DISTRIBUTION, HABITAT OCCUPANCY AND POPULATION DENSITY OF THE ELFIN-WOODS WARBLER (*Dendroica angelae*) IN PUERTO RICO

by

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DISTRIBUTION, HABITAT OCCUPANCY AND POPULATION DENSITY OF THE ELFIN-WOODS WARBLER (*Dendroica angelae*) IN PUERTO RICO

ABSTRACT

The Elfin-woods Warbler (*Dendroica angelae*) is a threatened species endemic to montane forests in Puerto Rico. The objectives of this study were to determine the current geographical distribution, spatial distribution pattern, habitat occupancy and abundance, and population density of the Elfin-woods Warbler (EWWA). Surveys were conducted in montane forests in 2003-2004. Survey routes 0.8 to 3km in length with point-count stations 200m apart were established in sample habitats 200 to 1,030m in elevation. EWWA distribution was limited to the Maricao State Forest and the Caribbean National Forest. EWWA in the Maricao State Forest was more abundant in *Podocarpus* with a positive correlation between EWWA mean number and elevation. Most EWWA in the Caribbean National Forest were located in Palo Colorado and Dwarf Forest with no elevation significance. In conclusion, the EWWA has disappeared from former range along the Cordillera Central and Sierra de Cayey. Current distribution is limited to the Caribbean National Forest (eastern Puerto Rico) and Maricao State Forest (western Puerto Rico), and extant populations occur at low densities. It is recommended that the species be reclassified as an endangered species under the Endangered Species Act and the International Union for the Conservation of Nature.

DISTRIBUCIÓN, OCUPACIÓN DE HÁBITAT Y DENSIDAD POBLACIONAL DE LA REINITA DEL BOSQUE ENANO (*Dendroica angelae*) EN PUERTO RICO

RESUMEN

La Reinita del Bosque Enano (*Dendroica angelae*) es una especie amenazada endémica a los bosques montanos de Puerto Rico. Los objetivos de este estudio eran determinar la distribución geográfica actual, el patrón de distribución espacial, la ocupación de hábitat y abundancia, y la densidad poblacional de la Reinita del Bosque Enano (EWWA). Se realizaron muestreos en los bosques montanos en el 2003-2004. Las rutas de muestreos median de 0.8 a 3km de largo con estaciones de puntos de conteos cada 200m, establecidos para muestrear hábitat a elevaciones de 200 a 1,030m. La distribución de las EWWA estaba limitada al Bosque Estatal de Maricao y al Bosque Nacional del Caribe. Las EWWA en el Bosque Estatal de Maricao eran más abundantes en *Podocarpus* con una correlación positiva entre el número promedio de EWWA y la elevación. La mayoría de las EWWA en el Bosque Nacional del Caribe se localizaron en Palo Colorado y el Bosque Enano sin que la elevación fuera significativa. En conclusión, las EWWA han desaparecido de su rango de distribución anterior a través de la Cordillera Central y la Sierra de Cayey. La distribución actual es limitada al Bosque Nacional del Caribe (en el este de Puerto Rico) y al Bosque Nacional del Caribe (en el oeste de Puerto Rico), y las poblaciones existentes ocurren a densidades bajas. Se recomienda que la especie sea reclasificada como una especie en peligro en el Acta de Especies en Peligro y la Unión Internacional para la Conservación de la Naturaleza.

DEDICATION

To the sunshine in my life, my niece and nephews who in their own special way, gave me the strength to complete this manuscript.

To my parents, family and friends for their support and encouragement every step of the way in this learning process.

To those who care and work hard to conserve OUR NATURAL RESOURCES for future generations.

Figure 1. Elfin-woods Warbler *Dendroica angelae*, Maricao State Forest, Puerto Rico [modified from Rodríguez- Mojica (2004)]

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INTRODUCTION

The endemic Elfin-woods Warbler (EWWA hereafter) (*Dendroica angelae* Kepler and Parkes) is a rare parulid found in various upland forests of Puerto Rico (American Ornithologist's Union, 1998; Oberle, 2000) (Figure 1). It is a small bird with black and white plumage and a prominent eye ring (Kepler and Parkes, 1972) (Figure 2). It has a blackish bill and dark bluish-gray legs, two white wing bars and two white spots in the outer tail feathers. The under parts are white, with black streaks on the throat, breast and flanks (Curson *et al.,* 1994) (Figure 2). The sexes are alike but males tend to have larger amounts of black streaking on the breast and throat (Delannoy, pers. com.). The EWWA has a long bill and relative short rounded wings, both characteristic of island species. Its song comprises a series of short, rapidly uttered, unmusical notes on one pitch, increasing in volume and ending with a short series of distinct double notes (Curson *et al.,* 1994). It also produces a short metallic "chip" call and a contact call which is similar to the song but without the double-note ending.

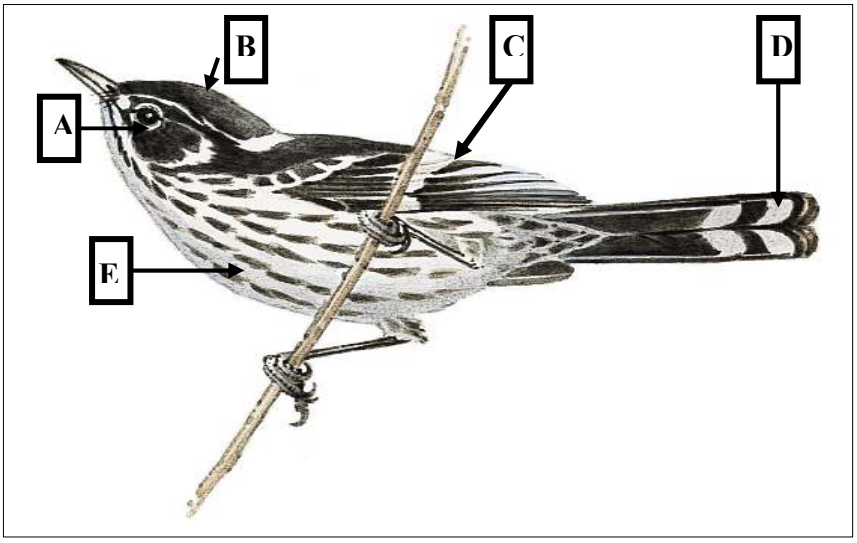

Figure 2. Plumage characters used to identify the Elfin-woods Warbler. A. Prominent eye ring. B. Entirely black crown C. Two white wing bars. D. Two white spots in the outer tail feathers. E. Under parts white with black streaks. Drawing modified from Raffaele *et al*., (1998).

It feeds on insects, foraging at high levels, mostly in the canopy, and gleaning very actively from leaves and small branches. It also joins mixed-species foraging (Curson *et al.,* 1994). Breeding occurs between March and June (Raffaele *et al*., 1998). Nests have been found placed in trees among leaf-litter trapped in vegetation or vines at heights between 1.3-7.6m, and also in tree cavities (Arroyo-Vázquez, 1992; Rodríguez-Mojica, 2004). Nests can contain broods of up to four nestlings (Rodríguez-Mojica, 2004). Immature birds have greenish plumage and molting lasts almost a year (Kepler and Parkes, 1972). First-year birds have olive-green head, upperparts with yellowish wing bars and tertial spots, and pale yellowish-olive underparts with dusky olive streaks (Curson *et al.,* 1994).

The historical range of the EWWA in Puerto Rico is limited to humid montane habitats in protected forests along the Cordillera Central, Sierra de Cayey and Sierra de Luquillo (Figure 3). Wiley and Bauer (1985) reported EWWA from Dwarf, Palo Colorado and Sierra Palm Forests within the Caribbean National Forest. Cruz and Delannoy (1984a) reported EWWA most abundant in the *Podocarpus* forest type of the Maricao State Forest. Due to the limited range of EWWA, surveys to determine current geographical distribution (especially away from its known range) and maintaining population size are considered conservation priorities (BirdLife International, 2004).

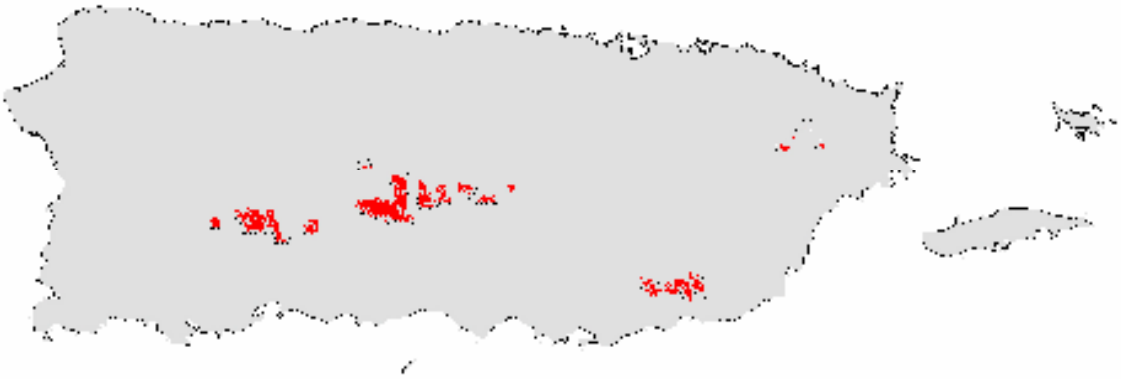

Figure 3. Historical distribution map of the Elfin-woods Warbler in Puerto Rico. [Drawing from BirdLife International (2004)].

The EWWA is a globally threatened species, listed as an endangered species candidate by the United States Fish and Wildlife Service (US FWS) and considered vulnerable by the Puerto Rican Department of Natural and Environmental Resources (PR DNER) due to its small range and estimated population size of only 300 pairs (BirdLife International, 2004). EWWA current range is threatened by the lack of comprehensive public forest management plans and conflicting management objectives that arise from an increasing human population (Delannoy, 1997). Road construction and the installation of power-lines and communication infrastructure (i.e., microwave, TV, and radio antennas) in the past 20 years have resulted in substantial habitat destruction, fragmentation, and alteration within the ranges of the endemic and endangered Puerto Rican Broad-winged Hawk (*Buteo platypterus brunnescens*) and Sharp-shinned Hawk (*Accipiter striatus venator*) (Delannoy, 1997). EWWA shares most of its range and habitat with these two raptors, thus it is likely that it has suffered from habitat loss as well.

Natural disasters, such as hurricanes, pose a threat to EWWA habitat and can affect its population size and distribution (Dr. Wayne Arendt, US Forest Service, pers. com.). The direct struck by Hurricane Hugo on the Caribbean National Forest in 1989 resulted in a 40% decline of the wild flock of the endemic and endangered Puerto Rican Parrot, *Amazona vittata* (Wilson *et al.,* 1994).

This study assesses the distribution, habitat occupancy and population density of the EWWA in order to update and lay the foundations for its long-term conservation in Puerto Rico. The questions posed were: (1) What is the EWWA current geographical distribution? (2) What is the EWWA spatial distribution pattern? (3) What is the EWWA habitat occupancy and abundance in Puerto Rico? (4) What is the EWWA population density? These baseline data will be of importance for the conservation of the species.

LITERATURE REVIEW

Cameron and Angela Kepler discovered EWWA in 1968 while conducting research on the Puerto Rican Tody (*Todus mexicanus*) and the Puerto Rican Parrot *(Amazona vittata*) in the Caribbean National Forest in eastern Puerto Rico. It was named for Mrs. Kepler (Kepler and Parkes, 1972). It was the first new species to be described from the West Indies since 1927, and the first in Puerto Rico in the Twentieth Century (Parkes, 1991). They attributed this late discovery to the difficult detection of this species and the superficial likeness with the migratory Black-and-white Warbler (*Mniotilta varia).* Kepler and Parkes (1972) determined that EWWA occurs primarily in Dwarf Forest (at elevations of 640 through 1,030m) and occasionally in Palo Colorado Forest (at elevations of 370-600m). They indicated that the available EWWA habitat comprised 450ha suggesting an approximate population of 300 pairs. Wiley and Bauer (1985) reported the EWWA from Dwarf Forest, Palo Colorado and Sierra Palm forests in the Caribbean National Forest.

Waide (1995) studied the species' distribution, abundance, and provided recommendations for EWWA conservation in the Caribbean National Forest. He estimated EWWA population of 138 pairs scattered through 329ha of Dwarf Forest. Waide's surveys showed considerable EWWA activity outside of Dwarf Forest, particularly in Palo Colorado Forest. The aggregated nature of EWWA distribution in the Caribbean National Forest and its presence in habitats other than Dwarf Forest made the population estimation difficult and warranted the note of caution on its interpretation and use. According to Waide, the EWWA aggregated distribution could be related to vegetation, elevation, or both.

EWWA surveys were conducted along the Icacos Valley, East Peak, Mount Britton, El Yunque Peak, Caimitillo Trail, El Cacique Peak, Tradewinds Trail, and El Toro Trail. EWWA counts were much higher along the Tradewinds Trail and Icacos Valley and considerably lower in El Toro Trail, El Yunque Peak and Mount Britton. The scarcity of EWWA in El Yunque Peak and Mount Britton departed from the historical pattern (Kepler and Parkes, 1972). However, these counts revealed that the EWWA is rarely found in habitats other than Dwarf Forest; and

even in Dwarf Forest, numbers are very low. The relatively high counts in the Icacos Valley were surprisingly based on previous knowledge. There was considerable annual variability in EWWA counts, particularly in the Icacos Valley and East Peak. Waide attributed some of the seasonal variations variability in EWWA numbers to a drop in detections due to reduced singing activity during May and June. There were certain points with high EWWA counts regardless of season. These results suggested strong site attachment or fidelity.

