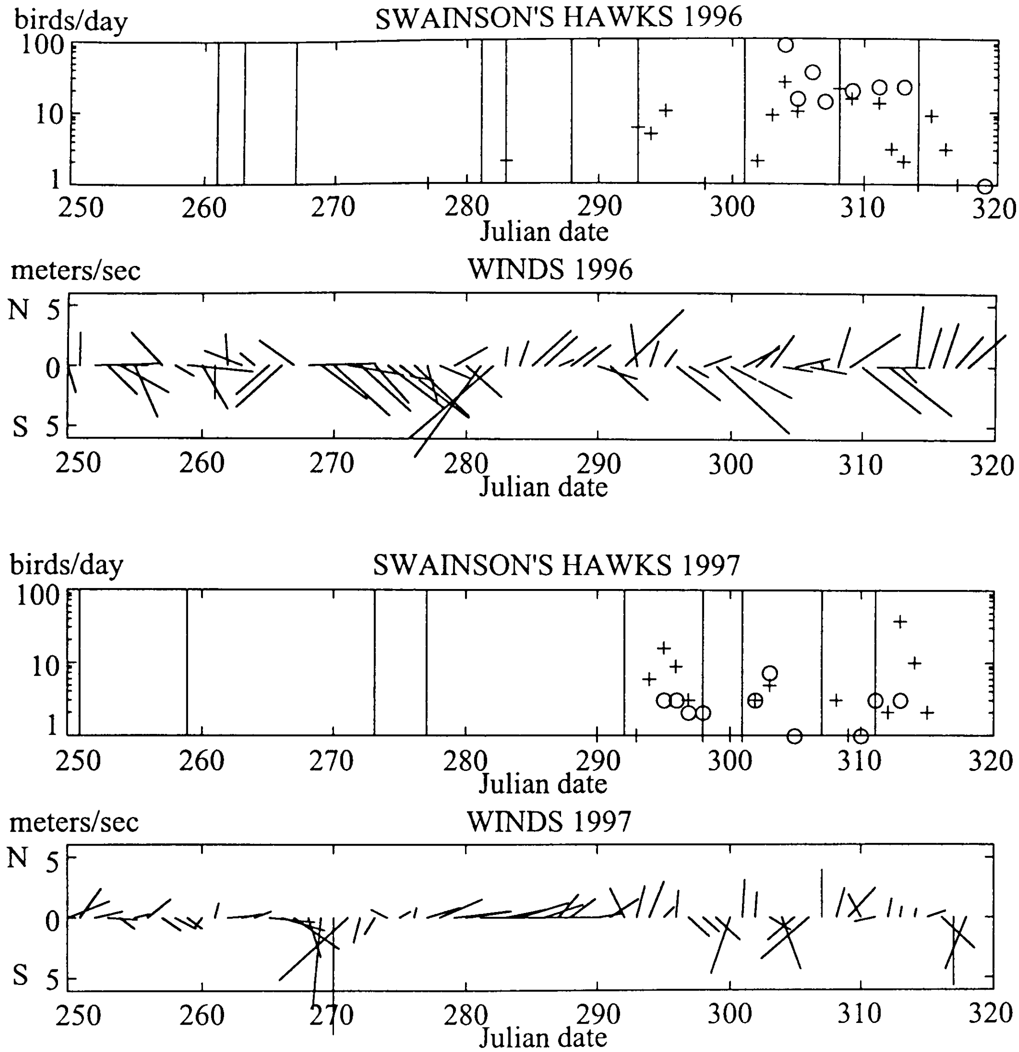


Fig. 3.8. Daily totals of migrant Swainson's Hawks by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 30 Oct (304) 1996 and 09 Oct (282) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage.In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

