Avian abundance and breeding biology of birds in Florida citrus groves

by

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Signatures have been redacted for privacy

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GENERAL INTRODUCTION

Citrus groves in central Florida have replaced large amounts of the native vegetation originally available to breeding birds. Information on bird use of citrus groves is needed because populations of many songbirds are thought to be declining (Robbins et al. 1986, Terborgh 1989) as more habitat is lost to domestic and agricultural uses. Habitat selection by birds has been widely studied (e.g., Hilden 1965, Verner et al. 1984), and bird use of exotic habitats including Caribbean pine plantations (Cruz 1988) and eucalyptus plantations (Cody 1985) has been investigated. Kale and Webber (1968) and Webber and Kale (1969) counted birds in Florida citrus groves, and Nicholson (1937) documented the breeding activities of Common Ground-Doves (*Columbina passerina*) in a Florida citrus grove, but ours is the only study which has extensively examined avian habitat selection and nest-site selection in citrus groves.

The objectives of the first section of this thesis were to determine bird species composition and abundance in Florida citrus groves and to examine the factors that are likely to influence bird selection and use of groves. These factors included the vegetation parameters within citrus groves that would be influenced by citrus culture practices (e.g., tree height, tree canopy diameter) and the proportions of the edge habitat types that bordered the citrus groves. Vegetation within the groves was believed to be important because it likely affects opportunities for foraging and nesting. Many studies have investigated the effects of edge habitats on bird species diversity and have demonstrated that avian use of various edge types differ markedly (e.g., Morgan and Gates 1982). Thus, edge habitats adjacent to the citrus groves could influence bird species composition and abundance within the groves.

In the second section of this thesis the objectives were to document nesting success and characterize nest-site selection. Nest-site selection is fundamentally important to birds and has been subjected to intensive natural selection (Cody 1981). The questions of most interest were: Do breeding birds show preferences in selecting nest sites? What factors likely influence nesting outcome? Does nest-site selection affect nesting success and, if so, how? By measuring habitat variables around each nest, nest-site selection could be evaluated at the levels of the nest vicinity, nest tree, and placement of the nest within the tree.

This study also provided an opportunity to monitor growth in nestling Common Ground-Doves. Information about the biology of Common Ground-Doves is scarce. Jones (1988) investigated habitat use of Common Ground-Doves in Alabama, and Passmore (1981) studied the breeding biology of Common Ground-Doves in South Texas, but no one has described growth in this species. The third section of my thesis describes mass and tarsus development in Common Ground-Dove nestlings.

Explanation of Thesis Format

A general introduction is followed by the three sections of my thesis. A general summary of the three papers is included after the third section. All references in the general introduction are in the additional literature cited. All three papers in my thesis were prepared separately for submission to professional journals and will have joint or multiple authorship. I collected data and supervised data collection for each of the papers, and was the principle author of all three. I performed all of the statistical analyses for the papers on bird abundance and nest-site selection and nesting outcome. I also was involved in the planning of experimental designs. Each paper was written in the style recommended by the journal to which it was submitted.

SECTION I. BIRD ABUNDANCE IN FLORIDA CITRUS GROVES

Bird abundance in Florida citrus groves

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ABSTRACT

We studied bird species composition and bird abundance in 13 Florida citrus groves. Birds were counted in the interiors and the perimeters of the citrus groves. Total bird abundances in the groves averaged 2306 birds / count / 100 ha with a range of 877-4880, and 30 bird species were recorded. The most abundant species were the Northern Cardinal (*Cardinalis cardinalis*), Mourning Dove (*Zenaida macroura*), Common Ground-Dove (*Columbina passerina*), Brown Thrasher (*Toxostoma rufum*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), and Northern Mockingbird (*Mimus polyglottos*). The Northern Cardinal was recorded in all the groves, and the Brown Thrasher and Common Ground-Dove were recorded in all but one grove. Birds observed in the citrus groves were breeding birds that nested in the groves, transients that temporarily used the groves for foraging, or breeding birds that nested in the adjacent edge habitats. The 6 most abundant species nested in the groves. Vegetation parameters in the groves, the proportions of the edge habitat types that surrounded groves, and grove isolation from other citrus groves were studied to determine if they influenced bird abundance. The abundance of Common Ground-Doves was negatively correlated with the age of citrus groves, suggesting a preference for small trees. A negative correlation between the abundance of Northern Cardinals and inter-canopy distance (spacing between tree canopies) may have reflected the importance of concealed nest sites for this species. The abundance of Northern Mockingbirds seemed to be related to the presence of residential areas adjacent to citrus groves, whereas Mourning Dove abundance was correlated with the percentage of herbaceous canal edge habitat bordering the groves. Because herbaceous canal edges had few or no trees or shrubs, they may have provided the open areas that this species prefers.

INTRODUCTION

Citrus production is a large agricultural enterprise in Florida, California, Texas, and Central America. Because nearly 400,000 hectares of native vegetation have been converted into citrus production (U.S Bureau of the Census 1990), groves represent a substantial proportion of the habitat available to birds in some areas. Kale and Webber (1968) and Webber and Kale (1969) counted birds in Florida citrus groves, but bird use of citrus groves has not been extensively studied, nor have the factors influencing use of citrus groves by breeding birds been evaluated. Winter bird use of citrus groves has been documented in Belize, Costa Rica, and Jamaica (C.S. Robbins, pers. commun.).

Our objectives were to (1) determine bird species composition and bird abundance in Florida citrus groves and (2) evaluate the factors that likely influence bird use of groves.

STUDY AREA AND METHODS

Thirteen citrus groves on Merritt Island in Brevard County, Florida were used as study sites. Eight of the groves were part of the Merritt Island National Wildlife Refuge; five were privately owned and managed. Study groves were 1.2-18.0 ha and planted to orange or grapefruit trees.

Birds were counted within fixed-width transects from 10 May through 4 June 1988. Four counts were conducted during the early morning; and two were completed in the late afternoon or early evening. Birds were not counted on days with strong wind or heavy rain. Counting was done within transects positioned around the perimeters of the citrus groves (grove-edge transects) and within the interiors of the groves (mid-grove transects). Each transect consisted of the area between two adjacent tree rows (25 m). Large groves were subsampled because they could not be completely traversed during the cooler early morning hours when birds were most active. When subsampling, transects were spaced at regular intervals throughout the grove (e.g., every 4th tree row) to insure representative sampling. During the count, all birds currently in the transect, those that landed within the transect, and those observed flying over the transect in search of ground-dwelling prey were recorded. Birds observed flying over the transect in transit between two locations outside the transect area were not recorded. Species and behavior were recorded for all observations of birds (visual or aural).

Numbers of individuals of each bird species observed during counts (morning and afternoon) were totaled separately for the mid-grove and grove-edge transects in each citrus grove. Abundances were calculated for the most common bird species and for all species combined and expressed as birds observed per count per 100 ha.

The vegetation within each citrus grove was characterized by grove age, tree height and canopy diameter, inter-canopy distance (spacing between canopy perimeters), relative openness below the tree canopy (height above ground of the lowest tree foliage), and height and coverage of herbaceous vegetation. Differences in these variables among the groves resulted from the citrus culture practices of orchard design (spacing and tree number), hedging and pruning, mowing, and spraying. Grove tree heights, canopy diameters, inter-canopy distances, and relative openness below the tree canopy were average values based on 10 randomly chosen trees per grove. The percent coverage of herbaceous vegetation was visually estimated and the maximum height of herbaceous foliage was measured at 10 randomly selected locations between the tree rows. Herbaceous vegetation was measured once in each grove in June. Because percent coverage and height of herbaceous vegetation were dependent upon when and if the groves were mowed or treated with herbicides, broad classes were used to categorize these measurements. The dominant herbaceous vegetation in the groves were guinea grass (*Panicum maximum*), Bermuda grass (*Cynodon dactylon*), ragweed (*Ambrosia artemesiifolia*), and common cattail (*Typha latifolia*).

Study citrus groves were surrounded by other groves, residential areas, or undeveloped parts of the wildlife refuge. Groves were characterized on the basis of their relative isolation from other citrus groves. Isolation from other groves was estimated as none to slight (<0.5 km), moderate (0.5-2.0 km), or high (>2.0 km).

The vegetation within edge habitats adjacent to each grove was classified into cover types based upon plant structure and composition. The cover types were herbaceous canal, woody canal, Australian pine (*Casuarina cunninghamiana*), shrubland, deciduous woodland, roadside, and herbaceous. For each study grove, the lengths of the various edge habitat types bordering the grove were divided by the total length of edge to determine the percentages of each edge habitat type. Canals and ponds within the groves were considered internal edges and were treated as part of the total edge habitat.

Spearman's rank correlation was used to test for correlations between bird abundances (mid-grove and grove-edge combined) and vegetation variables characterizing the groves, the percent coverage of edge habitat types bordering study groves, and the degree of isolation of groves.