There is little quantitative information about EWWA habitat preferences and requirements and limited understanding of its distribution. Waide (1995) identified habitat destruction and modification as the major threat to this species. Threats to the EWWA habitat in the Caribbean National Forest come from communication infrastructure development and recreation, which have resulted in the reduction of the available habitat. Dwarf Forest, a very small and limited type of forest, has a disproportionate share of use in terms of special use permits, roads, research, ecotourism, and educational programs. Since the productivity of Dwarf Forest is low, disturbance effects are long-lasting (Waide, 1995). For this reason, Waide's recommendation was to conduct management of the Dwarf Forest with extreme caution. Other conservation and management recommendations were: 1) to implement a long-term monitoring program to study EWWA populations and distribution within the Caribbean National Forest; 2) to conduct vegetation studies at sampling points to develop a better understanding of habitat requirements and aggregated distribution; 3) to undertake detailed studies related to EWWA natural history, such as seasonal movements, territorial behavior, breeding biology, and population dynamics; and 4) to maintain timber management, recreation, ecotourism, expansion of trail and road system, research and educational activities compatible with the EWWA protection. Waide (1995) concluded that current knowledge of the EWWA biology was not sufficient to develop a management plan to improve habitat quality, reproductive output and survival.

A second population of EWWA was discovered a year after the first (1972) in Maricao State Forest in western Puerto Rico at an elevation of 800m (Gochfeld *et al*., 1973). Gochfeld *et al*. (1973) concluded that the two independent discoveries in Maricao State Forest and Caribbean National Forest were about 150km apart representing distinct populations. They also discarded

the possibility of population interchanging because of the distance and the destruction of suitable habitat in the intervening highlands. Shortly thereafter, EWWA were reported in Carite (Pérez-Rivera and Maldonado, 1977) and Toro Negro Forests in the late 1970s (Woodbury in Pérez-Rivera, 1979). Small populations could remain undiscovered in the central mountain range (Cordillera Central) of the island but these have not been surveyed.

Cruz and Delannoy (1984a) studied the distribution, habitat use and the population densities of the EWWA and associated insectivore birds in the Maricao State Forest. Transects were distributed across three life zones in the Maricao State Forest; the Subtropical Moist, Subtropical Wet, and Subtropical Lower Montane Wet Forests. Sampled trails within these life zones were Los Viveros, Campamento Santana and Rosario Alto. The authors recorded the highest EWWA densities in Los Viveros (20.9/25ha) at elevations of 600 to 880m; and lower densities in Rosario Alto (3.0/25ha) and Campamento Santana (1.2/25ha) at lower elevations (600-750m). The Puerto Rican Tody had the highest mean estimated density of 23.9/25ha compared to Puerto Rican Vireo *Vireo latimeri* (11.3/25ha), Lesser Antillean Pewee *Contopus latirostris* (4.0/25ha), Adelaide's Warbler *Dendroica adelaide* (3.8/25ha), Black-whiskered Vireo *Vireo altiloquus* (3.2/25ha) and EWWA (3.8/25ha). The EWWA was not uniformly distributed throughout the Maricao State Forest but it was found in different habitat within Los Viveros, Campamento Santana and Rosario Alto.

Podocarpus Forest in Los Viveros was less disturbed, had greater structural complexity, and higher tree species diversity compared with the other surveyed trails. These characteristics provided substantial foraging areas for EWWA. Cruz and Delannoy (1984a) suggested that if similar habitat were maintained throughout its distribution range, EWWA population would thrive.

Cruz and Delannoy (1984b) also studied the foraging ecology of EWWA and associated insectivores (Puerto Rican Vireo, Lesser Antillean Pewee, and the Puerto Rican Tody) in the Maricao State Forest. The EWWA foraged more frequently in the middle of the tree and higher than other insectivores studied except the Lesser Antillean Pewee. EWWA and the Puerto Rican

Vireo primarily used foliage gleaning to trap prey rather than sally-hover (foraging maneuver in which the bird flies from a perch to attack a food item and hovers over it with fluttering motions at the end of sally) and probing maneuvers. However, the Puerto Rican Tody and the Lesser Antillean Pewee preferred sally-hover as the predominant mode. Cruz and Delannoy (1984b) recommended further studies of the factors that cause foraging variability among members.

In 1991, Arroyo-Vázquez analyzed the niche relationships among species of the genus *Dendroica* along an elevation gradient in Puerto Rico. Clutch size was 2-3 eggs. Arroyo-Vázquez (1991, 1992) reported an average of 8.9 ± 5.01 EWWA/25ha in the Maricao State Forest with a total of 95 individuals reported. He also reported fluctuations in the number of EWWA reported between seasons. The highest EWWA density was recorded in June 1990 in Los Viveros. Only one observation was made in June and July of the same year in La Quinina Maricao State Forest, and none in the Lajas Valley. EWWA were observed at an average elevation of 831.9 ± 21.3m in the Maricao State Forest. Population densities of EWWA were highest where neither Adelaide's (*Dendroica adelaidae*) nor Yellow (*Dendroica petechia*) Warblers' occurred. Arroyo-Vázquez (1992) recommended continuous monitoring of EWWA in order to prepare wise management decisions to conserve the species in the future.

Information related to the breeding biology of the EWWA is scarce. Wiley and Bauer (1985) found five nests in the Caribbean National Forest. Clutch size was 2-3 eggs. Arroyo-Vázquez (1992) described two nests found in aerial leaf litter within the *Podocarpus* Forest in the Subtropical Lower Montane life zone of the Maricao State Forest. These nests were found in April and May. They were built from the leaves of yagrumo (*Cecropia peltata)*, *Chusquea abietifolia* and almendrillo (*Byrsonima wadsworthii*), and the interior was lined with dry strands of hierba de guinea (*Panicum maximum*) leaves. Arroyo-Vázquez (1992) suggested that nests in aerial leaf litter provided adequate protection from predation. Rodríguez-Mojica (2004) reported EWWA nesting in a tree cavity in Maricao State Forest. The nest had been built inside a rotten tree stump of Palo Colorado (*Cyrilla racemiflora*). The tree was in a man-modified habitat with no ground cover and a scattered canopy. Four nestlings were observed. This cavity nesting is the first reported for the genus *Dendroica* either in the tropics or in North America. Rodríguez-

Mojica (2004) suggested that nesting in cavities could be in response to predation, but more information on its breeding biology is needed.

STUDY AREAS

Surveys of Elfin-woods Warbler (EWWA) were conducted in the upland forests of Luquillo, Carite, Maricao, Toro Negro, Guilarte and Bosque del Pueblo (Figure 4). (See also Appendix 1)

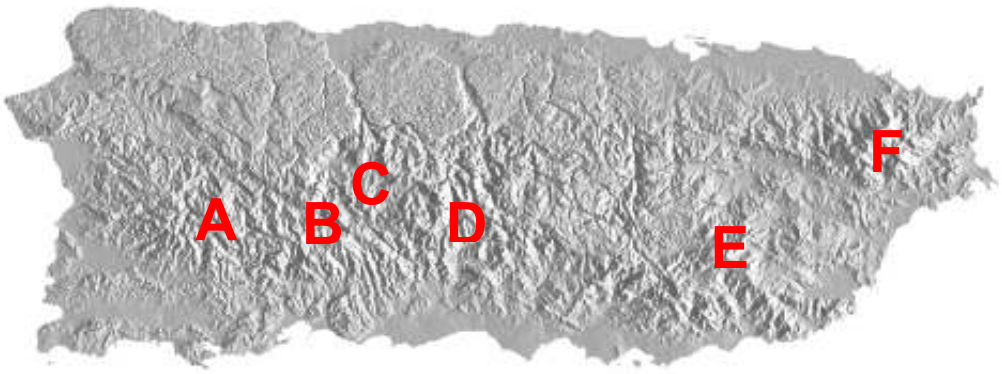

Figure 4. Areas surveyed for the presence of the Elfin-woods Warbler in Puerto Rico during 2003. A. Maricao. B. Guilarte. C. Bosque del Pueblo. D. Toro Negro. E. Carite. F. Luquillo. US Geological Survey DEM Map of Puerto Rico.

Caribbean National Forest (also known as the Luquillo Experimental Forest) – The Caribbean National Forest (11,330ha) is located in the Sierra de Luquillo, eastern Puerto Rico (18°19'N 66°45'W). Elevations range from 100 to 1,075m. Temperatures change with altitude, with averages of 77˚F in the lowlands and 66.2˚F above 1,000m (Weaver, 1972; Delannoy, 1997). Mean annual rainfall ranges from approximately 245cm/yr at lower elevations to approximately 400cm/yr at higher elevations (Brown *et al*., 1983). Wadsworth (1951) distinguished four forests types from low to high elevations in Sierra de Luquillo: Tabonuco (*Dacryodes excelsa*), Palo Colorado (*Cyrilla racemiflora*), Sierra Palm (*Prestoea montana*) and Dwarf forest.

Ninety-seven point-count stations were established 200m apart along 19km of trails to determine EWWA distribution and density within the Caribbean National Forest. Surveys were conducted along 3km of trail in East Peak (Dwarf Forest; elevations ranging from 680-900m),

3km of trail in Icacos Valley (Palo Colorado; 590-620m), 3km of trail along Tradewinds Trail (Palo Colorado and Dwarf forest; 680-750m), 3km of trail along El Toro Trail (Palo Colorado and Dwarf forest; 560-920m), 3km of trail in Mount Britton-El Yunque Peak (Sierra Palm; 680-890m), 2km of trail in Baño de Oro (Sierra Palm; 580-770m) and 2km of trail in Rio Cristal (Tabonuco; 200-300m).

Carite Forest- Carite Forest (2,777ha) is situated in the Sierra de Cayey, southeastern Puerto Rico (18°07'N 66°05'W). Elevations range from 250-900m with an annual precipitation of 235cm and a mean annual temperature of 71.6˚F (Delannoy, 1997). The Department of Natural Resources (1976) described six types of forests: Slope Forest, Tabonuco, Ausubo *(Manilkara bidentata*), Sierra Palm, *Micropholis* and *Buchenavia* and Dwarf forest. *Eucalyptus robustus* and *Pinus caribaea* have replaced native forest in some areas (Perez-Rivera and Nadal, 1996).

Twenty-nine point-count stations were established 200m apart along 5km of trails to determine EWWA distribution and density within the Carite Forest. Surveys were conducted in 1 km of trail in Charco Azul 1 (Ausubo, *Micropholis* and *Buchenavia*; elevations ranging from 540 to 560m), 1.2km of trail in Charco Azul 2 (Ausubo, *Micropholis* and *Buchenavia*; 580-620m), 1.2km of trail in Cerro La Santa (Dwarf forest and Sierra Palm; 730-810m) and 1.6km of trail in El Seis (Sierra Palm, *Micropholis* and *Buchenavia*; 700-800m).

Maricao State Forest – The Maricao State Forest (4,150ha) lies at the western end of the Cordillera Central (18°09'N 66°58'W). Elevations range from 15 to 900m, with mean annual temperature of 71.2˚F and precipitation of 235cm (Cruz and Delannoy, 1986; Delannoy, 1997). The Department of Natural Resources (1976) described five types of forests: Dry Slope, Slope Forest, Mixed Hardwood, Exposed Woodland and *Podocarpus* Forest.

Sixty-four point-count stations were established 200m apart along 11.6km of trail to determine EWWA distribution and density within the Maricao State Forest. Surveys were conducted along 3km of trail in Alto del Descanso (Plantations of *Eucalyptus robusta*, and Exposed Woodland; elevations of 550 to 740m), 3km of trail in Caín Alto (*Podocarpus*, Dry

Slope and Exposed Woodland; 470-800m), 1km of trail in Merenderos (*Podocarpus*, Dry Slope and Caribbean Pine plantation [*Pinus caribaea*]; 680-840m), 1km of trail in Viveros (*Podocarpus*; 640-870m), 1km of trail in Campamento Santana (Dry Slope and Exposed Woodland; 610-680m),1km of trail in Caballeriza (*Podocarpus*; 820-880m) and 1.6km of trail in Talitas (Plantations of *Eucalyptus robusta*; 630-720m).

Toro Negro Forest - Toro Negro Forest (2,733.1ha) is located in the central portion of the Cordillera Central (18°07'N 66°22'W). Elevations range from 440 to 1,338m on Cerro Punta, the highest peak in the island (Silander *et al.,* 1986). Average annual precipitation varies from 203.1 to 291.9cm and the temperature range is 66.9-77˚F (Delannoy, 1997). Rainfall usually declines between November and April, but there is rarely a prolonged dry period (Birdsey and Jiménez, 1985). Silander *et al.* (1986) described four forest types: Tabonuco, Dwarf, *Micropholis* and *Buchenavia* and Sierra Palm forests.

Thirty point-count stations were established 200m apart along 5.8km of trail to determine EWWA distribution and density within the Toro Negro Forest. Surveys were conducted along 2km of trail in El Bolo (Sierra Palm; elevations of 910 to 1,000m), 0.8km of trail in Vega Grande (Sierra Palm; 843-850m), 1km of trail in Doña Tona (Sierra Palm and plantations; 780-840m) and 2km of trail in Maravilla (Sierra Palm, Dwarf, *Micropholis* and *Buchenavia* forests; 860-1,140m).

Guilarte Forest – Guilarte Forest (1,457ha) also lies in the center of the Cordillera Central (18°08'N 66°47'W), west of Toro Negro Forest. Elevations range from 760 to 1,205m. The average annual precipitation is 200.1cm and the mean annual temperature is 70.3˚F (Silander *et al.* 1986). The Department of Natural Resources (1976) described four types of forests: Sierra Palm, *Microphollis* and *Buchenavia,* dwarfed vegetation comprising small-leaved evergreen species (e.g. *Tabebuia schumanniana*, *Ocotea spathulata* etc.) and plantations (e.g. coffee and *Eucalyptus*).

