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WINTER HABITAT OF KIRTLAND'S WARBLER: AN ENDANGERED NEARCTIC/NEOTROPICAL MIGRANT

PAUL W. SYKES, JR.[1,4] AND MARY H. CLENCH[2,3]

ABSTRACT.—Habitats of Kirtland's Warbler (*Dendroica kirtlandii*) on the wintering grounds in the Bahama Archipelago are presented based upon data from 29 specimens, two bandings, and 67 sightings of at least 61 individuals on 13 islands scattered through the region. We placed a major emphasis on a study site in central Eleuthera, with additional information from sites on Grand Turk, North Caicos, and Crooked Island. The warblers used upland habitats that have a low shrub/scrub component with a mosaic of small openings and openings within the vegetation at the ground level. Six broad habitats were used: natural shrub/scrub, secondary shrub/scrub, low coppice, pineland understory, saline/upland ecotone, and suburban; high coppice was not used. The structure and floristic composition of the habitats are described. Observations (n = 451) of a Kirtland's Warbler male (uniquely color banded) and female over three months indicated the birds generally stayed within 3 m of the ground (98% of observations), and used a territory of 8.3 ha. A crude estimate of potential winter habitat suggests that not only is there more than an adequate amount in the Bahama Archipelago for the current small population of warblers (733 singing males in 1997), but also enough for a considerably larger population. No serious future threat to the amount of that habitat is foreseen. *Received 5 May 1997, accepted 13 Jan. 1998.*

Kirtland's Warbler (*Dendroica kirtlandii*) breeds in the Upper Peninsula (rarely) and northern Lower Peninsula of Michigan and winters in the Bahama Archipelago (Fig. 1) (Mayfield 1960, 1972, 1992, 1996; Radabaugh 1974; Clench 1978; Walkinshaw 1983; Sykes 1989; C. I. Bocetti and J. Weinrich, pers. comm.). The small population (200 singing males during the breeding season in 1976, 219 in 1977, 215 in 1984, and 217 in 1985 during periods of this study; more recently 766 in 1995, 692 in 1996, and 733 in 1997; Weinrich 1995, pers. comm.) is widely dispersed in the islands during winter. On the wintering grounds the species is a skulker in low, dense vegetation and does not sing, but will give loud chip notes similar to those of the Ovenbird (*Seiurus aurocapillus*). Surveys for passerines in the Bahamas have located only four Kirtland's Warblers before this study in 1985 and 1986 (Van Tyne 1951; Van Tyne and Mayfield 1952; Paulson 1966; Mayfield 1960, 1972, 1992; Radabaugh 1974; Emlen 1977; Clench 1978; Buden 1987a, 1987b, 1990, 1992a, 1992b). Since the end of extensive collecting in the late 1800s and early 1900s, most warblers have been located by chance. Except for observations by Radabaugh (1974) on Crooked Island (<2 h on 3 days over a 12-day period), and Sykes' work on Eleuthera, all sightings of this species in winter have been brief one-time events. For this reason, little has been published on the winter habitat of Kirtland's Warbler. Mayfield (1972, 1996) summarized what little was known of the warbler's winter habitat, Radabaugh (1974) described the site where he found a bird in March 1973 on Crooked Island, and Clench (1978) briefly described where she observed a warbler in February 1978 on North Caicos. Because this endangered species spends at least 40%–60% of the year on its wintering grounds (Mayfield 1972, 1992; Walkinshaw 1983; Sykes et al. 1989), it is important for its long-term management and conservation to know more about its habitat requirements. In this paper we summarize what is known of the winter habitat of Kirtland's Warbler and report our more recent findings on the subject.

STUDY AREA

The Bahama Archipelago consists of the islands of the Commonwealth of the Bahamas and the British Crown Colony of the Turks and Caicos Islands in the British West Indies. They rise from a multisectioned platform of shallow-water marine limestones on a northwest-southeast axis spanning some 1,012 km. The islands extend from 20° 55′ to 27° 30′ N latitude and from 71° 10′ to 79° 20′ W longitude and lie within the East Trade Wind belt of the western North Atlantic

[1] USGS, Patuxent Wildlife Research Center, Warnell School of Forest Resources, Univ. of Georgia, Athens, GA 30602-2152; E-mail: Paul_Sykes@usgs.gov

[2] Carnegie Museum of Natural History, Pittsburgh, PA 15213.

[3] Present address: 3943 NW 42nd Court, Gainesville, FL 32606.

[4] Corresponding author.

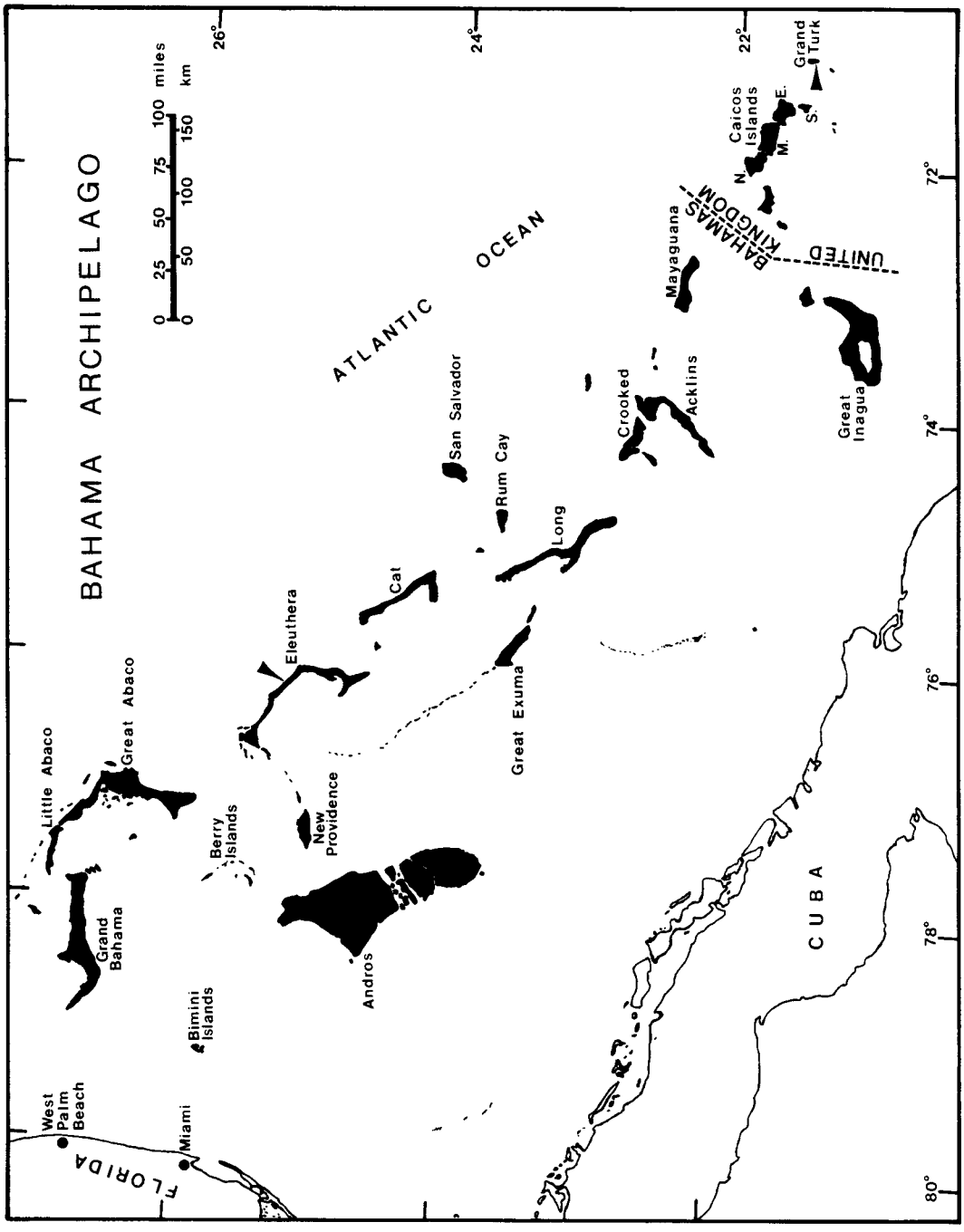
(Gillis 1977, Correll and Correll 1982, Sealey 1994). The islands have relatively low topography (maximum elevation above sea level is 64 m on Cat Island), and are geologically similar and distinctly oceanic. Floristically, they are also similar, although the northern islands with pine forest (*Pinus caribaea*) are more mesic, and the drier islands to the south are covered by dense scrub. The archipelago encompasses 260,000 km^2 and has 35 major islands, about 700 cays, and an estimated 2400 exposed rocks that have some type of vegetation. The land mass is approximately 14,500 km^2. The climate is tropical (no record of freeze): Grand Bahama (Freeport, 1973–1982), mean annual temperature 24° C, mean annual range 17–29° C; Great Inagua (Matthew Town, 1973-1982), mean 26° C, range 22–29° C (N. E. Sealey, pers. comm.); and Grand Turk, mean 27° C, range 16–36° C (Pearce and Smith 1990). Rainfall is highest in the north, decreasing southeastward: Grand Bahama (Freeport, 1973–1990), mean annual rainfall 141 cm, mean annual range 92–186 cm; Great Inagua (Matthew Town, 1973–1990), mean 67 cm, range 31–99 cm (N. E. Sealey, pers. comm.); and Grand Turk, mean 73 cm (no range available; Pearce and Smith 1990). The islands have an annual rainfall cycle, are subject to hurricanes, and are generally wettest from May through November. Rainfall varies between years on any given island and between islands at the same latitude. The Bahamas have no surface-flowing freshwater streams or rivers nor large freshwater lakes (Gillis 1977, Correll and Correll 1982). The highly variable landforms are well described in Sealey (1994). The primary island landscapes are ridges formed from old dunes and relatively flat rocklands formed from limestone deposits. Secondary landscapes include coastal cliffs and headlands, wave–cut platforms, dunes, beaches, and coastal and inland wetlands. Kirtland's Warbler habitats occur mainly on the two primary landscapes.