In addition, Spearman's rank correlation was used to test for correlations between pairs of vegetation variables. Statistical significance was set at $P \leq 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

Characteristics of Citrus Groves. -Of the measured vegetation parameters, tree height varied the least among the groves, whereas tree canopy diameter varied the most (Table 1). Three groves were immediately adjacent to other groves, seven were moderately isolated (0.5-2.0 km) from other groves, and the remaining were highly isolated (>2.0 km). Generally, those groves most isolated from other citrus groves were not in residential areas, but were surrounded by undeveloped parts of the wildlife refuge.

Canals commonly bordered the citrus groves on Merritt Island and, accordingly, the predominate edge types were herbaceous canal and woody canal. The Australian pine edge was a canal planted with closely spaced Australian Pines about 18 m tall. Deciduous woodland edges had closed shrub and tree canopies (>75% canopy coverage), whereas shrubland edges had dense shrubs but only scattered trees. Roadside edges consisted of herbaceous vegetation and paved roads. In some cases, citrus groves or residences bordered the opposite side of the road adjacent to the study grove. The herbaceous edges were distinguished by dense herbaceous ground cover and few or no shrubs and trees.

Bird Use of Citrus Groves. - Bird abundances (mid-grove and grove-edge) in the 13 groves averaged 2306 ± 1139 (S.D.) birds observed per count per 100 ha and ranged from 877 to 4880. The most abundant species (listed in order of decreasing abundance) were the Northern Cardinal, Mourning Dove, Common Ground-Dove, Brown Thrasher, Rufous-sided Towhee, and Northern Mockingbird (Table 2). (Scientific names are given in Table 2.) Twelve of the most abundant species in the groves were among the 20 most commonly reported species in Breeding Bird Surveys in Florida (Cox 1987). The number of bird species counted in individual study groves ranged from 6 to 18 and averaged 10. The cardinal was observed in all 13 groves, and the thrasher and ground-dove were observed in all but one grove (Table 2). A total of 30 bird species was observed in the 13 study groves. Bird species found in the citrus groves consisted of

Table 1. Characteristics of the 13 Florida study groves.

Characteristics	Mean ± SD	Range
Age (years)	51 ± 20	25-90
Size (ha)	5.7 ± 5.4	1.2-18.0
Tree height (m)	4.1 ± 0.5	3.4-5.5
Tree canopy diameter (m)	6.3 ± 1.2	4.8-8.8
Inter-canopy distance (m)	2.0 ± 0.6	0.9-3.2
Openness below canopy (m)	1.2 ± 0.7	0.1-2.4
Herbaceous height class [a]	2.6 ± 0.9	1.0-4.0
Percent herbaceous cover class [b]	3.0 ± 0.8	2.0-4.0

[a] 1 = 0-0.30m, 2 = 0.31-0.60m, 3 = 0.61-0.90m, 4 = 0.91-1.2m.

[b] 1 = 0-25, 2 = 26-50, 3 = 51-75, 4 = 76-100.

Table 2. Bird abundance (numbers of birds observed/ count/ 100 ha) and occurrence in the 13 Florida citrus groves. List only includes the most common species. [a]

		Mid-grove	
Species	Scientific Name	Mean ± SD	Range
Turkey Vulture	*Cathartes aura*	5.9±14.6	0.0-44.1
Northern Bobwhite	*Colinus virginianus*	35.0±86.4	0.0-259.7
Mourning Dove *	*Zenaida macroura*	268.1±373.4	0.0-1363.6
Common Ground-Dove *	*Columbina passerina*	263.1±345.1	0.0-1201.3
Red-bellied Woodpecker *	*Melanerpes carolinus*	30.9±52.1	0.0-178.6
Downy Woodpecker *	*Picoides pubescens*	20.3±49.2	0.0-170.8
Great Crested Flycatcher	*Myiarchus crinitus*	4.5±16.3	0.0-58.8
Blue Jay	*Cyanocitta cristata*	5.7±14.1	0.0-41.7
Carolina Wren	*Thryothorus ludovicianus*	9.1±27.1	0.0-97.4
Northern Mockingbird *	*Mimus polyglottos*	58.6±96.5	0.0-291.7
Brown Thrasher *	*Toxostoma rufum*	121.2±142.4	0.0-535.7
White-eyed Vireo *	*Vireo griseus*	15.7±30.9	0.0-89.3
American Redstart	*Setophaga ruticilla*	22.2±26.1	0.0-68.2
Northern Cardinal *	*Cardinalis cardinalis*	571.0±331.2	187.5-1324.6
Rufous-sided Towhee *	*Pipilo erythrophthalmus*	72.1±119.2	0.0-389.6
Red-winged Blackbird *	*Agelaius phoeniceus*	15.0±54.0	0.0-194.8

[a] Other species that occurred in small numbers (<100 birds observed/census count/100 ha): Cattle Egret (Casmerodius albus), Black Vulture (Coragyps atratus), American Kestrel (Falco spaverius), Wild Turkey (Meleagris gallopavo), Yellow-billed Cuckoo (Coccyzus americana), Northern Flicker (Colaptes auratus), Hairy Woodpecker (Picoides villosus), American Crow (Corvus brachyrhynchos), Fish Crow (Corvus ossifragus), Blackpoll Warbler (Dendroica striata), Common Yellowthroat (Geothlypis trichas), Painted Bunting (Passerina ciris), and Brown-headed Cowbird (Molothus ater).

*=confirmed nesting in citrus groves.

Grove-edge		Number of groves occupied
Mean ± SD	Range	
2.1±7.7	0.0-27.8	3
1.0±2.5	0.0-7	3
113.5±130.9	0.0-446.4	11
60.8±57.6	0.0-171	12
24.3±34.6	0.0-116.7	10
6.0±14.8	0.0-53.6	5
4.9±14.0	0.0-50	2
2.7±9.9	0.0-35.7	3
22.4±29.4	0.0-104.2	8
33.1±66.3	0.0-232.1	6
16±21.7	0.0-69.4	12
5.6±14.7	0.0-50	4
2.7±7.9	0.0-28.1	7
289.2±172.4	42.1-613.6	13
31.0±47.4	0.0-175	9
6.2±15.6	0.0-50	2

two groups: those that nested in the groves and those that did not; both groups used the groves for feeding. The six most abundant species all nested in the groves. Species not nesting in the groves included transients (e.g., American Redstart) and species that typically nested in the edges bordering the groves (e.g., White-eyed Vireo and Carolina Wren).

The most species and individuals were observed in the citrus groves during morning counts. Ten species were observed only during morning counts, most notably the American Redstart and Cattle Egret. Four other species (Carolina Wren, Rufous-sided Towhee, Downy Woodpecker, and Red-bellied Woodpecker) were recorded in both morning and afternoon counts, but more often in the morning. Wild Turkeys and Black Vultures were the only species observed in afternoon but not in morning counts. In addition, Mourning Dove and Common Ground-Dove numbers were greater during afternoon than morning counts.

Bird abundances in the middle of the citrus groves were usually greater and more variable than those in the grove perimeters (Table 2). The number of bird species observed in individual groves ranged from 1 to 15 mid-grove and from 0 to 14 in the perimeter. Twenty-six bird species were observed in the interiors of the 13 study groves, whereas 27 species were recorded in the grove perimeters. The most abundant species mid-grove also were usually the dominant species in the grove perimeters. Exceptions were Red-bellied Woodpeckers and Carolina Wrens, which were among the most common species in the perimeters, and Brown Thrashers and Northern Bobwhites, which were among the dominants mid-grove.

Relationships Between Bird Abundance and Grove Characteristics–There were no significant relationships between bird abundances and tree canopy diameter, openness below the tree canopy, herbaceous vegetation height, or percent coverage of herbaceous vegetation. Bird abundances were, however, significantly correlated with grove age, tree height, inter-canopy distance, the degree of isolation of the citrus groves, and the percentages of four of the six edge habitat types (Table 3).

Table 3. Significant ($P \leq 0.05$, df=11) Spearman rank correlation coefficients comparing bird abundance with citrus grove variables.

	Grove characteristics				Percentage of edge habitat type			
Species	Age of grove	Tree height	Inter-canopy distance	Degree of isolation	Herbaceous canal	Herbaceous	Deciduous woodland	Roadside
Vultures [a]		0.706*						
Common Ground-Dove	-0.570							
Mourning Dove					0.586		-0.594	
Crows [b]		0.583						
Carolina Wren						-0.553		
Northern Mockingbird							-0.570	0.584
Brown Thrasher				0.576				
Northern Cardinal		0.567	-0.552			-0.621		
Total number of species		0.619						

[a] Vultures = Turkey Vulture and Black Vulture.

[b] Crows = Fish Crow and American Crow.

*=Highly significant ($P \leq 0.01$).