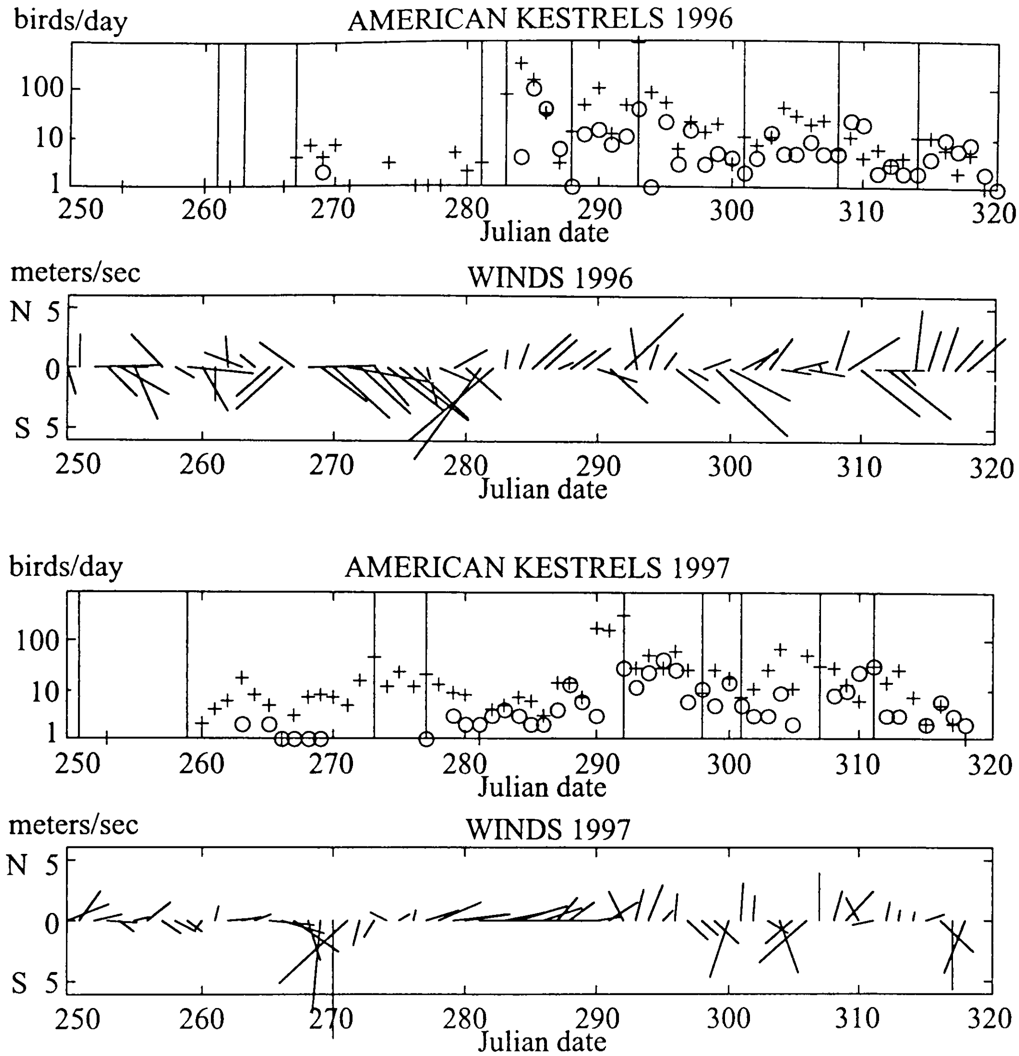


Fig. 3.9. Daily totals of migrant American Kestrels by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 19 Oct (293) 1996 and 19 Oct (292) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

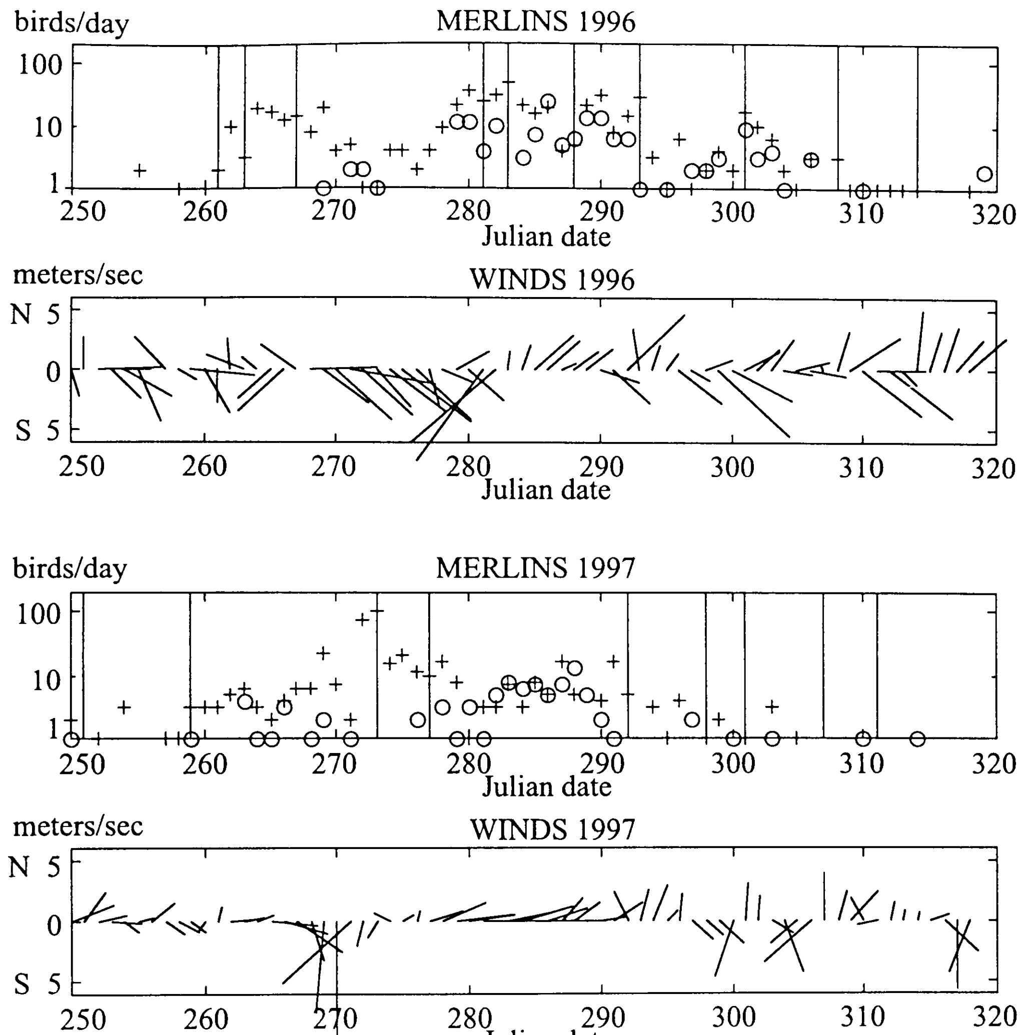


Fig. 3.10. Daily totals of migrant Merlins by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 09 Oct (283) 1996 and 30 Sep (273) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