Bahamian vegetation has been seriously altered since the Eighteenth Century (Mooney 1905). After 1718, when pirates had been subdued, European settlers made widespread attempts at agriculture on many of the islands. The land was planted to cotton and later with other crops like sisal, citrus, tobacco, and tomatoes. After the abolition of slavery in 1834, little commercial agriculture continued and the land reverted to scrub, but the damage to native habitats had been done. Today Bahamian agriculture is largely limited to individual farm plots cleared in the scrub, where the thin remaining soil lies in depressions in the surface limestone. The history of land use in the Bahamas is yet to be thoroughly documented, but the ravages of the early attempts at agriculture are clearly evident. Today, as one walks over the stony ground and pavement limestone of uninhabited scrub, the soil is gone (if it was ever there), yet wild cotton plants still grow on some islands (Clench, pers. obs.).

The biotic communities in the archipelago have been classified into a number of broad categories. Gillis (1977) referred to five major vegetation types: pineland, coppice, scrubland, strand, and mangrove, but did not mention freshwater communities or salt marshes. Correll (1979) and Correll and Correll (1982) recognized the following generalized plant communities: coastal rock, sand strand and *Uniola,* coastal coppice, whiteland (low dunes and flats), fresh water, tidal flats and salt marshes, mangrove, blackland (includes high and low coppice), and pineland (wet and dry barrens). With some modifications, we have used the works of Gillis (1977) and Correll and Correll (1982), plus our own field experience in the islands to describe the six habitat types in which Kirtland's Warblers have been found.

The habitats described herein are based upon sites where Kirtland's Warblers have been found throughout the archipelago, 1879 through 1994, but with emphasis on our work on Eleuthera, Grand Turk, and North Caicos. Several additional reports (specimens and sightings) could not be assigned to a habitat type because of insufficient data. Descriptions of the habitats include some general physiognomic characteristics and dominant floristic composition. These upland, mostly well-drained, habitats include: (1) natural shrub/scrub, (2) secondary shrub/scrub, (3) low coppice, (4) pineland understory, (5) saline/upland ecotone, and (6) suburban. The term coppice is widely used throughout the Bahamas and refers to the mostly tropical broad-leaved mixed evergreen-deciduous woodlands in which most of the plant species can propagate from stumps and roots as well as from seeds. Common names of plants are used throughout. (An alphabetical listing of all plants by common name, scientific name and family, growth form, status, and maximum height is given in the Appendix). Vernacular and scientific names mostly follow Correll and Correll (1982). The six principal Kirtland's Warbler wintering habitats are described as follows.

Natural shrub/scrub (coastal coppice).—Also known as sand *Coccothrinax*-shrub community, silver palm association, or *Erithalis-Reynosia* association (Correll and Correll 1982), natural shrub/scrub is low-growing because of natural environmental conditions. Vegetation generally ranges from 1–4 m in height, often with scattered taller emergent plants, on flat or gently rolling topography, and on substrate of sand, mixed sand and fractured limestone, or limestone rock. Depending on its location, this habitat may be exposed to periodic high winds, fire, flooding, and salt spray, all of which tend to retard growth of the woody species. Thus, most plants are bush-like or shrubby in growth form. A mosaic of openings of varying sizes and shapes, with ground cover or exposed substrate, may or may not be present. Silver thatch palm may occur. Other primary plants include black bead, black torch, cocobey, coco plum, darling plum, joe-wood, myrsine, narrow-leaved blolly, poison wood, sea grape, small-flowered prickly apple, Spanish stopper, spreading torch, torchwood, touch-me-not, wild guava, wild saffron, wild sage (widely known as lantana), and woolly corchorus. Morning glory and smooth passionflower vines as well as ground covers of black-headed


BAHAMA ARCHIPELAGO
ATLANTIC OCEAN
0 25 50 75 100 miles
0 50 100 150 km
26°
24°
22°
72°
74°
76°
78°
80°
Grand Turk
Caicos Islands
N.
M.
E.
S.
BAHAMAS
KINGDOM
UNITED
Mayaguana
Crooked
Acklins
Great Inagua
San Salvador
Rum Cay
Long
Cat
Eleuthera
Great Exuma
Little Abaco
Great Abaco
Berry Islands
New Providence
Grand Bahama
Andros
Bimini Islands
West Palm Beach
Miami
FLORIDA
CUBA

sedge and *Fimbristylis* also are common (Correll and Correll 1982).

Secondary shrub/scrub.—This habitat occurs as the direct result of human activities; it usually develops on subsistence farms (on which slash-and-burn techniques were used) after they have been abandoned, most often in areas that were coppice (mainly blacklands; see Correll and Correll 1982). Thus, this habitat is an early stage of seral vegetative succession, and in the northern islands may be dominated for a period by wild sage. Vegetation generally ranges from 1.0–1.5 m in height, with bushy growth form, often with taller emergent individual plants; it grows on flat, gently rolling topography or on ridge slopes, and on substrates of thin pockets of lateritic and black soils, exposed limestone rock, fractured limestone, etc. This habitat is generally more sheltered from wind and salt spray than is natural shrub/scrub. In addition to wild sage, some of the more common plants are black bead, black torch, broom-bush, cinnecord, coco plum, darling plum, gumbo-limbo, mahogany, myrsine, pigeon plum, poison wood, Spanish stopper, torchwood, white stopper, and woolly corchorus. As with natural shrub/scrub, there is often a mosaic of openings of various sizes and shapes with ground cover and exposed substrate.

Low coppice.—Low coppice is the younger or shorter growth of the whiteland and blackland communities of Correll and Correll (1982) in which the height of the vegetation is shorter than 4.6 m (15 feet), as originally described by Coker (1905). High coppice is over 4.6 m in height. Whiteland is generally near the coasts, while blackland is usually in island interiors. The southern islands of the archipelago have relatively more whiteland coppice than do the northern islands.

