AVIAN BIODIVERSITY AND BREEDING ECOLOGY ALONG THE NORTHERN BOUNDARY OF MAR NEGRO UNIT AT JOBOS BAY NATIONAL ESTUARINE RESEARCH RESERVE: A BASELINE ASSESSMENT

By

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ABSTRACT

AVIAN BIODIVERSITY AND BREEDING ECOLOGY ALONG THE NORTHERN BOUNDARY OF MAR NEGRO UNIT AT JOBOS BAY NATIONAL ESTUARINE RESEARCH RESERVE: A BASELINE ASSESSMENT

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Birds, as well as other wildlife species, have been affected negatively by habitat degradation due to anthropogenic activities. Restoration activities can enhance the habitat conditions which result in an increase in the resources available to supply needs like food and breeding sites that promote avian biodiversity. Jobos Bay National Estuarine Research Reserve (Jobos Bay NERR) has been planning to implement a restoration strategy for the enhancement of hydrology and mangrove wetland habitat at the northern boundary of the Mar Negro Unit. This research presents baseline data about the bird community in two contrasting areas along the northern boundary of the Mar Negro Unit that will help the staff on the Jobos Bay NERR evaluate the effectiveness of mangrove wetland restoration after its implementation. The bird surveys showed that species richness was higher in the Referenced Area but the species are more evenly distributed in the Designated-Restoration Area, consequently the avian diversity was higher. Greater Antillean Grackle (*Quiscalus niger*), Bananaquit (*Coereba flaveola*), Yellow Warbler (*Dendroica petechia*) and doves were the most abundant species which can be influenced with the presence of preferred habitat in the reserve. The nesting attempts of 9 species were monitored and the nest success determined. Mourning Dove was the species with the highest number of located nesting attempts, most success and had high daily survival rates in both study areas. Nest height (m) and the canopy cover (%) near the nest were the microhabitat characteristics significantly different among bird species in both study areas.

To my lovely mother Josefina Vega, for her unconditional support during my graduate studies, and for your great effort as volunteer during summer 2012 fieldwork.

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KEY TO SYMBOLS OR ABBREVIATIONS

AIC	Akaike Information Criterion
ANOVA	Analysis of variance
°C	Celsius degree
cm	centimeters
CAS	Central Aguirre Syndicate
$\boldsymbol{CI}$	Confidence intervals
C	Count
$\boldsymbol{S_d}$	Daily survival rate
dbh	Diameter at breast height
J	Evenness
GPS	Global positioning system
ha	hectare
HSD	Honest Significant Difference
IIRAAPR	Instituto de Investigaciones sobre Recursos de Agua y el Ambiente de Puerto Rico (Puerto Rico Water Resources and Environmental Research Institute)
Jobos Bay NERR	Jobos Bay National Estuarine Research Reserve
km	kilometer
km/h	kilometer per hour
LSD	Least Significant Difference
LCD	Liquid crystal display

$\boldsymbol{H_{max}}$	Maximum value of diversity (*H)*
m	meter
m/s	meter per seconds
mm	millimeters
NOAA	National Oceanic and Atmospheric Administration
No.	Number
$\boldsymbol{\widehat{N}}$	Population size estimate
$\boldsymbol{p}$	Probability of detection
$\boldsymbol{\widehat{p}}$	Probability of detection estimates
PRDNER	Puerto Rico Department of Natural and Environmental Resources
$\boldsymbol{H'}$	Shannon-Weaver index of diversity
psi	Temporary used of an area by species (e.g. sampling site **)**
$\boldsymbol{Z}$	Test statistic
$\boldsymbol{S}$	Total number of species presented in the sampling
$\boldsymbol{Var}$	Variance

Introduction

Estuarine and coastal habitats represent highly productive and diverse ecosystems that support large numbers of resident and migratory species including fish, invertebrates and birds (Chícharo 2004). These habitats have been impacted by natural and anthropogenic disturbances which caused short- and long-term damage such as habitat degradation, nutrient loading, pollution, sedimentation and introduction of exotic species (Chícharo 2004). Mangrove wetlands along the northern boundary of the Mar Negro Unit at Jobos Bay National Estuarine Research Reserve (Jobos Bay NERR) have been negatively impacted by such natural and anthropogenic disturbances (Robles et al. 2002, Demopoulos 2004). The Mar Negro Unit has experienced changes in the natural drainage and local hydrology due to underground water extraction for residential and industrial use, and by agricultural activities such as destruction of irrigation channels in the adjacent farms, runoff and construction of dikes (Robles et al. 2002, Demopoulos 2004). As a consequence, mangrove forest has been replaced by salt flats (Robles et al. 2002). For example, an increase in mortality has been seen particularly in black mangrove (*Avicennia germinans*) due to high salinity and low freshwater input in the Reserve (Robles et al. 2002, Demopoulos 2004). Hence, habitat management may be necessary to restore these degraded estuarine and coastal ecosystems.

In wetland habitats, both biotic and abiotic components of degraded wetlands can be improved by natural processes under human management (Cui et al. 2009). Jobos Bay NERR has been planning to implement a restoration strategy for the enhancement of hydrology and mangrove wetland habitat at the northern boundary of the Mar Negro Unit. This restoration will manage rain water flows through two small channels which extend from the adjacent farm to the Reserve (IIRAAPR 2012). The strategy consists first of taking water running through those channels and changing its flow over terrain along the east side of the northern boundary of the

Mar Negro Unit (IIRAAPR 2012). Then, an agricultural buffer strip will be planted along the northern boundary using specific plant species which will filter the water to improve water quality and help to reduce superficial erosion (PRDNER 2010, IIRAAPR 2012).

An important aspect of restoration activities is, after its implementation, to monitor effectiveness (Chapman 2010). Wildlife can be used to assess the effectiveness of wetland restoration, particularly studying the effect of restoration implementation on bird species (Chapman 2010, Cui et al. 2009). Birds are a good indicator of habitat health and integrity (Maurer 1993) because they may be long lived, top predators, and sensitive to environmental conditions (Maurer 1993; Burton et al. 2002, Steen et al. 2006, Antos et al. 2007, Cardoni et al. 2008, cited in Cui et al. 2009). In wetlands, bird species can be impacted by the loss of habitats and feedings areas (Chapman 2010), making bird species a good indicator of the effectiveness of restoration programs designed to improve habitat quality (Cui et al. 2009). The objectives of this research are to (1) conduct a baseline assessment of avian biodiversity in two contrasting areas, and (2) study the breeding ecology through determination of nesting attempts and breeding success of selected bird species along the northern boundary of Mar Negro Unit at Jobos Bay NERR.

This research presents baseline data about the bird community along the northern boundary of Mar Negro Unit that will help the staff on the Jobos Bay NERR evaluate the effectiveness of mangrove wetland restoration after its implementation. Birds, as well as other wildlife species, have been affected negatively by habitat degradation due to anthropogenic activities. Restoration activities can return the conditions of degraded habitat to pre-disturbance conditions that enhance the biotic and abiotic component of an ecosystem and as a consequence, increase the resources available to supply needs like food and breeding sites that promote avian biodiversity.

First, this research will examine biodiversity which reflects bird species diversity, species richness and relative abundance along the northern boundary of Mar Negro Unit, such information identifies the species known to be present before the restoration is implemented. Then, after its implementation, researchers can examine how species diversity, species richness and its relative abundance have been changed over the restored habitat. The purpose of wetland restoration is to restore ecological functions that link both biotic and abiotic components (Loomis et al. 2000, Zedler 2000, Ruiz-Jaen and Aide 2005, Gallego Fernandez and Garcia Novo 2007 cited in Cui et al. 2009) and that contribute to ecosystem biodiversity on degraded habitats (Cui et al. 2009). Thus restoration activities improve ecological conditions creating favorable habitat for many bird species (Cui et al. 2009). Previous studies found that bird species richness and abundances are often enhanced by implementation of restoration activities (Passell 2000, Twedt et al. 2002, Hamel 2003, Gaines et al. 2007, Aerts et al. 2008, Farwig et al. 2008 cited in MacGregor-Fors et al. 2010).

In addition to biodiversity, the breeding success of several bird species is documented in this research. It is important to assess which species used the habitats along the northern boundary of Mar Negro Unit for such essential activities as breeding and examine what factors in that habitat can contribute to breeding success. The wetland restoration at Jobos Bay NERR will restore the hydrology of degraded habitat and theoretically improve the quality of habitat that is used by birds for breeding. Previous studies indicate that the improvement of the water regime showed a positive effect on breeding birds because the breeding habitat changed through vegetation development and transformation (Wan et al. 2001, Armitage et al. 2007, Forcey et al. 2007 cited in Cui et al. 2009). Cui et al. (2009) observed an improvement in the soil’s chemical and physical conditions seven years after the implementation of a restoration project in a degraded wetland that permitted the re-colonization of plants. In addition, they found that ecosystem function can be restored through nutrient retention which increased the biodiversity of bird and plant species (Cui et al. 2009). Therefore, restoration should improve habitat physical conditions and vegetation that in turn may promote more resources related to breeding such as nesting sites, nest building material and food availability. Accordingly breeding success should increase after implementation of a wetland restoration strategy.

Methodology

The field work along the northern boundary of Mar Negro Unit at Jobos Bay NERR was conducted from May 14, 2012 to August 22, 2012.

Study Area

The study was conducted along the northern boundary of Jobos Bay National Estuarine Research Reserve (Jobos Bay NERR). Jobos Bay NERR is located on the south coast of Puerto Rico (Figure 1), in the life zone classified as Subtropical Dry Forest (Ewel and Whitmore 1973). The mean annual rainfall is 1,129 mm, where October is the wettest month (228 mm annual rainfall) and March is the driest month (5 mm annual rainfall) (PRDNER 2010). Mean annual

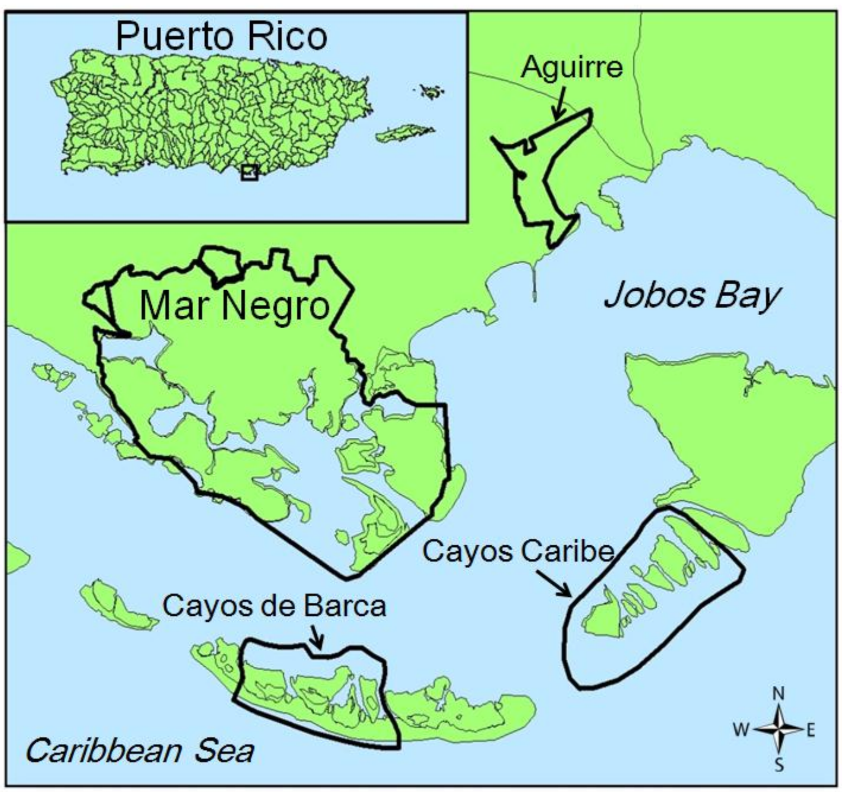

Figure 1: Localization of Jobos Bay National Estuarine Research Reserve (Jobos Bay NERR). Jobos Bay NERR is comprised of various units including Aguirre, Mar Negro and Cayos Caribe. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

temperature is 26.5º C, where August presents the highest average temperature (27.4º C) and February the lowest average temperature (24.8º C) (PRDNER 2010). Wind direction is regularly from the East with an average of 11.11-12.96 km/h (PRDNER 2010).

Jobos Bay, the second largest estuary in Puerto Rico, receives groundwater as the principal source of freshwater (PRDNER 2010). In addition, the Rio Seco at the east end of Jobos Bay NERR, a river joined to the streams Quebrada Aguas Verdes and Quebrada Coquí, drains into the Jobos Bay (PRDNER 2010). Jobos Bay NERR consists of three principal habitat types: upland, wetlands and submerged habitats. Upland habitat is composed of subtropical dry forest and scrub shrub, the wetlands habitat of emergent wetlands (mangrove forests) and salt flats, and the submerged habitats of mudflats, algae beds, seagrass beds and coral reefs (PRDNER 2010).

In the past, land of Jobos Bay NERR was used for agricultural purposes, particularly for sugar cane production and processing. During the mid-nineteenth century, Ignacio Rodríguez Lafuente funded the Hacienda Aguirre Central Sugar Mill comprising 813.01 ha of which 115.34 ha was used for sugar cane plantation and produced 6 tons of sugar cane per year (EPR 2010). Later, in 1899, Hacienda Aguirre was purchased by US investors who formed the "Central Aguirre Syndicate" (CAS) (RNIEBJ 1997). In the 1900's, development of Aguirre Community began in different aspects which included the creation of infrastructure (e.g. houses, hospitals and roads), economic (e.g. hotels, stores) and socio-cultural (e.g. theaters, social clubs) (RNIEBJ 1997). Also, the transportation improved with the construction of 12 miles of railroad and use of 2 engines transporters. In 1905, CAS was sold to Central Aguirre Sugar Mill Company, and started to export product to a company in Massachusetts, USA in 1933 (RNIEBJ 1997). In 1947 the sugar mill was mechanize to reduce cost of production, replacing the human workforce with machines (RNIEBJ 1997, EPR 2010). The socioeconomic change in Puerto Rico during the

1960's to 1970's resulted in the end of production by Central Aguirre (RNIEBJ 1997, EPR 2010). The government continued with the production but the site was finally closed in 1990 (RNIEBJ 1997, EPR 2010). In 1981, the Puerto Rico Department of Natural and Environmental Resources (PRDNER) acquired land in the Aguirre Community and it was designated in the same year as National Estuarine Research Reserve by National Oceanic and Atmospheric Administration (NOAA) (PRDNER 2010).

The northern boundary of Jobos Bay NERR is comprised of the Mar Negro Unit (844.635 ha) (PRDNER 2010). This area is characterized as a critical mangrove habitat; its features include salt flats, lagoons, upland littoral vegetation, Jagüeyes forest and a wildlife pond. The upland is classified as evergreen littoral woodland composed of secondary and shrubby vegetation, which is dominated by buttonwood (*Conocarpus erectus*) (Robles et al. 2002). The northern boundary of the Reserve has been altered by anthropogenic activities (e.g., recreation, agricultural, industry, and urbanization). Jobos Bay NERR will be implementing a restoration strategy to improve the hydrology of black mangrove and control superficial erosion. The restoration consists of changing the flow of water through two channels which extend from the adjacent farm to the east side of the northern boundary of the Mar Negro Unit. Also a vegetative buffer strip will be planted to contain the chemicals from runoff of anthropogenic activities (e.g. agricultural practices) and enhance the habitat quality, especially for the black mangrove.

This research was conducted in two study areas (see Figure 2). The first is a Designated-Restoration Area located at the east side of the northern boundary of Jobos Bay NERR (17° 57' N, 66° 14' W). This is the area altered by the anthropogenic activities (e.g. agricultural) and where the Jobos Bay NERR staff has been planning to implement the restoration to improve the hydrology of black mangrove. One of the important features in this area is the wildlife pond (Figure 2). The wildlife pond was constructed originally to filter water discharged from the

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Figure 2: Study sites along the northern boundary of Jobos Bay NERR. The referenced area is represented within white rectangle (west side) and the designated-restoration area within gray rectangle (east side).

thermoelectric plant but serves as an important avian forage habitat, particularly for wading and coastal birds (PRDNER 2010). The second study area is a Referenced Area located at the western side of the northern boundary of Jobos Bay NERR (17° 57' N, 66° 15' W). This is an area adjacent to the restoration and represents the control site for the research. In this area is located the Jagüeyes forest (Figure 2) and consist of 10.623 ha with a variety of habitats including evergreen littoral woodland forest, mangrove forests, salt flats, and mudflats (PRDNER 2010). Jagüeyes forest is important to the wildlife because it supports several species in the area including migratory and resident birds and reptiles (PRDNER 2010).

Bird Census

The study sites sampled within the study areas along the northern boundary of Jobos Bay NERR were randomly selected. Using grid squares in a map of the northern boundary of the

Jobos Bay NERR (obtained from Google ™ Earth), each cell was individually identified by coordinates written on slips of paper (Gregory et al. 2004). The 19 sampling sites were selected randomly by picking blindly from the slips of papers for each study area: 9 coordinates were allocated to the Designated-Restoration Area (experimental) and 10 were allocated to the Referenced Area (control). Each of the sampling site coordinates was recorded using a GPS device (Garmin GPS V®) and is documented in the Appendix A.

