MONITORING NEOTROPICAL MIGRATORY BIRD USE AT A WOODLAND STOPOVER ENHANCEMENT PROJECT

PACKERY CHANNEL NATURE PARK
NUECES COUNTY, TEXAS

Prepared for
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September 2023

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Monitoring Neotropical Migratory Bird Use at a Habitat Enhancement Project Packery Channel Nature Park, Nueces County, Texas

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FOREWARD

This report involves an ongoing assessment of Neotropical migratory bird use within a 2-acre woodland stopover habitat enhancement site on a Texas coastal barrier island. The project is located at the 38-acre Packery Channel Nature Park (PCNP), North Padre Island, Nueces County, Texas. Although this 2015 woodland construction project was not designed for scientific analyses, apparent migrant usage trends are noted and discussed herein.

During a literature search and review, it became apparent that significant research is being conducted to better understand the importance of Neotropical migratory bird woodland stopover habitats along the Gulf of Mexico and how to conserve critical stopover sites. In 2014, Nueces County Coastal Parks expressed an interest in the "Field of Dreams" hypothesis, which implies that "if you build it, they will come." Could stopover habitats be constructed to provide cover, water, and enough food resources for fat-depleted migrants to use before moving on to more sustainable habitats? If so, what plants would offer the vegetative structure and species composition that are compatible with the needs of these woodland migratory birds? What plants will survive short- and long-term in this inhospitable barrier island landscape? Ultimately, would the created woodland habitat be used by migrants, and if so, how, and to what degree?

The project received grant funding and was constructed in the fall 2015 and completed in January 2016. Over the past seven years, the project has proved to be successful in both plant condition/survival and use by migrants as a barrier island stopover habitat. The success of this project is based on the comprehensive plant monitoring results in 2016, 2017, and 2018, and the Spring Neotropical migratory bird surveys in 2017, 2020, and 2023.

SUMMARY

This unique project involved planting 2,222 native trees, shrubs, forbs, and vines. The 41 plant species selected are components of South Texas Tamaulipan thornscrub, live oak, palm grove, riparian, and coastal woodland plant communities. The 2-acre woodland project was constructed parallel to the park's boardwalk to enhance viewing opportunities for bird

watchers, nature photographers, and other park visitors and to serve as an educational outreach tool.

Plant monitoring (2016-2018) identified high, mid, and low plant survival groups. Twenty-one of the 41 species planted had an 82%-100% survival rate two years post-construction. The average survival rate for the high survival group (primarily trees and shrubs) was 96%, with 477 of the 496 transplants surviving after two years. Mid and low survival groups consisted of short stature shrubs and forbs that were eventually covered by dense mats of encroaching island vegetation. The surviving trees and shrubs have endured prolonged droughts, Hurricane Harvey, and extended flooding events, yet they continue to flourish.

Annual Spring bird surveys were conducted at the project site. The total number of birds in the transplant plots during the Spring 2017, 2020, and 2023 survey dates was 216, 295, and 159 Neotropical migrants, respectively. The dominant bird behavior in the transplant plots was foraging, which suggests that the migrants were probably exhibiting hyperphagia (intensive feeding to build fat reserves) to meet the high energy costs of long-range migration. This is important because it supports the assumption that this newly created woodland site is needed for and used by migrants during fallout events.

Surveys consisted of 10-minute observations per transplant plot and at three nearby mature oak woodland survey stations. When bird abundance was converted to bird numbers/unit effort, the results for the transplant plots (3.3 birds/survey/plot) and nearby mature live oak woodland stations (2.9 birds/survey/station) in 2017 were nearly identical. Similarly, the transplant plots had 5.7 birds/survey/plot, and the mature oak woodland stations had 7.0 birds/survey/station during the Spring 2020 surveys. In 2023, the transplant plots had 7.6 birds/survey/plot, and the mature oak woodland stations had 11.0 birds/survey/station. This suggests that these two habitat types may be quite similar in habitat suitability for migratory birds during spring fallout events. Therefore, it can be deduced that the newly created woodland habitat does provide some level of food resources for spring migrants during fallout events.

Foraging was the primary bird behavior in the transplant plots and mature oak survey stations. Migratory birds used a variety of plants and food items, which supports the assumption that plant diversity is important.

The four bird families most heavily represented at the transplant plots and mature oak survey stations were Tyrannidae, Parulidae, Cardinalidae, and Icteridae. The close relationship between birds at the transplant plots and nearby mature oak woodlands suggests that the two habitat types, despite very distinct differences in plant species composition, maturity, and physical structure, may be quite similar in habitat suitability, at least at the broad taxonomic level of bird families.

Conservationists agree that stopover sites can at least be defined based on their capacity to meet migrant's needs at a given point in space and time. They further describe "fire escape" stopover sites as being infrequently used but utterly vital during emergency fallouts (groundings). The resources within a fire escape may be too low to allow birds to replenish fat stores or recover muscle mass, but the stop enables them to survive and continue migrating from the site.

Fire escapes are typically located adjacent to significant barriers, such as the Gulf of Mexico. They are generally small and isolated habitat patches surrounded by unusable habitat. Weather is a critical factor in determining when fire escape sites are used, and migrant densities can be very high at times. The situations where high densities of migrants utilize fire escape stopover sites are often predictable due to overriding extrinsic factors such as weather. The 2-acre woodland enhancement project at Packery Channel Nature Park has been shown to effectively meet the "fire escape" stopover habitat criteria described in the literature.

1.0 STUDY AREA AND PROJECT BACKGROUND

The project site is located in the Packery Channel Nature Park (PCNP) on North Padre Island, Nueces County, Texas (Figure 1). This 38-acre public park is owned and managed as a nature preserve by the Nueces County Coastal Parks Department.

Figure 1. Barrier islands along the Texas Coast. North Padre Island is a 77-mile-long barrier island that extends from Corpus Christi to Port Mansfield Channel. Map adapted from Wikipedia, 2020.

1.1 AN IDEAL PROJECT LOCATION

The PCNP site was ideal for implementing an experimental woodland stopover enhancement project for several reasons. Padre Island, comprised of North Padre Island and South Padre Island, is the southernmost major barrier island along the Texas Coast. The Texas Gulf Coast has been recognized for decades as being vital for sustaining long-term populations of migratory birds. As migrating birds cross the Gulf of Mexico, habitats along the coast provide the first possible landfall as they migrate north in the spring, and the last possible stopover while making the 600-mile nonstop flight south during fall (Zenzal 2020). Fulbright et al. (2008) estimated that more than 80% of long-distance North American migratory birds travel through a coastal area of Central Texas known as the Texas Coastal Bend.

North Padre Island is 77 miles long; however, it is primarily devoid of woodlands except for an isolated area at the extreme northern end of the island known as the Packery Woodlands (Figure 1). These live oak woodlands are renowned among the birding community for their spectacular fallout events during spring migration. Although the PCNP is primarily comprised of coastal grasslands, one sizeable live oak motte occurs at the park's entrance. The live oak woodlands (Packery Woodlands) occur adjacent to the park.

Although the Packery Woodlands have historically served as an essential site for migrants, these local woodlands are rapidly disappearing due to urban sprawl and island development. The public 38-acre PCNP is a popular ecotourism site that is consciously maintained, monitored, and protected by Nueces County Coastal Parks as an important local nature preserve.

1.2 PROJECT FUNDING, PLANNING, AND CONSTRUCTION

A Coastal Impact Assistance Program (CIAP) grant was awarded to Nueces County Coastal Parks by the Texas General Land Office in 2015. This funding supported construction of a 2-acre experimental woodland stopover site consisting of 13 woodland transplant plots. The project, which specifically targeted native plants that would provide cover and food resources for Neotropical migrants, involved research, planning, and design by a team of ecologists, avian biologists, arborists, and landscape architects (Naismith Engineering, Inc. 2015). The initial project goals were to:

1) Increase food, cover, and water resources for long-distance Neotropical migrants.
2) Monitor and document the survival and barrier island compatibility of 41 species of native trees, shrubs, forbs, and vines.
3) Document Neotropical migratory bird use of the newly planted woodland habitats.
4) Identify potential bird use trends between the 13 transplant plots and three nearby mature live oak woodland sites.
5) Identify specific plants used by migrants during spring fallout events.

The woodland enhancement project, which was completed in early January 2016, utilized 2,222 native potted plants that were obtained from plant nurseries in South Texas. The plant species associated with six different native South Texas woodland communities were selected based on their expected contributions (cover and structure, insects, fruit, seeds, nectar, and pollen) to spring and fall Neotropical migrants. Plants were evaluated relative to their potential to survive short-term and to thrive long-term based on the barrier island's physical attributes, including sandy soils, a shallow groundwater table, soil salinities, salt spray drift, and strong, often persistent, and gusting winds.

1.3 PLANT MONITORING

This unique project also involved comprehensive monitoring efforts to better understand each transplant's condition and survival, both short- and long-term. Recommendations were developed as guidance for future woodland stopover enhancement, creation, or restoration projects. In addition to the monthly post-construction monitoring efforts in 2015 and 2016 (Naismith Engineering 2016), Nueces County Coastal Parks funded comprehensive plant monitoring efforts for three additional years (Vega Environmental 2016, 2017, and 2018).

1.4 SPRING BIRD SURVEYS

Although numerous attempts were made to conduct annual spring Neotropical migratory bird surveys, Spring 2017, 2020, and 2023 were the only years where meaningful data could be collected (Vega et al. 2017, 2019). Bird surveys were not completed in 2018, 2019, and 2021 due to the lack of bird groundings and paucity of data that could be used in comprehensive analyses. According to the literature, this variation in the lack of groundings is not unusual. The phenomena of few to no groundings one year and multiple robust groundings another year is well documented in the literature. Locally, groundings are strongly dictated by weather conditions, such as persistent strong southerly winds in the spring that allow birds to continue flying north rather than landing to rest and feed. Climatic conditions can also cause birds to veer from their migratory pathway to the east or west.

2.0 PURPOSE AND OBJECTIVES

2.1 REPORT PURPOSE

The purpose of this report is to introduce the reader to Neotropical migratory bird migration and critical stopover habitat conservation needs, to describe how this experimental woodland barrier island stopover site was planned and constructed, plant monitoring results and recommendations relative to plant survival, and spring survey results documenting Neotropical migratory bird use within the 2-acre experimental stopover project site.

2.2 REPORT OBJECTIVES

Report objectives are to:

1) Address the importance of stopover habitats during migration, recent research and conservation strategies, and the immediate need for quality stopover habitats along the Texas coast.

2) Review the funding, planning, design, and construction of the experimental woodland enhancement stopover project at PCNP.
3) Summarize three years of plant monitoring results, short- and long-term survival, and subsequent recommendations for future similar projects.
4) Quantify and evaluate the abundance and diversity of migratory species and specific plant use acquired during the Spring 2023 Neotropical migratory bird survey and compare 2023 results to the Spring 2017 and 2020 surveys to see if any trends are apparent.

3.0 MIGRATION AND CONSERVATION NEEDS

3.1 MIGRATION

Migration, or the seasonal movement from one region to another, is common among many species of birds. Some bird species, such as Neotropical migrants, fly 500 to 600 miles over the Gulf of Mexico without food or water during their 26- to 80-hour flights (Fern and Morrison 2017, Tangley 2020). These migrants, which total in the billions, fly north each spring to breeding grounds in the United States and Canada, then fly south to spend winters in Mexico, Central America, South America, and the West Indies (Gulf Coast Bird Observatory 2020, Smithsonian Conservation Biology Institute 2020). They spend spring and summer at the more northern latitudes because food resources are abundant, and competition for food and nesting sites is reduced. At northern latitudes, summertime also means longer daylight hours to seek food for themselves and their offspring (Shackelford et al. 2005). They contend with winter by migrating south in the fall as they return to the tropics. Approximately 2.1 billion birds journey across the Gulf Coast each spring as they migrate north (Tangley 2020). Shackelford et al. (2005) indicate that 333 (or 98.5%) of the 338 species listed as Nearctic-Neotropical migrants in North America (north of Mexico) have been recorded in Texas.

Nearctic-Neotropical migrants spend up to one-third of each year migrating (Mehlman et al. 2005). Long-distance migrants can fly hundreds, or even thousands of miles twice each year. While migrating twice annually between breeding and wintering grounds, Neotropical migrants briefly interrupt their migratory journeys to pause at stopover habitats, where they rest, feed, replenish their fat reserves, and seek shelter before continuing their energetically costly migrations (Hutto 1998, Moore 1992). A lack of suitable stopover habitat can result in delays to their breeding grounds, poor physical condition, and susceptibility to predation (Hutto 2000, Cohen et al. 2020). Migration is highly stressful and taxing on birds; these bi-annual migrations are considered the most perilous stage of a bird’s life cycle (Moore 2000, Sillett and Holmes 2002, Audubon Great Lakes 2020).

3.1.1 MIGRATION ROUTES

Many migratory birds follow specific routes (flyways), often over long distances. North America has four flyways; Texas is located within the Central and Mississippi Flyways (Figure 2).

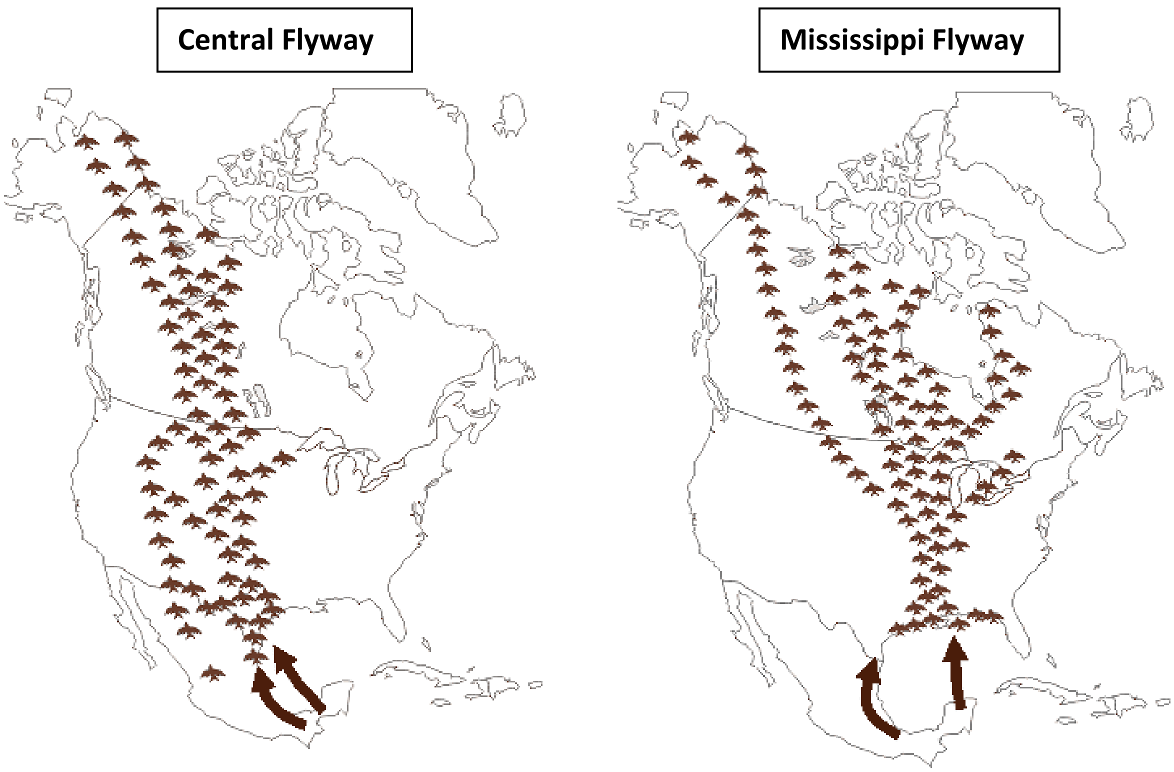

Figure 2. Central and Mississippi Flyways (Source: Shackelford et al. 2005).

The Gulf of Mexico is an ecological barrier that migrants must negotiate by migrating over or around twice yearly (Lafleur et al. 2016). Winds and weather occurring over the Gulf of Mexico have likely shaped the evolution of migration routes in this region, influencing both migratory flight and where birds stop to rest and refuel during their migratory treks (Able 1972, Moore and Kerlinger 1989, Moore et al. 1990, Rappole and Ramos 1994, and Gauthreaux et al. 2005).

3.1.2 WHY ARE STOPOVER HABITATS IMPORTANT?

The quality of stopover habitats can affect a bird's ability to meet its high energy demands and minimize increased predation risks in unfamiliar or suboptimal stopover habitats (Moore and Woodrey 1993); these habitats are unquestionably critical for rapid rebuilding of fat reserves by long-distant migrants (Moore and Kerlinger 1987, Moore et al. 2005, Tangley 2020). This is particularly true for small migratory bird species which can deplete their modest fat reserves relatively quickly, especially if their migratory pathways include flights over large bodies of open water (e.g., the Gulf of Mexico), or if their migration is interrupted by adverse weather conditions (Moore et al. 1995, Cohen et al. 2017). Birds can be exhausted and emaciated when they reach stopover areas, where they gorge themselves to replenish their fat reserves before preparing for the next leg of their flight (Shackelford et al. 2005).

3.1.3 HOW DOES WEATHER AFFECT MIGRATION?

Although 70 years have passed since G. G. Williams published a scientific article in 1950 regarding the effects of weather on migrants, his description of this harsh relationship appropriately describes the plight of these birds. "Birds flying at night may become pawns of the weather. They may advance, retreat, or veer off at an angle from the direct course. They may be borne far off-course by moving air masses catching them aloft on dark nights; they may flee for hundreds of miles before an advancing cold front, and they may reach, or be borne to, unaccustomed places before dawn comes and they can see how to land or are safe from inclement weather. Considering the frequency of advancing cold fronts in spring, it is likely that most spring migratory flights do not proceed in a direct south-north line, or in any straight line; there are probably few spring seasons in which most birds that breed in the northern United States or Canada do not have to alter their course at some time, retreat in the face of bad weather, suffer dissemination indiscriminately over the continent, seek refuge in unfamiliar areas, and then return to their regular course along abnormal routes."

Broad-scale weather events experienced during migration can influence when and where birds stop to rest and refuel (Clipp et al. 2020). Weather is one of the main external influences on migration, and sudden changes in weather conditions can be disastrous for migrating birds. During spring migration, a southward-moving cold front meeting the Gulf of Mexico's warm air mass can result in heavy rains and high winds. As a result, migrating birds fall from the sky into sheltered areas seeking food and refuge (Shackelford et al. 2005). Coastal stopover sites are particularly critical during adverse climatic events. Although these spring "fallouts" or "groundings" can be quite spectacular for birders to witness along the Gulf Coast, severe weather conditions may also cause millions of migrating birds to perish at sea. Migration over water is one of the most hazardous times for birds, especially small songbirds. Less than half of the birds that leave their breeding grounds during fall migration are believed to return the following spring (Shackelford et al. 2005).

3.2 GULF OF MEXICO STOPOVER HABITATS

Successful migration is highly dependent upon the availability and quality of stopover habitats along migration routes. The Gulf of Mexico coastline contains some of the most important resting and refueling areas for Neotropical migratory birds. For birds crossing the Gulf of

Mexico, habitats along the Gulf provide the first possible landfall as they migrate north in the spring and the last possible stopover while making the 600-mile nonstop flight south during fall (Zenzal 2020). With individuals weighing less than 0.53 ounces, these birds cross the 600-mile Gulf of Mexico and continue north to complete a total distance of 1,200-2,000 miles during their 26- to 80-hour flight (Moore and Kerlinger 1987, Shackelford et al. 2005). The physiologically demanding nature of this incredible feat makes the Texas coastline crucial to a migrant's success (Fern and Morrison 2017).

Adverse weather can cause migrants to "fall out" in substantial numbers on barrier islands (Lowery 1945, Moore et al. 1990, Kuenzi et al. 1991) and inland habitats (Gauthreaux 1971). Lester et al. (2016) found considerable use of barrier island habitats along the north coast of the Gulf of Mexico. They found that migrants were most abundant in areas with low elevation, high canopy height, and high coverage of forests and scrub/shrub vegetation. As most migratory bird species are declining, Gulf Coast stopover habitats will likely be increasingly crucial for species conservation (Cohen et al. 2020).

3.2.1 TEXAS STOPOVER HABITATS

The greatest densities of spring migrants consistently arrive during mid-April to early May along the Texas and Louisiana coasts (Cohen et al. 2017). Texas Gulf Coast stopover habitats have been recognized for decades as being vital for sustaining long-term populations of migratory birds (Hunter et al. 1993), including both overland (circum-Gulf) and trans-Gulf migrants (Forsyth and James 1971). Fulbright et al. (2008) estimated that more than 80% of long-distance North American migratory birds travel through a coastal area of Central Texas known as the Texas Coastal Bend.

Two of the top twelve birding sites in the United States are located along the Texas Coast: the Sabine Woods along the northern coast and Joan and Scott Holt Paradise Pond along the central coast (Kerlinger 1993). Paradise Pond, a small, wooded oasis in the middle of a developed area in Port Aransas, produced 119 migratory species with 5,456 individuals counted during a four-year study from 1998-2001 (Gulf Coast Bird Observatory 2020). Several hotspots occur within the Texas Coastal Bend, including Paradise Pond, PCNP, and the nearby Packery Woodlands (Sand Dollar Road area) (eBird Basic Dataset 2023). Although eBird is a citizen-contributed database and migrant sightings and reporting are likely to be clustered in areas of high accessibility or near development, this data can serve as a tool to identify historic high-use sites.

3.3. ECOTOURISM

The Great Texas Coastal Birding Trail (GTCBT), managed by Texas Parks and Wildlife Department (TPWD), is a state-designated system of hiking and driving trails, bird sanctuaries, and nature preserves along the entire length of the Texas Gulf Coast. Texas hosts more bird species than any other state in the U.S., so this trail system offers some of the world's most unusual bird-watching opportunities. GTCBT sites provide various viewing opportunities with boardwalks, observation decks, and other amenities. According to TPWD (2020), coastal stopover sites are important not only ecologically for long-distance Neotropical migrants, but also economically, serving as popular attractions for birdwatchers.

Because of the frequent occurrence of impressive fallouts of Neotropical migrants at PCNP, TPWD designated the park as an official GTCBT site. Tourism and nature tourism attracted 8.1 million visitors to Corpus Christi in 2012-2013, contributing $1.2 billion to the city's economy during that time interval (Lee 2014).

3.4 COASTAL HABITAT LOSS

Coastal zones along the Gulf of Mexico are expected to experience significant land development pressures for many years (Culliton et al. 1990). Residential and commercial developments are projected to continue their rapid expansion in coastal zones. The human population along the Gulf of Mexico coast (estimated to number more than 60 million people by 2025) has increased more than double the national average, while wetland habitats are being lost faster than anywhere else in the country (Gulf Partnership 2014). Coastal stopover habitats are undoubtedly being lost to urbanization. These changes may contribute to bird population declines (Cohen et al. 2017).

3.5 WOODLAND STOPOVER HABITATS ON NORTH PADRE ISLAND

Padre Island, the southernmost major barrier island in Texas, is comprised of native coastal grasslands that occur between the primary dune system located along the Gulf of Mexico and the bayside flats along the backside of the island. These grasslands are dominated by little bluestem (*Schizachyrium scoparium*) and other native coastal grasses (Judd 2002). Padre Island is primarily devoid of woodlands except for an isolated Southern live oak (*Quercus virginiana*) woodland area located at the extreme northern end of North Padre Island. These live oak woodlands occur adjacent to the PCNP; one sizeable live oak motte occurs at the park's entrance.

The live oak woodland habitat on North Padre Island is renowned among birdwatchers for its notable diversity of migrants during spring fallout events, particularly when strong frontal passages of cool air moving southward intersect the Gulf Coast. These weather fronts can cause northward-bound Neotropical migrants to alight in the oaks, where they will feed, rest, and renew fat levels and energy reserves before continuing their migratory journeys. Live oak woodlands in the Packery Channel area experience impressive fallouts of Neotropical migrants.

The Audubon Outdoor Club owns and manages the nearby Packery Oak Motte Sanctuary which contains 21 undeveloped oak-covered residential lots. The sanctuary is a Gulf Coast Bird Observatory Partner Network Site. The limited remaining oak woodlands on North Padre Island occur within residential lots and privately owned undeveloped lands (Figure 3).

Figure 3. Local Live Oak Woodlands. Padre Island's woodland habitat is limited to the island's extreme north end where it occurs at the Audubon Sanctuary properties, Packery Channel Nature Park, and nearby residential areas.

Although the critical importance of Southern live oak for migratory birds has been documented by several researchers (e.g., Fulbright et al. 2008), these local live oak woodlands are rapidly disappearing due to urban sprawl and island development. A large residential/commercial development project is in the planning stages and, if constructed, may result in the loss of more than one-half of the remaining live oak woodlands depicted in Figure 3. Individual residential lots in this area are also being cleared as homes are constructed.

4.0. POPULATION DECLINES IN MIGRANTS

Many migratory populations are in steep decline, and migration is often identified as the most significant source of annual mortality (Bayly et al. 2018). According to a recent, widely publicized report published in Science, nearly a dozen prominent ornithologists analyzed data from decades of weather radar images and on-the-ground bird observations. They concluded that the North American continent is home to 2.9 billion fewer breeding birds today than five decades ago, dropping nearly 30% (Tangley, 2020). Some of the most considerable losses have occurred among Neotropical migrants and, with all Neotropical migrant species combined, have resulted in a net loss of 820 million birds (Rosenberg *in* Flight Risk, Tangley 2020). According to Rosenberg et al. (2019), although many contributing factors range from cat predation to collisions with windows and towers, habitat loss is the most alarming overall driver of bird declines. When up to 85% of migrant mortality can occur during migration, it becomes evident that strategically located stopover sites, such as the Gulf Coast, count among the birds' most vital habitats.

In his book, "Where Have All the Birds Gone?", Terborgh (1989) helped galvanize an emerging wave of interest in Neotropical migratory birds. This increased interest resulted in monitoring projects, research initiatives, conservation workshops, and national and international conferences on Neotropical migrants, culminating in Congressional legislation, the Neotropical Migratory Bird Conservation Act of 2002. The enhanced conservation focus on Neotropical migratory birds was designed to improve the management and conservation of birds and their habitats, including breeding, wintering, and migratory stopover habitats.

Although bird conservation has historically focused on the loss of breeding habitat or threats on wintering grounds in the tropics, recent attention has been placed on understanding the needs of birds during migration. Many migratory bird species' populations are declining, and degradation and loss of barrier island stopover habitats may further increase the cost of migration for many individuals. Several forest-dwelling migratory species have experienced long-term population declines (Robbins et al. 1993), and forests, woodlots, and shrublands along the northern rim of the Gulf of Mexico are known to be especially crucial as coastal stopover habitats for these species (Forsyth and James 1971, Moore et al. 1993). Conservation and wise management of these critical stopover areas will be essential, particularly as sea levels rise (Lester et al. 2016). Over the past three decades, it became apparent that action was needed to focus on identifying, prioritizing, and protecting stopover sites for Neotropical migrants (Moore et al. 1995, Petit 2000, Mehlman et al. 2005).