Whiteland substratum is typically sterile coral sand that forms low dunes and flats of hard-packed light gray soils. Where it is inland, it becomes somewhat loamy, but overall it is poor in nutrients and moisture retention. Whiteland soils contain lime and rock and support a hardier assemblage of plants, but the forest itself is impoverished compared to that on blacklands (Correll and Correll 1982, Campbell 1991). The dominant plants of whitelands are black bead, cinnecord, darling plum, joe-wood, lignum vitae, narrow-leaved blolly, poison wood, whitewood, wild dilly, and wild saffron as well as a number of epiphytes (Correll and Correll 1982).

Blackland includes most of the rolling hills, highest ridges, and flatlands inland of the coast. It frequently has solution or sink holes (called "banana holes" because they are large enough to hold one or more banana plants) and has the greatest plant diversity and density of all the broad habitat types in the archipelago. Most soil is black, with limited areas of red loam. These fertile soils are the most heavily used for agriculture and are formed from a mixture of weathered substratum and organic matter. A few of the several hundred dominant trees and shrubs include bitter bush, black ebony, cow-bush, crabwood, gumbo-limbo, jumbie bean, logwood, mahogany, maiden bush, quicksilver-bush, rat-wood, short-leaved wild fig, soap-berry, strangler fig, strong back, sweet torchwood, white ironwood, and wild tamarind, plus many species of ferns and terrestrial orchids (Coker 1905, Correll and Correll 1982).

Pineland understory.—The pinelands are confined to the northern islands (Grand Bahama, Great Abaco, Little Abaco, New Providence, and Andros; formerly included the Berry Island group), with a widely disjunct occurrence in the southern islands of Pine Cay, North Caicos, and Middle Caicos. This habitat is dominated by a single species, the Caribbean pine. The pine stands are characterized by broken/open canopy and widely spaced trees, and are divided into two types, wet and dry pine barrens. In wet pine barrens, the substratum is typically honeycombed limestone with the water table (usually a lens of fresh water overlying brackish) within a few centimeters of the surface. The presence of cabbage palm is an indicator of the wet pine barrens. The pines generally form the main canopy, while all other trees and shrubs make up the understory stratum, among which are black bead, candle-berry, narrow-leaved blolly, pigeon plum, poison wood, princewood, strong-back, wild sage, and woolly corchorus. Among the vines and herbs are auricled green-brier, finger-grass, mangrove swamp vine, prickly green-brier, and wild yam (Correll and Correll 1982).

Wet and dry pine barrens are often intermixed, but silver thatch palm replaces cabbage palm in the dry barrens. The same species of plants may be present in both wet and dry barrens, but the following are more prevalent in the dry type: bastard stopper, cinnecord, cocobey, common ernodea, pigeonberry, poison wood, St. Andrew's cross, southern bracken fern, tetrazygia, vernonia, wild lime, and yellow alder (Correll and Correll 1982). For a more detailed description of pinelands, see Emlen (1977).

Saline/upland ecotone.—This is the transition zone between the salt marsh and mangrove communities and the upland coppice; it occurs on relatively flat terrain and is often subject to flooding with salt water during extreme high tides and intense storms, and washed with fresh water during heavy rains. This is a saline-to-brackish habitat with a substrate of pavement limestone, broken limestone fragments, marl and sand mixture, etc., generally on the leeward (west) sides of

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FIG. 1. The winter range of the Kirtland's Warbler in the Bahama Archipelago with study sites on Eleuthera, Bahamas (2.1 km NW of Governor's Harbour) and Grand Turk (south end of island near airport) shown by black arrowheads.

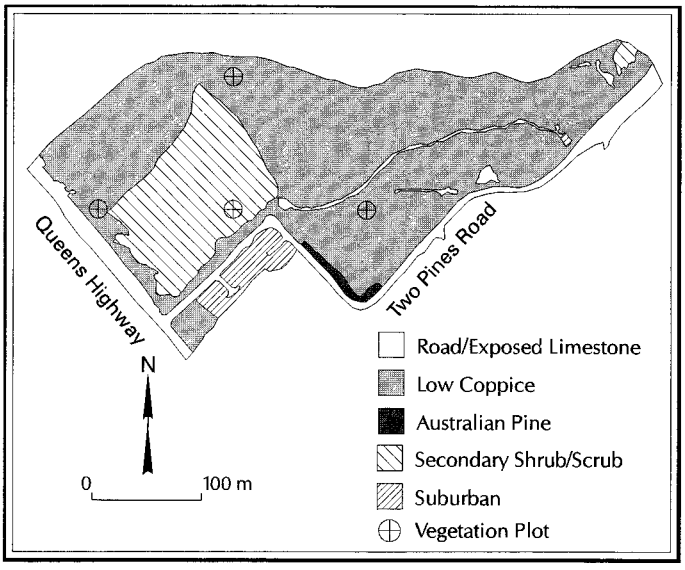

FIG. 2. Winter territory of a uniquely color-banded (in 1985) male and an unbanded female Kirtland's Warbler on Eleuthera 1985 and 1986, based on 451 sightings of the two birds, plus five mist-net captures of the male. The four vegetation plots within the territory are shown.

the islands. Vegetative zonation within this habitat forms a mosaic of shrub/scrub patches or stands of trees interspersed with bare substrate or ground cover. Because the archipelago contains so many islands, and most have this ecotone in abundance (W. T. Gillis, pers. comm.), it is an important component of Bahamian habitats. Some of the more abundant plants include black mangrove, bonita, broom-bush, buttonwood, cat's claw, horse bush, joe-wood, saltwort, sea grape, sea ox-eye, seashore rush-grass, seaside purslane, spurge, varnish leaf, wild sage, and woody glasswort.

Suburban.—This habitat occurs on the well-drained sites of human habitation within any of the principal upland natural habitats; it consists of buildings (homes, cottages, etc.) surrounded by mowed/grazed lawns with mixed plantings of native and/or introduced shrubs and trees. Among some of the common introduced plants are Australian pine, avocado, bougainvillea, Chinese hibiscus, common oleander, copper leaf, croton, frangipani, various lawn grasses, ixora, Japanese pittosporum, mango, natal-plum, Norfolk Island pine, orange-jessamine, orchid-tree, many species of palms, powder-puff, red periwinkle, royal poinciana, scarlet sage, trailing wedelia, and weeping bottlebrush.

METHODS

Eleuthera study site.—A study area was established in late February 1985 by Sykes and Paul R. Sievert 2.1 km NW of Governor's Harbour (Figs. 1 and 2) on Eleuthera where they had found a male Kirtland's Warbler 22–28 February 1985. This bird was captured and uniquely color-banded (U. S. Fish and Wildlife Service aluminum band no. 2020-67020 above an unnumbered red band on the left leg and unnumbered green over red on the right leg). Data from this warbler are central in this paper and other reports in preparation. The study site (25° 12′ 41″ N, 76° 15′ 20″ W) is located at the intersection of Queens Highway and Two Pines Road (Figs. 2, 4). From mid-December 1985 through late March 1986, Sykes, David A. Jett, William H. Howe, and Daniel M. Taylor studied the banded male (present 19 December 1985 through at least 28 March 1986) and a female (present 18 December 1985 through 23 January 1986) on winter territory at this locale. The territory consisted primarily of shrub/scrub, low coppice, and suburban habitats; it extended from the crest of the central limestone ridge on the lee (southwest) side of the island downslope, averaging about 5%, to Queens Highway (a two-lane paved road running the length of the island). This is the only intensively studied Kirtland's Warbler site in the archipelago. The territory was mapped and analyzed using a combination of remote sensing and geographic information system (GIS) techniques. Habitat types were interpreted from false color infrared aerial photographs acquired at a scale of 1:10,000 on 3 June 1987. A portion of a single positive transparency covering the warbler's territory was scanned at 600 dots per inch (dpi) and transferred to the Desktop Mapping System (DMS)™ software package operating on a Pentium personal computer. Geocoding procedures of the DMS were used to rectify the scanned photograph to the Universal Transverse Mercator (UTM) ground coordinate system within ±5 m root-mean-square-error (RMSE) using ground control obtained from the 1:25,000 scale Bahamas Dept. of Lands and Surveys

map (1975). Planimetric mapping of habitat types was then performed by digitizing vegetation and land use boundaries on-screen using the scanned air photo as a backdrop. Habitat types and land uses were classified as low coppice, secondary shrub/scrub, Australian pine, suburban, and road/exposed limestone. The digital vector data for habitat and land use boundaries within the Kirtland's Warbler territory were captured in ARC/INFO format for direct input to the GIS system. ARC/INFO, resident on a SUN Sparc 10-512 workstation, was used to edit the digital file, enter habitat information, and create a GIS coverage. Areal statistics summarizing the total coverage of each habitat type were then derived using ARC/INFO procedures and a hardcopy plot of the territory created.

