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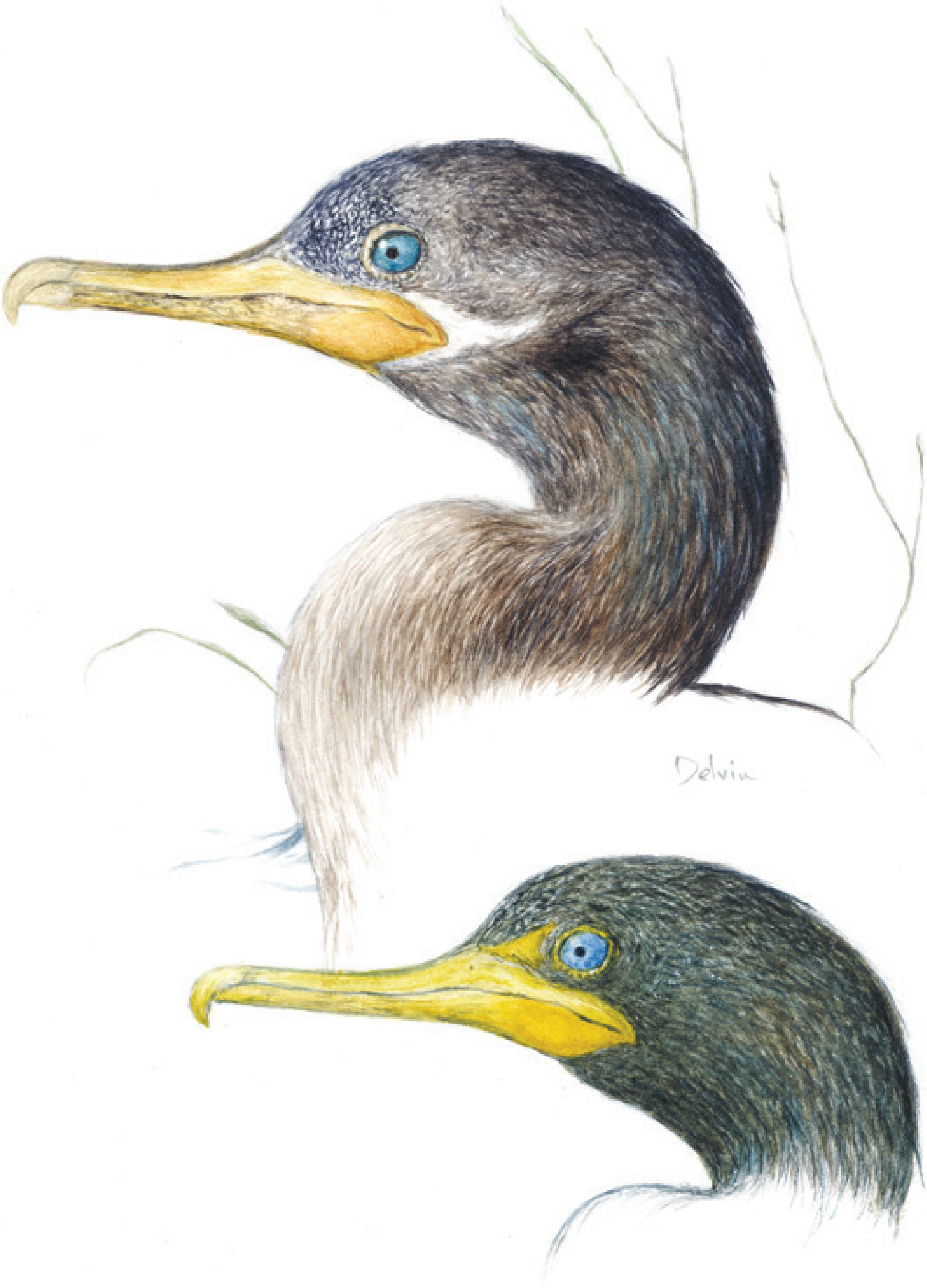
[1] Starting with Vol. 42 both issues were combined..

Cover Figure: Adult Eastern (top) (TX), Northern (center) (T), and Western (bottom) (CA) Red-tailed Hawk.
Heard Museum. McKinney.



Frontispiece. (top) Neotropical Cormorant (bottom) Double-Crested Cormorant. Artwork by Lynn Delvin..

BULLETIN OF THE

TEXAS ORNITHOLOGICAL SOCIETY

ASSESSING CORMORANT POPULATIONS AND ASSOCIATION WITH FISH STOCKING IN TEXAS

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ABSTRACT.—Double-Crested Cormorants (*Nannopterum auritum*) and Neotropic Cormorants (*Nannopterum brasilianum*) are thought to be expanding their populations across Texas. This expansion is cause for a concern for both fish stocking and fisheries management in public waters. To examine the historic and current populations and distributions of cormorants, we first evaluated the temporal and spatial patterns of cormorants in Texas. Also, because cormorants are thought to depredate public fisheries, we conducted a small observational field study to assess cormorant presence and behavior at lakes relative to fish stocking. We compiled Christmas Bird Count (CBC) data for both species over a period of fifty years (1970 to 2019). We assessed changes in detection rates at CBCs among years as evidence of population trends during the winter, and changes in distance from the Gulf Coast of CBCs reporting cormorants for evidence of changes in distribution. Our results suggest that winter populations of Double-Crested Cormorants are relatively stable, with no meaningful change in distribution. In contrast, Neotropic Cormorants appear to be both increasing in number and expanding their range. Our assessment of cormorant abundance and behavior at stocked and unstocked lakes from December through February revealed a significant difference in detections among the stocked lakes during pre- and post-stocking but no significant difference among the control lakes.

Cormorants (*Phalacrocoracidae*) are medium-to-large-sized piscivorous birds that dive underwater to hunt opportunistically on bottom feeding and schooling fishes (Hatch and Weseloh 2014). Cormorants are found primarily in coastal regions but can also be found at inland lakes and reservoirs. There are two species of cormorant found in Texas, the larger Double-Crested Cormorant (*Nannopterum auritum*) and the smaller Neotropic Cormorant (*Nannopterum brasilianum*). The Double-Crested Cormorant has been the focus of conservation and management concern across much of the United States and Canada. Initially this was focused on conservation, as the species experienced a significant population decline across North America from 1950-1970 due to pesticide use and development along coastlines (Dorr et al. 2016). Subsequent to the population declines, Double-Crested Cormorant numbers have been increasing across their geographic range, with most of the population growth occurring through the late 1970s to the early 1990s (Wires et al. 2001). The Neotropic Cormorant is a tropical species found across most of South and Central America, and only reaching as far north as Texas and Louisiana in the United States (Telfair and Morrison 2021). Similar to

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Double-Crested Cormorants, Neotropic Cormorants experienced a population decline prior to the 1970s (Telfair 2006b). The population has been steadily increasing since the early 1970s (Telfair and Morrison 2021). More extensive research has been conducted on Double-Crested Cormorants than of Neotropic Cormorants (Telfair and Morrison 2021) due to their relative abundance across the United States and Canada and concerns for depredations on fisheries (Dorr et al. 2014).

