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Authors: Pearlstine, Elise V., Mazzotti, Frank J., and Kelly, Mary Hudson

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RELATIVE DISTRIBUTION AND ABUNDANCE OF WINTERING RAPTORS IN AGRICULTURAL AND WETLAND LANDSCAPES OF SOUTH FLORIDA

ELISE V. PEARLSTINE,[1] FRANK J. MAZZOTTI,[2] AND MARY HUDSON KELLY
University of Florida, IFAS, Ft. Lauderdale Research and Education Center, 3205 College Avenue, Davie, FL 33314 U.S.A.

KEY WORDS: *American Kestrel*; Falco sparverius; *Turkey Vulture*; Cathartes aura; *Red-tailed Hawk*; Buteo jamaicensis; *habitat use*; *agriculture*; *perch choice*; *south Florida*; *Everglades*.

South Florida provides important winter habitat for a variety of migratory and resident raptor species (Bohall and Collopy 1984). In this area, habitat loss has occurred as natural habitat has been modified for either agriculture or urban use. Two predominant features of the current vegetated landscape are Everglades wetland communities and agricultural areas (Pearlstine et al. 2001), including sugarcane-dominated (*Saccharum* sp.) fields south and east of Lake Okeechobee in the Everglades Agricultural Area (EAA). Although the two habitats are open and contain superficially similar components such as upland, wetland, temporary and permanent water, and sparsely-distributed trees, structure and composition varies greatly between natural and agricultural habitat.

Roadside surveys are convenient for obtaining information on distribution, population trends, and abundance of raptors (Fuller and Mosher 1981). Such surveys have been used extensively to determine relative abundance (e.g., Woffinden and Murphy 1977, Leptich 1994, Eakle et al. 1996, Meunier et al. 2000), population trends (e.g., Layne 1980), habitat associations (e.g., Preston 1990, Sorley and Anderson 1994, Garner and Bednarz 2000, Thiollay and Rahman 2002), perch use (e.g., Bohall and Collopy 1984, Smallwood et al. 1996, Meunier et al. 2000, Leyhe and Ritchison 2004), activity patterns (e.g., Meunier et al. 2000), and species richness and diversity (e.g., Leptich 1994, Sorley and Anderson 1994). However, a number of factors may cause variation in raptor counts including differences in detectability across cover types, distance of observation (Millsap and LeFranc 1988) and time of day (Bunn et al. 1995).

Migratory and wintering hawks begin arriving in south Florida in October and are present throughout the winter. They can be easily observed along roadsides and flying over the landscape. The purpose of our study was to compare relative distribution and abundance of common wintering raptors in agricultural and wetland landscapes. Our null hypotheses were that there was no difference in raptor abundance and diversity between the two habitats and that perch types were chosen randomly.

[1] Email address: epearls@ufl.edu
[2] Present affiliation: University of Florida, Department of Wildlife, Ecology and Conservation, Ft. Lauderdale Research and Education Center, 3205 College Ave., Davie, FL 33314 U.S.A.

METHODS

Study Area. Historically, south Florida was dominated by the greater Everglades ecosystem. From Lake Okeechobee southward, water flowed across a wide landscape of marshes, sloughs, tree islands, and mangrove swamps into Florida Bay (Porter and Porter 2002). Before the turn of the century, drainage of the northern part of the Everglades commenced with production of a system of canals and dikes in the vicinity of and around Lake Okeechobee. The EAA came into being in the early 1950s (Light and Dineen 1994). The major road through these two habitat types is U.S. Route 27, a four-lane, divided highway passing through two counties, Palm Beach County to the north and Broward County to the south. The county line follows a demarcation between agriculture and Everglades vegetation. Vegetation along the roadside consists of mowed strips, powerlines, trees and shrubs of mostly exotic species, and canals. Beyond the canals, the landscape is dominated either by huge expanses of agricultural fields or of natural marsh and tree islands; both habitats are open with few scattered trees.

The EAA dominates western Palm Beach County and is comprised mostly of sugarcane fields with a small percentage of other crops including rice, sod, and various vegetables (Izuno et al. 1991). The agricultural fields are intermixed with a grid system of unpaved roads, permanent canals, and shallow ditches that provide varying degrees of irrigation and drainage for the fields. This system of fields and canals produces a patchwork of agricultural crops with field and canal-edge cover consisting of herbaceous and shrubby vegetation, usually exotic species, and sparse trees.

A single large canal on the east side of the road in Palm Beach County was fringed by tall brush and short trees, some of which were dead and used as nighttime roosts by various species of egrets (*Egretta* spp., *Bubulcus ibis*, *Butorides virescens*) and Anhingas (*Anhinga anhinga*). Few live trees were present in the area, but in some places there was significant tall brushy growth. There was a mean of 12.5 powerline poles per km on the west side of the road. Roadsides were mowed to a distance of 25 m and trees were found in less than 1% of roadside edge cover type.