A 25 m fixed-radius point count was established on each of the 19 sampling sites. Each 25 m fixed-radius point count was used to identify bird species visually or by their sounds for 9 minutes from 6:00 am to 10:30 am. The 9-minute census period was divided into intervals of 3 minutes to assess species detectability on each point count. All point counts were conducted twice a month during the summer season in 2012 (Mid-May to July). The point counts were not conducted if the weather conditions, particularly rain, could diminish bird activity (e.g. reduce its visibility or the intensity of song activity); (Ralph et al. 1996). The order of sampling sites was alternated to avoid always starting the bird survey in the same sampling site at the same time.

The point counts were conducted in silence to avoid missing the songs and calls of birds. During the 9 minutes of a sampling period, each individual bird seen or heard within 25 m radius was recorded, by species, in the order of detection. Any flocks seen during the count were followed after the sampling period ended to accurately determine its size (Ralph et al. 1996). In addition, the number of individuals outside the 25 m radius or flying over the point counts was documented independently of the main count. The field identification guides that were used are *Puerto Rico's birds in photographs* (Oberle 2006) and *A guide to the birds of Puerto Rico and the Virgin Islands* (Raffaele 1989).

The fixed-radius point count method is appropriate for studying Caribbean land birds (Wunderle 1994) because this method is adequate to determine species presence and is recommended to measure relative abundance in Caribbean bird species (Wunderle 1994). Point counts can be used to relate birds with used habitat types (Ralph et al. 1996), can be applied in all habitat types, and have good rare species detection (Ralph et al. 1996). The 25 m fixed-radius was selected because it is recommended for use in tropical forest and noisy environments (Ralph et al. 1996). The study areas receive constant noise from the thermoelectric plant located at the east side of the Mar Negro Unit of Jobos Bay NERR.

Nesting attempts and breeding success

Nest searches were used to study the breeding ecology along the northern boundary of Jobos Bay NERR. A 1 km transect was established in each of the two study areas, and each transect was divide in five 200 m x 50 m sub-transects to conduct the nest searches. Transects and sub-transects were established using the Garmin MapSource ™ WorldMap v3 CD. First, during a preliminary visit through the main trails on both study areas several references waypoints were recorded using a GPS device (Garmin GPS V®). Later, the waypoints were downloaded in the Garmin MapSource ™ WorldMap Software to design the 1 km transects and the five 200 m sub-transects, creating routes and new waypoints. Then, these routes and waypoints were downloaded to the GPS device to use as reference to establish transects and sub-transects in both study areas. Each sub-transect covered two principal habitat types along the northern boundary: uplands (forested and scrub shrub) and wetland (emergent wetlands and salt flats). In the Designated-Restoration Area, sub-transects 3 and 4 are located in uplands habitats, while sub-transects 1, 2 and 5 covered upland and wetland habitats. In the Referenced Area all sub-transects (1-5) covered uplands and wetland habitats.

Nest searching was conducted in the morning and in the afternoon to locate nesting attempts on both study areas during the summer season 2012 (Mid-May to August). A nesting attempt implies that a female initiated egg-laying in the located nest (Salgado-Ortiz et al. 2008). Located nests were inspected to detect the presence of eggs or nestlings and to determine the date of first egg-laying, clutch size, and the period of incubation. Nests located in high places (shrub or tree) were inspected with a mirror attached to a telescoping pole (Rivera-Milán 1999) or with a wireless portable camera with an attached LCD monitor that allowed for the observation of the nest contents. For nests with enclosed cups, a wireless inspection camera was used to observe the interior through the small entrance hole. Every three or four days from May to August the plots were visited to monitor the known nesting attempts and look for new nesting attempts. For bird species that fledge earlier than others, such as warblers, nesting attempts were monitored daily. The nest searching and inspections were conducted carefully to avoid nest predation or nest desertion (Ralph et al. 1996). In the case of apparent nest predation (eggs or fledglings removed), observations about possible evidence in the nest structure (e.g., nest torn up, hole in a nest) and around nest site (e.g., egg shell fragments) were recorded.

In August, after the end of the nesting season, microhabitat characterization was made of the nest and nest-site (e.g. tree or shrub). The measurements taken include: the nest-plant species, nest-plant height (m), nest height (m), nest-plant diameter at breast height (dbh) (cm), and canopy cover. The nest height is the measure of the distance of the nest above the ground (Ralph et al. 1996). For the taller nest-plants (tree and shrub species) and nests placed higher in a tree, its height was calculated using a clinometer and metric measuring tape. The method consists of taking the percent of inclination (%) from the top of the nest-plant species or bottom of the nest, to the ground, by viewing through the crosshair the percent scale of the clinometer. Then, taking the distance (m) from the nest-plant species or nest to the reading point. The height was calculated by dividing the percent of inclination by 100 and then, that value is multiply by the distance (m). Finally the eye's height from the ground (1.54 m) is added to obtain the estimation of height (m).

$$\text{Height} = \left(\frac{\%\ \text{inclination}}{100} \times \text{distance (m)}\right) + 1.54\ \text{m}$$

For the nest-plant height measured from a sloping ground (e.g. nest plants species of nest #132, #141 in the Designated-Restoration Area, and #176 in the Referenced Area), 2 measurements were taken with the clinometer. The first measure was the percent of inclination of the tree-top (above ground level) and the second was the percent of inclination of the base of the stem. Then, the final percent of inclination is obtained adding those measurements in the equation:

$$\%\ \text{inclination} = \%\ \text{top tree} + \%\ \text{stem base}$$

The height is calculated using the previous equation. The nest-plant dbh is the measure of stem diameter at 1.3 m above the ground (Chinea and Helmer 2004). The canopy cover is the measure of percentage of tree canopy near to the nest (Ralph et al. 1996). This measurement was taken using a spherical densiometer. Four readings, one on each cardinal direction (North, East, South and West) were taken using the spherical densiometer to count the number of squares (for a total 24 squares) that are filled by the tree canopy. Then, the percent of canopy cover was calculated as the average of the # of filled squares (*x*) of the 4 cardinal directions multiplied by 4.17:

$$\%\ \text{Canopy Cover} = \left[\frac{(x_N + x_E + x_S + x_W)}{4}\right] \times 4.17$$

Habitat Evaluation

Vegetation

Eight of the nineteen established sampling sites were randomly selected for vegetation sampling. Each sampling site was individually identified by its numbers written on a slip of paper (Gregory et al. 2004). The 8 sampling sites were selected randomly by picking blindly from the slips of papers, four sampling sites on each study area. In the Designated-Restoration Area, the sampling sites 14, 17, 18, and 20 were sampled, while in the Referenced Area sites 2, 4, 6 and 10 were sampled. In August, sampling was conducted in the major vegetation layers; these are the tree layer and the shrub layer. The tree layer represents plant species taller than 5 m, and the shrub layer represent species between 50 cm to 5 m tall (Ralph et al. 1996). Each vegetation layer was sampled using transect and plot methods. The tree layer was sampled using a 50 m x 2 m transect. Two 6 m x 2 m plots were established within that transect to conduct the shrub layer sampling (see Figure 3). The plant species were identified using the following taxonomic keys: *trees of Puerto Rico and the Virgins Islands, Second Volume* by Little et al. (1974), *Common trees of Puerto Rico and the Virgin Islands* by Little and Wadsworth (1964), *Bejucos y plantas trepadoras de Puerto Rico e Islas Vírgenes* by Acevedo-Rodríguez (2003), and *Las plantas indeseables en los cultivos tropicales* by Vélez (1950).

The structural information recorded for each layer was the dbh (cm) of canopy tree (where trees were present), dominant plant species, and average height (m). The dbh (cm) of the canopy tree was taken using a diameter tape to measure stem diameter at 1.3 m from the ground. The average height (m) was taken for the dominant species in the tree and shrub layers using a clinometer and metric measuring tape (as described above).

Weather conditions

Weather data for the summer season 2012 were obtained from the long-term Jobos Bay Weather Station at Jobos Bay NERR. Jobos Bay Weather Station is operated by Centralized Data Management Office, NOAA National Estuarine Research Reserve. The weather station was installed in front of the Visitor Center of Jobos Bay NERR since 1999 (NOAA 2012). Currently the weather station was equipped by a Campbell Scientific data telemetry system installed in July 2006 (NOAA 2012). The weather parameters are sampled in intervals of 15 minutes, and then are transmitted each hour to the NOAA GOES satellite (NOAA 2012). The weather data can be accessed through the Data Export System in the Centralized Data Management Office website http://cdmo.baruch.sc.edu/get/export.cfm.

The weather data for May, June, July and August 2012 were downloaded from the Centralized Data Management Office website. The weather parameters considered in this research are the average air temperature (°C), relative humidity (%), wind speed (m/s), and the total precipitation (mm). All parameters data sets were tabulated by the daily minimum, maximum and average values.

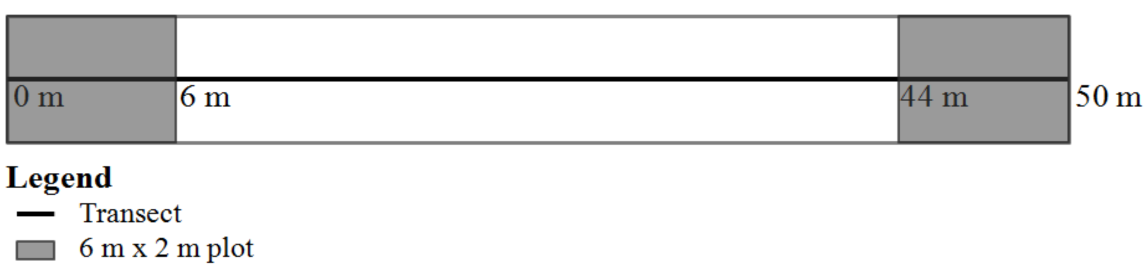

Figure 3: Vegetation sampling design. Tree layer was sampled using along the 50 m x 2 m transect, and the shrub layer using the 6 m x 2 m plots.

Data analysis

Bird census

The bird census data were used to determinate the species diversity and evenness, species richness and relative abundance in each study area. Species diversity was calculated using the Shannon-Weaver index of diversity (H'):

$$H' = -\sum_{i=1}^{S} p_i \cdot \ln p_i$$

where *S* is the total number of species presented in the sampling, and p_i is the fraction of the total number of individuals that correspond to species *i* in the sampling (Morin 1999). The evenness (*J*) was calculated using the following equation:

$$J = \frac{H'}{H_{max}}$$

where H' is the observed value of species diversity and H_{max} is the value which represents the even distribution of individuals of the species in the community (Morin 1999), and was calculated as

$$H_{max} = \ln S$$

where *S* is the total number of species presented in the sampling (Beals et al. 2000).

Species richness was calculated as the total number of bird species recorded in each study area (Lindenmayer et al. 2010). The relative abundance of a particular bird species was calculated as the total number of recorded individuals of that species divided by the total number of all bird species recorded on the point counts (Mizrahi et al. 2007).

The single-species, single season occupancy model was used for each species to estimate the probability of detection (p_j) and the probability that a sampling site is used (psi) (Program

PRESENCE version 5.2 <121012.0912>). The probability of detection (p_j) estimate was excluded for those species for which the numerical convergence may have not been reached in the estimation of in PRESENCE. The single season model was developed for each species using the detection history for each sampling site i (i = 1 to 6). The detection history (h_i) consists of detection (1) and non detection (0) in at least one of the three intervals during the survey period in each sampling site from survey 1 to survey 6, resulting in 6 sampling occasions.

Two candidate models were used in the program PRESENCE to assess which one is the most suitable to estimate the p for each species. The first is the constant probability model "psi(.),p(.)", for which the probability of detection of the species is constant in all 6 surveys conducted in all point counts in both study areas. The second model examined allows for survey-specific probability of detection "psi (.),p(t)". This model implies that use (psi) is constant but the probability of detection (p) is specific for each survey conducted in all point counts in both study areas. The candidate models were ranked based on the ranking of the Akaike Information Criterion (AIC). The models were averaged for species when the difference between the AIC values was less than 1.5. The resultant parameters $\hat{p}$ were used to estimate the population size ($\widehat{N}$) of the species in each study area:

$$\widehat{N} = \frac{C}{\hat{p}},$$

where C is calculated for each study area as the total of the maximum number of individuals of a particular species detected in each survey on all point counts divided by 60, then the result is divided by πr^2 (where r =25 m). Finally, that value is multiply by 10000 to determined number of individual per hectare (ha).

The singles-species, single-season model assumes: (1) the temporary use of the sampling sites does not change during the survey period; (2) the probability of temporary use is equal across all sampling sites; (3) the probability of detection of the bird species in a survey, given presence, is equal across all sampling sites; (4) the detection of the bird species in each survey of a sampling site is independent of detections during surveys of the sampling site, and (5) the detection histories observed at each location are independent (Mackenzie et al. 2005). The bird surveys were conducted from May to July, a period in which factors that can affect the temporary use or detection, such as weather conditions, were constant. Thus, no violations of assumptions #1, #2 and #3 were expected. The surveys were conducted in the 25 m fixed-radius point counts which were randomly selected from a gridded map in which the cell size represented 100 m in the actual study area. That means the centers of each point count were at least 100 m apart and the only the species included in the analysis were those detected within a 25 m radius. Then, the design used to establish the point counts, in which the 25 m fixed-radius represents the limit for the surveys, allows the assumption #4. Finally the surveys were conducted alternating the order of the point counts, and the species were recorded separately in each interval, which should have assured an adequate level of independence.

<u>Nesting attempts monitoring</u>

Breeding success was determined by comparing successful and failed nests in both study areas. A successful nest is considered a nest that presents evidence that at least one nestling survived to fledgling. Such evidence could be recorded up to 10 m away from the nest site (e.g., fecal droppings in nest or on the ground, seeing fledglings or parents feeding fledglings, or hearing parents giving distress calls near the nest) (Nolan 1963, Ralph et al. 1996, Lindell et al.

2011). A failed nest is a nest where the nestlings are missing before they reach fledging age or a nest that presents evidence of predation (Nolan 1963, Lindell et al. 2011).

The daily survival rate was calculated for Northern Mockingbird (*Mimus polyglottos*) and Mourning Dove (*Zenaida macroura*) on both study areas using the Mayfield Method (Mayfield 1975). The Mayfield Method (Mayfield 1975) provides an estimate of the daily survival rate (S_d) considering the total number of failed nests (d) of all nesting attempts during the total exposure days (t):

$$S_d = 1 - \left(\frac{\sum d_i}{\sum t_i}\right)$$

In addition, the variance ($Var(S_d)$) and the confidence intervals (CI) were calculated to compare the daily survival rates in both study areas:

$$Var(S_d) = V_d = \frac{[S_d(1 - S_d)]}{\sum t_i}$$

$$CI = S_d \pm 2\sqrt{V_d}$$

The difference in daily survival rates between study areas were evaluated using the statistical test described in Pollock et al. (1989):

$$Z = \frac{|\hat{S}_1 - \hat{S}_2|}{\sqrt{Var\hat{S}_1 + Var\hat{S}_2}} \ ,$$

where $\hat{S}_1$ is the estimate daily survival rate on Referenced Area, and $\hat{S}_2$ is the estimate daily survival rate on Designated-Restoration Area.

Nest and nest-plant microhabitat characterization

The variables measured for the nest and nest-plant in each study area were statistically evaluated using One-Way ANOVA, Fisher's Least Significant Difference (LSD), and Tukey's Studentized Range (HSD) using SAS 9.2 (SAS Institute 2010). One-Way ANOVA was used for all the nest and nest-plant variables except the plant dbh in Referenced Area where the data set did not meet the assumption of equal variance and normal distribution. The PROC GLM procedure was used in SAS to conduct the One-Way ANOVA for unbalanced design since the sample size (*n*) for each variable is different. For the nest-plant species, the test determines if the means of the plant height (m) and dbh (cm) are significantly different among species in the Designated-Restoration Area, and for the plant height in the Referenced Area. For the bird species, the test determines if the means of nest height (m) and the percent of canopy cover near the nest are different between species in the Designated-Restoration and Referenced Area. For those variables where the null hypothesis that all means are equal, was rejected then the Fisher's Least Significant Difference (LSD) was conducted to determine which means are different. Tukey's Studentized Range (HSD) was used only for plant dbh in the Referenced Area to compare the means of the plant species and determine if dbh are significantly different.

This project is exempt from filing an Institution Animal Care and Use Committee Animal Use Form because wild vertebrate animals were only observed in their natural habitat. The exemption was approved on 3 July 2012 and is on file in the Department of Fisheries and Wildlife at Michigan State University.

Results

Avian biodiversity along the northern boundary of Mar Negro Unit

<u>Species diversity and evenness, species richness and relative abundance</u>

Table 1 shows the species richness, species diversity and evenness calculated on each of the study areas. The Shannon-Weaver index of diversity shows that the species diversity and evenness is higher in the Designated-Restoration Area compared with the Referenced Area. The species richness in the Referenced Area was 37 bird species (a complete list of species is presented in the Appendix B-Table B1) and 32 species in the Designated-Restoration Area (a complete list of species is presented in the Appendix B-Table B2). The bird species detected in the Referenced Area are members of 22 different families (see Appendix B-Table B3) whereas species in the Designated-Restoration Area belong to 18 families (see Appendix B-Table B4). Five endemic species were detected in the Designated-Restoration Area, these are the Adelaide's Warbler (*Dendroica adelaidae*), Puerto Rican Emerald (*Chlorostilbon maugaeus*), Green Mango (*Anthracothorax viridis*), Puerto Rican Flycatcher (*Myiarchus antillarum*), and Puerto Rican Woodpecker (*Melanerpes portoricensis*). Only four of these species were detected in the Referenced Area. The Puerto Rican Emerald was not detected. Six introduced species were detected in the Designated-Restoration Area: the Bronze Mannikin (*Lonchura cucullata*), Orange Bishop (*Euplectes franciscanus*), Pin-tailed Whydah (*Vidua macroura*), Indian Silverbill (*Lonchura malabarica*), Orange-cheeked Waxbill (*Estrilda melpoda*) and Monk Parakeet

Table 1: Species diversity (H') and evenness (J) in the Referenced Area and the Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR.