Specific to Texas, Double-Crested Cormorants are winter residents at inland lakes, reservoirs, and coastal areas but the winter population in the state is not well known (Campo et al. 1993, Thompson et al. 1995). A small number also breed in Texas, but that population segment is poorly understood (Wires et al. 2001, Telfair 2006a). It is estimated the wintering population of Double-Crested Cormorants in Texas fluctuates from approximately 50,000-90,000 birds (Telfair 2006a). Neotropic Cormorants are present year-round and were found to be present in breeding colonies along the Gulf Coast and some inland reservoirs (Telfair 2006b). The more restricted distribution has facilitated a better understanding of the species in the state. In Texas, based on Christmas Bird Count data, wintering Neotropic Cormorants were found almost entirely along the Gulf Coast in the 1960s, but as much as 17% were found inland by the mid-2000s (Treflair 2006b). The population of Neotropic Cormorants fluctuates but was estimated at 7,400 breeding individuals in 2004 (Telfair and Morrison 2005).

The conservation success of recovery and increase in cormorant populations since the early 1970s has had the downside of created challenges for management. Over the last decades, there has been an increasing conflict between conservation of cormorants, the perceived and real predatory impacts they pose to managed fisheries, and the justification of setting population objectives based on human values such as sport fishing (Taylor and Dorr 2003, Wires and Cuthbert 2006, Dorr et al. 2021). Continentally, most of these conflicts have been in the northern Great Lakes region and in the southeastern United States; by the late 1990's 27 state agencies had reported that fish stocks were being depredated by cormorants (Dorr et al. 2016).

More recently, there is a common perception that cormorants have increased across interior Texas and that their depredations may be of concern in inland water bodies stocked for recreational fishing. This has led to increased requests for permits for lethal removal to reduce depredations. The little quantitative information for both species in Texas, however, impedes the assessment of the validity of conflict and justification of management actions. Given cormorants are protected in the United States under the Migratory Bird Treaty Act of 1918 as amended (16 U.S.C. §§ 703 – 712), justification for control efforts is not a negligible issue and requires specific authorizations (16 U.S.C. § 703). In 2020 we initiated a study to assess the historic and current populations of Double-Crested Cormorants and Neotropic Cormorants in Texas and to assess their association with fish stocking schedules at a small sample of lakes. Our goal was to obtain information to inform current management decisions and future research planning for cormorants in Texas.

METHODS

Study Area

For population estimates we considered the entire state of Texas. For pre- and post-stocking surveys and time-constrained foraging observations, we used 6 lakes of similar size (~1.0 – 5.0 ha; Table 1) located in the Dallas – Fort Worth metropolitan area. These were Chisholm Park Lake (32° 51' 25" N, 97° 10' 21" W), Bedford Boys Park Lake (32° 50' 51" N, 97° 8' 56" W), Greenbriar Park Lake (32° 40' 12" N, 97° 20' 8" W), Echo Lake (32° 41' 57" N, 97° 18' 52" W), Lakeside Park Lake (32° 39' 20" N, 96° 55' 14" W), and Emerald Lake (32° 39' 10" N, 96° 57' 53" W).

Population Assessment

We used Christmas Bird Count (hereafter, CBC) data to examine population changes of cormorants in Texas. We considered other methods but found Breeding Bird Survey data were inadequate due to poor representation of cormorants, and eBird data were not useful due to lack of consistency in data collection and no standardization of effort.

We approached this assessment with goals of estimating the population sizes of each species in Texas, assessing changes in population sizes over time, and examining changes in distribution. We compiled data from all CBCs in Texas conducted from 1970 – 2019. CBC data are standardized by detections of individual species per unit of effort at each CBC. We examined data on basis of 1) total numbers of each cormorant species detected each year at CBCs and 2) the detections/observer hour at CBCs. The former may be influenced by an increase in the number of CBCs across the 50-years study period. Thus, an increase in the count may be an artifact of more CBCs being conducted, but it provides an estimate of the winter population size. In contrast, the detections/observer hour is independent of the number of CBCs conducted; increases or decreases would be indicative of actual population trends. Finally, if either species was expanding their distribution, we would expect to see an increase in the average distance that CBC locations with cormorant detections were from the Texas coast.

To facilitate analysis, we pooled data into 5-year blocks (e.g., 1970 – 1974 = block 1). We then used an analysis of variance (ANOVA) test to examine average cormorant detections per observer hour at each CBC across the ten 5-year time blocks. To assess if ranges were expanding, we used ANOVAs to compare average distance of detections from the coast among the ten 5-year blocks of time. We conducted these analyses for each cormorant species.

For our second objective, we conducted periodic surveys at 6 lakes in the Dallas – Fort Worth metropolitan area from late November through early March. Three of these lakes were part of the Texas Parks and Wildlife Department neighborhood fishing lake program and were regularly stocked with rainbow trout, and three were ‘control’ lakes of similar size that were not stocked. We paired a stocked lake with a control lake of similar size for comparison and for logistical practicality. We conducted ANOVAs to assess changes in cormorant counts before and after stocking at control lakes and stocked lakes. We did not differentiate cormorant species during these surveys. Surveys were conducted by personnel from Texas Tech University and from Texas Parks and Wildlife Department.

We sampled cormorant foraging efforts by conducting 5-minute observations of randomly selected cormorants that were swimming during lake visits post-stocking. During these observation periods, a cormorant was selected and followed for the 5-minute block of time, with the observer attempting to constantly track the cormorant, count the number of dives it made, record when it came up with a fish, and if possible, identify fish to species. There was the possibility of the observer switching cormorants if the cormorant under observation dove and a different cormorant surfaced and was mistaken for the focal individual.

RESULTS

The number of CBCs conducted in Texas increased from 53 in 1970 to 112 in 2019 (average increase of 1.6 ± 4.0/yr.). Thus, there was a substantial change in the number of CBCs/year across the sampling period (Fig. 1). Reports of Double-Crested Cormorants increased from 11 CBCs (21% of all CBCs) in 1970 to 90 CBCs (82% of all CBCs) in 2019 (average increase of 4.9% ± 11.6/yr). Reports of Neotropic Cormorants increased from 5 CBCs (9% of all CBCs) in 1970 to 67 CBCs (61% of all CBCs) in 2019 (average 6.9% ± 19.6/yr). Increases in CBCs reporting cormorants have been ~ 4 – 6 x greater than the increase in CBCs conducted (Fig. 1). This suggests, but does not exclude the possibility, that detections of both species reveals an increase that is not an artifact of more CBCs conducted over time.

A more informative means of assessing population changes is by detections/observer hour, which standardizes the index across years. We found detections/observer hour for Double-Crested Cormorants (Fig. 2) increased across the 50-year period, but that the increase was not statistically significant ($F_{9,2831} = 1.4021$, $P < 0.1812$). Despite the lack of statistical significance, it appears populations have fluctuated with peaks occurring in the late 1980s through the 1990s (Fig. 2). Consistent with this, the mean distance to the Gulf Coast from the CBCs reporting the species has not increased ($F_{9,2831} = 1.3753$, $P = 0.1935$).