The age of citrus groves seemed important to Common Ground-Doves because the youngest groves tended to have the greatest numbers of these doves. A nearly significant relationship between grove age and tree height (Spearman's *rho*=0.525, P=0.07) may explain this preference for younger groves. Jones and Mirarchi (1990) found that doves favored sites with smaller trees.

Tree height was correlated with the numbers of crows, vultures, Northern Cardinals, and of all birds present in the study groves. Thus, it appeared to be an important determinant of bird abundance, even though the range of average tree height was small (3.4-5.5 m). Crows were common nest predators in the citrus groves (Crowe et al., in press) and may have been responding to the abundance of the other species. Dow (1969) found that Northern Cardinals select trees that provide maximum foliage density for nest concealment. Because the shortest trees in the groves were either young trees or older, dying trees that provided less foliage than mature trees, cardinals may have avoided short trees. Dow also reported that cardinals prefer high song perches.

The negative correlation between inter-canopy distance and cardinal abundance also may reflect this species preference for well-concealed nest sites. We found that cardinals tended to choose nest trees with closed canopies (Crowe et al., in press). Erhart and Conner (1986) also reported that adequate nesting cover was important for cardinals.

Brown Thrasher abundance was correlated with the degree of isolation of the study groves from other citrus groves. This correlation may have reflected an affinity of Brown Thrashers for the natural vegetation bordering the isolated study groves. The natural vegetation in the edges was an association of mixed hardwoods and pines which included cabbage palmetto (*Sabal palmetto*), laurel oak (*Quercus laurifolia*), slash pine (*Pinus elliottii*), groundsel tree (*Baccharis halmifolia),* longleaf pine (*Pinus palustris*), live oak (*Quercus virginiana*), winged sumac (*Rhus copallina*), wax myrtle (*Myrica cerifera*), coastal plain willow (*Salix caroliniana*), and elderberry (*Sambucus canadensis*). Optimum Brown Thrasher habitat has been described as dense thickets and hedgerows or hardwood draws that have young trees and shrubs with low percent canopy coverage (Cade 1986). Because the mixed hardwood/pine association consisted of a shrub layer of variable canopy coverage and scattered trees, these edges may have provided favorable habitat for Brown Thrashers. Although this is the most likely explanation of the correlation between Brown Thrasher abundance and the degree of isolation of the groves, it does not explain why thrashers were not more abundant in the grove-edge than at mid-grove (Table 2).

The abundance of only four species was correlated with edge habitat types. Northern Mockingbird abundance was positively correlated with the percentage of roadside edge bordering the groves, and groves with the most roadside edge also were those in residential areas. Stewart and Robbins (1958) and Woolfenden and Rohwer (1969) found high densities of mockingbirds in suburban residential areas and Woolfenden and Rohwer described the ideal mockingbird habitat as large lawns with an abundance of shrubs. The percentage of deciduous woodland edge surrounding a grove seemed to negatively influence the abundance of Northern Mockingbirds and Mourning Doves. Because deciduous woodland edges had closed shrub and tree canopies, this correlation suggests that these species avoid heavily wooded habitats. Woolfenden and Rohwer (1969) found that, in addition to residential areas, Northern Mockingbirds preferred land only moderately wooded. Although Mourning Dove abundance was negatively correlated with the percentage of deciduous woodland edge, it was positively correlated with the percentage of herbaceous canal edge, an open edge habitat with few or no shrubs and trees. Harris et al. (1963) reported that Mourning Doves select nest sites adjacent to open habitats that provide an unobstructed view and flight path. The herbaceous edge, similar to the herbaceous canal in structure and composition of vegetation, appeared to have a negative effect on the abundance of Northern Cardinals and Carolina Wrens. Although these two species are known to favor woody vegetation, their abundance was not correlated with edges that had a predominance of trees or shrubs.

In this study, we documented species composition and abundance of birds in Florida citrus groves. Citrus groves are highly altered environments, and are subject to periodic applications of herbicides and pesticides, yet these groves make up a sizeable percentage of the breeding habitat available to birds in Florida. Several species were found in all or nearly all the groves, including the Northern Cardinal, Brown Thrasher, Common Ground-Dove, and Mourning Dove. For species whose numbers are declining, such as the Common Ground-Dove (Robbins et al. 1986), an understanding of how habitat variables influence abundance is critical. We attempted to explain the wide range of bird abundance by determining if it was influenced by the vegetational differences among the groves resulting from citrus culture practices, the proportions of the various edge habitat types that surrounded the groves, or the isolation of the groves from other groves. Several significant relationships were found between bird abundance and grove age, tree height, inter-canopy distance, the degree of isolation of the study groves, and the proportions of four of the edge habitat types. Variables that we did not study, such as food availability and nest-site selection and nesting outcome in the groves (See Crowe et al. part II) and surrounding edges, may explain some of the differences in abundance among groves.

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SECTION II. AVIAN NEST-SITE SELECTION AND NESTING SUCCESS IN TWO FLORIDA CITRUS GROVES

Avian nest-site selection and nesting success in two Florida citrus groves

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ABSTRACT

We studied nesting success and nest-site selection of Common Ground-Doves (*Columbina passerina*), Northern Mockingbirds (*Mimus polyglottos*), Brown Thrashers (*Toxostoma rufum*), and Northern Cardinals (*Cardinalis cardinalis*) in two Florida citrus groves. Predation resulted in the loss of more than half of all nests. Fish Crows (*Corvus ossifragus*) and yellow rat snakes (*Elaphe obsoleta*) appeared to be the major predators. Human disturbance in the groves likely increased depredation by the crows. Nesting success differed between the groves and may have resulted from differences in human activities, predator populations, or vegetation structure. Nesting success of Northern Cardinals and Brown Thrashers was lower than that reported from other studies and may have been below the replacement level. Habitat variables were measured around each nest to characterize the nest site. Northern Mockingbirds had the most open nest sites with the largest inter-canopy distances (spacing between tree canopies), whereas Brown Thrashers seemed to select areas of the groves with the greatest canopy closure. Northern Cardinals tended to select nest trees with full canopies, perhaps to increase nest concealment. Common Ground-Dove nests were supported by limbs with small angles (degrees deviation from horizontal) and the largest diameters. In one of the groves, openness of the nest vicinity was greater around failed Northern Cardinal nests than successful nests, evidence that nest concealment is important to Northern Cardinals. Successful Common Ground-Dove nests in both groves were supported by limbs with smaller angles than were unsuccessful nests. Nearly horizontal limbs may have added stability to ground-dove nests which normally consist of a few sticks.

INTRODUCTION

Citrus groves represent a substantial proportion of the breeding habitat available to birds in Florida, yet no studies have measured nest-site selection or evaluated nesting success of birds in these groves. Kale and Webber (1968) and Webber and Kale (1969) studied birds in Florida citrus groves but only reported species composition and density of breeding males. Because the populations of many species of birds are thought to be declining (Robbins et al. 1986, Terborgh 1989), studies that document nesting success and the factors that may influence it are vital. As more habitat is converted to agricultural and other domestic uses, birds may be forced to nest in altered habitats for which they may be poorly adapted (e.g., Dow 1969a, Rodenhouse and Best 1983, Best and Rodenhouse 1984).

Our objectives were to document nesting success and characterize nest-site selection in 2 Florida citrus groves. We attempted to answer the following questions: What preferences do breeding birds show in selecting their nest sites? What factors influence nesting success? Is nesting success affected by nest-site selection and, if so, how? Are citrus groves suitable nesting habitat for songbirds?

STUDY AREA AND METHODS

Two citrus groves on Merritt Island in Brevard County, Florida were used as study sites. Study grove 1, about 71 ha, was privately owned and managed and was almost entirely planted with orange trees. Study grove 5 was part of the Merritt Island National Wildlife Refuge, was 45 ha, and had a mixture of orange and grapefruit trees. The major herbaceous vegetation in the citrus groves was guinea grass (*Panicum maximum*), poorman's pepper (*Lepidium virginicum*), day-flower (*Commelina diffusa*), Richardia (*Richardia* spp.), prickly sida (*Sida spinosa*), Bermudagrass (*Cynodon dactylon*), vaseygrass (*Paspallum urvellei*), and amaranth (*Amaranthus* spp.). The study took place from mid-March through early June in 1989. Nests were found by systematically examining each tree in the groves four times during the study and by observing bird behavior such as nest building and food carrying. The location of each nest tree was marked on a map of the grove and a tree adjacent to the nest tree was flagged with colored tape.

Nests were monitored on alternate days until they were no longer active. The number and condition of the eggs or young were recorded. Inaccessible nests were checked by using a pole-mounted mirror, climbing the nest tree, or by using a stepladder in the bed of a pickup truck. As part of a concurrent study, nestlings were weighed and measured during each visit until there was a risk of inducing premature fledging. Broods of Northern Cardinals (*Cardinalis cardinalis*) and Brown Thrashers (*Toxostoma rufum*) also were ligatured during the nestling period to collect food samples (see Johnson et al. 1980). To avoid attracting predators to the nest site, the young were processed at least 10 m. from the nest.