5.0 CONSERVATION STRATEGIES

Moore et al. (1993, 1995) and other authors emphasized that conservation priority should be given to the protection and management of habitats (e.g., small woodlands along the northern coast of the Gulf of Mexico) used by these migrants. Coastal development, fragmented habitats, hurricanes, and pollutants have degraded stretches of coastline for birds and caused population declines. Rosenberg et al. (2019) suggest that some of the critical habitats that have disappeared would need to be restored to reverse this trend.

5.1 GULF OF MEXICO STOPOVER HABITAT: A FRAMEWORK FOR CONSERVATION

A workshop was held in 2001 to discuss Neotropical migratory bird conservation concerns and develop planning efforts to address them. Unless otherwise noted, the information in Sections 5.1 through 5.2 of this report is from "Conserving Stopover Sites for Forest-Dwelling Migratory Landbirds," a publication by Mehlman et al. (2005) that summarizes information developed during the 2001 workshop. This information subsequently led to the development of a framework to protect stopover habitats for forest-inhabiting migratory birds along the Gulf of Mexico and the Great Lakes region of North America (Duncan et al. 2002). Pertinent elements of this framework, as well as current research, are presented in this report.

Identifying how a particular stopover site will contribute to a successful migration is challenging due to intrinsic factors (ecological variability), such as food availability and landscape structure, and extrinsic factors, such as prominent weather events or a migrant's condition. Therefore, workshop conservationists agreed that they could hypothesize that stopover sites can at least be defined based on their capacity to meet migrants' needs at a given point in space and time. This "capacity" was defined as the ability to facilitate an individual's survival, its need to complete short migratory flights to the next stopover site, or its ability to perform long-distance flights over barriers (such as the Gulf of Mexico).

Workshop participants developed a conservation framework for categorizing stopover sites into three functional types while recognizing that these categories represent points on a continuum of the function of stopover sites. The concepts had to be simple to communicate with the scientific and conservation communities and public audiences. The workshop participants ultimately adopted three terms to denote the function of each type of stopover site: "fire escapes," "convenience stores," and "full-service hotels."

5.1.1 FIRE ESCAPE STOPOVER SITES

Fire escape stopover sites are described as being infrequently used but are utterly vital in emergencies; if a fire escape is not available at the critical place and time, migrants are not likely to survive to continue migration. The resources within a fire escape may be too scarce to allow birds to replenish fat stores or recover muscle mass, but the stop will enable them to survive and continue migrating from the site. Fire escapes are typically located adjacent to significant barriers, like large bodies of water, deserts, or intensively altered landscapes. They are often small and isolated habitat patches surrounded by unusable habitats. Weather is critical in determining when fire escape sites are used; therefore, migrant densities can be very high at times. The situations where high densities of migrants utilize fire escape stopover sites are often predictable due to overriding extrinsic factors such as weather. Ideal fire escape stopover sites serve as refugia when surrounded by unsuitable landscapes.

5.1.2 CONVENIENCE STORE STOPOVER SITES

Convenience store stopover sites represent habitat patches that vary in size, such as parks, woodlots, or small forest blocks in a landscape matrix of mostly inhospitable or unusable habitats. Migrants can briefly rest (i.e., a stopover for two days or less) and quickly replenish some fat, muscle, or both. These sites support birds between short flights to higher-quality sites or when migrants' fuel needs are moderate. Because these sites are relatively small and isolated, migrants stopping at these sites may be vulnerable to density-dependent limits to food and shelter. Examples of convenience store stopover sites may include parks and cemeteries in many large cities. The ideal convenience store site is structurally heterogeneous, contains source(s) of freshwater, and provides various food resources, including insects and fruit. Like fire escape sites, there is no minimum size; however, as sites increase in size and heterogeneity, they will merge into the next (full-service hotel) category.

5.1.3 FULL-SERVICE HOTEL STOPOVER SITES

Full-service hotel stopover sites are comprised of extensive, predominantly forested areas that provide all necessary resources (i.e., food, water, and shelter) that are relatively abundant and available and can serve many individuals of many species. Migrants may stay at these sites for one to several days because their immediate resource needs are supplied and associated risks are relatively low. These sites allow birds to attain their top physiological condition to migrate to the next stop or their final destination. Ideal full-service hotel stopover sites are ecologically heterogeneous, with various food resources across environmental gradients such as wetlands, streams, and uplands. Examples include national and state forests and parks.

5.2 IDENTIFYING AND PRIORITIZING STOPOVER SITES

There is yet to be an objective way to rank stopover sites due to the tremendous spatial and temporal variation in use and resource availability within and between seasons and years. Workshop attendees determined that stopover sites can be classified based on three criteria:

1) Ecological context (e.g., extrinsic factors such as proximity to ecological barriers and degree of spatial isolation).
2) Intrinsic characteristics (e.g., diversity and abundance of resources).
3) migrant use (e.g., relative abundance, including frequency and consistency of use as a stopover site).

A key feature of this ranking method is that site quality can be evaluated within rather than across functional categories. This method subsequently avoids the problem of unsuitable and inappropriate comparisons among sites when prioritizing them for conservation concerns. Each category has its own value for migratory birds and criteria for assessing meaningful comparisons and their prioritization. For example, fire escape stopover sites will not be discounted because of high bird use one year and low use another year compared to a full-service hotel site.

5.3 STOPOVER HABITAT RESEARCH NEEDS

Although migration activities are responsible for most adult migrant mortality, habitat requirements and stopover concentrations of migratory birds remain poorly understood (Sillett and Holmes 2002). Furthermore, the migratory routes that many Neotropical landbirds utilize also occur in some of the most urbanized regions of North America. Although migrants are known to use urban habitats as stopover sites, often occurring within cities in exceptional densities, knowledge of migrant behavior and ecology in such places is surprisingly limited (Hostetler et al. 2005, Seewagen et al. 2010).

Fern and Morrison (2017) recently studied stopover habitats along the Texas Central Coast using a fusion of multi-spectral remote sensing data and distribution modeling techniques to generate and evaluate predictive maps that identify critical areas. Although findings are preliminary, this technique may allow for a more sophisticated approach to identifying critical areas used by migratory passerines across large spatial areas in a short amount of time.

Stopover habitats on St. George Island, a large barrier island separating the Gulf of Mexico from Apalachicola Bay, Florida, are consistently used by spring migrants (Lester et al. 2016). Trans-Gulf migrants display high abundance and diversity within the island’s forested and scrub/shrub habitats. Stopover habitat use at St. George Island is similar to migrant use of other barrier islands along the Gulf’s northern coast. For example, migrants on Horn Island, Mississippi, were found to select scrub/shrub, pine forest, and relic dune habitats over primary dune or marsh/meadow habitats (Moore et al. 1990). According to Lester et al. (2016), St. George Island is comparable in species diversity to western and central Gulf Coast migratory stopover sites in Texas, Louisiana, Mississippi, and Alabama.

5.4 LANDSCAPE COMPOSITION

Quality migratory stopover habitat should allow *en route* migrants to lower migration risks while meeting their energetic demands more efficiently, thereby increasing chances for a successful migration (Rodewald and Matthews 2005). The composition of a landscape may serve as a cue that allows migrants to assess landscape quality before landing (Chernetsov 2006, Buler et al. 2007). Tall and structurally diverse forested landscapes may support greater numbers of migratory landbirds than unforested landscapes (Petit 2000, Rodewald and Matthews 2005).

5.5 FACTORS AFFECTING HABITAT SELECTION

After they make landfall, habitat selection is influenced by habitat factors including food abundance, floristics, and structure (Aborn and Moore 1997, Cohen et al. 2012, Moore and Aborn 2000). Once migrants are on the ground, they often display habitat preference, efficiently exploring and selecting habitats that vary in structure and food availability. They attempt to adjust their behaviors when they land in non-preferred habitats (Hutto 1985, Moore et al. 1990, Petit 2000, Cohen et al. 2012, Slager et al. 2015, Moore 2018). According to Barrow et al. (2000), 44% of the migrant species along the Gulf Coast of Louisiana and Texas consumed fruit during spring, and only 24% of the migrants consumed fruit during the fall, illustrating behavioral changes based on food availability. It has been emphasized that future research should include understanding which plants migrants forage on and their role in satisfying the energetic requirements during migration (Cohen et al. 2017).

5.6 LACK OF RESEARCH ALONG THE TEXAS GULF COAST

The phenomenon of massive Neotropical migrant fallout (or groundings) is widely recognized at stopover habitats along the Texas Gulf Coast, yet quantitative assessments have been completed at only a few locations. Furthermore, the creation, enhancement, and restoration of coastal woodland habitats, especially on barrier islands, has been minimal and needs to be better studied and evaluated. Key research and monitoring recommendations include future field studies of plant and insect foods used during migration, the energetic value of these foods, and how habitats can be created, enhanced, and restored as stopover sites. If stopover habitat projects can attract long-distance Neotropical migrants, then perhaps creation, enhancement, and restoration can mitigate and offset woody habitat losses on barrier islands and in other Gulf coastal zones experiencing or facing future habitat loss.

5.7 A CONSERVATION PRIORITY: FIRE ESCAPE AND CONVENIENCE STORE STOPOVER SITES

Conservationists attending the 2001 workshop mentioned earlier suggested that fire escape and convenience store stopover sites receive the most attention during initial conservation planning efforts. This recommendation was based on three reasons:
1) These sites (typically occurring in urban areas) are the least likely to be identified and managed with conservation objectives in mind.
2) Because many geographic areas are primarily comprised of unsuitable habitat with few remaining opportunities to protect these types of sites.
3) These small remnants of habitat are rapidly being destroyed and degraded.

These three characteristics of fire escape and convenience store habitats combine to leave them vulnerable to unpredictable external forces. Full-service hotels, however, are vast forests and woodlands already managed or are targeted for wildlife management (Mehlman et al. 2005).

6.0 PCNP WOODLAND STOPOVER ENHANCEMENT PROJECT

6.1 FUNDING AND PROJECT FOCUS

Nueces County Coastal Parks Department recognizes the importance of the local live oak woodland/shrubland habitat for its current and historical use by Neotropical migratory birds, the vital ecological role that coastal woodland stopover sites play during migration, and the area's rapid rate of urban sprawl and development. In 2014, Nueces County Coastal Parks Director Scott Cross applied for and received a Texas General Land Office Coastal Impact Assistance Program (CIAP) grant to enhance/create 2.0 acres of coastal woodland stopover habitat at the PCNP site. CIAP monies from the royalties associated with offshore oil and gas leases in federal waters are allocated to the State of Texas (Texas General Land Office) by the U.S. Fish and Wildlife Service.

Although the phenomenon of heavy Neotropical migrant fallout events is widely recognized at other stopover habitats located along the Gulf Coast, assessments of stopover habitat enhancement, creation, and restoration (especially on Texas barrier islands) have been very limited. Nueces County Coastal Parks has committed time and resources to monitor and evaluate this experimental woodland stopover project, transplant survival, and migrant use at the site. One of the County's initial goals was to collect data that could be applied to similar future Gulf of Mexico barrier island projects.

6.2 PLANNING AND DESIGN

Project construction started in September 2015 and was completed in early January 2016. The project focused on native plants that would provide cover and food resources for Neotropical migratory birds during spring migration.

The project was developed by a team of ecologists, avian biologists, landscape architects, and arborists. A geographic (South Texas) subset of tree-dwelling, songbird, perching, and ground-feeding Neotropical migratory bird species was evaluated to better understand the need for critical landscape features such as vertical structure and appropriate canopy and understory layers.

The project involved creating six native South Texas woodland communities: Tamaulipan thornscrub, South Texas palm grove, live oak, riparian (moist soil), and mixed coastal woodland communities within the 2-acre project site (Appendix A-1). Native trees, shrubs, forbs, and vines were selected based on the resources (cover, insects, fruit, seeds, nectar, and pollen) that they provide to migrants (Appendix A-2). Some plants were selected due to the prolific insect populations they host during the spring months.

Target plant species were also evaluated to determine if they would survive and thrive long-term based on the island's physical attributes, including sandy soils, a shallow groundwater table, soil salinities, salt spray drift, and strong, often persistent, and gusting winds (Appendix A-3). Plant resource values and plant/island compatibility information were combined to determine the type and number of plants used within each of the 13 transplant plots (Appendix A-3). Finally, each transplant plot was designed to include optimal plant height and growth rates to achieve the desired vertical structure and canopy layers.

6.3 CONSTRUCTION AND PLANTING

A landscape layout was prepared, and detailed construction plans were developed. Photos were taken during construction and annual post-construction monitoring events. The landscape layout was used to locate and delineate the boundaries of the 13 transplant plots (Photo 1). The plots were initially prepared using weed eaters to cut and stockpile the native coastal grassland vegetation (Photo 2). This viable plant material was spread over denuded areas once the project was completed.

Photo 1. Marking the boundaries of the transplant plots. The park's existing large oak motte is visible at the boardwalk entrance.

Photo 2. Native island grassland vegetation was cut and stockpiled so it could be used to restore denuded areas.

Biodegradable weed mats were used (Photo 3); loam soil was added to some plots (Photo 4).

Photo 3. Construction included weed mats, mulch, and drip irrigation lines.

Photo 4. Loam soils were added to some of the sandy transplant plots.

The moist soil (riparian woodland) plot was excavated to the groundwater table (Photo 5). Excavated sand was used to build up the nearby live oak woodland plot (Photo 6).

Photo 5. The excavated moist soil plot revealing the groundwater table.

Photo 6. Excavated material increased the height of the live oak woodland plot.

An automatic (timer-controlled) drip irrigation system was installed. The drip irrigation lines extended across the length of each transplant plot (Photo 7). The irrigation lines were laid on top of the existing dense grassland thatch instead of installing them below ground. This was done to limit ground disturbance and to reduce potential underground line damage by gophers.

Photo 7. Drip irrigation lines installed on top of the weed barrier.

During the planting process, 41 native trees, shrubs, forbs, and vines were planted. A total of 2,222 plants were installed in the 13 plots. Pot and plant sizes varied; most pot sizes ranged from 1 gallon to 30 gallons. Large trees were transported and planted using a front-end loader (Photos 8 and 9).

Photo 8. Large trees ready for planting.

Photo 9. Initial planting of live oak trees.

Grassland impacts were restored using stockpiled native vegetation (Photos 10 and 11).

Photo 10. The site was restored by re-contouring rutted areas.

Photo 11. The stockpiled native vegetation/seed material was spread over the denuded areas.

The disturbed grassland habitat recovered quickly, and the ground cover was near 100% in just a few months. This rapid recovery may partly be due to the time of year (late winter-early spring) and associated seasonal rains. Three bird drip fountains were also constructed within the 2-acre project site.

6.4 MONITORING AND MAINTENANCE: A SUMMARY

This unique project involved comprehensive monitoring to better understand short- and long-term plant condition and survival. Information obtained from systematic monitoring efforts allowed for the development of recommendations that could be applied to future similar projects. Aside from the initial monthly post-construction monitoring efforts in 2015 and early 2016, annual comprehensive plant monitoring continued for three additional years (Vega Environmental 2016, 2017, and 2018).

The project was designed to require little or no long-term maintenance. Initially, maintenance included checking the drip irrigation system, removing non-target invasive plants from the plots, and replacing plants that did not survive. Once the transplants became firmly established, the drip irrigation water source was reduced and eventually turned off.

Although several variables affected plant survival initially (2016) and two years post-construction (2018), distinct performance trends were noted among the different species selected for this project. Initial construction and transplant installation variables such as the size and condition of the transplants, where and how they were planted, and irregularities associated with the drip irrigation system did affect initial survival rates, but they were not significant. Post-construction variables (discussed below) play a much more prominent role in short- and long-term transplant performance and survival.

The 2,222 transplants were grouped into high, mid, and low survival groups based on percent survival 2-years post-construction.

6.4.1 HIGH SURVIVAL GROUP

Twenty-one (21) of the 41 species planted had an 82%-100% survival rate two years post-installation. The average survival rate for the high survival group was 96% with 477 of the 496 transplants surviving after two years (Table 1).

Table 1. Transplant survival two years post-construction

Transplant Species	Total Number Planted	Survival (Total Number) 2 Years Post-planting	Percent Survival (Total Number) 2 Years Post-planting
Buttonbush *(Cephalanthus occidentalis)*	34	34	100%
Cedar Elm *(Ulmus crassifolia)*	6	6	100%
Coral Bean *(Erythrina herbacea)*	28	28	100%
Honey Mesquite *(Prosopis glandulosa)*	17	17	100%
Kidneywood *(Eysenhardtia texana)*	26	26	100%
Live Oak *(Quercus virginiana)*	44	44	100%
Mexican Ash *(Fraxinus berlandieriana)*	16	16	100%
Spanish Dagger *(Yucca treculeana)*	29	29	100%
Texas Ebony *(Ebenopsis ebano)*	10	10	100%
Wax Myrtle (Morella cerifera)	24	24	100%
Dewberry *(Rubus trivialis)*	39	38	97%
Fiddlewood *(Citharexylum angustifolia*)	40	39	97%
Retama *(Parkinsonia aculeata*)	30	29	97%
Prickly Pear *(Opuntia engelmannii var. lindheimeri)*	24	23	96%
Yaupon Holly *(Ilex vomitoria)*	20	19	95%
Texas Sabal Palm (*Sabal mexicana)*	15	14	93%
Anaqua (Ehretia anacua)	12	11	92%
Black Willow *(Salix nigra)*	11	10	91%
Texas Persimmon *(Diospyros texana)*	11	10	91%
Elbowbush *(Forestiera angustifolia)*	43	36	84%
Wild Olive (Cordia boissieri)	17	14	82%
American Beautyberry *(Calicarpa americana)*	294	187	64%
Sugar Hackberry *(Celtis laevigata)*	28	16	57%
Desert Willow (*Chilopsis linearis*)	10	5	50%
Southern Lantana *(Lantana horrida*)	108	51	47%
Cenizo *(Leucophyllum frutescens*)	28	13	46%
Agarita (*Mahonia trifoliolata*)	133	58	44%
Padre Island Mistflower *(Conoclinium betonicifolium)*	31	13	42%
Calico Bush (*Lantana urticoides*)	54	21	39%
Spiny Hackberry *(Celtis pallida*)	35	11	31%
Turks Cap (*Malvaviscus drummondii*)	144	45	31%
Barbados Cherry (*Malpighia glabra*)	74	21	28%
Flame Acanthus *(Anisacanthus quadrifidus var. wrightii)*	98	25	25%
Brazil Bush (*Condalia hookeri*)	25	5	20%
La Coma *(Bumelia celastrinum*)	15	3	20%
Butterfly Weed (Asclepias tuberosa)	86	4	5%

Transplant Species	Total Number Planted	Survival (Total Number) 2 Years Post-planting	Percent Survival (Total Number) 2 Years Post-planting
White Mistflower (*Eupatorium havanense*)	124	4	3%
Chili Pequin (*Capsicum annuum*)	126	1	1%
Hog Plum *(Colubrina texensis*)	2	0	0%
Pigeonberry *(Rivinia humilis*)	211	0	0%
Texas Sage (Salvia coccinea)	100	0	0%

Table 1. Plant survival two years post-construction. Total number of native plants installed in the 13 woodland transplant plots = 2,222.

Although the high survival rate group is primarily comprised of trees and shrubs (Table 1), Spanish dagger, prickly pear cactus, and southern dewberry vines also had high survival rates. Some species such as live oak, wax myrtle, yaupon, coral bean, honey mesquite, retama, and prickly pear were expected to do well because these species already occur in the nearby Packery Woodlands and surrounding neighborhoods.

Other species in the high survival group, as well as several from the mid survival group, typically occur in South Texas Tamaulipan thornscrub or South Texas palm grove habitats (Photo 12), so their ability, as transplants, to survive and thrive in deep sands on a barrier island along the Central Texas Coast is noteworthy.

Photo 12. Tamaulipan thornscrub species such as Texas ebony, kidneywood, and retama 20 months post-construction.

6.4.2 MID SURVIVAL GROUP

Fourteen (14) of the 41 species planted had a 20%-64% survival rate after two years. The average survival rate for this group was 44% with only 474 of the 1,077 transplants surviving after two years. The mid-survival rate group (primarily shrub species) includes American beautyberry, desert willow, southern lantana, agarita, calico bush, spiny hackberry, Turk's cap, Barbados cherry, flame acanthus, Brazil, and la coma.

6.4.3 LOW SURVIVAL GROUP

Six (6) of the 41 species planted had a 0%-5% survival rate after two years. The average survival rate for this group was 1% with only 9 of the 649 transplants surviving after two years. This group consists of the following shrubs and forbs: butterfly weed, white mistflower, chili pequin, pigeonberry, Texas sage, and hog plum.

6.5 TRANSPLANT MORTALITY

6.5.1 GRASSLAND SPECIES ENTERING THE PLOTS

During the first-year post-construction, fast-growing non-target plant species such as dollarweed (*Hydrocotyle umbellata*), western ragweed (*Ambrosia psilostachya*), and crotons (*Croton* spp.) quickly entered the plots and began to cover and block sunlight to the smaller transplants. The regular source of water (drip irrigation system) undoubtedly caused some grassland species to rapidly invade the plots and create extremely dense mats of vegetation which covered and killed large numbers of shorter (understory and groundcover) transplants. As a result, the 100 Texas sage and 211 pigeonberry transplants had zero survival two years post-construction and only 1 of the 126 chili pequins and 4 of the 124 white mistflowers survived during this same period.

6.5.2 TRANSPLANT HEIGHT AND GROWTH RATE

Clearly, the transplant height and growth rate were important factors relative to short- and long-term survival rates. Short-statured transplants (less than 2' tall) had the highest mortality rates. If a transplant could not grow fast enough to avoid being covered with dense intruding vegetation, then it could not survive. Vines such as southern dewberry exhibited a high survival rate (with 38 of the 39 transplants surviving two years post-construction) because they quickly grew over the dense mats of encroaching vegetation.

Some species, such as spiny hackberry, were installed as both short (20") and tall (3'-4') transplants. The short 1-gallon spiny hackberry plants had a 20% survival rate, but the taller 5-gallon pots resulted in 100% survival.

6.5.3 HEAVY RAINFALL EVENT

It should be noted that although Hurricane Harvey struck slightly north of PCNP in 2017, it did not significantly impact the project site from a structural standpoint (see Section 6.7). The associated flooding and extended high water events did, however, dramatically increase non-target plants in the transplant plots. It became difficult to discern where the edges of the plots were relative to the surrounding landscape (Photos 13 and 14).

Photo 13. Surrounding vegetation entered the plots and covered short-statured transplants.

Photo 14. Native coastal prairie grasses and forbs spread into the transplant plots.

6.5.4 DRIP IRRIGATION SYSTEM

The drip irrigation system associated with the 13 woodland transplant plots was time-controlled; each plot was watered for 45 minutes per 24-hour period during the first nine months post-planting. The system automatically turned off during rainfall events until it was re-set. Some species, such as cenizo, may have been impacted by receiving too much water because each plot (regardless of the habitat type) received the same amount of water on this system.

6.5.5 GROUNDWATER TABLE

The park contains a shallow monitor well which tracks a fresh to slightly brackish (0-4 ppt) shallow groundwater table occurring 0'-4' below the ground's surface. This shallow water table, which is approximately 23' deep, lies on top of a salt wedge associated with the nearby Upper Laguna Madre and the Gulf of Mexico.

The site's shallow water table may occur at the ground's surface for weeks following heavy or prolonged rainfall events. Tidal amplitudes in the nearby Laguna and Gulf also affect the location of this shallow groundwater table. Although the moist (riparian) woodland plot was excavated just deep enough to reach the groundwater table (Photo 15), this plot experiences water levels ranging from moist soil to ponding (Photo 16) depending on the factors mentioned above.

Overall, there is no doubt that the groundwater table played an important role in the long-term survival of the transplants, particularly once the drip irrigation system was turned off.

Photo 15. The riparian woodland plot was excavated to the surface of the groundwater table.

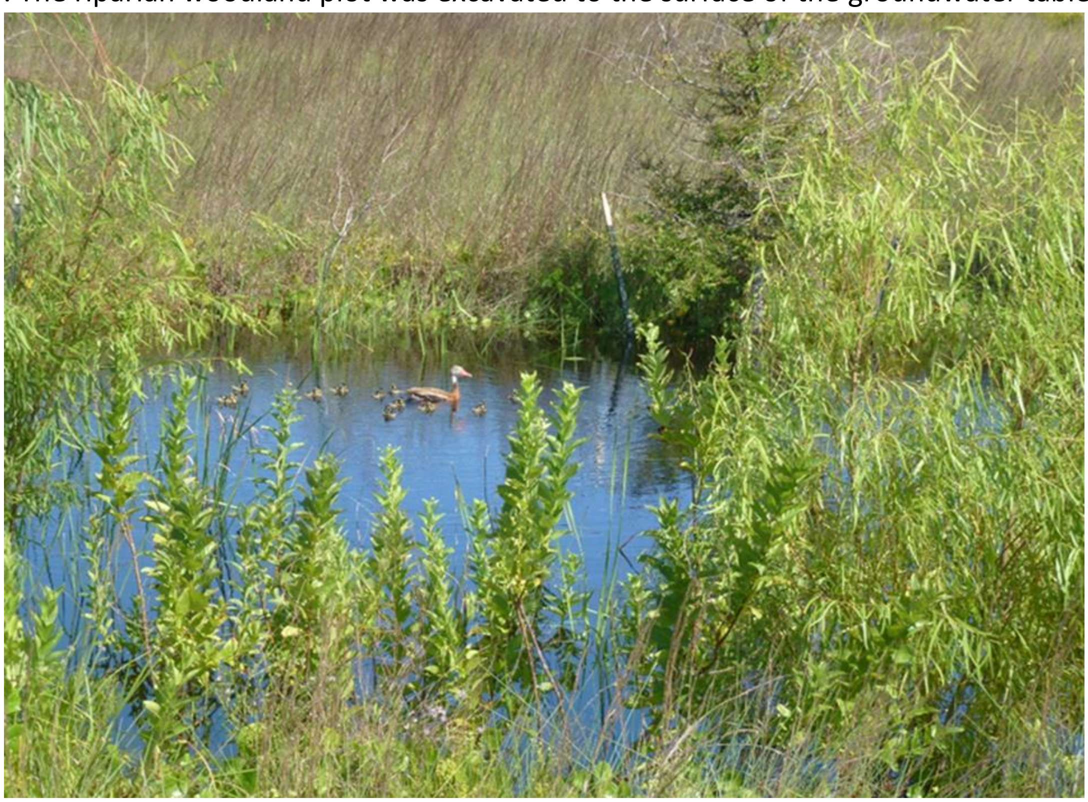

Photo 16. The riparian woodland plot six months post-construction.

6.6 RECOMMENDATIONS FOR FUTURE SIMILAR PROJECTS

6.6.1 SITE SELECTION

As this experimental project has shown, existing site conditions will greatly affect a project's outcome. Once a regular water source (drip irrigation) was introduced, vegetation growing outside the transplant plots rapidly colonized the irrigated transplant plots. Rhizomatous plants, such as dollarweed, were the most aggressive intruders. Although weed mats and mulch were used, they only helped initially and minimally.