In contrast to Double-Crested Cormorants, we found detections/observer hour for Neotropic Cormorants (Fig. 3) increased significantly across the 50-year period ($F_{9,1394} = 5.1117$, $P < 0.0001$). Additionally, the average distance from the Gulf Coast to CBCs reporting Neotropic Cormorant significantly increased ($F_{9,1394} = 7.8420$, $P < 0.0001$) each 5-year block. This increase in distance from 68 km in 1970-74 to 156 km in 2015-19 occurred at an average increase of 9.9% ± 7.4% per 5-year block (Fig. 3).

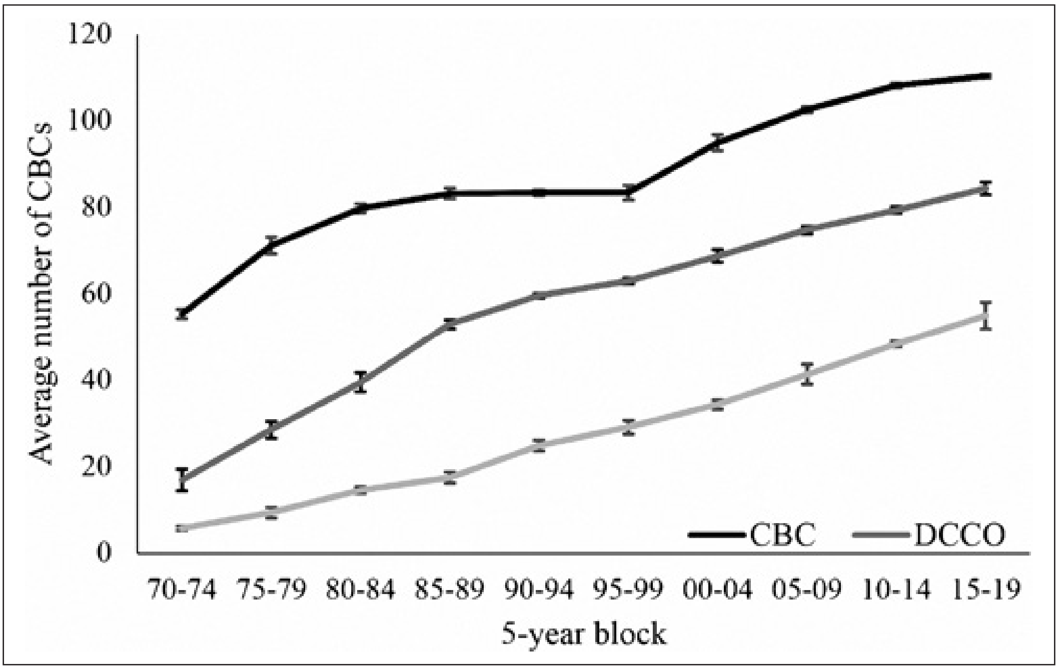

Figure 1. Average numbers and standard errors of Christmas Bird Count (CBC) locations conducted in each 5-year block and of those locations where Double Crested Cormorants (DCCO) and Neotropic Cormorant (NECO) were detected.

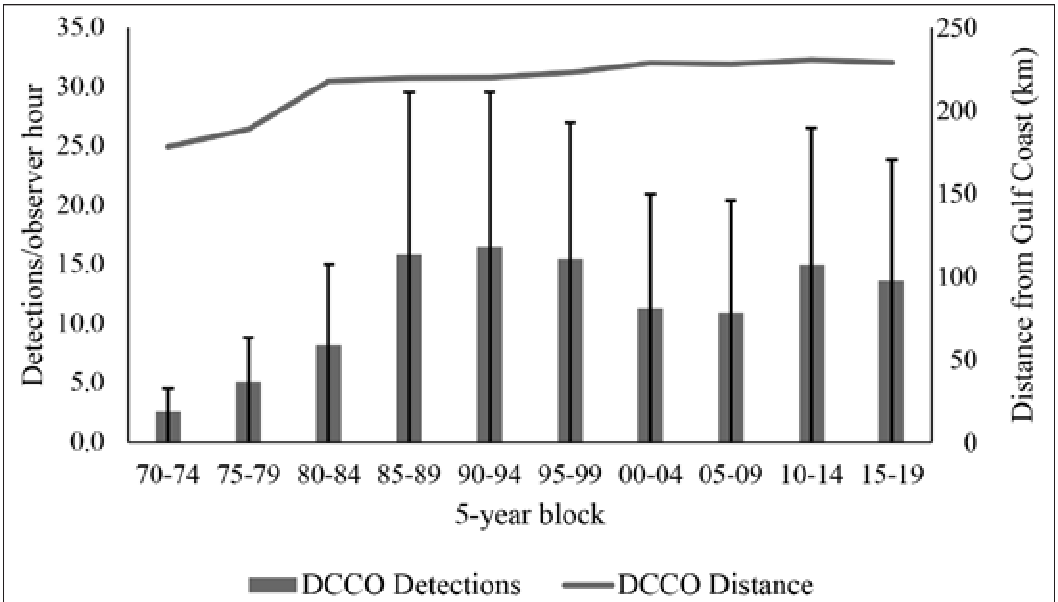

Figure 2. Average distance (line) from Gulf Coast at which Double-Crested Cormorants (DCCO) were detected and mean and standard errors for detections/observer hour at Christmas Bird Count (columns) for each 5-year block in Texas, 1970-2019.

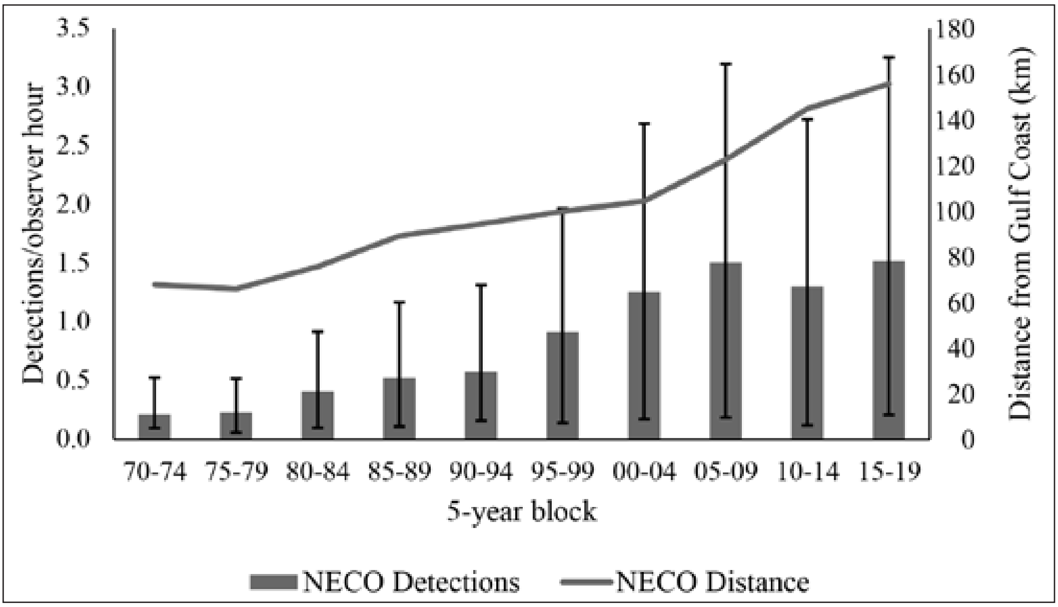

Figure 3. Average distance (line) from Gulf Coast at which Neotropic Cormorants (NECO) were detected and mean and standard errors for detections/observer hour at Christmas Bird Count (columns) for each 5-year block in Texas, 1970-2019.