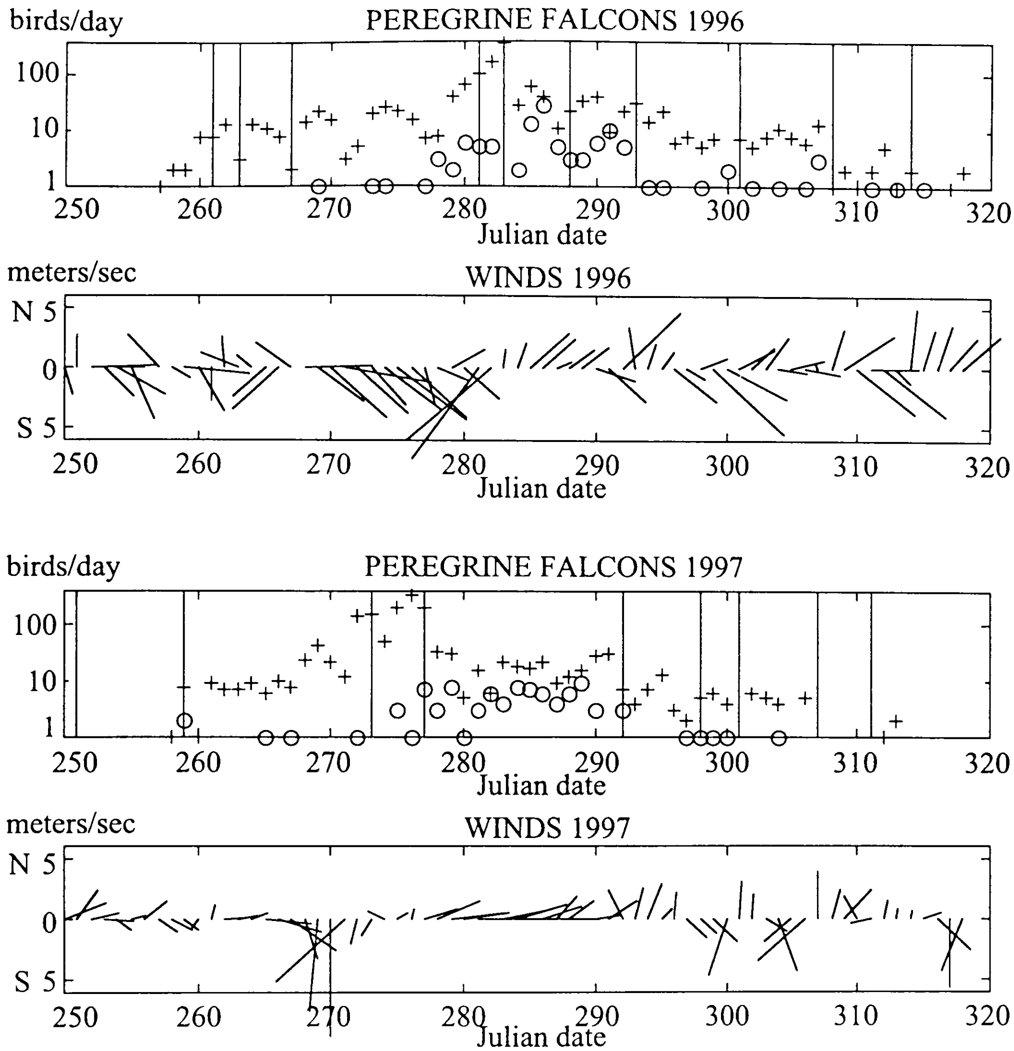


Fig. 3.11. Daily totals of migrant Peregrine Falcons by Julian date observed passing Grassy Key, Florida from 06 Sep (250) - 15 Nov (320) 1996 and 07 Sep (250) - 14 Nov (318) 1997. Southbound peak dates are 09 Oct (283) 1996 and 03 Oct (276) 1997. The ordinate "birds/day" is plotted on a log 10 scale. In the raptor count plots "+" is southbound, "O" is northbound, and the vertical lines indicate cold front passage. In the wind plots, daily mean wind vectors point in the direction from which the wind is blowing and the length of the line is velocity in meters/second ("N" = north, "S" = south).

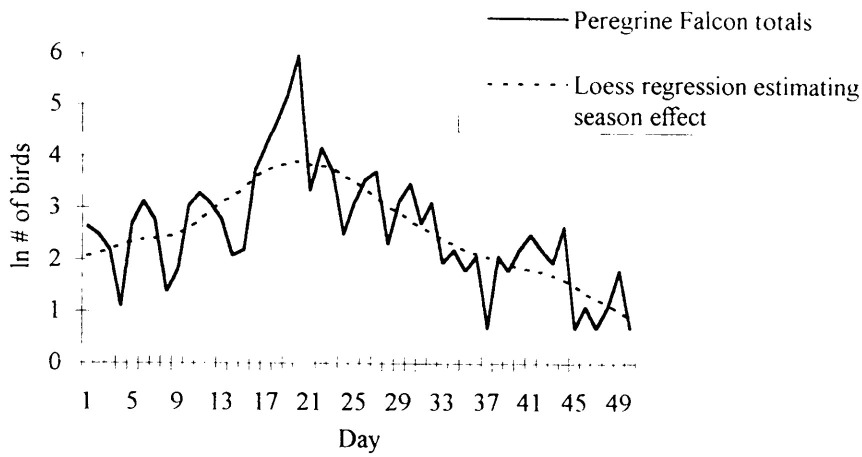


Fig. 3.12. The number of Peregrine Falcons counted at Grassy Key, Florida, 20 Sep - 8 Nov 1996 and the season effect (produced by filtering data using Loess regression).

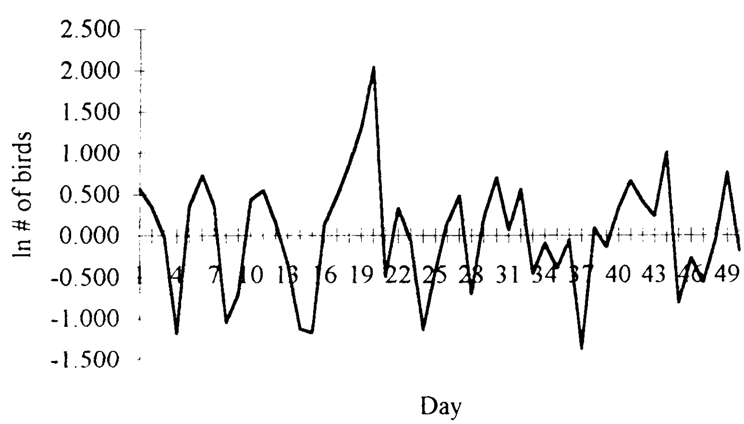


Fig. 3.13. The transformed frequency (residual) of Peregrine Falcons passing south over Grassy Key, Florida, 20 Sep - 8 Nov 1996 after removing the season effect.

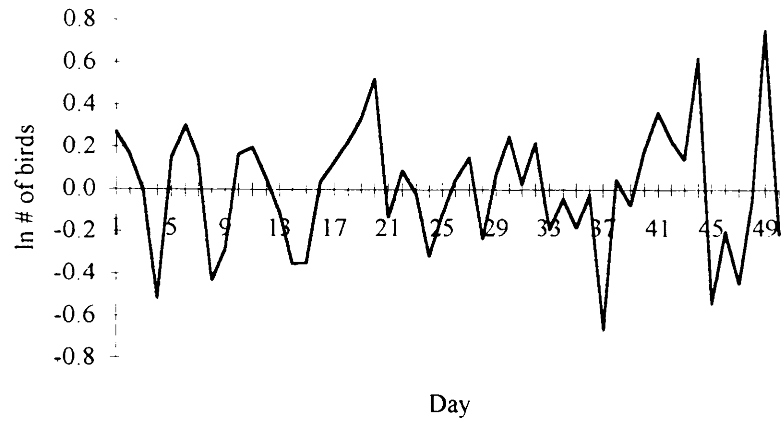


Fig. 3.14. The scaled residual of Peregrine Falcons passing south over Grassy Key, Florida, 20 Sep - 8 Nov 1996 after removing the season effect.