Table 1. Species observations for each habitat and relative abundance (birds/km) in parentheses. All seven species listed here were used in the analysis of habitat and perch use. The number of individuals in each habitat was significantly different for the subset of seven species (χ^2, all $P < 0.01$).

Species	Number Observed		
	Agriculture	Natural	Total
American Kestrel (*Falco sparverius*)	480 (0.53)	74 (0.09)	554 (0.31)
Black Vulture (*Coragyps atratus*)	11 (0.01)	85 (0.10)	96 (0.05)
Northern Harrier (*Circus cyaneus*)	49 (0.05)	4 (0.0)	53 (0.03)
Osprey (*Pandion haliaetus*)	14 (0.02)	65 (0.08)	79 (0.04)
Red-shouldered Hawk (*Buteo lineatus*)	31 (0.03)	63 (0.07)	94 (0.05)
Red-tailed Hawk (*B. jamaicensis*)	126 (0.14)	2 (0.00)	128 (0.07)
Turkey Vulture (*Cathartes aura*)	293 (0.32)	207 (0.24)	500 (0.28)
Other species[a]	11 (0.01)	3 (0.00)	14 (0.02)
Total	1015 (1.11)	502 (0.59)	1517 (0.86)

[a] Other species included Bald Eagles (*Haliaeetus leucocephalus*), Crested Caracaras (*Caracara cheriway*), Merlins (*F. columbarius*), Peregrine Falcons (*F. peregrinus*), Sharp-shinned Hawks (*Accipiter striatus*), and Short-tailed Hawks (*B. brachyurus*).

Sugarcane forms a very dense canopy as it grows and supports populations of reptiles, mammals, and birds, either in the field or adjacent habitat. During the winter months, beginning in October, sugarcane was burned and then harvested, which attracted large numbers of predators and scavengers. The landscape then became a patchwork of mature, fallow, harvested, and newly-grown sugarcane fields until harvest was completed in early spring. Rice was grown on less than 10% of the area and provided flooded habitat for ca. 4–6 mo of the year, from early spring to late fall. Rice fields were permanently flooded and attracted large numbers of waterbirds, especially during the drawdown of water just prior to harvest, usually in July and August (Pearlstine et al. 2005).

In contrast, the natural areas of the Everglades are comprised of stretches of sawgrass (*Cladium jamaicense*) marshes, sloughs, and wet prairies broken up by flowing open water and scattered tree islands (Gunderson 1994). Rows of trees no more than a few trees deep stand on the verge at the far edge of the roadside on the east side of Highway 27. The roadside is bordered by nonnative Australian pine (*Casuarina* sp.) trees on 10–70% ($\bar{x}$ = 58%) of its length. Shrubs are present on much of the remaining roadside. There are canals on both sides of the road for about half the distance in Broward County. The canal on the west side of the road is smaller and flanked by shorter marsh vegetation. There are small areas of introduced species, Melaleuca (*Melaleuca quinquenervia*), as well as a local landfill in Broward County. Roadside trees offer natural perch sites, primarily dead snags. Otherwise the foliage is very dense and may be suitable only for perching by smaller raptors such as the Red-shouldered Hawk (*Buteo lineatus*) and American Kestrel (*Falco sparverius*). Like the EAA, the view over the marsh is generally unbroken except where there are stands of trees.

Survey Methods. We conducted 23 raptor/vulture surveys between October 1998–April 2003, with no surveys in winter 2001–02, along a section of Route 27 beginning at Sheridan Street in Pembroke Pines, Broward County and ending at State Road 80 in South Bay, Palm Beach County. The distance of the road transect was 76.48 km with 39.52 in agriculture and 36.96 in natural vegetation types.

We recorded species, activity, habitat, location and perch type of any raptors observed, also recording age and gender of individuals if possible. Because Route 27 is a highway, the minimum speed we were able to drive was ca. 88 km/hr. When a raptor was sighted, we stopped the vehicle and recorded location with a GPS receiver and other data if possible. In the last 2 yr of the survey, the start location and time of day of surveys were varied to avoid potential biases (Bunn et al. 1995). We alternated the survey start point between the northern end of the route and the southern end. Morning surveys began within an hour of sunrise and ended before noon, afternoon surveys began shortly after noon and ended before sunset. One or two observers were present for all surveys. On five occasions, we recorded large kettles (>25) of Turkey Vultures (*Cathartes aura*) that were attracted to burning fields. These observations were not used in the analyses. We recorded the type of perch used by each individual; natural perches included trees, brush, and dead snags, and artificial perches were predominantly powerlines or poles. We also recorded individuals that were flying over roadside habitat or flew from perch to perch. Species diversity was calculated for both habitats using proportions, as the route lengths varied (Simpson 1949, MacArthur and MacArthur 1961). Relative abundance was estimated using an index of total number of a species observed divided by total number of km traveled multiplied by 1000 (Woffinden and Murphy 1977). Habitat use in relation to availability was analyzed (using chi-square analysis following Neu et al. 1974) for linear km of each habitat type.