Nineteen point-count stations were established 200m apart along 3.4km of trails to determine EWWA distribution and density within the Guilarte Forest. Surveys were conducted

along 1km of trail in Cerro Guilarte (shade-coffee plantations and Sierra Palm; elevations of 940-1,080m), 1.2km of trail in Silla de Calderón (secondary forest; 720-760m) and 1.2km of trail in Mata de Plátano (shade-coffee plantations; 760-820m).

Bosque del Pueblo Forest– Bosque del Pueblo Forest (283ha) is located in the municipality of Adjuntas in the Cordillera Central (18°10'N 66°40'W). Elevations range from 400–700m, the mean annual temperature is 72ºF and the average annual precipitation is 31.5-35.0cm (Junta Rectora Consejo de Manejo Comunitario, 2002).

Fifteen point-count stations were established 200m apart along 3km of trails to determine EWWA distribution and density within Bosque del Pueblo. Surveys were conducted along 1km in Trail 1 (elevations of 560 to 590m), 1km in Trail 2 (500-590m) and 1km in Trail 3 (575-650m). All three trails were in secondary forests.

METHODS

Surveys were conducted from March through May, and again from August through November 2003, in the forests of the western half of the island (Maricao, Toro Negro, Bosque del Pueblo and Guilarte Forests). Surveys in the Maricao State Forest continued until December 2004. Surveys were conducted in the Caribbean National Forest and Carite Forest during a nine-week period in June-August 2003.

Seventeen field assistants (graduate and under-graduate students) participated in the island-wide surveys. Since Elfin-woods Warbler (EWWA) identification and detection skills among field assistants varied and thus could affect the precision and accuracy of counts, the assistants were trained before the surveys began. The training focused on standardizing survey procedures and improving visual and auditory EWWA identification skills. These exercises were conducted in the Maricao State Forest. Tape playback of vocalizations and repeated on-site observations of EWWA were used to help improve the field assistants' identification skills. Pictures were also used to emphasize EWWA characteristics such as plumage, size and behavior. The assistants worked in pairs to maximize safety in the field. Assistants were rotated in the surveyed areas to diminish any detection biases (Ralph *et al*., 1993).

Accessibility in the study areas was limited by tough terrain and controlled access so survey routes were established along existing forest trails, primitive (dirt) roads and isolated trails. Each surveyed route was 0.8-3km in length with point-count stations 200m apart to avoid counting the same individual bird twice. Counts were limited to 10 minutes per point-count station and began 30 minutes after sunrise and finished at approximately 11:00. Tape playback of EWWA song was used at all point-count stations during five of the 10 minutes in order to determine species presence. EWWA always responded to song playback within an average distance of 72m, and almost always came very close to the observer. This distance was taken as the EWWA maximum detection distance. All EWWA within a circular area of 1.6ha (radius = 72m) around each point-count station were assumed to respond to playbacks and were reported (Appendix 5). Densities (No. EWWA/ha/count) were calculated dividing the total of EWWA recorded between the area sampled and counts. Playbacks of EWWA vocalizations were not

used during surveys conducted from January through May 2003 to avoid interference with breeding pairs' behavior. However, because the species has a reduced period of singing in June and July (at the end of the breeding season) (Waide, 1995), playback was used from then on to improve detection rates. The EWWA density in the Maricao State Forest was determined using counts from August 2003 to December 2004, excluding data from January to May 2003 when playback was not used.

Field-work effort was approximately 261 hours (h) (18 counts) in Maricao State Forest, 138h (7 counts) in the Caribbean National Forest, 55h (8 counts) in Toro Negro Forest, 35h (7 counts) in Carite Forest, 31h (8 counts) in Guilarte Forest, and 19h (9 counts) in Bosque del Pueblo. Field data included EWWA age class (juvenile or adult) general behavior (singing, foraging, mating, nest building, feeding juveniles, moving in mixed-species flocks) and name of the observers, date, weather conditions and time of count at each point-count stations.

Other field data taken at each point-count stations included Global Position System (GPS) readings. These readings were taken with a Garmin etrex Venture GPS instrument to read UTM (Universal Transverse Mercator) grid coordinates. Each reading was transferred to a digital topographic map. A Sun Pocket altimeter was used to record elevation data. The altimeter was calibrated next to a USGS Bench Mark plaque prior to its use. Forest types were recorded in each point-count station, plotting each point-count station in vegetation zones maps available in scientific literature as Snyder *et al,*. (1987) and the Department of Natural Resources (1976). EWWA abundance and density estimation statistics in the Maricao State and the Caribbean National forests were compared using forest types. Abundance and density estimation were strictly representative of the areas surveyed.

Statistical Analyses

The point-count data were analyzed using the statistics program Statistix 8.0. The spatial pattern within each forest was analyzed with the Index of Dispersion, a variance-to-mean ratio test. Statistical significance was determined by a chi-squared goodness-of-fit test. Nonparametric tests were used to analyze the habitat occupancy because there was not a normal data distribution. Data transformations such as square root, exponential, arc sin, factorial and logarithmic were tried but they did not transform the data to a normal distribution. Nonparametric tests used were Kruskal-Wallis statistic, Kruskal-Wallis All-Pairwise Comparison and Spearman Rank Correlation (Ott and Longnecker, 2001).

RESULTS

Geographical distribution of the Elfin-woods Warbler in Puerto Rico

The island-wide surveys revealed that EWWA were only present in the sampled areas of Maricao State Forest and the Caribbean National Forest (Figure 5).

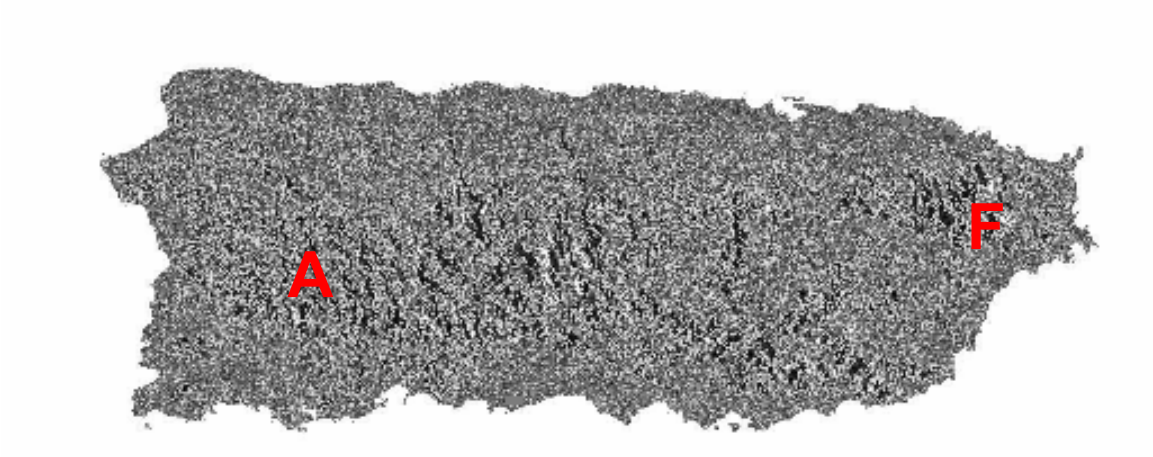

Figure 5. Distribution map of the Elfin-woods Warbler based on results of the 2003-2004 survey in Puerto Rico. [Drawing modified from BirdLife International (2004)]. EWWA has disappeared from former range along the Cordillera Central and Sierra de Cayey. Current distribution is limited to the Maricao State Forest (A) and Caribbean National Forest (F).

Table 1 demonstrated that in every repetition of counts in all 64 stations in the Maricao State Forest the variance was greater than the mean, resulting in an Index of Dispersion larger than 1. Though each Index of Dispersion suggests an aggregated distribution, not all were statistically significant. A chi-square goodness-of-fit test for the Index of Dispersion in the Maricao State Forest resulted in 33.3% (6 of 18 repetitions) aggregated and 66.7% (12 of 18 repetitions) random (Table 1)(Krebs, 1999). This suggests that a low percent of repetitions resulted in a significant aggregated pattern. However, in each repetition EWWA were not reported in more than 50% of the point-count stations surveyed (Table 2). EWWA observations in the Maricao State Forest indicate an aggregated distribution in each repetition (Table 2, Figure 6).

A sign test statistic (B) was conducted to determine whether the median (M) of the Index of Dispersion was greater than 1 (H_o: $M \leq 1$; H_a: $M>1$) per repetition. The 18 Index of

Dispersion were positive, thus B = 18 which is greater than $C_{0.05, 18} = 5$ (percentiles from a binomial distribution). I concluded that the data set of the Index of Dispersion demonstrate that the median (1.3590) is larger than 1. The sign test statistic result implies that EWWA has an aggregated distribution pattern according to the Index of Dispersion.

Between zero and four birds were found in each point-count station. Zero birds per point-count station were the most frequent category in all repetitions. Two birds per point-count station was the next most frequent category, exceeding frequency of categories 1, 3 and 4 (Table 2). These results suggest that territories are occupied by pairs of EWWA. Further studies have to be conducted to confirm this pattern.

Table 1. Elfin-woods Warbler distribution pattern per repetition and the sign test statistic for the Maricao State Forest.

Repetition	Variance (s^2)	Mean ($\tilde{y}$)	Index of Dispersion (ID)	X^2 = ID (n - 1)	Distribution pattern*	W í = I – 1 **
1	1.075	0.687	1.564	98.545	Aggregated	0.564
2	1.221	0.781	1.563	98.480	Aggregated	0.563
3	0.816	0.593	1.375	86.631	Random	0.375
4	1.538	0.718	2.140	134.869	Aggregated	0.140
5	1.023	0.762	1.343	84.590	Random	0.343
6	1.053	0.797	1.322	83.270	Random	0.322
7	0.737	0.656	1.123	70.760	Random	0.123
8	0.737	0.656	1.123	70.760	Random	0.123
9	0.944	0.766	1.233	77.690	Random	0.233
10	1.032	0.875	1.179	74.290	Random	0.179
11	0.845	0.609	1.387	87.360	Random	0.387
12	0.619	0.375	1.650	104	Aggregated	0.650
13	1.071	0.766	1.399	88.140	Aggregated	0.399
14	1.022	0.656	1.558	98.190	Aggregated	0.558
15	0.813	0.609	1.335	84.080	Random	0.335
16	0.944	0.766	1.233	77.690	Random	0.233
17	0.563	0.406	1.385	87.230	Random	0.385
18	0.884	0.687	1.287	81.090	Random	0.287

* Distribution patterns were determined using Figure 4.5 from Krebs (1999).
** The sign test statistic B is the number of positive W í = ID - M

Table 2. Summary of Elfin-woods Warbler observation per point–count stations per repetition in the Maricao State Forest.

Repetition	EWWA per point count stations				
	0	**1**	**2**	**3**	**4**
1	40	10	9	4	1
2	38	10	9	6	1
3	43	5	15	1	0
4	44	6	6	4	4
5	37	8	14	4	0
6	38	3	22	0	1
7	38	10	16	0	0
8	38	10	16	0	0
9	38	4	21	1	0
10	35	4	23	2	0
11	44	1	19	0	0
12	49	8	6	0	1
13	38	7	16	2	1
14	42	6	13	2	1
15	41	9	12	2	0
16	36	10	15	3	0
17	47	9	7	1	0
18	40	5	18	1	0

In the Caribbean National Forest the variance was also greater than the mean in every repetition, resulting in Indexes of Dispersion larger than 1 (Table 3). The chi-square goodness-of-fit test for the Index of Dispersion resulted in a significant aggregated distribution pattern in every repetition (n=7) (Table 3 and 4), opposed to the findings in the Maricao State Forest. This difference could be related to the quantity of point-count stations without any EWWA reported which is greater in the Caribbean National Forest.

A sign test statistic (B) was conducted to determine whether the median (M) of the Index of Dispersion was greater than 1 (H_o:$M \leq 1$;H_a:$M > 1$) per repetition. The 7 Indexes of Dispersion were positive, thus B=18 which is greater than $C_{0.05,7}=0$ (percentiles from a binomial distribution) and demonstrated that the median (1.7022) was larger than 1. The sign test statistic results confirmed that EWWA have an aggregated distribution pattern according to the Index of Dispersion of the Caribbean National Forest data.

Table 3. Elfin-woods Warbler distribution patterns per repetition and the sign test statistic for the Caribbean National Forest.

Repetition	Variance (s^2)	Mean ($\tilde{y}$)	Index of Dispersion (ID)	X^2 = ID (n - 1)	Distribution pattern*	W í = y í – 1 **
1	0.566	0.299	1.893	181.7	Aggregated	0.893
2	0.490	0.227	2.159	207.3	Aggregated	1.159
3	0.474	0.278	1.702	163.4	Aggregated	0.702
4	0.332	0.206	1.610	154.6	Aggregated	0.61
5	0.328	0.278	1.178	113.1	Aggregated	0.178
6	0.407	0.268	1.517	145.6	Aggregated	0.517
7	0.876	0.464	1.889	181.3	Aggregated	0.889

* Distribution patterns were determined using Figure 4.5 from Krebs (1999).
** The sign test statistic B is the number of positive W í = ID - M

Table 4. Summary of Elfin-woods Warbler observation per point–count station per repetition in the Caribbean National Forest.

	EWWA per point count stations				
Repetition	**0**	**1**	**2**	**3**	**4**
1	81	6	8	1	1
2	86	3	6	1	1
3	81	7	7	2	0
4	83	10	2	2	0
5	76	15	6	0	0
6	80	9	7	1	0
7	74	7	12	2	2

Although EWWA spatial pattern was aggregated as determined by the Index of Dispersion, they were recorded in every trail sampled in the Maricao State Forest (Figure 6).