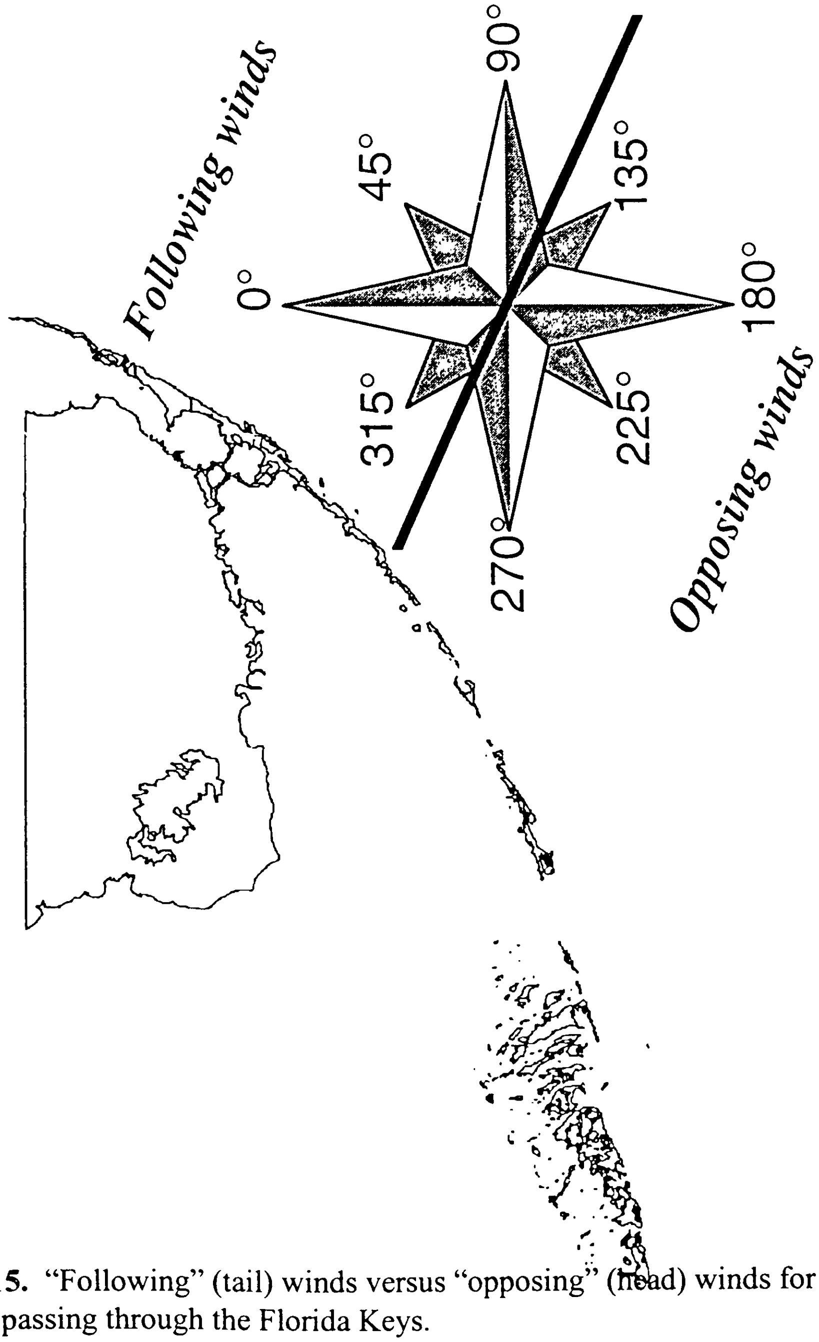


Fig. 3.15. "Following" (tail) winds versus "opposing" (head) winds for migrant raptors passing through the Florida Keys.

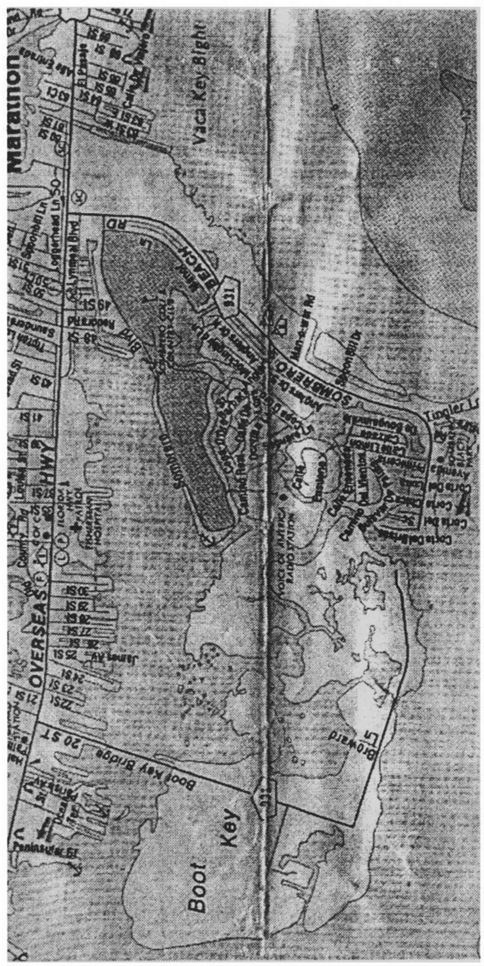


Fig. 4.1. Map of Boot Key showing the drawbridge, key, and road. Roosting raptors were identified along road surveys (evening) and from soaring surveys (bridge).

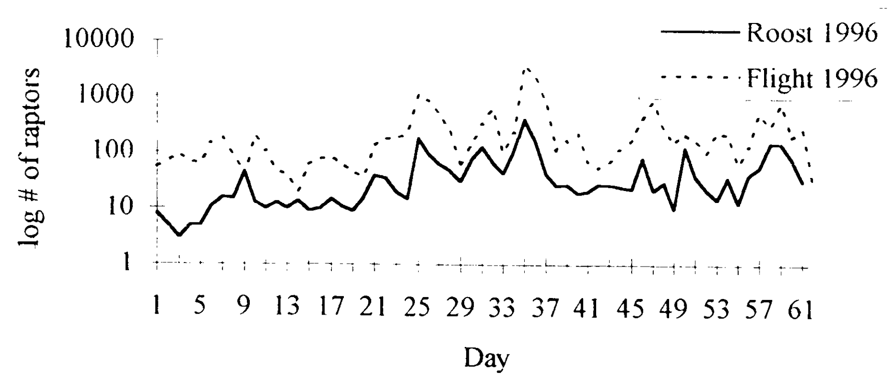


Fig. 4.2. Daily numbers of raptors observed roosting at Boot Key and flying southbound past Grassy Key, Florida, 15 Sep - 13 Nov 1996.

