

HISTORICAL STATUS OF THE AMERICAN KESTREL (*FALCO SPARVERIUS PAULUS*) IN FLORIDA

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ABSTRACT.—We investigated the magnitude and cause of the decline in numbers of Florida's resident population of American Kestrels (*Falco sparverius paulus*) by contrasting the records of early oologists and present-day observations. Historical information was available for three different region-habitat type combinations. In areas formerly dominated by longleaf pine (*Pinus palustris*) flatwoods in north-central Florida (Alachua and Levy counties), kestrels have declined an estimated 82% since the early 1940s; nest-site availability has decreased significantly due to the clearing of isolated longleaf pine trees from agricultural fields. Along the central Florida ridge in Lake, Orange, and Seminole counties, kestrels declined with the conversion of the original longleaf pine-turkey oak (*Quercus laevis*) vegetation to citrus groves. Recent observations indicate a very small population now exists in this area. In Dade County, the kestrel apparently disappeared as a breeding species from the pine forests of the Miami Rocklands between 1935 and 1950. The cause of the kestrel's extirpation in this region is unclear. Received 18 Mar. 1987, accepted 31 July 1987.

Although the American Kestrel (*Falco sparverius*) is one of the most common and widely distributed raptors of the Western Hemisphere (Cade 1982), field ornithologists in Florida have noted a decline in the abundance of the state's resident population (*F. s. paulus*) (Kale 1971, 1980; Ogden 1971, 1972; MacFarlane 1973; Wiley 1978). In 1977, *F. s. paulus* was formally listed as "threatened" in Florida (Kale 1978); the magnitude and cause of the decline in numbers were unknown, but they were thought to be associated with nest-site destruction (Wiley 1978).

Historical records are necessary to assess changes in the status of *F. s. paulus* in Florida; however, published information concerning the kestrel's former distribution and abundance has been of a general nature, preventing the determination of population trends. For example, Howell (1932) and Sprunt (1954) simply considered *F. s. paulus* to be "locally common" in Florida, north of the Everglades; other early avifauna lists of specific locations (as reviewed in Howell 1932) are similarly vague. Two important factors contributed to this lack of information in the literature: (1) most early ornithological work in the state was conducted during winter and early spring (Howell 1932) and (2) *F. s. sparverius* is a common winter resident and migrant throughout the state, which tends to mask the true status of *F. s. paulus* (Bent 1938).

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In contrast, substantial unpublished information, which refers specifically to breeding *F. s. paulus*, exists in the records and specimens of oologists active in Florida during the first half of the 1900s. Elsewhere, this type of oological data has proven useful in understanding the population changes of several raptor species (Ratcliffe 1980, Bechard 1981). Our review of specimen material in American museums indicated there existed three substantial series of American Kestrel egg sets from restricted geographical regions of Florida, which we used to assess the population's former abundance and habitat preferences in detail. Additionally, by examining the kestrel's current population status in these same areas, our objective was to determine the magnitude and cause of the kestrel's decline, and the extent to which decreased availability of nest sites and foraging habitat contributed to the decline.

STUDY AREAS AND METHODS

Doe's oological records.—Specimens and field notebooks of Charles E. Doe archived at the Florida State Museum provided records of 307 clutches of kestrel eggs from Alachua and Levy counties between 1935 and 1942. For each clutch collected or described, we recorded date, location, incubation stage, clutch number (first, second, or third clutch of pair that year), characteristics of nest tree, and surrounding land use or vegetation. We determined clutch number based on Doe's comments, date of collection, the kestrel's ability to renest (Bird and Lague 1982), and stage of incubation.

We identified 6 specific and 5 general collecting locations, in which to conduct surveys for nesting kestrels, by comparing road numbers and landmarks used by Doe with present-day analogs (Fig. 1). Specific collecting locations were areas where exact fields or farms could be identified as the collecting site. General collecting locations refer to areas adjacent to roads where Doe collected kestrel egg sets, but for which the specific location of collection is unknown. The precise location of historical sites and the recent surveys is described by Hoffman (1983).

Four major plant communities occurred along Doe's travel routes: (1) slash pine (*Pinus elliotii*) flatwoods, (2) longleaf pine (*Pinus palustris*) flatwoods, (3) longleaf pine-turkey oak (*Quercus laevis*) sandhills, and (4) hardwood hammocks. These communities are described in detail by Laessle (1942), Monk (1968), and Veno (1976). None of the collecting locations was dominated by slash pine flatwoods, and sandhill vegetation was limited to a portion of the Bronson Road area. Throughout the study area the original associations have been altered extensively for agriculture and commercial slash pine plantations.