Apparent nest success was determined for species with a combined total for both groves of 5 or more nests with known outcomes. A nest was considered successful if at least one nestling fledged. Nest failures were assumed to be the result of avian or snake predation if the nest was empty but undamaged. Nest losses where the nests were torn apart or dislodged or where eggshell fragments or nestling remains were present were attributed to mammalian predators. Nests destroyed by falling fruit or mechanical equipment and losses from pesticide toxicity, starvation or sickness, and egg breakage were grouped into one category. Nests abandoned due to natural causes was another category. Weather did not cause any nest failures, and Brown-headed Cowbird (*Molothrus ater*) parasitism did not occur.

Nesting success also was determined by using the number of days of nest exposure (Mayfield 1975). This reduced the bias associated with finding nests at different stages in the nesting cycle. If the exact date of nest failure was unknown, it was assumed to have occurred midway between the visit when the nest loss was discovered and the previous visit. Because the nesting cycles of species breeding in the groves differed in length and, hence, the number of exposure days, nesting success was calculated separately for each species with an adequate sample size. The computer program MICROMORT (Heisey and Fuller 1985) was used to calculate survival rates for the egg and nestling stages and for the entire nesting period. Deserted nests were excluded from the analyses.

Chi Square contingency analysis (2x3) was used to test for differences in nesting outcomes between the groves. Nests were classified as successful, failed due to predation, or failed due to the following causes: desertion, egg breakage, starvation, sickness, injury, or poisoning of nestlings, or destruction of the nest by falling fruit or mechanical equipment. Tests were made for all species combined [Common Ground-Doves (*Columbina passerina*), Brown Thrashers, Northern Mockingbirds (*Mimus polyglottos*), and Northern Cardinals] and for each species separately, except for the Northern Mockingbird where the sample size was too small to include in individual species analysis. Red-winged Blackbirds were excluded from both analyses because their nests only were found in Grove 5 in localized areas associated with drainage canals.

After a nest became inactive, we recorded variables characterizing the nest vicinity, nest substrate, and nest position within the substrate. Inter-canopy (between canopy perimeters) and inter-tree (between trunks) distances within and between tree rows, and the number of young trees or open spaces where a tree was missing in an area around the nest tree which includes the 8 nearest trees (a measure of the openness of the nest tree vicinity) were determined. In addition, herbaceous ground cover in the nine-tree zone was sampled with 1 m square quadrats placed 5 m from the base of the trunk in the four cardinal directions around the nest tree. (With the exception of one section in one grove, citrus trees were planted using a rectangular planting scheme resulting in rows that all ran in the same direction). Within each quadrat, maximum herbaceous cover height was measured with a tape and the percent coverages of herbaceous vegetation, bare ground, and plant litter were estimated. Citrus type (orange, grapefruit, or hybrid root stock); nest tree height; canopy diameter; and the openness of the nest tree canopy (a visual estimate of the percent closure of the entire canopy) were used to define the nest tree, whereas nest height; relative nest height (the height of the nest divided by the height of the nest tree); the number, angles (degrees deviation from horizontal), and diameters of the six largest limbs supporting the nest, and percent foliage density of the nest tree estimated visually above and below the nest in the area immediately around the nest described the position of the nest within the substrate. Nest-site measurements also were recorded for nests abandoned before discovery if the species could be identified.

Means and variances were calculated for the nest-site variables of Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals. A series of Student's t-tests was used to test for differences in nest-site characteristics among species. Differences in these variables between the nest sites and the groves in general also were evaluated with the Student's t-test. Because sections within the groves were managed differently, tree age and height, canopy diameter, inter-canopy and inter-tree distances, and the amount of herbaceous growth varied. Groves were thus blocked by management units, and the vegetation was randomly sampled within each unit. For the analyses, 25 samples were randomly selected from each plot with the number of samples proportionately distributed among the management units. Student's-t tests were used to test for differences in the variables between successful and failed nests of Common Ground-Doves; Northern Cardinals; and the combined nests of Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals in Grove 1. (Sample sizes for Brown Thrashers and Northern Mockingbirds were too small to run separate t-tests.) Similarly, successful and failed nests of Common Ground-Doves, Brown Thrashers, and Northern Cardinals were compared in Grove 5. All significant relationships are presented in the discussion of the selection of nest-site variables. After testing for correlations between variables with Spearman's rank correlation, we eliminated citrus type, inter-tree distance, and the number of limbs supporting the nest from consideration. Statistical significance was set at $P \leq 0.05$ for all tests unless otherwise stated.

RESULTS AND DISCUSSION

Nesting Success

A total of 54 nests representing five species was found in Grove 1, while 65 nests of seven species were discovered in Grove 5. Of these, the outcome was determined for 46 nests in Grove 1 and 39 nests in Grove 5 (Table1). The most abundant nests were of Northern Cardinals, Brown Thrashers, and Common Ground-Doves, which also were the most common species found in the Merritt Island citrus groves (Crowe and Best, in press).

Potential predators in the citrus groves included the Fish Crow (*Corvus ossifragus*), American Crow (*C. brachyrhynchos*), Blue Jay (*Cyanocitta cristata*), Scrub Jay (*Aphelocoma coerulescens*), yellow rat snake (*Elaphe obsoleta*), eastern indigo snake (*Drymarchon corais*), Everglades racer (*Coluber constrictor paludicola*), eastern coachwhip (*Masticophis flagellum flagellum*), American alligator (*Alligator mississippiensis*), lizards, raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), nine-banded armadillo (*Dasypus novemcinctus*), bobcat (*Felis rufus*), and feral pig (*Sus scrofa*). Fish Crows were probably responsible for most of the predation because they were seen near nests that had recently been depredated and they were observed carrying nestlings out of the groves on several occasions. Although otherwise intact, some depredated nests had their linings pulled up, which also lead us to suspect that crows lifted young out of nests. Constrictors also were thought to be a significant source of nest loss because many depredated nests were intact. A yellow rat snake was seen at the base of a nest tree prior to our discovery that the nest had been recently depredated, and a yellow rat snake was found in another nest consuming nestlings.

Avian or snake predation caused the loss of about two-thirds of all cardinal, thrasher, and mockingbird nests in Grove 1(Table 1). The remaining nest failure categories only accounted for 18% of the nest losses. Of the nests found in Grove 1, only 17% (8 of 46 nests) were successful. A greater percentage of the known nests were successful in Grove 5 (13 of 39 or 33%). Avian or

Table 1. Nesting outcome (percentage of the total number of nests with known outcomes) of Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, Red-winged Blackbirds, and Northern Cardinals in Florida citrus groves.

	Total nests		Successful fledging		Avian or snake predation	
Species	Grove 1	Grove 5	Grove 1	Grove 5	Grove 1	Grove 5
Common Ground-Dove	11	6	36%	66%	46%	17%
Brown Thrasher	13	15	0%	27%	76%	53%
Northern Mockingbird	4	2	0%	50%	75%	0%
Red-winged Blackbird	0	5	0%	0%	0%	80%
Northern Cardinal	18	11	22%	36%	72%	18%
All Nests Combined	46	39	17%	33%	67%	38%

[a] Includes deaths from pesticide exposure, starvation, sickness, or injury, egg breakage, physical disturbance of the nest by heavy equipment, and unknown causes.

Mammalian predation		Desertion		Other causes of nest failure[a]	
Grove 1	Grove 5	Grove 1	Grove 5	Grove 1	Grove 5
9%	0%	9%	0%	0%	17%
8%	7%	8%	13%	8%	0%
0%	0	25%	0%	0%	50%
0%	20%	0%	0%	0%	0%
0%	18%	0%	0%	6%	27%
4%	10%	6%	5%	4%	13%

snake predation also was responsible for most nest failures in Grove 5 (Table 1), but mammalian predation, desertion, and other causes accounted for 28% of the unsuccessful nesting attempts. Red-winged Blackbirds and Brown Thrashers suffered heavy losses from avian or snake predation. Fish Crows were thought to be responsible for four of the five cases of predation on Red-winged Blackbird nests. The crows were seen either at or near the nest sites before we discovered the nest failures. Two of the thrasher nests were depredated when the citrus was being picked. Because Fish Crows were sighted more often during or immediately after picking activity, we suspect that they caused the thrasher nest losses.

The frequency of occurrence of successful and unsuccessful nesting outcomes in the two groves did not differ significantly for Common Ground-Doves (χ^2=2.4, df=2). However, the nesting success of all species combined (χ^2=7.6), of Brown Thrashers (χ^2=4.1), and of Northern Cardinals (χ^2= 4.4) differed between the groves.