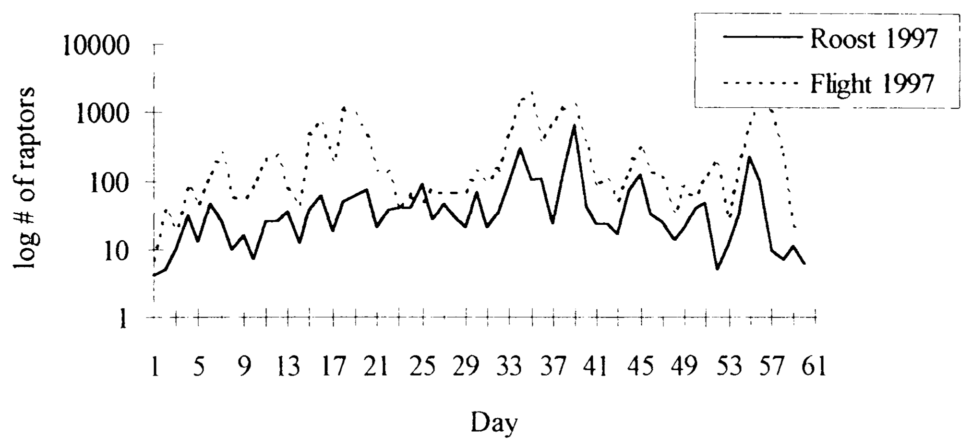


Fig. 4.3. Daily numbers of raptors observed roosting at Boot Key and flying southbound past Grassy Key, Florida, 15 Sep - 13 Nov 1997.

APPENDICES

APPENDIX 1

Appendix 1. Migrant raptor census at Grassy Key, Florida, 1 Sep - 15 Nov 1995.

Species	South	North	Net	Gross
Turkey vulture	747	294	453	1,041
Osprey	641	33	608	674
Bald eagle	14	1	13	15
Northern harrier	254	20	234	274
Sharp-shinned hawk	1,292	207	1,085	1,499
Cooper's hawk	160	25	135	185
Unidentified accipiter	366	15	351	381
Swallow-tailed kite	54	0	54	54
Red-shouldered hawk	83	3	80	86
Broad-winged hawk	2,201	580	1,621	2,781
Short-tailed hawk	62	17	45	79
Swainson's hawk	7	0	7	7
Unidentified buteo	144	0	144	144
American kestrel	1,517	69	1,448	1,586
Merlin	397	30	367	427
Unidentified falcon not peregrine	105	19	86	124
Peregrine falcon	852	30	822	882
Unidentified falcon	775	65	710	840
Unidentified raptor	309	28	281	337
Total	9,980	1,436	8,544	11,416

APPENDIX 2

SOUTHBOUND AND NORTHBOUND DAILY MIGRANT RAPTOR COUNTS AT GRASSY KEY, FLORIDA - 1996, 1997.

Alpha code abbreviations for migrant raptors in Appendix 2.

Alpha Code	Common Name
Tuvu	Turkey Vulture
Ospr	Osprey
Baea	Bald Eagle
Noha	Northern Harrier
Ssha	Sharp-shinned Hawk
Coha	Cooper's Hawk
Unac	Unidentified Accipiter
Stki	Swallow-tailed Kite
Miki	Mississippi Kite
Rsha	Red-shouldered Hawk
Bwha	Broad-winged Hawk
Stha	Short-tailed Hawk
Swha	Swainson's Hawk
Rtha	Red-tailed Hawk
Unbu	Unidentified Buteo
Amke	American Kestrel
Merl	Merlin
Unfa-np	Unidentified Falcon not Peregrine
Pefa	Peregrine Falcon
Unfa	Unidentified Falcon
Unra	Unidentified Raptor

Appendix 2.1. September 1996 daily counts of southbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
Tuvu				2									1						1		2										6
Ospr	59	51	4	3	10	76	30	9	16	7	9		8	55	46	47	57	12	19	44	83	33	7	111	14	14	21	10	32	33	920
Baea						1			1							1	3			1		1		1				2			11
Noha		1	1			3	3	1	1		1	1	10	11	4	2	7	9	3	11		1	3	9	5	1	3	1	1	3	96
Ssha					1		1					1		1		3	1		1	2	3				7					1	22
Coha													1					1		4											6
Unac						1								1						4	1										7
Stki	3				1	1	1								1		2			2		4		1	1	1			1		19
Miki					5	1		1		12	2		1									1	1	1	1						26
Rsha																		1													1
Bwha			1											1			6	5	28	33	40	27		26	23	5	5	1	4	1	206
Stha																	1								1						2
Swha																															0
Rtha																															0
Unbu						1													2	1											4
Amke										1						1		1				1	4	7	4	7	1			3	30
Merl						1					2			1		1	2	10	3	19	17	12	14	8	19	4	5	1	1	4	124
Unfa-np									1						1	1		4		1	5		3	5	3				1	2	27
Pefa													1	2	2	8	8	13	3	13	11	8	2	14	22	15	3	5	20	26	176
Unfa														3			2	4	2	4	3	5	3	5	4	1			1	3	40
Unra			1				2					1	3	1	1	3	3	11		2	7	1	1	5	1		2			1	46
Total	62	52	7	5	17	85	37	11	19	20	14	3	25	76	55	67	92	71	62	141	172	94	38	193	105	48	40	20	61	77	1,769