Study Area	Shannon-Weaver Index (H')	H_{max}	Evenness (J)
Referenced Area	2.83	3.56	0.797
Designated-Restoration Area	2.95	3.43	0.859

(*Myiopsitta monachus*). These species also were detected on the Referenced Area except for the Indian Silverbill. Black-whiskered Vireo (*Vireo altiloquus*) a migrant species and the Antillean Nighthawk (*Chordeiles gundlachii*) a summer residents in Puerto Rico; both were detected in the Referenced Area, with only the vireo being detected in the Designated-Restoration Area. The most represented family was Columbidae (doves and pigeons), six members were detected in the Referenced Area and four in the Designated-Restoration Area.

The relative abundance of each species detected in both study areas was calculated except for the shorebirds (Black-necked Stilt- *Himantopus mexicanus*, Wilson's Plover- *Charadrius wilsonia* and Willet-*Tringa semipalmata*) because the surveys were focused on determining the abundance of upland bird species. The relative abundance for each of the bird species is presented in the Appendix B-Table B5. Birds were ordered as passerine (Order Passeriformes) which are species characterized to have a feet adapted for perching in thin branches and trunk (Hickman et al. 2002) and non-passerine (e.g. Cuculiformes, Columbiformes) to compare relative abundance and frequency in both study areas. The relative abundance of passerines on each study area is presented in Figure 4. In the Referenced Area, the Greater Antillean Grackle (*Quiscalus niger*) (14%) has the highest percent relative abundance. Bananaquit (*Coereba flaveola*) and Yellow Warbler (*Dendroica petechia*) were each relatively abundant (> 10%) in the Referenced Area. Also, Gray Kingbird (*Tyrannus dominicensis*), Shiny Cowbird (*Molothrus bonariensis*), and Northern Mockingbird (*Mimus polyglottos*) were relatively abundant in the Referenced Area. In the Designated-Restoration Area, Bananaquit (13.35%) was the species with the highest relative abundance. Another species with a high percent of abundance compared to the other passerines was the Yellow Warbler (10.35%). As in the Referenced Area, Gray Kingbird and Northern Mockingbird were relatively abundant compared with the other passerines.

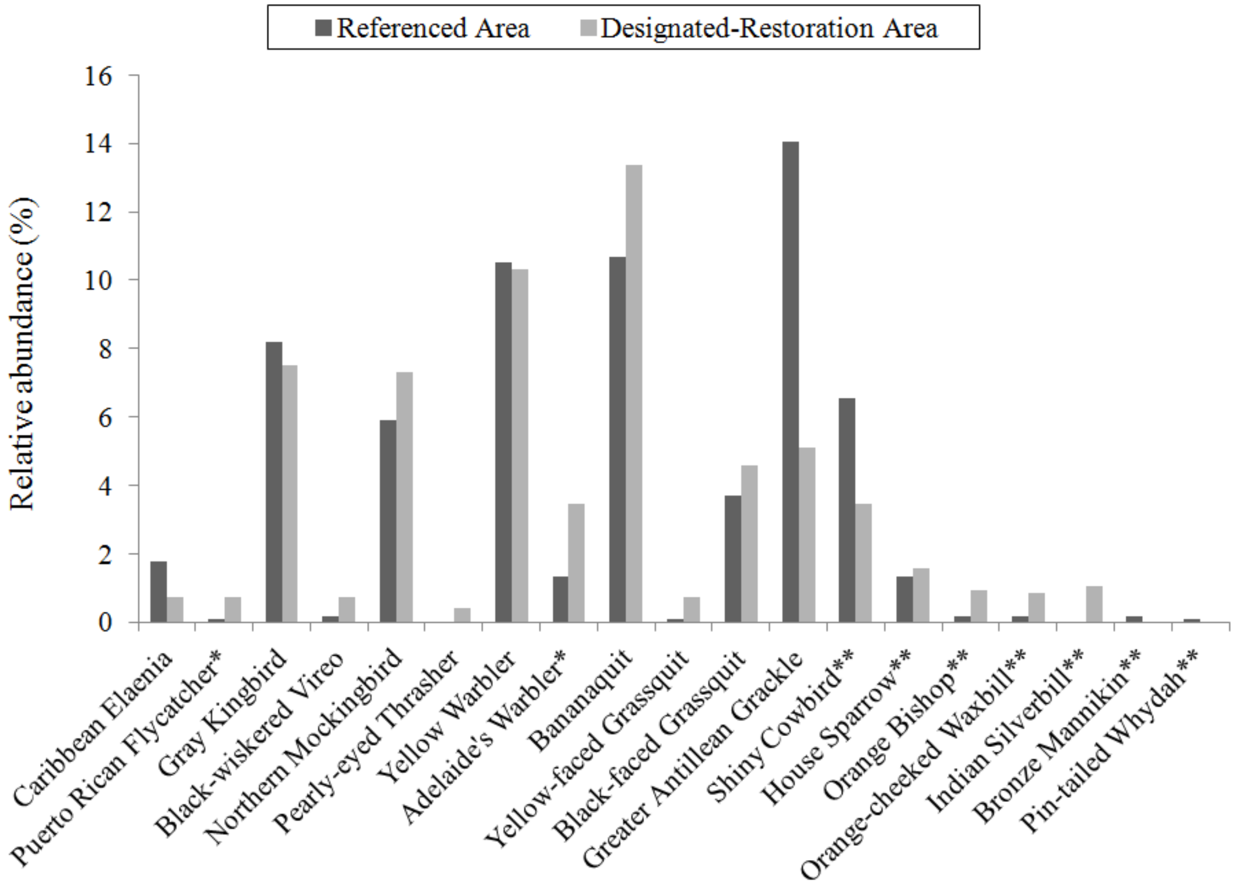

Figure 4: Relative abundance (%) of passerine species in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR. Endemic species are represented with an asterisk mark (*), and introduced species with two asterisks (**).

Comparing the frequency of species in the point counts (Figure 5), four species were found in all sites in both study areas; these were Bananaquit, Yellow Warbler, Gray Kingbird and Northern Mockingbird. Black-faced Grassquit (*Tiaris bicolor*), Greater Antillean Grackle and Shiny Cowbird were species with high percent of frequency in both study areas. The Black-faced Grassquit which had low relative abundance in both study areas (3.7% in the Referenced Area and 4.5% in the Designated-Restoration Area) was found in 18 of 19 point counts. Other species found in more than 50% of the point counts in both study areas were Adelaide's Warbler, Caribbean Elaenia (*Elaenia martinica*) and House Sparrow.

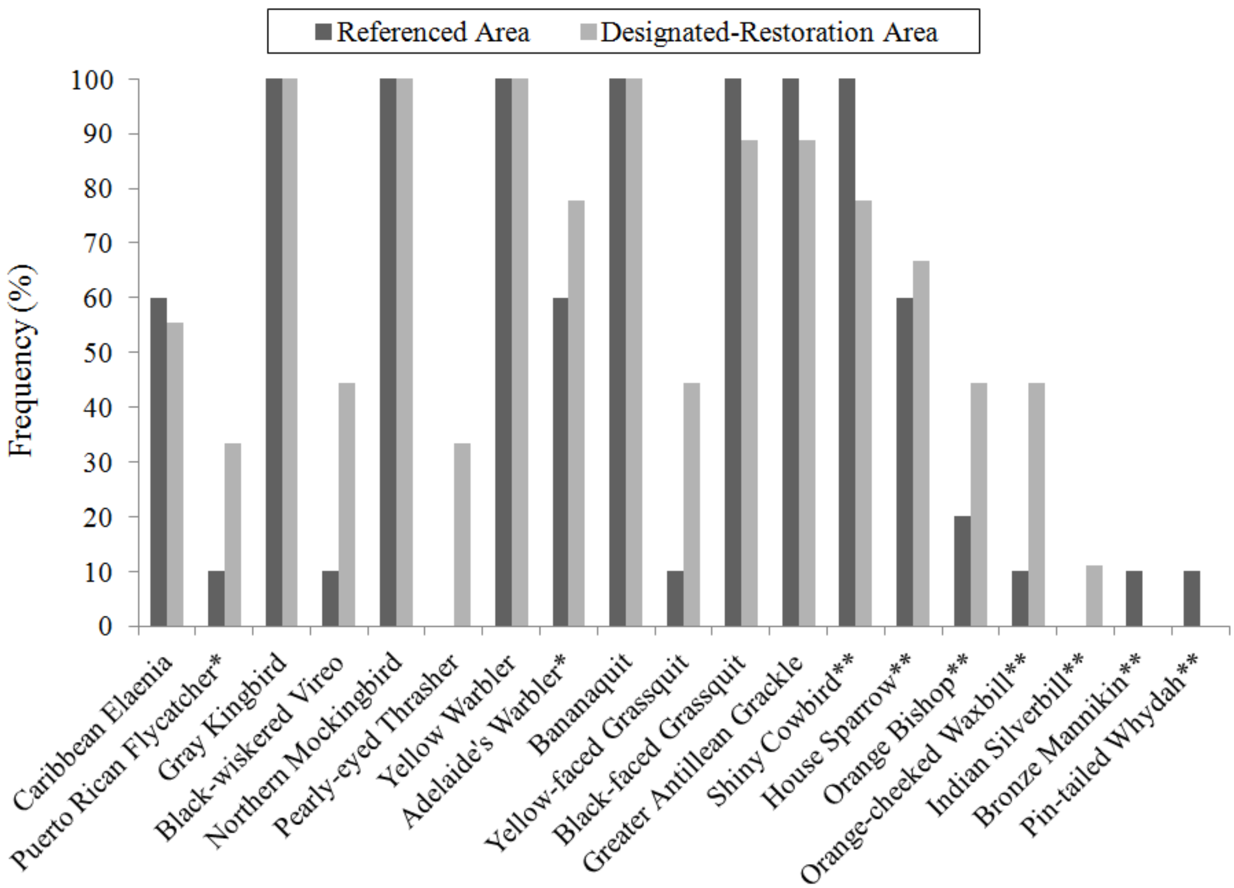

Figure 5: Frequency (%) of passerine species in the point counts in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR. Endemic species are represented with an asterisk mark (*) and introduced species with two asterisks (**).

The Figure 6 shows the percent of relative abundance of non-passerine species in both study areas. Doves are the most abundant non-passerine species. In the Referenced Area, the Common Ground-Dove (*Columbina passerina*) (9.71%) and Mourning Doves (*Zenaida macroura*) (8.83%) had higher relative abundance compared with other species. Zenaida Dove (*Zenaida aurita*), White-winged Dove (*Zenaida asiatica*), Monk Parakeet and Smooth-billed Ani (*Crotophaga ani*) had more than 2% of abundance in the Referenced Area. In the Designated-Restoration Area, Common Ground-Dove (9.38%) and the White-winged Dove (8.03%) were most abundant. Other relatively abundant species in the Designated-Restoration Area were

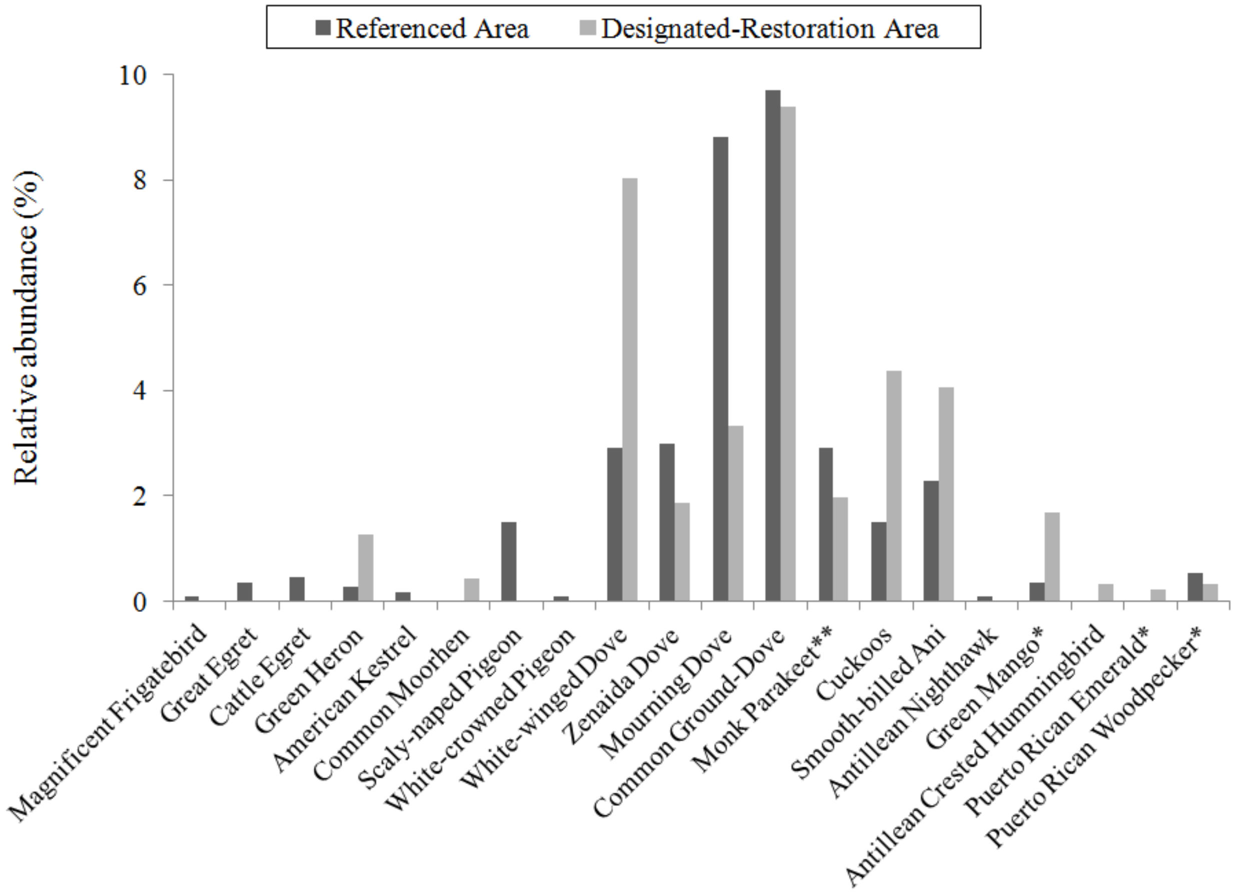

Figure 6: Relative abundance (%) of non-passerine species in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR. Endemic species are represented with an asterisk mark (*), and introduced species with two asterisks (**).

Mangrove Cuckoo (*Coccyzus minor*) and Yellow-billed Cuckoo (*Coccyzus americanus*) (referred to as Cuckoos in the Figure 6) and the Smooth-billed Ani with more than 4% of abundance. Figure 7 presents the frequency of the non-passerine species in the point counts of both study areas. Dove (Common Ground-Dove, Mourning Dove, Zenaida Dove and White-winged Dove) and Cuculidae species (Mangrove Cuckoo, Yellow-billed Cuckoo and Smooth billed-Ani) were found in 90% or more of the point counts in both study areas. Another species found frequently in both study areas was the Monk Parakeet (70% in the Referenced Area and 90% in the Designated-Restoration Area). Other species found in 60% or more of the point counts were Scaly-naped Pigeon (*Patagioenas squamosa*) in the Referenced Area and Green Heron

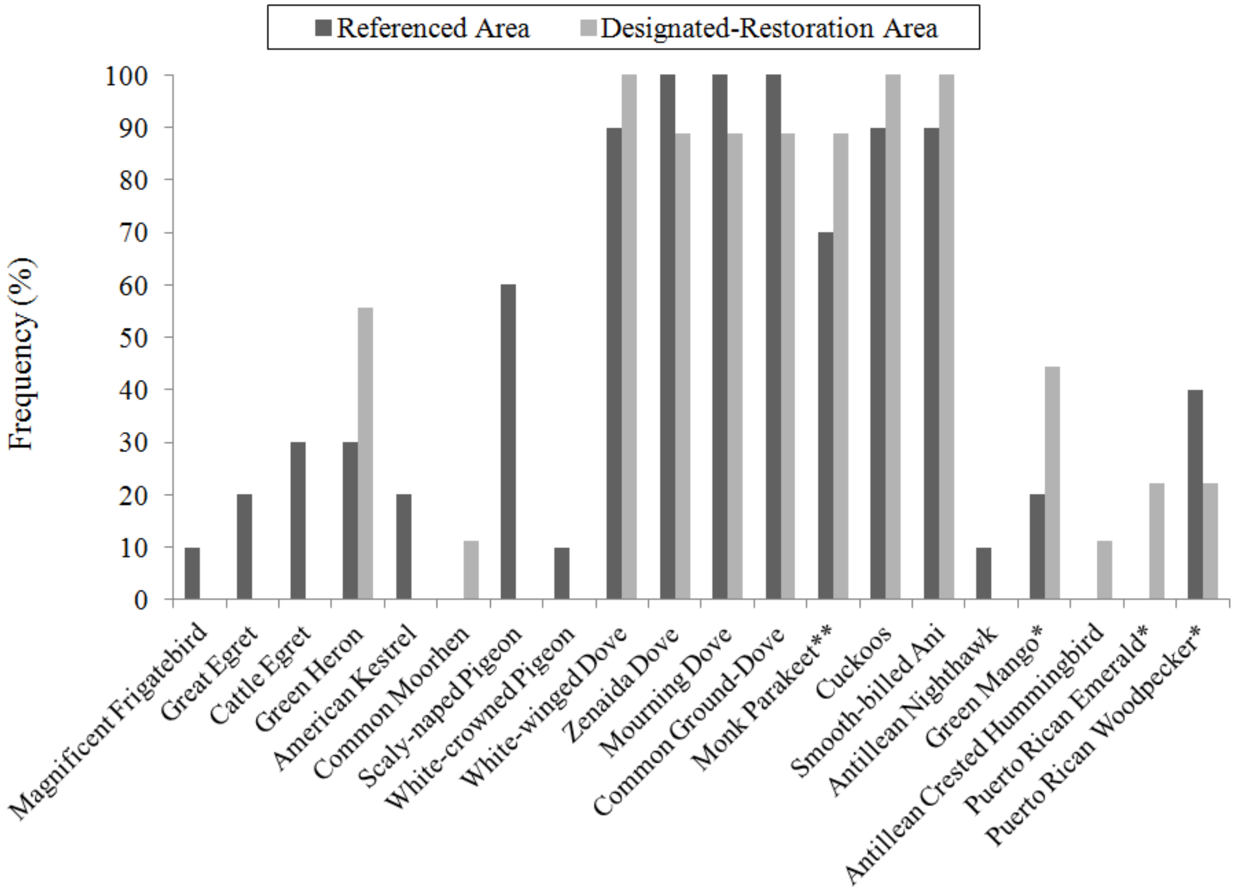

Figure 7: Frequency (%) of non-passerine species in the point counts in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR. Endemic species are represented with an asterisk mark (*) and introduced species with two asterisks (**).