Grand Turk study sites.—Two study areas, about 1 km apart, were established by Sykes and Sievert for short periods near the southern end of Grand Turk Island (Fig. 1) at sites where two individual Kirtland's Warblers were each seen once for several minutes. One site (21° 26′ 44″ N, 71° 08′ 08″ W) in natural shrub/scrub (male seen 7 March 1985 by Sykes) was north of the Grand Turk Airport runway. Three mist nets were used 7–10 and 14–15 March 1985, but no Kirtland's Warblers were captured. The second site (21° 26′ 25″ N, 71° 08′ 33″ W) in saline/upland ecotone (male seen 11 February 1985 by Sievert) was south of Grand Turk Airport runway, but no mist netting was done.

Vegetation sampling.—Vegetation was sampled on Grand Turk in March 1985 and on Eleuthera in January through March 1986. Circular 0.04-ha plots were sampled using techniques described by James and Shugart (1970) with some modifications. Foliage density was measured with a density board held vertically at 11.3 m from the center of the plot at the four cardinal directions (Noon 1981). On Grand Turk, the first of each cluster of five plots was placed where a Kirtland's Warbler had been seen, and the remaining four plots were randomly located around the site at various distances from the reference plot. The first plot on Eleuthera was placed centrally in the habitat where two Kirtland's Warblers were seen frequently, and the remaining four plots (Kirtland's seen on three of the four) were 125 m (center to center) in each of the four cardinal directions from the reference plot.

Elevations at the plot centers were determined from topographic maps [Grand Turk: Turks and Caicos Islands, Series E8113, Dept. of Surveys 209, Turks Islands Sheet 14B, Edition 2, 1973; Eleuthera: Commonwealth of the Bahamas, Series 314, Dept. of Lands and Surveys, Eleuthera Sheet 14B, Edition 1, 1975; contour interval for both maps was 25 feet (7.6 m)] with a scale of 1:10,000 (Grand Turk) and 1:25,000 (Eleuthera). Slope was estimated at each site (amount of drop per 30 m) and distance to the nearest different habitat was measured to the nearest whole meter from plot centers. A tree was defined as having a diameter at breast height (dbh; 1.37 m above ground) of at least 3 cm and usually with one main stem, and a shrub was 0.5 m or less in height with one or multiple stems less than 3 cm dbh. Ground cover was less than 0.5 m in height. A density board 0.5 m wide and 3 m tall was divided into four height intervals (0–0.3 m, 0.31–1.0 m, 1.1–2.0 m, and 2.1–3 m). Foliage density measurements for the lower two intervals were taken from a kneeling position and those from the upper two intervals from a standing position, all from the center to the edge of the plot along the four cardinal directions. Foliage density was then recorded as the number of squares (10 × 10 cm each) in each height interval at least 50% obscured by green foliage (details in Noon 1981). Another estimate of foliage density, which we refer to as vertical foliage cover, was made at the precise site within the vegetation used by foraging warblers. Vertical foliage cover was determined by imagining the foraging bird at the center of a 1-m diameter sphere and estimating the percentage of cover (0, 20, 40, 60, and 80) around the bird within the sphere if superimposed upon a vertical plane bisecting the sphere. Canopy, shrub and ground cover, leaf litter, bare soil, and exposed rock were determined by counting the number of hits out of a total of 40 along the four cardinal directions (10 each at 1 m intervals along line transects). Dominant shrub and ground cover were based upon greatest number of stems per plot, the second most abundant shrub being the subdominant.

With W. T. Gillis, Clench visited Radabaugh's 1973 site on Crooked Island on 18 March 1976. They collected botanical specimens, took habitat photographs, and made notes on the habitat type. On 10 February 1978, Clench took plant samples, notes, and photographs at the North Caicos Island site the day after she saw a female Kirtland's Warbler there. The plant samples were later sent to Gillis for identification.

The study of Kirtland's Warbler in the Bahama Archipelago by the U.S. Fish and Wildlife Service was planned for three years, but because of problems that arose beyond the team's control, the project was terminated before the first field season was completed; there was no funding thereafter. Hence, the sample sizes are small, precluding statistical analysis.

RESULTS

Winter habitats used by Kirtland's Warbler in the Bahama Archipelago are based on 98 observations (Table 1), including data from 29 specimens, two bandings, and 67 sightings. These 98 observations represent at least 61 individual warblers. The majority of the specimens were collected by C. J. Maynard (Mayfield 1960) on New Providence before 1900, and most sightings were made on Eleuthera (mainly this study), with the remainder of the sightings distributed among 11 other islands with one to six occurrences each.

Six broad habitats were identified as used by wintering Kirtland's Warblers: natural shrub/scrub, secondary shrub/scrub, low cop-

TABLE 1. Specimens, bandings, and sightings of Kirtland's Warblers in the Bahama Archipelago for which the general habitat type is known.[a]

Island	Number			
	Specimens	Bandings	Sightings	Total
Andros	1		1	2
Cat	1			1
Cat Cay[b]			1	1
Crooked			1	1
Eleuthera		1	43[c]	44
Grand Bahama		1	3	4
Grand Turk			3	3
Great Abaco			3	3
Great Inagua			3	3
New Providence	26		8	34[d]
North Caicos			1	1
San Salvador	1			1
Total 12	29	2	67	98[e]

[a] Data from the literature and unpublished reports through 1994 and this study.
[b] Cat Cay lies approximately 16 km south of South Bimini on the western edge of the Great Bahama Bank.
[c] Includes multiple recaptures and sightings of an uniquely color-banded male and accompanying unbanded female as a part of this study, plus sightings by other observers of four unsexed individuals at other localities on Eleuthera over the years.
[d] Includes Paradise (Hog) Island (two sightings).
[e] This number represents 61 individual Kirtland's Warblers.

pice, pineland understory, saline/upland ecotone, and suburban. The shrub/scrub category (Table 2), a combination of natural and secondary shrub/scrub, and low coppice are the most frequently recorded, but it should be kept in mind that the habitats and islands have not been systematically surveyed. Most reports, aside from our study site on Eleuthera, have come from incidental observations on those islands most readily accessible and favored by birders and ornithologists (Mayfield 1972). Over the past 100 years or so, reports have been sporadic with few or no details as to specific location, habitat, behavior, or plumage. No Kirtland's Warblers have been reported in high coppice, although it is frequented by other wintering warblers. The suburban habitat is probably of little importance to Kirtland's Warbler (Clench and Sykes, unpubl. data) in winter but may be used on occasion when adjacent to one of the favored habitats; it is, however, frequented by visiting birders. Saline/upland ecotone and, perhaps, pineland understory are probably of greater importance than the small sample indicates.