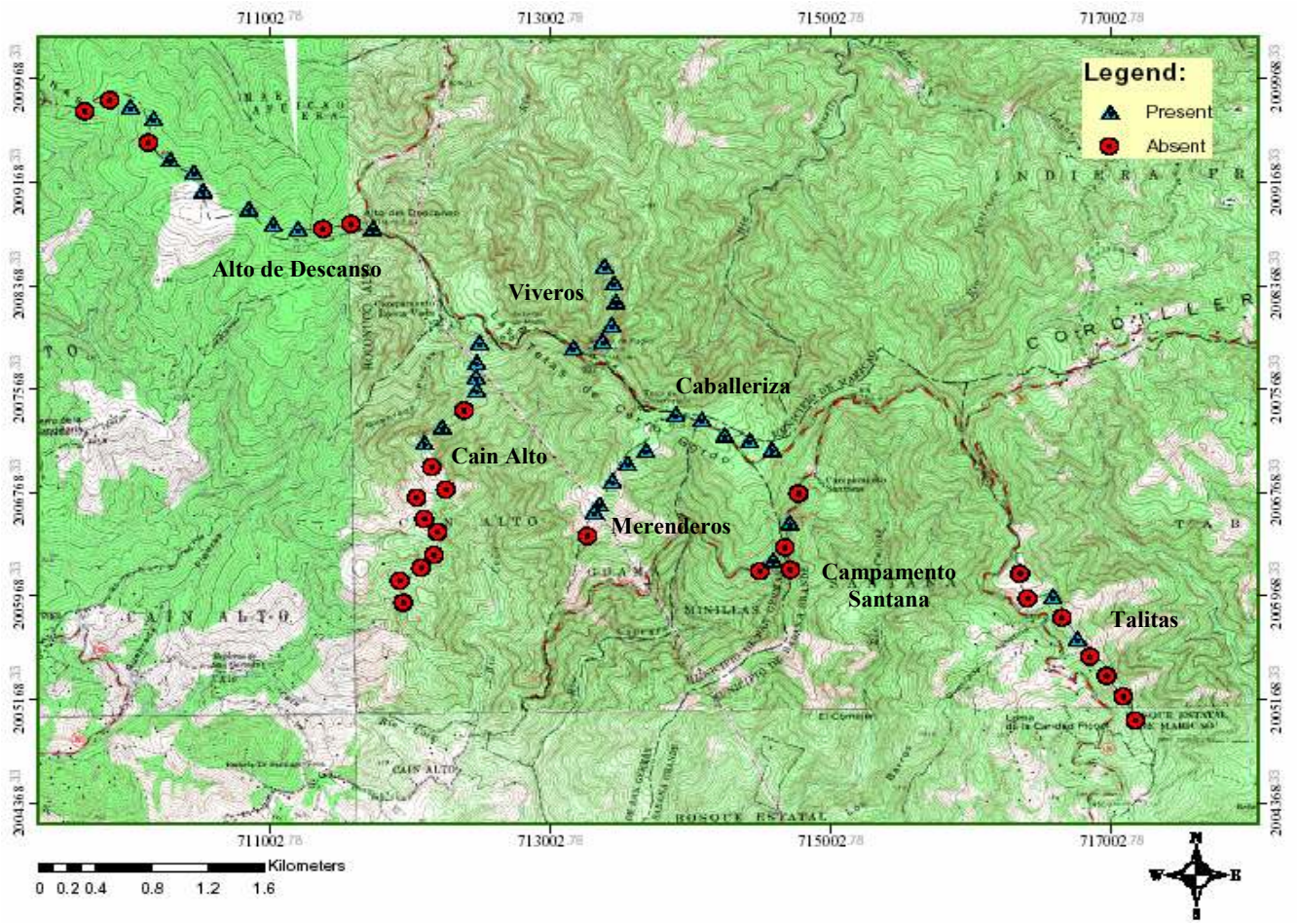

Figure 6. Distribution pattern of the Elfin-woods Warbler (EWWA) within surveyed areas of the Maricao State Forest. The blue triangles represent presence and the red circles represent absence of the EWWA per point-count stations. Map prepared by Heinz Weidisch of the Biology Department, University of Puerto Rico-Mayagüez Campus. Two point-count stations from Alto del Descanso are not shown in the map.

EWWA abundance was higher in Viveros, Caballeriza, Merenderos and Caín Alto trails. Fewer EWWA were recorded along Campamento Santana, Alto del Descanso and Talitas trails (Table 5, Figure 6). The Kruskal Wallis statistic (25.54, $p<0.5$) calculated for the trails' mean rank suggests that these are different enough to reject the null hypothesis. Therefore, there are significant differences in EWWA mean abundance among the sampled trails. The Kruskal Wallis All Pairwise Comparisons identified mean ranks with significant differences between Viveros and Cain Alto trails; Viveros and Talitas trails; and Caballeriza and Talitas trails (Appendix 2).

Table 5. Average number of Elfin-woods Warbler per point-count station along sampled trails in the Maricao State Forest

Sampled trail [a]	Mean ± S.D.	Number of sampled point (N)	Percent of EWWA abundance per trail
Viveros	1.73 ± 0.64	6	31
Caballeriza	1.47 ± 0.39	5	26
Merenderos	0.66 ± 0.60	6	12
Cain Alto	0.60 ± 0.64	16	11
Campamento Santana	0.54 ± 0.65	6	10
Alto del Descanso	0.47 ± 0.32	16	8
Talitas	0.13 ± 0.15	9	2

[a] Trails are identified in Figure 6

Most EWWA in the Caribbean National Forest were recorded along the Tradewinds Trail, with fewer in Icacos Valley, El Toro Trail and East Peak (Table 6, Figure 7). There was one sighting in Rio Cristal watershed and none in Mount Britton nor Baño de Oro trails (Table 6, Figure 7). The Kruskal Wallis statistic (56.52, $p < 0.5$) suggested differences in the trails mean rank. The Kruskal Wallis All Pairwise Comparisons identified three homogenous groups (Appendix 2). Differences in mean EWWA abundance were not statistically significant between Tradewinds and Icacos trails; Icacos, El Toro, East Peak, Rio Cristal and Baño de Oro trails; and El Toro, East Peak, Rio Cristal, Baño de Oro, and Mt. Britton trails.

Table 6. Average number of Elfin-woods Warbler per point-count station along sampled trails in the Caribbean National Forest

Sampled trail [a]	Mean ± S.D.	Number of sampled point (N)	Percent of EWWA abundance per trail
Tradewinds	1.10 ± 0.61	15	59
Icacos	0.35 ± 0.29	15	19
El Toro	0.29 ± 0.48	16	16
East Peak	0.10 ± 0.18	15	5
Rio Cristal	0.01 ± 0.04	11	1
Mt. Britton	0	15	0
Baño de Oro	0	10	0

[a] Trails are identified in Figure 7

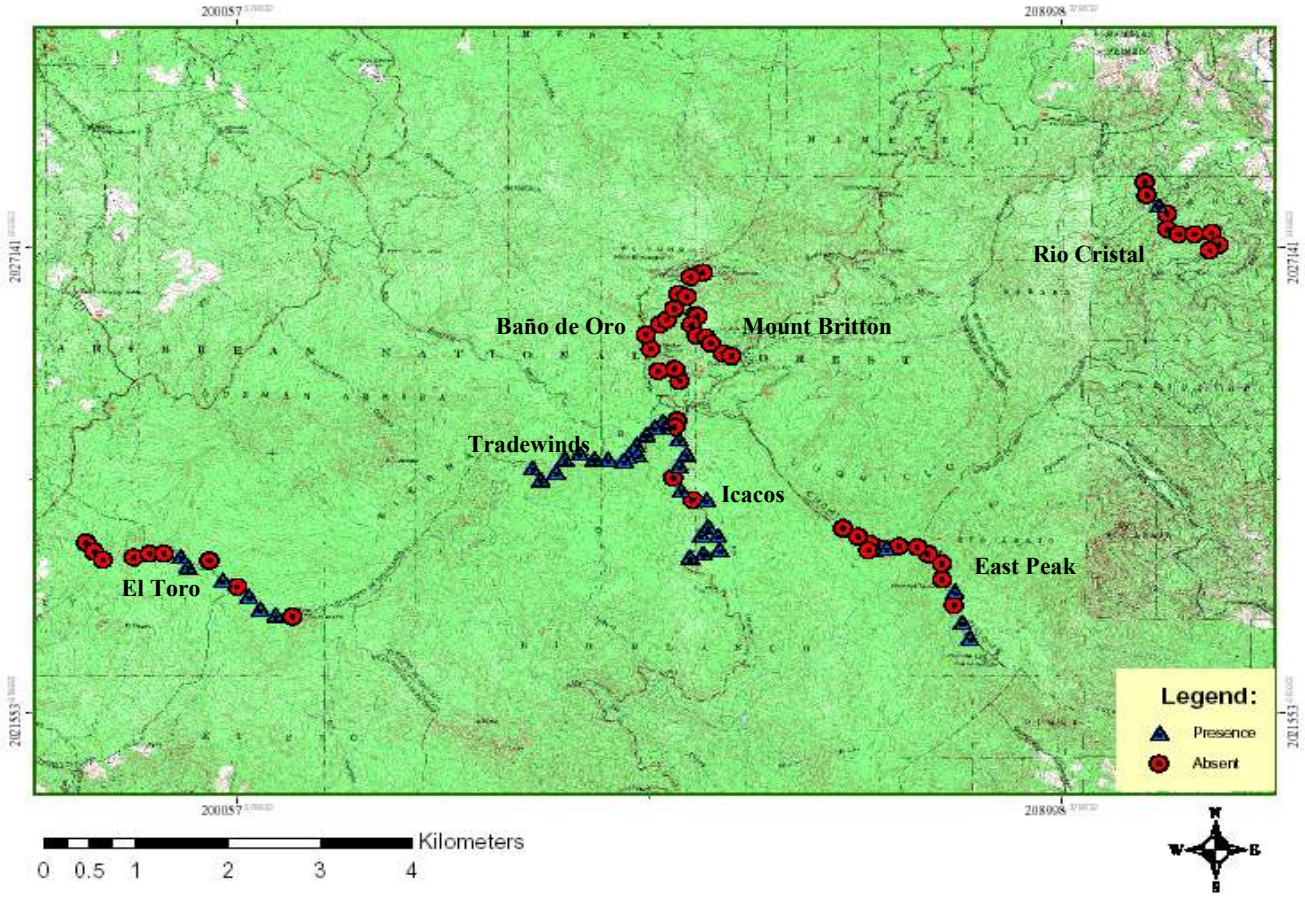

Figure 7. Distribution pattern of the Elfin-woods Warbler (EWWA) within the surveyed areas of the Caribbean National Forest. The blue triangles represent presence and the red circles represent absence of the EWWA per point-count stations. Map prepared by Heinz Weidisch of the Biology Department, University of Puerto Rico-Mayagüez Campus.

Habitat occupancy of the Elfin-woods Warbler in Puerto Rico

EWWA were not evenly distributed within the Caribbean National Forest nor Maricao State Forests. Two variables were selected to evaluate their relationship to the aggregated distribution pattern found in this study; forest type and elevation.

Forest type - The highest mean number of EWWA per point-count stations in Maricao State Forest was recorded in the *Podocarpus* Forest (Table 7, Figure 8). Lower mean values were recorded in Exposed Woodland, Plantations and Dry Slope Forest (Table 7, Figure 8). The Kruskal-Wallis statistic (39.64, $p<0.5$) calculated for the above mean values per forest type suggest that these are different enough to reject the null hypothesis. The Kruskal Wallis All-Pairwise Comparison identified two homogenous groups in which *Podocarpus* differed from Exposed Woodland, Plantations and Dry Slope Forests (Appendix 3).

Table 7. Average number of Elfin-woods Warbler per point-count station along sampled forest types in the Maricao State Forest

Forest types	Mean ± S.D.	Number of sampled point (N)	Percent of EWWA abundance per forest types
Podocarpus	1.50 ± 0.47	19	62
Exposed Woodland	0.47 ± 0.42	15	19
Plantations	0.33 ± 0.33	19	14
Dry Slope	0.11 ± 0.17	11	5

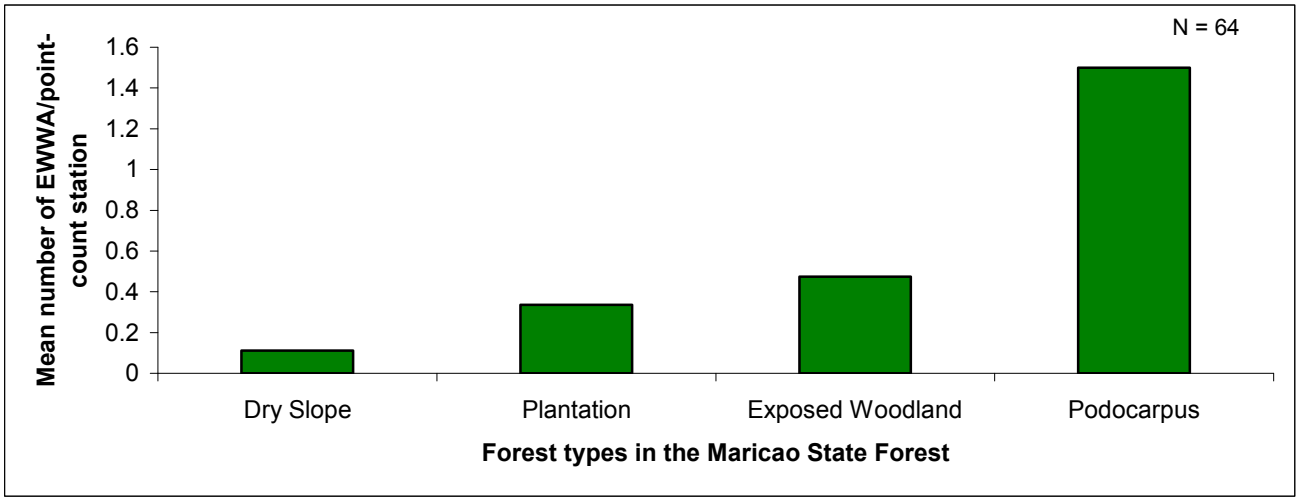

Figure 8. Average number of Elfin-woods Warbler per point-count stations per forest types in the Maricao State Forest. [Kruskal-Wallis = 39.6, $p<0.05$. N = number of sampled point-count stations].