Our survey methods were designed to be analogous to Doe's methods. We searched intensively each specific collecting location on foot, scanning likely perches for kestrels. General collecting locations were searched by driving slowly (17–40 km/h) along roadside survey routes. When kestrels were found, Doe would attempt to flush incubating females from nearby snags; we spent additional time monitoring dead trees and other potential nest sites. Observations were focused on all areas within 0.4 km of the roadside survey routes, the normal distance to the next parallel field edge or hedgerow from the survey route. This distance was selected because Doe's notes indicated he invariably collected in fields adjacent to roads and rarely searched less accessible areas. We surveyed each area four times between 1 May and 30 June (see results for years of survey). Because of the conspicuous nature of

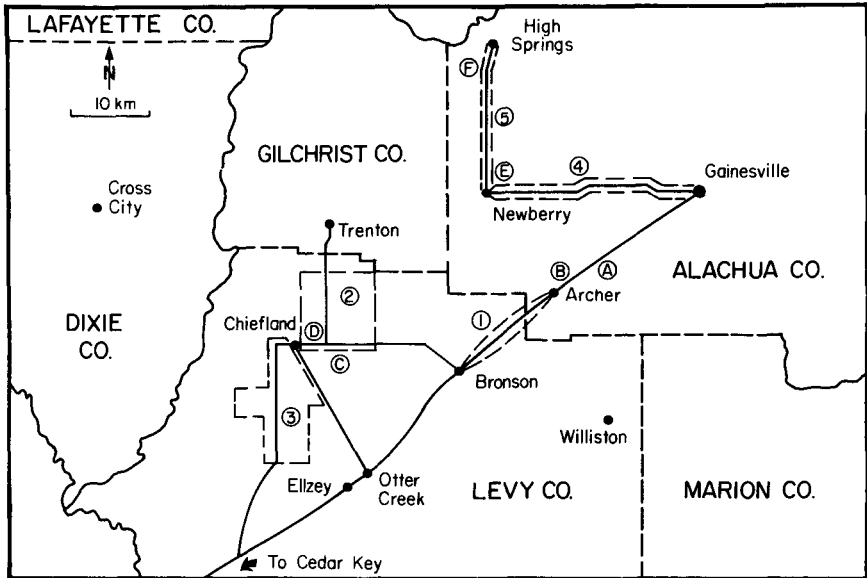


FIG. 1. Approximate location of collecting areas of C. Doe in north-central Florida. Letters indicate specific collecting locations: (A) Parker Church Road, (B) East of Archer, (C) Booth Farm, (D) East of Chiefland, (E) Turpentine Still, (F) Behind Church. Numbers indicate general collecting locations: (1) Bronson Road, (2) Trenton Cross-roads, (3) Southwest of Chiefland, (4) Newberry Road, and (5) High Springs Road. Broken lines adjacent to numbers signify outer boundaries of general collecting locations.

most kestrel nest sites in these areas (dead pines in fields), we felt 4 surveys were sufficient to locate any kestrel nests that would have been found by Doe.

We determined the minimum number of kestrel pairs in each collecting location, which could have produced the egg sets collected or observed by Doe. Because of large annual variation in Doe's efforts, we used his data from 1938–1940, the years of most consistent coverage, to represent the population size in each area during his era. The medians of these values were compared to the maximum number of pairs found in the recent surveys using the sign test (Siegel 1956).

To assess changes in vegetation and land use between Doe's era and the present we quantified, for each collecting location, the number of standing longleaf pines in agricultural fields and the percent composition of 6 cover types: hardwood hammocks, longleaf pine forests, slash pine plantations, agricultural fields (including pastures), farm sites, and urban areas. For specific collecting locations, the entire area was quantified. Habitat analyses of general collecting locations were based on a random sample of 25% of the 16-ha plots within 0.4 km of the roadside survey routes. This analysis was not performed for the general collecting location on Bronson Road because Doe only collected in two fields, neither of which we located. The time periods compared for changes in land use and vegetation were based on USDA aerial photographs and varied due to their availability (see results for years).

For purposes of comparison between the two time periods, we assumed that nest-site

availability was proportional to the number of standing live longleaf pine trees in agricultural fields. Doe's notes indicated that kestrels were found nesting in dead pine trees in cultivated or fallow fields and pastures. Because these dead trees are not readily discernible on aerial photographs, we used the number of live pines as an index of the number of dead pines in a particular field. Because dead pines originate as live pines, there should exist a correlation between these counts. It is assumed that the proportion of live to dead pines is similar between time periods. If snag removal has increased in recent years, then our estimate of habitat (snag) loss is conservative. We recorded counts of dead pines in the plots sampled for cover type analysis to assess the magnitude of the association and found an average of 4.8 live pines per dead pine ($N = 97$ live pines).

We considered kestrel foraging habitat to be agricultural fields, which includes pasture, cultivated fields, and fallow fields (Cade 1982, Bohall-Wood and Collopy 1987). Although not all cultivated fields are used by kestrels for foraging, distinction between potential foraging and nonforaging areas was not possible from the aerial photos. We used Wilcoxon's matched-pairs signed-ranks test (Siegel 1956) to compare the number of pines and area of each cover type per sample plot between the two time periods for the general collecting locations.