The diversity and structure of warbler winter habitats are shown in Figures 3 and 4. All of these communities have a well-developed shrub layer interspersed with many small irregularly shaped openings (also descriptive of

TABLE 2. Habitats in which Kirtland's Warblers have been reported in the Bahama Archipelago.[a]

Island	Occurrences[b]					
	Habitat					
	Shrub/scrub[c]	Low coppice	Pineland understory	Saline/upland ecotone	Suburban	Total
Andros		2				2
Cat	1					1
Cat Cay	1					1
Crooked				1		1
Eleuthera	3	5			2	10
Grand Bahama[d]		2	1		1	4
Grand Turk	2			1		3
Great Abaco[d]	1	2				3
Great Inagua	1	2				3
New Providence	27	6	2			35
North Caicos				1		1
San Salvador		1				1
Total	36	20	3	3	3	65

[a] Many specimen records and reported sightings are not included; their information was insufficient to determine habitat category.
[b] Most numbers represent different individual Kirtland's Warblers; two individuals studied on Eleuthera were seen using three different habitats.
[c] Both natural and secondary shrub/scrub combined; most accounts were not detailed enough to distinguish between the two.
[d] There is a problem of correct identification of many sightings on these islands (Sykes and Kepler, unpubl. data); all such reports have been excluded from the paper.

FIG. 3. Habitats at selected sites where Kirtland's Warblers have been observed in the Bahama Archipelago in winter. A. Natural shrub/scrub at lighthouse at Hole in the Wall, Great Abaco (25° 51′ 32″ N, 77° 11′ 02″ W), sighting January 1989 (R. S. Gnam, pers. comm.). B. Low coppice invaded by non-native plants with overstory of Australian pine on northwest edge of golf course along nature trail, Paradise (Hog) Island (22° 05′ 08″ N, 77° 18′ 06″ W), sighting 2 February 1985 (J. A. Gerwin and L. G. Sorenson, pers. comm.). C. Pineland understory southeast of Nassau International Airport, New Providence (25° 00′ 36″ N, 77° 27′ 05″ W), sightings 13 December 1989 and 1992 (P. W. and S. A. Smith, pers. comm.) and sighting in same general area 20 August 1970 by R. W. Schreiber and G. E. Woolfenden (Robertson 1971; G. E. Woolfenden, pers. comm.). D. Saline/upland ecotone about 900 m north of south shoreline and halfway between Brown's Settlement and Cove Point, Crooked Island (22° 43′ 07″ N, 74° 01′ 45″ W), sightings of same bird 11, 12, and 22 March 1973 (Radabaugh 1974, pers. comm.). E. Saline/upland ecotone about 335 m northwest of Bellefield Landing, North Caicos (21° 54′ 30″ N, 72° 02′ 00″ W), sighting 10 February 1978 (Clench 1978). F. Natural shrub/scrub 75 m north of airport perimeter fence near east end of runway and just south of old canal between south end of Great Salina complex and South Creek, Grand Turk (21° 26′ 42″ N, 71° 08′ 09″ W), sighting 7 March 1985 (Sykes). All photographs reproduced from color transparencies; A and F by Sykes, B by A. W. White, C by S. A. Smith, and D and E by Clench.

FIG. 4. Winter territory of an uniquely color banded male Kirtland's Warbler 1984–1985 and 1985–1986 and an unbanded female 1985–1986. This is the study site 2.1 km northwest of Governor's Harbour, Eleuthera (25° 12′ 41″ N, 76° 15′ 20″ W) at the intersection of Queens Highway and Two Pines Road. A. Low coppice, typical of much of the habitat within this warbler territory. Vegetation in center of this photo is where the male was first discovered along the edge on Two Pines Road in 1985. B. Overview of the territory at the lower elevation with secondary shrub/scrub surrounded by low coppice with Australian pine saplings projecting above the shrub and coppice layers. C. Low coppice in background interfacing secondary shrub/scrub of mostly wild sage. D. Mist net lane in stand of wild sage. E. Secondary shrub/scrub showing height (note meter stick held in right hand) and relative density of vegetation. This was the center of the first vegetation plot in study area. F. The ground level with leaf litter showing the general openness beneath secondary shrub/scrub, most of which is wild sage. Photos by Sykes 1985 and 1986.

breeding sites in Michigan). The shrub layer is often open at ground level (Fig. 4F). In both the natural and secondary shrub/scrub where warblers have been recorded, the vegetation is relatively easy to walk through. Suburban habitat, while highly modified and fragmented, also contains these key elements in the form of plantings and expanses of trimmed

grass or bare substrate. In strong contrast, most Bahamian habitats are densely vegetated and difficult to traverse.

Kirtland's Warbler winter territories on Eleuthera (8.3 ha) and on Crooked (about 6.9 ha) are larger than breeding territories in Michigan. Mayfield (1960) reported a mean Michigan territory of 3.4 ha (range, 0.6–6.7 ha) from 20 sites, and Sykes, C. B. Kepler, and C. I. Bocetti (unpubl. data) found 38 breeding territories to have a mean of 2.7 ha. This may result from more (perhaps poorer quality) habitat being available and/or lower density of warblers in winter than on the breeding grounds, where the territories are clumped in loose colonies. It could also simply be the result of the small sample of wintering territories.

At the winter territory study site on Eleuthera in 1985 and 1986 (Figs. 2 and 4), the 8.3-ha territory consists of 74.8% low coppice, 19.3% secondary shrub/scrub, 3.4% suburban habitats, 1.7% openings (old clearings $\geq 10^2$ m with exposed limestone substrate), and 0.8% Australian pine (planted in a strip along Two Pines Road). While the warblers were seen in all three habitats and the two miscellaneous categories, 98% of the observations were of birds in secondary shrub/scrub and low coppice.

Ninety-eight percent of all foraging (n = 448 observations) of the two warblers on Eleuthera was from the ground up to 3 m. Only 2% of foraging was between 3 to 6 m, and none was higher than 6 m. Vertical foliage cover at the point where a warbler was foraging was estimated to the nearest 20%. The cover usage ranged from 25 observations in zero (completely open) cover, 50 in 20%, 114 in 40%, and 18 in 60% (n = 207 observations); none was greater than 60%. Seventy-five percent of all foraging observations in vegetation were in wild sage (Table 3), with the remainder distributed among 10 other plant species (331 observations). Additional foraging occurred on the ground (Sykes, unpubl. data).

The structure of the secondary shrub/scrub and low coppice based upon vegetation plot measurements at the study sites in the Eleuthera and Grand Turk territories is summarized in Table 4. On Eleuthera, the slope ranged from 0–5% in the four plots. Few trees (25/ha) were present in the secondary shrub/scrub, whereas the low coppice had a mean of 2248/ha. Shrub density in secondary shrub/scrub was 54,711 stems/ha (1 plot), with a shrub cover of 50%; in low coppice the mean was 31,246 stems/ha (3 plots) with 62% cover. Mean ground cover was relatively low, with 14% in secondary shrub/scrub and 25% in low coppice, as was mean bare soil at 18% and 7%, and mean exposed rock at 15% and 17%. Mean leaf litter was higher at 68% and 77%. Mean foliage density (as measured by the density board) from ground level to 1 m in height was about 100% and decreased thereafter as the height increased. Of the two Eleuthera habitats, canopy was present only in low coppice. Mean shrub height in the secondary shrub/scrub was 1.1 m; this measurement was not taken in low coppice which had a mean canopy height of 3.3 m.

TABLE 3. Species of plants in which two Kirtland's Warblers were observed foraging (n = 331 observations) at one territory on Eleuthera winter 1986.

Common name	Scientific name	Percent observations
Wild sage	*Lantana involucrata*	76
Soldier-bush	*Tournefortia volubilis*	8
West Indian snowberry	*Chiococca alba*	4
Cinnecord	*Acacia choriophylla*	3.5
Black torch	*Erithalis fruticosa*	3.3
Wild lime	*Zanthoxylum fagara*	1.8
Australian Pine	*Casuarina equisetifolia*	1
Wild cassada	*Bumelia salicifolia*	0.9
Black bead	*Pithecellobium keyense*	0.9
Beef-bush	*Tabebuia bahamensis*	0.3
Slender nut-rush	*Scleria lithosperma*	0.3

At the natural shrub/scrub and saline/upland ecotone territories on Grand Turk (Table 4), the slope at the natural shrub/scrub vegetation plots ranged from 0–1% (5 plots) and at saline/upland ecotone it was zero (5 plots). No trees were present at these two sites. Mean shrub density in natural shrub/scrub was 8601 stems/ha with shrub cover of 68%, and in saline/ upland ecotone it was 10,611 stems/ha with shrub cover of 37%. Mean ground cover was low in natural shrub/scrub (11%), but high in saline/upland ecotone (45%) while mean leaf litter was 55% and 19%, respectively. Bare soil was high at both sites, with

TABLE 4. Structure of habitats within four Kirtland's Warbler winter territories at three sites on two islands. See Methods for definitions and measurement procedures.