The mean number of EWWA per point-count station in the Caribbean National Forest was highest in Palo Colorado, slightly lower in Dwarf Forest, lowest in Tabonuco and none recorded in Sierra Palm Forest (Table 8, Figure 9). The Kruskal-Wallis statistic (31.13, $p<0.5$) calculated for forest type mean suggests that these are different enough to reject the null hypothesis. The Kruskal Wallis All-Pairwise Comparison Test identified three homogenous groups. Palo Colorado formed a homogenous group with Dwarf Forest; Dwarf Forest with Tabonuco; and Tabonuco with Sierra Palm (Appendix 3).

Table 8. Average number of Elfin-woods Warbler per point-count station along sampled forest types in the Caribbean National Forest

Forest types	Mean ± S.D.	Number of sampled point (N)	Percent of EWWA abundance per forest types
Dwarf Forest	0.42 ± 0.50	26	46
Palo Colorado	0.48 ± 0.61	35	53
Tabonuco	0.01 ± 0.04	11	1
Sierra Palm	0.00 ± 0.00	25	0

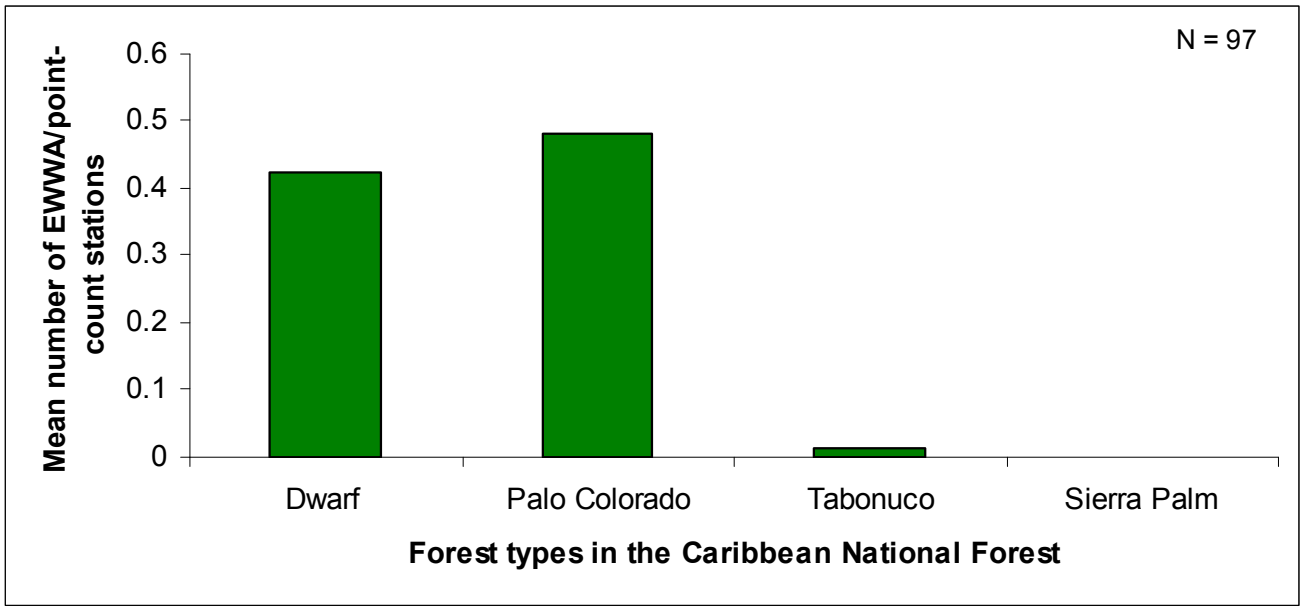

Figure 9. Average number of Elfin-woods Warbler per point-count stations per forest types in the Caribbean National Forest. Kruskal-Wallis = 31.13, $p<0.05$. N = number of sampled point-count stations.

Elevation - The average number of EWWA recorded per point-count station increased with elevation in the Maricao State Forest (Figure 10). The Spearman Rank Correlation coefficient (0.5813, $p<0.05$) resulted in a moderately strong and positive relation implying that EWWA per point-count station increased as elevation increased (Appendix 4).

EWWA in the Caribbean National Forest were recorded from 250 to 949m with a peak at 600-800m (Figure 10). The Spearman Rank Correlation coefficient (0.0475, $p>0.05$) resulted in a weak and non significant relation (Appendix 4).

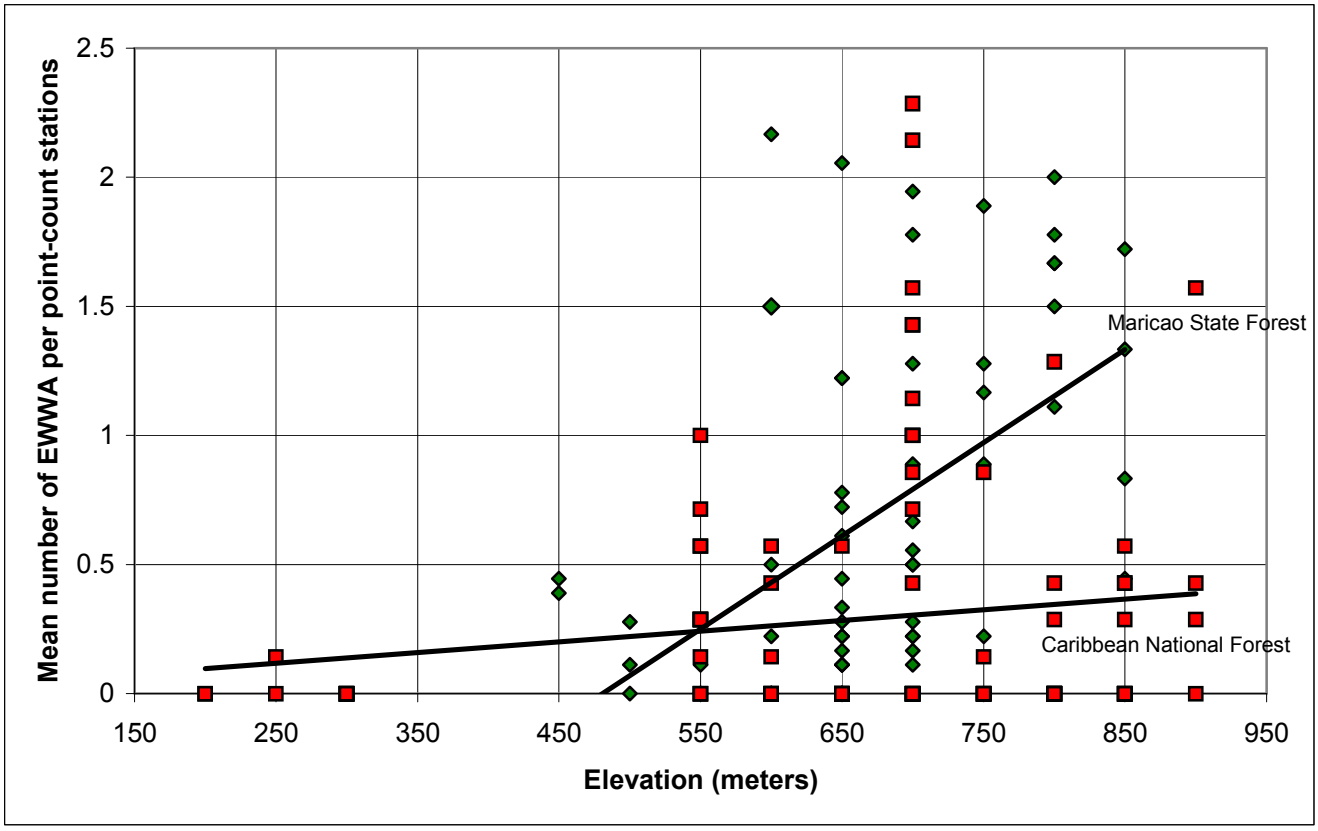

Figure 10. Average number of Elfin-woods Warbler per point-count station per elevation in the Caribbean National Forest (red squares) and Maricao State Forests (green diamonds). [Total number of point-count stations sampled in the Caribbean National Forest N=97, and N=64 in Maricao State Forest. The lines are simple linear regression. The graphic illustrates point-count stations with superimposed data].

Elfin-woods Warbler Estimated Density

EWWA estimated density presented below is strictly representative of the areas surveyed. EWWA density estimate for the surveyed area (102.4ha) in the Maricao State Forest was 0.42 EWWA/ha/count (Table 9). EWWA density estimates were higher in the *Podocarpus* Forest, moderate in Exposed Woodland and Plantation Forests, and lower in the Dry Slope Forest.

Table 9. Elfin-woods Warbler population estimate for the surveyed areas in the Maricao State Forest

Forest Type	Number of sampled points (N)	Total area sampled (ha)	Total of EWWA recorded in 18 counts	Average of EWWA in the total area sampled (EWWA/ha/count)
Dry Slope	11	17.6	22	0.07
Exposed Woodland	15	24.0	128	0.30
Plantation	19	30.4	115	0.21
Podocarpus	19	30.4	513	0.94
Total	64	102.4	778	0.42

EWWA density estimate for the Caribbean National Forest was 0.18 EWWA/ha/count in a surveyed area of 155.2ha (Table 10). EWWA density estimates were higher in Palo Colorado and Dwarf Forests, quite lower in Tabonuco Forest, and not recorded in Palm Forest.

Table 10. Elfin-woods Warbler population estimate for the surveyed areas in the Caribbean National Forest

Forest Type	Number of sampled points (N)	Total area sampled (ha)	Total of EWWA recorded in 7 counts	Average of EWWA in the total area sampled (EWWA/ha/count)
Dwarf Forest	26	41.6	77	0.26
Palo Colorado Forest	35	56.0	118	0.30
Tabonuco Forest	25	40.0	1	0.004
Palm Forest	11	17.6	0	0
Total	97	155.2	196	0.18

DISCUSSION

Geographical distribution of the Elfin-woods Warbler in Puerto Rico

EWWA populations found in this study were approximately 150km apart suggesting two disjunct populations (Gochfeld *et al*., 1973). One population was in the Caribbean National Forest and another population in the Maricao State Forest. These are the montane forests with the largest territorial extension and protection in the island. The Caribbean National Forest has approximately three times the area of the Maricao State Forest. However, coffee plantations at the boundaries of the later forest extend the vegetation cover making the area larger for species dispersion (Tossas and Delannoy, 2001).

Apparently, EWWA are no longer present in previously reported areas of the Carite and Toro Negro Forests, which were formerly part of its historical range. This critical finding reduces EWWA limited range even more, threatening its long-term existence. This finding, however, only represents the surveyed area. The possibility of finding EWWA in areas not searched is always present. EWWA were not recorded in the montane forest of Los Tres Picachos, located in the municipalities of Ciales and Jayuya (Miranda-Castro *et al.,* 2000), and Bosque del Pueblo and Guilarte in the municipality of Adjuntas (this study). A natural or human disturbance in one of the two current populations could reduce EWWA numbers and drive the species to a higher of endangerment category. Puerto Rico's current urban extension makes it difficult for this species to move from one end of the island to the other and probably prevents gene flow between the populations.

Changes in EWWA historical distribution could be due to continued development of mountain peaks for communication infrastructure and roads, thus causing destruction, fragmentation, and alteration of high elevation habitats (Delannoy, 1997). Dwarf Forest alteration and modification along the Cordillera Central have occurred in Cerro La Santa in Carite Forest, Cerro Maravilla and Cerro Punta in Toro Negro Forest, and El Yunque peak in the Caribbean National Forest. Many of the large scale declines of whole groups of species can be viewed as the results of habitat alteration (Gaston, 1994).

Taking this into consideration, the Department of Natural and Environmental Resources and the community based Grassroot Group Casa Pueblo have introduced an initiative for a central corridor in the Cordillera Central. The objective is to join central protected areas by a wide corridor of forested land which will benefit movements of species without any obstruction or alteration. If extended eastward towards the Luquillo Forest this corridor could promote EWWA dispersion. The disjunct EWWA distribution, together with evidence that until recently it was found also in Toro Negro and Carite, suggests that it was once a widespread species that has been isolated in pockets because of habitat destruction (Cruz and Delannoy, 1984a).

EWWA spatial pattern in the Maricao State Forest was aggregated though the bird was found along every trail sampled. EWWA were more abundant in Los Viveros trail which is consistent with previous studies (Cruz and Delannoy, 1984a; Arroyo-Vázquez, 1992). In similarly accord with Cruz and Delannoy (1984a), few EWWA were reported in Campamento Santana.

The spatial pattern in the Caribbean National Forest was also aggregated. In this study and in Waide (1995) some point-count stations consistently had EWWA while others did not, indicating that within the isolated population EWWA had an aggregated spatial pattern and demonstrated site fidelity. EWWA site fidelity could be related to protection from predators, association with rich food supply and scarcity of other suitable nest sites in an area. More than half of the total detections in the Caribbean National Forest in this study were along the Tradewinds Trail. Waide (1995) suggests that the species is rare in the areas of El Yunque and Mount Britton and more common at Pico del Este along the Tradewinds Trail to El Toro Trail, and in the upper part of the Icacos Valley. In this study EWWA were not reported in Mount Britton nor El Yunque Trail, which is consistent with Waide's (1995) finding. Reasons for the absence of EWWA on El Yunque Trail and Mount Britton are unclear (Waide, 1995). El Toro Trail has the third highest count in this study; this differs from Waide's (1995) report which was low for this part of the forest.