Nicholsons' and Bailey's oological records.—In 1983, we solicited copies of the data slips associated with kestrel egg sets collected in Florida from museums with over 1000 total egg sets or having Florida as an area of special representation (Kiff 1979). This survey and examination of field notebooks revealed 57 *F. s. paulus* clutches were collected in south-central Florida between 1909 and 1959 by Donald J. Nicholson and his co-workers; from these data we summarized information on nest-site characteristics. Copies of Donald and Wray Nicholson's field notes were made available for reference through the Western Foundation of Vertebrate Zoology. No attempt was made to assess current kestrel population levels in areas covered (primarily Lake, Orange, Osceola, and Seminole counties) by the Nicholsons through field work. We did, however, collect and summarize recent (post-1960) records of *F. s. paulus* from these counties, published in *American Birds* (formerly *Audubon Field Notes*) and solicit reports from field observers.

Data on 34 kestrel egg sets collected in Dade County by H. H. Bailey and his relatives (H. B. and M. P. Bailey) between 1922 and 1932 were found during the survey of museums. Additional information on the kestrel's historical status in Dade County came from published works by Bailey (1924, 1925, 1927) and others (Howell 1921, Holt and Sutton 1926). The present status of the *F. s. paulus* in south Florida was assessed using the literature (Robertson 1955, Robertson and Kushlan 1974) and contact with local ornithologists.

RESULTS

Doe's oological records.—The number of kestrel pairs in Doe's collecting locations declined significantly ($P < 0.01$) between 1938–1940 and 1981–1983 (Table 1). The estimated population size for all collecting locations combined was similar each year (1938, 45 pairs; 1939, 45; 1940, 46) during Doe's era. A maximum of 8 pairs was recorded in the recent surveys, a decrease of 82% from the 1938–1940 median.

Comparing vegetation and land-use characteristics between Doe's era and 1982 for the specific collecting locations reveals that nest-site availability (number of standing longleaf pine trees) decreased in each area (Table 2). Parker Church Road was the only specific collecting location that still had a living longleaf pine in 1982; it also was the only specific

TABLE 1
ESTIMATED NUMBER OF AMERICAN KESTREL PAIRS OCCURRING IN DOE'S COLLECTING
LOCATIONS IN 1935-1942 AND IN 1981-1983

Collecting location*	Year										
	'35	'36	'37	'38	'39	'40	'41	'42	'81	'82	'83
Parker Church Road	0	0	0	<u>1</u> ^b	3	0	2	2	1	0	— ^c
East of Archer	0	0	0	1	<u>0</u>	0	0	0	0	0	—
Booth Farm	—	5	6	<u>6</u>	8	2	—	1	—	0	0
East of Chiefland	—	2	2	4	<u>3</u>	1	—	0	—	0	0
Turpentine Still	—	—	—	1	<u>2</u>	2	2	1	—	0	0
Behind Church	—	—	—	<u>0</u>	0	2	0	0	—	0	0
Bronson Road	1	2	1	2	<u>1</u>	0	1	1	1	0	—
Trenton Cross-roads	—	2	2	14	<u>21</u>	21	—	2	—	3	2
Southwest of Chiefland	—	5	8	7	<u>3</u>	3	—	2	—	0	0
Newberry Road	—	—	—	<u>6</u>	4	11	0	9	—	1	0
High Springs Road	—	—	—	<u>3</u>	0	4	0	2	—	1	2

* See Fig. 1 for reference to collecting locations.

^b Median of kestrel numbers during 1938-1940.

^c Area not surveyed.

collecting location with nesting kestrels. Kestrel foraging habitat was greatly reduced or eliminated in the Booth Farm and Turpentine Still areas, due to the conversion of agricultural fields to pine plantations (Table 2). In the other specific collecting locations, foraging habitat had not decreased to less than 75%.

In all of the general collecting locations, the density of pines decreased significantly between Doe's era and 1982 (Table 3). A greater than 95% decline in pine tree densities was recorded in each location, except the Newberry Road area, where the decrease was of smaller magnitude. Analysis of cover type composition indicated that despite significant increases in hardwood hammocks, pine plantations, and urbanization in some areas, over 50% of each area remains in agriculture (Fig. 2). No changes in the amount of agricultural land was found in the Trenton Cross-roads and Southwest of Chiefland areas and the declines in the Newberry Road and High Springs Road areas were 24-28%.