For assessment of cormorant presence in relation to fish stocking we constrained our analysis to 'before' data consisting only of surveys conducted the day before or day of stocking, and 'after' data that were collected the day after stocking (Table 1). When assessing the control lakes, we found no difference in ($F_{1,14}$ = 0.0836, P = 0.7767) in mean detections of cormorants before (4.75 ± 9.004 SD) or after (6.12 ± 9.992 SD) stocking. In contrast, we found average detections among stocked lakes were 1.12 (0.834 SD) cormorants during pre-stocking and 5.75 (3.919 SD) cormorants during post stocking surveys (Table 1). This difference was statistically significant ($F_{1,14}$ = 10.6596; P = 0.0056).

We recorded 77 5-minute observation bouts (total of 385 minutes) of swimming cormorants, with 20 observation periods (26%) at control lakes and 57 observation periods (74%) at stocked lakes

Table 1. Mean and standard deviations for cormorant counted at 3 control lakes and 3 stocked lakes prior to and subsequent to stocking of rainbow trout, December 2020 – March 2021, Dallas – Fort Worth area, Texas. Data constrained to surveys conducted the day before or day of stocking (pre-count) and the day following stocking (post-count).

				Pre-count		Post-count	
Lake	Type	Size (ha)	n	Mean	SD	Mean	SD
Bedford Boys	Control	2.0	2	0.5	0.71	1.0	1.41
Echo Lake	Control	5.2	3	12.0	12.53	15.7	11.37
Emerald Lake	Control	3.1	3	0.3	0.58	0.0	0.00
Chisolm Park	Stocked	1.0	2	0.5	0.71	7.0	1.14
Greenbriar	Stocked	1.1	3	1.3	0.57	7.0	4.58
Lakeside	Stocked	1.2	3	1.3	1.15	3.7	4.62

Table 2. Observations of foraging effort and success of cormorants among control and stocked lakes, Fort Worth, TX, November 2020 – March 2021.

Lake	Category	Minutes observed	Total cormorants observed	Cormorants observed foraging	Percent of observations foraging	Average captures/dive	SD
Bedford	Control	10	2	2	100	0.100	0.1414
Echo	Control	90	18	11	61	0.035	0.1004
Chisolm	Stocked	50	10	4	40	0.083	0.1667
Greenbriar	Stocked	115	23	11	48	0.048	0.0930
Lakeside	Stocked	120	24	22	92	0.050	0.0811

(Table 2). When assessing all observations, we found no difference ($F_{1,75} = 0.266$, $P = 0.8708$) in the average number of dives/min between control (1.1 ± 1.119 SD) and stocked (1.1 ± 1.004 SD) lakes. However, we recorded no diving activity during 27 observation periods (35%). When examining the 50 observation periods (65%) in which we observed cormorants foraging, we recorded an average of 1.64 (±0.819 SD) dives per minute and an average of 0.06 (±0.106 SD) fish captured per dive. We did not detect any difference in foraging success ($F_{1,47} = 0.0602$, $P = 0.8072$) in terms of average number of fish captured per dive between control (0.04 ± 1.103 SD) and stocked (0.05 ± 0.093 SD) lakes (Table 2).

We identified fish as trout or non-trout in 14 (78%) of 18 observed captures (Table 3). Only 3 captures, none of which were trout, were observed at control lakes. At stocked lakes, 7 captures were trout, 4 were non-trout, and 4 could not be reliably identified (Table 3). Sampling effort was not equal between control (100 total minutes of observation) and stocked (285 minutes of observation) lakes; on basis of sampling, 0.03 fish were captured per minute of survey effort at control lakes compared to 0.05 fish captured per minute at stocked lakes.

DISCUSSION

Multiple lines of evidence suggest increases in the numbers of both Double-Crested and Neotropic Cormorants has occurred in Texas over the last 50 years. Although there was an increase in CBCs over the same time period, which increased the sampling locations, the increase in proportions of CBCs reporting cormorants quickly outpaced the increasing number of the CBCs. The population increases, however, differed between species. Double-Crested Cormorant detections suggest an increase may have occurred from the early 1970s to the late 1980s (Fig. 2), matching a similar pattern of population increases seen outside of Texas during these decades (Wires et al. 2001). The species population in Texas has since appeared to slightly decrease and fluctuate based on CBC data, but none of these changes were found to be statistically significant. Furthermore, the average distance at which Double-Crested Cormorants were detected from the Gulf Coast has not changed significantly, increasing only from 178 km in 1970-74 to 230 km in 2010-2014. This suggesting the distribution of the species has not changed over the last few decades. The consistency of distance from the Gulf Coast but variable detection rates among years over

Table 3. Counts of trout and non-trout captured during foraging observations at control and stocked lakes in Fort Worth, TX, November 2020 – March 2021.

	Trout	Other	Uncertain	Total	Observationminutes	Capture /minute
Control	0	3	0	3	100	0.03
Stocked	7	4	4	15	285	0.0526
Total	7	7	4	18	385	0.0467

the last 30-35 years suggest inland areas, at least those where CBCs are conducted, may be relatively at saturation with the species.

In contrast, Neotropic Cormorants have increased in both distribution and detections at CBCs. Originally detected at an average distance of only 68 km from the Gulf Coast, they have slowly but progressively doubled that to 156 km. This pattern of expansion inland is consistent with Telfair's (2006b) estimate of only 1% of the population occurred inland from 1957 – 1970, but the inland population accounting for 17% of the population by 2006, based on CBC counts. Even with the apparent increase of Neotropic Cormorants in Texas, based on CBC counts the species remains relatively uncommon compared to Double-Crested Cormorants. These data suggest that an increase in the population has occurred and is continuing, and that expansion of the species farther inland is still ongoing. Although the online eBird database is not useful for population estimates or trend data, reported sightings of Neotropic Cormorants suggest they are more widespread across Texas than the CBC counts indicate.

Our observations of cormorant presence and behavior at lakes were based on short-term behavioral/numerical responses to fish stocking. We found there was no difference in cormorant abundance at control lakes during the pre-stocking and post-stocking sampling periods but there was a difference among control lakes. In contrast, cormorant counts increased notably following stocking at stocked lakes. Further, with the exception of one control lake (Echo Lake) the stocked lakes held more cormorants pre-stocking than did control lakes. Fish stocking not only attracts cormorants, but those stocked lakes continue to have more cormorants present after stocking than do control lakes. It is clear that cormorants discover the stocking of lakes within a day of, if not the day of, stocking. This is similar to great cormorants (*Phalacrocorax carbo*) that will alter their foraging to river areas being stocked for anglers (Kumada et.al 2013). Further, surveys conducted 2 and 4 days post-stocking (but not included in our analysis due to inconsistent sampling) suggest the numbers continue to increase.