Daily nest survival rates were similar for all species in the egg stage, but varied widely in the nestling stage (Table 2). Brown Thrashers in Grove 1 had the lowest daily nest survival rate for nestlings. Interval survival rates were highest during the egg stages, except for Common Ground-Doves. Ground-dove nestlings had a much smaller chance of being destroyed than did the eggs. Nest survival rates spanning both the egg and nestling intervals were greatest for Common Ground-Doves in both groves, followed by Northern Cardinals in Grove 5. Brown Thrashers had the lowest rate of survival, particularly in Grove 1. Survival spanning the entire nesting cycle was higher in Grove 5 than in Grove 1. The nest success of Brown Thrashers and Northern Cardinals in the citrus groves was lower than that reported from other studies. Nesting success rates reported for Brown Thrashers range from 44 to 59% (Kendeigh 1942, Partin 1977, Murphy and Fleischer 1986). In calculating success, Partin only considered nests found during nest building or egg laying periods, whereas Murphy and Fleischer corrected for exposure time with the Mayfield method. Kendeigh reported apparent nest success. For Northern Cardinals,

Table 2. Reproductive success of Common Ground-Doves, Brown Thrashers, and Northern Cardinals in Florida citrus groves.

Species	Exposure days		Daily nest survival rate		Interval nest survival rate		Nest survival rate across egg and nestling stages
	Egg stage	Nestling stage	Egg stage	Nestling stage	Egg stage	Nestling stage	
Common Ground-Dove							
Grove 1	118	104	0.915	0.981	0.32	0.81	0.25
Grove 5	57	44	0.947	0.977	0.49	0.78	0.38
Brown Thrasher							
Grove 1	210	87	0.919	0.736	0.26	0.03	<0.01
Grove 5	281	151	0.947	0.894	0.42	0.29	0.12
Northern Cardinal							
Grove 1	380	132	0.953	0.864	0.48	0.27	0.13
Grove 5	101	97	0.960	0.887	0.54	0.34	0.18

Kinser (1973), using only those nests found before egg laying was complete, calculated success rates of 33% and 53% for eggs and nestlings, respectively, whereas Booth (1980) reported a Mayfield nest success rate of 51%. Information on Common Ground-Dove nesting success is scant, but all the young in seven nests located and monitored in a pine plantation survived to fledging (Landers and Buckner 1979).

The high failure rates of Brown Thrasher nests in both groves and of Northern Cardinal nests in Grove 1 due to avian predation may have resulted from our nest monitoring activities. Both species became vocal when field technicians were near the nest site. Corvids have learned to associate human activity and the response of some nesting passerine species with the presence of active nests (Gottfried and Thompson 1978, Best, pers. obs.) and may have discovered more nests because of our presence. Prior experience with citrus fruit pickers that disturb nesting birds also may have conditioned the crows. Salathe (1987) found that crows that successfully depredated coot (*Fulica atra*) nests would increase their searching around the depredated nests, sometimes resulting in destruction of all nests in the area. He concluded that disturbance created by investigator nest monitoring activities affected crow behavior by revealing nests and providing positive reinforcement. When Common Ground-Doves were flushed from the nest, they did not vocalize but sometimes gave a broken wing display. Those doves that did not display were probably inconspicuous to predators. Those that feigned injury sometimes continued the behavior as far as several tree rows away from the nest which may have lured predators from the nest site. Although Common-Ground Dove eggs are white, the dense citrus tree canopies probably shielded exposed eggs from view. Because Common Ground-Dove nests were small and often placed on thick branches, they were more cryptic than the larger nests of Northern Cardinals and Brown Thrashers. These differences may have accounted for the higher nesting success of Common Ground-Doves.

Differences in nesting success between the groves may have resulted from differences in predator populations, human activities, or vegetation structure. Grove 1, where nests suffered higher predation rates, was in a residential area, whereas Grove 5 was within the Merritt Island National Wildlife Refuge where human disturbance may have been less. The vegetation also differed substantially between the two groves (Tables 3 &4) and may have influenced nest predation.

Citrus culture operations were largely responsible for differences in grove vegetation. Tree hedging, topping, and skirt pruning influenced the geometry of the tree canopies and the inter-canopy distance, whereas mowing and herbicide application controlled the amount of herbaceous cover. Because the citrus groves were managed differently, tree canopy diameters were greater in Grove 5 than in Grove 1 and the relative openness below tree canopies, represented by the height above the ground of the lowest tree foliage, tended to be smaller in Grove 5. Herbaceous and litter coverages were greater in Grove 5 than in Grove 1, whereas bare ground coverage was greater in Grove 1 (Tables 3 &4). Less vegetative cover in Grove 1 may have resulted in decreased nest concealment. Although some investigators have found no correlation between nesting cover and nesting success (Reynolds 1981, Conner et al. 1986), Ehrhart and Conner (1986) reported a correlation between vegetative cover around the nest and nesting success, and Martin and Roper (1988) found predation to be greater around less well-concealed nests.

In addition to altering herbaceous and tree-canopy cover, citrus culture operations may have affected breeding birds by creating disturbances which may have increased nest desertion, particularly during nest building. We suspect this because at least two nests were deserted in the nest building stage because of our nest monitoring activities. Also, pesticides were routinely applied in the groves and had the potential of poisoning adults and nestlings, resulting in decreased survival and nesting success.

The low nesting success of the breeding birds in the citrus groves suggests that their

Table 3. Habitat variables ($\bar{X} \pm SD$) characterizing nest sites and from representative samples of Grove 1. Levels of significance: * = $P \leq 0.05$, ** = $P \leq 0.01$.

	Nest sites				
Habitat variables	Common Ground-Dove n=14	Brown Thrasher n=18	Northern Mockingbird n=4	Northern Cardinal n=20	Citrus grove in general n=25 [a]
Nest vicinity					
Litter (%)	55 ± 26 **	57 ± 26 **	46 ± 24 **	60 ± 22 **	21 ± 25
Bare ground (%)	23 ± 27 **	19 ± 25 **	19 ± 25 *	16 ± 19 **	40 ± 37
Herbaceous vegetation (%)	13 ± 22	12 ± 23	23 ± 27	14 ± 22	21 ± 30
Herbaceous vegetation height (cm)	22 ± 14	21 ± 13	47 ± 16	21.5 ± 14	
Intercanopy distance (cm)	159 ± 77	153 ± 107	287 ± 135 *	149 ± 88	143 ± 130
Openness near nest tree [b]	1.2 ± 2.0	1.9 ± 2.6	5.0 ± 3.6	1.3 ± 1.3	
Nest tree					
Canopy diameter (cm)	497 ± 79	513 ± 103	474 ± 128	461 ± 105	480 ± 175
Openness of tree canopy (%)	51 ± 29	55 ± 23	44 ± 23	43 ± 28	
Tree height (cm)	413 ± 85	433 ± 88	436 ± 79	423 ± 135	475 ± 157
Nest placement					
Limb angle (°)	28 ± 33	38 ± 31	60 ± 35	33 ± 27	
Limb diameter (cm)	5.4 ± 4.5	1.9 ± 0.5	1.5 ± 0.7	1.2 ± 0.9	
Foliage density class above nest [c]	2.5 ± 0.7	2.2 ± 0.4	2.0 ± 0.8	2.15 ± 0.7	
Foliage density class below nest [c]	1.1 ± 0.5	1.6 ± 0.5	1.75 ± 1.0	1.25 ± 0.5	
Nest height (cm)	200 ± 41	263 ± 93	299 ± 85	261 ± 73	
Relative nest height (%)	49 ± 7	60 ± 12	68 ± 12	67 ± 33	

[a] Number of samples from the grove.

[b] Number of young trees or open spaces where trees were missing in an area around the nest tree.

[c] Foliage density estimates: 1 = cover <25%, 2 = 25-50%, 3 = >50%.

Table 4. Habitat variables ($\bar{X} \pm SD$) characterizing nest sites and from representative samples of Grove 5. Levels of significance: $* = P \le 0.05$, $** = P \le 0.01$.