Examination of aerial photographs for a portion of the Southwest of Chiefland area illustrates the changes in vegetation and land-use that have occurred between Doe's era and 1974 (Fig. 3). In the 1940 photo, agricultural fields dotted with longleaf pine trees are located throughout, with concentrations in blocks 1, 8, 9, 11, 15, and 16 (see figure legend for block

TABLE 2
 NUMBER OF STANDING LONGLEAF PINES AND % COVER-TYPE COMPOSITION FOR SPECIFIC
 COLLECTING LOCATIONS DURING DOE'S ERA AND 1982

Collecting location*	Size of area (ha)	Year	Number standing longleaf pines	% cover type					
				Hard-wood ham-mocks	Longleaf pine forest	Pine plantation	Agriculture	Farm sites	Urban
Parker	48.6	1937	5				100.0		
Church Road		1982	1				100.0		
East of Archer	22.7	1937	3				98.2	1.8	
		1982	0				98.2	1.8	
Booth Farm	97.1	1940	170		18.7		80.0	1.2	
		1982	0		7.9	56.6	33.8	1.6	
East of	48.6	1940	52				98.4	1.6	
Chiefland		1982	0			1.6	78.4	1.6	18.3
Turpentine	109.3	1949	24				99.6	0.4	
Still		1982	0			100.0			
Behind Church	24.2	1949	46				96.7	3.3	
		1982	0				96.7	3.3	

* See Fig. 1 for reference to collecting locations.

numbering scheme). In the 1974 photo, isolated pines are generally confined to the western portion of block 16 and block 8. The latter block accounted for 55% of the pines found in the Southwest of Chiefland vegetation sampling; most fields are totally devoid of isolated pines. Areas of former native pasture with an abundance of longleaf pines in blocks 2, 3, and 13 have been cleared or converted to pine plantations (block 3).

In the Trenton Cross-roads area, where sample size was the largest, kestrels nested in 3 different 16-ha plots adjacent to the survey route during 1982 and 1983. A comparison of the density of longleaf pines and major cover types in this survey area (Table 4) showed that the plots with nests were similar to the random sample from 1940 in having high average values for number of standing longleaf pines and longleaf pine forest cover and low values for pine plantation, as opposed to recent averages.

Doe characterized the vegetation surrounding nest sites as: field (N = 56); old field (13); plowed field (12); brush field (6); not cultivated (5); watermelon or corn field (3); cultivated field (3); in woods (2); and field of stubs (2). He also described 8 nests as "pine stubs" and listed 104 additional nest trees simply as "stubs"; we suggest these trees also were pines.

TABLE 3
STANDING LONGLEAF PINE DENSITY (MEAN NUMBER/16-HA PLOTS) FOR GENERAL
COLLECTING LOCATIONS DURING DOE'S ERA AND 1982

Collecting location ^a	Size of area (km ²) ^b	N ^c	Year	Mean (SE)	% change	P ^d
Trenton Cross-roads	75.6	97	1940	7.42 (1.15)	95	<0.01
			1982	0.39 (0.22)		
Southwest of Chiefland	61.5	92	1940	14.22 (3.13)	98	<0.01
			1982	0.22 (0.13)		
Newberry Road	11.0	34	1949	1.55 (0.65)	43	<0.05
			1982	0.88 (0.72)		
High Springs Road	13.0	40	1949	5.15 (1.20)	96	<0.01
			1982	0.20 (0.11)		

^a See Fig. 1 for reference to collecting locations.

^b Area within 0.4 km of roadside survey route.