(*Butorides virescens*) in the Designated-Restoration Area.

Estimation of probability of detection (p_j)

Table 2 shows the probability of detection estimated with the constant probability model in the Referenced Area. Yellow Warbler was the species with the highest probability of detection followed by the Mourning Dove and Shiny Cowbird. Orange Bishop, Puerto Rican Flycatcher and Green Mango which had lower probabilities of detection.

Table 2: Probability of detection (*p*) of bird species estimated with the constant probability model in Referenced Area

Species	*p*
Scaly-naped Pigeon (*Patagioenas squamosa*)	0.211
White-winged Dove (*Zenaida asiatica*)	0.408
Zenaida Dove (*Zenaida aurita*)	0.400
Mourning Dove (*Zenaida macroura*)	0.783
Monk Parakeet (*Myiopsitta monachus*)	0.223
Smooth-billed Ani (*Crotophaga ani*)	0.233
Green Mango (*Anthracothorax viridis*)	0.166
Caribbean Elaenia (*Caribbean Elaenia*)	0.491
Puerto Rican Flycatcher (*Myiarchus antillarum*)	0.166
Yellow Warbler (*Dendroica petechia*)	0.933
Adelaide's Warbler (*Dendroica adelaidae*)	0.363
Shiny Cowbird (*Molothrus bonariensis*)	0.717
House Sparrow (*Passer domesticus*)	0.211
Orange Bishop (*Euplectes franciscanus*)	0.033

Table 3: Probability of detection (*p*) of bird species estimated with the constant probability model in Designated-Restoration Area

Species	*p*
Green Heron (*Butorides virescens*)	0.244
Zenaida Dove (*Zenaida aurita*)	0.222
Common Ground-Dove (*Columbina passerina*)	0.833
Monk Parakeet (*Myiopsitta monachus*)	0.204
Cuckoos species	0.667
Smooth-billed Ani (*Crotophaga ani*)	0.463
Green Mango (*Anthracothorax viridis*)	0.346
Puerto Rican Flycatcher (*Myiarchus antillarum*)	0.291
Gray Kingbird (*Tyrannus dominicensis*)	0.796
Northern Mockingbird (*Mimus polyglottos*)	0.796
Pearly-eyed Thrasher (*Margarops fuscatus*)	0.211
Yellow Warbler (*Dendroica petechia*)	0.815
Adelaide's Warbler (*Dendroica adelaidae*)	0.491
Bananaquit (*Coereba flaveola*)	0.889
Yellow-faced Grassquit (*Tiaris olivaceus*)	0.232
Greater Antillean Grackle (*Quiscalus niger*)	0.580
Shiny Cowbird (*Molothrus bonariensis*)	0.465
Orange Bishop (*Euplectes franciscanus*)	0.291
Orange-cheeked Waxbill (*Estrilda melpoda*)	0.166

Table 3 shows the probability of detection estimated with the constant probability model in the Designated-Restoration Area. Bananaquit, Common Ground-Dove, Yellow Warbler, Gray Kingbird and Northern Mockingbird were the species with higher probabilities of detection in the Designated-Restoration Area. Orange-cheeked Waxbill was the species with the lowest probability of detection.

Table 4 shows the probabilities of detection estimated with survey-specific probability of detection in the Referenced Area. In general, all species show high probability through the six surveys with the exception of Cuckoos species (Mangrove Cuckoo and Yellow-billed Cuckoo) and Black-faced Grassquit. Greater Antillean Grackle was the species with the highest probability of detection which ranged from 0.9 to 1.0 through all surveys. Other species, such as the Common Ground-Dove and Bananaquit with high probability of detection through all surveys showed p decreased in a particular survey. While for the Black-faced Grassquit, the probability of detection was low from survey 1 to survey 5, and the last survey increased to 0.9. The species with the lowest probabilities of detection were the Cuckoos species (Mangrove Cuckoo and Yellow-billed Cuckoo).

Table 5 shows the probabilities of detection estimated with survey-specific probability of detection in the Designated-Restoration Area. The probability of detection for White-winged

Table 4: Probability of detection (p) of bird species estimated with the survey-specific probability model in Referenced Area

Species	p_1	p_2	p_3	p_4	p_5	p_6
Common Ground-Dove (*Columbina passerina*)	0.8	0.6	1.0	0.9	0.8	1.0
Cuckoos species	0.2	0.2	0.3	0.1	0.2	0.4
Gray kingbird (*Tyrannus dominicensis*)	0.7	0.9	0.8	0.8	1.0	0.8
Northern Mockingbird (*Mimus polyglottos*)	0.7	1.0	0.8	0.9	0.5	0.5
Bananaquit (*Coereba flaveola*)	0.9	0.9	0.5	0.6	0.9	0.9
Black-faced Grassquit (*Tiaris bicolor*)	0.2	0.3	0.3	0.4	0.2	0.9
Greater Antillean Grackle (*Quiscalus niger*)	0.9	1.0	0.9	0.9	1.0	1.0

Dove varied through all surveys, with survey 3 having the highest probability of detection (0.889).

Table 6 shows the probabilities of detection estimated with model-averaged estimates in the Designated-Restoration Area. In general, all species show low probabilities of detection compared with the estimates using the previous methods. The probability of detection for Caribbean Elaenia decreased through the surveys from 0.323 to 0.046. While other species such as the Black-faced Grassquit and Mourning Dove had a high probability of detection ($\bar{p}$) in a particular survey compared with the others. For the Black-faced Grassquit, the $\bar{p}$ in survey 6 was higher than in the other surveys, and in survey 4 for Mourning Dove.

Estimation of population size ($\widehat{N}$)

Population size ($\widehat{N}$) was estimated for each of 25 species for which the probability of detection was estimated. The count (C) and estimated population size ($\widehat{N}$) in the Referenced Area are presented in the Appendix B-Table B6 and in the Appendix B-Table B7 for the Designated-Restoration Area. Figure 8 shows the estimated population size of bird species in

Table 5: Probability of detection (p) of bird species estimated with the survey-specific probability model in Designated-Restoration Area

Species	p_1	p_2	p_3	p_4	p_5	p_6
White-winged Dove (*Zenaida asiatica*)	0.000	0.556	0.889	0.444	0.222	0.333

Table 6: Probability of detection ($\bar{p}$) of bird species estimated with the model-averaged estimates in Designated-Restoration Area

Species	$\bar{p}_1$	$\bar{p}_2$	$\bar{p}_3$	$\bar{p}_4$	$\bar{p}_5$	$\bar{p}_6$
Mourning Dove (*Zenaida macroura*)	0.423	0.423	0.493	0.528	0.353	0.458
Caribbean Elaenia (*Caribbean Elaenia*)	0.323	0.231	0.046	0.231	0.046	0.046
Black-faced Grassquit (*Tiaris bicolor*)	0.449	0.499	0.348	0.298	0.399	0.549
House Sparrow (*Passer domesticus*)	0.101	0.207	0.101	0.136	0.172	0.172

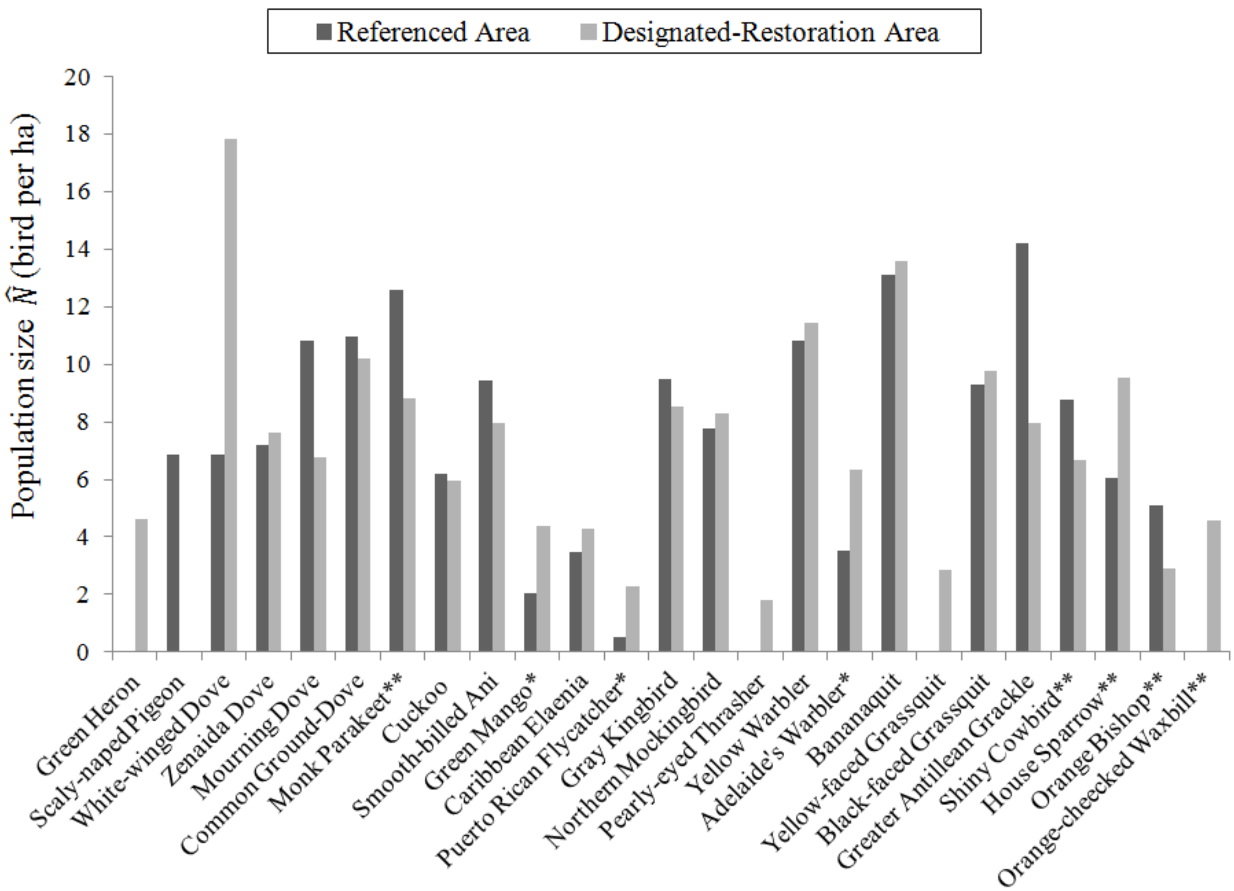

Figure 8: Estimated population size ($\hat{N}$) for selected bird species in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR. Endemic species are represented with an asterisk mark (*) and introduced species with two asterisks (**).

each study area. In the Referenced Area, the Greater Antillean Grackle had the highest population size estimate ($\hat{N}$ = 14.21 birds per ha). Other species with high population size estimates were Bananaquit, Monk Parakeet, Common Ground-Dove, Mourning Dove, and Yellow Warbler ($\hat{N}$ > 10 per ha). Puerto Rican Flycatcher and Green Mango were the species with lower population size estimates ($\hat{N} \leq 2$ per ha). In the Designated-Restoration Area, White-winged Dove was the species with the highest population size ($\hat{N}$ = 17.83 per ha). Also, Bananaquit, Yellow Warbler and Common Ground-Dove were species with high population size estimates ($\hat{N} \geq 10$ per ha). Pearly-eyed Thrasher and Puerto Rican Flycatcher were the species with lower population estimates ($\widehat{N} \leq 2$ per ha). Others species such Zenaida Dove, Cuckoos, Northern Mockingbird and Black-faced Grassquit showed similar population size estimates in both study areas.

Breeding ecology along the northern boundary of Mar Negro Unit

Nesting attempts searching and monitoring

The nesting attempts of nine bird species were monitored and their fates are summarized in the Table 7. Wilson's Plover (*Charadrius wilsonia*), Zenaida Dove, Mourning Dove, Common Ground-Dove, Mangrove Cuckoo, Gray Kingbird, Northern Mockingbird, Yellow Warbler and Bananaquit were monitored in both study areas, except for the Bananaquit in the Referenced Area where no nesting attempts were initiated during the monitoring period. In the Referenced Area a total of forty-six nesting attempts of eight different species were analyzed.

Mourning Dove was the species with the most nesting attempts in that study area. Twenty-seven of the forty-six nesting attempts in the Referenced Area failed to reach fledgling stage. Particularly, the Gray Kingbird had no successful nesting attempts. For other species,

Table 7: Summary of nesting attempts in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR.

Species	Referenced Area				Designated-Restoration Area			
	n	Failed	Successful	Censored	*n*	Failed	Successful	Censored
Wilson's Plover	2	1	1	0	2	2	0	0
Zenaida Dove	5	3	2	0	2	1	1	0
Mourning Dove	12	3	9	0	10	1	8	1
Common Ground-Dove	6	3	2	1	2	0	1	1
Mangrove Cuckoo	1	0	1	0	3	1	1	1
Gray Kingbird	5	5	0	0	2	1	0	1
Northern Mockingbird	8	6	1	1	4	1	2	1
Yellow Warbler	7	6	1	0	2	1	1	0
Bananaquit	0	0	0	0	2	0	1	1

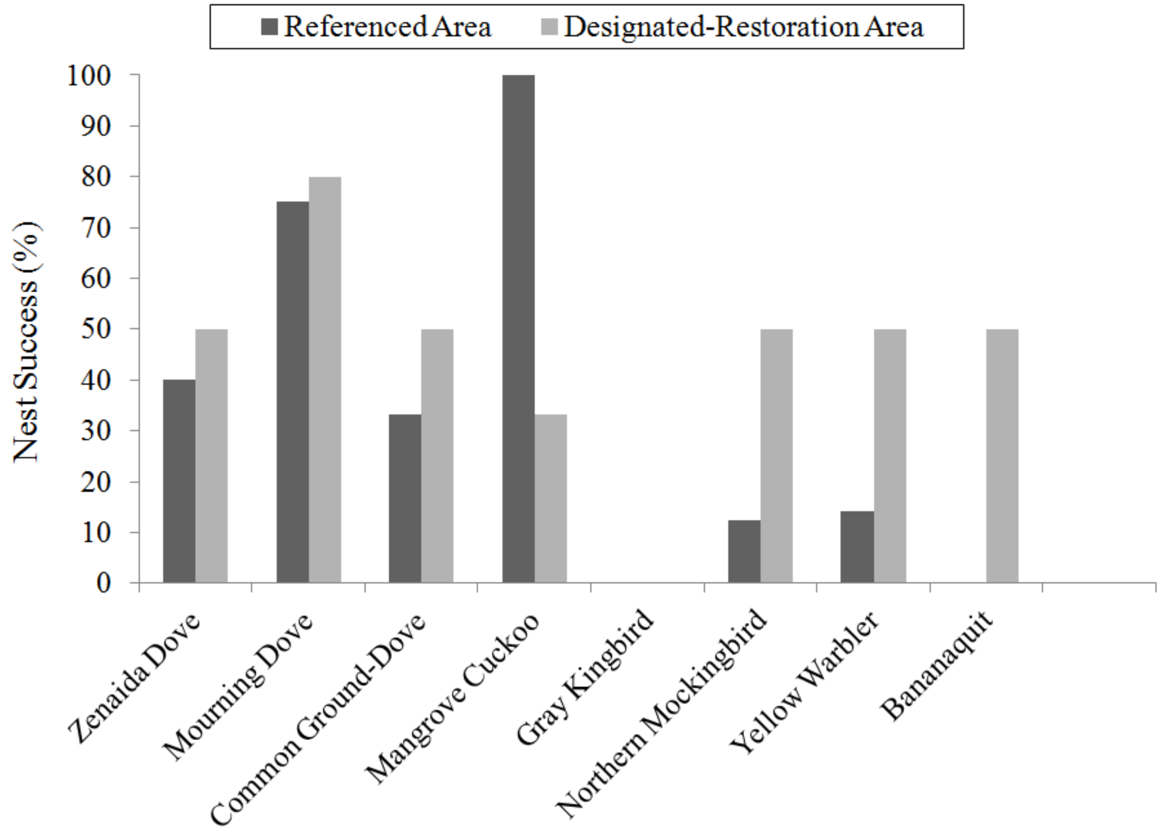

Figure 9: Percent of nest success of nine bird species in the Referenced Area and Designated-Restoration Area in Mar Negro Unit at Jobos Bay NERR. For each species the nest success is presented as the proportion of successfully nesting attempts to the total number of nesting attempts analyzed in each study area.

such as the Northern Mockingbird and Yellow Warbler only one nesting attempt reached the fledgling stage. Mangrove Cuckoo and dove species had more successful nesting attempts than did other species (Figure 9). Mourning Dove was the species with the most successful nesting attempts, with 9 of 12 successful attempts. Two censored nesting attempts were recorded in the Referenced Area, one for Northern Mockingbird and one for the Common Ground-Dove.