Habitat variables	Nest sites Common Ground-Dove n=7	 Brown Thrasher n=25	 Northern Mockingbird n=3	 Northern Cardinal n=14	Citrus grove in general n=25[a]
Nest vicinity					
Litter (%)	29 ± 26	36 ± 29	27 ± 24	23 ± 23	30 ± 25
Bare ground (%)	12 ± 20	11 ± 21	0.2 ± 0.7	18 ± 36	10 ± 18
Herbaceous vegetation (%)	45 ± 27	45 ± 31	71 ± 19 **	54 ± 24	44 ± 27
Herbaceous vegetation height (cm)	48 ± 18	58 ± 24	59 ± 31	50 ± 16	
Intercanopy distance (cm)	220 ± 83	144 ± 104 *	468 ± 66	275 ± 126	250 ± 223
Openness near nest tree[b]	2.4 ± 2.8	1.3 ± 1.4	7.3 ± 11	2.4 ± 2.9	
Nest tree					
Canopy diameter (cm)	560 ± 157	585 ± 100	228 ± 65 **	534 ± 174	528 ± 156
Openness of tree canopy (%)	69 ± 26	66 ± 18	69 ± 27	50 ± 24	
Tree height (cm)	456 ± 69	507 ± 90	334 ± 102	456 ± 146	485 ± 135
Nest placement					
Limb angle (°)	30 ± 24	34 ± 29	80 ± 17	45 ± 35	
Limb diameter (cm)	2.5 ± 0.9	1.7 ± 0.9	1.5 ± 0.7	1.9 ± 2.2	
Foliage density class above nest[c]	2.7 ± 0.5	2.4 ± 0.6	2.7 ± 0.6	2.5 ± 0.6	
Foliage density class below nest[c]	1.4 ± 0.5	1.4 ± 0.6	2.0 ± 1.0	1.6 ± 0.7	
Nest height (cm)	220 ± 45	316 ± 80	130 ± 17	214 ± 95	
Relative nest height (%)	49 ± 10	61 ± 13	41 ± 11	46 ± 13	

[a] Number of samples from the grove.

[b] Number of young trees or open spaces where trees were missing in an area around the nest tree.

[c] Foliage density estimates: 1 = cover <25%, 2 = 25-50%, 3 = >50%.

reproductive output was below the replacement level. Such sink populations have been documented in other agricultural environments (Wray et al. 1982, Frawley 1989, Bryan 1990). Low reproductive success per breeding attempt may be compensated for by the long breeding season in Florida. Common Ground-Doves are thought to breed year-round in Florida (Baynard 1909 in Howell 1932, Landers and Buckner 1979), Northern Mockingbirds and Northern Cardinals nest from March through August (Bent 1968, Woolfenden and Rohwer 1969), and Brown Thrashers nest from March through July (Bent 1948).

Selection of the Nest Vicinity

In Grove 1, litter coverage was significantly greater around the nest trees of all species than in the grove in general, whereas the coverage of bare ground was significantly less (Table 3). Litter and bare ground coverages around nest vicinities in Grove 5 did not differ significantly from the grove overall, but the coverage of herbaceous vegetation around Northern Mockingbird nests was significantly greater than from representative samples of the grove (Table 4). A nonsignificant trend of greater herbaceous coverage around Northern Cardinal nest vicinities than in the grove in general also was found in Grove 5. When all species were compared, Northern Mockingbird nest vicinities had significantly more herbaceous vegetation coverage (Table 5). Because Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals commonly forage on the ground (De Graaf et al. 1985), the coverages of herbaceous vegetation, litter, and bare ground may have been important in their selection of a nest vicinity. Selection of the nest vicinity also may have been influenced by grove edges because edge habitats may have been important foraging areas. Fichter (1959) concluded that the breeding density of Mourning Doves (*Zenaida macroura*) in Idaho apple orchards was not affected as much by nesting cover as it was by the adjacent habitat type.

Inter-canopy distance was greater around Northern Mockingbird nest trees in Grove 1 than in the grove in general (Table 3). In Grove 5, there was a nonsignificant trend of greater

Table 5. Habitat variables ($\bar{X} \pm SD$) characterizing nest sites. For each habitat variable, means not followed by the same letter differed significantly ($P \leq 0.05$) when compared with a series of Student's t-tests.

	Nests			
Habitat variables	Common Ground-Dove n=21	Brown Thrasher n=43	Northern Mockingbird n=7	Northern Cardinal n=34
Nest vicinity				
Litter (%)	48 ± 28 A	46 ± 30 AB	38 ± 25 ABC	46 ± 28 ABC
Bare ground (%)	20 ± 26 A	14 ± 23 AB	11 ± 21 ABC	16 ± 25 ABC
Herbaceous vegetation (%)	22 ± 28 A	30 ± 32 AB	44 ± 34 C	29 ± 30 AB
Herbaceous vegetation height (cm)	31 ± 20 A	42 ± 27 AB	53 ± 21BC	33 ± 20 AB
Intercanopy distance (cm)	179 ± 83 A	143 ± 100 AB	365 ± 142 C	201 ± 121 A
Openness near nest tree	1.6 ± 2.3 A	1.5 ± 2.0 AB	6.0 ± 2.9 C	1.7 ± 2.1 AB
Nest tree				
Canopy diameter (cm)	518 ± 111A	555 ± 106 AB	369 ± 163 C	493 ± 138 A
Openness of tree canopy (%)	57 ± 28 A	61 ± 21 AB	55 ± 26 ABC	46 ± 26 AC
Tree height (cm)	427 ± 81A	476 ± 95 B	392 ± 98 AC	437 ± 139 ABC
Nest placement				
Limb angle (°)	28 ± 30 A	35 ± 30 AB	69 ± 28 C	38 ± 31 AB
Limb diameter (cm)	4.4 ± 3.9 A	1.8 ± 0.8 B	1.5 ± 0.6 ABC	1.5 ± 1.6 BC
Foliage density above nest [a]	2.5 ± 0.6 A	2.3 ± 0.6 AB	2.3 ± 0.8 ABC	2.3 ± 0.7 ABC
Foliage density below nest [a]	1.2 ± 0.5 A	1.5 ± 0.6 AB	1.9 ± 0.9 BC	1.4 ± 0.7 ABC
Nest height (cm)	207 ± 43 A	297 ± 84 B	227 ± 109 AC	241 ± 85 AC
Relative nest height (%)	49 ± 8 A	61± 13 B	56 ± 18 ABC	58 ± 28 ABC

[a] Foliage density estimates: 1= cover <25%, 2= 25-50%, 3= >50%.

inter-canopy distance around Northern Mockingbird nest trees than in the grove overall (Table 4). When all species were compared, a significant difference was found in inter-canopy distance around mockingbird nests (Table 5). The number of young trees or open spaces where a tree was missing near the nest tree, another measure of the openness of the nest vicinity, also was highest around Northern Mockingbird nest sites in both groves (Tables 3 &4) and was significantly different from the nest sites of the other species (Table 5). Woolfenden and Rohwer (1969) described ideal Northern Mockingbird nesting habitat as areas of "spaced" trees and found that nests were usually located in the more sparsely wooded or open sections of their plots. Brown Thrasher nest sites in Grove 5 had smaller inter-canopy distances than did a representative sample of the grove (Table 4), suggesting that thrashers chose sections of the grove with more closed tree canopies. Inter-canopy distances for Brown Thrasher nest sites were similar in both groves (Tables 3 &4), and differed significantly from both mockingbirds and cardinals (Table 5). Fischer (1980) found that Long-billed Thrasher (*Toxostoma longirostre*) nests often were placed in thickets with dense leaf canopies that provided excellent concealment.

Selection of the Nest Tree

Canopy diameter, which was negatively correlated (Spearman's rho=-0.595, P=0, df=106) with inter-canopy distance, was largest for Brown Thrasher and Common Ground-Dove nest trees in both groves (Tables 3 &4). Northern Mockingbird nest trees in Grove 5 had the smallest canopy diameters and these were significantly different from canopy diameters in the grove overall (Table 4). Northern Mockingbird nest tree canopy diameters were significantly less than those of all other species (Table 5).

Nest-tree canopies tended to be less open in Grove 1 than in Grove 5. The openness of the nest-tree canopy was smallest for Northern Cardinals (Tables 3 &4), and was significantly different from Brown Thrashers (Table 5). In choosing a nest tree, Northern Cardinals may try to maximize nest concealment. In his study of Northern Cardinal habitat selection, Dow (1969b) stressed the importance of adequate nest cover.

Nest-tree height in Grove 1 was similar for all species, but it varied more widely among species in Grove 5 (Tables 3 &4). Both groves primarily had even-aged trees, but sections of young trees in both groves and older, dying trees in Grove 1 provided variation in tree height. (In Grove 1, those trees that we measured ranged from 1.4 to 8.7 m tall, whereas in Grove 5, the range was 1.2 to 10.3 m.) The shortest nest trees were chosen by mockingbirds in Grove 5, whereas the tallest nest trees were selected by Brown Thrashers in this grove. Northern Cardinals in both groves selected nest trees of similar heights, as did Common Ground-Doves. When all species were compared, only Brown Thrashers' nest tree heights differed significantly (Table 5).

Placement of the Nest

The angle of limbs supporting the nest was largest for Northern Mockingbirds and smallest for Common Ground-Doves in both groves (Tables 3 &4), but only the Northern Mockingbird differed significantly when all species were compared (Table 5). The diameter of limbs supporting nests was similar for all species, except for ground-doves, which had nests supported by the largest limbs. As none of the nests that we monitored were dislodged by wind or rain, the sturdy limbs of mature citrus trees seemed to provide adequate nest support for all species.