Habitat occupancy of the Elfin-woods Warbler in Puerto Rico

Forest type - EWWA was found in a variety of forest types within the Maricao State Forest. This study found significant differences in average number of EWWA per point count stations between *Podocarpus* and the other forest types. Cruz and Delannoy (1984a) had higher EWWA density in the *Podocarpus* forest type in the Maricao State Forest, which is consistent with this study. Viveros Trail has the highest EWWA abundance in the Maricao State Forest and *Podocarpus* was its dominant vegetation. This forest type has the greatest structural complexity such as tree of different diameter at breast high (d.b.h) and tree species diversity (Cruz and Delannoy, *op cit*.). EWWA has been more abundant in *Podocarpus,* which needs to be protected for its long-term conservation.

The forest type with the lowest abundance was Dry Slope. Campamento Santana with Dry Slope Forest was one of the trails with fewer EWWA detections. In the three transects surveyed by Cruz and Delannoy (1984a) Campamento Santana was the trail with fewest EWWA. Since completion of this study further investigation by Delannoy (pers. com.) and field assistants finds EWWA in second growth forest outside Maricao State Forest boundaries which support Cruz and Delannoy's (1984a) suggestion that the species was not restricted to undisturbed habitats. EWWA use of habitats in the Maricao State Forest has remained consistent over the years.

There were significant differences in mean EWWA abundance among forest types in the Caribbean National Forest. Kepler and Parkes (1972) observed higher EWWA abundance in Dwarf Forest in contrast to this study which found them more abundant in Palo Colorado Forest. However, no significant statistical difference in abundance resulted between Palo Colorado and Dwarf Forest.

EWWA shift in use of Palo Colorado over Dwarf Forest could be related to loss and unavailability of the latter habitat due to land conversion to recreational use and installation of communication infrastructure (Waide, 1995). The low productivity of Dwarf Forest was demonstrated by the slowness of regeneration after disturbance (Waide, 1995). Since the

productivity of Dwarf Forest is low, these changes are in essence irreversible (Waide, *op. cit.*). The major threat to EWWA existence is the destruction or alteration of its preferred habitat (Waide, 1995).

Hurricane Hugo (1989) and Georges (1998) severely damaged the Dwarf Forest as well as other forest types in the Caribbean National Forest. Response of bird populations to hurricane damage includes shifts in diet, foraging sites or habitats, and reproductive changes (Wiley and Wunderle, 1993). A vertical movement or changing of primary habitat in response to hurricane damage has been shown by different species (Wiley and Wunderle, *op. cit*.). This shift in forest type use also reveals ecological plasticity and adaptation to forest type changes, which may increase the resilience of the species. Hugo's effects on EWWA in Dwarf Forest were difficult to assess without quantitative data, but there are ample records of the negative effects of hurricanes on bird populations (Wiley and Wunderle, 1993). However, the small population of EWWA and the exposed nature of its habitat suggest that hurricane effects might have been much larger for this species (Waide, 1995).

Absence of EWWA from the Sierra Palm Forest in the Caribbean National Forest was unexpected as other investigators have reported the species from this forest type (Wiley and Bauer, 1985). This pattern suggests that EWWA does not occupy all the available forest types in the Caribbean National Forest (Waide, 1995). Perhaps there is a seasonal use of this forest type by the EWWA that was not detected because this survey was limited to nine weeks during June-August 2003. Monthly counts conducted from 1989-1993 at Mount Britton (which has extensive areas with Sierra Palm Forest), revealed very low EWWA abundance and in most months no birds were observed (Waide, 1995).

Previous investigators have related low EWWA abundance in El Yunque and Mount Britton to heavy foot traffic by visitors, but from this study it seems to be directly related to forest types. However, heavy foot traffic affecting this area should not be discarded until a study is conducted to answer this question. Also, it should be remembered that El Yunque Trail was battered by hurricane winds in 1989. Waide (1995) suggests that birds in the Icacos Valley may represent a temporary response to disturbance. Ten years have elapsed since Waide's (1995)

study so the "temporary response" has to be analyzed in detailed. How much time does a species need to return to its former habitat where it was more abundant? Other examples on shifting habitats following hurricanes are available in the writings of Wiley and Wunderle (1993).

No EWWA were reported in Toro Negro although it has Dwarf Forest. Other habitats (as shade-coffee plantations, timber plantations and secondary habitats) outside of its historical distribution range yielded negative results from samplings in Bosque del Pueblo and Guilarte Forests. EWWA were not found in Dwarf Forest, Tabonuco or Sierra Palm in Los Tres Picachos Forests (Miranda-Castro *et al*., 2000). Although, there seems to be available habitat left for the EWWA in these upland forests, the species is not present. This could be related to the alteration and fragmentation of the habitat making the areas unsuitable for foraging and reproduction. Given the lack of understanding, the most conservative approach to protect the species is to conserve the entire remaining habitat.

Elevation - The historical altitudinal record of EWWA in the Maricao State Forest is consistent with this study. Cruz and Delannoy (1984a) found most of them between 600 to 880m. Most EWWA were reported between 600-850m, which happens to be *Podocarpus*, the forest type with the highest EWWA abundance. On the other hand, less EWWA abundance was reported at 450m. This altitudinal variation could be related to changes in forest structure that influenced EWWA foraging behavior, reproduction and predation. The species was found mainly in elevations from 700-900m, but can also be observed at lower elevations (Tossas and Delannoy, 2001). This finding seems to support Gochfeld's (1973) remarks about the possibility of some EWWA seasonal vertical migration within the Maricao State Forest. There is a consistent altitudinal pattern in abundance in the Maricao State Forest which shows very low numbers at lower elevations and an increase in abundance with elevation though with considerable variation.

EWWA has experienced a slight altitudinal shift in distribution in the Caribbean National Forest. Kepler and Parkes (1972) pointed out that this species was found from 640 to 1,030m in elevation in the Caribbean National Forest. Later, Waide (1995) observed its presence between 710 to 954m. This study determined the altitudinal range to be from 550-910m. However, a new elevation record was obtained when one bird was reported at 270m, the lowest ever. This

outlying detection could be related to seasonal altitudinal movements within the Caribbean National Forest. These altitudinal shifts could be related to changes in food abundance, breeding behavior and predation pressure variations between forest types.

Elfin-woods Warbler Estimated Density

This study only estimated the population of the surveyed areas with totals of 43.01 EWWA in 102.4 ha/count in the Maricao State Forest and 27.94 EWWA in 155.2 ha/count in the Caribbean National Forest. A higher EWWA number was reported for the Maricao State Forest, although the Caribbean National Forest has a larger area. These density differences could be related to forest vegetation structure, which seems more suitable for EWWA in the Maricao State Forest. This partial estimate was not extrapolated to a population estimate because of the EWWA aggregated distribution. The aggregated distribution complicates the estimation of the total population size and the determination of habitat requirements.

Cruz and Delannoy (1984a) reported the highest EWWA density in Los Viveros (20.9/25ha) and significantly lower density in Rosario Alto (3.0/25ha) and Campamento Santana (1.2 /25ha). This study also reflects that Los Viveros and Caballeriza, which were composed of *Podocarpus* have the highest EWWA estimate density in the Maricao State Forest.

The historical population estimate for the Caribbean National Forest has remained a benchmark statistic for many years. Kepler and Parkes (1972) estimated the population as 300 pairs. Waide (1995) believed the 300 pairs estimate was high and came up with a new estimate of 138 pairs (275 individuals). Waide (1995) warns caution with his estimate due to detections of EWWA outside Dwarf Forest. In this study EWWA has the highest detection rate in Palo Colorado Forest and Dwarf Forest, and almost zero in Tabonuco Forest. Tradewinds Trail has a composition of Palo Colorado and Dwarf Forests, which at the same time has the highest EWWA numbers in this study. Likewise, Waide (1995) has the highest maximum detection density of 11.3 birds per 15 point-count stations recorded at any site.

CONCLUSIONS

This thesis is an effort to increase the knowledge of the distribution, habitat occupancy and abundance, and population density of the Elfin-woods Warbler. The main conclusions from this survey are:

- In the six areas surveyed EWWA was present in only two.
- EWWA had a non-random (aggregated) distribution within Maricao State Forest and the Caribbean National Forest.
- Significant relationship was found between the type of forest and EWWA abundance in the Caribbean National Forest and the Maricao State Forest.
- A positive correlation was discovered between EWWA abundance and elevation in the Maricao State Forest.
- No significant relation was found between EWWA abundance and the elevation in the Caribbean National Forest.
- EWWA densities were low suggesting that conservation management is necessary to assure the survival of the species.

RECOMMENDATIONS

In accordance with the conclusions, the immediate protection of the species is recommended by listing it endangered under the Endangered Species Act and the International Union for Conservation of Nature (IUCN). The Center for Biological Diversity (2003) has petitioned a Federal Endangered Species status for the Elfin-woods Warbler. The recommended endangered category is based on IUCN Red List Categories and Criteria (IUCN, 2004) (Appendix 6).

As a rare species with small range there are some traits which may alter their vulnerability to extinction. In order to create more accurate recommendations to protect EWWA, other scientific studies have to be conducted to understand why this species distribution is fragmented in the island. A priority should be to study EWWA biology which could include reproductive success, clutch size, territorial behavior, seasonal movements and mortality. Studies in habitat requirements are crucial to the survival of this species. Vegetation at each sampling point should be measured and analyzed to develop a better understanding of the reason for aggregated distribution. Other studies that will help to formulate clear guideline management for the survival of the species are dispersal ability, range size and predation.

Long-term populations monitoring should be continued at existing sites in Maricao and Luquillo and extended to other parts of the forests. Surveys have to be established in forest of its historical distribution to detect if reintegration of the species occurs in those forests in the future. Maps of EWWA distribution should be updated regularly to compare changes of population movements inside the forests. This species will not be conserved by managing the species, but EWWA will be indirectly protected by preserving the habitat it occupied and historically used. A current initiative that will help the dispersion of the species in the Central Mountains is the creation of a corridor to join protected areas. This initiative is being supported by the Department of Natural and Environmental Resources and the community based Grassroot Group Casa Pueblo.

It is imperative to protect the habitat the species occupies. Permits for the construction of communication towers in the mountain areas which include EWWA current and historical distribution should not be authorized. No human disturbance or construction should be allowed in order to avoid worsening habitat fragmentation and risk population decline.

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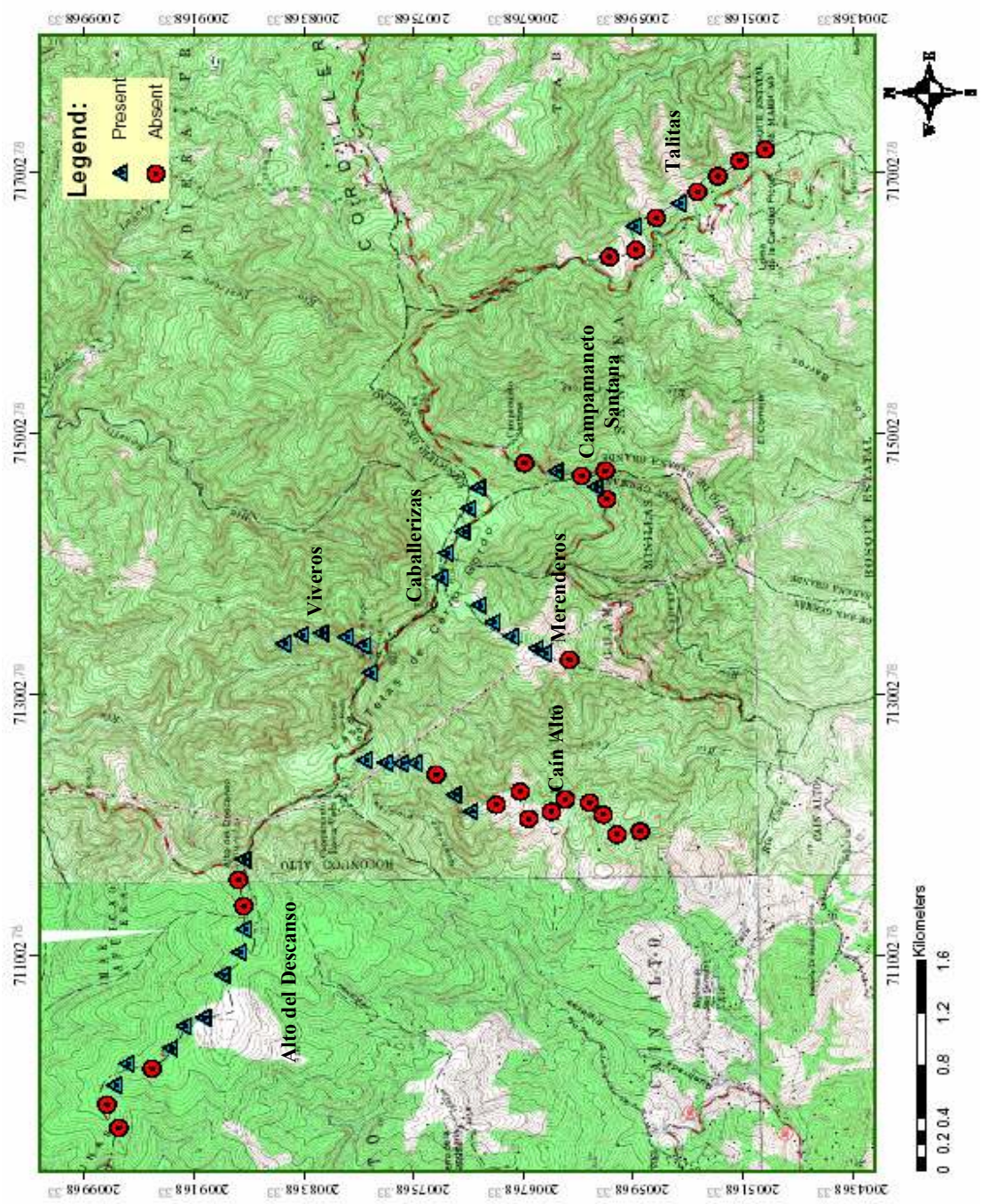
Appendixes