	Habitats						
	Eleuthera (1 territory, male & female)			Grand Turk (2 territories. 2 males)			
	Secondary shrub/scrub (n = 1 plot)	Low coppice (n = 3 plots)		Natural shrub/scrub (n = 5 plots)		Saline/upland ecotone (n = 5 plots)	
Variable	Number	Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE
Elevation (m)	7.6	6.0–9.1	7.6 ± 1.4	2.4–2.5	2.4 ± 0.02	0	1.0 ± 0
Slope (%)	3	0–5	1.7 ± 1.7	0–1	0.4 ± 0.2	0	0 ± 0
Nearest habitat (m)	20	25–40	31.7 ± 4.4	48–100	66 ± 12	75–150	111 ± 16
Trees/ha	25	1112–3829	2248 ± 818	0	0	0	0
Shrub stems/ha	54,711	18,031–39,275	31,246 ± 1328	5607–15,438	8601 ± 1835	1457–18,896	10,611 ± 2887
Palms/ha	0	0–1482	580 ± 91.4	0	0	0	0
Shrub cover (%)	50	58–68	62 ± 3.1	53–78	68 ± 4.2	18–50	37 ± 5.3
Ground cover (%)	14	11–39	25 ± 8.0	0–25	11 ± 4.3	30–63	45 ± 7.0
Leaf litter (%)	68	70–80	77 ± 3.3	38–80	55 ± 7.4	10–33	19 ± 3.7
Bare soil (%)	18	0–18	7 ± 5.7	20–63	43 ± 6.9	68–83	77 ± 2.8
Exposed rock (%)	15	3–30	17 ± 4.6	0–15	1.5 ± 1.5	0–15	4 ± 2.9
Canopy cover (%)	0	28–73	50 ± 13	0	0	0	0
Foliage density 0–0.3 m ht. (%)	100	98–100	99 ± 0.7	100	100 ± 0	27–100	84 ± 14.4
Foliage density 0.31–1.0 m ht. (%)	100	98.5–99	99 ± 0.3	96–100	99 ± 0.7	31–71	60 ± 7.5
Foliage density 1.1–2.0 m ht. (%)	47	80–100	90 ± 33	54–87	69 ± 7.1	0–50	17 ± 9.1
Foliage density 2.1–3 m ht. (%)	0	77–100	85 ± 8	0–52	26 ± 11.4	0–47	9.4 ± 9.4
Mean canopy ht. (m)	—	2–5	3.3 ± 0.5	—	—	—	—
Mean shrub ht. (m)	1.1	—	—	1.0–1.2	1.1 ± 0.04	0.8–1.8	1 ± 0.19

TABLE 5. Principal shrub and ground cover in five Kirtland's Warbler winter territories.

Island	Warbler territory	Habitat	Veg.[b] plot	Species[a] Shrub Dominant	Shrub Subdominant	Ground cover Dominant
Eleuthera	1	Secondary shrub/scrub	1	wild sage	cinnecord	grass sp.
		Low coppice	1	cinnecord	wild sage	grass sp.
			2	wild sage	cinnecord	grass sp.
Grand Turk	2	Natural shrub/scrub	1	darling plum	cassia	seashore rush-grass
			2	darling plum	sea grape	seashore rush-grass
			3	sea grape	darling plum	borreria
			4	sea grape	spurge	borreria
			5	varnish leaf	spurge	seaside purslane
Grand Turk	3	Saline/upland ecotone	1	buttonwood	bonita	seashore rush-grass
			2	sea ox-eye	broom-brush	seashore rush-grass
			3	broom-brush	varnish leaf	seashore rush-grass
			4	spurge	varnish leaf	seashore rush-grass
			5	spurge	broom-brush	seashore rush-grass
Crooked[c]	4	Saline/upland ecotone	—[d]	buttonwood and black mangrove	—	woody grasswort and seashore rush-grass
North Caicos[e]	5	Saline/upland ecotone	—[d]	black olive	—	white-top sedge

[a] For scientific names and families see Appendix.
[b] No data on shrub and ground cover veg. plot 3 on Eleuthera.
[c] Territory of March 1973 (Radabaugh 1974) visited February 1976 by William T. Gillis and Clench.
[d] No vegetation sampling plots measured.
[e] Territory of February 1978 (Clench 1978).

means of 43% and 77%, respectively, but mean exposed rock was low (1.5% and 4%). Mean foliage density in natural shrub/scrub was circa 100% from ground level to 1 m in height, decreasing to 69% between 1–2 m, and to 26% between 2–3 m. Mean foliage density in saline/upland ecotone was 84% at the height of 0–0.3 m, decreasing to 60% at 0.3–1 m, 17% at 1–2 m, and 9.4% at 1–3 m. No canopy was present in either the natural shrub/scrub or saline/upland ecotone. Mean shrub height was 1.1 m and 1 m in the two Grand Turk territories.

Dominant shrub cover (Table 5) in the winter territory in secondary shrub/scrub (one plot) on Eleuthera was wild sage, with unidentified grasses as dominant ground cover, while the dominant shrubs in low coppice in the same territory (2 plots) were cinnecord and wild sage, also with grasses as the dominant ground covers. At Grand Turk, the dominant shrubs in natural shrub/scrub (5 plots) were darling plum (2 plots), sea grape (2 plots), and varnish leaf, with dominant respective ground covers of seashore rush-grass (2 plots), borreria (2 plots), and seaside purslane. In the Grand Turk saline/upland ecotone (5 plots) dominant shrubs were buttonwood, sea ox-eye, broom-bush, and spurge (2 plots), with seashore rush-grass the dominant ground cover in all plots. At Crooked Island, in the warbler territory 900–1000 m north of the coast in saline/upland ecotone, co-dominant shrub covers were buttonwood and black mangrove with co-dominant ground covers of woody glasswort and seaside rush-grass; saltwort, seaside purslane, horse bush, and sea ox-eye were also common on the rocky salt flat with broken honeycomb limestone (Gillis and Clench, unpubl. data). At North Caicos, the vegetation in saline/upland ecotone was structurally similar to that in the Crooked Island locality since it had the same parkland appearance. At the North Caicos site, the dominant shrub was black olive, with a dominant ground cover of white-top sedge. A *Fimbristylis,* common ernodea, box briar, silver thatch palm, varnish leaf, and wild tamarind were also collected at the site (Gillis, pers. comm.) and poison wood and sea grape noted. Overall, the dominant shrub and ground covers appeared to vary widely among plots,

sites, and islands. Large sample sizes would be required to determine which species are the most frequent dominants within warbler winter territories.

DISCUSSION

From our observations (Sykes and his group also did cursory surveys of habitat on Eleuthera and to a lesser degree on Cat Island in 1986, and Clench visited 26 islands and cays looking for Kirtland's Warbler), the observations of others, and the published literature, there appears to be no shortage of winter habitat for Kirtland's Warbler in the Bahama Archipelago. The warbler population is relatively small. If one assumes about an equal number of females to the singing males counted, this comes to 1500+ adults (1995–1997 figures), plus 1000–3000 hatching-year birds, or a total of 2500–4500 individuals at the beginning of winter. The land mass of the Bahama Archipelago is 14,500 km^2. We believe it is reasonable to assume that at least a third of the land mass offers suitable habitat, resulting in about 4829 km^2 or 1.1–1.9 km^2 available per individual. This crude estimate of the amount of winter habitat suggests that it is more than adequate for the population at present and allows for a considerable increase.