In Grove 1, relative nest height was greatest for the mockingbird and cardinal and least for the ground-dove (Table 3). In Grove 5, thrasher nests had the highest relative nest height, whereas mockingbird nests had the lowest (Table 4). Because mockingbirds in Grove 5 chose short trees (2 were young starts), potential nest height was limited. Woolfenden and Rohwer (1969) calculated a nest height range for Florida mockingbirds of 0.9 -6.7m, with an average of 2.4 m, whereas Laskey (1962) reported a range of 0.5 -6.0 m. The average height of mockingbird nests in both citrus groves fell within these ranges. When all species were compared, however, only the Common Ground-Dove and Brown Thrasher differed significantly from one another (Table 5).

Factors Influencing Nesting Outcome

When successful and unsuccessful nests were compared for each species, only 6 of the nest site variables seemed to influence nesting success (Table 6). The nest vicinity and the placement of the nest in the tree were important, but the nest tree variables did not appear to be.

In Grove 1, openness near the nest tree was greater for failed Northern Cardinal nests than for successful ones. Nest concealment is believed to have a large influence on Northern Cardinal success (Ehrhart and Conner 1986), and an open nest vicinity may have facilitated Fish Crows' observing activity around the nest site. In Grove 5, the height of herbaceous vegetation in the vicinity of Northern Cardinal nests was significantly less for successful nests than for unsuccessful nests, but we have no evidence to suggest that this finding is biologically meaningful. Successful Common Ground-Dove nests in Grove 5 were placed in trees with significantly larger inter-canopy distances than were unsuccessful nests, but again we do not think this is biologically meaningful.

Nest placement appeared to affect only Common Ground-Dove nesting success. Successful Common Ground-Dove nests in Grove 5 had supporting limbs with significantly smaller angles than did unsuccessful nests. Successful Common Ground-Dove nests in Grove 1 also had smaller angles than did unsuccessful nests, although this difference was not significant. Because Common Ground-Doves build frail nests with shallow depressions (Howell 1932), they may have chosen smaller-angled limbs for added nest stability. Mourning Doves preferentially place their nests on flat, horizontal limbs (Harris et al. 1963, Knight et al. 1984). Successful Common Ground-Dove nests in Grove 5 also were significantly closer to the ground than unsuccessful ones.

Citrus groves seemed to be suitable breeding habitat for songbirds and doves, based on the number of active nests. Birds appeared to be making choices about the openness of the nest

Table 6. Nest site variables ($\bar{X}$ ± SD) near successful and failed nests in the groves. Significant differences (t-test) are indicated by asterisks ($P \leq 0.05$).

	Common Ground-Dove		
Nest site variables	Successful		Failed
Nest vicinity	Grove 1		
Openness near nest tree [b]	1.2 ± 2.5		1.4 ± 2.1
Nest vicinity	Grove 5		
Intercanopy distance (cm)	267 ± 28	*	141 ± 51
Herbaceous vegetation height (cm)	46 ± 28		51 ± 11
Nest placement			
Limb angle (°)	10 ± 17	*	50 ± 17
Nest height (cm)	180 ± 12	*	260 ± 34
Relative nest height (%)	40 ± 9	*	57 ± 2

[a] Includes Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals.

[b] Number of young trees or open spaces where trees were missing in an area around the nest tree.

Northern Cardinal			All species combined[a]	
Successful		Failed	Successful	Failed
Grove 1			Grove 1	
0.5 ± 0.6	*	1.7 ± 0.9	0.9 ± 1.7	2.0 ± 2.5
Grove 5			Grove 5	
287 ± 181		258.5 ± 125	246 ± 140	186.5 ± 133
33 ± 10	*	54.5 ± 10	45 ± 21	55 ± 21
22 ± 29		35 ± 29	24 ± 29	38 ± 27
205 ± 106		232 ± 96	222 ± 110	268 ± 81
40 ± 8		49 ± 15	46 ± 12	55 ± 14

vicinity, the diameter and openness of the tree canopy, tree height, limb angle and diameter, and nest height. These choices may have been based on nest concealment and nest support, but did not necessarily influence nesting outcome. For example, the selection of nest trees with closed canopies did not appear to affect nesting outcome of Brown Thrashers, whereas the choice of small-angled limbs may have increased nesting success for Common Ground-Doves. Because citrus groves are unnatural environments subjected to periodic human disturbances which may have inflated predation levels, the choices of some nest site variables that are adaptive in natural habitats may be neutral or maladaptive in citrus groves.

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SECTION III. GROWTH OF COMMON GROUND-DOVES

Growth of Common Ground-Doves

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INTRODUCTION

Nestling growth and development, and the selective forces that may influence them, have been extensively reviewed (e.g., Ricklefs 1968,1973; O'Connor 1977; Case 1978). Pigeons and doves are unusual among birds in having rapid growth rates and a small clutch size (Ricklefs 1968). Westmoreland et al. (1986) proposed that rapid growth in columbids may result from the highly nutritious crop milk fed to the young. Interest in this group has lead to growth studies in Mourning Doves (*Zenaida macroura*) (Hanson and Kossack 1963, Holcomb and Jaeger 1978, Westmoreland and Best 1987), Ruddy Ground-Doves (*Columbigallina talpacoti*) (Haverschmidt 1953), Wood-Pigeons (*Columba palumbus*) (Robertson 1986), Collared Doves (*Streptopelia decaocto*), Feral Pigeons (*C. livia*), and Stock Doves (*C. oenas*) (Robertson 1986), but not in Common Ground-Doves (*Columbina passerina*). Here we report on the growth of the Common Ground-Dove and on the parameters that describe logistic growth curves for its mass and tarsus development.

Hanson and Kossack (1963) used wing, tarsus, and total body length and feather development to create a guide for aging nestling Mourning Doves. However, some investigators characterize growth only by measuring mass. Because mass may fluctuate more on a daily basis than tarsus development, we felt that it was important to characterize growth by using both mass and skeletal growth. Best (1977) found that variation in mass of nestling Field Sparrows (*Spizella pusilla*) was greater than the variation in tarsus length and concluded that skeletal growth is less affected by external factors. Likewise, Westmoreland and Best (1987) reported that in Mourning Doves, carpometacarpus length had smaller coefficients of variation than did nestling mass. They postulated that differences in the fullness of crops was responsible.

STUDY AREA AND METHODS

Two citrus groves on Merritt Island in Brevard County, Florida were the study sites. Nest searches were conducted about every two weeks from 20 March until 24 May, 1989. Howell (1932) reported that Common Ground-Doves in Florida nest from February to October, and Passmore (1981) reported finding Common Ground-Dove nests in south Texas from late March through mid-October. Once nests were located, their status was monitored on alternate days. After the eggs hatched (no nests in our study contained more than the usual two eggs), the claws of nestlings were clipped for individual identification. During each visit to the nest, nestlings were weighed to the nearest 0.1g using a 50-g Pesola scale, and tarsus length was measured to the nearest 0.1 mm with a dial caliper. Nestlings usually were measured until there was a risk of inducing premature fledging. According to Goodwin (1983), incubation normally lasts 13-14 days, and the young fledge at 11 days. We also found that the young fledge at 10 or 11 days, but they were sometimes found in or near the nest for one or two days afterwards.

Growth rates were evaluated using both body mass and skeletal dimensions. For all statistical tests, broods were used as sample units ($N= 8$ broods) because measurements of nestlings within a brood are not independent. We used a nonlinear least squares iterative technique to estimate growth parameters (PROC NLIN, SAS Institute 1985). A logistic model of growth seemed to fit our data better than a natural growth function (negative exponential), based on smaller residual mean square error, smaller asymptotic standard errors of parameters, and more normally distributed residuals. We fit the logistic equation in the form: $Y=A/\{1+G*\exp[-K(\mathrm{day})]\}$, where Y is mass or tarsus length, A is the asymptote of Y, G is a parameter positioning the inflection point, and K is the growth rate constant.