Also due to pandemic-caused constraints, we did not conduct as many observations during the pre- and post-stocking periods as we had planned. Our limited surveys, however, suggest no apparent difference in foraging effort between control and stocked lakes in terms of dives/minute. When assessing only the foraging bouts, we found a low capture rate per dive (0.06 fish/dive) suggesting that some dives may not be related to foraging or that hunting success was low. We did not observe any difference in success rates between control and stocked lakes, but our sampling effort was low and unlikely to answer these questions with reliability.

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INFLUENCE OF BRUSH COVER AND ARTHROPODS ON AVIAN INSECTIVORES IN NATIVE RANGELANDS OF SOUTH TEXAS

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ABSTRACT.—Bewick's Wren (*Thryomanes bewickii*), Yellow-billed Cuckoo (*Coccyzus americanus*), Golden-fronted Woodpecker (*Melanerpes aurifrons*), Ladder-backed Woodpecker (*Picoides scalaris*), White-eyed Vireo (*Vireo griseus*), and Verdin (*Auriparus flaviceps*) are all residents of the South Texas landscape. While the species are unique in appearance, they share the diet of arthropods with each of these species categorized as an insectivore during the breeding season. During this time, they need more nutrients to keep up with the pressures of finding a suitable mate and maintaining their young. The objective of this study was to investigate the influence of brush cover and arthropods on avian insectivores in native rangelands of South Texas. It is important to look at relationships because it can help determine what is impacting bird abundance if populations are low. We established 600 m x 100 m line transects in two levels of brush cover (high [>50%] and low [<50%]). We placed pitfall traps at every 100 m along transects to capture arthropods utilizing ground habitat. We also used beatsheets and branch clippings at each pitfall site to sample arthropods living in shrubs and trees. Bird surveys were conducted once a week on transects and the focal bird species were recorded by visual and auditory means. Our results showed that there was a significant effect of brush cover level (high and low) and arthropod diversity on the relative abundance of avian insectivores. We observed a higher relative abundance of birds as arthropod diversity increased in high brush, and a lower relative abundance of birds as arthropod diversity increased in low brush. There were no significant effects of brush cover level and arthropod metrics on avian richness or diversity. Having a mosaic habitat with different canopy heights and diverse vegetation communities can positively influence animal populations and is important when considering land management strategies.

Avian insectivores consume arthropods as their main diet source; they are very common and are diverse in species which makes them essential to any ecosystem (Powell et al. 2015). Bewick's Wren (*Thryomanes bewickii*), Yellow-billed Cuckoo (*Coccyzus americanus*), Golden-fronted Woodpecker (*Melanerpes aurifrons*), Ladder-backed Woodpecker (*Picoides scalaris*), White-eyed Vireo (*Vireo griseus*), and Verdin (*Auriparus flaviceps*) are resident insectivores based on foraging guilds described by Graaf et al. (1985). These birds are classified as insectivores because their diet consists of 20% insects, either year-round or during the breeding period (Graaf et al. 1985). This has been further supported with results from fecal samples that have shown that Coleoptera, Hymenoptera, Orthoptera, Formicidae, and Arachnids are common prey for understory insectivores, making up about 75% of their individual diet (Şekercioğlu et al. 2002). The substrate in which these birds hunt arthropods differs from species to species as some find their prey on the ground, shrub, bark, and/or canopy.

The Golden-fronted Woodpecker, Ladder-backed Woodpecker, and Bewick's Wren remain insectivorous year-round (Graaf et al.1985). Schroeder et al. (2013) found the diet of Golden-fronted and Ladder-backed Woodpeckers had a high percentage of animal matter, consisting of larvae and adult invertebrates. Ladder-backed Woodpeckers brought 100% of the animal matter to their nestlings with 99.5% being invertebrate

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larvae and only 0.5% being adult invertebrates. Golden-fronted Woodpeckers brought back 77.5%, yet with more invertebrate adults (56.3%), and fewer invertebrate larvae (21.2%) compared to the Ladder-backed Woodpecker, as well as 20.1% vegetation (Schroeder et al. 2013). The insects that the woodpeckers brought back were reflective of their foraging behavior (i.e., excavating and prying into bark). Yard et al. (2004) took stomach content samples from Bewick's Wrens which resulted in a variety of arthropods including Araneae, Hemiptera, Homoptera, Coleoptera, Diptera, Hymenoptera, Lepidoptera larvae, and other smaller samples with a higher proportion of Araneae. These orders are all reflective of an insectivore's diet and can all be found in the native rangelands of South Texas.

Arthropods are the most diverse group of animals and have the largest number of species in the world (Misof et al. 2014). The origin of insects has been dated back to derive from the Early Ordovician period, nearly 479 million years ago (Misof et al. 2014). Insects occur in almost any possible environment and play a crucial part of our ecosystem since they fulfill many roles ranging from decomposing organic matter to serving as food for fish and wildlife (Rosenberg et al. 1986). Due to the large abundance of insects practically everywhere in the world, it makes it rather easy to sample them and see the impact they make in both aquatic and terrestrial ecosystems as predators, prey, parasites, herbivores, among others (Rosenberg et al. 1986). Serving as prey, insects play a crucial role in the life cycles of many South Texas avian species, specifically insectivores that need protein year-round as well as during the breeding season for themselves and nestlings (Dhondt and Hochachka 2001).

Habitat and prey relationships of avian insectivores are important to their conservation and management, yet have not been fully explored in South Texas. The objective of our study was to determine the influence of brush cover level and arthropods on avian insectivores. We hypothesized that higher brush cover and higher relative abundance and diversity metrics of arthropods would yield a higher abundance and diversity metrics of birds. This was hypothesized because higher brush cover offers more protection and more resources benefitting both arthropods and insectivores. Having this information can provide further support in the precautions taken when considering land management practices used in ranching and wildlife conservation that may alter vegetation patterns that will impact arthropod and avian populations.