Existing native grasses and herbaceous plants can readily serve as a ground cover. An additional woodland stopover project within this park is currently being planned. Small groundcover shrub and forb transplants will not be used. Instead, the existing native grassland habitat will be retained to serve as the ground layer. This will be accomplished by initially mowing a transplant plot site, omitting the weed barrier and mulch, installing the drip irrigation lines (above ground) directly to the individual transplants, and transplanting only larger specimens that will not be affected by native grassland species as they recover from the mowing.

Proper drainage is critical as most non-wetland plants cannot tolerate water-logged soils. Soil permeability, drainage, topography, and location of the groundwater table are essential factors to consider in site selection and project design. If an area is currently devoid of plants, then certain site conditions (such as regular flooding, high salt content in the soil, etc.) may already exist that will likely render poor results.

6.6.2 INVASIVE SPECIES

Surrounding and nearby vegetation will significantly influence a project's success, particularly if these areas contain invasive species such as guineagrass (*Panicum maximum*), buffelgrass (*Cenchrus ciliaris*), King Ranch bluestem (*Bothriochloa ischaemum*), johnsongrass (*Sorghum halepense*), Brazilian peppertree (*Schinus terebinthifolia*), and others.

Guineagrass is particularly destructive due to its exceptionally rapid growth rate and prolific seed production. When selecting a project site, it is important to consider if highly invasive plant species already occur within or near the site. Invasive plants such as guineagrass and Brazilian peppertree can become even more aggressive near water sources such as roadside ditches or irrigated areas. Implementing a monitoring/maintenance program to remove invasives regularly is critical to project success.

It is also prudent to minimize a project site's construction footprint as much as possible because ground and soil disturbance allows for weedy species (both native and invasive) to rapidly colonize disturbed areas.

6.6.3 SELECTION OF TARGET PLANT SPECIES

Planning and designing woodland stopover projects to be as low maintenance and self-sustaining as possible is essential. Aim to use native species that will thrive without long-term irrigation and maintenance.

Studying the plant types, species, and community structures best suited for woodland stopover habitats is beneficial based on geographic location. The goal is to select a variety of native plants that will ultimately mature into structurally complex communities, offering an abundant and diverse array of food and cover options.

Plant selection involves when (spring/fall) and how each plant species will contribute the most available food (insects, fruit, nectar, and pollen) resources. This experimental project has also shown that transplant size, condition, and growth rates are very important factors relative to existing adjacent plant communities. Investigating available nursery stock and the need for early propagation of some plant species is also prudent.

Existing soil types, permeability, and salt content, the groundwater table's location, the site's topography and drainage features, the amount of direct sunlight, and a plant's tolerance to strong winds and salt spray drift are important factors as desired plant species are selected.

6.6.4 DRIP IRRIGATION SYSTEMS

Minimizing drip irrigation (or an alternate water supply) will help conserve water and reduce the amount/density of non-target plants spreading into a project site. Regularly monitoring drip irrigation systems is important; this need quickly became apparent when gopher-damaged irrigation lines prevented water from reaching several newly transplanted plots.

6.6.5 CONSTRUCTION MONITORING AND OVERSIGHT

Initial construction oversight, short- and long-term plant monitoring, regular site monitoring and maintenance, and invasive species control are critical to a successful project. It is vital to address these needs early during project planning and budgeting.

6.7 HURRICANE HARVEY, FREEZES, FLOODING, AND DROUGHTS

6.7.1 HURRICANE HARVEY

Although Hurricane Harvey struck slightly north of PCNP in 2017 (Photo 17), it did not significantly impact the project site from a structural standpoint (Vega and Price 2019).

Photo 17. Transplant Plot GB11. Photo taken shortly after Hurricane Harvey made landfall.

The associated flooding and extended high water events did result in a dramatic increase of adjacent plants spreading into the transplant plots (Photo 18). Many native grassland species quickly colonized the transplant plot ground layers (Photo 19).

Photo 18. Flooding and extended high water event associated with Hurricane Harvey.

Photo 19. Dollarweed and other non-target plants spreading into the transplant plots.

6.7.2 EXTENDED FREEZE EVENT (FEBRUARY 2021)

Unseasonably cold air temperatures occurred in the Corpus Christi area from February 11, 2021, to February 20, 2021 (National Weather Service; 2022). During those ten days, minimum (low) temperatures ranged from 17 to 37 degrees (F). Maximum (high) temperatures ranged from 31 to 65 degrees. Record low temperatures for the area were set or met during five of the ten days. Precipitation and icy conditions occurred on eight of the ten days. Traces of snow were recorded on February 14^{th} and 15^{th}. The highest wind speed ranged from 17 to 31 mph, with wind gusts up to 38 mph. Prevailing winds were from the north during this period of cold weather.

Photographs taken in February 2021 following the freeze event were compared to some taken in February 2022 (Photos 20–25). Although it initially appeared that the freeze event may have killed many of the transplants, almost all the damaged trees, shrubs, and vines were found to contain live plant material after the damaged limbs were pruned away.

The transplant species experiencing the greatest amount of limb damage were coral bean, Texas kidneywood, and retama. Retama is a weak-wooded tree that is often damaged by high winds. Most of these three plant species did recover. Once the coral bean plants were pruned back to the ground, new plant material emerged from the root crowns and many of the coral bean plants rapidly recovered. The remaining transplant species appeared to be affected only minimally.

Photo 20. Transplant Plot GB3. Photo taken February 2021 (post freeze event)

Photo 21. Transplant Plot GB3. Photo taken February 2022.

Photo 22. Transplant Plot GB11. Photo taken February 2021 (post freeze event).

Photo 23. Transplant Plot GB11. Photo taken February 2022.

Photo 24. Transplant Plot GB13. Photo taken February 2021 (post freeze event).

Photo 25. Transplant Plot GB13. Photo taken February 2022.

6.7.3 A WET SPRING AND A DROUGHT

Once the February 2021 freeze event passed, the remainder of the year continued to set climatic records with 2021 being the 3rd wettest spring on record. Then, a drought appeared later in 2021 and extended into 2022. This drought began in September 2021 and was one of the worst statewide droughts since 2011. By Aug. 16, 2022, over 97% of the state was in some level of drought, ranging from abnormally dry to exceptionally dry. The lack of rain, and triple-digit summer temperatures, also intensified drought conditions. The summer 2022 season was the 11th driest summer on record. Finally, in August 2022, several heavy rainfall events (not associated with tropical systems) provided some drought relief.

The transplant plots were removed from the drip irrigation system once the plants became established in 2017. Although comprehensive plant monitoring (evaluating the 2,222 transplants individually) ended in 2018, annual photo-documentation of the plots has continued. Annual photographs illustrate transplant survival and rapid growth despite the extreme weather conditions.

6.8 TRANSPLANT SURVIVAL: CURRENT SITE CONDITIONS

Recent Spring 2023 photographs depicting current site conditions are compared to photos taken in Spring 2017 (approximately 13 months post-construction/planting). One of the project objectives was to determine if native transplants could not only survive harsh barrier island conditions and extreme weather events, but also thrive long-term once the drip irrigation was turned off in 2017. The following comparative photographs (Photos 26-51) illustrate the growth and resilience of these native plants.

Photo 26. Transplant Plot GB1. Photo taken Spring 2017 (1-year post-planting).

Photo 27. Transplant Plot GB1. Photo taken Spring 2023.

Photo 28. Transplant Plot GB2. Photo taken Spring 2017 (1-year post-planting).

Photo 29. Transplant Plot GB2. Photo taken Spring 2023.

Photo 30. Transplant Plot GB3. Photo taken Spring 2017 (1-year post-construction).

Photo 31. Transplant Plot GB3. Photo taken Spring 2023.

Photo 32. Transplant Plot GB4. Photo taken Spring 2017 (1-year post-construction).

Photo 33. Transplant Plot GB4. Photo taken Spring 2023.

Photo 34. Transplant Plot GB5. Photo taken Spring 2017 (1-year post-construction).

Photo 35. Transplant Plot GB5. Photo taken Spring 2023.

Photo 36. Transplant Plot GB6. Photo taken Spring 2017 (1-year post-construction).

Photo 37. Transplant Plot GB6. Photo taken Spring 2023.

Photo 38. Transplant Plot GB7. Photo taken Spring 2017 (1-year post-construction).

Photo 39. Transplant Plot GB7. Photo taken Spring 2023.

Photo 40. Transplant Plot GB8. Photo taken Spring 2017 (1-year post-construction).

Photo 41. Transplant Plot GB8. Photo taken Spring 2023.

Photo 42. Transplant Plot GB9. Photo taken Spring 2017 (1-year post-construction).

Photo 43. Transplant Plot GB9 (black willows and pond). Photo taken Spring 2023.

Photo 44. Transplant Plot GB10. Photo taken Spring 2017 (1-year post-construction).

Photo 45. Transplant Plot GB10. Photo taken Spring 2023.

Photo 46. Transplant Plot GB11. Photo taken Spring 2017 (1-year post-construction).

Photo 47. Transplant Plot GB11. Photo taken Spring 2023.

Photo 48. Transplant Plot GB12. Photo taken Spring 2017 (1-year post-construction).

Photo 49. Transplant Plot GB12. Photo taken Spring 2023.

Photo 50. Transplant Plot GB13. Photo taken Spring 2017 (1-year post-construction)

Photo 51. Transplant Plot GB13. Photo taken Spring 2023.

7.0 SPRING 2017, 2020, and 2023 BIRD SURVEYS

7.1 PCNP SURVEY STATIONS

Five (5) bird surveys were conducted during Spring 2017 (April 23, April 24, May 1, May 6, and May 13), four were conducted during Spring 2020 (April 6, April 19, April 30, and May 10), and two were conducted Spring 2023 (April 25 and April 30). The 13 transplant plots were designated as Plots GB1 through GB13 for this bird monitoring study (Figure 4). Table 2 lists the transplant species within each transplant plot/habitat type.

Figure 4. Layout of transplant plots. Thirteen transplant plots (GB1 through GB13) within a 2-acre woodland enhancement site at PCNP. Observations were made using designated survey points along the boardwalk.

Table 2. Transplant species within each woodland transplant plot.

13 Woodland Transplant Plots	Transplant Species (*USDA Common Name)	No. Surviving as of 2/26/18
GB-1 Tamaulipan Woodlands		
	Agarita (Algerita*) (*Mahonia trifoliolata*)	6
	Anaqua (Knockaway*) (*Ehretia anacua*)	5
	Barbados Cherry* (*Malpighia emarginata*)	5

13 Woodland Transplant Plots	Transplant Species (*USDA Common Name)	No. Surviving as of 2/26/18
GB-1 Tamaulipan-Con't.		
	Cenizo (Texas Barometer Bush*) (*Leucophyllum frutescens*)	4
	Dwarf Palmetto* (*Sabal minor*) (Not Planted)	2
	Honey Mesquite* (*Prosopis glandulosa*)	5
	Southern Lantana (West Indian Shrubverbena*) (*Lantana urticoides*)	1
	Spiny Hackberry* (*Celtis ehrenbergiana*)	2
	Sugar Hackberry (Sugarberry*) (*Celtis laevigata*)	1
	Texas Kidneywood* (*Eysenhardtia texana*)	4
	Texas Persimmon* (*Diospyros texana*)	1
	Turk's Cap (Wax Mallow*) (*Malvaviscus arboreus* var. *drummondii*)	41
	Yaupon* (*Ilex vomitoria*)	5
GB-2 Coastal Woodlands		
	Cenizo (Texas Barometer Bush*) (*Leucophyllum frutescens*)	4
	Dwarf Palmetto* (*Sabal minor*) (Not Planted)	1
	Elbowbush (Texas Swampprivet*) (*Forestiera angustifolia*)	11
	Flame Acanthus (Wright's Desert Honeysuckle*) (*Anisacanthus quadrifidus* var. *wrightii*)	8
	Southern Dewberry* (*Rubus trivialis*)	10
	Southern Lantana (West Indian Shrubverbena*) (*Lantana urticoides*)	26
	Spanish Dagger (Don Quixote's Lace*) (*Yucca treculeana*)	5
	Sugar Hackberry (Sugarberry*) (*Celtis laevigata*)	2
	Wax Myrtle* (*Morella cerifera*)	6
GB-3 Coastal Woodlands		
	Agarita (Algerita*) (*Mahonia trifoliolata*)	16
	American Beautyberry* (*Callicarpa americana*)	13
	Barbados Cherry* (*Malpighia emarginata*)	1
	Brazil (Brazilian Bluewood*) (*Condalia hookeri*)	1
	Calico Bush (Lantana*) (*Lantana camara*)	10
	Coral Bean (Redcardinal*) (*Erythrina herbacea*)	9
	Dwarf Palmetto* (*Sabal minor*) (Not Planted)	4
	Fiddlewood (Berlandier's Fiddlewood*) (*Citharexylum berlandieri*)	2
	Honey Mesquite* (*Prosopis glandulosa*)	3
	Spanish Dagger (Don Quixote's Lace*) (*Yucca treculeana*)	3
	Spiny Hackberry* (*Celtis ehrenbergiana*)	9
	Texas Persimmon* (*Diospyros texana*)	3
	Texas Pricklypear* (*Opuntia engelmannii* var. *lindheimeri*)	8
	White Mistflower (Havana Snakeroot*) (*Ageratina havanensis*)	4

13 Woodland Transplant Plots	Transplant Species (*USDA Common Name)	No. Surviving as of 2/26/18
GB-3 Coastal Con't.		
	Wild Olive (Anacahuita*) (*Cordia boissieri*)	5
GB-4 Coastal Woodlands		
	Brazil (Brazilian Bluewood*) (*Condalia hookeri*)	4
	Cenizo (Texas Barometer Bush*) (*Leucophyllum frutescens*)	5
	Elbowbush (Texas Swampprivet*) (*Forestiera angustifolia*)	8
	Padre Island Mistflower (Betonyleaf Thoroughwort*) (*Conoclinium betonicifolium*)	2
	Retama (Jerusalem Thorn*) (*Parkinsonia aculeata*)	3
	Southern Dewberry* (*Rubus trivialis*)	10
	Southern Lantana (West Indian Shrubverbena*) (*Lantana urticoides*)	19
	Spanish Dagger (Don Quixote's Lace*) (*Yucca treculeana*)	5
	Sugar Hackberry (Sugarberry*) (*Celtis laevigata*)	1
	Wax Myrtle* (*Morella cerifera*)	6
GB-5 Coastal Woodlands		
	Cenizo (Texas Barometer Bush*) (*Leucophyllum frutescens*)	4
	Elbowbush (Texas Swampprivet*) (*Forestiera angustifolia*)	10
	Southern Dewberry* (*Rubus trivialis*)	5
	Southern Lantana (West Indian Shrubverbena*) (*Lantana urticoides*)	5
	Spanish Dagger (Don Quixote's Lace*) (*Yucca treculeana*)	5
	Wax Myrtle* (*Morella cerifera*)	6
GB-6 Tamaulipan Woodlands		
	Agarita (Algerita*) (*Mahonia trifoliolata*)	20
	Anaqua (Knockaway*) (*Ehretia anacua*)	6
	Cedar Elm* (*Ulmus crassifolia*)	1
	Cenizo (Texas Barometer Bush*) (*Leucophyllum frutescens*)	7
	Desert Willow* (*Chilopsis linearis*)	5
	Dwarf Palmetto* (*Sabal minor*) (Not Planted)	2
	Flame Acanthus (Wright's Desert Honeysuckle*) (*Anisacanthus quadrifidus* var. *wrightii*)	15
	Honey Mesquite* (*Prosopis glandulosa*)	3
	Sugar Hackberry (Sugarberry*) (*Celtis laevigata*)	7
	Texas Kidneywood* (*Eysenhardtia texana*)	3
	Texas Persimmon* (*Diospyros texana*)	1
	Yaupon* (*Ilex vomitoria*)	6
GB-7 Coastal Woodlands		
	Agarita (Algerita*) (*Mahonia trifoliolata*)	16
	American Beautyberry* (*Callicarpa americana*)	16
	Calico Bush (Lantana*) (*Lantana camara*)	9

13 Woodland Transplant Plots	Transplant Species (*USDA Common Name)	No. Surviving as of 2/26/18
GB-7 Coastal Woodlands-Con't.		
	Chili Pequin (Cayenne Pepper*) (*Capsicum annuum* var. *glabriusculum*)	1
	Coral Bean (Redcardinal*) (*Erythrina herbacea*)	11
	Dwarf Palmetto* (*Sabal minor*) (Not Planted)	3
	Fiddlewood (Berlandier's fiddlewood*) (*Citharexylum berlandieri*)	22
	Honey Mesquite* (*Prosopis glandulosa*)	3
	Padre Island Mistflower (Betonyleaf Thoroughwort*) (*Conoclinium betonicifolium*)	3
	Spanish Dagger (Don Quixote's Lace*) (*Yucca treculeana*)	3
	Texas Live Oak* (*Quercus fusiformis*)	1
	Texas Persimmon* (*Diospyros texana*)	3
	Texas Pricklypear* (*Opuntia engelmannii* var. *lindheimeri*)	8
	Wild Olive (Anacahuita*) (*Cordia boissieri*)	6
GB-8 Live Oak Woodlands		
	American Beautyberry* (*Callicarpa americana*)	42
	Coral Bean (Redcardinal*) (*Erythrina herbacea*) (Not Planted)	5
	Padre Island Mistflower (Betonyleaf Thoroughwort*) (*Conoclinium betonicifolium*)	3
	Texas Live Oak* (*Quercus fusiformis*)	42
	Turk's Cap (Wax Mallow*) (*Malvaviscus arboreus* var. *drummondii*)	4
	Yaupon* (*Ilex vomitoria*)	8
GB-9 Riparian Woodlands		
	Black Willow* (*Salix nigra*)	9
	Buttonbush (Common Buttonbush*) (*Cephalanthus occidentalis*)	34
	Cattail* (*Typha* spp.) (Not Planted)	
	Cedar Elm* (*Ulmus crassifolia*)	5
	Mexican Ash* (*Fraxinus berlandieriana*)	5
	Texas Sabal Palm (Rio Grande Palmetto*) (*Sabal mexicana*)	2
GB-10 Coastal Woodlands		
	American Beautyberry* (*Callicarpa americana*)	10
	Calico Bush (Lantana*) (*Lantana camara*)	1
	Coral Bean (Redcardinal*) (*Erythrina herbacea*)	8
	Dwarf Palmetto* (*Sabal minor*) (Not Planted)	3
	Fiddlewood (Berlandier's Fiddlewood*) (*Citharexylum berlandieri*)	12
	Honey Mesquite* (*Prosopis glandulosa*)	3
	Spanish Dagger (Don Quixote's Lace*) (*Yucca treculeana)*	3
	Spiny Hackberry* (*Celtis ehrenbergiana*)	3

13 Woodland Transplant Plots	Transplant Species (*USDA Common Name)	No. Surviving as of 2/26/18
GB-10 Coastal Woodlands-Con't		
	Texas Live Oak* (*Quercus fusiformis*)	1
	Texas Persimmon* (*Diospyros texana*)	2
	Texas Pricklypear* (*Opuntia engelmannii* var. *lindheimeri*)	7
	Wild Olive (Anacahuita*) (*Cordia boissieri*)	2
GB-11 Palm Grove Woodlands		
	American Beautyberry* (*Callicarpa americana*)	61
	Barbados Cherry* (*Malpighia emarginata*)	6
	Black Willow* (*Salix nigra*)	1
	Butterfly Milkweed* (*Asclepias tuberosa*)	4
	Calico Bush (Lantana*) (*Lantana camara*)	1
	Coral Bean (Redcardinal*) (*Erythrina herbacea*) (Not Planted)	2
	Fiddlewood (Berlandier's Fiddlewood*) (*Citharexylum berlandieri*)	2
	Flame Acanthus (Wright's Desert Honeysuckle*) (*Anisacanthus quadrifidus* var. *wrightii*)	2
	La Coma (Saffron Plum*) (*Sideroxylon celastrinum*)	3
	Mexican Ash* (*Fraxinus berlandieriana*)	2
	Padre Island Mistflower (Betonyleaf Thoroughwort*) (*Conoclinium betonicifolium*)	1
	Retama (Jerusalem Thorn*) (*Parkinsonia aculeata*)	11
	Texas Ebony* (*Ebenopsis ebano*)	5
	Texas Kidneywood* (*Eysenhardtia texana*)	10
	Texas Sabal Palm (Rio Grande Palmetto*) (*Sabal mexicana*)	6
GB-12 Coastal Woodlands		
	Cenizo (Texas Barometer Bush*) (*Leucophyllum frutescens*)	3
	Coral Bean (Redcardinal*) (*Erythrina herbacea*) (Not Planted)	1
	Elbowbush (Texas Swampprivet*) (*Forestiera angustifolia*)	7
	Mexican Ash* (*Fraxinus berlandieriana*)	7
	Padre Island Mistflower (Betonyleaf Thoroughwort*) (*Conoclinium betonicifolium*)	4
	Southern Dewberry* (*Rubus trivialis*)	13
	Spanish Dagger (Don Quixote's Lace*) (Yucca *treculeana*)	5
	Sugar Hackberry (Sugarberry*) (*Celtis laevigata*)	1
	Wax Myrtle* (*Morella cerifera*)	6
GB-13 Palm Grove Woodlands		
	American Beautyberry* (*Callicarpa americana*)	45
	Barbados Cherry* (*Malpighia emarginata*)	9
	Coral Bean (Redcardinal*) (*Erythrina herbacea*) (Not Planted)	3
	Fiddlewood (Berlandier's Fiddlewood*) (*Citharexylum berlandieri*)	1

13 Woodland Transplant Plots	Transplant Species (*U SDA Common Name)	No. Surviving as of 2/26/18
GB-13 Palm Grove Woodlands – Con't.		
	Huisache (Sweet Acacia*) (*Vachellia farnesiana*) (Not Planted)	1
	Mexican Ash* (*Fraxinus berlandieriana*)	2
	Retama (Jerusalem Thorn*) (*Parkinsonia aculeata*)	18
	Texas Ebony* (*Ebenopsis ebano*)	5
	Texas Kidneywood* (*Eysenhardtia texana*)	9
	Texas Sabal Palm (Rio Grande Palmetto*) (*Sabal mexicana*)	6
	Turk's Cap (Wax Mallow*) (*Malvaviscus arboreus* var. *drummondii*) (Not Planted)	1

*Common and scientific names obtained from U.S. Department of Agriculture (USDA) website: plants.usda.gov>core>profile

7.2 NEARBY MATURE LIVE OAK WOODLAND SURVEY STATIONS

Three (3) nearby mature live oak woodland sites (PCNP, Corpus Christi Water Plant (CCW), and the Audubon Sanctuary (AUD) were also included in the survey (Figure 5).

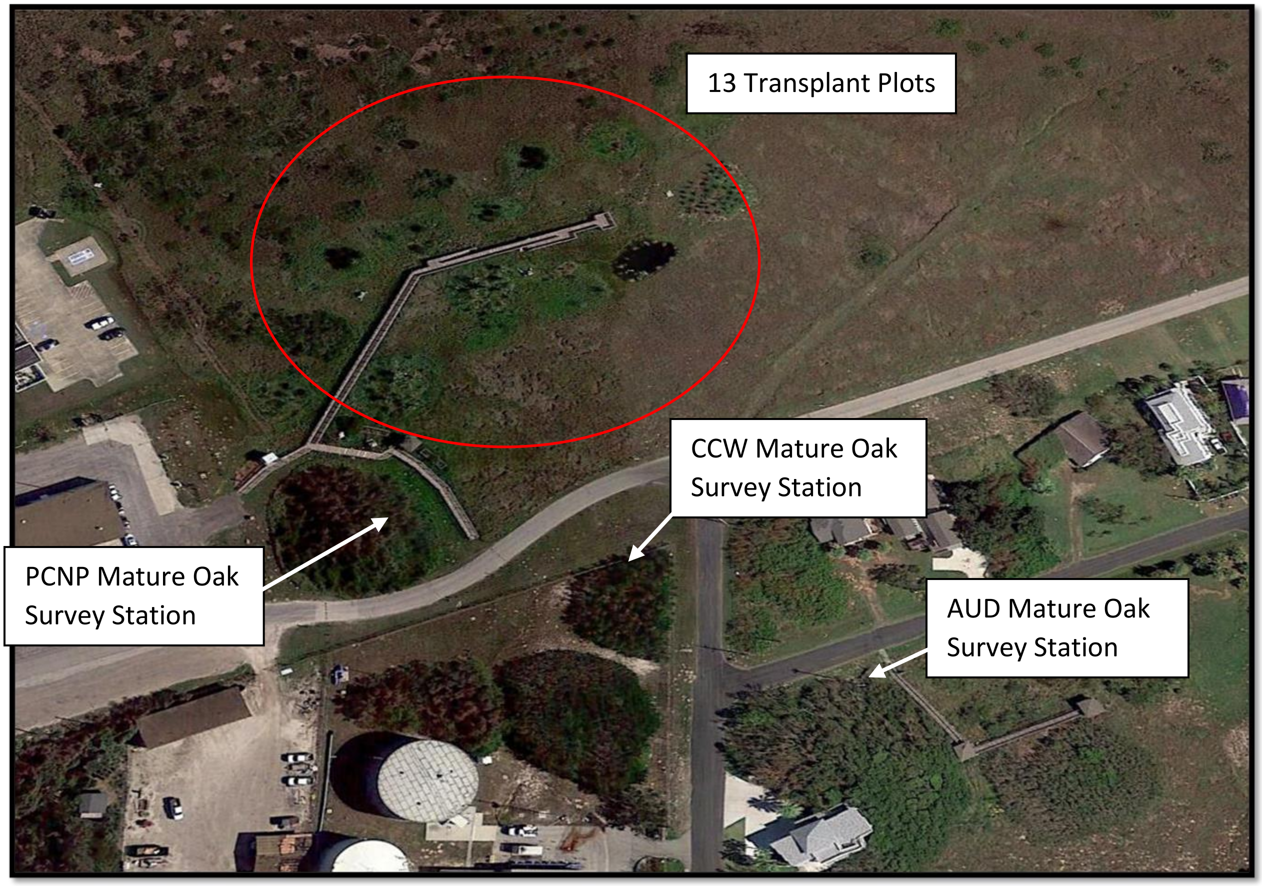

Figure 5. Bird survey stations. Location of the 13 transplant plots and 3 nearby mature oak survey stations.

The word "mature" denotes the area's live oak woodlands that have been in place for over 100 years. The mature woodlands are dominated by Southern live oak trees with varying amounts of dwarf wax myrtle, yaupon, coral bean, Turk's cap, and redbay (*Persea borbonia*). Mustang grape (*Vitis mustangensis*) and greenbrier (*Smilax bona-nox*) are common throughout; ground cover is primarily leaf litter. The oak trees form extensive clones of low-stature shrubs locally known as running live oak; these thickets are dense and largely impenetrable.

One of the three mature live oak survey stations is within the PCNP (Photo 52).


Photo 52. The mature live oak woodland survey station located along the PCNP boardwalk.