Twenty-nine nesting attempts of nine species were analyzed in the Designated-Restoration Area. As in the Referenced Area, Mourning Dove was the species with the most nesting attempts and was most successful in reaching the fledgling stage. The nesting success of particular species in the Designated-Restoration Area appear be higher than those in the

Referenced Area. Two of four nesting attempts of the Northern Mockingbird were successful, compared with one of eight in the Designated-Restoration Area. Other species, including the Gray Kingbird and Wilson's Plover were not successful in the Designated-Restoration Area. The Designated-Restoration Area had more censored nesting attempts than did the Referenced Area. The nesting attempt fate for six species was unknown in the Designated-Restoration Area compared with 2 in the Referenced Area.

Daily Survival Rate

The daily survival rate was calculated for the Mourning Dove and the Northern Mockingbird in each study area. For Mourning Dove, the daily survival rate was calculated in the Referenced area with twelve nesting attempts and with ten in the Designated-Restoration Area (Table 8). The resultant daily survival rate was similar in both study areas, with 0.977 in the Referenced Area and 0.992 in the Designated-Restoration Area. For the Northern Mockingbird, the daily survival rate was calculated in the Referenced Area with eight nesting attempts and with four in the Designated-Restoration Area (Table 9). The daily survival rate in the Referenced Area was 0.852 with a confidence 95% confidence interval of 0.740 to 0.963. While the daily survival rate in the Designated-Restoration Area was 0.986 with a 95%

Table 8: Summary of daily survival rate estimation of Mourning Dove in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR.

Study Area	*n*	# Failed Nest	# Exposure Days	Daily Survival Rate (Sd)	Variance (Vd)	Confidence Interval (CI)	
Referenced Area	12	3	129	0.977	0.000176	0.950	1.0
Designated-Restoration Area	10	1	125	0.992	0.000063	0.976	1.0

Table 9: Summary of daily survival rate estimation of Northern Mockingbird in the Referenced and Designated-Restoration Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR

Study Area	*n*	# Failed Nest	# Exposure Days	Daily Survival Rate (Sd)	Variance (Vd)	Confidence Interval (CI)	
Referenced Area	8	6	40.5	0.852	0.003116	0.740	0.963
Designated-Restoration Area	4	1	73.5	0.986	0.000183	0.959	1.0

confidence interval of 0.959 to 1.00. The test statistic (*Z*) determined that the daily survival rates of Northern Mockingbird in the Designated-Restoration Area was significantly higher than it was in the Referenced Area ($\alpha = 0.05$).

<u>Nest-plant and nest microhabitat characterization</u>

The nest-plant variables of 45 nesting attempts from the Referenced Area were analyzed and are presented in Table 10. Nests were placed in five different plant species, of which Mesquite (*Prosopis juliflora*) and Black Mangrove (*Avicennia germinans*) were the species most used by the birds. The height of the nest-plant were not significantly different (One-Way ANOVA, F = 0.62, df = 4, p = 0.6485). Tukey's Studentized Range (HSD) was conducted to test difference of the dbh for each plant species and determined that there were no significant differences.

The height and the percent of canopy cover near the nest of 43 nesting attempts of eight bird species in the Referenced Area were analyzed and presented in the Table 11. Gray Kingbird has the highest mean nest height, whereas the Yellow Warbler had the lowest. One-Way ANOVA determined that the nest heights were significantly different for the bird species (F = 2.2, df = 7, p = 0.0579). The result of the Fisher’s Least Significant Difference (LSD) conducted for nest height is presented in the Appendix C-Table C1. The LSD determined the nest height mean of Gray Kingbird was significantly different from that for the Common Ground-Dove and Yellow Warbler. The canopy cover (%) near the nest ranged from 63.27 ± 0.00 to 26.81 ± 7.28, in which Mangrove Cuckoo was the species that placed nests nearer to the higher percent of canopy cover. The Mourning Dove and Northern Mockingbird placed their nests in lower percent of canopy cover compared with the other species. One-Way ANOVA determined that those differences were significant (F = 2.21, df = 7, p = 0.0571), but the LSD was unable to detect any pairwise significant differences.

The nest-plant height and dbh were analyzed for 28 nesting attempts of eight plant species in the Designated-Restoration Area and the results are presented in the Table 12. Mesquite was the plant species most used by bird species to place their nest. Another species used by various birds was the Black Mangrove. The height of plant species were significantly different (One-way

Table 10: Nest-plant characterization of nesting attempts in the Referenced Area

Nest Plant	*n*	Plant height (m)		Plant dbh (cm)	
		Mean	SE	Mean	SE
Blackbead (*Pithecellobium dulce*)	1	4.58	0	11.00	0
Black Mangrove (*Avicennia germinans*)	16	4.22	0.326	20.91	2.44
Limber Caper (*Capparis flexuosa*)	2	4.90	0.49	10.13	1.13
Mesquite (*Prosopis juliflora*)	24	4.75	0.364	27.13	3.75
Rubber Vine (*Cryptostegia madagascariensis*)	2	2.68	0	5.75	0.25

Table 11: Nest characterization of nesting attempts in the Referenced Area

Bird Species	*n*	Nest height (m)		Canopy cover (%)	
		Mean	SE	Mean	SE
Zenaida Dove	5	2.32	0.38	55.04	7.89
Mourning Dove	13	3.08	0.33	26.81	7.28
Common Ground-Dove	4	2.2	0.21	41.44	13.94
Dove sp.	2	3.4	0.54	49.52	34.92
Mangrove Cuckoo	1	2.25	0	63.27	0
Gray Kingbird	5	4.06	0.44	42.74	6.09
Northern Mockingbird	7	2.33	0.57	26.81	7.52
Yellow Warbler	6	1.82	0.44	39.44	13.09

ANOVA, F = 9.87, df = 7, p = 0.0001). The LSD determined that the height of Oxhorn Bucida (*Bucida buceras*) and Maria (*Calophyllum basilliense*) species are higher than that of Mesquite, Cork Tree (*Thespesia populnea*), Wild Tamarind (*Leucaena leucocephala*), Black Mangrove and *Acacia sp*. (Appendix C-Table C2). The height of Maria and Indian Almond (*Terminalia catappa*) were not significantly different. Also, the dbh of the plant species were significantly different (One-Way ANOVA, F = 4.59, df = 7, p = 0.003). The LSD test determined that dbh of Oxhorn Bucida is higher than that for Indian Almond, Black Mangrove, Mesquite, Wild Tamarind and *Acacia sp*. (Appendix C-Table C3). The dbh of Oxhorn Bucida, Maria and Cork Tree were not significantly different.

The nest height and the canopy cover (%) near the nest of 30 nesting attempts from nine birds in the Designated-Restoration Area were analyzed and are presented in the Table 13. The nest heights were significantly different among bird species (One-Way ANOVA, F = 4.14, df = 8, p = 0.0042). The LSD determined that the nest height mean of Zenaida Dove and other doves were significantly different from that of Northern Mockingbird, Bananaquit, Mangrove Cuckoo and Yellow Warbler (Appendix C-Table C4). The nest height of all dove species and the Gray Kingbird are not significantly different. In addition, the percent of canopy cover near the nest

Table 12: Nest-plant characterization of nesting attempts in the Designated-Restoration Area

Nest Plant	*n*	Plant height (m)		Plant dbh (cm)	
		Mean	SE	Mean	SE
Acacia sp.	2	5.8	2.74	19	9
Black Mangrove (*Avicennia germinans*)	6	4.07	0.7	29.19	12.66
Cork Tree (*Thespesia populnea*)	1	7.14	0	41	0
Indian Almond (*Terminalia catappa*)	1	8.9	0	38	0
Maria (*Calophyllum basilliense*)	1	13.63	0	51	0
Mesquite (*Prosopis juliflora*)	11	7.75	0.58	28.96	2.64
Oxhorn Bucida (*Bucida buceras*)	4	16.77	2.2	81.88	12.79
Wild Tamarind (*Leucaena leucocephala*)	3	5.37	1.65	11.33	3.42

Table 13: Nest characterization of nesting attempts in the Designated-Restoration Area

Bird Species	n	Nest height (m)		Canopy cover (%)	
		Mean	SE	Mean	SE
Zenaida Dove	2	5.55	0.59	63.59	3.13
Mourning Dove	12	5.08	0.4	73.41	4.3
Common Ground-Dove	2	3.39	0.25	74.02	3.13
Dove sp.	2	5.77	2.23	77.15	17.72
Mangrove Cuckoo	2	1.94	0	84.44	0
Gray Kingbird	2	4.72	0.03	32.84	0.52
Northern Mockingbird	3	2.49	0.91	52.13	1.04
Yellow Warbler	2	1.66	0.21	21.89	0
Bananaquit	3	2.25	0.71	66.03	9.04

was significantly different among the bird species (One-Way ANOVA, $F = 4.12$, $df = 8$, $p = 0.0054$). The LSD determined that the mean of canopy cover (%) near the nest of Mangrove Cuckoo was significantly different from that of the Northern Mockingbird, Gray Kingbird and the Yellow Warbler (Appendix C-Table C5). The canopy cover (%) means for Mangrove Cuckoo were not significantly different from the other species.

Habitat evaluation of the study areas along the northern boundary of Mar Negro Unit

Weather conditions

The weather parameters evaluated for the summer, from May to August 2012 are summarized in the Appendix D. Overall, all weather parameters showed minimal variations in the measures along the summer period. The average air temperature ranged from 21.8° C to 35.1° C during the summer period and the average measure by month varied from 27.6° C (May) to 28.1° C (June) and from 28° C (July) to 27.7° C (August). The relative humidity ranged from 43% to 92% during the summer period. The average relative humidity by month varied from 73% (May) to 70% (June) and from 70.2% (July) to 72.9% (August). The wind speed was low during the summer period in which maximum measures ranged from 5.5 m/s to 7.9 m/s. The average wind speed in each month was around 2 m/s. The total precipitation varied in the maximum measures by month. June was the month with the lowest precipitation (2.8 mm) and the month that received the most precipitation were July (14.7 mm) and August (14.5 mm). Only one rainfall event was registered in the Jobos Bay Weather Station, this occurred on July 5, 2012. The daily average of the precipitation was less than 1 mm during the summer period for the Jobos Bay Weather Station.

Vegetation

In the Referenced Area, three species were dominant in the tree and shrub layers, these are Black Mangrove, Mesquite and the Cork Tree (Table 14). In the tree layer, the height varied from 5.03 m to 7.07 m and the dbh from 28.5 cm to 36.5 cm. Black Mangrove was the species with the highest height and dbh. In the shrub layer, the height varied from 1.98 m to 2.69 m in which Black Mangrove was the tallest plant. Other species recorded in the Referenced Area were the Limber Caper (*Capparis flexuosa*) in both layers, the White Mangrove (*Laguncularia racemosa*), and the Rubber Vine (*Cryptostegia madagascariensis*) in the shrub layer.

In the Designated-Restoration Area, four species were dominant in the sampling sites surveyed in each layer (Table 15). Wild Tamarind (*Leucaena leucocephala*), Mesquite, Cork Tree and Wild Cotton (*Gossypium barbadense*) are the dominant species in the tree layer. The height varied from 4.97 m to 8.17 m, in which the Wild Tamarind was the tallest tree. The dbh

Table 14: Structural information of two main vegetation layers in the Referenced Area

Dominant Species	Tree Layer		Shrub Layer
	Height (m)	DBH (cm)	Height (m)
Black Mangrove (*Avicennia germinans*)	7.07	36.50	2.69
Mesquite (*Prosopis juliflora*)	5.03	31.33	2.40
Cork Tree (*Thespesia populnea*)	6.46	28.50	1.98

Table 15: Structural information of two main vegetation layers in the Designated-Restoration Area

Dominant Species	Tree Layer		Shrub Layer
	Height (m)	DBH (cm)	Height (m)
Wild Cotton (*Gossypium barbadense*)	4.97	12.33	2.72
Wild Tamarind (*Leucaena leucocephala*)	8.175	17.75	2.28
Mesquite (*Prosopis juliflora*)	7.54	31.00	2.21
Cork Tree (*Thespesia populnea*)	6.58	26.00	-
Limber Caper (*Capparis flexuosa*)	-	-	2.31

varied from 12.33 cm to 31 cm, with the Cork Tree having the highest value. Other species found in the tree layer were Calabash-Tree (*Crescentia cujete*), Indian Almond, and *Acacia sp*. In the shrub layer, the dominant species were Wild Cotton, Limber Caper, Wild Tamarind and Mesquite. The height of dominant species varied ranged from 2.21 m to 2.72 m, Wild Cotton was the tallest shrub species. Other species found in the shrub layer were Rubber Vine and *Acacia sp*.

Discussion

Avian biodiversity along the northern boundary of Mar Negro Unit

The results show that the avian biodiversity in the Designated-Restoration Area is higher than that in the Referenced Area along the northern boundary of Mar Negro Unit at Jobos Bay NERR. The species richness was higher in the Referenced Area but species are more evenly distributed in the Designated-Restoration Area which results in high species diversity compared with the Referenced Area. Thirty-seven species were detected in the Referenced Area compared with thirty-two in the Designated-Restoration Area. Terrestrial birds, sea birds and shore birds were detected in mangrove wetlands and forests habitats of each study area. Most of these species are common residents in Puerto Rico, two are summer residents and one migratory. Only five endemic species were detected during the bird census, but two other endemics were observed outside of the census in the Designated-Restoration Area, the Puerto Rican Tody (*Todus mexicanus*) and the Yellow-shouldered Blackbird (*Agelaius xanthomus*). The Yellow-shouldered Blackbird is listed as an endangered species which is negatively impacted by Shiny Cowbird brood nest parasitism. In the Designated-Restoration Area, flocks of Yellow-shouldered Blackbird were observed near the wildlife pond; sometimes the flocks are mixed with Shiny Cowbirds and Greater Antillean Grackles. Other species that were observed out of census include the Cave Swallow (*Petrochelidon fulva*) and the Turkey Vulture (*Cathartes aura*). Columbidae, the family of doves and pigeons, was the most represented during the bird census, with 6 species detected during the surveys in the study areas and the African-collared Dove (*Streptopelia roseogrisea*) which was observed out of census. Previous preliminary bird surveys found that doves and pigeon are one of the more representative terrestrial bird families in the Jobos Bay NERR (G. Bonilla, Jobos Bay NERR, *unpublished report*). Columbids are characterizing by their high mobility and opportunistic feeding habits on a wide diet of tree fruits and grass seeds (Rivera-Milán 2001). A total of 106 avian species have been documented in the Jobos Bay NERR (PRDNER 2010). Factors that contribute to the high diversity of birds is the variety of habitats and its proximity to the Aguirre State Forest which provide important resources such shelter covert, food and nesting sites (G. Bonilla, Jobos Bay NERR, *unpublished report*).

The Greater Antillean Grackle had the highest relative abundance relative to others species detected in the Referenced Area (Figure 4). This species is native to the Greater Antilles and its habitats are primary lowlands in open areas including swamps and mangrove edges (Raffelle 1989), habitats that is found along the northern boundary of the Mar Negro Unit. Many of the point counts in the Referenced Area are adjacent to mangrove forest and wetland, and the presence of this preferred habitat may contribute to the high relative abundance of Greater Antillean Grackles in that study area. Bananaquit, Yellow Warbler and Common Ground-Dove are other species with a high percent of relative abundance in both study areas. The Bananaquit was the species with the highest relative abundance value in the Designated-Restoration Area and had a relative abundance value of more than 10% in the Referenced Area. This is the most abundant species in Puerto Rico and is found in a variety of habitats where trees, shrubs and flowers are present (Oberle 2006). Yellow Warbler is a common permanent resident in Puerto Rico but some individuals migrate from North America (Oberle 2006). The mangroves, coastal dry forest and shrubs are the typical habitat for this warbler (Oberle, 2006) which may explain its high abundance compared with other species. The Common Ground-Dove is an abundant species in open areas from middle to lower elevations in Puerto Rico (Oberle 2006) and its diet consists mainly of grass seeds (Perez-Rivera1987 cited in Rivera-Milán 1996). This dove can be found in farms and towns because it is adapted to the urbanization (Oberle 2006). The Common

Ground-Dove may be well adapted in the Jobos Bay NERR because the habitat is typical for this species.