RESULTS

We observed 13 raptor species, of which we saw only seven in sufficient numbers for analysis; six species had relative abundances of 5.0 or fewer than seven observations (Table 1). The species with the greatest index of relative abundance (Woffinden and Murphy 1977) were the American Kestrel and the Turkey Vulture. For the seven most common species, we found the relative abundance of raptors in agricultural habitat to average 1.13 individuals per km and in natural habitat to be 0.61/km with an overall mean of 0.88/km. There were significantly more raptors than expected in agricultural habitat compared with natural habitat (χ^2 = 387.4, $P <$ 0.001; Neu et al. 1974). The species richness for each was equal, as all seven of the most common raptors were found in each landscape. Diversity was lower in agricultural than

Table 2. Number of individuals observed using different perches. All were significantly different (χ^2 tests $P < 0.01$).

LOCATION	AGRICULTURE	NATURAL
Brush/tree/snag		
Observed	7	191
Expected	99.9	228.8
Pole/powerline		
Observed	659	114
Expected	566.1	76.3

natural landscapes (0.66 vs. 0.74, respectively) using Simpson's index, but higher in agricultural using the Shannon-Wiener measure (1.15 vs. 0.64) and significantly different ($t_{0.05(2),\ 75}$, $P < 0.001$). Simpson's index indicates the likelihood that two randomly-chosen individuals will be different species and tends to emphasize common species (Simpson 1949). The Shannon-Wiener index measures the information content of a sample unit; higher diversity yields higher uncertainty (MacArthur and MacArthur 1961). For all species encountered, species richness (number of species) was greatest in agriculture with 12 of 13 recorded in these counts. Eight of the 13 species were sighted in natural cover types. Diversity, using both measures discussed above, was similar.

Four of the species, American Kestrel, Northern Harrier (*Circus cyaneus*), Red-tailed Hawk (*Buteo jamaicensis*), and Turkey Vulture were more abundant in agricultural than in natural cover types (all $P < 0.01$). Three species, Black Vulture (*Coragyps atratus*), Osprey (*Pandion haliaetus*), and Red-shouldered Hawk were observed more frequently in natural cover types than in agricultural areas (all $P < 0.01$).

Table 3. Locations of individuals by species either perched or in flight. Locations for each species were significantly different than expected.

SPECIES	IN FLIGHT	NATURAL PERCH	POWERLINE OR POLE PERCH	OTHER	P[a]
American Kestrel	1	18	526	0	<0.001
Black Vulture	3	18	30	24	<0.001
Northern Harrier	10	2	5	0	0.004
Osprey	10	47	14	0	<0.001
Red-shouldered Hawk	5	27	59	2	<0.001
Red-tailed Hawk	0	5	117	2	<0.001
Turkey Vulture	148	68	7	12	<0.001

[a] Determined by chi-square test.

Bohall and Collopy (1984) also found both Red-shouldered and Red-tailed hawks in open habitats. However, in their study, these hawks used natural perches more than man-made. In our study, Red-tailed Hawks were observed more frequently in agricultural landscapes, and Red-shouldered Hawks were observed more frequently in natural habitat. Both hawks used powerlines and poles more often than natural perches (Table 3). Our observations also were in contrast with Preston (1990), who found that habitat use was influenced by natural perch availability in Red-tailed Hawks. Red-tailed Hawks are known to use agricultural areas in high numbers as winter habitat in Arkansas (Garner and Bednarz 2000), but were found more frequently in natural than agricultural habitat in Idaho (Leptich 1994).

More raptors used powerlines/poles than natural perches such as brush, live trees, or snags ($P < 0.001$; Table 2). In natural and agricultural areas, raptors perched on poles and powerlines with greater frequency than relative availability would predict. Conversely, natural perches were selected less frequently than availability would predict ($P < 0.001$ for agriculture and for natural habitat). All raptors exhibited significant differences in perch use or flight (Table 3).

DISCUSSION

The greater abundance of raptors in agricultural habitat seemed to reflect species-specific responses to perch type availability, cover type, or both factors in combination. Both agricultural and natural habitats in this study were open and, away from the roadsides, contained only sparsely-distributed perches in the form of trees and shrubs.