The Corpus Christi Water Treatment Plant (CCW) survey station contains mature live oak woodlands, but the woodlands only occur as fragmented patches within the water plant facility (Photo 53). The Audubon Sanctuary mature live oak survey station (Photo 54) is part of a larger woodland area that is not nearly as fragmented or isolated as the PCNP and CCW mature live oak survey stations.

Photo 53. The mature live oak woodland survey station within the nearby Corpus Christi Water Treatment Plant facility (CCW).

Photo 54. The mature live oak woodland survey station within the nearby Audubon Sanctuary (AUD).

7.3 SURVEY METHODS AND MATERIALS

The PCNP habitat enhancement project for Neotropical migratory birds was not designed as a scientific study; nevertheless, efforts were made to collect baseline data to see if any migratory bird use trends could be identified. Bird surveys were conducted at the 13 transplant plots and the three mature oak woodland stations on the five Spring 2017 and four Spring 2020 dates. Surveys were not performed in Transplant Plot GB12 during the two Spring 2023 survey events. Plot GB12 is situated behind two other transplant plots and is no longer visible among or through the dense vegetation.

All surveys were conducted within 24 hours of the passage of a northern cool front and after strong winds had lessened or subsided. Online BirdCast Live Migration Maps (Cornell Lab of Ornithology 2023) were used to help predict and identify bird grounding (fallout) events, triggering field checks to ensure that a fallout had occurred before commencing a survey event. Bird surveys were limited to one to four observers. Ten-minute surveys were conducted at each survey station. All birds detected by sight or sound were tallied by species, behavior, and plant use.

For all birds recorded, behaviors were classified as one of the following three activities:

1) Foraging, which involved direct observation.
2) Resting, which included birds seen within the 10-minute survey period, but then flew away.
3) Others, which included birds heard but not seen.

After the 10 minutes had elapsed, the observers continued to the next survey location where they systematically repeated this data collection process until all transplant plots and mature oak woodland stations were surveyed.

Bird surveys at the transplant plots and the PCNP mature oak woodland station were conducted from an elevated boardwalk. Since the boardwalk was not equidistant from all transplant plots, limited-distance surveys were not used to calculate avian densities for the plots. Surveys at the two nearby mature live oak woodland stations (CCW and AUD) were conducted from the ground.

For data analysis, the numbers of males and females, when determined, were combined for each species. Data for abundance (bird count of individuals), number of bird families, species richness (number of species), species diversity, plant use, and bird behaviors are presented as simple raw numbers and percentages.

Bird survey count numbers (individuals) and species richness (number of species counted in a survey) were used to compute habitat unit species diversity using the Shannon-Wiener diversity index (H’) (Shannon 1948). The Shannon-Wiener index was used to calculate how evenly distributed the number of bird species observed in the surveys fit on a logarithmic scale. The formula calculates the equation: $H' = \sum (p1) |\ln p1|$. Where "p" is the proportion of the total number of individuals in the population in species "1", and ln indicates the natural logarithm. This is the portion each species makes towards the total. More evenly distributed individuals to species proportions result in higher index values. The index has a maximum value when all species are in equal proportions. The Shannon-Wiener Index (H'), one of the most used indices in ecological studies, ranges from 0 to 5, usually ranging from 1.5 to 3.5. Kerkoff (2010) similarly defines the diversity index, stating typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4.

Species richness measures the number of species counted in a survey. The Bird Species Richness Index estimates the number of species that may inhabit an area based on potential habitat (EnviroAtlas 2014). Bird count survey numbers were used to compute species richness using the Menhinick's Index (D) (Whittaker, 1977). The formula for the Species Richness index is ($D = s/\sqrt{N}$), where s = the number of bird species divided by the square root of N (the number of birds of each species).

7.3.1 SURVEY LOCATIONS: VIEWING CHARACTERISTICS

Viewing characteristics for the transplant plots and the nearby mature oak woodland survey stations are depicted in Table 3. The viewing distance is the span between the observer(s) and the nearest edge of the plot or station being surveyed.

Survey Plot/Station	Viewing Distance (in feet)
PCNP Transplant Plot GB1	17
PCNP Transplant Plot GB2	26
PCNP Transplant Plot GB3	19
PCNP Transplant Plot GB4	18
PCNP Transplant Plot GB5	67
PCNP Transplant Plot GB6	62
PCNP Transplant Plot GB7	111
PCNP Transplant Plot GB8	70
PCNP Transplant Plot GB9	25
PCNP Transplant Plot GB10	27
PCNP Transplant Plot GB11	11
PCNP Transplant Plot GB12	51
PCNP Transplant Plot GB13	13
PCNP – Mature Live Oak Woodland Station	22
City Water Plant – Mature Oak Woodland Station	20
Audubon Sanctuary – Mature Oak Woodland Station	24

Table 3. Viewing characteristics: transplant plots and mature oak woodland stations.

8.0 RESULTS

8.1 BIRDS AND HABITATS

Only birds defined as Neotropical migrants under the Neotropical Migratory Bird Conservation Act were included in the bird surveys. The total number of birds detected during the five Spring 2017, four Spring 2020, and two Spring 2023 survey dates were tabulated by bird family and species.

Total bird abundance summed across the 13 (12 in 2023) transplant plots and the three mature oak woodland stations was 259 Neotropical migrants, represented by 42 species and 12 bird families in 2017 (Table 4), 379 Neotropical migrants, represented by 44 species and 11 bird families in 2020 (Table 5), and 225 Neotropical migrants, represented by 40 species and 13 bird families in 2023 (Table 6).

Table 4. Total number of Neotropical migrants detected during the 5 Spring 2017 survey dates.

	Bird Numbers	
Bird Families and Species (Spring 2017)	**Transplant Plots**	**Woodland Stations**
Family Columbidae (Doves and Pigeons)		
Mourning Dove (*Zenaida macroura*)	3	--
Family Cuculidae (Cuckoos)		
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	--	2
Yellow-billed Cuckoo (*Coccyzus americanus*)	2	--
Family Trochilidae (Hummingbirds)		
Ruby-throated Hummingbird (*Archilochus colubris*)	5	1
Family Tyrannidae (Tyrant Flycatchers)		
Alder/Willow Flycatcher (*Empidonax* spp.)	13	--
Couch's Kingbird (*Tyrannus couchii*)	1	--
Eastern Kingbird (*Tyrannus tyrannus*)	19	--
Eastern Wood-Pewee (*Contopus virens*)	6	6
Great Crested Flycatcher (*Myiarchus crinitus*)	1	1
Least Flycatcher (*Empidonax minimus*)	2	2
Olive-sided Flycatcher (*Contopus cooperi*)	4	--
Scissor-tailed Flycatcher (*Tyrannus forficatus*)	7	--
Western Kingbird (*Tyrannus verticalis*)	13	--
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	1	--

Bird Families and Species (Spring 2017)	Bird Numbers: Transplant Plots	Bird Numbers: Woodland Stations
Family Vireonidae (Vireos)		
Blue-headed Vireo (*Vireo solitarius*)	1	--
Philadelphia Vireo (*Vireo philadelphicus*)	--	2
Red-eyed Vireo (*Vireo olivaceus*)	--	1
Warbling Vireo (*Vireo gilvus*)	10	2
Family Troglodytidae (Wrens)		
Sedge Wren (*Cistothorus platensis*)	1	--
Family Turdidae (Thrushes)		
Gray-cheeked Thrush (*Catharus minimus*)	--	1
Family Parulidae (Wood-Warblers)		
American Redstart (*Setophaga ruticilla*)	--	2
Bay-breasted Warbler (*Setophaga castanea*)	1	1
Chestnut-sided Warbler (*Setophaga pensylvanica*)	--	1
Common Yellowthroat (*Geothlypis trichas*)	2	--
Mourning Warbler (*Geothlypis philadelphia*)	--	1
Nashville Warbler (*Leiothlypis ruficapilla*)	8	1
Northern Parula (*Setophaga americana*)	--	1
Tennessee Warbler (*Leiothlypis peregrina*)	24	1
Yellow Warbler (*Setophaga petechia*)	11	1
Family Icteriidae (Monospecific)		
Yellow-breasted Chat (*Icteria virens*)	1	--
Family Passerellidae (Sparrows)		
Chipping Sparrow (*Spizella passerina*)	3	--
Lincoln's Sparrow (*Melospiza lincolnii*)	7	--
Family Cardinalidae (Grosbeaks, Tanagers, and Buntings)		
Blue Grosbeak (*Passerina caerulea*)	2	1
Dickcissel (*Spiza americana*)	2	--
Indigo Bunting (*Passerina cyanea*)	17	2
Painted Bunting (*Passerina ciris*)	3	1
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	3	3
Scarlet Tanager (*Piranga olivacea*)	1	--
Summer Tanager (*Piranga rubra*)	5	1

Bird Families and Species (Spring 2017)	Bird Numbers	
	Transplant Plots	Woodland Stations
Family Icteridae (Blackbirds and Orioles)		
Baltimore Oriole (*Icterus galbula*)	27	5
Orchard Oriole (*Icterus spurius*)	9	1
Red-winged Blackbird (*Agelaius phoeniceus*)	1	2
Total	**216**	**43**
Total Number of Birds in the Transplant Plots and Woodland Stations = 259		

Table 4. Total number of Neotropical migrants detected during the 5 Spring 2017 survey dates within the transplant plots (n=13) and at the nearby mature oak woodland survey stations (n=3). Bird numbers for the transplant plots and the woodland stations cannot be compared directly because of unequal sample sizes.

Table 5. Total number of Neotropical migrants detected during the 4 Spring 2020 survey dates.

Bird Families and Species (Spring 2020)	Bird Numbers	
	Transplant Plots	Woodland Stations
Family Cuculidae (Cuckoos)		
Yellow-billed Cuckoo (*Coccyzus americanus*)	4	3
Family Trochilidae (Hummingbirds)		
Black-chinned Hummingbird (*Archilochus alexandri*)	1	--
Ruby-throated Hummingbird (*Archilochus colubris*)	96	21
Family Tyrannidae (Tyrant Flycatchers)		
Couch's Kingbird (Tyrannus couchii)	4	1
Eastern Kingbird (*Tyrannus tyrannus*)	9	--
Eastern Wood-Pewee (*Contopus virens*)	2	--
Least Flycatcher (*Empidonax minimus*)	1	--
Olive-sided Flycatcher (*Contopus cooperi*)	1	--
Scissor-tailed Flycatcher (*Tyrannus forficatus*)	4	--
Western Kingbird (*Tyrannus verticalis*)	5	--
Family Vireonidae (Vireos)		
Bell's Vireo (*Vireo bellii*)	--	2
Blue-headed Vireo (*Vireo solitarius*)	--	1
Philadelphia Vireo (*Vireo philadelphicus*)	7	5
Red-eyed Vireo (*Vireo olivaceus*)	2	1

Bird Families and Species (Spring 2020)	Bird Numbers Transplant Plots	Woodland Stations
Family Vireonidae (Vireos) Con't.		
Warbling Vireo (*Vireo gilvus*)	8	2
White-eyed Vireo (*Vireo griseus*)	2	4
Family Polioptilidae (Gnatcatchers)		
Blue-gray Gnatcatcher (*Polioptila caerulea*)	6	--
Family Troglodytidae (Wrens)		
Marsh Wren (*Cistothorus palustris*)	1	--
Sedge Wren (*Cistothorus platensis*)	1	--
Family Mimidae (Mockingbirds and Thrashers)		
Gray Catbird (*Dumetella carolinensis*)	5	2
Family Parulidae (Wood-Warblers)		
American Redstart (*Setophaga ruticilla*)	2	--
Black-and-white Warbler (*Mniotilta varia*)	--	2
Black-throated Green Warbler (*Setophaga virens*)	1	--
Canada Warbler (*Cardellina canadensis*)	1	3
Chestnut-sided Warbler (*Setophaga pensylvanica*)	--	1
Common Yellowthroat (*Geothlypis trichas*)	9	2
Golden-winged Warbler (*Vermivora chrysoptera*)	1	--
Hooded Warbler (*Setophaga citrina*)	3	3
Magnolia Warbler (*Setophaga magnolia*)	--	1
Tennessee Warbler (*Leiothlypis peregrina*)	--	5
Wilson's Warbler (*Cardellina pusilla*)	1	--
Worm-eating Warbler (*Helmitheros vermivorum*)	--	2
Yellow Warbler (*Setophaga petechia*)	6	2
Yellow-rumped Warbler (*Setophaga coronata*)	--	1
Yellow-throated Warbler (*Setophaga dominica*)	2	--
Family Icteriidae (Monospecific)		
Yellow-breasted Chat (*Icteria virens*)	2	1
Family Cardinalidae (Grosbeaks, Tanagers, and Buntings)		
Indigo Bunting (*Passerina cyanea*)	4	1
Painted Bunting (*Passerina ciris*)	--	1
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	2	--
Scarlet Tanager (*Piranga olivacea*)	--	1
Summer Tanager (*Piranga rubra*)	3	2

Bird Families and Species (Spring 2020)	Bird Numbers Transplant Plots	Woodland Stations
Family Icteridae (Blackbirds and Orioles)		
Baltimore Oriole (*Icterus galbula*)	25	5
Orchard Oriole (*Icterus spurius*)	73	8
Red-winged Blackbird (*Agelaius phoeniceus*)	1	1
Total	**295**	**84**
Total Number of Birds in the Transplant Plots and Woodland Stations = 379		

Table 5. Total number of Neotropical migrants detected during the 4 Spring 2020 survey dates within the transplant plots (n=13) and at the nearby mature oak woodland survey stations (n=3). Bird numbers for the transplant plots and the woodland stations cannot be compared directly because of unequal sample sizes.

Table 6. Total number of Neotropical migrants detected during the 2 Spring 2023 survey dates.

Bird Families and Species (Spring 2023)	Bird Numbers Transplant Plots	Woodland Stations
Family Cuculidae (Cuckoos)		
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	1	-
Family Trochilidae (Hummingbirds)		
Ruby-throated Hummingbird (*Archilochus colubris*)	17	8
Family Tyrannidae (Tyrant Flycatchers)		
Couch's Kingbird (*Tyrannus couchii*)	1	1
Eastern Wood-Pewee (*Contopus virens*)	6	4
Least Flycatcher (*Empidonax minimus*)	2	1
Willow Flycatcher (*Empidonax traillii*)	-	1
Family Vireonidae (Vireos)		
Blue-headed Vireo (*Vireo solitarius*)	1	-
Red-eyed Vireo (*Vireo olivaceus*)	5	1
Warbling Vireo (*Vireo gilvus*)	4	-
White-eyed Vireo (*Vireo griseus*)	1	1

Bird Families and Species (Spring 2023)	Bird Numbers	
	Transplant Plots	Woodland Stations
Family Regulidae (Kinglets)		
Ruby-crowned Kinglet (*Corthylio calendula*)	1	2
Family Troglodytidae (Wrens)		
House Wren (*Troglodytes aedon*)	1	-
Family Turdidae (Thrushes)		
Swainson's Thrush (*Catharus ustulatus*)	3	1
Family Mimidae (Mockingbirds and Thrashers)		
Gray Catbird (*Dumetella carolinensis*)	40	9
Family Parulidae (Wood-Warblers)		
Black-and-white Warbler (*Mniotilta varia*)	1	-
Black-throated Green Warbler (*Setophaga virens*)	2	--
Chestnut-sided Warbler (*Setophaga pensylvanica*)	5	5
Common Yellowthroat (*Geothlypis trichas*)	9	1
Connecticut Warbler (*Oporornis agilis*)	1	-
Hooded Warbler (*Setophaga citrina*)	0	3
Louisiana Waterthrush (*Parkesia motacilla*)	2	-
Magnolia Warbler (*Setophaga magnolia*)	8	-
Nashville Warbler (*Leiothlypis ruficapilla*)	1	-
Northern Parula (*Setophaga americana*)	-	2
Northern Waterthrush (*Parkesia noveborancensis*)	2	-
Ovenbird (*Seiurus aurocapilla*)	-	1
Tennessee Warbler (*Leiothlypis peregrina*)	3	-
Yellow Warbler (*Setophaga petechia*)	-	3
Family Icteriidae (Monospecific)		
Yellow-breasted Chat (*Icteria virens*)	-	2
Family Passerellidae (Sparrows)		
Lincoln's Sparrow (*Melospiza lincolnii*)	2	-
Savannah Sparrow (*Passerculus sandwichensis*)	-	1
Family Cardinalidae (Grosbeaks, Tanagers, and Buntings)		
Blue Grosbeak *(Passerina caerulea*)	1	-
Indigo Bunting (*Passerina cyanea*)	4	2
Painted Bunting (*Passerina ciris*)	1	-
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	4	2
Scarlet Tanager (*Piranga olivacea*)	6	1

Bird Families and Species (Spring 2023)	Bird Numbers Transplant Plots	Woodland Stations
Family Cardinalidae (Grosbeaks, Tanagers, and Buntings) Con't.		
Summer Tanager (*Piranga rubra*)	3	7
Family Icteridae (Blackbirds and Orioles)		
Baltimore Oriole (*Icterus galbula*)	9	5
Brown-headed Cowbird (*Molothrus ater*)	2	-
Orchard Oriole (*Icterus spurius*)	10	2
Total	**159**	**66**
Total Number of Birds in the Transplant Plots and Woodland Stations = 225		

Table 6. Total number of Neotropical migrants detected during the 2 Spring 2023 survey dates within the transplant plots (n=12) and at the nearby mature oak woodland survey stations (n=3). Bird numbers for the transplant plots and the woodland stations cannot be compared directly because of unequal sample sizes.

8.1.1 SPECIES OF CONSERVATION CONCERN

Six (6) of the 42 migrant species observed during the 2017 surveys, seven of the 44 migrant species recorded during the 2020 surveys, and three of the 40 migrant species recorded during the 2023 surveys possess a designated conservation status from one or several of the following: U.S. Endangered Species Act (ESA), International Union for Conservation of Nature Red List (IUCN), U.S. Fish and Wildlife Service Birds of Conservation Concern (BCC), National Audubon Society/American Bird Conservancy Watch List (WL Red), and the National Audubon Society/American Bird Conservancy Watch List (WL Yellow). Appendix A-4 contains the conservation status for the species listed: in 2017 Yellow-billed Cuckoo (*Coccyzus americanus*), Olive-sided Flycatcher (*Contopus cooperi*), Painted Bunting (*Passerina ciris*), Willow Flycatcher (*Empidonax traillii*), Bay-breasted Warbler (*Setophaga castanea*), and Dickcissel (*Spiza americana*); in 2020 Yellow-billed Cuckoo, Olive-sided Flycatcher, Painted Bunting, Bell's Vireo (*Vireo bellii*), Canada Warbler (*Cardellina canadensis*), Golden-winged Warbler (*Vermicora chrysoptera*), and Worm-eating Warbler (*Helmitheros vermivorum*); and in 2023 Yellow-billed Cuckoo, Willow Flycatcher, and Painted Bunting.

An endangered Black-capped Vireo (*Vireo atricapilla*) was observed and photographed by bird watchers during the April 30, 2023, survey effort. This was an extremely rare occurrence for this geographic area. Although this vireo was present in Transplant Plot GB1, it was not included in the survey data because it occurred outside the 10-minute survey period for this particular transplant plot. The photographer posted the photo on the eBird website. The Black-capped Vireo is designated as endangered throughout its range (ESA) and vulnerable with a high risk of endangerment in the wild (IUCN). The WL Red List indicates that this species is declining rapidly, has very small populations or limited ranges, faces major conservation threats, and is a species of global conservation concern.

8.2 BIRD ABUNDANCE

8.2.1 TRANSPLANT PLOTS

The total abundance (total number of birds) occurring in the 13 transplant plots during the five Spring 2017 survey dates was 216 birds represented by 34 species and 11 families (Table 4). In the transplant plots, there was an average of 43.2 birds/survey date and an average of 3.3 birds/survey/plot.

Total abundance recorded in the 13 transplant plots during the four Spring 2020 survey dates was 295 birds represented by 34 species and 11 families (Table 5). In the transplant plots, there was an average of 73.7 birds/survey date and an average of 5.7 birds/survey/plot.

Total abundance recorded in the 12 transplant plots during the 2 Spring 2023 survey dates was 159 birds represented by 33 species and 12 families (Table 6). In the transplant plots, there was an average of 79.5 birds/survey date and an average of 7.6 birds/survey/plot.

8.2.2 MATURE LIVE OAK WOODLANDS

Total bird numbers recorded at the three mature oak woodland stations during the five Spring 2017 survey dates were 43 birds represented by 25 species and eight bird families (Table 4). In the live oak woodlands, there was an average of 8.6 birds/survey and an average of 2.9 birds/survey/station.

Total bird numbers recorded at the three mature oak woodland stations in 2020 were 84 birds, represented by 28 species and nine bird families (Table 5). In the live oak woodlands, there was an average of 21.0 birds/survey and an average of 7.0 birds/survey/station.

Total bird numbers recorded at the three mature oak woodland stations in 2023 were 66 birds, represented by 24 species and 11 bird families (Table 6). In the live oak woodlands, there was an average of 33.0 birds/survey and an average of 11.0 birds/survey/station.

8.3 SPECIES COMPOSITION

8.3.1 TRANSPLANT PLOTS: SPRING 2017

During the 2017 surveys, four bird families were especially prominent within the transplant plots. Ten (10) species of tyrant flycatchers (Family Tyrannidae), totaling 67 birds, occurred in the transplant plots and accounted for 31% of the total 216 birds (Table 4). The most frequently detected flycatcher species occurring in the transplant plots included Eastern Kingbird (*Tyrannus tyrannus*) (19), Western Kingbird (*T. verticalis*) (13), and Alder/Willow Flycatcher (*Empidonax* spp.) (13) (Figure 6). These three species together accounted for 67.2% of all flycatchers detected within the transplant plots (Table 4). Eastern kingbird, the most common tyrant flycatcher species observed, accounted for 28.4% of all flycatchers and 8.8% of all birds occurring within the transplant plots.

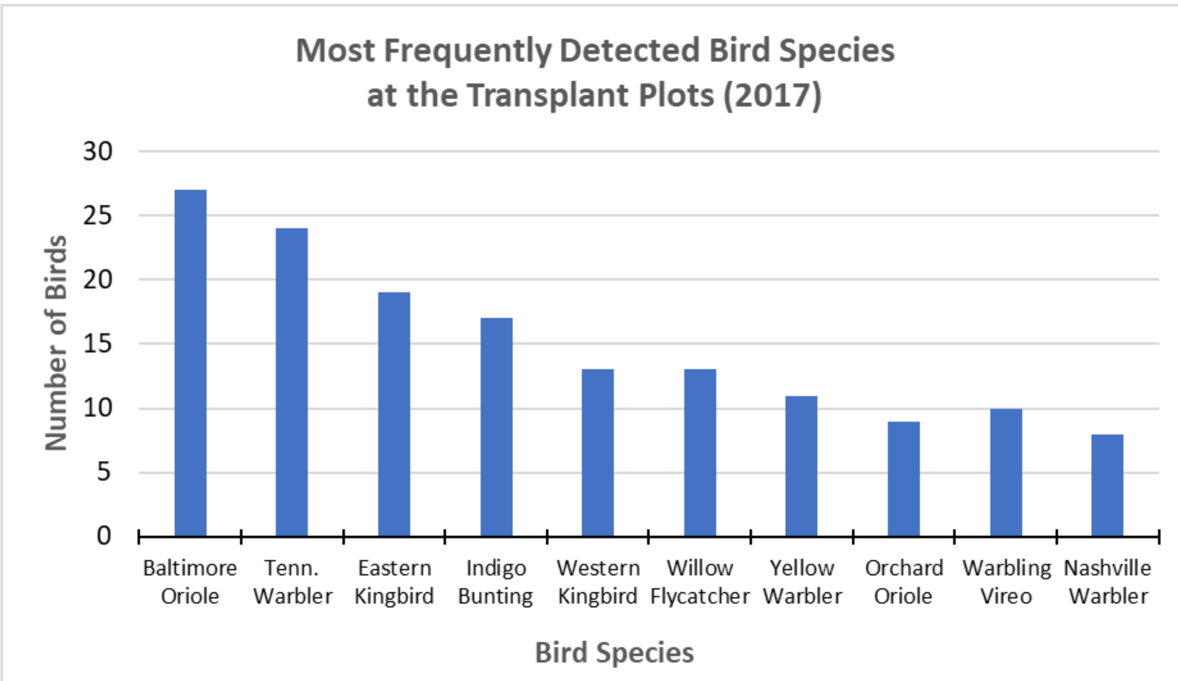

Figure 6. Spring 2017: Most frequently detected bird species at the transplant plots.

Five (5) species of wood warblers (Family Parulidae), which totaled 46 birds within the transplant plots, accounted for 21.3% of the total 216 birds (Table 4). The most frequently detected wood warbler species occurring at the transplant plots were the Tennessee Warbler (*Oreothlypis peregrina*) (24) and Yellow Warbler (*Setophaga petechia*) (11) (Figure 6). These two species together accounted for 76.1% of all wood warblers detected at the transplant plots (Table 4). Tennessee Warbler, the most common wood warbler species observed, accounted for 52.2% of all wood warblers and 11.1% of all birds detected in the transplant plots.

Three (3) species of blackbirds and orioles (Family Icteridae), which totaled 37 birds at the transplant plots, represented 17.1% of the total bird number (Table 4). The most frequently detected bird species in this family was the Baltimore Oriole (*Icterus galbula*) (27) (Figure 6).

Baltimore Oriole accounted for 73% of all Icterids, and 12.5% of all birds within the transplant plots.

Seven (7) species of grosbeaks, tanagers, and buntings (Family Cardinalidae), which totaled 33 birds at the transplant plots, represented 15.3% of the total bird number (Table 4). The most frequently detected bird species in this family was Indigo Bunting (*Passerina cyanea*) (17) (Figure 6). Indigo Bunting alone accounted for 51.5% of all Cardinalidae, and 7.9% of all birds observed within the transplant plots.

Less abundant groups of birds within the transplant plots included families accounting for 5.1% vireos (Vireonidae), 4.6% sparrows (Passerellidae), 2.3% hummingbirds (Trochilidae), 1.4% doves and pigeons (Columbidae), 0.9% cuckoos (Cuculidae), 0.5% wrens (Troglodytidae), and 0.5% yellow-breasted chat (Icteriidae - Monospecific) of all birds detected within the transplant plots (Table 4).

8.3.2 TRANSPLANT PLOTS: SPRING 2020

During the 2020 surveys, birds in two families were especially prominent within the transplant plots. Although hummingbirds (Family Trochilidae) accounted for 32.9% of the total 295 birds, one hummingbird species, the Ruby-throated Hummingbird (*Archilochus colubris*) totaled 96 individuals within the transplant plots (Figure 7), accounting for 32.5% of the total 295 birds and 99% of all hummingbirds (Table 5).

The second most frequently detected bird family within the transplant plots were the orioles (Family Icteridae), accounting for 33.6% of the total 295 birds (Table 5). The most frequently detected species were Orchard Oriole (*Icterus spurius*) (73) and Baltimore Oriole (25) (Figure 7). These two species together accounted for 99% of all Icteridae detected in the transplant plots. Orchard Oriole, the single most common oriole species observed in the transplant plots, accounted for 73.7% of all orioles, and 24.7% of the 295 birds (Table 5).