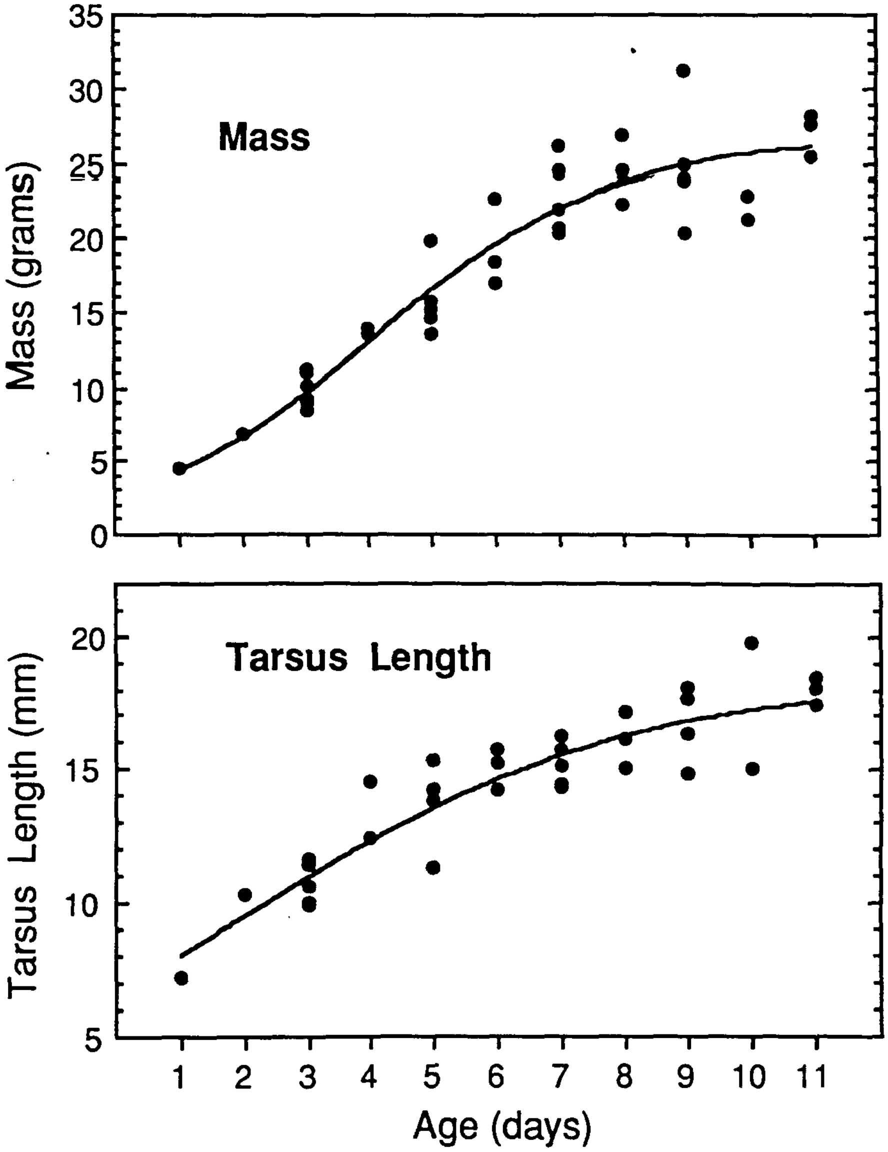
RESULTS AND COMMENTS

The growth pattern of young Common Ground-Doves appears to be sigmoidal (Fig. 1). The increase in mass per day (K=0.53±0.08) occurred more rapidly than that of tarsus length (K=0.32±0.07). Tarsus growth approached an asymptote at 18.5±1.1(S.E.) mm, whereas daily mass gain leveled off at 26.8±1.3 g. The faster growth rate of mass resulted in a shorter time to body mass asymptote of about eight days. Nearly 10 days were required for the tarsus length to approach the asymptote. The parameter G, which positioned the inflection point, was 8.67±2.5 for mass gain and 1.79±0.29 for tarsus development. The growth rate constant and the asymptote were highly negatively correlated (-0.78 for increase in mass, -0.90 for tarsus growth), as is expected when simultaneously fitting these parameters.

Comparisons of growth rate constants among columbids are limited by the fact that equations other than the logistic have been used to fit the data, and parameters are frequently published without estimates of statistical precision. Blockstein (1989) modeled growth in Mourning Doves with Richards curves, but we did not have enough data to reasonably estimate the four parameters required for this equation. Ricklefs (1968) obtained a growth rate constant of 0.22 for Wood-Pigeon mass, but he used the Gompertz equation. The logistic equation was used by Westmoreland and Best (1987), who estimated a carpometacarpus growth rate constant of 0.405 for the Mourning Dove. Ricklefs (1968) also used the logistic equation and obtained a growth rate constant of 0.46 for Ruddy Ground-Dove mass. The differences between the other estimates and our own are due, at least in part, to the inability of the others' methods to account for the correlation among parameter estimates.

The ratio (R) of the asymptotic mass at fledging to adult body mass (Ricklefs 1968) has been calculated for several columbids and can be used for comparative purposes. Values less than 1.0 for fledgling-adult body mass ratios are predicted for ground-foraging birds (Ricklefs 1968), and, accordingly, ratios for most columbids range from 0.26 to 0.77 (Robertson 1986), with

Figure 1. Mass and tarsus-length growth of Common Ground-Doves in Florida. The dots represent measured values; the curves were generated from the best fit non-linear least squares logistic equation for these data.


Mass
Mass (grams)
0
5
10
15
20
25
30
35
Tarsus Length
Tarsus Length (mm)
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
Age (days)

many species fledging before attaining 62% of adult body mass. Adult Common Ground-Doves weigh about 42 g (Crowe and Best, unpubl. data), and we calculated an R value of 0.64 for this dove species. Using data from Haverschmidt (1953), Robertson (1986) determined that the R value of Ruddy Ground-Doves was 0.62. Adults of this species weigh only a few grams more than the Common Ground-Dove and occupy similar habitats (Haverschmidt 1953). The ratio between the asymptotic tarsus length of Common Ground-Dove fledglings and adult tarsus length is 0.90. This ratio may reflect the importance of rapid development of the tarsus in a terrestrial species. Because many columbids are ground-foragers, future studies of growth should include an analysis of tarsus length.

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GENERAL SUMMARY

The most abundant species in the 13 citrus groves were the Northern Cardinal (*Cardinalis cardinalis*), Mourning Dove (*Zenaida macroura*), Common Ground-Dove (*Columbina passerina*), Brown Thrasher (*Toxostoma rufum*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), and Northern Mockingbird (*Mimus polyglottos*). Total bird abundances in the groves averaged 2306 birds/ count / 100 ha with a range of 877-4880. Thirty bird species were recorded. Birds observed in the citrus groves were breeding birds that nested in the groves or adjacent edges and transients that temporarily used the groves for feeding. A negative correlation between Common Ground-Dove abundance and the age of citrus groves suggested that this species prefers small trees. Northern Cardinal abundance was negatively correlated with inter-canopy distance (spacing between tree canopies) and may have reflected the importance of nest concealment for cardinals. The abundance of Northern Mockingbirds appeared to be influenced by the presence of adjacent residential areas, whereas the abundance of Mourning Doves was correlated with the proportion of herbaceous canal edge habitat bordering the groves. Because herbaceous canal edges typically had few trees and shrubs, they may have provided open areas for this dove.

Nesting success and nest-site selection of Common Ground-Doves, Northern Mockingbirds, Brown Thrashers, and Northern Cardinals was documented in 2 Florida citrus groves. Predation resulted in the failure of more than half of all nests, with Fish Crows (*Corvus ossifragus*) and yellow rat snakes (*Elaphe obsoleta*) the major predators. Human disturbance in the groves was thought to have increased crow depredation. Differences in nesting success between the groves may have resulted from differences in human activities, predator populations, or vegetation structure. Nesting success of Northern Cardinals and Brown Thrashers was lower than that reported from other studies and may have been below the replacement level. Brown Thrashers appeared to choose sections of the groves with the most canopy closure, whereas Northern Mockingbirds had the most open nest sites with the largest inter-canopy distances (spacing between tree canopies). In general, Northern Cardinals selected nest trees with full canopies, perhaps to maximize nest concealment. Common Ground-Dove nests were supported by limbs with small angles (degrees deviation from horizontal) and the largest diameters. In one of the groves, openness of the nest vicinity was less around successful Northern Cardinal nests than failed nests, evidence of the importance of nest concealment to Northern Cardinals. Successful Common Ground-Dove nests were supported by limbs with smaller angles than were unsuccessful nests, suggesting that horizontal limbs may have added stability to ground-dove nests.

Growth rates of Common Ground-Doves were evaluated using body mass and skeletal dimensions, and a nonlinear least squares iterative technique was used to estimate growth parameters (PROC NLIN, SAS Institute 1985). A logistic model of growth seemed to best fit the data based on smaller residual mean square error, smaller asymptotic standard errors of parameters, and more normally distributed residuals. The increase in mass per day ($K=0.53\pm0.08$) occurred more rapidly than that of tarsus length ($K=0.32\pm0.07$). The parameter G, which positioned the inflection point, was 8.67 ± 2.5 for mass gain and 1.79 ± 0.29 for tarsus development. The growth rate constant and the asymptote were highly negatively correlated (-0.78 for increase in mass, -0.90 for tarsus growth). We calculated an R value [the ratio of the asymptotic mass at fledging to adult body mass (Ricklefs 1968)] of 0.64 for Common Ground-Doves. This value fell within the range reported for most columbids (Robertson 1986). The ratio between the asymptotic tarsus length of Common Ground-Dove fledglings and adult tarsus length is 0.90, and may reflect the importance of rapid development of the tarsus in a terrestrial species.

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