During winter, the warblers appear to be widely dispersed throughout the islands. Since the turn of the century, each of the few sightings have been of only one or two birds, despite extensive searches. There seems to be no concentration of the warblers in the archipelago, a theory investigated and then discarded by Clench after visiting 22 islands by boat from 26 February to 4 April 1976; most islands were off the usual tourist track and included five that were uninhabited: Green Cay on the edge of the Tongue of the Ocean, Little San Salvador between Eleuthera and Cat islands, Conception Island, West Plana (French) Cay between Acklins and Mayaguana, and Little Inagua (Clench 1977). No Kirtland's Warblers were found. This probable wide dispersion is also strongly supported by the fact that D. W. Buden spent eight years conducting field work mostly in the southern Bahamas and Turks and Caicos and never saw a Kirtland's Warbler. With this lack of concentration, the population should be buffered to some degree from negative factors such as droughts, severe storms, habitat losses, and predation. For example, annual rainfall is highly variable (Sealey 1994; Sykes, pers. obs.). Drought on a given island or group of islands may greatly reduce local food abundance and availability, but would not affect the entire archipelago. Consequently, at least some warblers would not be affected by such conditions. In a few places such as Abaco, free-roaming house cats (*Felis domestica*) may be a problem (R. S. Gnam, pers. comm.).

Wintering Kirtland's Warblers probably use nearly all upland habitats except high coppice within the Bahama Archipelago. Available data are not sufficient to show absolute preference for natural and secondary shrub/scrub, low coppice, and saline/upland ecotone; however, use of these four habitats comprises the majority of the observations to date.

Kirtland's Warbler in winter is clearly a bird attracted to low vegetation in the habitats in which it occurs. Since most of the upland habitats in the archipelago are structurally shrubby, that explains, at least in part, the broad use of upland habitats. Cory (1879), who collected the first specimen on Andros Island on 9 January 1879, said the bird seemed to prefer thick brush. C. J. Maynard (1896) collected 33 specimens, in or near Nassau, New Providence, and five on Eleuthera between 1884 and 1915, a period of high Kirtland's Warbler population. Maynard stated that the warblers inhabit low scrub, preferring scrub only 1–1.3 m high; with one or two exceptions, he always found the birds singly and in old fields grown up to low shrubbery (Mayfield 1996). Similarly, the site near Governor's Harbour on Eleuthera, where we studied the two individuals, had been cleared and then overgrown with shrubby vegetation. With the land use history of the Bahamas, overgrown old fields are very common. The sites on Crooked Island (Radabaugh 1974), North Caicos (Clench 1978), and Grand Turk (this study) were not old fields but natural clearings with shrub communities. A specimen taken by Paulson (1966) on San Salvador on 27 December 1963 was at the edge of scrub forest or low coppice with a 2.4–3 m canopy, having been flushed from an adjacent old field. Mayfield (1972), in his assessment of winter habitats for the

Kirtland's Warbler, concluded that the species inhabits low broad-leaved scrub, and that cleared areas allowed to grow back but that have not yet reached their maximum height and density may hold particular promise. This statement, however, was made before the birds were found in saline/upland ecotone on Crooked Island, North Caicos, and Grand Turk.

On the breeding grounds the warbler is restricted to young jack pine (*Pinus banksiana*) habitat early in the sere (usually 6–20 years of age). On the wintering grounds, a similar situation is created by the widespread subsistence agricultural practice of slash-and-burn of relatively small farms (generally 4 ha or less). Because money is seldom available for fertilizer, the nutrients are depleted from these farm plots within several years and the roughly cleared land is abandoned and reverts to upland habitat. In the course of this succession, the shrubs and trees regrow, creating habitat for the warbler. Depending on conditions, a given site may remain in a shrub stage or eventually become coppice. In the early seral stages, wild sage is often one of the most common plants. This plant produces abundant small berries that are one of the most heavily used winter foods of the Kirtland's Warbler in the northern Bahamas (Sykes, unpubl. data). Wild sage is also common in the southern Bahamas, but it seldom occurs in the saline-upland ecotone which has other shrubby plant species.

Even in the pinelands, the understory consists of a shrub layer, and it is the shrub layer the warblers are using rather than the pines. This was first mentioned by Mayfield (1992, 1996), and our observations lead us to agree. Lee and coworkers (1997) also believe that wintering Kirtland's Warblers primarily use scrub/shrub habitat, but they conclude that the species depends almost entirely on pinelands. In light of the number of old and modern records in natural habitats on non-pine islands, we cannot agree with their statement, "Prior to pre-colonial deforestation we suspect that there was little to no habitat for this bird on Eleuthera or most other non-pine islands" (Lee et al. 1997:28). Most sightings in the pinelands of Grand Bahama and the Abacos also have been compromised by frequent confusion among many observers between winter-plumaged Kirtland's Warbler and the similar plumage of the endemic race of the Yellow-throated Warbler (*Dendroica dominica flavescens*) which is quite different in appearance from the three continental races of *D. dominica* (White 1996; Sykes and Kepler, unpubl. data). Apparently, most visitors to the northern Bahamas have been unaware of the existence of the *D. d. flavescens* race of the Yellow-throated Warbler, with its yellow underparts (except for white undertail coverts) and dark streaking on the sides, because it was not adequately described or pictured in any of the popular field guides up until about 1994.

In conclusion, Kirtland's Warbler uses most of the upland habitats in the Bahama Archipelago, except high coppice, that have a shrub/scrub component with patchy small openings and openings within the vegetation at ground level. Such conditions are abundant in relatively large tracts and are widespread in the islands. Any future studies of habitat or other aspects of the species' biology during the winter period should consider using a tape recording to locate the warblers. From September through March, one might try using a tape of the call notes, and late March through April, call notes in combination with the primary song. All habitats should be searched with uniform effort.

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APPENDIX. Alphabetical listing of plants mentioned: common name, scientific and family names, growth form, status, and height. Common, scientific, and family names follow Correll and Correll (1982).