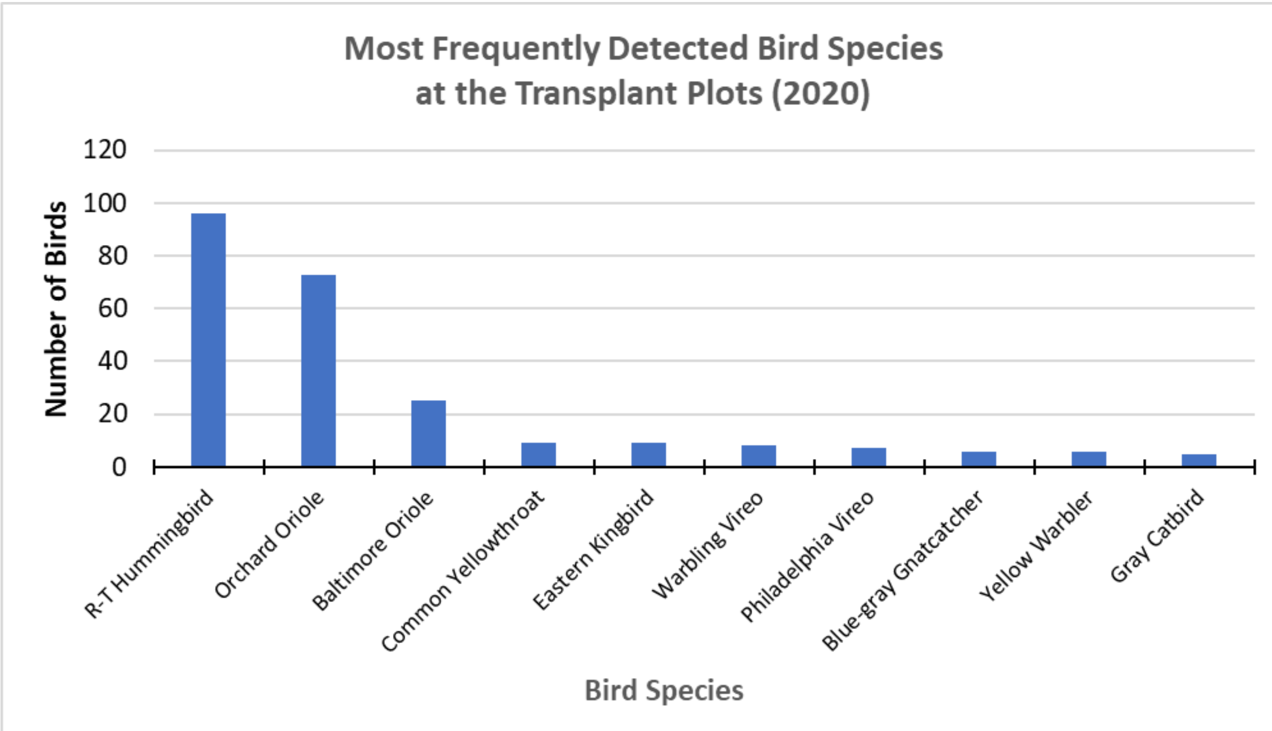

Figure 7. Spring 2020: Most frequently detected bird species at the transplant plots.

Seven (7) species of Tyrant flycatchers totaled 26 birds at the transplant plots, accounting for 8.8% of the total 295 birds (Table 5). The most frequently detected flycatcher species within the transplant plots were Eastern Kingbird (9), Western Kingbird (5), Scissor-tailed Flycatcher (*Tyrannus forficatus*) (4), and Couch's Kingbird (*T. couchii*) (4) (Table 5). These four species together accounted for 84.6% of all flycatchers detected at the transplant plots. Eastern Kingbird, the most common tyrant flycatcher species observed, accounted for 34.6% of all flycatchers.

Nine (9) species of wood warblers (Family Parulidae), which totaled 26 birds at the transplant plots, accounted for 8.8% of the total 295 birds (Table 5). The most frequently detected wood warbler species at the transplant plots were Common Yellowthroat (*Geothlypis trichas*) (9) and Yellow Warbler (6) (Figure 7). These two species together accounted for 57.7% of all wood warblers detected within the transplant plots. The Common Yellowthroat, the most common wood warbler species observed, accounted for 34.6% of all wood warblers at the transplant plots.

Four (4) species of vireos (Family Vireonidae), which totaled 19 birds at the transplant plots, represented 6.4% of the total 295 birds (Table 5). The two most frequently detected vireo species were Warbling Vireo (*Vireo gilvus*) (8) and Philadelphia Vireo (*V. philadelphicus*) (7) (Figure 7); together they accounted for 78.9% of all vireos within the transplant plots (Table 5).

Less abundant groups of birds included families accounting for 3% (Cardinalidae), 2% (Polioptilidae), 1.7% (Mimidae), 1.4% (Cuculidae), 0.7% (Troglodytidae), and 0.7% (Icteriidae - Monospecific) of all birds detected within the transplant plots (Table 5).

8.3.3 TRANSPLANT PLOTS: SPRING 2023

During the 2023 surveys, birds in two families were especially prominent within the transplant plots. Although Family Mimidae accounted for 25.2% of the total 159 birds in the transplant plots, this family was represented by only one species: Gray Catbird (*Dumetella carolinensis*) (Table 6 and Figure 8).

The second most frequently detected bird family within the transplant plots was the wood-warblers (Family Parulidae), accounting for 21.4% of the total 159 birds (Table 6). Unlike the Gray Catbird (Figure 8), no single wood warbler species was particularly dominant. Family Parulidae had the greatest diversity (10 species) of birds among the families occurring in the transplant plots. The most frequently detected Parulidae species were Common Yellowthroat (*Geothlypis trichas*) (9), Magnolia Warbler (*Setophaga magnolia*) (8), and Chestnut-sided Warbler (5) (Figure 8).

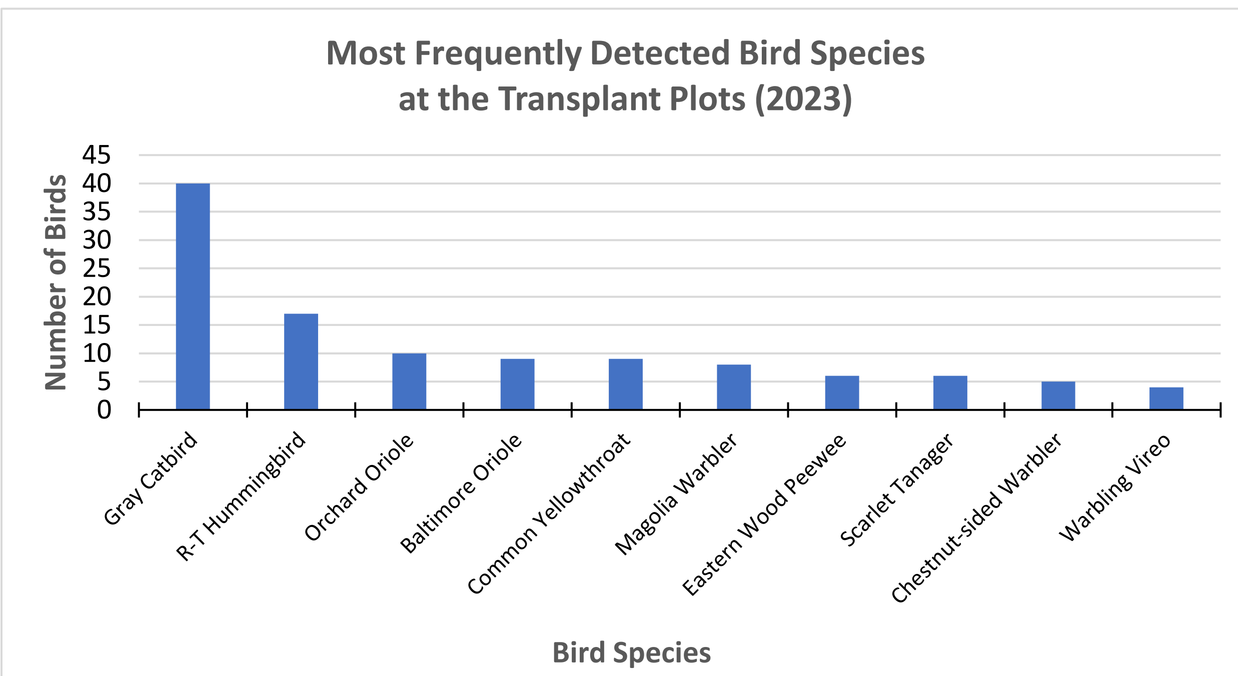

Figure 8. Spring 2023: Most frequently detected bird species at the transplant plots.

Three (3) species of blackbirds and orioles (Family Icteridae), which totaled 21 birds at the transplant plots, represented 13.2% of the total 159 birds (Table 6). The two most frequently detected oriole species were Orchard Oriole (*Icterus spurius*) (10) and Baltimore Oriole (*Icterus galbula*) (9) (Figure 8); together, they accounted for 90.5% of all Icteridae species within the transplant plots (Table 6).

Six (6) species of grosbeaks, tanagers, and buntings (Family Cardinalidae), which totaled 19 birds at the transplant plots, represented 11.9% of the total 159 birds (Table 6). The most frequently detected species included Scarlet Tanager (*Piranga olivacea*) (6), Rose-breasted Grosbeak (*Pheucticus ludovicianus*) (4), Indigo Bunting (*Passerina cyanea*) (4), and Summer Tanager (*Piranga rubra*) (3) (Table 6).

Although hummingbirds (Family Trochilidae) accounted for 10.7% of birds in the transplant plots, this family was represented by only one species: Ruby-throated Hummingbird (*Archilochus colubris*) (Figure 8).

Less abundant groups of birds included families accounting for 6.9% vireos (Vireonidae), 5.7% tyrant flycatchers (Tyrannidae), 1.9% thrushes (Turdidae), 1.3% sparrows (Passerellidae), 0.6% cuckoos (Cuculidae), 0.6% kinglets (Regulidae), and 0.6% wrens (Troglodytidae) of all birds detected within the transplant plots (Table 6).

8.3.4 MATURE LIVE OAK WOODLANDS: SPRING 2017

In Spring 2017, 3 species of tyrant flycatchers totaled nine birds at the mature oak woodlands, representing 21% of the total 43 birds (Table 4). The most frequently detected flycatcher species at the oak woodland stations was the Eastern Wood-Pewee (*Contopus virens*) (6) (Figure 9). This species accounted for 66.7% of all flycatchers, and 14% of all birds at the oak woodland survey stations (Table 4).

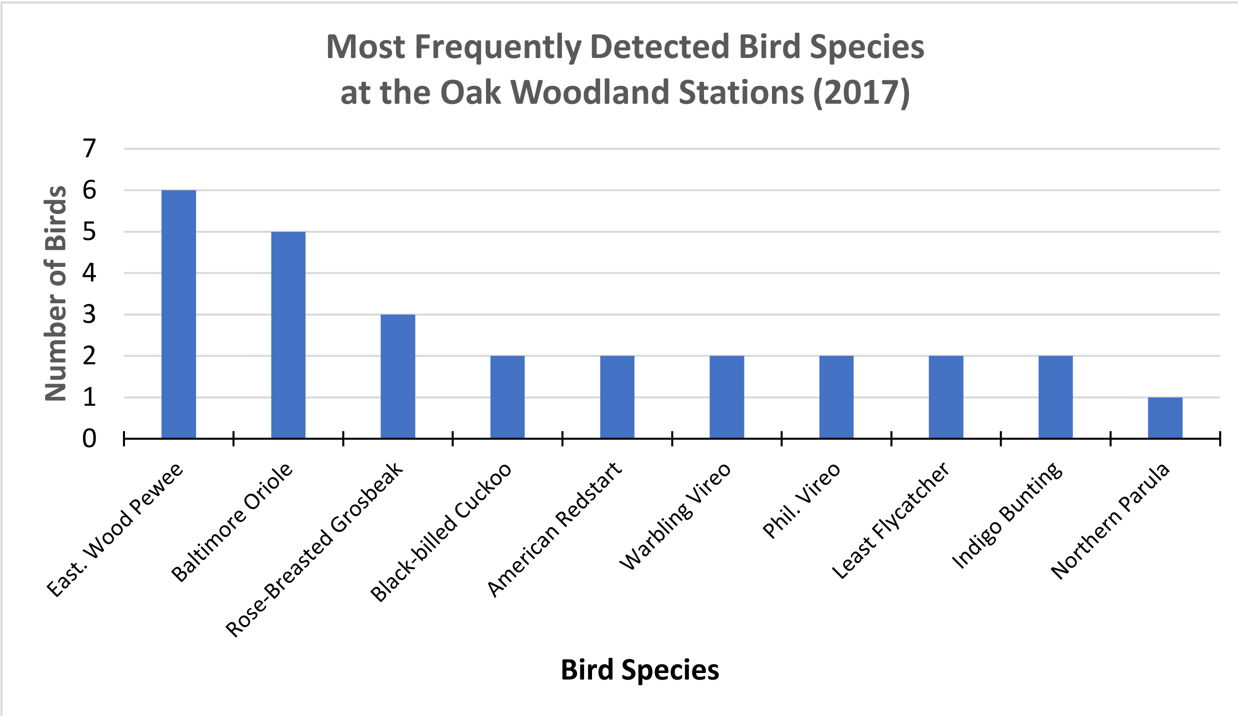

Figure 9. Spring 2017: Most frequently detected bird species at the oak woodland stations.

Although eight species of wood warblers totaled nine birds and represented 21% of the total bird number during the Spring 2017 survey at the nearby oak woodlands, no single wood warbler species predominated (Table 4).

Five (5) species of grosbeaks, tanagers, and buntings totaled eight birds at the oak woodland stations, representing 18.6% of the total 43 birds. No single species of this family predominated at the oak woodland sites (Table 4).

Three (3) species of blackbirds and orioles totaled 8 birds at the mature oak woodland survey stations, representing 18.6% of the total 43 birds (Table 4). The most frequently detected Icterid species at these oak woodland sites was the Baltimore Oriole (5) (Figure 9). This species, which accounted for 62.5% of all Icteridae, represented 11.6% of all birds seen at the oak woodland stations.

Other less abundant bird families included Vireonidae (11.6%), Cuculidae (4.6%), Trochilidae (2.3%), and Turdidae (2.3%) of the total 43 birds detected at the oak woodland survey stations (Table 4).

8.3.5 MATURE LIVE OAK WOODLANDS: SPRING 2020

During the 2020 surveys, birds from four different families were detected most frequently at the mature oak woodland stations. Wood warblers (Family Parulidae) were represented by ten species, totaling 22 birds and representing 26.2% of the total 84 birds. No single wood warbler species predominated at the oak woodland sites (Table 5). Although hummingbirds (Family Trochilidae) were only represented by one species (Ruby-throated Hummingbird) (Figure 10), 21 individuals occurred at the three oak woodland stations, accounting for 25% of the total 84 birds (Table 5).

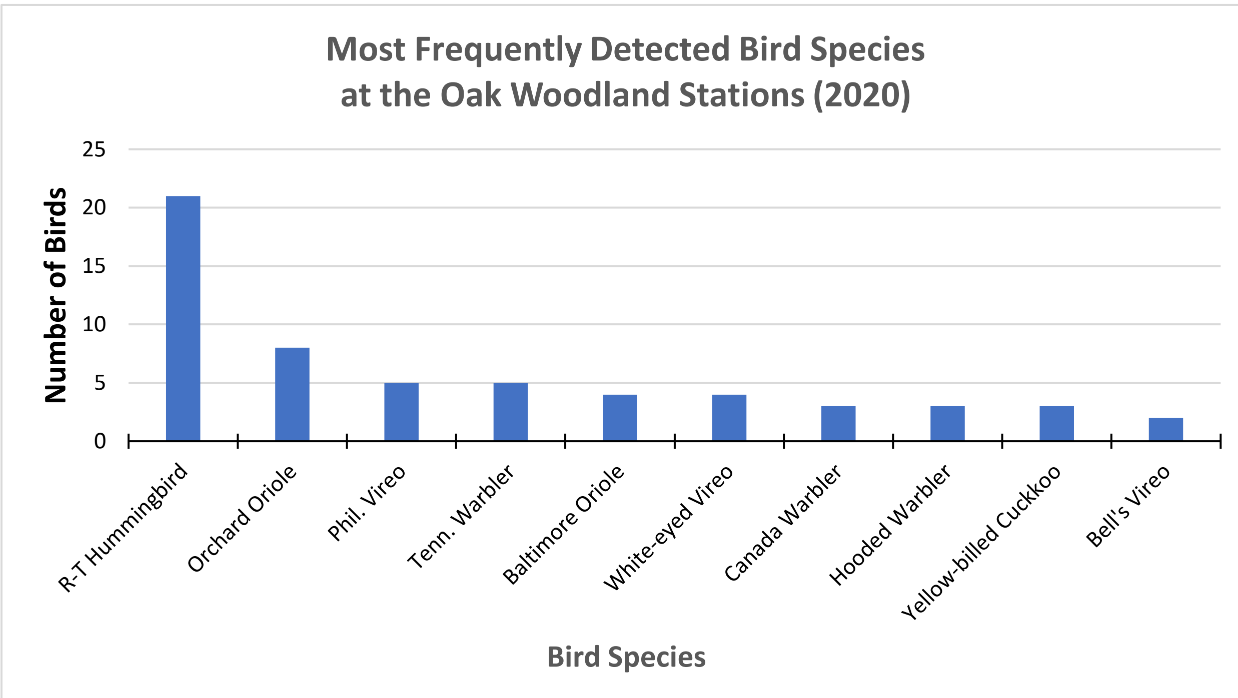

Figure 10. Spring 2020: Most frequently detected bird species at the oak woodland stations.

Three (3) species of blackbirds and orioles (Family Icteridae) totaled 14 individuals at the mature oak woodland survey stations, representing 16.7% of the total 84 birds. Six (6) species of vireos (Family Vireonidae) totaled 15 birds at the oak woodland sites and represented 17.8% of the total bird number (Table 5). Philadelphia Vireo (5) and White-eyed Vireo (*Vireo griseus*) (4) together accounted for 60% of all vireos detected in the three oak woodland stations.

Other less abundant bird families included Cardinalidae (5.9%), Cuculidae (3.6%), Mimidae (2.4%), Tyrannidae (1.2%), and Icteriidae (Monospecific) (1.2%) of the total 84 birds detected at the oak woodland survey stations (Table 5).

8.3.6 MATURE LIVE OAK WOODLANDS: SPRING 2023

During the 2023 surveys, two bird families were detected most frequently in the mature oak woodland stations. Wood warblers (Family Parulidae) were represented by six species, totaling 15 birds and representing 22.7% of the total 66 birds. No single wood warbler species predominated at the oak woodland sites (Table 6).

The second most abundant family (Cardinalidae) was represented by four species, totaling 12 birds and representing 18.2% of the total 66 birds. Summer Tanager (*Piranga rubra*) (7) was the most abundant species in this family (Figure 11).

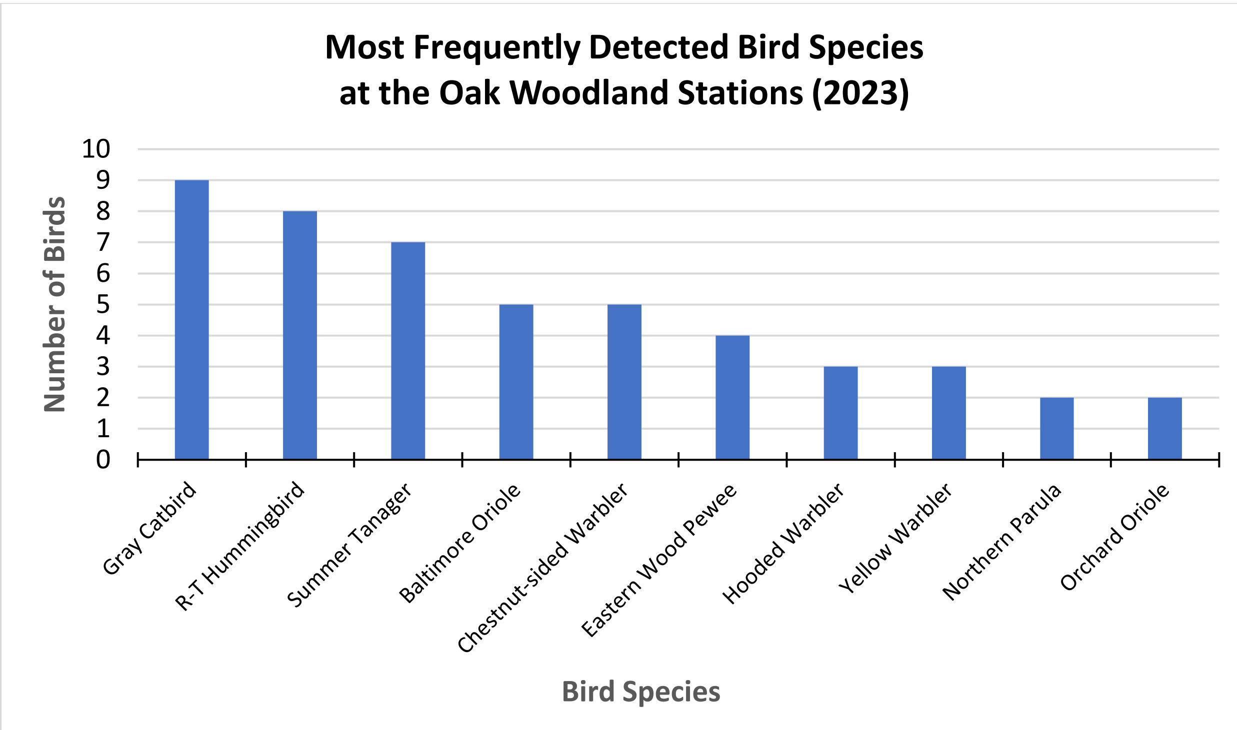

Figure 11. Spring 2023: Most frequently detected bird species at the oak woodland stations.

The third and fourth most abundant families were each represented by only one species. Gray Catbird (*Dumetella carolinensis*) (Family Mimidae) comprised 13.6% of the birds, and Ruby-throated Hummingbird (*Archilochus colubris*) (Family Trochilidae) comprised 12.1% of the birds (Table 6 and Figure 11).

Other less abundant bird families included Tyrannidae (10.6%), Icteridae (10.6%), Icteriidae (Monospecific) (3%), Vireonidaae (3%), Regulidae (3%), Turdidae (1.5%), and Passerellidae (1.5%) (Table 6).

8.4 BIRDS AND PLANT ASSOCIATIONS

8.4.1 TRANSPLANT PLOTS: SPRING 2017

During the five surveys in 2017, migratory bird use of plants within the 13 transplant plots was noted. Although the number of birds detected during the Spring 2017 transplant plot surveys totaled 216, associated plant use could only be detected for 214 birds. Plant species could not be identified for two birds because the associated plants were obscured from view.

Most birds (58.4%) in the transplant plots were observed using trees. The most frequently utilized tree species was honey mesquite, which was used by 75 individuals, 35.1% of all birds using plants, and 60% of all birds using trees within the transplant plots. Live oak was the second most frequently used tree species within the 13 transplant plots; it accounted for 19.2% of all trees used within the transplant plots (Table 7).

Table 7. Bird and plant associations during the 5 spring 2017 survey dates.

	Bird Numbers	
Plant Life Forms & Species	**Transplant Plots**	**Woodland Stations**
Life Form: Trees		
Honey Mesquite (*Prosopis glandulosa*)	75	--
Texas Live Oak (*Quercus fusiformis*)	24	35
Retama (*Parkinsonia aculeata*)	16	--
Cedar Elm (*Ulmus crassifolia*)	4	--
Red Bay (*Persea borbonia*)	--	3
Anaqua (*Ehretia anacua*)	3	--
Texas Sabal Palm (*Sabal mexicana*)	1	--
Wild Olive (*Cordia boissieri*)	1	--
Mexican Ash (*Fraxinus berlandieriana*)	1	--
Life Form: Shrubs		
Wax Myrtle (*Morella cerifera*)	22	--
Fiddlewood (*Citharexylum berlandieri*)	9	--
Texas Kidneywood (*Eysenhardtia texana*)	10	--
Turk's Cap (*Malvaviscus arboreus* var. *drummondii*)	8	--
Lantana (*Lantana* spp.)	4	--
American Beautyberry (*Callicarpa americana*)	1	--
Coral Bean (*Erythrina herbacea*)	2	--
Flame Acanthus (*Anisacanthus quadrifidus* var. *wrightii*)	1	--
Yaupon (*Ilex vomitoria*)	1	--
Life Form: Vines		
Mustang Grape (*Vitis mustangensis*)	--	2
Greenbrier (*Smilax bona-nox*)	--	1

	Bird Numbers	
Plant Life Forms & Species	**Transplant Plots**	**Woodland Stations**
Life Form: Forbs and Grasses		
Bermudagrass (*Cynodon dactylon*) and Vasey's Grass (*Paspalum urvillei*)	13	--
Western Ragweed (*Ambrosia psilostachya*)	6	--
Croton (*Croton* spp.)	2	--
Sow Thistle (*Sonchus oleraceous*)	2	--
Life Form: Leaf Litter/Ground		
Leaf Litter/Ground	8	2
Total	**214**	**43**
Total Number (Transplant Plots and Woodland Stations) = 257		

Table 7. Bird and plant associations during the 5 Spring 2017 survey dates (bird numbers for the 13 transplant plots and the 3 oak woodland stations cannot be compared directly because of unequal sample sizes).

Shrubs were the second most common plant life form used by birds in the 13 transplant plots; shrubs contained 58 individuals and 27.1% of all birds using the transplant plots (Table 7). The most frequently used shrub species was wax myrtle, which was used by 10.3% of all birds using plants and 38% of all birds using shrubs. Other commonly used shrub species within the transplant plots were kidneywood and fiddlewood.

Twenty-three birds were detected using forbs and grasses, representing 10.8% of all birds occurring within the 13 transplant plots (Table 7). Eight (8) birds were detected using leaf litter or the ground, representing 3.7% of all birds. There was no documented vine use by birds occurring within the 13 transplant plots.

8.4.2 TRANSPLANT PLOTS: SPRING 2020

Plant species use was determined for 295 birds using the 13 transplant plots during the four Spring 2020 survey dates. One hundred seventy-eight (178) birds, or 60.3% of all birds using the transplant plots, were observed using shrubs (Table 8). The most frequently used shrub species was the coral bean, used by 109 migrants, 36.9% of all birds using plants, and 61.2% of all birds observed in the shrubs. Wax myrtle, fiddlewood, and kidneywood were also commonly used.

Table 8. Bird and plant associations during the 4 Spring 2020 survey dates.