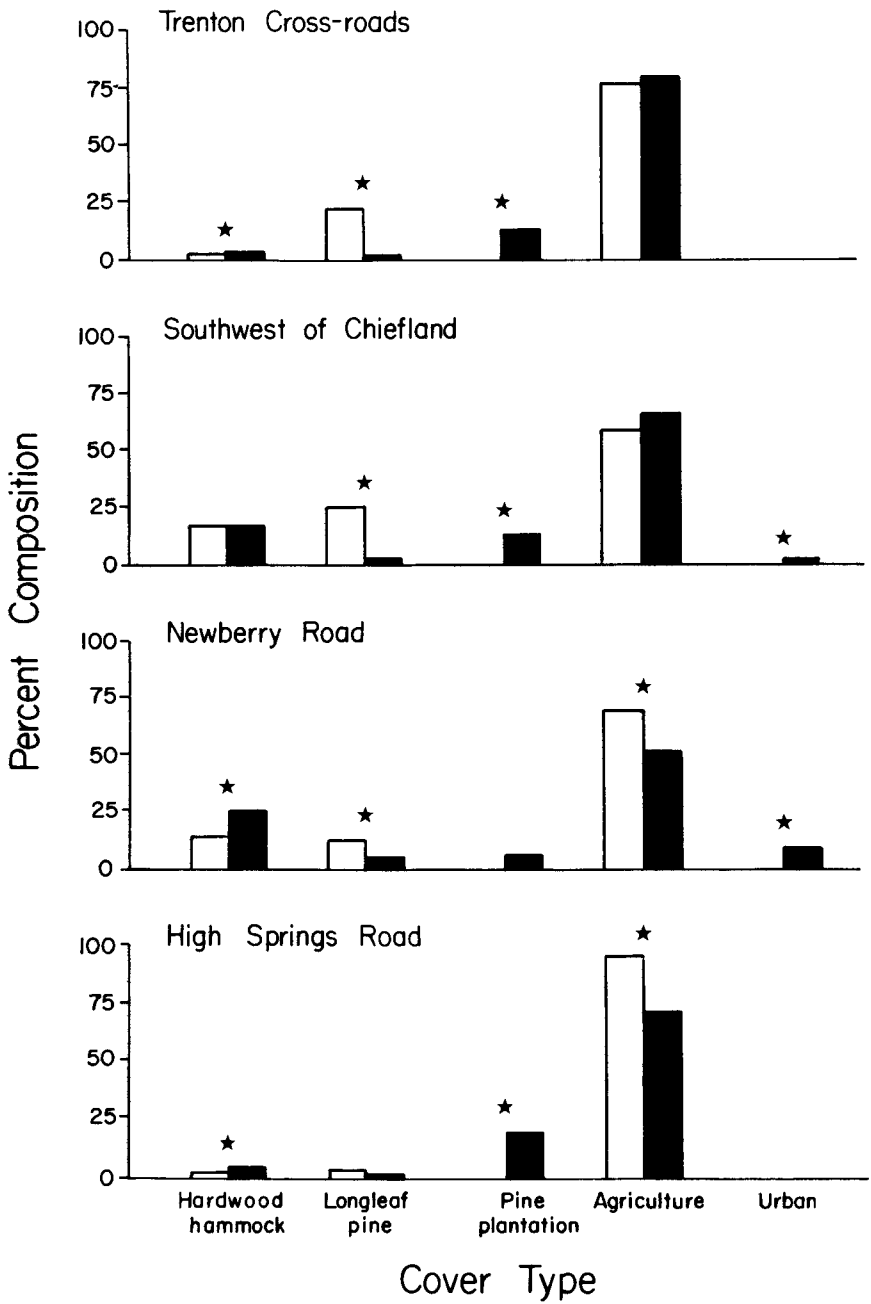
^c Number of 16-ha plots sampled for vegetation characterization.

^d Wilcoxon's matched-pairs signed-ranks test.

It is apparent that the agricultural fields during Doe's era had many standing pine trees, whereas today trees are nearly absent from these same fields. Foraging area also has been reduced in some locations due to the conversion of farmland to pine plantations, but not in a magnitude that could account for the kestrel's decline.

Nicholson's oological records.—All specimen data (N = 57 egg sets) collected in south-central Florida by D. Nicholson and his associates (C. E. Carter, J. C. Howell, W. H. Nicholson, F. W. Walker) indicated that kestrels formerly nested in the sandhill areas of Lake, Orange, and Seminole counties and in the vicinity of scrub and pine flatwoods in Osceola County. Unknown annual variation in collecting efforts and locations visited, combined with the lack of nesting habitat descriptions (except for those sets collected by D. Nicholson), limited analyses.

D. Nicholson described in detail the vegetation surrounding 11 kestrel breeding sites found between 1917 and 1923 in Orange and Seminole counties; all were in the longleaf pine-turkey oak sandhills (see Hoffman 1983 for complete descriptions). Between 1937 and 1959, he described 6 breeding locations in Lake, Orange, and Seminole counties; these also were in sandhill areas. These latter sites differed from those of the earlier period because the sandhill areas were being converted to citrus groves. For example, Nicholson wrote "the nest-site was but a few acres left of cut-over timber land—oak and pine—among many newly planted citrus groves" (Flat Lake, Lake County, 26 April 1954, notebook). The four



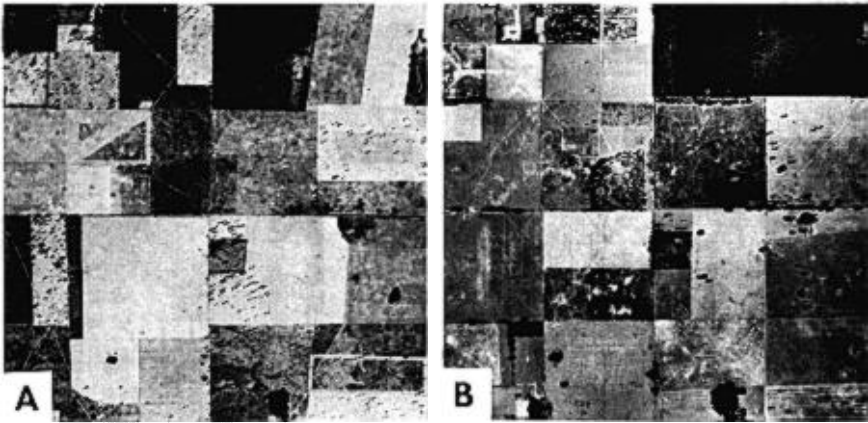


FIG. 3. Aerial photographs of Section 34, T 12 S, R 14 E, in 1940 (A) and 1974 (B) showing changes in land-use and vegetation between time periods. North is to the left. Size of area is 2.6 km² (1.0 square mile); linear distance along each edge is 1.6 km (1 mile). Note (particularly in 1974 photo) how area is divided into 16 equally sized square blocks, each 0.4 by 0.4 km and with an area of 16 ha. For reference purposes numbers (1 through 16) are assigned to each block left to right and top to bottom (e.g., upper-left corner block is 1, upper-right corner is 4, lower-left corner is 13, and lower-right corner is 16).

nesting locations in Osceola County described during this time period were pine flatwoods or scrub areas.