METHODS

Study Area

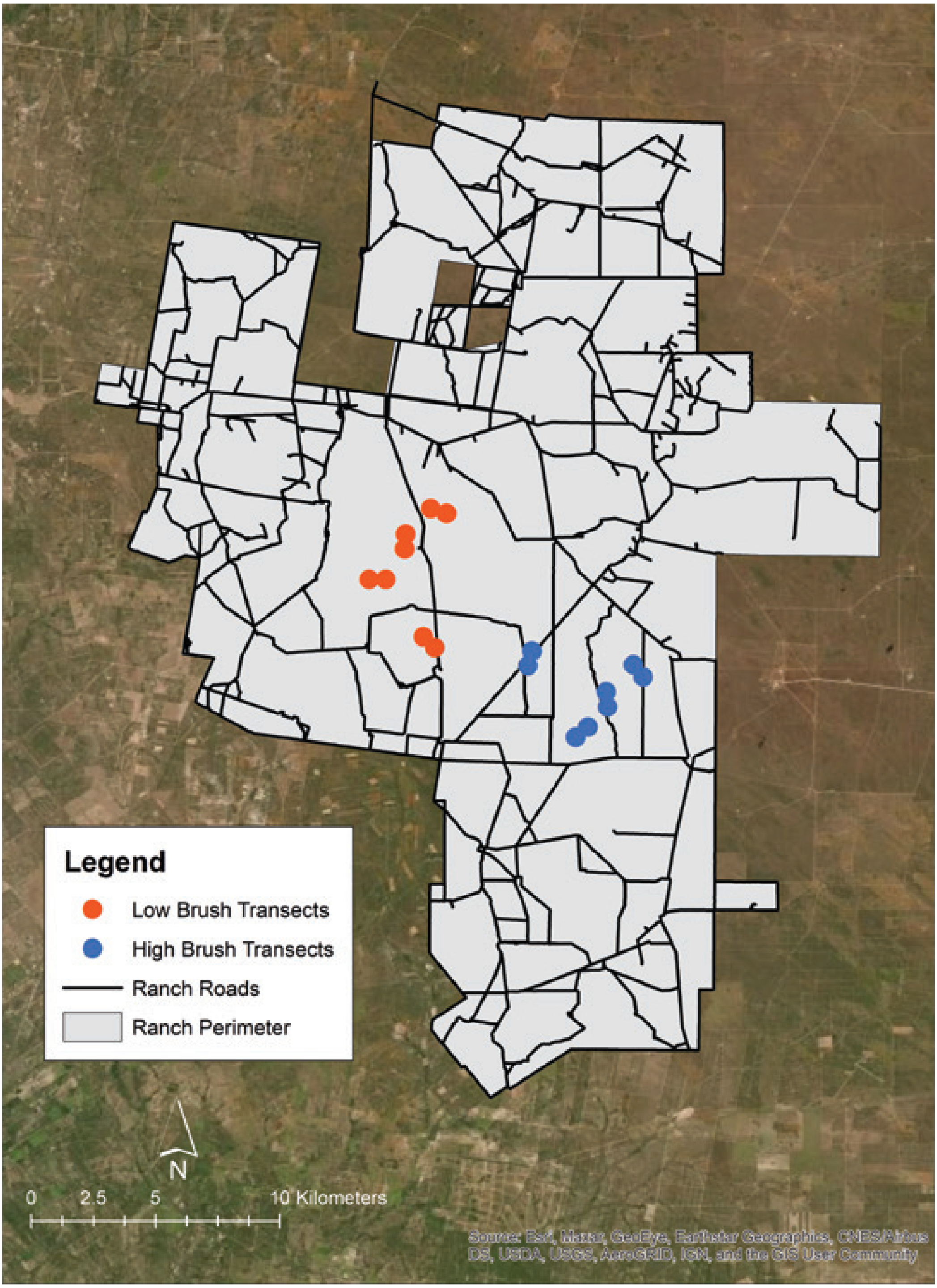
Our study occurred on the East Foundation's San Antonio Viejo Ranch (SAVR) from July to August 2019. The 60,000 ha ranch is in the southern plains of Texas in Jim Hogg and Starr counties located W of Hebbronville and N of Guerra. The SAVR is one of the 6 ranches operated by the East Foundation to promote land stewardship through ranching, science, and education. The ecological region of the area is characterized by coastal sand plain and Tamaulipan thornscrub with the general vegetation cover of honey mesquite (*Prosopis glandulosa*), grasslands, and shrubs (Omernik 1987). The average temperature at SAVR during the study was 33°C but had highs of 38°C and winds that ranged from 3-4 (6-20km/h) on the Beaufort scale.

Sampling Design

We sampled 8, 600 x 100 m transects located in the central part of the SAVR (Fig. 1). There were four transects located in each of two brush levels: 1) low brush cover (Fig. 2) and 2) high brush cover (Fig. 3) that were randomly assigned in ArcGIS 10.4 using a vegetation cover layer from the Texas Parks and Wildlife Landscape Ecology Program. We completed this by calculating the percent of brush in the area of the transects based on the vegetation layer. Brush cover for this study is defined as cacti, shrubs, and trees. Low brush transects had $<50\%$ of brush cover, whereas high brush transects had $>50\%$ brush cover.

Bird Surveys

Bird surveys were conducted twice per week with each transect surveyed once per week to ensure that all transects were completed before the heat of the day (approximately 1200 CST) when bird activity decreases. Transect visits were rotated and two transects per brush level were surveyed each day. On survey days, the vehicle was parked at least 50 m away from the starting point to avoid disturbing birds that may be inhabiting the location. At the start of the survey, environmental variables such as temperature, cloud coverage, and wind speed (Beaufort) were recorded using a Kestrel 2000.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. East Foundation's San Antonio Viejo Ranch in Jim Hogg and Starr counties, TX, USA. High (blue) and low (red) brush transects marked with circles indicating beginning and end of transects sampled from July-August 2019.

Figure 2. Example of vegetation found in a low brush (<50% brush cover) transect on the San Antonio Viejo Ranch, Jim Hogg and Starr counties, TX, USA in July-August 2019.

Figure 3. Example of vegetation found in a high brush (>50% brush cover) transect on the San Antonio Viejo Ranch, Jim Hogg and Starr counties, TX, USA in July-August 2019.

Surveys were performed by a single observer and all surveys began at sunrise with transects walked at the same pace while listening and observing for the focal species. The six focal species were year-round insectivores based on Graaf et al. (1985) and since we were at the end of the breeding season we also included breeding period insectivores. Focal species included: Bewick's Wren, Golden-fronted Woodpecker, Verdin, Ladder-backed Woodpecker, Yellow-billed Cuckoo, and White-eyed Vireo. No surveys were conducted with rainfall or winds with consistent ≥4 on the Beaufort scale.

Arthropod Sampling

We used three methods, accounting for the locations in which birds forage, to estimate arthropod populations:

1. Pitfall traps were set up at every 100 m along the transect (6 per transect) and sampled twice throughout the study period for one week.
2. Beatsheets were sampled at the nearest shrub to the pitfall trap and within 50 m of the transect and sampled twice throughout the study period.
3. Branch clippings taken from three different trees near each pitfall trap, each from a different height of the canopy (low canopy, center canopy, upper canopy) within 50 m of the transect and were sampled twice throughout the study period.

For pitfall traps, we used 16 garden staples, a plastic cup (9 oz), plastic plate, three nails, 50% propylene glycol (0.5 oz), and PVC flashing as walls in an X-shape following the recommendations of Koivula et al. (2003) (Fig. 4). The traps were alternated in which each transect was sampled twice for a week throughout the 6 weeks of the study. To sample arthropods in the trees and shrubs we used branch clippers and a white bed sheet. Three branches were clipped from three different trees per pitfall location at three different heights

Figure 4. Pitfall trap design with X-shaped guidance barriers used on the San Antonio Viejo Ranch, Jim Hogg and Starr counties, TX, USA in July-August 2019.

(lower canopy, center canopy, upper canopy), we visually analyzed the clipping for arthropods then beat branches onto the sheet to account for any remaining arthropods. We then placed a sheet directly under a shrub within 5 m of each pitfall trap and used a PVC pole to hit the shrub for 20-30 seconds to knock all arthropods onto the sheet. The sheet was dusted off each time and between each method to prevent double counting. Arthropods were counted and classified based on their order after each method.