	Bird Numbers	
Plant Life Forms & Species	**Transplant Plots**	**Woodland Stations**
Life Form: Trees		
Texas Live Oak (*Quercus fusiformis*)	2	45
Honey Mesquite (*Prosopis glandulosa*)	41	--
Huisache (*Vachellia farnesiana*)	15	--
Retama (*Parkinsonia aculeata*)	11	--
Cedar Elm (*Ulmus crassifolia*)	10	--
Sugar Hackberry (*Celtis laevigata*)	9	--
Black Willow (*Salix nigra*)	8	--
Texas Sabal Palm (*Sabal mexicana*)	3	--
Anaqua (*Ehretia anacua*)	1	--
Mexican Ash (*Fraxinus berlandieriana*)	1	--
Red Bay (*Persea borbonia*)	--	1
Texas Ebony (*Ebenopsis ebano*)	1	
Life Form: Shrubs		
Coral Bean (*Erythrina herbacea*)	109	15
Wax Myrtle (*Morella cerifera*)	23	--
Fiddlewood (*Citharexylum berlandieri*)	16	--
Texas Kidneywood (*Eysenhardtia texana*)	16	--
Turk's Cap (*Malvaviscus arboreus* var. *drummondii*)	8	3
American Beautyberry (*Callicarpa americana*)	2	--
Dwarf Palmetto (*Sabal minor*)	2	--
Barbados Cherry (*Malpighia emarginata*)	1	--
Yaupon (*Ilex vomitoria*)	1	--
Life Form: Vines		
Mustang Grape (*Vitis mustangensis*)	--	15
Southern Dewberry (*Rubus trivialis*)	12	--
Greenbrier (*Smilax bona-nox*)	--	3
Life Form: Grasses and Reeds		
Little Bluestem (*Schizachyrium scoparium*)	1	--
Cattails (*Typha* spp.)	1	--
Life Form: Leaf Litter/Ground		
Leaf Litter/Ground	1	2
Total	**295**	**84**

Total Number (Transplant Plots and Woodland Stations) = 379

Table 8. Bird and plant associations during the 5 Spring 2020 survey dates (bird numbers for the 13 transplant plots and the 3 oak woodland stations cannot be compared directly because of unequal sample sizes).

Trees were the second most common plant life form used by migrants in the 13 transplant plots. One hundred two (102) birds, or 34.6% of all birds in the 13 transplant plots, occurred in trees. The most frequently used tree species was honey mesquite, which was used by 13.8% of all birds using plants, and 40.2% of all birds using trees. Huisache, retama, cedar elm, sugar hackberry, and black willow were also commonly used (Table 8).

Although only 12 birds were observed using vines in the 13 transplant plots, southern dewberry vines were used by 100% of all birds using this plant group (Table 8). Less than 1% of all birds used grasses, reeds, and leaf litter.

8.4.3 TRANSPLANT PLOTS: SPRING 2023

Plant species use was determined for 159 birds using the 12 transplant plots during the two Spring 2023 survey dates. Seventy-five (75) birds, or 47.2% of all birds using the transplant plots, were observed using trees (Table 9). The most frequently used tree species included honey mesquite, black willow, and live oak.

Table 9. Bird and plant associations during the 2 Spring 2023 survey dates.

	Bird Numbers	
Plant Life Forms & Species	**Transplant Plots**	**Woodland Stations**
Life Form: Trees		
Texas Live Oak (*Quercus fusiformis*)	10	30
Honey Mesquite (*Prosopis glandulosa*)	21	--
Huisache (*Vachellia farnesiana*)	4	--
Retama (*Parkinsonia aculeata*)	6	--
Sugar Hackberry (*Celtis laevigata*)	8	--
Black Willow (*Salix nigra*)	18	--
Texas Sabal Palm (*Sabal mexicana*)	1	--
Anaqua (*Ehretia anacua*)	2	--
Mexican Ash (*Fraxinus berlandieriana*)	1	--
Red Bay (*Persea borbonia*)	--	17
Texas Ebony (*Ebenopsis ebano*)	4	--
Life Form: Shrubs		
Coral Bean (*Erythrina herbacea*)	10	1
Wax Myrtle (*Morella cerifera*)	8	--
Fiddlewood (*Citharexylum berlandieri*)	2	--
Texas Kidneywood (*Eysenhardtia texana*)	3	--
Turk's Cap (*Malvaviscus arboreus* var. *drummondii*)	7	2

	Bird Numbers	
Plant Life Forms & Species	**Transplant Plots**	**Woodland Stations**
Life Form: Vines		
Mustang Grape (*Vitis mustangensis*)	--	2
Southern Dewberry (*Rubus trivialis*)	19	--
Greenbrier (*Smilax bona-nox*)	--	1
Life Form: Leaf Litter/Ground		
Leaf Litter/Ground	35	13
Total	**159**	**66**
Total Number (Transplant Plots and Woodland Stations) = 225		

Table 9. Bird and plant associations during the 5 Spring 2023 survey dates (bird numbers for the 12 transplant plots and the 3 oak woodland stations cannot be compared directly because of unequal sample sizes).

The ground, shrubs, and vines were used by 22%, 19%, and 12% (respectively) of all birds within the transplant plots. Common shrub use included coral bean, wax myrtle, and Turk's cap. In 2023, the combined use of the ground/leaf litter and southern dewberry vines was 34% which is significantly greater than the same combined habitat use by 4% of the birds in 2017 and 4% in 2020. This is primarily due to the large number of Gray Catbird in 2023.

8.4.4 MATURE LIVE OAK WOODLANDS: SPRING 2017

During the five Spring 2017 surveys, plant species use was determined for 43 birds occurring at the three mature oak woodland stations. Most of the birds (88.4%) used trees; 92.1% were detected in live oak (Table 7). The red bay was the only other tree species used by migrants at the oak woodland stations.

Although birds were detected using vines (7%) and leaf litter (4.6%), there was no documented use of shrubs, forbs, or grasses at the three oak woodland survey stations (Table 7).

8.4.5 MATURE LIVE OAK WOODLANDS: SPRING 2020

Plant species use was determined for 84 birds using the three mature live oak woodland stations during the four Spring 2020 survey dates. Most of the birds (54.8%) used trees; 98.0% were detected in live oak (Table 8). Red bay was the only other tree species used by birds in the oak woodland stations.

Shrubs were used by 21.4% of all birds within the three oak woodland stations. Coral bean was used by 83.3% of the birds using shrub vegetation. Vines were similarly used by 21.4% of all birds at the woodland stations. Of all the birds using vines, 83.3% were associated with mustang grape vines (Table 8).

8.4.6 MATURE LIVE OAK WOODLANDS: SPRING 2023

During the two Spring 2023 surveys, plant species use was determined for 66 birds occurring within the three mature oak woodland stations. Most of the birds (71%) used trees; 64% were detected in live oak (Table 9). Red bay, which accounted for 36% of the birds, was the only other tree species used by birds in the oak woodland stations.

Although shrubs and vines were each used by 4.5% of the birds, the ground/leaf litter accounted for 20% of the birds using the mature oak woodlands. The ground/leaf litter was only used by 4.6% of the birds in 2017 and 2.4% in 2020.

9.0 BIRD BEHAVIORS

9.1 TRANSPLANT PLOTS: SPRING 2017

Behaviors were explicitly evaluated for the migrants that utilized the 13 transplant plots during the five Spring 2017 survey dates. The most frequent behavior observed, by far, was foraging. Of the 216 migrants, 154 (71.3%) were foraging, and 58 (26.9%) were resting. Activity could not be determined for four, or 1.9% of the 216 birds because these birds were heard, but their activity was obscured from view.

The foraging estimate (71.3%) should be considered conservative, however, as 34 (58.6%) of the birds observed to be resting or perching were tyrant flycatchers. Foraging flycatchers sit atop a branch in a tree or shrub, waiting for a flying insect to approach. When an insect flies nearby, flycatchers will set out in mid-air to capture the insect before returning to perch, consume the insect, and await more prey. Because of this foraging behavior, perching flycatchers will often be classified as perching or loafing, whereas, in reality, perching is also part of their overall sit-and-wait foraging behavior. Thus, up to 34 flycatchers classified as perching or resting during the surveys may have been foraging instead. As a result, as many as 188 of the 216 migrants (87%) may have been foraging within the 13 transplant plots.

9.2 TRANSPLANT PLOTS: SPRING 2020

Behaviors were again evaluated for migrants using the 13 transplant plots. During the four Spring 2020 survey dates, the most frequent behavior observed, by far, was foraging. Of the 295 migrants using the transplant plots, 211 (71.5%) were foraging. Of the 84 migrants observed to be resting or perching, 26 (30.6%) were tyrant flycatchers or kingbirds; therefore, foraging activity within the 13 transplant plots may have been as high as 80% of all bird activity.

9.3 TRANSPLANT PLOTS: SPRING 2023

Behaviors were evaluated for migrants using the 12 transplant plots. During the two Spring 2023 survey dates, the most frequent behavior observed was foraging. Of the 159 migrants using the transplant plots, 111 (69.8%) were foraging. Of the 33 migrants observed to be resting or perching, two were tyrant flycatchers or kingbirds; therefore, foraging activity within the 12 transplant plots may have been as high as 71.1% of all bird activity.

9.4 MATURE LIVE OAK WOODLANDS: SPRING 2017

The behaviors of 43 migrants using the mature oak woodland stations were documented in 2017. The most frequently observed behavior was foraging (83.7% of birds).

9.5 MATURE LIVE OAK WOODLANDS: SPRING 2020

The behaviors of 84 migrants using the mature oak woodland stations were documented during 2020. The most frequently observed behavior was foraging (77.4% of birds).

9.6 MATURE LIVE OAK WOODLANDS: SPRING 2023

Behaviors of 66 migrants using the mature oak woodland stations were noted during 2023. The most frequently observed behavior was foraging (66.7% of birds). Of the 16 migrants observed to be resting or perching, three were flycatchers or kingbirds; therefore, foraging activity within the three mature oak woodland stations may have been as high as 71.2% of all bird activity.

9.7 PATTERNS OF BIRD USE: TRANSPLANT PLOTS AND MATURE OAK WOODLANDS

Surveyors were not able to view and gather Spring 2023 bird data for Transplant Plot GB12 due to dense plant growth within the project site. Plot GB12, the only plot constructed behind other transplant plots, was surveyed in 2017 and 2020, but had to be eliminated from the 2023 survey. Transplant Plot GB12 was subsequently removed from some of the survey data.

Tables 10, 11, and 12 depict the number and species of birds occurring in each transplant plot and mature oak woodland survey station during the Spring 2017, 2020, and 2023 surveys.

Table 10. Spring 2017: Number of birds, by species, in each transplant plot and mature oak survey station.

Species	GB1	GB2	GB3	GB4	GB5	GB6	GB7	GB8	GB9	GB10	GB11	GB12	GB13	Pack	CC	Aud	TOTAL
American Redstart															1	1	**2**
Baltimore Oriole	9	1	4		2		7	1			1		2		2	3	**32**
Bay-breasted Warbler	1													1			**2**
Black-billed Cuckoo														2			**2**
Blue Grosbeak		1									1			1			**3**
Blue-headed Vireo								1									**1**
Chestnut-sided Warbler														1			**1**
Chipping Sparrow	2						1										**3**
Common Yellowthroat	1	1															**2**
Couch's Kingbird								1									**1**
Dickcissel							2										**2**
Eastern kingbird					1		5	5		8							**19**
Eastern Wood Pewee	2						1				1		2	3	1	2	**12**
Gray-cheeked Thrush														1			**1**
Great-crested Flycatcher											1				1		**2**
Indigo Bunting	12	1			2								2			2	**19**
Least Flycatcher	1	1												1	1		**4**
Lincoln's Sparrow		1	1								4		1				**7**
Mourning Dove							2	1									**3**
Mourning Warbler																1	**1**
Nashville Warbler	3	1					2	1					1	1			**9**
Northern Parula															1		**1**
Olive-sided Flycatcher		1					1	2									**4**
Orchard Oriole	1				4	1							3			1	**10**
Painted Bunting	3															1	**4**
Philadelphia Vireo														2			**2**
Red-winged Blackbird									1							2	**3**
Red-eyed Vireo																1	**1**
Rose-breasted Grosbeak							3								1	2	**6**
Ruby-throated Hummingbird	1						1	1	1		1			1			**6**
Scarlet Tanager	1																**1**

Species	GB1	GB2	GB3	GB4	GB5	GB6	GB7	GB8	GB9	GB10	GB11	GB12	GB13	Pack	CC	Aud	TOTAL
Scissor-tailed Flycatcher	1					2	4										**7**
Sedge Wren							1										**1**
Summer Tanager	1		2				1	1								1	**6**
Tennessee Warbler	8	3					3			1			9	1			**25**
Warbling Vireo	3	2	2	1				1	1					1		1	**12**
Western Kingbird			1			2	2	6	2								**13**
Willow Flycatcher	1	2	1	1	1			3			4						**13**
Yellow Warbler	4	1	1				2	1		2				1			**12**
Yellow-bellied Flycatcher							1										**1**
Yellow-breasted Chat			1														**1**
Yellow-billed Cuckoo													2				**2**
TOTAL	**55**	**16**	**13**	**2**	**10**	**5**	**39**	**25**	**5**	**11**	**13**	**0**	**22**	**17**	**8**	**18**	**259**

Table 10. Spring 2017: Number of birds, by species, in each transplant plot and mature oak survey station.

Table 11. Spring 2020: Number of birds, by species, in each transplant plot and mature oak survey station.

Species	GB1	GB2	GB3	GB4	GB5	GB6	GB7	GB8	GB9	GB10	GB11	GB12	GB13	Pack	CC	Aud	TOTAL
American Redstart		1	1														**2**
Baltimore Oriole	1	3	8	1			7		1	4				2		3	**30**
Bell's Vireo																2	**2**
Black-and-white Warbler														1		1	**2**
Black-chinned Hummingbird										1							**1**
Black-throated Green Warbler													1				**1**
Blue-gray Gnatcatcher	1	1	1							1			2				**6**
Blue-headed Vireo														1			**1**
Canada Warbler	1															3	**4**
Chestnut-sided Warbler																1	**1**
Common Yellowthroat	1		1				1			1			5	1		1	**11**
Couch's Kingbird		1					1			1		1			1		**5**
Eastern Kingbird			1				1		7								**9**

Species	GB1	GB2	GB3	GB4	GB5	GB6	GB7	GB8	GB9	GB10	GB11	GB12	GB13	Pack	CC	Aud	TOTAL
Eastern Wood Pewee	1												1				**2**
Golden-winged Warbler													1				**1**
Gray Catbird		1	3				1							1		1	**7**
Hooded Warbler													3	2		1	**6**
Indigo Bunting		1	1										2			1	**5**
Least Flycatcher													1				**1**
Magnolia Warbler																1	**1**
Marsh Wren										1							**1**
Olive-sided Flycatcher													1				**1**
Orchard Oriole	2	8	15	5	2	4	11		2	16	1	1	6	3	3	2	**81**
Painted Bunting																1	**1**
Philadelphia Vireo		1							1				5	5			**12**
Red-eyed Vireo	1												1	1			**3**
Red-winged Blackbird									1							1	**2**
Rose-breasted Grosbeak	1		1														**2**
Ruby-throated Hummingbird	9	1	16	2	2	1	11	6	2	29	3	2	12	17	2	2	**117**
Scarlet Tanager														1			**1**
Scissor-tailed Flycatcher	4																**4**
Sedge Wren		1															**1**
Summer Tanager		1	2												2		**5**
Tennessee Warbler														4		1	**5**
Warbling Vireo	5	2	1											2			**10**
Western Kingbird	5																**5**
White-eyed Vireo									1				1	2	1	1	**6**
Wilson's Warbler	1																**1**
Worm-eating Warbler																2	**2**
Yellow Warbler	4		2											1		1	**8**
Yellow-billed Cuckoo	2	1											1		1	2	**7**
Yellow-breasted Chat		1											1	1			**3**
Yellow-rumped Warbler																1	**1**
Yellow-throated Warbler	1												1				**2**
TOTAL	**40**	**24**	**53**	**8**	**4**	**5**	**33**	**6**	**15**	**54**	**4**	**4**	**45**	**45**	**10**	**29**	**379**

Table 11. Spring 2020: Number of birds, by species, in each transplant plot and mature oak survey station.

Table 12. Spring 2023: Number of birds, by species, in each transplant plot and mature oak survey station.

Species	GB1	GB2	GB3	GB4	GB5	GB6	GB7	GB8	GB9	GB10	GB11	GB13	Pack	CC	Aud	TOTAL
Baltimore Oriole		5					2			2			3		2	**14**
Black-billed Cuckoo									1							**1**
Black-and-white Warbler								1								**1**
Black-throated Green Warbler									2							**2**
Blue Grosbeak								1								**1**
Blue-headed Vireo						1										**1**
Brown-headed Cowbird				1			1									**2**
Chestnut-sided Warbler	3			1	1									4	1	**10**
Common Yellowthroat	1			3				1	2		1	1			1	**10**
Connecticut Warbler	1															**1**
Couch's Kingbird							1								1	**2**
Eastern Wood-Pewee				1			3	1		1			1	2	1	**10**
Gray Catbird	3	8	7	2			2	14		1		3	5	2	2	**49**
Hooded Warbler															3	**3**
House Wren											1					**1**
Indigo Bunting		1						3					2			**6**
Least Flycatcher		1								1				1		**3**
Lincoln's Sparrow								2								**2**
Louisiana Waterthrush			1						1							**2**
Magnolia Warbler	1			1		1			1		2	2				**8**
Nashville Warbler											1					**1**
Northern Parula													1		1	**2**
Northern Waterthrush									1			1				**2**
Orchard Oriole	1	2	1			2	4						1		1	**12**
Ovenbird														1		**1**
Painted Bunting	1															**1**
Red-eyed Vireo											1	4		1		**6**
Rose-breasted Grosbeak	3			1									1		1	**6**
Ruby-crowned Kinglet									1						2	**3**
Ruby-throated Hummingbird	1	1	2	1	1	2	2	1		1		5	3	4	1	**25**

Species	GB1	GB2	GB3	GB4	GB5	GB6	GB7	GB8	GB9	GB10	GB11	GB13	Pack	CC	Aud	TOTAL
Savannah Sparrow													1			**1**
Scarlet Tanager		4										2	1			**7**
Summer Tanager	2											1	2	5		**10**
Swainson's Thrush			1		1						1		1			4
Tennessee Warbler	2											1				**3**
Warbling Vireo						3			1							**4**
White-eyed Vireo												1			1	**2**
Willow Flycatcher															1	**1**
Yellow Warbler													2	1		**3**
Yellow-breasted Chat													2			**2**
TOTAL	**19**	**22**	**12**	**11**	**3**	**9**	**15**	**24**	**10**	**6**	**7**	**21**	**26**	**21**	**19**	**225**

Table 12. Spring 2023: Number of birds, by species, in each transplant plot and mature oak survey station.

Figures 12 and 13 illustrate the variation in bird abundance and the total number of bird species for each of the 12 transplant plots that were compared during the 5 Spring 2017, 4 Spring 2020, and 2 Spring 2023 survey events.

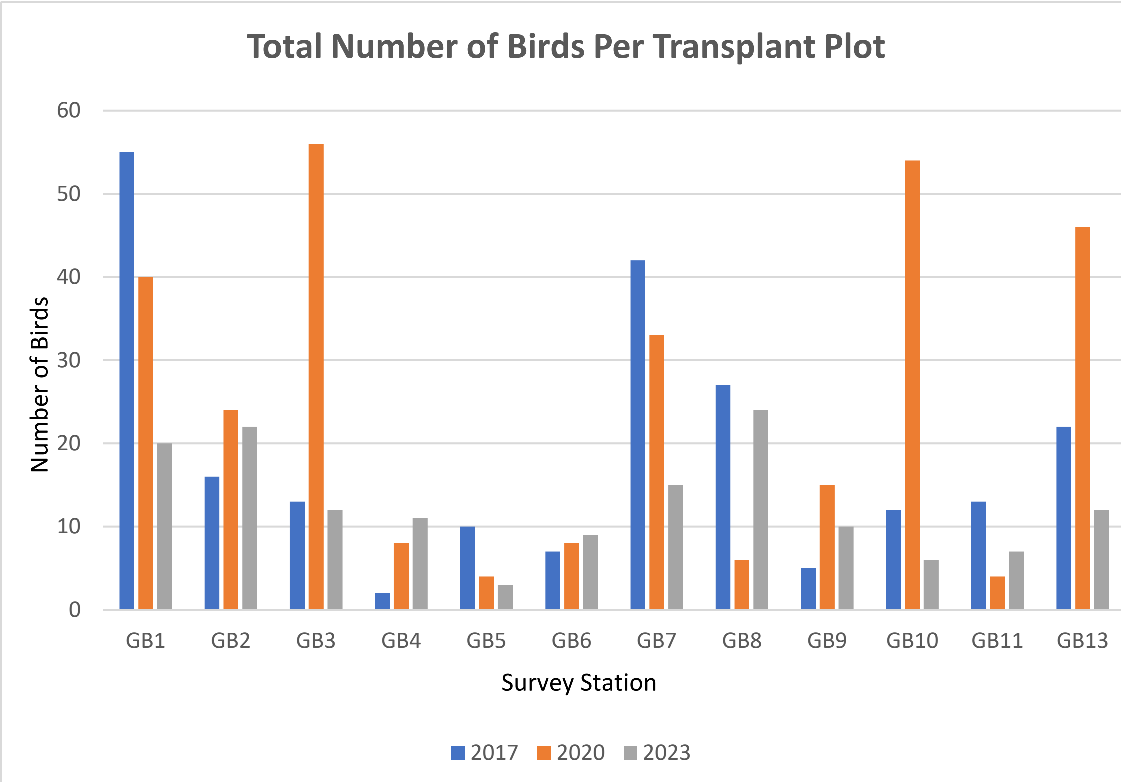

Figure 12. Total number of birds per transplant plot.

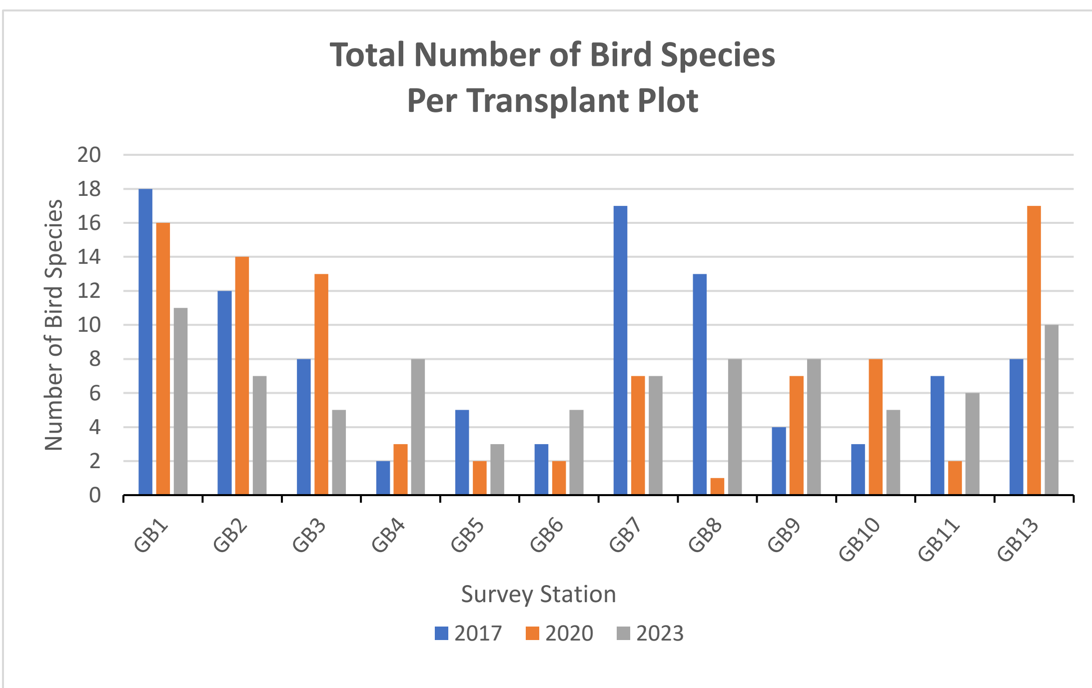

Figure 13. Total number of bird species per transplant plot.

9.7.1 ABUNDANCE AND DIVERSITY: TRANSPLANT PLOTS

Some transplant plots generally showed higher abundance than others. Abundance in transplant Plots GB1, GB7, GB8, and GB13 were relatively high during the Spring 2017 surveys (Table 10 and Figure 12). Although Spring 2020 Plots GB1, GB7, and GB13 once again had relatively high numbers of birds, Plots GB3 and GB10 contained the greatest number of birds (Table 11 and Figure 12). This dramatic increase in bird numbers can be attributed to high numbers of Ruby-throated Hummingbird and Orchard Oriole using the plot's coral bean plants. High numbers of Ruby-throated Hummingbird also occurred in Plots GB1, GB7, and GB13. In the Spring 2023, Plots GB1, GB2, GB7, and GB8 contained the greatest number of birds (Table 12 and Figure 12). Plots GB2 and GB8 had high numbers of Gray Catbird foraging on southern dewberries (Plot GB2) and on the ground (Plot GB8).

During all Spring surveys, bird diversity within the transplant plots was typically greatest among plots containing tall trees, distinct canopy layers, and open shrub/ground layers (Figure 13). Mesquite, hackberry, and live oak trees were often used as perch sites during foraging activities. Some plots, such as GB2, were utilized by a variety of birds that fed on large numbers of southern dewberries.

9.7.2 ABUNDANCE AND DIVERSITY: MATURE OAK WOODLANDS

Bird abundance and number of species varied at the mature oak woodland survey stations. The mature oak survey stations at Packery Channel Nature Park and the nearby Audubon Sanctuary consistently showed a high abundance and diversity of birds. Although the transplant plots and mature oak woodland survey stations cannot be compared directly, bird use trends are evident (Figures 14 and 15).