Appendix 2.2. October 1996 daily counts of southbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Tuvu		2			1	2			3	5	4				1	2	1	25	124	291	220	9	64	87	3	9	1	27	31	214	646	1,772
Ospr	44	27	11	10	26	57	26	10	64	23	46	20	5	27	25	36	5	18	10	44	16	17	16	9	5	11	10	10	12	19	7	666
Baea	1					1			2	2	1		1	1	2			2							1			1			1	16
Noha	1	8	2	1	8		1		34	13	24	7	2	7	4	20	1	9	72	39	16	8	14	10	6	5	4	8	5	12	20	361
Ssha	1	1	5		6				62	175	79	78	16	25	75	153	44	40	1,221	126	75	13	21	17	20	7	8	13	12	28	23	2,344
Coha	1	1	1		1				4	2	5	1	2	8	24	29	1	2	54	17	52	3	5	6		4	1	5	6	6	11	252
Unac			1	1	1	1			18	10	18	3	4	19	36	52	5	17	159	308	87	6	4	6		3	4		7	17	6	793
Stki		1	2							1																						4
Miki									1										1													2
Rsha										1	4					1					3			2							2	13
Bwha	4	1	7	1	8	1			308	164	45	12			21	61		7	975	1,036	185	15	9	55	4	6	2	17	39	27	72	3,082
Stha																1				1	4		1								5	12
Swha			1						2										6	5	10			1				2	9	25	10	71
Rtha																																0
Unbu											4					4				3	4	1		1				1	22	2	1	43
Amke		1	1	1	5	2	3		76	323	150	33	3	13	45	102	12	46	896	86	53	6	21	13	19	3	11	7	11	44	30	2,016
Merl	4	2	4	9	20	35	24	31	46	21	15	19	4	5	21	30	8	14	28	3	1	6	1	2	4	2	17	10	6	2	1	395
Unfa-np	3	1	1	4	6	9	8		11	9	16	25	5	5	18	25	11	14	56	26		4		4	2			2	3		3	271
Pefa	21	15	7	8	40	65	104	174	377	27	62	39	11	21	33	39	9	22	31	14	21	6	8	5	7	1	7	5	8	11	8	1,206
Unfa	3		1	1	1	7	9	5	24	5	11	7	5	10	10	26	5	7	23	19	7	1	3			1	2	3	2	5	3	206
Unra	2	2	3	1	3			1	27	65	37	4	6	2	19	44	1	13	209	413	110	16	1	3	5	2	3	2	4	13	4	1,015
Total	85	62	47	37	126	180	175	221	1,059	846	521	248	64	143	334	625	103	236	3,865	2,431	864	111	168	221	76	54	70	113	177	425	853	14,540

Appendix 2.3. November 1996 daily counts of southbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Tuvu	27	28	77	54	28	135	147	18	63	221	71	551	150	254	22	1,846
Ospr	14	19	12	26	30	42	20	18	5	9	13	12	7	10	1	238
Baea									2							2
Noha	17	6	5	17	9	8	21	3	7	9	2	10	2	3	1	120
Ssha	94	29	64	11	13	12	10	11	26	170	137	74	12	4	4	671
Coha	19	6	2	2	1	2	4		1	2	2	5	3	4		53
Unac	14	8	16	6	1	4	2	3	3	2	4	4				67
Stki																0
Miki																0
Rsha			1	1							2	3				7
Bwha	60	13	11	8	3	6	4		5	80	54	115	12	1		372
Stha	3		2	3		1		1		2		1				13
Swha			21	15	1	13	3	2	1	9	3	1				69
Rtha												2	1			3
Unbu	4		2	2	7	1	2	1	1	1	4	1	1			27
Amke	19	24	6	11	4	6	3	4	11	11	6	2	5	1		113
Merl	3		3	1	1	1	1	1	1				1			13
Unfa-np	1		2	1	1	1			1	3	1	1				12
Pefa	6	13	1	2	1	2	5	1	2			1	2			36
Unfa		1	1	1	1		1			3						8
Unra	1	5	9	6	3	4		1	3	7	9	4	2		1	55
Total	282	152	235	167	104	238	223	64	132	529	308	787	198	277	29	3,725

Appendix 2.4. September 1996 daily counts of northbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
Tuvu																				2											2
Ospr		1	1	1		1								3	5	5	1		1	1	6	1			4						31
Baea																			1	1		1									3
Noha													1		1																2
Ssha																1															1
Coha																			1												1
Unac																															0
Stki																															0
Miki																															0
Rsha																															0
Bwha				1					1																						2
Stha																															0
Swha																															0
Rtha																															0
Unbu																															0
Amke																									2						2
Merl																									1		2	2	1		6
Unfa-np																						1									1
Pefa																									1				1	1	3
Unfa																									3						3
Unra																					1										1
Total	0	1	1	2	0	1	0	0	1	0	0	0	1	3	6	6	1	0	3	4	7	3	0	0	11	0	2	2	2	1	58

Appendix 2.5. October 1996 daily counts of northbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Tuvu						1			1		4					1			4		129	2	1	5		2		10	11	76	301	548
Ospr		1	2			5	32	19		3	4	4		5	2	6	4	5	1	8	1	3	3	6	3	2	5	4	4	9	2	143
Baea																			1									1		1	2	5
Noha					1								1	2	2	1	7		2	1	5	2	6				2	1		4	1	38
Ssha										1		2	2	6	23	8	73	28	179	14	64	39	76	104	26	20	14	19	36	35	51	820
Coha																	1		1	2			7	7	2			6	2	3	1	32
Unac				1											7	4	5	1	13	14	10	9	23	7		2		3	5	12	4	120
Stki																																0
Miki																																0
Rsha																																0
Bwha					1		1		1		5				1				4	2	3		31	218	2	2		1	8	262	27	569
Stha																						1	1								1	3
Swha																														83	15	98
Ktha																																0
Unbu																															1	1
Amke										4	105	38	6	1	12	14	7	11	38	1	22	3	14	3	5	4	2	4	13	5	5	317
Merl					11	11	4	10		3	7	24	5	6	13	13	6	6	1		1		2	2	3		9	3	4	1		145
Unfa-np					2	6	6	3			7	25	5	3	14	15	11	12	9	1	3	2	1	2	1	1	4	2	8	1	1	145
Pefa			1	3	2	6	5	5		2	13	29	5	3	3	6	10	5		1	1			1		2		1		1		105
Unfa					1	2	11	5		1	6	6	3	4	4	1	3	1	2	2		1			1	2	2	1	1	2		62
Unra								1				1	2	1	1	9	9	1	8	15	8	4	6	7	1	3	4	1	4	9	2	97
Total	0	1	3	4	18	31	59	43	2	14	151	129	29	31	82	78	136	70	263	61	247	66	171	362	44	40	42	57	96	504	414	3,248