Appendix 1

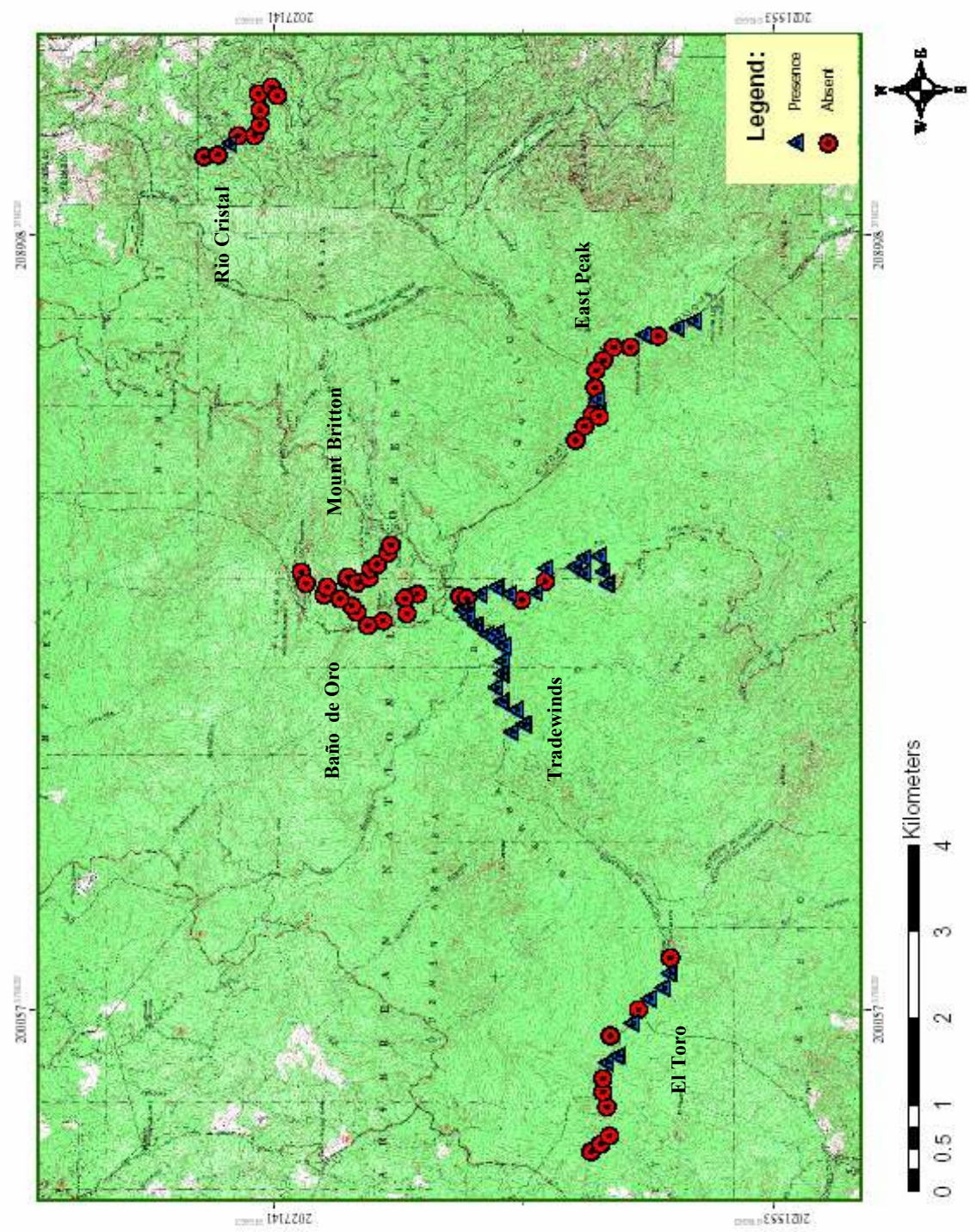
Spatial distribution maps of the Elfin-woods Warbler (EWWA) per point-count station in Puerto Rico in 2003.

Blue triangles represent EWWA presence and red circles represent absence. Map created by Heinz Weidisch in the Biology Department University of Puerto Rico Mayagüez Campus.

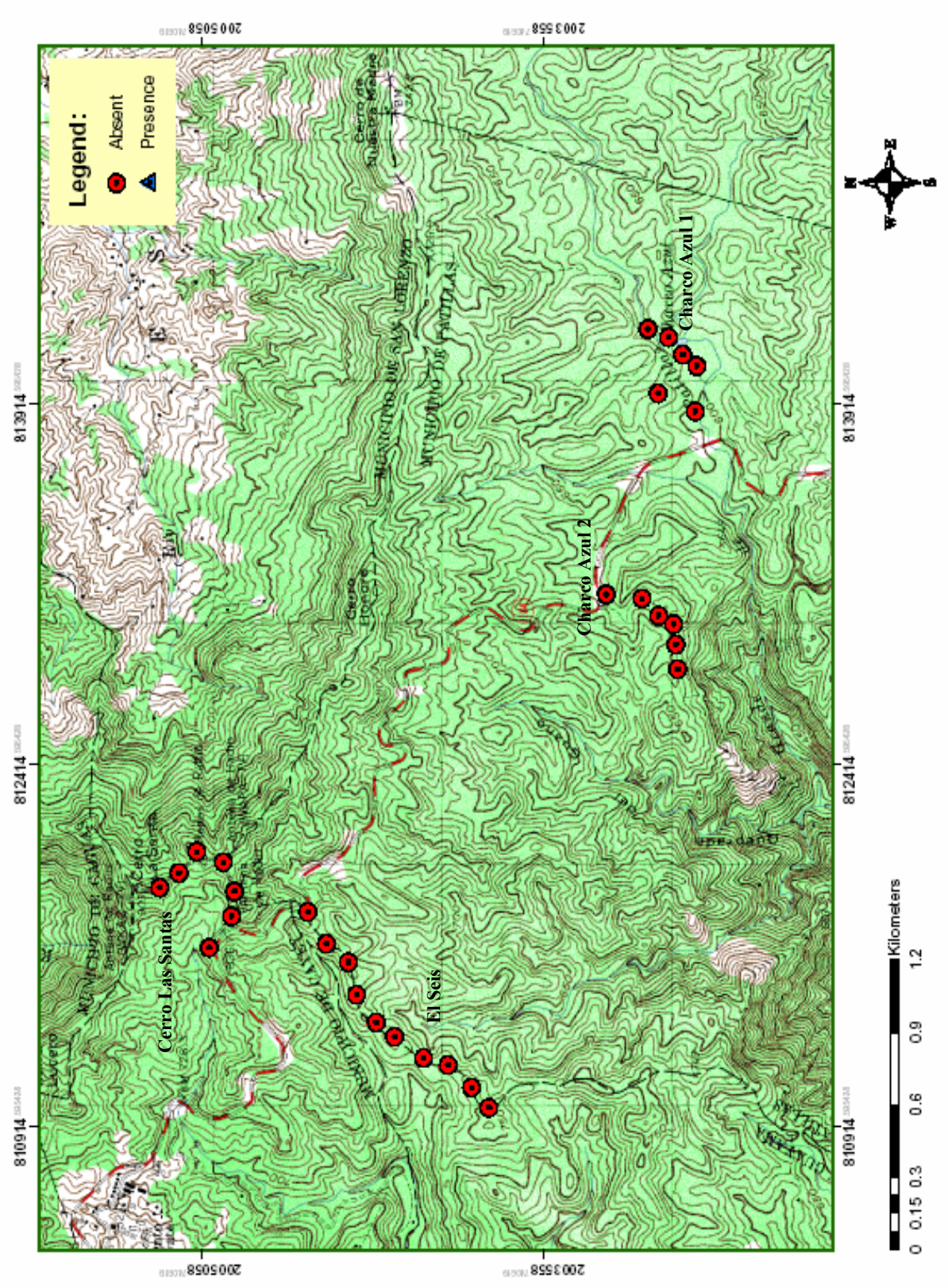
1a. Spatial distribution pattern of the EWWA per point-count stations in the Maricao State Forest.



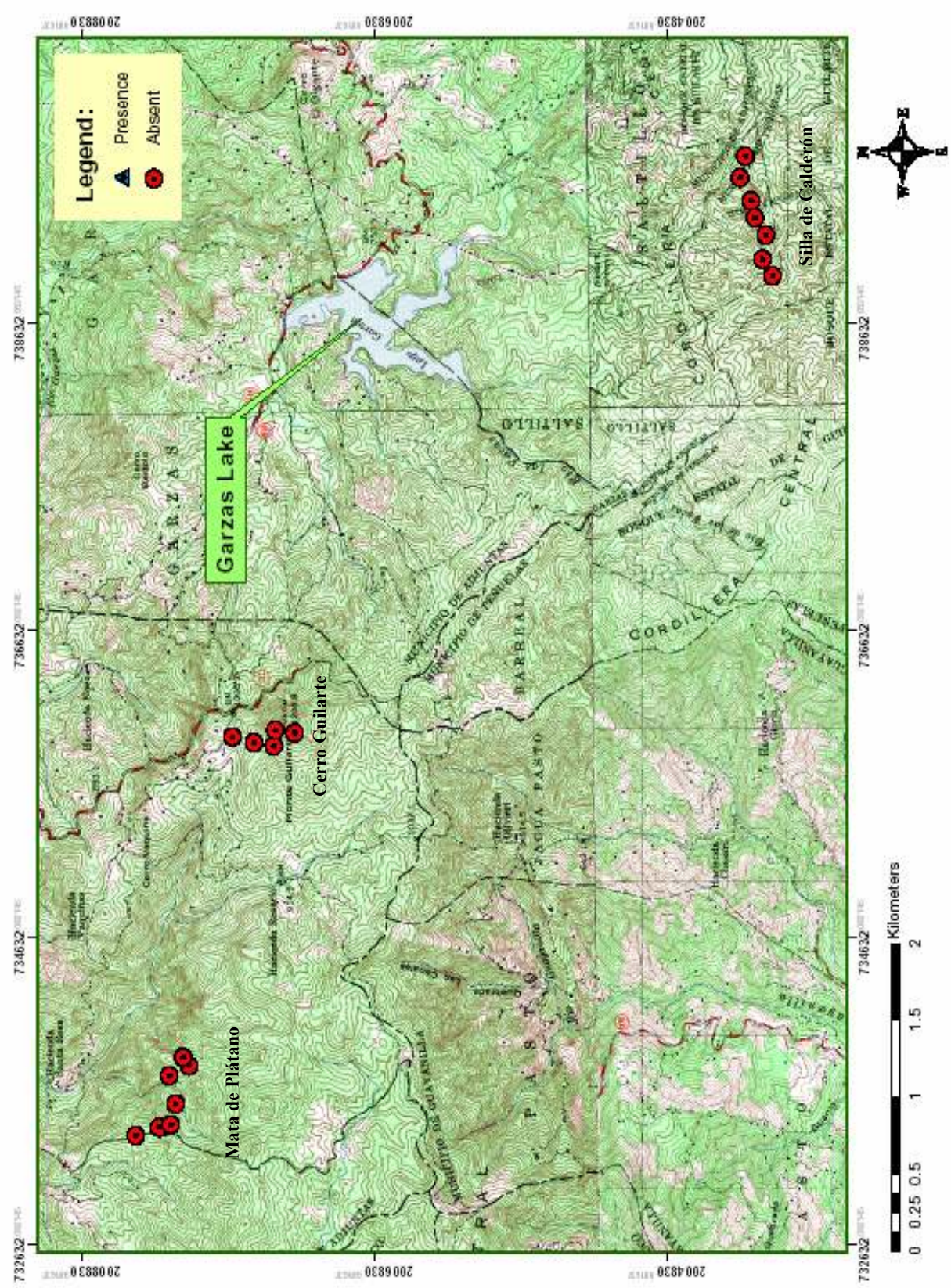
1.b Spatial distribution pattern of the EWWA per point-count stations in the Caribbean National Forest.