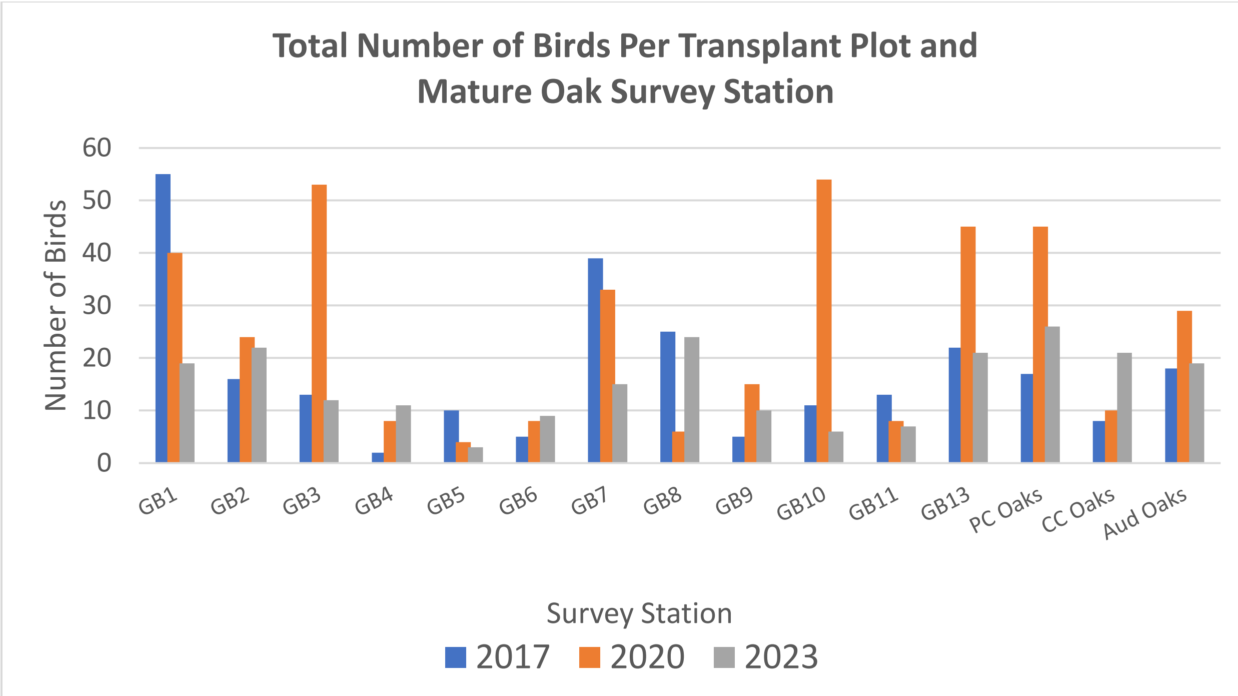

Figure 14. Total number of birds per transplant plot and mature oak woodland survey station.

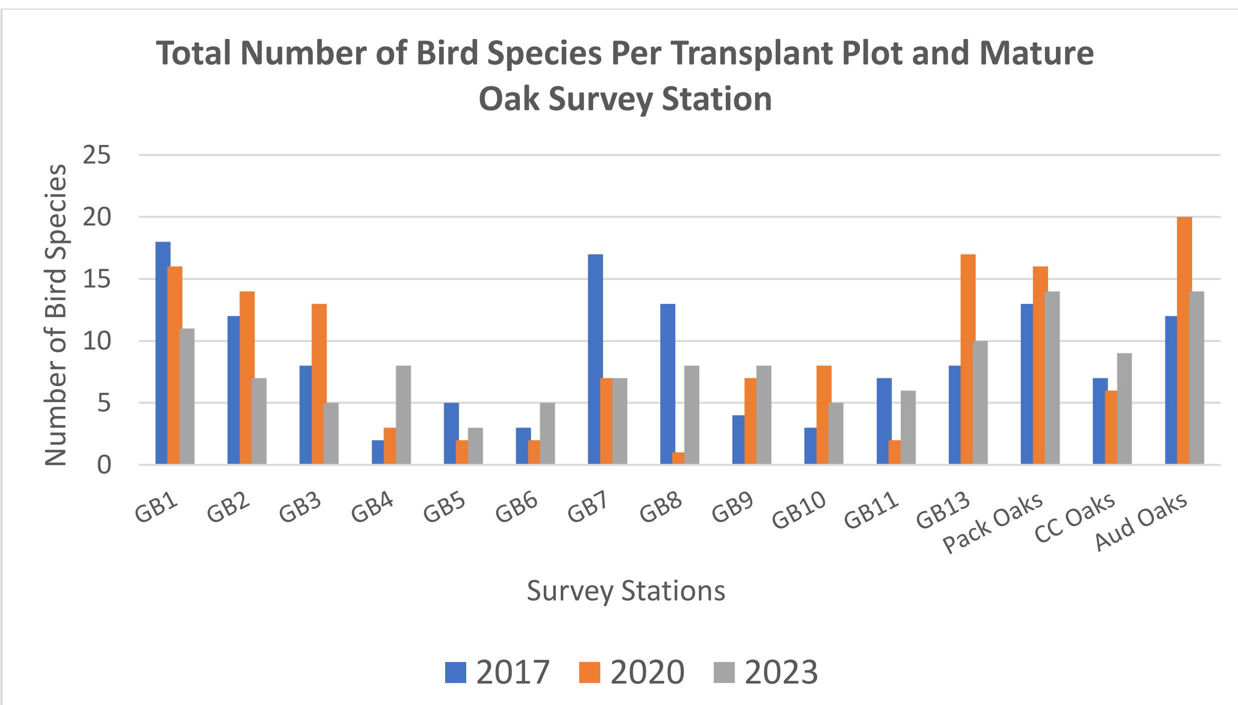

Figure 15. Total number of bird species per transplant plot and mature oak woodland survey station.

9.7.3 SPECIES DIVERSITY AND SPECIES RICHNESS

At the transplant plots in 2020, the highest diversity index (H') values were for sites GB13 (H'= 1.87), GB1 (H'= 1.91), and GB3 (H'= 1.78). The 2020 diversity index values are slightly less than the highest diversity values for 2017 plot sites GB7 (H'= 1.99), GB1 (H'= 1.90), and GB8 (H'= 1.79). In 2023, the highest diversity index (H') values at the transplant plots were for sites GB1 (H' = 1.83), GB13 (H' = 1.82), and GB11 (H' = 1.75). Figure 16 depicts the average species diversity indices for each transplant plot and mature oak woodland survey station.

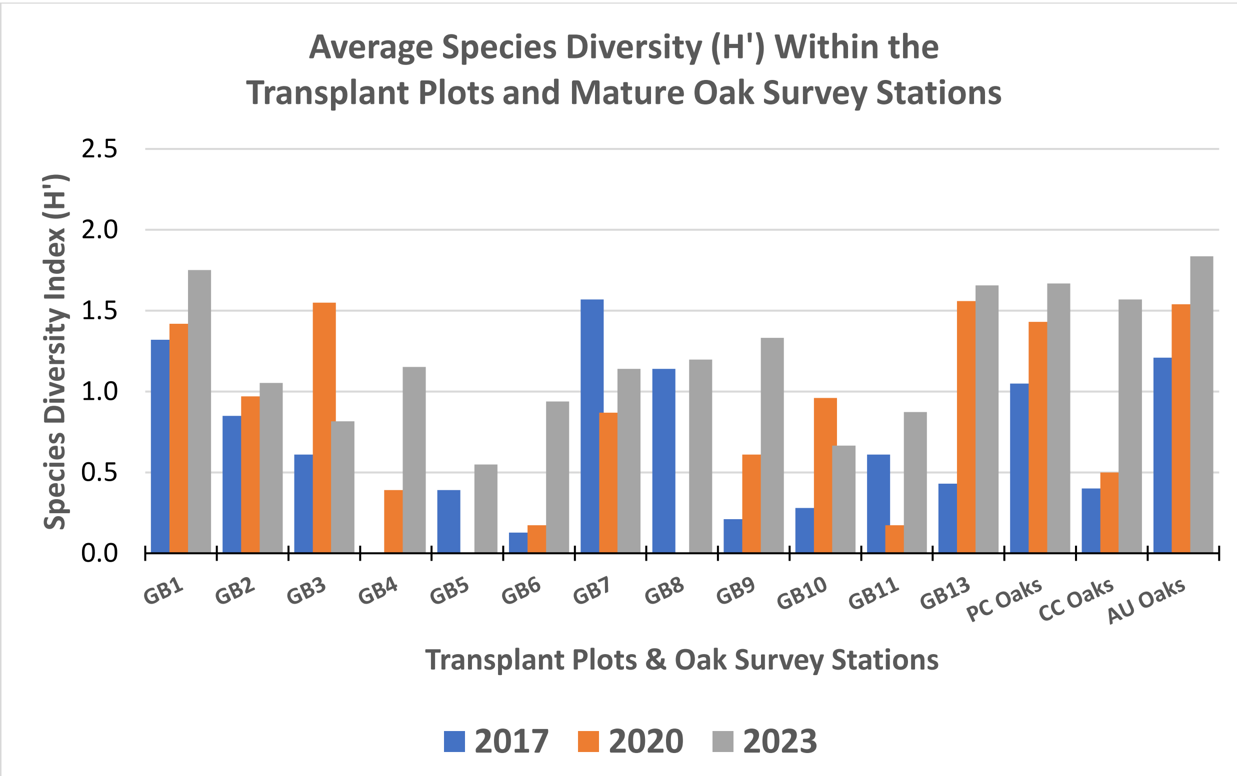

Figure 16. Species diversity within the transplant plots and mature oak woodland survey stations.

In 2017, the lowest average diversity index (H') values occurred in plots GB4 and GB6. The lowest average indexed plots in 2020 were GB5 and GB8. Plots with the lowest average diversity index (H') values in 2023 were GB3, GB5, and GB10. Most plots during the 2017, 2020, and 2023 bird surveys had positive species diversity numbers.

The nearby PCNP and CCW oak woodland stations had diversity index (H') values ranging from 0.0 to 1.33 in 2017, 0.00 to 1.75 in 2020, and 1.03 to 2.31 in 2023. The Audubon oak woodland station had the highest diversity index values (H') in 2017 (H'= 1.04 - 1.38), 2020 (H'= 1.01 – 1.89), and 2023 (H' = 1.33 - 2.34).

However, the diversity index (H') for bird species did not follow the same pattern as that of abundance and species richness when comparing 2017, 2020, and 2023 total survey species counts. The 2023 surveys had higher diversity index values, with fewer species and bird counts.

The 2023 bird surveys had a higher diversity index than the 2020 and 2017 surveys. However, the 2020 and 2017 surveys had higher bird and species counts. Ruby-throated Hummingbird and Orchard Oriole in 2020 and Baltimore Oriole and Tennessee Warbler in 2017 were recorded in greater numbers than other species. The evenness component of the species index that measures species evenness distribution takes into account how evenly the bird counts (individuals) were distributed among the surveys. A survey station with several different species having similar abundances is considered more diverse than another survey station dominated by only one or two species. An increase in species richness and evenness increases species diversity indices. The 2020 surveys included high bird counts for Ruby-throated Hummingbird (117 birds) and Orchard Oriole (81 birds). The highest bird counts in 2017 were Baltimore Oriole (32 birds) and Tennessee Warbler (25 birds). The highest bird counts in 2023 were Gray Catbird (49 birds) and Ruby-throated Hummingbird (25 birds).

Bird Species Richness (D) values serve as one measure of biodiversity that can represent the relative conservation value of a particular area (EnviroAtlas, 2014). In 2023, Transplant Plots GB1, GB9, and GB13 had the highest Species Richness values. Plots GB2, GB5, and GB11 had the lowest values. The Transplant Plot GB1 and the mature oak woodland station AU Oaks had the highest overall values of all the transplant plots and nearby oak woodland stations (Figure 17).

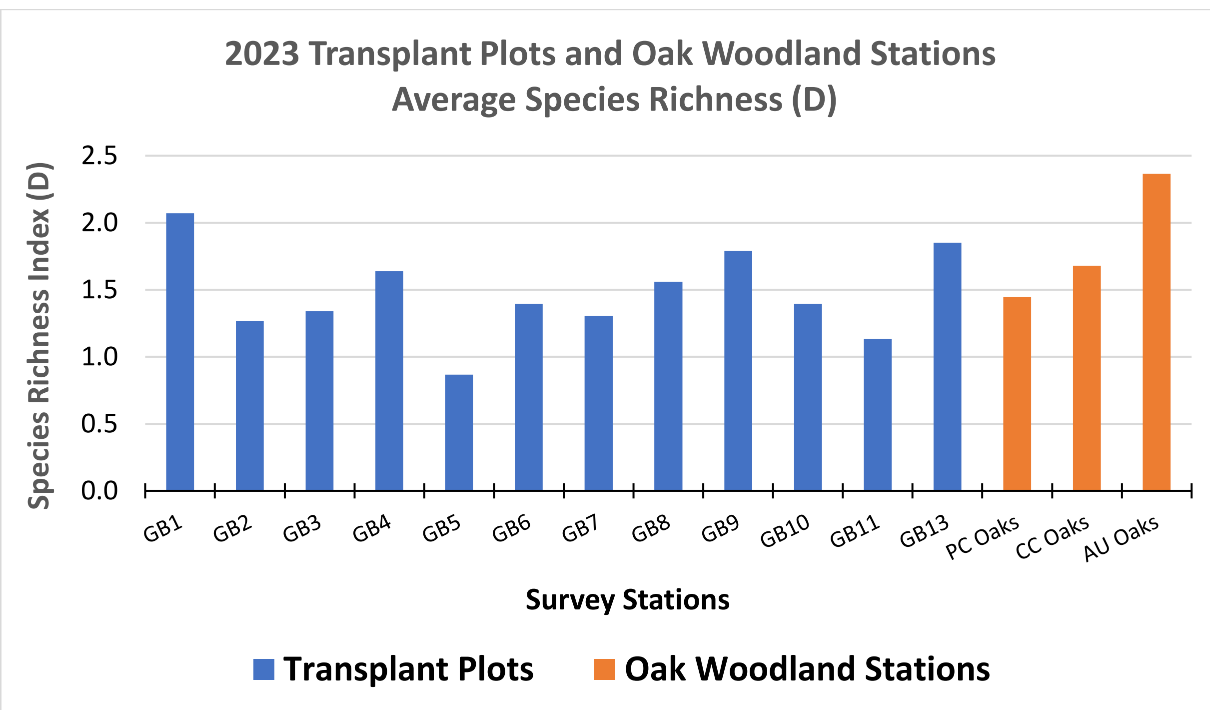

Figure 17. Dominant bird use within the transplant plots and woodland stations: species richness.

Average bird species counts varied among the transplant plots during the five Spring 2017 survey efforts. The greatest species counts (numbers of species averaged over the five Spring 2017 survey efforts) include Plot GB1 (5.2), Plot GB7 (5.4), and Plot GB8 (3.60). All other transplant plots averaged <3.0 species/survey. Similar trends were observed relative to species diversity.

Average bird species counts varied among the transplant plots during the four Spring 2020 surveys. The greatest species counts (numbers of species averaged over the four Spring 2020 survey efforts) include Plot GB13 (6.0), Plot G3 (5.7), and Plot G1 (5.2). All other transplant plots averaged <3.75 species/survey. Similar trends were observed relative to species diversity.

Average bird species counts varied among the transplant plots during the two Spring 2023 surveys. The greatest species count (numbers of species averaged per plot over the two Spring 2023 survey efforts) are as follows: Plot GB1 (6.6), Plot GB8 (4.5), and Plot GB13 (6). All other transplant plots averaged <4.1 species/survey.

10.0 DISCUSSION

10.1 BIRDS AND HABITATS

While this study yielded numbers of birds using the transplant plots and nearby mature live oak woodlands, the raw data for total bird numbers for these two habitats cannot be compared directly. Since sampling efforts differed between them, the larger number of sampling stations in the transplant plots was virtually assured of generating larger bird tallies than the three nearby mature oak woodland stations.

However, when bird abundance was converted to bird numbers/unit effort, the transplant plots (3.3 birds/survey/plot) and mature oak woodland stations (2.9 birds/survey/station) in 2017 were nearly identical. Similarly, the transplant plots had 5.7 birds/survey/plot, and the mature oak woodland stations had 7.0 birds/survey/station during the Spring 2020 surveys. In 2023, the transplant plots had 7.6 birds/survey/plot, and the mature oak woodland stations had 11.0 birds/survey/station. This suggests that these two habitat types may be quite similar in habitat suitability for migratory birds during spring fallout events.

The bird families most heavily represented at the transplant plots and nearby oak woodland stations during the Spring 2017 surveys were Tyrannidae (tyrant flycatchers), Parulidae (wood warblers), Grosbeaks, Tanagers, and Buntings (Cardinalidae), and blackbirds and orioles (Icteridae) (Table 4). Dominant families during the Spring 2020 surveys also included tyrant flycatchers, wood warblers, and blackbirds and orioles (Table 5). Again, in 2023, dominant families included Tyrannidae, Parulidae, Cardinalidae, and Icteridae. This close relationship between birds at the transplant plots and mature oak woodlands suggests that despite distinct differences in plant species composition, maturity, and physical structure, the two habitat types may be quite similar in habitat suitability, at least at the broad taxonomic level of bird families.

Many of the species of Neotropical migrants reported nearly fifty years ago at multiple stopover sites in the Texas Coastal Bend (Forsyth and James 1971) were from these same four families of birds. This indicates that coastal woodland habitats remaining in this region continue to meet the needs of the same array of Neotropical migratory birds.

The 2017, 2020, and 2023 bird survey results agree with the findings of Moore and Woodrey (1993), who noted differences in species-specific habitat use among Neotropical migrants on Horn Island, a Mississippi barrier island. Likewise, some of the same relatively abundant migrant species on North Padre Island were commonly found using stopover habitats during Spring surveys on Horn Island (Moore and Woodrey 1993). These species included Eastern Kingbird, Tennessee Warbler, Rose-Breasted Grosbeak, Indigo Bunting, and Orchard Oriole.

Two important differences between the Spring 2017 and the Spring 2020/Spring 2023 surveys were the very high numbers of Ruby-throated Hummingbird and Orchard Oriole during the 2017 survey. These high numbers are directly related to specific plant (coral bean) use (see Section 10.2.1).

Although the raw data cannot be used to compare the transplant plots to the nearby oak woodland stations due to sampling size, differences in migrant species' use of the transplant plots and mature oak woodlands during Spring 2017 and 2020 were evident. Relatively large numbers of Eastern Kingbird (28), Western Kingbird (18), and Alder/Willow Flycatcher (13) were observed in the transplant plots utilizing mesquite, live oak, wax myrtle, retama, and fiddlewood. None of these tyrant flycatchers were detected at the oak woodland stations during 2017 or 2020. Their absence is not unexpected, as these species often prefer open woodlands and woodland edges. Although the live oak trees within the transplant plots are still young with an open canopy, the vegetation at the three nearby mature oak woodland stations consists of dense running live oak thickets and occasional large live oak tree mottes with a closed canopy. According to Holmes and Robinson (1981), the physical structure of habitat, including plant species composition and foliage structure, influences habitat suitability by affecting how birds move through the habitat and how they see and capture prey.

10.2 BIRDS AND PLANT ASSOCIATIONS

10.2.1 TRANSPLANT PLOTS

Tree species showing the greatest migrant use in the transplant plots during Spring 2017 were honey mesquite (75), Texas live oak (24), and retama (16) (Figure 18). The greatest tree use during Spring 2020 was honey mesquite (41), huisache (11), retama (11), cedar elm (10), sugar hackberry (9), and black willow (8). Dominant tree use in the Spring 2023 included honey mesquite (21), black willow (18), and Texas live oak (10).

The number of different bird species using trees within the transplant plots during 2017 was 18 (mesquite), 12 (live oak), and 8 (retama) (Table 7). The number of bird species using transplant plot trees during 2020 were 16 (mesquite), 8 (huisache), 7 (retama), 6 (black willow), 4 (hackberry), and 3 (cedar elm) (Table 8). The number of bird species using transplant plot trees in 2023 were 14 (mesquite), 13 (black willow), 7 (live oak), 6 (retama), 5 (hackberry), and 3 (huisache) (Table 9).

Figures 18 and 19 depict dominant trees used by migrants and the diversity of birds using them. Various bird species used the tall mesquite trees with their open canopies as they perched and consumed food items or were ready to fly back and retrieve more food.

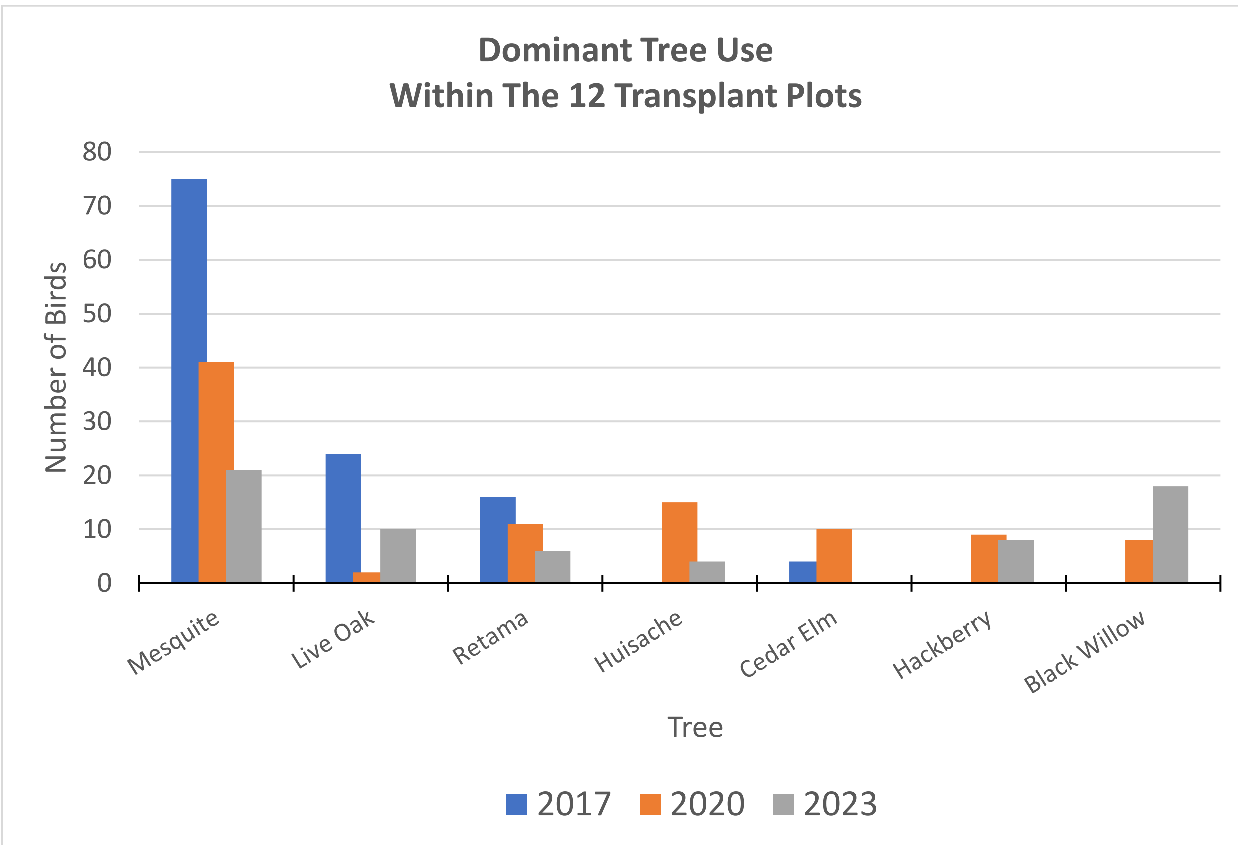

Figure 18. Dominant trees used within the 12 transplant plots: bird abundance.

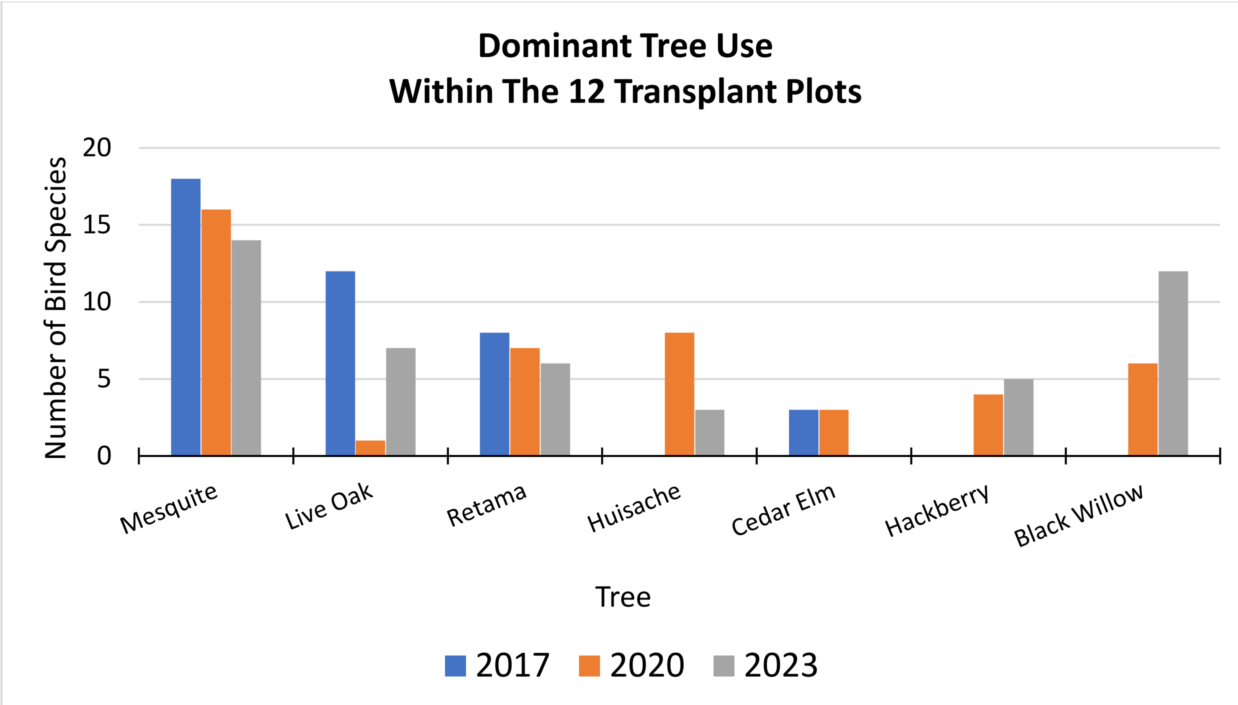

Figure 19. Dominant trees used within the 12 transplant plots: bird diversity.

Shrub species showing the greatest migrant use in the transplant plots during Spring 2017 included wax myrtle (22), Texas kidneywood (10), fiddlewood (9), and turk's cap (8) (Figure 20). The greatest shrub and vine use during Spring 2020 was coral bean (109), wax myrtle (23), Texas kidneywood (16), fiddlewood (16), southern dewberry (15), and turk's cap (8). Greatest shrub and vine use during Spring 2023 was southern dewberry (19), coral bean (10), wax myrtle (8), turk's cap (7), Texas kidneywood (3), and fiddlewood (2).

The number of different bird species using shrubs within the transplant plots during 2017 was 14 (wax myrtle), 6 (fiddlewood), 5 (kidneywood), and 5 (turk's cap) (Figure 21). The number of bird species using transplant plot shrubs and vines during 2020 were 6 (southern dewberry), 5 (coral bean), 8 (wax myrtle), 6 (fiddlewood), 4 (kidneywood), and 4 (turk's cap). In 2023, the number of shrub and vine bird species included 4 (southern dewberry), 4 (coral bean), 4 (wax myrtle), 3 (turk's cap), 3 (kidneywood), and 1 (fiddlewood).