Appendix 2.6. November 1996 daily counts of northbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Tuvu	261	237	3	47	3	404	19	573	4	6	9	47	184	251	14	2,062
Ospr	2	9	2	1	7	2	8	22	1	2	7	3	4	1		71
Baea		1									1					2
Noha		4		1	1		1	2			2			1		12
Ssha	14	41	19	6	24	19	19	40	7	13	10	12	10	8	2	244
Coha	3	14		1	2			2		1		1		1	1	26
Unac		28	2		1	1	2	21	1	2	1					59
Stki																0
Miki																0
Rsha							1									1
Bwha	103	114	11	7	2	6		7	3	3		4	3	3		266
Stha	2	3		2	1											8
Swha	34	14		19		22		22						1		112
Rtha																0
Unbu	4	9						3					1			17
Amke	9	5	5	23	20	2	3	2	2	4	10	6	8	2	1	102
Merl	3				1									2		6
Unfa-np		1	3	1	1			6		1				1		14
Pefa	1	3				1		1		1						7
Unfa		2	1					1								4
Unra	2	18	1	2	2	1		46	2	1	1		1	3		80
Total	438	503	47	110	65	458	53	748	20	34	41	73	211	274	18	3,093

Appendix 2.7. August 1997 daily counts of southbound migrant raptors passing Grassy Key, Florida.

Day	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Tuvu	4										3							1			4	1	2					15
Ospr	27	20	11	4	2	16	4	3	2	6	8	16	3	6	1	4	18	38	17	13	5	10	9	12	7	4	8	274
Baea	3	1		1	1	2														1								9
Noha																												0
Ssha																												0
Coha																							1					1
Unac																					1							1
Stki	74	5	49													1	7	16	52	20		4		2	4			234
Miki																												0
Rsha																												0
Bwha																												0
Stha																												0
Swha																												0
Rtha					1		1																					2
Unbu																							1					1
Amke																				1		1						2
Merl																												0
Unfa-np																												0
Pefa																												0
Unfa																												0
Unra																												0
Total	108	26	60	5	4	18	5	3	2	6	11	16	3	6	1	5	25	55	69	35	10	16	13	14	11	4	8	539

Appendix 2.8. September 1997 daily counts of southbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
Tuvu			1								3			2		1		1			2	4		2	2				1	4	23
Ospr	6	12	11	46	18	27	23	3	6	10	19	3	2	13	4	13	6	7	11	26	23	19	30	61	110	136	12	18	183	159	1,017
Baea								1											1					1		1	1		1		6
Noha	1				1	1		1	1		5		3	1		2		5	3	3	2								13	32	74
Ssha																3		6		6		3	5		1				30	139	193
Coha					1											1	1		1	4	4	1								2	15
Unac				1												1	1	3	1	13	1	2			34					13	70
Stki		6						1			5					3		2						1	1				3	3	25
Miki		1	3																	1	1	1									7
Rsha																															0
Bwha												2	3				1	38	5	23	181	12	1							11	277
Stha																															0
Swha																															0
Rtha																															0
Unbu																1	2	1		1		1	1								7
Amke										1							2	4	6	17	8	5	1	3	7	8	7	5	16	47	137
Merl							2		1		3			1	1	3	3	3	5	6	3	2	4	6	6	22	7	2	72	103	255
Unfa-np											1				1		2	4	4	3	7	8	1	2	2	10	14	3	25	47	134
Pefa															1	8	1	9	7	7	9	6	10	8	23	45	22	12	144	155	467
Unfa																1					1		1	1	4	5	10	2	8	15	48
Unra													1							8	7	2			7					9	34
Total	7	19	15	47	20	28	25	6	8	11	36	5	9	17	7	37	19	83	44	118	249	66	54	85	197	227	73	42	525	769	2,789

Appendix 2.9. October 1997 daily counts of southbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Tuvu		3	11	16	4	7	4	1	6	3	2	1	3	9	8	12	5	6	24	18	27	783	1,043	228	7	27		116	190	33	8	2,605
Ospr	9	59	62	48	16	16	3	10	5	7	12	10	13	17	18	7	17	14	13	12	24	11	12	26	33	26	10		10	26	20	566
Baea		1	1			1	1	1									1		1		1			1							1	10
Noha		20	14	8	9	5	1	3	3	4	8	6	4	8	1	16	3	19	17	53	33	3	10	4	3	1		3	13	25	1	298
Ssha	61	120	81	17	7	11	1	4	4	3	1	2	6	16	11	33	121	972	1,405	91	421	58	80	27	8	4	12	4	38	11	2	3,632
Coha		9	13	8		5		1	1	1	4	1		1			2	8	3	6	29	25	13		2		1	2	4	1		140
Unac		12	6	11	1	1	2		1		1	2	2	10	4	3	9	1		3	9	4	17	5	1			3	1	1		110
Stki	1	2																														3
Miki		5																														5
Rsha			•2		1					1				1	1		3			2	3	10	7	3	1	1	2					38
Bwha	15	643	353	97	21	29	1	14	11	7	3	3	2	12	13	28	95	178	85	131	87	159	59	41	4	6		6	52	11	1	2,167
Stha		1																		3	3	9	6							1		23
Swha																	1			1	6	16	9	3	1		1	1	3	5		47
Rtha			1																													1
Unbu		1	1			1		1								4	1			1	3	1	13		2	3			3	1		36
Amke	12	23	12	22	13	9	8	1	4	5	7	6	3	15	14	7	181	170	346	29	53	28	63	26	9	27	18	7	11	27	67	1,223
Merl	15	20	11	10	17	8	1	3	3	7	3	8	5	17	5		4	16	5		3	1	4		1	2		1		3		173
Unfa-np	26	64	22	19	16	9	9	4	1	11	6	10	10	14	6	13	13	135	70	10	9	4	13	11	4	3	3		3		7	525
Pefa	52	204	341	195	33	31	5	15	6	22	18	17	22	9	12	16	28	30	7	4	7	13	3	2	5	6	4		6	5	4	1,122
Unfa	2	6	3	1	4	1	2			1	1				2	1		5	1		2				2	1	1					36
Unra	1	6	2	3	6	3		2	3		2	1	1	2	3	4	3	14	11	2	17	10	5	2	1		2			1		107
Total	194	1,199	936	455	148	137	38	60	48	72	68	67	71	131	98	144	487	1,568	1,988	366	737	1,135	1,357	379	84	107	54	143	334	151	111	12,867