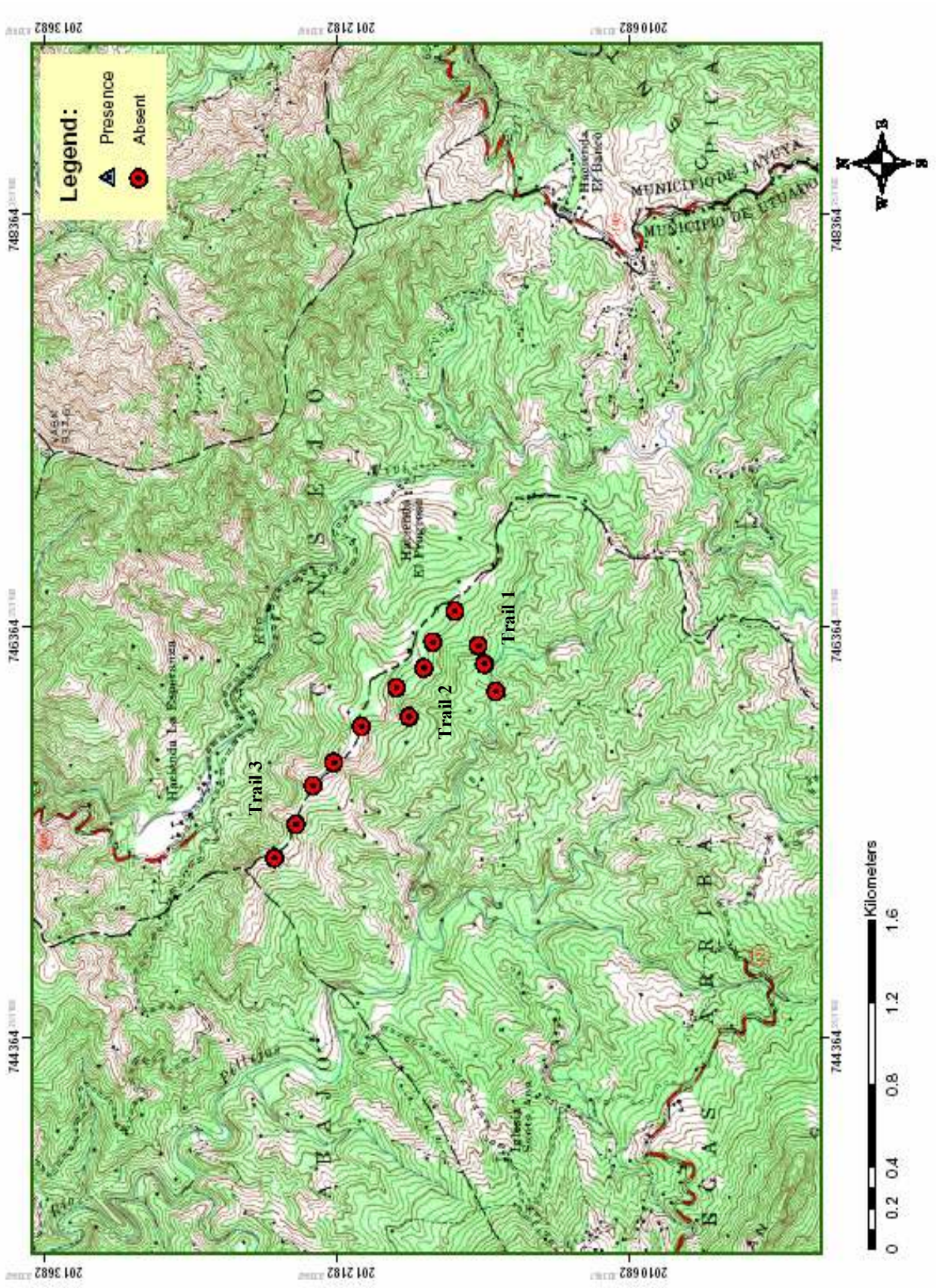
1c. Spatial distribution pattern of the EWWA per point-count stations in the Carite Forest.



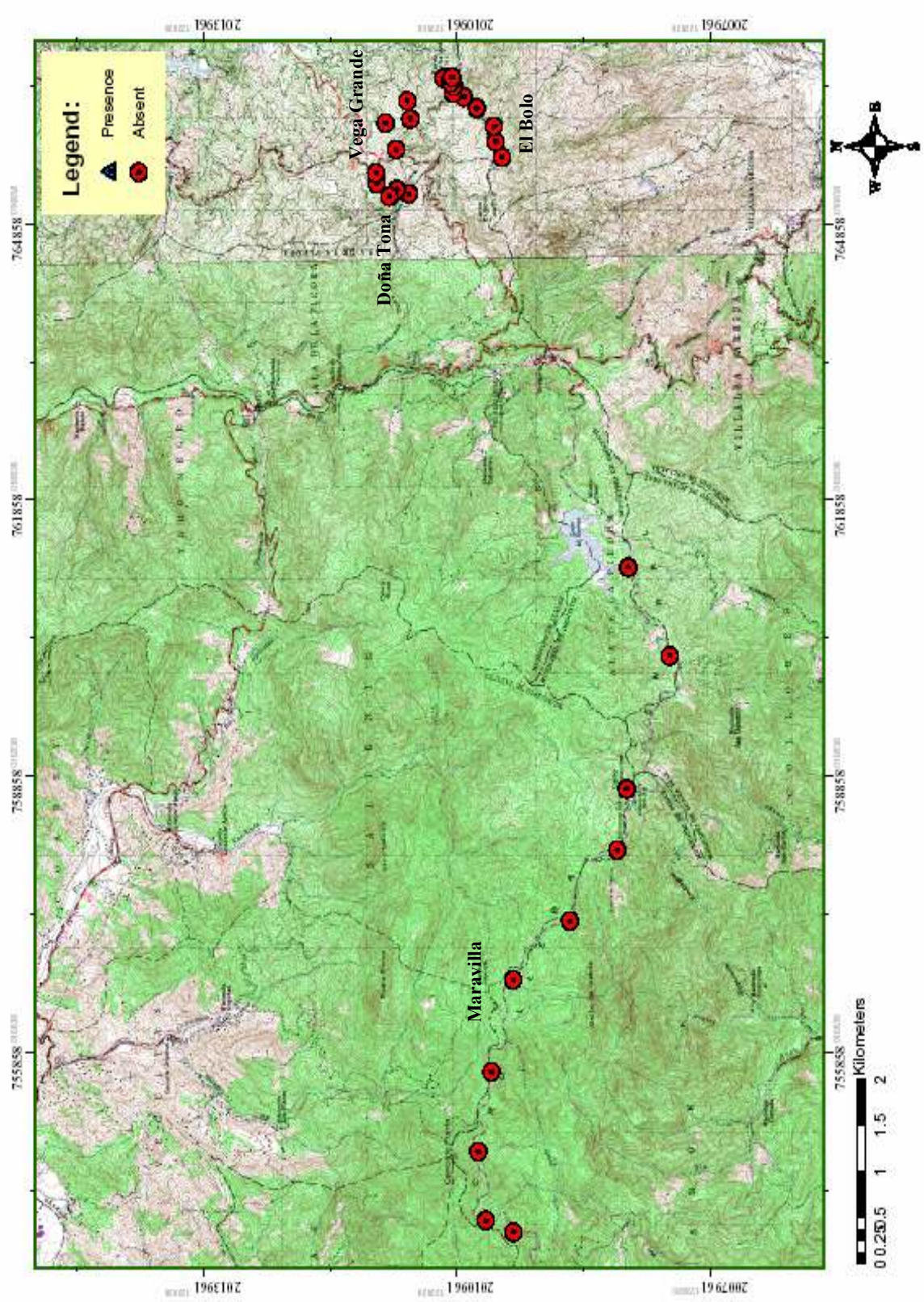
1d. Spatial distribution pattern of the EWWA per point-count stations in the Guilarte Forest.



1e. Spatial distribution pattern of the EWWA per point-count stations in Bosque del Pueblo Forest.



1f. Distribution pattern of the EWWA per point-count stations in Toro Negro Forest.



Appendix 2

Kruskal-Wallis One-Way Nonparametric Analysis of Variance and Kruskal-Wallis All Pairwise Comparisons for the trails' mean ranks in the Maricao State Forest and Caribbean National Forests.

2a. Kruskal-Wallis One-Way Nonparametric Analysis of Variance for EWWA per point-count stations per trail in the Maricao State Forest

Trail	Mean Rank	Sample Size
Alto del D	31.4	16
Caballeriz	53.2	5
Cain Alto	29.8	16
Campamento	27.3	6
Merenderos	32.5	6
Talitas	14.9	9
Viveros	56.9	6
Total	32.5	64

Kruskal-Wallis Statistic	25.5424
P-Value, Using Chi-Squared Approximation	0.0003

Parametric AOV Applied to Ranks

Source	DF	SS	MS	F	P
Between	6	8790.8	1465.14	6.48	0.0000
Within	57	12891.7	226.17		
Total	63	21682.5			

Total number of values that were tied	47
Max. diff. allowed between ties	0.00001

Cases Included 64

2b. Kruskal-Wallis All-Pairwise Comparison Test of EWWA per point-count stations per trail in the Maricao State Forest

Trail	Mean	Alto Descanso	Caballeriza	Cain Alto	Campamento
Alto del D	31.406				
Caballeriz	53.200	21.794			
Cain Alto	29.781	1.625	23.419		
Campamento	27.333	4.073	25.867	2.448	
Merenderos	32.500	1.094	20.700	2.719	5.167
Talitas	14.944	16.462	38.256*	14.837	12.389
Viveros	56.917	25.510	3.717	27.135*	29.583

Trail	Mean	Merenderos	Talitas
Merenderos	32.500		
Talitas	14.944	17.556	
Viveros	56.917	24.417	41.972*

Alpha	0.05
Critical Z Value	3.038

2c. Kruskal-Wallis One-Way Nonparametric Analysis of Variance for EWWA per point-count stations per trail in the Caribbean National Forest.

Trail	Mean Rank	Sample Size
Baño de Or	30.0	10
East Peak	40.8	15
El Toro	50.6	16
Icacos	64.1	15
Mount Brit	30.0	15
Rio Crista	32.9	11
Tradewinds	83.9	15
Total	49.0	97

Kruskal-Wallis Statistic 56.5234
P-Value, Using Chi-Squared Approximation 0.0000

Parametric AOV Applied to Ranks

Source	DF	SS	MS	F	P
Between	6	34662.1	5777.01	21.5	0.0000
Within	90	24208.4	268.98		
Total	96	58870.5			

Total number of values that were tied 93
Max. diff. allowed between ties 0.00001

Cases Included 97

2d. Kruskal-Wallis All-Pairwise Comparison Test of EWWA per point-count stations per trail in the Caribbean National Forest

Trail	Mean	Homogeneous Groups
Tradewinds	83.933	A
Icacos	64.100	AB
El Toro	50.563	BC
East Peak	40.800	BC
Rio Crista	32.864	BC
Baño de Or	30.000	BC
Mount Brit	30.000	C

Alpha 0.05
Critical Z Value 3.038
There are 3 groups (A, B, C) in which the means
are not significantly different from one another.

Appendix 3

Kruskal-Wallis One-Way Nonparametric Analysis of Variance and Kruskal-Wallis All Pairwise Comparisons for the forest types mean ranks in the Maricao State Forest and Caribbean National Forest.

3a. Kruskal-Wallis One-Way Nonparametric Analysis of Variance for EWWA per point-count stations per forest types in the Maricao State Forest

V003	Mean Rank	Sample Size
Dry Slope	13.5	11
Exposed Wo	30.3	15
Plantation	24.3	19
Podocarpus	53.4	19
Total	32.5	64

Kruskal-Wallis Statistic 39.6413
P-Value, Using Chi-Squared Approximation 0.0000

Parametric AOV Applied to Ranks

Source	DF	SS	MS	F	P
Between	3	13643.2	4547.74	33.9	0.0000
Within	60	8039.3	133.99		
Total	63	21682.5			

Total number of values that were tied 47
Max. diff. allowed between ties 0.00001

Cases Included 64

3b. Kruskal-Wallis All-Pairwise Comparison Test of EWWA per point-count stations per forest types in the Maricao State Forest

Forest types	Mean	Homogeneous Groups
Podocarpus	53.421	A
Exposed Wo	30.300	B
Plantation	24.342	B
Dry Slope	13.455	B

Alpha 0.05
Critical Z Value 2.638
There are 2 groups (A and B) in which the means
are not significantly different from one another.

3c. Kruskal-Wallis One-Way Nonparametric Analysis of Variance for EWWA per point-count stations per forest types in the Caribbean National Forest

V003	Mean Rank	Sample Size
Dwarf	57.5	26
Palo Color	61.3	35
Sierra Pal	30.0	25
Tabonuco	32.9	11
Total	49.0	97

Kruskal-Wallis Statistic 31.1322
P-Value, Using Chi-Squared Approximation 0.0000

Parametric AOV Applied to Ranks

Source	DF	SS	MS	F	P
Between	3	19091.3	6363.78	14.9	0.0000
Within	93	39779.2	427.73		
Total	96	58870.5			

Total number of values that were tied 93
Max. diff. allowed between ties 0.00001

Cases Included 97

3d. Kruskal-Wallis All-Pairwise Comparison Test of EWWA per point-count stations per forest types in the Caribbean National Forest

Forest types	Mean	Homogeneous Groups
Palo Color	61.343	A
Dwarf	57.481	AB
Tabonuco	32.864	BC
Sierra Pal	30.000	C

Alpha 0.05
Critical Z Value 2.638
There are 3 groups (A, B, etc.) in which the means are not significantly different from one another.

Appendix 4

Spearman Rank Correlation for EWWA per point-count stations and elevation in the Maricao State Forest and the Caribbean National Forest.

A. Maricao State Forest

	Elevation
Esta	0.5602
P-Value	0.0000

Maximum Difference Allowed Between Ties 0.00001
Cases Included 64

B. Caribbean National Forest

	V002
EWWA	0.0475
P-Value	0.6435

Maximum Difference Allowed Between Ties 0.00001
Cases Included 97

Appendix 5

Calculations for the Elfin-woods Warbler density estimation in the Maricao State Forest and the Caribbean National Forest.

The distance measured from three different point-counts stations with EWWA through the nearest EWWA pair that did not respond to the playbacks of the point-count studied, were 90 m, 56 m and 70 m. The average of EWWA maximum detection distance was 72 m.

EWWA maximum detection distance = 72 m = r

$A = \pi r^2 = 3.14\ (72\ m)^2 = 16286.0163\ m^2$

$$\text{Area per point-count stations} = 16286.0163\ m^2 / \frac{1\ ha}{10{,}000\ m^2} = 1.6286\ ha = 1.6\ ha$$

Appendix 6

International Union for the Conservation of Nature (IUCN) Red List Categories and Criteria.

Category: Endangered (EN)

Based Criteria:

B. 1. Extent of occurrence estimated to be less than 5000 km ^{2}, and estimates indicating:

Severely fragmented or known to exist at no more than five locations.

Continuing decline, observed, inferred or projected, in many of the following:

iv. number of locations or subpopulations

Extreme fluctuations in any of the following:

iii. number of locations or subpopulations

B 2. Area of occupancy estimated to be less than 500 km ^{2}, and estimates indicating:

Severely fragmented or known to exist at no more than five locations.

Continuing decline, observed, inferred or projected, in any of the following:

iv. number of locations or subpopulations.

Extreme fluctuations in any of the following:

iii. number of locations or subpopulations