D. Nicholson attributed the cause of the decline of *F. s. paulus* in sandhill areas of south-central Florida to the clearing of land for citrus groves and, in general, the cutting of timber. He wrote (Dec. 1956, notebook): "between 1900 and 1920 this little hawk was very numerous in all of south central Florida, particularly in Orange, Lake, and Polk counties. . . . Since 1940 the Little Sparrow Hawk has become extremely rare in all of this region due to the cutting of timber and land cleared for [orange] groves." Details on the kestrel's status in Osceola County were less clear; however, he suggested that the increased cutting of dead trees for firewood eliminated potential breeding sites.

Between 1960 and 1969, no breeding American Kestrels were reported

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FIG. 2. Percent cover type composition in general collecting locations, Doe's era (white bar) and 1982 (black bar). Star indicates significant difference ($P < 0.05$) between time periods. Sample sizes as in Table 3. Percent composition of "farm sites" not shown, less than 5% in each area and no significant differences between time periods.

TABLE 4

STANDING LONGLEAF PINE DENSITY AND % COVER TYPE COMPOSITION FOR THE TRENTON CROSS-ROADS STUDY AREA (DATA ARE PRESENTED FROM THE TOTAL AREA FOR DOE'S ERA [1940] AND FOR 1982, AND FROM THOSE 16-HA PLOTS THAT CONTAINED ACTIVE KESTREL NESTS IN 1982 OR 1983)

Sample	N ^a	Number standing longleaf pines/16 ha	% cover type ^b		
			Longleaf pine forest	Pine plantation	Agriculture
1940	97	7.4	21	0	77
1982	97	0.4	2	13	80
Plots with nests	3	4.7	27	0	68

^a Number of 16-ha plots sampled.

^b Cover types not listed (hardwood hammocks, farm sites, and urban) represent 2% or less cover in each sample.

in *Audubon Field Notes* from Lake, Orange, Osceola, and Seminole counties. Beginning in 1970, the "Florida Region" editors began emphasizing that *F. s. paulus* was apparently declining, and they solicited observations. Subsequent reports were limited to one observation in Osceola County (Kale 1980) and two in Lake County (Paul 1982); none were reported from Orange or Seminole counties, where the Nicholsons had found kestrels nesting in longleaf pine-turkey oak areas. Additionally, no independent reports were received for these counties; however, given the large size of the area and general scarcity of observers, the potential for a small kestrel population in these counties certainly exists, particularly in northern Lake County. Kestrels are fairly common in portions of the Ocala National Forest in Marion County (Hoffman 1983), and similar habitats extend into Lake County.

There continue to be scattered summertime observations of kestrels in Polk County (Kale 1970, Paul 1982, J. N. Layne, pers. comm.). Although not part of the regular collecting areas of Nicholson, this county includes a large portion of the central Florida ridge, which, as in Orange and Seminole counties, was formerly dominated by the longleaf pine-turkey oak association and has been largely converted to citrus production.

Bailey's oological records.—The museum survey revealed the Baileys collected 34 kestrel egg sets in Dade County between 1922 and 1932. Location data indicate sites scattered within the Miami Rockland pine forests (Loope et al. 1979) and include Coral Gables (N = 8), Princeton (5), Cutler (4), Goulds (3), Homestead (3), and Florida City (2).

Bailey (1925) refers to the nesting areas as the "pine timber," with each pair of birds having a "separate piece of woods." The egg set data include 14 sets with descriptions of kestrel nesting habitat: open pine woods (N =

7), "cut over pine barren" (4), field (2), and clearing (1). Sixteen of the egg-set data slips specifically mention evidence of fire on the nest tree or in the nest area. Twenty-nine (85%) of the egg sets were identified as coming from pine trees, with 4 sets collected from coconut palms (*Cocos nucifera*) in Coral Gables. Bailey (1927) describes kestrels nesting in human habitations in Dade County, although none of his egg sets came from these situations.

Other early ornithologists working in south Florida also found the kestrel to be closely associated with slash pine (*P. elliotii* var. *densa*) forests. Howell (1921) refers to *F. s. paulus* as being "not uncommon in pineland and between Florida City and the [Royal Palm] Hammock." Holt and Sutton (1926:429) wrote that *F. s. paulus* was "abundant in certain parts of the pine-lands as far west as Long Pine Key, but never seen anywhere but in the pines." They also state "it was so common in some areas that every separate clump of trees was certain to have its pair of birds" (Holt and Sutton 1926:429).