Statistical Analysis

Data were analyzed using a multivariate multiple regression in RStudio using the stats package (RStudio Team 2020) to assess the influence of brush level and arthropod metrics on avian insectivore metrics. Predictor variables included brush cover levels and arthropod metrics. Response variables included avian insectivore metrics. Metrics for birds and arthropods were relative abundance, diversity, and richness. Relative abundances of birds and arthropods were calculated using the ratio of the total number of individuals counted by the length of the transect by week and transect. The Shannon-Weiner Diversity Index ($H = -\Sigma P_i(\ln P_i)$;H = diversity, P_i = number of individuals of species i/ total number of samples) was calculated to measure the species diversity in each transect for birds and arthropods (Ali et al. 2016). The Menhinick's Index ($D = s \sqrt{N}$; D = species richness, s = number of different species represented in your sample, N = total number of individual organisms in your sample) was used to measure species richness in the area for both. Data for bird and arthropod metrics were log transformed to meet assumptions and are interpreted on the log scale.

RESULTS

We documented 407 avian insectivores and sampled 2587 arthropods. Bewick's Wren was the most abundant species in both the high and the low brush areas (Fig. 5). The Yellow-billed Cuckoo was the least abundant with none found in the low brush area and only one in the high brush. The Ladder-backed Woodpecker was not included in data analysis as there were birds in the area but they were not within the transect perimeter. There were more arthropod orders found in the high brush than the low brush with Hymenoptera being the most abundant order in both high and low brush areas (Fig. 6). Odonata, Siphonaptera, Trombidiformes, and Myriapoda were the least common orders found. Siphonaptera and Trombidiformes were found only in the high brush.

Avian diversity and avian richness were not significantly influenced by brush cover level or arthropod metrics (Table 1) but brush cover level and arthropod diversity had a significant influence on avian abundance ($P < 0.003$). Figure 7 demonstrates the interaction between arthropod diversity and brush cover. The effect of high brush

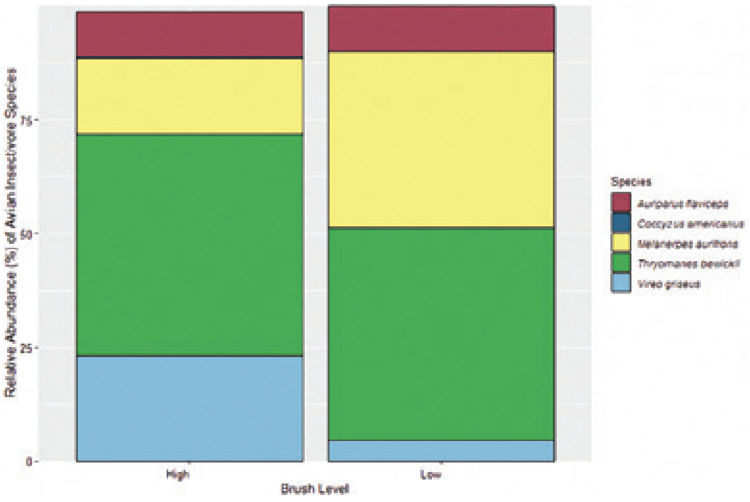


Figure 5. Relative abundance of avian insectivores in high and low brush areas on the San Antonio Viejo Ranch, Jim Hogg and Starr counties, TX, USA in July-August 2019.

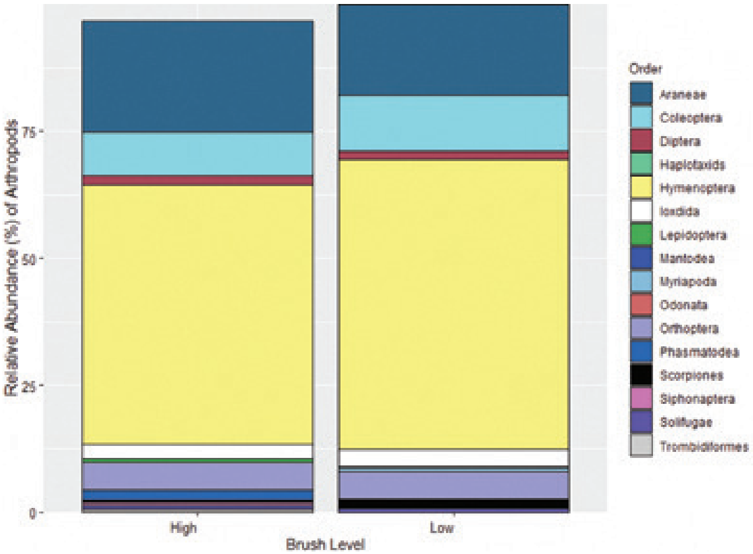


Figure 6. Relative abundance of arthropods in high and low brush areas on the San Antonio Viejo Ranch, Jim Hogg and Starr counties, TX, USA in July-August 2019.

cover on avian insectivores becomes more positive as arthropod diversity increases. The effect of low brush cover on avian insectivores become more negative as arthropod diversity increases. While there was a significant relationship between arthropod abundance and avian insectivore abundance ($P < 0.003$, Table 1) this was not as ecologically meaningful since the most abundant arthropod order (Hymenoptera) was primarily ants.

Table 1. Multivariate multiple regression results with log-transformed data for the effect of brush level cover and arthropod metrics on avian insectivore metrics on the San Antonio Viejo Ranch, Jim Hogg and Starr counties, TX, USA in July-August 2019.

Predictor	Response											
	Avian Relative Abundance				Avian Richness				Avian Diversity			
	Estimate	SE	t	P	Estimate	SE	t	P	Estimate	SE	t	P
Brush Level (Low, High)	0.080	0.120	0.664	0.515	−0.148	0.165	−1.651	0.197	0.082	0.151	0.547	0.712
Arthropod Relative Abundance	0.479	0.142	3.368	0.003**	−0.261	0.131	−2.00	0.061	0.042	0.119	0.354	0.728
Arthropod Richness	0.410	0.473	0.868	0.397	−0.350	0.434	−0.808	0.430	0.209	0.397	0.527	0.605
Arthropod Diversity	1.11	0.450	2.476	0.023*	−0.145	0.413	−0.351	0.730	0.108	0.378	0.286	0.778
Brush Level x Arthropod Richness	0.992	0.489	2.027	0.058	−0.256	0.449	−0.570	0.576	0.193	0.411	0.471	0.643
Brush Level x Arthropod Diversity	-2.81	0.831	-3.392	0.003**	1.02	0.762	1.34	0.199	-0.526	0.696	-0.775	0.466
Adjusted R^2	0.6438				-0.06169				0.1428			
F-Statistic	8.23				0.7676				1.666			