Passerine species which were relatively abundant compared with others were the Gray Kingbird, Northern Mockingbird and Shiny Cowbird. The common characteristic of these species is that their habitat includes open areas and urban landscapes. Gray Kingbird is a common species in Puerto Rico, and can be found in open areas, including urban areas, where they can catch insect in the air (Oberle 2006). In addition to open areas, Shiny Cowbird can be found in shrub areas, open forest and suburban gardens (Oberle 2006). Northern Mockingbird can found in open areas, either in farms or towns (Oberle 2006).

Doves were the non-passerine species with the highest relatively abundance compared with other species. As is true for other columbids, these species can respond quickly to variations in the environment that affects their foraging resources (Grant and Grant 1979, Rivera-Milán 1995,1999, Bancroft et al. 2000 cited in Rivera-Milán 2001) which may contribute in their abundance along the northern boundary of Mar Negro which has experienced habitat alterations. Mourning Dove was the second non-passerine species with high relative abundant in the Referenced Area. This species is a common species in Puerto Rico, which can found in open areas particularly near agricultural fields (Oberle 2006). The agricultural farm adjacent to Jobos Bay NERR may be a factor that influences their abundance along the northern boundary of Mar Negro Unit. In the Designated-Restoration Area, White-winged Dove was the second non-passerine with a high relative abundance. This species is common in Puerto Rico and its habitat includes mangrove, dry scrub forest and gardens (Oberle 2006). Another species, Zenaida Dove, which was less abundant compared with the other doves can be found in open forest, farms, mangroves, and towns (Oberle 2006). The northern boundary of Mar Negro Unit has the preferred habitat types for these species, which may contribute to it being the most represented family in the bird census conducted in this research.

Smooth-billed Ani and Cuckoos, members of the Cuculidae family, were other non-passerine species with high relative abundance in the Referenced Area. In Puerto Rico these species are permanent residents and the northern boundary of the Mar Negro Unit provides them with typical habitat. Yellow-billed Cuckoo and Mangrove Cuckoo can be found in the thick vegetation of coastal scrub forests, wetlands and mangroves (Oberle 2006). Smooth-billed Ani can be found in open lowlands with scattered shrubs or trees, including arid scrublands habitats (Raffaelle 1989).

Others species such as Black-faced Grassquit, Adelaide's Warbler, House Sparrow, Caribbean Elaenia, Zenaida Dove and Scaly-naped Pigeon had lower abundance compared to other species but were frequent in one or both study areas. Some species presented seasonal patterns of relative abundance, where its detections (visual and by their call or songs) varied through the year. Rivera-Milán (1992) conducted a three-year study of the relative abundance pattern of columbids in Puerto Rico and found that the Scaly-naped Pigeon presented a significant peak of calling activity during the spring period (March-April) in three different ecological life zones (wet, moist and dry zones). For this species, detection may be lower during the summer when the surveys were conducted and may explain its low relative abundance. Another possible explanation is that these species have a low probability of detection which tends to minimize their apparent actual abundance. The estimated detection probability (p_j) of these species was low compared with other species which were relatively abundant.

The models used to estimate the probability of detection (p_j) in PRESENCE showed that there were some species for which p_j was constant in all surveys whereas for other species, p_j

varied through the surveys. In addition, the p_j estimates were averaged for some species for which detectability was either similar or varied by survey. Variations in the probability of detection (p_j) may be for different reasons. One reason may be related to the particular characteristics or behaviors of the species. Cryptic species that move stealthfully or only vocalize during their breeding season will have a probability of detection that may be lower than for other species. For example, the Puerto Rican Flycatcher is a common species which can be found in the coastal dry forest, but is difficult to detect because it tends to be inconspicuous and inactive (Raffaelle 1989) and its vocalizations diminish after the breeding season (Oberle 2006). Similarly, cuckoos are more easily detected by their vocalization than visually because they have slow and deliberate movements through the tree branches (Raffaelle 1989). Also, the vocalizations of certain species are difficult to detect, such as the call of the Green Mango, which is infrequently heard (Raffaelle 1989). In other cases, specific environmental factors may contribute to the reduced probability of detection for a species in a particular survey. The northern boundary of the Mar Negro Unit received constant noise from the Thermoelectric Plant located at the eastern side of Jobos Bay NERR. Thus, the noise may be a factor that reduces the probability of detection of species with low frequency songs. Some dove species, like Zenaida Dove, were hard to hear in some point counts in the Designated-Restoration Area when their vocalization was lower than the noise coming from the Thermoelectric Plant.

Regarding the estimated population size ($\widehat{N}$), Greater Antillean Grackle, was the species with the highest estimates in the Referenced Area (Figure 8). Greater Antillean Grackles use mangrove edges as habitat (Raffaelle 1989); that is consistent with the observations in this study area, where many of the point counts are adjacent to mangrove areas. Also, Greater Antillean Grackle was observed crossing wetland areas to reach mangroves in those areas. Other species with higher estimates of population size in the Referenced Area were Bananaquit, Yellow Warbler, Common Ground-Dove, Mourning Dove, and Monk Parakeet a common introduced species in Puerto Rico (Figure 8). As discussed before, many of these species are common species in Puerto Rico, or used mangrove or dry forest habitats. Thus, the presence of mangrove and dry forest may provide their preferred habitat along the Referenced Area.

In the Designated-Restoration Area, the White-winged Dove was the species with the highest population size estimates (Figure 8). According to the description by Oberle (2006), this dove species benefits from agricultural alteration, which is consistent with features in the Designated-Restoration Area. The Designated-Restoration Area has been altered by the changes in agriculture practices, which clearly contributes to the abundance of White-winged Dove in this study area. As in the Referenced Area, Bananaquit, Yellow Warbler and Common Ground-Dove were others species with higher estimates of population size in the Designated-Restoration Area. In the same way, other birds did not show marked difference in the population size estimates between both study areas. Zenaida Dove, Black-faced Grassquit, Northern Mockingbird and Cuckoos species have similar population size estimates in both study areas. These species may be well adapted at the physical conditions and find the necessary resources, such food, roost and nesting site, along the northern boundary of Mar Negro Unit.

Inferences about the abundance of the species analyzed in this research are based in the dry forest and mangrove forest which are productive and support a high diversity of organisms that can provide the resources to support the populations of birds along the northern boundary of Mar Negro Unit. Many of the most abundant bird species are documented as tolerant and adaptable to anthropogenic alteration and practices, such as agriculture. They appear to not be affected by the closeness of the agricultural farm adjacent to the northern boundary of Mar Negro Unit. With other species being less abundant, it may be necessary in the future to include methods to evaluate the physical conditions, such as sampling of soil and water, to see if these are factors that may influence the abundance of the bird populations in the Reserve.

Breeding ecology along the northern boundary of Mar Negro Unit at Jobos Bay NERR

The nesting attempts of nine bird species were monitored in both study areas. Mourning Dove was the species with the highest number of nesting attempts and most success in both study areas. This dove is described as a highly adaptable species that can use a variety of habitats for nesting (Grue et al. 1983, Sayre and Silvy 1993 cited in Muñoz et al. 2008). The breeding season is from March to July (Raffaelle 1989). Many of the nesting attempts were recorded during the egg stage but some nests were first located during the nestling stage. The clutch size was 1-2 eggs per nesting attempts; in some cases only 1 egg was detected. The white eggs were laid in a platform nest made mainly with twigs. The incubation period is 13-14 days (Oberle 2006). In the Referenced Area, two plant species were used as nest substrate, 11 nesting attempts were placed in a Mesquite and 1in the Blackbead. While in the Designated-Restoration Area, the Mourning Dove used four different plant species as nest substrate, with Mesquite being the most used. Other species used were Black Mangrove (n = 6), Cork Tree (n = 1) and *Acacia sp.* (n = 2). Mesquite is one of the dominant species in the tree layer in both study areas, and Mourning Dove used the dominant tree species to place their nesting attempts. The nests were placed higher in the nest-plant in the Designated-Restoration Area than in the Referenced Area. Also, the canopy cover at the nest was higher in the Designated-Restoration Area than in the Referenced Area. This species successfully bred in both study areas, evidenced by the daily survival rate which showed that the Mourning Dove had a high probability of a nesting attempt surviving each day (Table 8). The daily survival rate is high compared with a previous study which was conducted in another dry coastal forest in the southwestern of Puerto Rico. Rivera-Milán (1996) estimate of the daily survival rate was 0.941± 0.0132 for Mourning Dove in the dry coastal forest in the municipality of Cabo Rojo. In this research, the predation (avian and mammalian) was the main cause of failed nesting attempts of columbids (Rivera-Milán 1996). Mourning Doves may not experience high nest predation pressure allowing them to breed successfully along the northern boundary of Mar Negro Unit at Jobos Bay NERR.

Zenaida Dove is another dove species for which nesting attempts were monitored in both study areas. The breeding success of Zenaida Dove appeared be higher in the Designated-Restoration Area (Figure 9) but the sample size (n = 2) is small, which makes it difficult to draw conclusions. Similar nest success (%) estimates were reported in previous studies. In southwestern Puerto Rico, the nest success was estimated at 40.9% in Guánica and Susúa forests during 1974-1975 (Wiley 1991 cited in Rivera-Milán 1996), whereas Rivera-Milán (1996) estimated it to be 49% in Guánica during 1987-1992. This species is described as a multibrooded habitat generalist that may change its nesting preferences opportunistically any time of the year (Rivera-Milán 1996). Zenaida Dove can breed year around with the peak from February to May (Oberle 2006) which may be a reason that few nesting attempts were found in each study area compared with the Mourning Dove. Similar to Mourning Dove, the clutch size was 2 white eggs laid in a platform nest made of twigs. The nests were placed in the dominant plant species. Zenaida Dove in the Referenced Area used three plants species to place their nest, Mesquite, Black Mangrove and Rubber Vine while only the Oxhorn Bucida was used in the Designated-Restoration Area. As with Mourning Dove, this species placed its nest higher in the nest-plant in the Designated-Restoration Area. In addition, the canopy cover near the nest was also higher in the Designated-Restoration Area.

Similar to Zenaida Dove, the breeding success of the Common Ground-Dove appeared be higher in the Designated-Restoration Area (Figure 9) but the small sample size (n = 2) makes it difficult to make conclusions. The breeding season is from February to October with the peak in April to June (Raffaelle 1989). As with the other doves, the clutch size was 2 white eggs laid in a platform nest made of twigs. Also, the nests were placed in the dominant species. Common Ground-Dove in the Referenced Area used mainly the Black Mangrove, and the Mesquite to place their nest, while using only the Oxhorn Bucida in the Designated-Restoration Area. Similar to others dove species, Common Ground-Dove placed it nest higher in the nest-plant in the Designated-Restoration Area. Also, the canopy near the nest was higher in the Designated-Restoration Area.

In general, the percent of the nest success of dove species appeared to be higher in the Designated-Restoration Area, particularly for the Common Ground-Dove (Figure 9). The nest height and the canopy cover near to the nest were the microhabitat characteristics which were significantly different between study areas for the doves. Doves placed their nest higher in the nest-plant and nearer to the high percent of canopy cover in the Designated-Restoration Area. Rivera-Milán (1996) founded that nest cover was the most important microhabitat variable to explain the failure or success of breeding of columbids in three different sites including a dry coastal forest. According to the author, columbids used their plumage coloration and vegetation cover to reduce the risk to be detected by predators during the incubation period (Swank 1955, Murton 1965, Best and Stauffer 1980, Tomialojc 1980, Yahner 1982, Westmoreland and Best 1987, Burger et al. 1989, Martin 1992 cited in Rivera-Milán 1996). Nest cover represents an important factor which influences the breeding success of doves along the northern boundary of Mar Negro Unit at Jobos Bay NERR.

Northern Mockingbird was more successful in the Designated-Restoration Area than in the Referenced Area. Similar percent of nesting success was estimated in a mangrove forest in the Roosevelt Road Naval Station in the east coast of Puerto Rico (Wiley 1985). Fifty-two percent of the active nests of Northern Mockingbird were successful from 1975 to 1981 (Wiley 1985). Their nesting season is from January to July (Raffaelle 1989). Most of the nesting attempts were recorded since the egg stage. The clutch size ranged from 3-4 spotted bluish-green eggs, laid in the cup nest made of sticks. In the Referenced Area, Mesquite was the most used species to place their nests; only one nest was placed in the Black Mangrove. Mesquite, Black Mangrove and *Acacia sp*. were the plants species used to place their nests in the Designated-Restoration Area. Similar to dove species, the Northern Mockingbird placed nests in spots with high canopy cover near the nest in the Designated-Restoration Area, but the nest height did not differ between study areas. The daily nest survival rate was higher in the Designated-Restoration Area than in the Referenced Area (Table 9). As discussed the only nest microhabitat characteristic that appears be differ between study areas was the percent of canopy cover near the nest. Therefore on average, nests in the Designated-Restoration Area should have been more protected from threats such as predators, increasing the probability of nestlings surviving to fledge and leave the nest. Previous study founded a nest surrounded with denser foliage presents lower predation rates (Martin 1992 cited in Martin 1993). Canopy cover is an important characteristic that provides protection against nest predation which is the main cause of nest failure of forest-nesting passerines (Ricklefs 1969 cited in Zhou et al. 2011).

Gray Kingbird was the only species for which all nesting attempts failed in both study areas. In a previous study, Gray Kingbird showed high percent of nest success in two mangrove forests classified in the subtropical dry forest zone of Puerto Rico. The nest success was 74% in the Roosevelt Roads Naval Station during 1975 to 1981, whereas 73% in the Boqueron Forest in the southwestern, during 1977 to 1980 (Wiley 1985). The breeding season is mainly from April to July (Raffaelle 1989). The clutch size was 3-4 pink mottled eggs laid in a stick nest. Like Northern Mockingbird, the adults of Gray Kingbirds show aggressive behavior when another species approaches the nest. Black Mangrove was the primary plant species used to place their nest in both study areas. Mesquite was used by a single pair to place their nest in the Referenced Area. The average height in which the nests were placed was closer between both study areas, though slightly higher in the Designated-Restoration Area. The average of canopy cover near the nest was higher in the Referenced Area. Predation may be one of the factors that contributes to the failure of the nesting attempts. One adult and the eggs were preyed upon in the sub-transect 3 of the Referenced Area. American Kestrel (*Falco sparverius*) was one of the predator species observed in the Referenced Area. Other predators observed in both study areas were Red-tailed Hawk (*Buteo jamaicensis*), Indian Mongoose (*Herpestes auropuctatus*) and rats.

The single nesting attempt of Mangrove Cuckoo was successful in the Referenced Area, whereas the breeding success was lower in the Designated-Restoration Area, only 33% of nesting attempts were successful. This species showed high nest success in a mangrove forest of Roosevelt Roads Naval Station in which 80% of the active nests (n = 5) were successful (Wiley 1985). Their breeding period is from February to June. The clutch size was 2-3 blue eggs laid in a stick platform nest. Black Mangrove was the only plant species used for nesting in the Referenced Area, whereas Wild Tamarind and Maria were used in the Designated-Restoration Area. The average height in which the nests were placed was close between both study areas, but slightly higher in the Referenced Area. The average canopy cover near the nest was higher in the Designated-Restoration Area. For the Mangrove Cuckoo, I failed to detect a relationship between breeding success and the nest microhabitat characterization. It may be necessary to have more data to reach to conclusions regarding which factors may influence breeding success along the northern boundary of Mar Negro Unit.

Yellow Warbler failed in most of its nesting attempts in the Referenced Area, whereas failed and successful nesting attempts were proportional in the Designated-Restoration Area. The breeding period is from February to June, but they can breed in other months (Raffaelle 1989). The clutch size ranged from 2-4 grayish or greenish white with brown spots eggs laid in an open woven nest. Yellow Warbler used the material to build its nest from the most abundant resources in each study area. The material used by Yellow Warblers to build nests in the Referenced Area was the silky hairs of the seed of the Rubber Vine, whereas in the Designated-Restoration Area the fiber of cotton obtained from the Wild Cotton fruits was used. Wild Cotton is an abundant species in the Designated-Restoration Area, and which can explain the use of cotton fiber by Yellow Warblers to build their nests in that study area. The Black Mangrove was the nest plant species more frequently used in both study areas. In addition, Mesquite and the Rubber Vine were used in the Referenced Area. The average of the height in which the nests were placed was similar between both study areas, but the average of canopy cover near the nest was higher in the Referenced Area. For Yellow Warblers, I did not detect a relationship between breeding success and the nest microhabitat characterization. Again, it may be necessary to have more data to reach conclusions regarding those factors related to the nest microhabitat characterization that may influence breeding success along the northern boundary of Mar Negro Unit. An important factor that may influence the breeding success of Yellow Warbler is brood nest parasitism by the Shiny Cowbird. In the sub-transect 1 of the Referenced Area, I observed one nesting attempt that was parasitized by the Shiny Cowbird. The evidence was one nestling was bigger than the other three. In this case, the nestling of the Shiny Cowbird was found dead on the ground below of the nest, apparently attacked by predators. A possible predator may be an American Kestrel, which was the only predator observed in this sub-transect. During the visits in both study areas I commonly observed adult Yellow Warblers feeding fledging or young Shiny Cowbirds. The brood nest parasitism by the Shiny Cowbird has been documented for several species in Puerto Rico. The Yellow Warbler is one of the common host species, which presumably has an impact on breeding success over the long term (Oberle 2006). Wiley (1985) documented the impact of parasitism by Shiny Cowbird on Yellow Warbler populations on two mangrove forests in Puerto Rico. In both forests the nest success was low in which only 40% and 45% of active nests were successful, whereas high percent of those active nests,75% and 80% respectively, were parasitized (Wiley 1985).