Robertson (1955) considered *F. s. paulus* to be a "species formerly occurring in the pine forests" of south Florida. Robertson and Kushlan (1974) believed breeding kestrels were gone from southeast Florida ca 1940. At present, the kestrel is still absent as a breeding species in Dade County (W. B. Robertson, Jr., pers. comm.).

DISCUSSION

From comparison of the records of Doe, Nicholson, and Bailey to present-day observations, it is apparent that *F. s. paulus* has declined greatly in the specific regions and habitat types of Florida where these oologists located nesting kestrels. Except for the records of T. G. Pearson (see Hoffman and Collopy 1987), oological data from other areas or habitats of the state are limited to scattered egg sets and is not amenable to a comparable analysis. We suggest the areas considered here represented a significant portion of the kestrel's historic range in Florida and greatly contributed to the historic belief that the kestrel was "locally common" in "open pine woods" (Howell 1932). Additionally, the magnitude, timing, and cause of the declines have varied in each region.

Doe's oological records. — Charles Doe found *F. s. paulus* to be relatively common during the late 1930s and early 1940s in the agricultural areas of western Alachua and northern Levy counties. Surveys in these same areas during 1981–1983 demonstrated that a significant decline in the kestrel population had occurred. We consider 82% (from 45 to 8 pairs) a conservative estimate of the decline, because the areas covered in the recent surveys near Chiefland (Trenton Cross-roads, Southwest of Chiefland) were likely larger than those visited by Doe. The areas sampled in

the other collecting locations, however, are thought to be the same as those visited by Doe.

Analysis of changes in vegetation and land use suggest the decline in the kestrel population has been due to a decrease in nest-site availability. Doe found kestrels nesting principally in pine trees standing in agricultural fields. Although most stands of old-growth longleaf pine had been cleared by Doe's era for pastures and cultivation, many isolated trees were left standing by farmers. In the early 1900s, farmers left these pine trees standing because mechanized farm equipment was not widely available and plowing and clearing of land was done with mules. The increased use of tractors after World War II (Black 1980, Chew 1983), however, provided the means to clear pines from the fields, thus eliminating the existing and potential nest sites of the kestrel.

Although the total area of agricultural land has not changed substantially, the quality of this land-use category for kestrel foraging may have declined with more intensive agricultural practices in recent years. Bohall-Wood and Collopy (1987) found that kestrels nesting in agricultural areas of western Alachua County captured more insect and less reptilian prey, than did birds nesting in sandhill habitats of Levy County, and that male kestrels captured more than twice as much biomass per unit time in the latter habitat type. Given the crucial role of the male kestrel as a food provider during the breeding cycle (Cade 1982), the kestrel's ability to reproduce successfully in agricultural locations may be affected negatively by prey availability. Agricultural areas in Florida lack the small mammal populations typical of most farmland in North America. Although the scattered longleaf pine forests present during Doe's era could have provided a refugia for reptilian prey, the magnitude of the change in nest-site availability has been so great that we consider it the primary factor in reducing and now limiting kestrel populations.

The extent to which kestrels were able to use the original old-growth longleaf pine forests of this region is unknown. Evidence indicates kestrels at least nested in "deadenings," a term used to describe a large area of dead trees within the old-growth forest (Hoffman and Collopy 1987). If kestrels were originally confined to these locations, the clearing of the land for agriculture may have resulted in an increase in the kestrel population. Any increase in abundance was shortlived, however, as demonstrated by the changes in kestrel numbers between Doe's era and the early 1980s.

The same factors that caused the decline of *F. s. paulus* in northern Levy and western Alachua counties, no doubt influenced kestrel populations throughout much of north Florida. Longleaf pine declined from 45% to 8% of Florida's forests between 1936 and 1980 (Bechtold and

Knight 1982). Parts of Gilchrist, Suwannee, and Lafayette counties are very similar in vegetation and settlement history to the former collecting locations of Doe. The comments of Stockard (1905) suggest the high density of nesting kestrels in cutover pinelands as observed by Doe may have been a widespread occurrence following the removal of the old-growth longleaf pine forest in the Southeast. He described a situation in Mississippi that must have been very similar to the areas visited by Doe: "I found them . . . nesting in a manner almost social or colonial. In a newly cleared field there were many old stumps of deadened trees . . . and many pairs of this little hawk were nesting in these stumps" (Stockard 1905:153).

Nicholson's oological records.—The records of Donald Nicholson suggest the decline of *F. s. paulus* numbers in the longleaf pine-turkey oak sandhills of Lake, Orange, Polk, and Seminole counties was due largely to the conversion of this native vegetation to citrus groves. Populations were reduced much earlier than in north Florida; Nicholson commented on fewer kestrels in his 1922 notes and made other references to a decreased population as of 1920.