Appendix 2.10. November 1997 daily counts of southbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Tuvu	2	9	9	22	16		41	668	1,506	1,019	213	1	3	3	3,512
Ospr	9	8	1	14	18		19	3	11	9	10	3	7		112
Baea	1	1	1								1				4
Noha		1	10	7	8	1	13	2	17	3	9	12	6	4	93
Ssha	6	2	4	33	83	16	35	7	27	10	7				230
Coha	1				8		3	1	8	6	4		1		32
Unac			2		4	1	2	1	2	1					13
Stki															0
Miki															0
Rsha						1									1
Bwha		1	1	2	38	1	5	14	90	29	13	1	1		196
Stha															0
Swha				3	1			2	38	10	2				56
Rtha															0
Unbu		1			1				1	1					4
Amke	11	51	31	29	13	6	33	15	26	7	2	5	2	1	232
Merl	1														1
Unfa-np	1	3		3	2	1			4	2	1		1		18
Pefa		5						1	2						8
Unfa					2										2
Unra				1	7	1	1	4	6	2	1				23
Total	32	82	59	114	201	28	152	718	1,738	1,099	263	22	21	8	4,537

Appendix 2.11. August 1997 daily counts of northbound migrant raptors passing Grassy Key, Florida.

Day	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Tuvu											5									1	5							11
Ospr	1	6	1	3	2	2		1	3	2	5	2	4	2		1	1		4	2		2	2	4	6			56
Baea	1																											1
Noha																												0
Ssha																												0
Coha																												0
Unac																												0
Stki		1																										1
Miki																												0
Rsha																												0
Bwha																												0
Stha																												0
Swha																												0
Rtha																												0
Unbu																												0
Amke																												0
Merl																												0
Unfa-np																												0
Pefa																												0
Unfa																												0
Unra																												0
Total	2	7	1	3	2	2	0	1	3	2	10	2	4	2	0	1	1	0	4	3	5	2	2	4	6	0	0	69

Appendix 2.12. September 1997 daily counts of northbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
Tuvu														1				2	1	1	5	2		1	2						15
Ospr	4	1	1	3	2	4	2	5	6	2	1	4	2	3	2	4	1	2	1	4	32	4	5	4	13	17	7	8	4	3	151
Baea																				1											1
Noha							1														1									1	3
Ssha																				2						1					3
Coha																3				1											4
Unac																4					3				1						8
Stki																1															1
Miki																															0
Rsha																															0
Bwha																3				1											4
Stha																															0
Swha																															0
Rtha																11															11
Unbu																1															1
Amke																				2		2	1	1	1	1					8
Merl							1									1				4	1	1	3		1	2		1			15
Unfa-np																	1		1	2			1		1	1		2	2		11
Pefa																2						1		1					1		5
Unfa																												2			2
Unra																				2	1	1									4
Total	4	1	1	3	2	4	4	5	6	2	1	4	2	4	2	30	2	4	3	20	43	11	10	7	19	22	7	13	36	34	247

Appendix 2.13. October 1997 daily counts of northbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Tuvu		2	4	2	2	5	3	1	1	4	1			1	1		1		1	2	3	1	3	556	312	2	20	1	103	179	5	1,216
Ospr	5	5	11	4	1	5	3	3	2	3	5	2	2	4		7	13	4	4	6	1	4	6	3	1	7	8	1	4	6	6	136
Baea																	1							1								2
Noha				2		1		1	1	3	3			3	6	1			2		4	1	2	2			2	1		7		42
Ssha				1	1	1			1			4	1	4	42	12	20	11	55	36	130	183	103	80	77	11	27	5	12	12	6	835
Coha										2					1		1					2	1	2			3	1	1			14
Unac			1	1			1					1	3	3	3	1					3	3	2	4	1		6	2	6			41
Stki																																0
Miki																																0
Rsha															1		1				1	4	2	3	6					1		19
Bwha		1		3		1	1	3	1			1		7			220	440	35	5	2	1	147	59	49	2	7	3	43	15	5	1,051
Stha																						1	3									4
Swha																						3	3	2	2				3	7		20
Rtha																																0
Unbu														1			4				1	2	1	1	3	1	2	2	5	3	1	27
Amke				1		3	2	2	3	4	3	2	2	4	13	6	3		29	12	23	41	26	6	11	5	14	5	3	3	9	235
Merl			2		3	1	3	1	5	8	6	7	5	7	13	5	2	1						2			1			1		73
Unfa-np	1	2				2		7	6	10	5	10	4	15	14	27	7	7	10	3	4	12	12	3	10	2	2		5		1	181
Pefa		3	1	7	3	8	1	3	6	4	8	7	6	4	6	9	3		3					1	1	1	1				1	87
Unfa	2						1			3	2	1	1	4		4		1														19
Unra				1								1		2	3	3	3			1	1	4	4	1	2	1	3		6	3		39
Total	8	13	19	22	10	27	15	21	26	41	33	36	24	59	103	75	279	464	139	65	173	262	315	726	475	32	96	21	191	237	34	4,041

Appendix 2.14. November 1997 daily counts of northbound migrant raptors passing Grassy Key, Florida.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Tuvu	491		1		9	297	360	3	186	570	82	3	2	4	2,008
Ospr	4			5	4	2	8		3	1	2	3	5		37
Baea											1				1
Noha	1			1	1		3					2	1		9
Ssha	13				1	8	29	4	2	1	3	1		1	63
Coha							3		1						4
Unac						1	2				1		1		5
Stki															0
Miki															0
Rsha							1								1
Bwha	7	3			1	10	76	3	2	13	1			1	117
Stha						1									1
Swha	1					1	3		3						8
Rtha															0
Unbu	1						2								3
Amke	2			8	10	23	32	3	3		2	6	3	2	94
Merl						1				1					2
Unfa-np	5					3	2	1		1	3	1	3		19
Pefa															0
Unfa		2													2
Unra	2					1	5			1					9
Total	527	5	1	14	26	348	526	14	200	588	95	16	15	8	2,383