Common name	Scientific name	Family	Growth form[a]	Status[b]	Max. ht. (m)
Auricled green-brier	*Smilax auriculata*	Smilacaceae	V	N	—
Australian pine	*Casuarina equisetifolia*	Casuarinaceae	T	I	20
Avocado	*Persea americana*	Lauraceae	T	I	4.6
Banana	*Musa sapientum*	Musaceae	T	I	15
Bastard stopper	*Petita domingensis*	Verbenaceae	T	N	20
Beef-bush	*Tabebuia bahamensis*	Bignoniaceae	S or T	N	10
Bitter bush	*Picramnia pentandra*	Simaroubaceae	S or T	N	10
Black bead	*Pithecellobium keyense*	Leguminosae	S	N	2
Black ebony	*Pera bumeliifolia*	Euphorbiaceae	T	N	12
Black-headed sedge	*Schoenus nigricans*	Cyperaceae	Se	N	0.6
Black mangrove	*Avicennia germinans*	Avicenniaceae	S or T	N	10
Black olive	*Bucida buceras*	Combretaceae	S or T	N	25
Black torch	*Erithalis fruticosa*	Rubiaceae	S or T	N	6
Bonita	*Bonita daphnoides*	Myoporaceae	S or T	N	9
Borreria	*Borreria verticillata*	Rubiaceae	PS or S	N	1
Bougainvillea	*Bougainvillea* spp.	Nyctaginaceae	V	I	4.6
Box briar	*Randia aculeata*	Rubiaceae	S	N	3
Broom-bush	*Baccharis dioica*	Asteraceae	S	N	3
Broom sedge	*Andropogon virginicus*	Gramineae	PG	N	1
Buttonwood	*Conocarpus erectus*	Combretaceae	S or T	N	20
Cabbage palm	*Sabal palmetto*	Palmae	T	N	15
Candle-berry	*Byrsonima lucida*	Malpighiaceae	S or T	N	8
Caribbean pine	*Pinus caribaea*	Pinaceae	T	N	30
Cassia	*Cassia lucayana*	Leguminosae	S	N	1.5
Cat's claw	*Pithecellobium unguis-cati*	Leguminosae	S or T	N	8
Chinese hibiscus	*Hibiscus rosa-sinensis*	Malvaceae	S	I	6
Cinnecord	*Acacia choriophylla*	Leguminosae	T	N	9
Cocobey	*Cordia bahamensis*	Boraginaceae	S or T	N	4
Coco plum	*Chrysobalanus icaco*	Chrysobalanaceae	S or T	N	6
Common ernodea	*Ernodea littoralis*	Rubiaceae	S	N	1
Common oleander	*Nerium oleander*	Apocynaceae	S or T	I	5
Copper leaf	*Acalypha wilkesiana*	Euphorbiaceae	S	I	4.6
Cow-bush	*Helicteres jamaicensis*	Sterculiaceae	S or T	N	6
Crabwood	*Ateramnus lucidus*	Euphorbiaceae	S or T	N	10
Croton	*Codiaeum variegatum*	Euphorbiaceae	S	I	3
Darling plum	*Reynosia septentrionalis*	Rhamnaceae	S or T	N	9
Fimbristylis	*Fimbristylis spathacea*	Cyperaceae	Se	N	0.5
Finger-grass	*Eustachys petraea*	Gramineae	PG	N	1.2
Frangipani	*Plumeria rubra*	Apocynaceae	T	I	8
Gumbo-limbo	*Bursera simaruba*	Burseraceae	T	N	15
Horse bush	*Gundlachia corymbosa*	Asteraceae	S	N	1.8
Ixora	*Ixora coccinea*	Rubiaceae	S	I	4.6
Japanese pittosporum	*Pittosporum tobira*	Pittosporaceae	S	I	3.7
Joe-wood	*Jacquiana keyensis*	Theophrastaceae	S or T	N	6
Jumbie bean	*Leucaena leucocephala*	Leguminosae	S or T	N	8
Lignum vitae	*Guaiacum officinale*	Zygophyllaceae	T	N	8
Logwood	*Haematoxylum campechianum*	Leguminosae	T	N	8
Mahogany	*Swietenia mahagoni*	Meliaceae	T	N	25
Maiden bush	*Savia bahamensis*	Euphorbiaceae	S or T	N	5
Mango	*Mangifera indica*	Anacardiaceae	T	I	15
Mangrove swamp vine	*Rhabdadenia biflora*	Apocynaceae	V	N	—
Morning glory	*Ipomoea indica*	Convolvulaceae	V	N	—
Myrsine	*Myrsine floridana*	Myrsinaceae	S or T	N	6
Narrow-leaved blolly	*Guapira discolor*	Nyctaginaceae	S or T	N	6
Natal-plum	*Carissa grandiflora*	Apocynaceae	S	I	5.5
Norfolk Island pine	*Araucaria excelsa*	Araucariaceae	T	I	18
Orange-jessamine	*Murraya paniculata*	Rutaceae	S or T	I	4.6

APPENDIX. Continued.

Common name	Scientific name	Family	Growth form[a]	Status[b]	Max. ht. (m)
Orchid-tree	*Bauhinia variegata*	Leguminosae	T	I	6
Pigeonberry	*Duranta repens*	Verbenaceae	S or T	N	6
Pigeon plum	*Coccoloba diversifolia*	Polygonaceae	S or T	N	7
Poison wood	*Metopium toxiferum*	Anacardiaceae	T	N	14
Powder-puff	*Calliandra haematocephala*	Leguminosae	S	I	4.6
Prickly green-brier	*Smilax havanensis*	Smilacaceae	V	N	—
Princewood	*Exostema caribaeum*	Rubiaceae	S or T	N	8
Quicksilver-bush	*Thovinia discolor*	Sapindaceae	S or T	N	5
Rat-wood	*Erythroxylum rotundifolium*	Erythroxylaceae	S or T	N	8
Red periwinkle	*Catharanthus roseus*	Apocynaceae	H	I	1
Royal poinciana	*Delonix regia*	Leguminosae	T	I	12
St. Andrew's cross	*Hypericum hypericoides*	Guttiferae	S	N	1
Saltwort	*Batis maritima*	Bataceae	S	N	0.6
Scarlet sage	*Salvia splendens*	Labiatae	H	I	0.4
Sea grape	*Coccoloba uvifera*	Polygonaceae	S or T	N	15
Sea ox-eye	*Borrichia arborescens*	Asteraceae	S	N	1
Seashore rush-grass	*Sporobolus virginicus*	Gramineae	PG	N	0.2
Seaside purslane	*Sesuvium portulacastrum*	Aizoaceae	PH	N	0.1
Short-leaved wild fig	*Ficus citrifolia*	Moraceae	S or T	N	15
Silver thatch palm	*Coccothrinax argentata*	Palmae	T	N	10
Slender nut-rush	*Scleria lithosperma*	Cyperaceae	Se	N	0.6
Small-flowered prickly apple	*Catesbaea parviflora*	Rubiaceae	S	N	2
Smooth passion-flower	*Passiflora cupraea*	Passifloraceae	V	N	—
Soap-berry	*Exothea paniculata*	Sapindaceae	S or T	N	20
Soldier-bush	*Tournefortia volubilis*	Boraginaceae	V	N	—
Southern bracken fern	*Pteridium aquilinum*	Polypodiaceae	F	N	3
Spanish stopper	*Eugenia foetida*	Myrtaceae	T	N	6
Spreading torch	*Erithalis diffusa*	Rubiaceae	S	N	1.5
Spurge	*Euphorbia abbreviata*	Euphorbiaceae	S	N	0.5
Strangler fig	*Ficus aurea*	Moraceae	T	N	20
Strong-back	*Bourreria ovata*	Boraginaceae	S or T	N	10
Strong back	*Krugiodendron ferreum*	Rhamnaceae	S or T	N	10
Sweet torchwood	*Nectandra coriacea*	Lauraceae	T	N	12
Tetrazygia	*Tetrazygia bicolor*	Melastomataceae	S or T	N	6
Torchwood	*Amyris elemifera*	Rutaceae	S or T	N	5
Touch-me-not	*Malpighia polytricha*	Malpighiaceae	S	N	3
Trailing wedelia	*Wedelia trilobata*	Asteraceae	PH	I	0.2
Varnish leaf	*Dodonaea ehrenbergii*	Sapindaceae	S or T	N	5
Vernonia	*Vernonia bahamensis*	Asteraceae	PS	N	1.5
Weeping bottlebrush	*Callistemon* spp.	Myrtaceae	S or T	I	6
West Indian snowberry	*Chiococca alba*	Rubiaceae	S	N	3
White ironwood	*Hypelate trifoliata*	Sapindaceae	T	N	13
White stopper	*Eugenia axillaris*	Myrtaceae	S or T	N	8
White-top sedge	*Dichromena colorata*	Cyperaceae	Se	N	0.5
Whitewood	*Drypetes diversifolia*	Euphorbiaceae	T	N	7
Wild cassada	*Bumelia salicifolia*	Sapotaceae	T	N	16
Wild cotton	*Gossypium hirsutum*	Malvaceae	H or S	I	4
Wild dilly	*Manilkara bahamensis*	Sapotaceae	T	N	10
Wild guava	*Psidium longipes*	Myrtaceae	S or T	N	4
Wild lime	*Zanthoxylum fagara*	Rutaceae	S or T	N	10
Wild saffron	*Bumelia americana*	Sapotaceae	S or T	N	13
Wild sage	*Lantana involucrata*	Verbenaceae	S	N	2
Wild tamarind	*Lysiloma latisiliquum*	Leguminosae	T	N	16
Wild yam	*Rajania hastata*	Dioscoreaceae	V	N	—
Woody glasswort	*Salicornia virginica*	Chenopodiaceae	PH	N	0.25
Woolly corchorus	*Corchorus hirsutus*	Tiliaceae	S	N	2
Yellow alder	*Turnera ulmifolia*	Turneraceae	H or S	N	1

[a] F = fern, G = grass, H = herb, P = perennial, S = shrub, Se = sedge, T = tree, V = vine.
[b] I = introduced non-native species, N = native species.