Several important factors contributed to the development of the citrus industry in the sandhill areas of south-central Florida and tend to support Nicholson's statements regarding the timing of the kestrel's disappearance. The severe freezes of 1894–1895 and 1899 resulted in a movement of the industry southward (Camp 1954). Prior to these winters, citrus was grown throughout the state, with areas of peak production surrounding Orange Lake in Alachua County, and along the northern portion of the St. John's River (Scott 1931). By 1928, however, Lake, Orange, and Polk counties dominated the citrus industry in Florida (Scott 1931).

The introduction of "rough lemon rootstock" for orange horticulture also facilitated the conversion of the sandhills to citrus groves. This rootstock came into extensive use sometime between 1905 and 1910 (Camp 1954), because it was found to grow well on the higher sandhill ridges. As Camp (1954:8) stated: "in a sense the industry's size today is based mainly on the discovery of rough lime (lemon) stock because it made possible the use of lands not formerly suited to citrus production." Also, it was soon realized that the high sand ridges provided additional protection against severe freezes and the development of sandhill areas along the central ridge of Florida proceeded at a rapid pace.

Studies of kestrels in north-central Florida sandhill areas demonstrate that high density kestrel populations can be supported in these areas (Hoffman 1983, Bohall-Wood and Collopy 1986); however, the scarcity of observations of breeding kestrels in south-central Florida suggests the population is small in this region. The replacement of native sandhill

vegetation with citrus groves has been on a massive scale, involving almost all the original sandhills in Orange and Polk counties and most sites in Lake and Seminole counties (Bechtold and Knight 1982). Remaining sandhill areas are small, isolated, and depauperate of the original fauna (Humphrey et al. 1985). Unlike the situation in the former collecting areas of Doe, however, both foraging and nesting habitat have been eliminated. Consequently, the potential for natural kestrel reestablishment is low.

Bailey's oological records. — H. H. Bailey and other field observers found *F. s. paulus* to be relatively common during the 1920s in the slash pine flatwoods extending from Miami to Long Pine Key. Robertson's (1955) extensive field work in the same area during the early 1950s failed to locate any breeding kestrels, and the subspecies is still absent from this area. Thus it appears kestrels disappeared from this area between the mid-1930s and late 1940s.

Robertson and Kushlan (1974) reviewed changes in the south Florida avifauna in historic times and considered the kestrel a species whose disappearance was "probably not primarily in response to man's impact on the environment." They considered habitat destruction (i.e., lumbering of the pine forests) inadequate to account for the extirpation of the kestrel and several other pine forest species. Robertson (1955) summarized the history of the cutting of the pine forests in south Florida and noted that the virgin slash pine had been cut by the time of his field work in the early 1950s. Lumbering began in the early 1900s and continued unabated, with many areas being cut several times (Robertson 1955). The virgin slash pine forests of Long Pine Key were cut in the late 1930s and 1940s (Olmsted et al. 1983), corresponding to the time of the kestrel's disappearance. The references of Bailey (1925) and Holt and Sutton (1926) that each pair of kestrels had its "own woods" is interpreted to mean that pairs were found in stands of old-growth pines surrounded by cut-over forests and agriculture. The kestrel, however, is not solely dependent upon old-growth forests; the records of Bailey include nesting in cut-over pine forests.

Because the kestrel requires an open understory in which to maneuver and visually locate prey, a decrease in the frequency of ground fires in the pine forests and the resultant effects on the understory (Loope and Dunnevit 1981, Taylor and Herndon 1981) could negatively impact habitat quality. There is no evidence, however, that fires decreased significantly between the 1920s and the 1950s (Robertson 1955, Taylor 1981). It also is possible that the thick understory created by pine regeneration in cut forests adversely influenced kestrel populations, acting in a manner similar to fire exclusion; with the widespread cutting of the old-growth slash pine, large areas may have been rendered unsuitable for kestrel occupancy.

Robertson and Kushlan (1974) suggest that the extirpation of the kestrel from southern Florida is part of a larger trend caused by the warming of the postglacial climate and the concomitant northward retreat of the continental fauna. The records of Doe and Nicholson, however, indicate the kestrel's recent scarcity in two significant habitats of north-central and south-central Florida is due to man-induced changes. Although it is not possible to identify a particular cause for the kestrel's disappearance in Dade County, we believe the most significant influences include the cutting of the virgin slash pine forest and changes in the understory of the pine forest in response to clearing and fire. Given the conversion of pine forests to agricultural land and housing developments, there is little likelihood of the kestrel becoming reestablished in extreme southern Florida; both foraging and nesting habitat largely have been eliminated.

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The Deutsche Ornithologen-Gesellschaft will hold its 100th annual meeting as the "International 100th Annual Meeting" Sept. 24 through Oct. 1, 1988, at the Museum Alexander Koenig in Bonn, West Germany. The two key themes will be "Zoogeography and Systematics," and "Behavioral Ecology." All interested in participating should contact:

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