Only two nestng attempts by Bananaquits were monitored in the Designated-Restoration Area. In the Referenced Area, adults were recorded building a nest but egg laying was never initiated. In adults of this species, it is documented that they build various nests within a short distance of each other, one for roosting and the other to initiate the nesting attempt (Hernandez 2000, Oberle 2006). In the Designated-Restoration Area, many of the empty nests were destroyed by weather (e.g. rain, wind). Also, empty nests were recorded in the Referenced Area. The empty nests recorded in both study areas could have been used for roosting instead of for nesting. Both nesting attempts were found in the nestling stage but only one nesting attempt was successful. Another nesting attempt disappeared without knowing the fate of any of at least 2 nestlings. The Bananaquit can breed in any season and can lay 2-3 brown-spotted eggs (Raffaelle 1989, Oberle 2006). The nest was globular shaped and made of grasses, twigs and plant fibers, in particular many nests were built with cotton fiber. The nesting attempts analyzed in the Designated-Restoration Area were placed in Wild Tamarind. The average canopy cover near the nest was 66.3 ± 9.04%. Bananaquits may prefer to place the nest near high canopy cover that provides protection.

Wilson's Plover was the only nestling attempt of a shorebird monitored in this research. One nesting attempt was successful in the Referenced Area whereas the two nesting attempts failed in the Designated-Restoration Area. The nests were a depression in the ground (salt flats and mudflats) surrounded by shell pieces. The clutch size was 2-3 whitish eggs with black spots.

The ground nests of Wilson's Plover are susceptible to disturbance by predators and humans (Oberle 2006). These nests were placed in the ground without canopy cover making it more susceptible to predators.

Considering the significant differences in the nest microhabitat characteristics of all bird species allows inference about interactions or factors that are important in the nest-site selection of the avian community in each study area. In a community, species interact in different ways to use the available resources in the habitat. Species coexistence, competition and predation are some interactions that influence nest-site selection (Martin 1993). Bird species can differ vertically and horizontally in the nesting space in a community, using different layers in the vegetation, and different microhabitats and nest substrate within the vegetation layer to place their nests (Martin 1988 cited in Martin 1993). In both study areas, some birds showed preferences for certain nest substrates and showed differences in the nest height and canopy cover compared with other species. Some birds in the Designated-Restoration Area exclusively used certain tree species as nest substrate. Zenaida Dove and Common Ground-Dove used only the tallest tree species Oxhorn Bucida to place their nest in the Designated-Restoration Area (Table 12). Those dove species may have a preference for taller tree as nest substrate. Also, Wild Tamarind was used as nest substrate by Mangrove Cuckoo and Bananaquit. Nest height was a microhabitat characteristic for which some species differed in both study areas. In the Referenced Area, Gray Kingbird placed its nest ($\bar{x} = 4.08$ m) higher than did the Common Ground-Dove and Yellow Warbler ($\bar{x} \leq 2.20$ m) (Appendix E-Figure E1). Those species may prefer to place nests at different heights as a way to partition the resource (nesting sites), Gray Kingbird used upper sites in the tree whereas the Common Ground-Dove and Yellow Warbler used lower sites. Similarly, in the Designated-Restoration Area, Zenaida Dove placed their nest ($\bar{x} = 5.56$ m) higher than did Mangrove Cuckoo and Yellow Warbler ($\bar{x} \leq 1.94$ m) (Appendix E-Figure E1). Zeniada Dove used high sites to select its nest-sites whereas Mangrove Cuckoo and Yellow Warbler used the lower level in a tree. Another difference among species is the selection of higher nest-sites by Zenaida Dove, Mourning Dove and Gray Kingbird compared with Northern Mockingbird, Bananaquit, Mangrove Cuckoo and Yellow Warbler (Appendix E-Figure E1). Others bird species did not showed significant differences in nest height, suggesting that those species may coexist using the nest-site at similar height. Some species showed similar patterns of selection of nest-site in both study areas. Yellow Warbler may prefer used nest-sites lower than other species in each study area. In addition, Mourning Doves used higher nest-sites in each study area. The canopy cover near the nest was a significant microhabitat characteristic for bird species in the Designated-Restoration Area (Appendix E-Figure E2). Mangrove Cuckoo ($\bar{x} =$ 84.44%) prefers to select nest-sites with higher canopy cover than do Yellow Warbler and Gray Kingbird which select those in lower canopy cover ($\bar{x} \leq 32.84\%$). Particularly, Mangrove Cuckoo and Yellow Warbler selected nest-sites at a lower distance from the ground (lower level) but differ on the percent of canopy cover. Also, Mangrove Cuckoo, doves and Bananaquit used nest-site with higher canopy cover than did Yellow Warbler and Gray Kingbird. As with nest height, others bird species did not show significant differences in the average canopy cover near the nest; those species may coexist while selecting the nest sites with similar canopy cover.

Finally, examining the nest-plants used by all birds in both study areas I determined that nests are placed in the dominant species recorded in the tree and shrub layers. In the Referenced Area, five plant species were used to as nest substrate. Mesquite, Black Mangrove, Blackbead and Limper Camper are tree species whereas Rubber Vine is a climber shrub. Mesquite and Black Mangrove are the most used nest-plant species. These species are two of three dominant species in the tree and shrub layers in the Referenced Area (Table 14). Most bird species in the

Referenced Area used the dominant plant species to place their nests. While in the Designated-Restoration Area, birds used eight plant species to place their nests. Mesquite was the dominant plant species used by the birds, followed by the Black Mangrove which is a dominant species in the Mar Negro Unit. Contrary to the Referenced Area in which Mesquite and Black Mangrove were exclusively used by birds, in the Designated-Restoration Area others plant species were used in less frequency. For example, Oxhorn Bucida, Wild Tamarind and *Acacia sp.* were used less frequently, but are recorded as dominant in the Mar Negro Unit (PRDNER 2010, Robles et al. 2002). Some of these species were previously documented as being used as nest substrate. Mesquite, Oxhorn Bucida and Black Mangrove were reported as nest substrate for dove species in dry forest in Puerto Rico (Rivera-Milán 1996).

Management Implications

The staff on the Jobos Bay NERR can use the baseline data presented in this research about attributes of the bird community along the northern boundary of Mar Negro Unit. The information about the species diversity and evenness, species richness and relative abundance can be used to evaluate how those changes after the implementation of mangrove wetland restoration. Thus, the staff can assess the short- and long-term effectiveness of the restoration along the northern boundary of Mar Negro Unit.

Using the results of bird surveys, I can suggest that some species may be positively impacted with the restoration. First, some species were detected only in the 25 m fixed-radius point counts in the Referenced Area. These species are Magnificent Frigatebird (*Fregata magnificens*), Great Egret (*Ardea alba*), American Kestrel, White-crowned Pigeon (*Patagioenas leucocephala*), Scaly-naped Pigeon, Antillean Nighthawk, Bronze Mannikin and Pin-tailed Whydah. Bird surveys can be conducted after the implementation of the black mangrove restoration to assess if those species are detected in the Designated-Restoration Area. Also, others species showed a higher relative abundance in the Referenced Area than in the Designated-Restoration Area. Mourning Dove, Greater Antillean Grackle and Shiny Cowbird showed high relative abundance in the Referenced Area. Another species that can be considered is the Monk Parakeet which showed a high population size estimates ($\widehat{N}$) in the Referenced Area. The staff on the Jobos Bay NERR can evaluate if the relative abundance or population size estimates ($\widehat{N}$) of these species changes after the restoration to determinate if it results in a benefit to them. In addition, some species were less frequent in the surveys than others. Species such Common Moorhen (*Gallinula chloropus*), Antillean Crested Hummingbird (*Orthorhyncus cristatus*), Puerto Rican Emerald, Indian Silverbill, Pearly-eyed Thrasher, Puerto Rican

Flycatcher, Black-whiskered Vireo and Yellow-faced Grassquit (*Tiaris olivaceus*) were less frequently observed during the surveys. These species can be monitored to assess if it frequency changes after the restoration as well. On the other hand, some species could be negatively impacted by the restoration. White-winged Dove and Cuckoos species showed high relative abundance in the Designated-Restoration Area. All these species can be of interest for the staff on the Jobos Bay NERR to assess the effectiveness of the restoration of the hydrology of black mangrove in the Mar Negro Unit.

In addition, the presence of Shiny Cowbird and Monk Parakeet may be of interest for the staff on the Jobos Bay NERR. Shiny Cowbird is a brood nest parasite with documented hosts that include the endangered Yellow-shouldered Blackbird, Yellow Warbler, Black-whiskered Vireo, and Puerto Rican Flycatcher (Wiley 1985, 1988), all of which were detected in the northern boundary of Mar Negro Unit. Wiley (1988) found that more than 75% of the nest of Yellow-shouldered Blackbird, Black-cowled Oriole (*Icterus dominicensis*), Troupial (*Icterus icterus*), Puerto Rican Flycatcher, Yellow Warbler and Black-whiskered Vireo were parasitized by the cowbirds, species which are described as high-quality foster species. Previous research reported that the effects of cowbird parasitism in the host species depressed nesting success an average of 40% below that of the non-parasitized nest and decreased the productivity of hosts (Wiley 1985). A factor that contributes to the impact of parasitism in high-quality foster species are shared similar characteristics or behaviors including the breeding season, egg size, food habits (Wiley 1988). In this research, Yellow Warbler showed evidence of brood nest parasitism by Shiny Cowbird but the surveys indicated high relative abundance in both study areas. Yellow-shouldered Blackbird was observed only in the Designated-Restoration Area where the Shiny Cowbird showed lower relative abundance compared with the Referenced Area. For the Shiny

Cowbird, the presence of these host species provides more opportunities for reproduction, which may be another factor that contributes to the increase in its population.

Monk Parakeet is considered an agricultural pest in South America and an invasive species in United States and Spain (Johnson and Logue 2009). This species is native in South America, where it caused up to 45% of agricultural crops damages during the mid-1970 (Johnson and Logue 2009). In their native range this species can be found in a variety of habitats including open forest, dry *Acacia* scrubland, palm grove, farmlands and urban parks (Sol et al. 1997). In the United States, this species was reported since 1960's and documented in 14 states but its population is concentrated in Florida and the southeastern region of Texas (Johnson and Logue 2009). In Florida, this parakeet is founded in urban and sub-urban areas where it caused problems with the electric utility structures (e.g. light poles, distribution lines poles) where they placed their large communal nests (Johnson and Logue 2009). Other countries where this species has been introduced are Canada, Bahamas, Italy, England and Spain (Johnson and Logue 2009). In Barcelona, Spain this species was established in the mid-1970's (Batllori and Nos 1985 cited in Sol et al. 1997) and increased its population (Clavell et al. 1991 cited in Sol et al. 1997). A study conducted by Sol et al. (1997) found that palms are the preferred nest-substrate for Monk Parakeets in Barcelona, Spain. In this research, Monk Parakeets obtained high population size estimates ($\widehat{N}$) in both study areas, particularly in the Referenced Area with ~12 individuals per ha (Figure 8). This species has a broad diet including palm nuts, seed, fruits and insects (Oberle 2006) and uses towers and trees, particularly palm species, for nesting (Oberle 2006). Thus, the availability of all these types of food, and the presence of palm along the northern boundary of Mar Negro Unit may positively influence the population of this parakeet species, particularly in the Referenced Area.

I recommend a study to assess if the presence of Monk Parakeet and Shiny Cowbird represents a threat to the wildlife and adjacent agricultural farms along the northern boundary of Mar Negro Unit. The negative impact of brood nest parasitism of Shiny Cowbird to other birds in Puerto Rico can be studied to determine their impact on other avian species, particularly in the breeding success and population size in the Jobos Bay NERR. The Monk Parakeet can be studied to examine if the population is or may be a potential threat to the agriculture activities adjacent to the northern boundary of Mar Negro Unit.

APPENDICES

APPENDIX A

Coordinates of the established sampling sites in the study areas along the northern boundary of

Mar Negro Unit at Jobos Bay NERR

Table A1: List of coordinates of the established sampling sites (point counts) in the Referenced Area

Sampling site #	Latitude	Longitude
1	N 17° 57' 13.5 "	W 66° 15' 05.7"
2	N 17° 57' 09.8"	W 66° 15' 05.7"
3	N 17° 57' 13.3"	W 66° 15' 09.6"
4	N 17° 57' 13.4"	W 66° 15' 20.3"
5	N 17° 57' 13.4"	W 66° 15' 24.0"
6	N 17° 57' 10.3"	W 66° 15' 27.5"
7	N 17° 57' 13.4"	W 66° 15' 30.9"
8	N 17° 57' 16.7"	W 66° 15' 35.0"
9	N 17° 57' 13.8"	W 66° 15' 38.6"
10	N 17° 57' 16.8"	W 66° 15' 40.4"

Table A2: List of coordinates of the established sampling sites (point counts) in the Designated-Restoration Area

Sampling site #	Latitude	Longitude
11	N 17° 57' 14.0"	W66° 14' 55.7"
12	N 17° 57' 13.9"	W66° 14' 52.1"
13	N 17° 57' 18.9"	W66° 14' 51.8"
14	N 17° 57' 16.9"	W66° 14' 48.2"
15	N 17° 57' 16.5"	W66° 14' 44.5"
16	N 17° 57' 19.9"	W66° 14' 44.6"
17	N 17° 57' 09.6"	W66° 14' 37.3"
18	N17° 57' 14.4"	W66° 14' 37.3"
20	N 17° 57' 19.8"	W66° 14' 33.7"

APPENDIX B

Additional information of avian biodiversity along the northern boundary of Mar Negro Unit at Jobos Bay NERR

Table B1: List of bird species detected in the 25 m fixed-radius point counts located in the Referenced Area

Scientific Name	Common Name (English)	Common Name (Spanish)
Fregata magnificens	Magnificent Frigatebird	Tijereta
Ardea alba	Great Egret	Garza Real
Bubulcus ibis	Cattle Egret	Garza Ganadera
Butorides virescens	Green Heron	Martinete
Falco sparverius	American Kestrel	Falcón Común
Charadrius wilsonia	Wilson's Plover	Chorlito Marítimo
Himantopus mexicanus	Black-necked Stilt	Viuda
Tringa semipalmata	Willet	Playero Aliblanco
Patagioenas squamosa	Scaly-naped Pigeon	Paloma Turca
Patagioenas leucocephala	White-crowned Pigeon	Paloma Cabeciblanca
Zenaida asiatica	White-winged Dove	Tórtola Aliblanca
Zenaida aurita	Zenaida Dove	Tórtola Cardosantera
Zenaida macroura	Mourning Dove	Tórtola Rabilarga
Columbina passerina	Common Ground-Dove	Rolita
Myiopsitta monachus	Monk Parakeet	Perico Monje
*Coccyzus americanus**	Yellow-billed Cuckoo	Pájaro bobo piquiamarillo
*Coccyzus minor**	Mangrove Cuckoo	Pájaro bobo menor
Crotophaga ani	Smooth-billed Ani	Garrapatero
Chordeiles gundlachii	Antillean Nighthawk	Querequequé
Anthracothorax viridis	Green Mango	Zumbador Verde
Melanerpes portoricensis	Puerto Rican Woodpecker	Carpintero
Elaenia martinica	Caribbean Elaenia	Jui Blanco
Myiarchus antillarum	Puerto Rican Flycatcher	Jui
Tyrannus dominicensis	Gray Kingbird	Pitirre
Vireo altiloquus	Black-whiskered Vireo	Julián Chiví
Mimus polyglottos	Northern Mockingbird	Ruiseñor
Dendroica petechia	Yellow Warbler	Canario de Mangle
Dendroica adelaidae	Adelaide's Warbler	Reinita mariposera
Coereba flaveola	Bananaquit	Reinita Común
Tiaris olivaceus	Yellow-faced Grassquit	Gorrión Barba Amarilla
Tiaris bicolor	Black-faced Grassquit	Gorrión Negro
Quiscalus niger	Greater Antillean Grackle	Mozambique
Molothrus bonariensis	Shiny Cowbird	Tordo Lustroso
Passer domesticus	House Sparrow	Gorrión Doméstico
Euplectes franciscanus	Orange Bishop	Obispo Anaranjado
Estrilda melpoda	Orange-cheeked Waxbill	Veterano
Lonchura cucullata	Bronze Mannikin	Diablito
Vidua macroura	Pin-tailed Whydah	Viuda Colicinta

*Species referred as Cuckoos species in the bird census data analysis

Table B2: List of bird species detected in the 25 m fixed-radius point counts located in the Designated-Restoration Area