American Kestrels in Florida have demonstrated sexual segregation by cover type with males tending to occupy sites that were more wooded and less open. But both genders include open habitat in their winter territories (Smallwood 1987, 1988). We found kestrels in agricultural habitat 87% of the time in this study, and they used powerlines almost exclusively as perches.

Our studies showed that Northern Harriers mostly used open areas and included agriculture as part of their winter habitat (MacWhirter and Bildstein 1996). Only the Osprey used natural perches in numbers more frequently than expected (Table 3).

The two vulture species showed different distributions in relation to cover types. Turkey Vultures seemed to respond positively to agricultural activities, especially harvesting of sugarcane, where they fed on animals killed by harvest activities, and were often seen concentrated in areas of active harvest. Black Vultures did not respond to harvest activities and were observed more frequently in natural habitat, roosting on a variety of perch types including Australian pine, bridge structures, and radio towers. We observed several large kettles (>10) of Turkey Vultures in the agricultural areas near harvesting activities. Black Vultures, on the other hand, were usually seen in numbers less than 10 and did not obviously respond to sugarcane harvests.

We used the index of abundance (Woffinden and Murphy 1977) or birds per 1000 km to compare with other studies. American Kestrels exhibited higher densities in our study than in southwestern New Mexico and Idaho (Eakle et al. 1996, Leptich 1994), but were similar to other Florida studies (Layne 1980). Red-tailed Hawks were less abundant in our study area than in Arkansas, about the same as Idaho (but higher in agriculture), and lower than New Mexico (Garner and Bednarz 2000, Leptich 1994, Eakle et al. 1996, respectively). Turkey Vultures were more abundant than in New Mexico and Northern Harrier numbers were similar to those found in Idaho (Eakle et al. 1996, Leptich 1994, respectively).

As sugarcane fields are harvested from October through April, many small animals (rice rats [*Oryzomys palustris*], marsh rabbits [*Sylvilagus palustris*], cottontails [*S. floridanus*], Florida kingsnakes [*Lampropeltis getula floridana*], leopard frogs [*Rana utricularia*], and a variety of birds) are crowded into marginal habitat along canals and roads. This may provide an artificial concentration of prey sources during the harvest season. Turkey Vultures are especially apparent in the area of sugarcane harvest and respond quickly to the intentional burning of fields (pers. obs.). We also saw Northern Harriers, Bald Eagles (*Haliaeetus leucocephalus*), and Crested Caracaras (*Caracara cheriway*) at recently-harvested fields.

High densities of raptors in agriculture and an apparent selection for artificial perches present in this habitat suggest that agricultural lands in south Florida may provide important habitat for wintering and migrating raptors. Because agricultural fields away from roads have no perches of any kind, we have worked with the farm manager to install tall T-shaped perches in several interior fields to provide access to more of the landscape by wintering raptors. This may also assist in control of rodents and other agricultural pests.

DISTRIBUCIÓN Y ABUNDANCIA RELATIVA DE AVES RAPACES DURANTE EL INVIERNO EN PAISAJES AGRÍCOLAS Y DE HUMEDALES EN EL SUR DE FLORIDA

RESUMEN.—Investigamos la distribución y abundancia relativa de las aves rapaces entre ambientes agrícolas y naturales con base en censos realizados a lo largo de una autopista de cuatro carriles en el sur de Florida durante los inviernos de 1998–2003, sin incluir el de 2001–02. Registramos la presencia de acuerdo al tipo de cobertura, el uso de tipos de percha y la densidad de rapaces a lo largo de la carretera, además de la riqueza y diversidad de especies en cada tipo de cobertura. *Cathartes aura*, *Circus cyaneus*, *Buteo jamaicensis* y *Falco sparverius* fueron más abundantes en los paisajes agrícolas que en los ambientes naturales, mientras que *Coragyps atratus*, *Pandion haliaetus* y *Buteo lineatus* fueron registrados con mayor frecuencia en los ambientes naturales. Encontramos un sesgo significativo en el tipo de percha: las líneas eléctricas y los postes fueron empleados más frecuentemente que las perchas naturales. Todas las especies fueron observadas con mayor frecuencia de la esperada en uno o más de los cinco tipos de percha o al vuelo. Las siete especies se encontraron en ambos hábitats y la diversidad de especies fue generalmente igual entre éstos. Cada especie pareció exhibir distintos patrones de uso de hábitat y de perchas. Nuestros datos sugieren que el paisaje agrícola del sur de Florida es importante para las poblaciones de rapaces invernantes y migratorias.

[Traducción del equipo editorial]

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