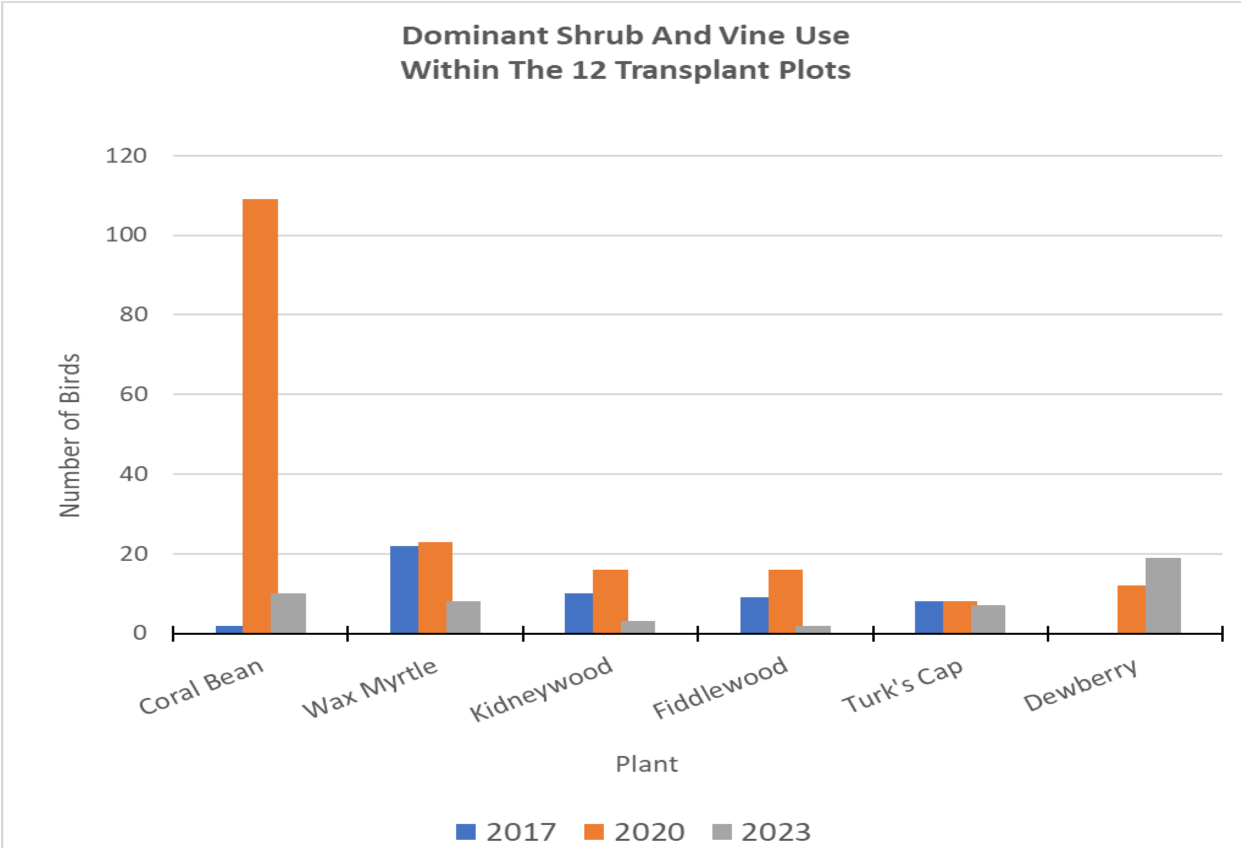

Figure 20. Dominant shrub and vine use within the 12 transplant plots: bird abundance.

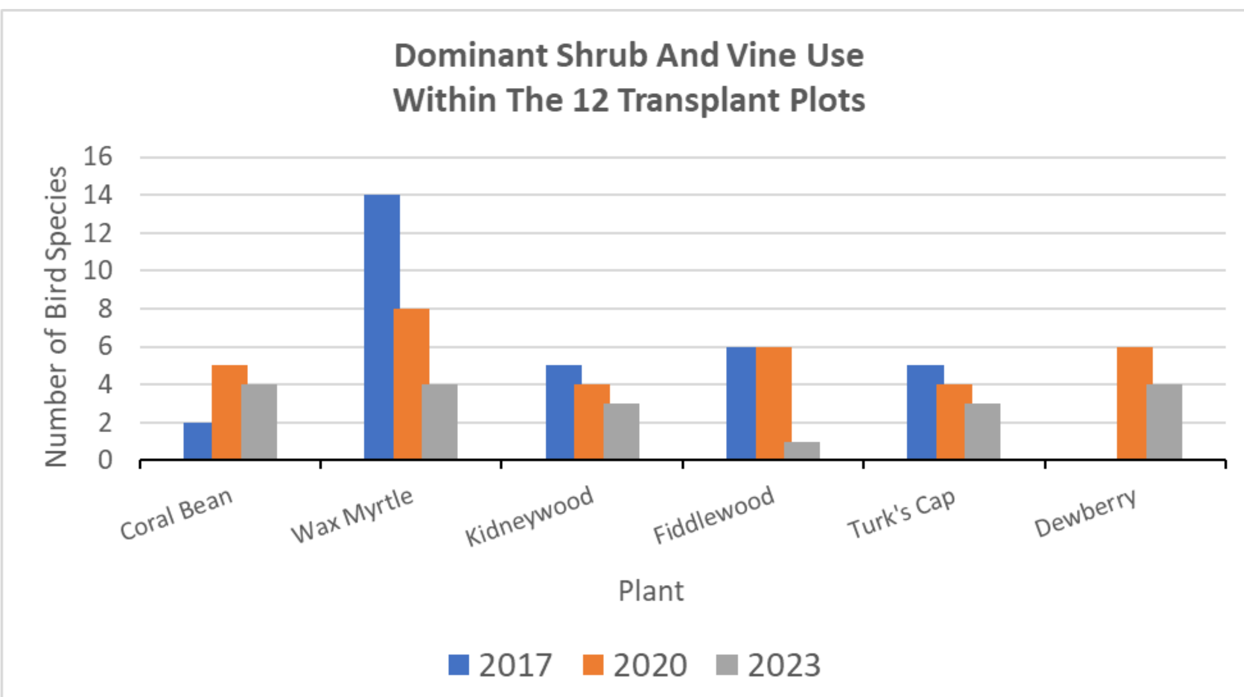

Figure 21. Dominant shrub and vine use within the 12 transplant plots: bird diversity.

Specific plant use among the transplant plots varied in both total bird numbers and diversity. Some plants, such as coral bean, had very high bird use (abundance), but low diversity. A total of 109 birds were observed using coral bean in the transplant plots during the four combined Spring 2020 survey events: 63 (57.9%) were Ruby-throated Hummingbird, 32 (29.3%) were Orchard Oriole, 12 (11.0%) were Baltimore Oriole, 1 (0.9%) was Black-chinned Hummingbird (*Archilochus alexandri*), and 1 (0.9%) was Blue-gray Gnatcatcher (*Polioptila caerulea*).

The variation in bird numbers and species among the Spring 2017, 2020, and 2023 surveys within the transplant plots implies that food resources, for which migrants are using these plots, vary temporally as the spring season progresses. Also, the data shows that some transplant plots were favored more by Neotropical migrants. Those plots showing consistently low bird or species numbers seemed less attractive to migratory birds (for example Plots GB4, GB5, GB6, and GB11 (Figure 12). This could reflect spatial variation in how food items were available. For instance, Plots GB3 and GB10 had high bird use during the Spring 2020 surveys due to the heavy use of coral bean shrubs by Ruby-throated Hummingbird and Orchard Oriole. Multiple studies have shown that both spring and fall migrants select habitats based on food availability in many regions of North America (Martin 1980, Graber and Graber 1983, Hutto 1985, Hoppes 1987, Weisbrod et al. 1993).

Other factors could also contribute to the observed variability in bird numbers and species diversity within the transplant plots. Among the factors that could influence the distribution of Neotropical migrants are structural complexity, vegetation density at different heights, the extent of ground cover, heights of tree saplings and shrubs, and the variety of available foods. Measuring these variables, especially over time, can be highly labor-intensive and could not be undertaken during the Spring 2017, 2020, and 2023 survey efforts.

Nevertheless, given the available data and field observations from the Spring surveys and results from supporting studies, additional insights can be offered to discuss why bird numbers and species diversity were relatively greater at specific transplant plots. For example, Plots GB1 and GB13 may have attracted more birds because of their proximity to the park's sizeable mature oak motte. Plot GB1 also contains taller trees and distinct canopy layers. Many of the birds observed in this plot were moving back and forth by temporarily perching in the open canopy of the mesquite trees and then flying down into the shrubs or grassy groundcover to feed. According to Moore et al. (1990), spring migrants prefer habitats with greater structural diversity when they arrive on the northern Gulf coast following a trans-Gulf flight.

This pattern was also prominent in Plot GB7, where Baltimore Oriole and Red-breasted Grosbeak (*Pheucticus ludovicianus*) were observed flying into the plot, temporarily perching in the open-canopied mesquite trees, and then flying down into a stand of fiddlewood to feed on the ripe berries. According to the 2018 plant survival monitoring report, Plot GB7 had the highest plant survival rate (99%) and the greatest transplant diversity. The high structural diversity of shrub/scrub habitats on Gulf Coast barrier islands has been implicated in habitat selection by spring migrants (Moore et al. 1990). Both species composition and physical structure have been shown to affect habitat use by migratory birds (Robinson and Holmes 1982, 1984).

Certain transplant plots were also relatively close to several bird drip fountains and ponds, which may have made them more attractive because of a nearby water source. Transplant Plot GB9, a riparian woodland, contained open water throughout the Spring 2017, 2020, and 2023 bird survey events. Dehydration following long-distance migration has been offered as another factor that could affect habitat use and migratory behavior (Fogden 1972, Leberg et al. 1996).

10.2.2 MATURE OAK WOODLANDS

Birds were primarily detected utilizing trees in the nearby mature oak woodland stations. Although vines are prominent, these oak woodlands do not contain many shrubs. During Spring 2017, 38 birds were observed using trees (Table 7). Of the 38 birds, 35 occurred in live oak (Figure 22), and three occurred in red bay. In 2020, 46 birds were detected using trees (Table 8) with 45 birds occurring in live oak (Figure 22), and one in red bay. In 2023, 47 birds occurred in trees, 17 in red bay (Table 9), and 30 occurred in live oak (Table 9 and Figure 22).

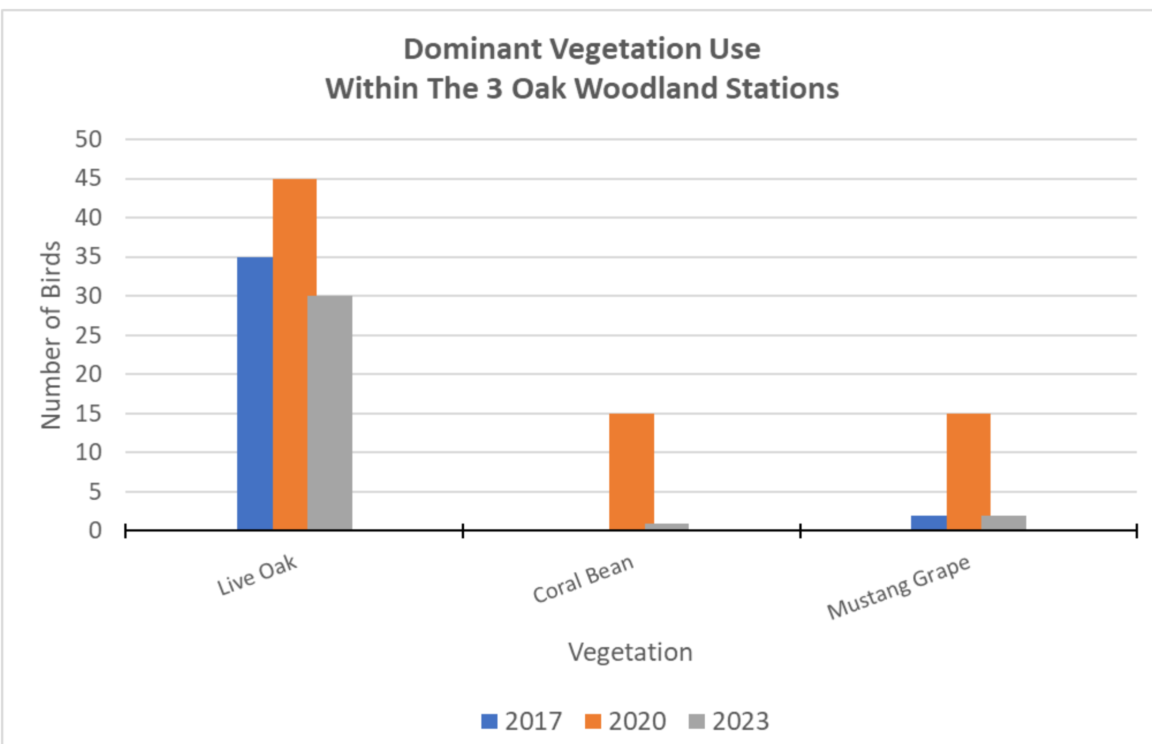

Figure 22. Dominant plant use within the 3 oak woodland stations: bird abundance.

Species diversity was greatest among the live oaks with 21 species in 2017, 23 species in 2020, and 16 species in 2023 (Figure 23).

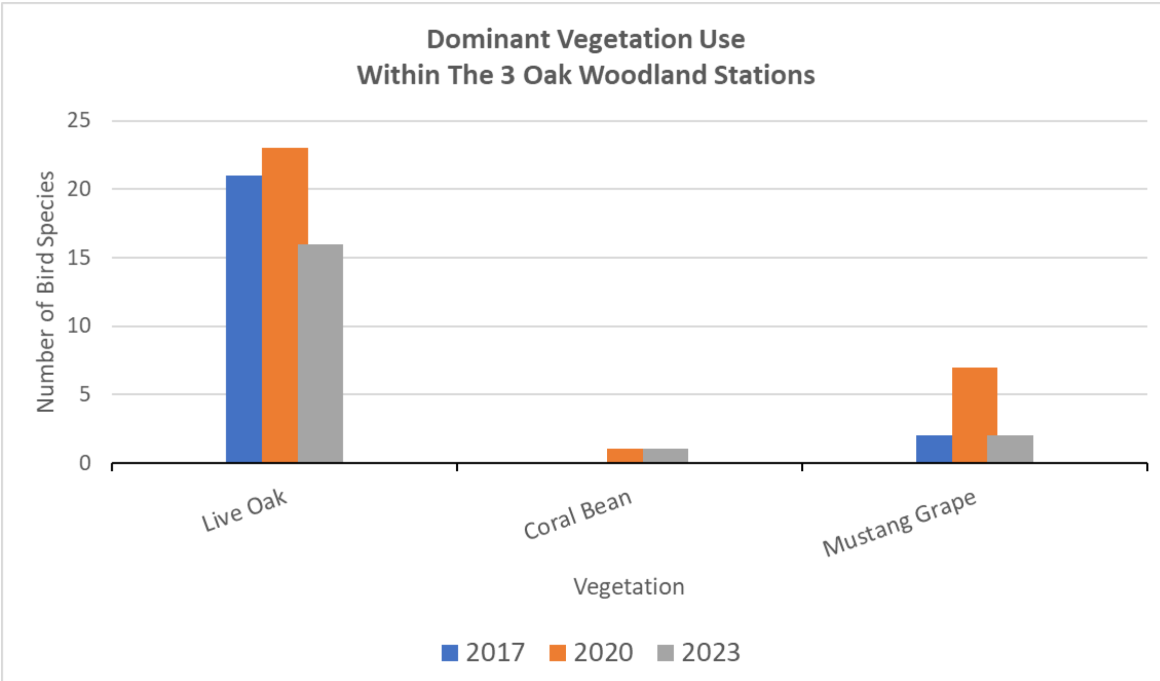

Figure 23. Dominant plant use within the 3 oak woodland stations: bird diversity.

Mustang grape and greenbrier vines were also utilized during all spring survey events. A total of two birds used mustang grape vines in 2017, 15 in 2020, and two in 2023 (Figure 22). Species diversity can be high for mustang grape (Figure 23) and other vines. According to Barrow et al. (2000), vines easily entrap falling dead leaf clumps, which provide essential food patches for a variety of migrants, such as Worm-eating Warbler.

Some of the bird use patterns unquestionably relate to the differences in plant age, species composition, and structural complexity between the transplant plots and the nearby mature oak woodlands. Although the transplant plots contain a greater diversity of plant species and plant life forms, they are still immature. The nearby oak woodlands represent a mature climax forest, and these woodlands have been in their current state for 70-100+ years. The oak woodlands are dominated nearly entirely by live oak, often with a closed canopy. These characteristics create understory conditions of reduced light, intense competition for water, and litter composed mainly of oak leaves, none of which favors the development of a dense understory of shrubs, forbs, and grasses beneath the oak canopy.

10.3 BIRD BEHAVIORS

Birds behaved quite similarly in the transplant plots and the mature oak woodlands. Foraging was the dominant behavior of most migrants in both habitat types, suggesting that fallout migrants were likely exhibiting hyperphagia, by intense feeding to build fat reserves to meet the high energy costs of long-range migration.

10.4 FOODS CONSUMED

According to the Natural Resource Conservation Service (NRCS, 2001), the broadest array of different insects will provide food for the most extensive variety of songbirds. Some of the common types of insects consumed by songbirds include caterpillars, bagworms, webworms, moths, butterflies, beetles of all kinds, plant lice (aphids), scale insects, leaf hoppers, tree hoppers, leaf rollers, stinkbugs, spittlebugs, grasshoppers, crickets, katydids, cicadas, roaches, dragonflies, mayflies, craneflies, flies, gnats, mosquitoes, wasps, bees, ants, termites, and earwigs. The larvae and eggs of these adult forms are also readily consumed. Other invertebrates such as spiders, scorpions, millipedes, sowbugs, snails, slugs, ticks, and earthworms are also eaten. A large variety of trees, shrubs, vines, forbs, and grasses will, in turn, support a large number and diverse array of insects.

While food items consumed by birds observed in the transplant plots and nearby mature live oak woodlands were not enumerated or contrasted, it was apparent that the birds foraging in the transplant plots were consuming a variety of foods. For example, worms (presumed to be sawfly larvae) occurring in coral bean flower clusters (Photo 55) were aggressively fed upon by Orchard Oriole, Baltimore Oriole, tanagers, and several species of flycatchers during the 2017 and 2020 surveys. Spittle masses containing two-lined spittlebug (*Prosapia bicinta*) nymphs (Photo 56) were observed on several different plant species within the transplant plots, including non-target groundcover plants such as western ragweed (*Ambrosia psilostachya*) and Texas goldentop (*Euthamia gymnospermoides*). Various warblers (particularly Tennessee Warbler), vireos (particularly Warbling Vireo), and tyrant flycatchers were observed aggressively feeding on the nymphs during the Spring 2017 survey events. According to research conducted by Carlisle et al. (2012), several invertebrate taxa were eaten preferentially by migrants, including spittlebugs, stink bugs, and beetles.

Photo 55. Sawfly larvae (presumed) occurring within coral bean flower clusters.

Photo 56. Spittlebug nymphs were aggressively consumed by migrants.

Although the identification and enumeration of specific food items were not included in the survey efforts, general observations were noted. After each survey was completed, notes were taken relative to prey items, which plants were in bloom, and if fruit or seeds were present. Not surprisingly, plants that were in bloom or contained ripened fruit during the survey events often had the greatest number of foraging birds. Some plants in bloom during the spring surveys included mesquite, kidneywood, coral bean, retama, huisache, black willow, and turk's cap. Migrant species may specialize in using different foraging substrates; therefore, stopover habitats containing diverse plant communities that produce a variety of pollen, nectar, fruits, seeds, and insects are best equipped to provide sufficient food resources for migratory species (Barrow et al. 2000, Moore et al. 1993).

Plants that produce fruit or flowers during the spring migration season appear to be especially important to several migrant species (Barrow et al. 2000). Fruit that occurred on southern dewberry, wax myrtle, fiddlewood, yaupon, and mustang grape within the transplant plots and nearby oak woodland stations were in various ripening stages but once ripe, were rapidly consumed during a single grounding event. This suggests that a diversity of plant species, plant life forms, and seasonality may be important considerations during the planning stages.

There is mounting evidence that fruits are essential dietary components during the non-breeding season for many migrant species that were previously viewed as primarily insectivorous (Carlisle et al. 2012, Jordano 1988, Blake and Loiselle 1992, Parrish 1997, 2000, Smith et al. 2007, Smith and McWilliams 2010). According to Moore et al. (1990), fruit facilitates fat deposition and provides a rapid (short-term) solution to nutrient deficiencies resulting from prolonged activities such as migratory flight. Jordano (1988) and Parrish (1997) found that diets combining fruit and arthropods led to migrants gaining weight more rapidly than diets comprised of only fruit or insects. According to Carlisle et al. (2012), migrating birds appear flexible enough to adjust their behavior at stopover sites by foraging where prey and fruit are abundant and consuming the most readily available food types that still allow them to gain mass.

11.0 SUMMARY

11.1 FINDINGS

The number of birds in the transplant plots during the Spring 2017, 2020, and 2023 survey dates was 216, 295, and 150 Neotropical migrants, respectively. Most of the birds using the transplant plots were foraging, which suggests that the migrants were probably exhibiting hyperphagia (intensive feeding to build fat reserves) to meet the high energy costs of long-range migration. This is important because it supports the assumption that this newly created habitat type is needed for and used by migrants during fallout events.

When bird abundance was converted to bird numbers/unit effort, the results for the transplant plots (3.3 birds/survey/plot) and nearby mature live oak woodland stations (2.9 birds/survey/station) in 2017 were nearly identical. Similarly, the transplant plots had 5.7 birds/survey/plot and the mature oak woodland stations had 7.0 birds/survey/station during the Spring 2020 surveys. In 2023, the transplant plots had 7.6 birds/survey/plot, and the mature oak woodland stations had 11.0 birds/survey/station. This suggests that these two habitat types may be quite similar in habitat suitability for migratory birds during spring fallout events. Therefore, it can be deduced that the newly created woodland habitat does provide some level of food resources for spring migrants during fallout events.

Foraging was the most frequently observed behavior of birds detected in the transplant plots and the mature oak woodland stations. Migratory birds were foraging on a variety of plants and food items which supports the assumption that plant diversity is important.

Certain plants were more heavily used by migrants for foraging. Honey mesquite, retama, sugar hackberry, cedar elm, and black willow experienced the greatest migrant use among the transplant plots. Over 60% of all migrants using the transplant plots in Spring 2020 were observed using shrubs. The most frequently used shrub species included coral bean, wax myrtle, fiddlewood, and kidneywood. Some plants, such as coral bean, had very high bird use during Spring 2020 surveys with 109 migrants (Ruby-throated Hummingbird, Orchard Oriole, and Baltimore Oriole) using this plant species.

During the PCNP spring surveys, birds consumed fruit (particularly southern dewberry and fiddlewood) and insects. These observations are consistent with other studies where migrating birds appear to be flexible enough to adjust their behavior at stopover sites by foraging where prey and fruit are abundant.

The four bird families most heavily represented at the transplant plots and nearby mature oak woodland stations were Tyrannidae, Parulidae, Cardinalidae, and Icteridae. Although Family Trochilidae was also heavily represented in the survey data, this family was only represented by one species: Ruby-throated Hummingbird. The close relationship between birds at the transplant plots and nearby mature oak woodlands suggests that the two habitat types, despite very distinct differences in plant species composition, maturity, and physical structure, may be quite similar in habitat suitability, at least at the broad taxonomic level of bird families. Many of the Neotropical migrant species reported nearly fifty years ago at multiple stopover sites in the Coastal Bend (Forsyth and James 1971) were from these same five families of birds. This indicates that the coastal woodland habitat remaining in this region continues to meet the needs of the same array of Neotropical migratory birds.

11.2 CONSERVATION APPLICATIONS

According to Mehlman et al. (2005), it is very challenging to identify how a particular stopover site will contribute to a successful migration due to the range of intrinsic factors (ecological variability) such as food availability and landscape structure, to extrinsic factors such as prominent weather events or a migrant's condition. Therefore, conservationists agreed that stopover sites can at least be defined based on their capacity to meet migrant's needs at a given point in space and time. Based on the Spring 2017, 2020, and 2023 bird survey results, the newly created habitats within the transplant plots do provide adequate shelter, water, and food resources (immediate needs) for migrants during spring fallout events on the Central Texas Coast.

"Fire escape" stopover sites are described as being infrequently used but are utterly vital in emergency situations (Melman et al. 2005). The resources within a fire escape may be too low to allow birds to replenish fat stores or recover muscle mass, but the stop enables them to survive and continue migrating from the site. Fire escapes are typically located adjacent to significant barriers, like large bodies of water (e.g., the Gulf of Mexico), deserts, or intensively altered landscapes. They are generally small and isolated habitat patches surrounded by unusable habitat. Weather is a very important factor in determining when fire escape sites are used. Therefore, migrant densities can be very high at times. The situations where high densities of migrants utilize fire escape stopover sites are often predictable due to overriding extrinsic factors such as weather. Based on 2017, 2020, and 2023 Spring bird survey data and the criteria described in the literature, the 2-acre woodland stopover habitat project currently functions as a fire escape stopover site.

Gautreaux (2013) studied migrant use of urban coastal landscapes along the Gulf of Mexico. Study results show that coastal woodlots embedded in heavily urbanized settings likely provide valuable opportunities for temporary resting by *en route* migrants after crossing the Gulf of Mexico and before continuing to stopover sites further inland. Gautreaux recommended that coastal habitats be considered critical primary refueling sites due to the emergency energetic situation faced by some migrants at landfall after costly flights across the Gulf of Mexico. It was also recommended that coastal woodlots within urban environments along the immediate coast be designated as valuable refuges for *en route* migrants. The PCNP Spring 2017, 2020, and 2023 bird surveys support the assumption that woodland habitat creation projects on Central Texas barrier islands can meet the immediate needs of spring migrants even within urbanized areas.

Although Barrow et al. (2000) found hackberry, red mulberry, honey locust, green hawthorn, vine tangles, and other plants that fruit or flower during the spring migration period to be important microhabitat features for *en route* migrants in the Chenier Plain, the identity of suitable plant species for the Central Texas Coast may not be available in the literature. The

PCNP habitat creation project has successfully identified and evaluated native plant species that contribute important vegetative structure and food resources for migrants.

According to Barrow et al. (2000), invasive plants may pose one of the most serious threats to the integrity of chenier forests in southwest Louisiana and southeast Texas. One of the most aggressive and damaging invasive plants along the Central Texas Coast is the Brazilian peppertree (*Shinus terebinthifolius*), a native of Argentina, Paraguay, and Brazil. This invasive plant has infested coastal habitats around Port Aransas and Corpus Christi. According to the Texas Invasives Database, this peppertree is considered one of the greatest threats to Texas' native biodiversity for its dramatic effect on plant and animal communities.

During the PCNP habitat creation project, Nueces County developed a proclamation that gives the County high priority to controlling this Brazilian peppertree on County coastal parklands. An aggressive peppertree control program, which has been in place for seven years, ensures that peppertrees are eradicated from the entire 38-acre park site. As Barrow et al. (2000) point out, invasive plants may be one of the most serious threats to the integrity of coastal woodlands. Based on local knowledge of the rapid and significant damage Brazilian peppertrees have wrought on Central Texas coastal habitats, it would be prudent to address short- and long-term management of invasive plants when attempting to create, enhance, or preserve habitats for use by Neotropical migrants along the Texas Coast.

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