Scientific Name	Common name (English)	Common Name (Spanish)
Butorides virescens	Green Heron	Martinete
Gallinula chloropus	Common Moorhen	Gallareta Común
Himantopus mexicanus	Black-necked Stilt	Viuda
Zenaida asiatica	White-winged Dove	Tórtola Aliblanca
Zenaida aurita	Zenaida Dove	Tórtola Cardosantera
Zenaida macroura	Mourning Dove	Tórtola Rabilarga
Columbina passerina	Common Ground-Dove	Rolita
Myiopsitta monachus	Monk Parakeet	Perico Monje
*Coccyzus americanus**	Yellow-billed Cuckoo	Pájaro bobo piquiamarillo
*Coccyzus minor**	Mangrove Cuckoo	Pájaro bobo menor
Crotophaga ani	Smooth-billed Ani	Garrapatero
Anthracothorax viridis	Green Mango	Zumbador Verde
Orthorhyncus cristatus	Antillean Crested Hummingbird	Zumbadorcito Crestado
Chlorostilbon maugaeus	Puerto Rican Emerald	Zumbadorcito de Puerto Rico
Melanerpes portoricensis	Puerto Rican Woodpecker	Carpintero
Elaenia martinica	Caribbean Elaenia	Jui Blanco
Myiarchus antillarum	Puerto Rican Flycatcher	Jui
Tyrannus dominicensis	Gray Kingbird	Pitirre
Vireo altiloquus	Black-whiskered Vireo	Julián Chiví
Mimus polyglottos	Northern Mockingbird	Ruiseñor
Margarops fuscatus	Pearly-eyed Thrasher	Zorzal Pardo
Dendroica petechia	Yellow Warbler	Canario de Mangle
Dendroica adelaidae	Adelaide's Warbler	Reinita mariposera
Coereba flaveola	Bananaquit	Reinita Común
Tiaris bicolor	Black-faced Grassquit	Gorrión Negro
Tiaris olivaceus	Yellow-faced Grassquit	Gorrión Barba Amarilla
Quiscalus niger	Greater Antillean Grackle	Mozambique
Molothrus bonariensis	Shiny Cowbird	Tordo Lustroso
Passer domesticus	House Sparrow	Gorrión Doméstico
Euplectes franciscanus	Orange Bishop	Obispo Anaranjado
Estrilda melpoda	Orange-cheeked Waxbill	Veterano
Lonchura malabarica	Indian Silverbill	Gorrión Picoplata

*Species referred as Cuckoos species in the bird census data analysis

Table B3: Number of species detected, by family, in the 25 m fixed-radius point counts located in the Referenced Area

Family	No. species detected
Fregatidae	1
Ardeidae	3
Falconidae	1
Recurvirostridae	1
Scolopacidae	1
Columbidae	6
Psittacidae	1
Cuculidae	3
Caprimulgidae	1
Trochilidae	1
Picidae	1
Tyrannidae	3
Vireonidae	1
Mimidae	1
Parulidae	2
Coerebidae	1
Emberizidae	2
Icteridae	2
Passeridae	1
Estrildidae	2
Ploceidae	1
Viduidae	1

Table B4: Number of species detected, by family, in the 25 m fixed-radius point counts located in the Designated-Restoration Area

Family	No. species detected
Ardeidae	1
Rallidae	1
Recurvirostridae	1
Columbidae	4
Psittacidae	1
Cuculidae	3
Trochilidae	3
Picidae	1
Tyrannidae	3
Vireonidae	1
Mimidae	2
Parulidae	2
Coerebidae	1
Emberizidae	2
Icteridae	2
Passeridae	1
Estrildidae	2
Ploceidae	1

Table B5: Relative abundance of the bird species across all point counts in each study area

Species Name	Referenced Area		Designated-Restoration Area	
	Total individuals	Relative abundance	Total individuals	Relative abundance
Magnificent Frigatebird	1	0.0009	0	0
Great Egret	4	0.0035	0	0
Cattle Egret	5	0.0044	0	0
Green Heron	3	0.0026	12	0.0125
American Kestrel	2	0.0018	0	0
Common Moorhen	0	0	4	0.0042
Scaly-naped Pigeon	17	0.015	0	0
White-crowned Pigeon	1	0.0009	0	0
White-winged Dove	33	0.0291	77	0.0803
Zenaida Dove	34	0.03	18	0.0188
Mourning Dove	100	0.0883	32	0.0334
Common Ground-Dove	110	0.0971	90	0.0938
Monk Parakeet	33	0.0291	19	0.0198
Cuckoos species	17	0.015	42	0.0438
Smooth-billed Ani	26	0.0229	39	0.0407
Antillean Nighthawk	1	0.0009	0	0
Green Mango	4	0.0035	16	0.0167
Antillean Crested Hummingbird	0	0	3	0.0031
Puerto Rican Emerald	0	0	2	0.0021
Puerto Rican Woodpecker	6	0.0053	3	0.0031
Caribbean Elaenia	20	0.0177	7	0.0073
Puerto Rican Flycatcher	1	0.0009	7	0.0073
Gray Kingbird	93	0.0821	72	0.0751
Black-whiskered Vireo	2	0.0018	7	0.0073
Northern Mockingbird	67	0.0591	70	0.073
Pearly-eyed Thrasher	0	0	4	0.0042
Yellow Warbler	119	0.105	99	0.1032
Adelaide's Warbler	15	0.0132	33	0.0344
Bananaquit	121	0.1068	128	0.1335
Yellow-faced Grassquit	1	0.0009	7	0.0073
Black-faced Grassquit	42	0.0371	44	0.0459
Greater Antillean Grackle	159	0.1403	49	0.0511
Shiny Cowbird	74	0.0653	33	0.0344
House Sparrow	15	0.0132	15	0.0156
Orange Bishop	2	0.0018	9	0.0094
Orange-cheeked Waxbill	2	0.0018	8	0.0083
Indian Silverbill	0	0	10	0.0104
Bronze Mannikin	2	0.0018	0	0
Pin-tailed Whydah	1	0.0009	0	0

Table B6: The count (C) and estimated population size ($\widehat{N}$) of bird species in the Referenced Area.

Species	C (birds per ha)	$\widehat{N}$ (birds per ha)
Scaly-naped Pigeon	1.44	6.86
White-winged Dove	2.80	6.87
Zenaidad Dove	2.89	7.22
Mourning Dove	8.49	10.84
Common Ground-Dove	9.34	10.98
Monk Parakeet	2.80	12.58
Cuckoos species	1.44	6.18
Smooth-billed Ani	2.21	9.46
Green Mango	0.34	2.05
Caribbean Elaenia	1.70	3.46
Puerto Rican Flycatcher	0.08	0.51
Gray kingbird	7.89	9.47
Northern Mockingbird	5.69	7.76
Yellow Warbler	10.10	10.82
Adelaide's Warbler	1.27	3.51
Bananaquit	10.27	13.11
Black-faced Grassquit	3.57	9.30
Greater Antillean Grackle	13.50	14.21
Shiny Cowbird	6.28	8.76
House Sparrow	1.27	6.05
Orange Bishop	0.17	5.10

Table B7: The count (C) and estimated population size ($\widehat{N}$) of bird species in the Designated-Restoration Area.

Species	C (birds per ha)	$\widehat{N}$ (birds per ha)
Green Heron	1.13	4.64
White-winged Dove	7.26	17.83
Zenaida Dove	1.70	7.64
Mourning Dove	3.02	6.76
Common Ground-Dove	8.49	10.19
Monk Parakeet	1.79	8.80
Cuckoos species	3.96	5.94
Smooth-billed Ani	3.68	7.94
Green Mango	1.51	4.37
Caribbean Elaenia	0.66	4.29
Puerto Rican Flycatcher	0.66	2.27
Gray Kingbird	6.79	8.53
Northern Mockingbird	6.60	8.29
Pearly-eyed Thrasher	0.38	1.79
Yellow Warbler	9.34	11.46
Adelaide's Warbler	3.11	6.33
Bananaquit	12.07	13.58
Yellow-faced Grassquit	0.66	2.85
Black-faced Grassquit	4.15	9.79
Greater Antillean Grackle	4.62	7.97
Shiny Cowbird	3.11	6.69
House Sparrow	1.41	9.55
Orange Bishop	0.85	2.92
Orange-cheeked Waxbill	0.75	4.55

APPENDIX C

Fisher's Least Significant Difference (LSD) results for nest-plant and nest characterization variables in the Referenced Area and Designated-Restoration Area

Table C1: LSD results for the nest height (m) in the Referenced Area

Bird Species	N	Nest height (m)
Gray Kingbird (*Tyrannus dominicensis*)	5	4.06 a*
Dove sp.	2	3.40 ab
Mourning Dove (*Zenaida macroura*)	13	3.08 ab
Northern Mockingbird (*Mimus polyglottos*)	7	2.33 ab
Zenaida Dove (*Zenaida aurita*)	5	2.32 ab
Mangrove Cuckoo (*Coccyzus minor*)	1	2.25 ab
Common Ground-Dove (*Columbina passerina*)	4	2.20 b
Yellow Warbler (*Dendroica petechia*)	6	1.82 b

*means followed by the same letter are not significantly different from each other (α = 0.05)

Table C2: LSD results for the nest plant height (m) in the Designated-Restoration Area

Nest Plant	*n*	Plant height (m)
Oxhorn Bucida (*Bucida buceras*)	4	16.77 a*
Maria (*Calophyllum basilliense*)	1	13.63 ab
Indian Almond (*Terminalia catappa*)	1	8.90 bc
Mesquite (*Prosopis juliflora*)	11	7.75 c
Cork Tree (*Thespesia populnea*)	1	7.14 c
Acacia sp.	2	5.80 c
Wild Tamarind (*Leucaena leucocephala*)	3	5.37 c
Black Mangrove (*Avicennia germinans*)	6	4.07 c

*means followed by the same letter are not significantly different from each other (α = 0.05)

Table C3: LSD results for the plant dbh (cm) in the Designated-Restoration Area

Nest Plant	*n*	Plant dbh (cm)
Oxhorn Bucida (*Bucida buceras*)	4	81.88 a*
Maria (*Calophyllum basilliense*)	1	51.00 ab
Cork Tree (*Thespesia populnea*)	1	41.00 ab
Indian Almond (*Terminalia catappa*)	1	38.00 b
Black Mangrove (*Avicennia germinans*)	6	29.19 b
Mesquite (*Prosopis juliflora*)	11	28.96 b
Acacia sp.	2	19.00 b
Wild Tamarind (*Leucaena leucocephala*)	3	11.33 b

*means followed by the same letter are not significantly different from each other (α = 0.05)

Table C4: LSD results for the nest height (m) in the Designated-Restoration Area

Bird Species	*n*	Nest height (m)
Dove sp.	2	5.77a*
Zenaida Dove (*Zenaida aurita*)	2	5.55a
Mourning Dove (*Zenaida macroura*)	12	5.08ab
Gray Kingbird (*Tyrannus dominicensis*)	2	4.72abc
Common Ground-Dove (*Columbina passerina*)	2	3.39abcd
Northern Mockingbird (*Mimus polyglottos*)	3	2.49bcd
Bananaquit (*Coereba flaveola*)	3	2.246cd
Mangrove Cuckoo (*Coccyzus minor*)	2	1.94d
Yellow Warbler (*Dendroica petechia*)	2	1.66d

*means followed by the same letter are not significantly different from each other (α = 0.05).

Table C5: LSD results for the canopy cover (%) near the nest in the Designated-Restoration Area

Bird Species	n	Canopy cover (%)
Mangrove Cuckoo (*Coccyzus minor*)	2	84.44a*
Dove sp.	2	77.15ab
Common Ground-Dove (*Columbina passerina*)	2	74.02ab
Mourning Dove (*Zenaida macroura*)	12	73.41ab
Bananaquit (*Coereba flaveola*)	3	66.03ab
Zenaida Dove (*Zenaida aurita*)	2	63.59ab
Northern Mockingbird (*Mimus polyglottos*)	2	52.13bc
Gray Kingbird (*Tyrannus dominicensis*)	2	32.84cd
Yellow Warbler (*Dendroica petechia*)	1	21.89d

*means followed by the same letter are not significantly different from each other (α = 0.05).

APPENDIX D

Summary of select summer 2012 weather parameters in the Jobos Bay NERR

Table D1: Air temperature (°C) and relative humidity (%) during the summer 2012 at Jobos Bay NERR

Month	Average Air Temperature (°C)			Relative Humidity (%)		
	Min.	Max.	Avg.	Min.	Max.	Avg.
May	21.8	31.5	26.7	48.0	90.0	73.1
June	23.8	31.8	28.1	46.0	88.0	70.0
July	22.0	34.2	28.0	46.0	92.0	70.2
August	23.1	35.1	27.7	43.0	91.0	72.9

Table D2: Wind speed (m/s) and precipitation (mm) during the summer 2012 at Jobos Bay NERR

Month	Wind Speed (m/s)			Total Precipitation (mm)		
	Min.	Max.	Avg.	Min.	Max.	Avg.
May	0.0	6.5	2.0	0.0	8.6	0.023
June	0.0	5.5	2.3	0.0	2.8	0.005
July	0.0	6.2	2.1	0.0	14.7	0.042
August	0.0	7.9	2.0	0.0	14.5	0.047

APPENDIX E

Microhabitat characteristic that influence in the nest-site selection in the avian community along the northern boundary of Mar Negro Unit at Jobos Bay NERR

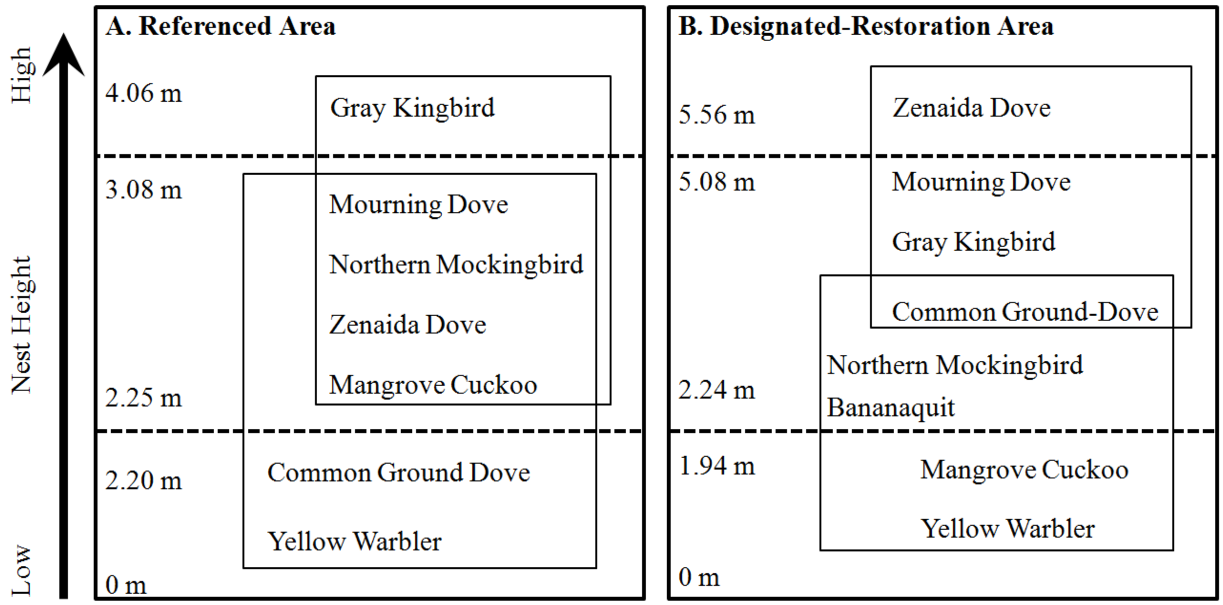

Figure E1: Nest-site selection based in the nest height differences among species in the avian communities along the northern boundary of Mar Negro Unit at Jobos Bay NERR. Diagram represents spatial distribution of bird species based in the significant differences among species in the average nest height (m) in (A) Referenced Area and (B) Designated-Restoration Area. Species enclosed in the same square are those that not showed significant differences in the average nest height in the pair wise statistical test. Then square illustrate coexistent species which used nest site at similar height in the respective study areas.

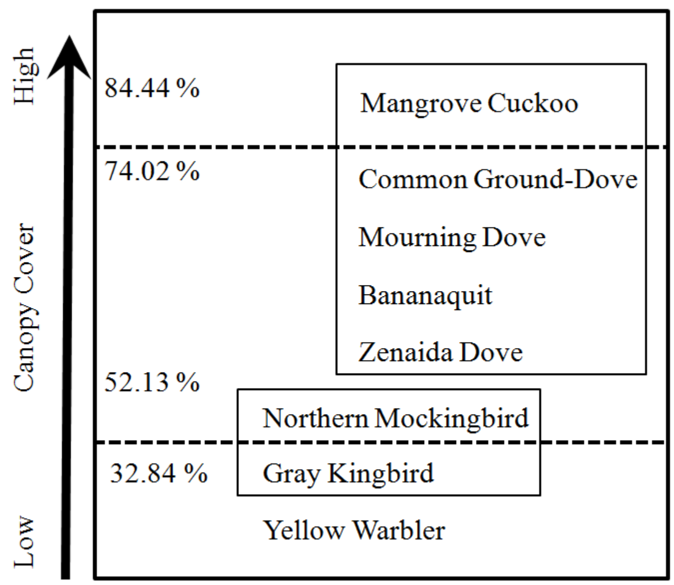

Figure E2: Nest-site selection based in the differences on the canopy cover near the nest (%) among species in the avian communities along the northern boundary of Mar Negro Unit at Jobos Bay NERR. Diagram represents spatial distribution of bird species based in the significant differences among species in the average canopy cover near the nest (%) in the Designated-Restoration Area. Species enclosed in the same square are those that not showed significant differences in the average canopy cover near the nest (%) in the pair wise statistical test. Then square illustrate coexistent species which used nest site at similar height in the respective study areas.

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