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.00$

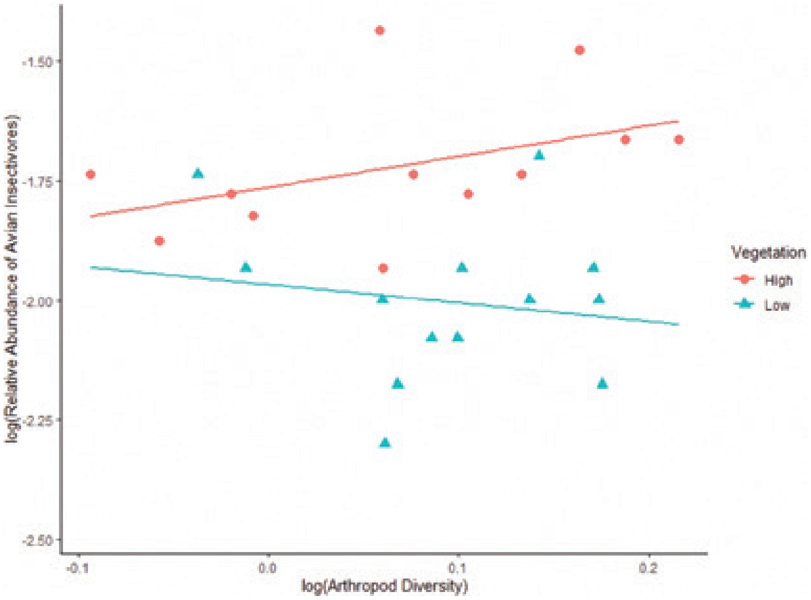


Figure 7. The effect of brush cover level (high and low) and arthropod diversity on the relative abundance of avian insectivores on the San Antonio Viejo Ranch, Jim Hogg and Starr counties, TX, USA in July-August 2019.

DISCUSSION

There was a higher total number of insectivorous birds found in the high brush than in the low brush, which was expected as birds look for places that provide the best coverage and have space to reproduce (Krausman 1999). There were 16 orders of arthropods identified, with the most abundant being Hymenoptera. Arthropod diversity and brush cover as an interaction had an effect on the relative abundance of birds which could be a result of birds having a broader diet. Since there was a higher diversity of arthropods in high brush, birds may not have to compete for one type of arthropod which may lead to a higher abundance of avian insectivores. Brush cover and arthropod metrics did not influence avian diversity or avian richness. This could have occurred due to that area already being high in avian diversity and richness therefore brush cover and arthropod metrics did not matter.

The relative abundance of arthropods was relatively equal which was expected since arthropods can live anywhere in the world and occur in almost any possible environment (Rosenberg et al. 1986). Fewer orders were found in the low brush than the high brush area which can be because the high vegetation provides more area for shelter and food (Rosenberg et al. 1986). Since there are fewer arthropod orders in the low brush, this should lead to less diversity in bird species as there is potentially more competition between avian insectivore species if they are specialists that seek out specific arthropod types.

Many environmental variables can affect the presence of birds. The Yellow-billed Cuckoo was found only in the high brush area which was expected since they are upper canopy gleaners meaning they spend an abundant amount of the time in trees (Graaf et al. 1985). More Verdins were found in the high brush area which is expected since they are lower canopy and shrub gleaners, and the high brush area is dense with vegetation. A higher number of Golden-fronted Woodpeckers were found in the low brush area, yet they are typically found in dense vegetation areas (Schroeder et al. 2013). Within the United States, Golden-fronted Woodpeckers are closely associated with mesquite brushlands and riparian corridors (Husak and Maxwell 2000), however in this study they were primarily found within grassland areas which may be due to food availability and vegetation condition. The number of Bewick's Wrens was relatively similar in both high and low brush which is likely due to the fact that they are a generalist species and can be found almost anywhere (Kroodsma 1985).

For both high and low brush, there were instances where no birds were recorded, which could have resulted for two reasons. There could have been possible human disturbance by the vehicle, and while it was parked at least 50 m from the start of the transect it could have possibly flushed any birds in the area. At times, birds were heard but they were not within the transect limits and therefore not recorded. Overall, there were also environmental factors that could have hindered the study. The temperature changed throughout the course of the five-week period. Temperatures rose from the start to the end of the study from 32° C to 38° C. At the beginning of the study, there were many more birds recorded as the temperature was at an ideal range for them to be active. As temperatures rose, less birds were recorded as birds are generally not very active in hot temperatures and it alters their activity (Vafidis et al. 2019). There are some birds, like the Yellow-billed Cuckoo, that were not vocal which could have reduced our opportunity of recording them during surveys. The Yellow-billed Cuckoo was seen or heard the least out of all the bird species of the study which can be a result of the species being active on the nest rather than vocalizing or foraging.

Further research is required to determine associations between arthropod and avian insectivore abundance. Having a longer study period or more transects would improve this study as it will give a better representation of the birds and arthropods in the area. Having additional observers in the study would also help as this would allow for multiple transects to be surveyed at the same time while covering more ground but will have to come with more rigorous analysis of observer reliability. Implementing these changes will yield improved information which will give a better representation of what is happening with our avian populations on South Texas ranches. Having information regarding the importance of brush cover will help ranchers make important land management decisions that help the wildlife that resides there.

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EARLY FALL MIGRANT BLACK-AND-WHITE WARBLERS *MNIOTILTA VARIA* IN THE LOWER RIO GRANDE VALLEY DETECTED BY NOCTURNAL FLIGHT CALLS

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ABSTRACT.—What began as a general exploration of the passerine nocturnal flight call (nfc) phenomenon in Cameron Co., TX in 2012, took a more focused turn when we uncovered an early and surprisingly pure flight of the Black-and-white Warbler *Mniotilta varia* (BAWW) that July. The small but intriguing nfc sample led us to collect three more seasons of data to solidify our understanding of the early migration pattern. Our results suggest a wave of night-migrating BAWWs begins passing over Harlingen, TX at least by the first week in July and peaks in a 2-week period from about July 20 to August 4. The flight then falls off by mid-August before a new wave of migrant BAWWs may arrive, we presume from a more northerly breeding population. To ground truth the early BAWW nfc pattern, we correlated eBird frequency data from Cameron County and found a strong linear relationship. We speculate that in some years southbound BAWW migrants are already passing over the lower Rio Grande River into Mexico in late June.

There are no modern-day breeding records of the Black-and-white Warbler *Mniotilta varia* (BAWW) in the Lower Rio Grande Valley (LRGV), and the generally accepted equation is that their spring migration is largely over by the end of the third week in May and fall migration does not begin until mid-July. So, if you find a BAWW warbler in the Valley in June one might say you have entered the twilight zone. The closer the sighting is to late May, the more one might suspect a late spring migrant. The closer the sighting is to early July, the more one might suspect an early fall migrant. But how do we explain June birds? As a vagrant of some sort? Perhaps an injured bird or one that was delayed in northbound migration and then the migration urge shut off?

We present data that sheds light on early July BAWWs in the LRGV and suggests that late June birds are early fall migrants. During May-Dec 2012, we monitored avian nocturnal flight calls (nfcs) in Cameron County, TX from a skyward-facing microphone mounted on the roof of Harlingen High School South (HHSS, 26° 10’ 35.7888” N, 97° 43’ 11.3514” W). The school is on the southwest side of Harlingen, TX and was part of a Dickcissel nfc monitoring project across the LRGV from 2000-2003 (Larkin et al. 2002). With advances in technology, now the audio for a whole night could be digitally recorded while software detected and extracted copies of bird calls; these data potentially put online in near real time via the Internet.

A primary focus of the new project was on warbler & sparrows. Most have similar nfcs that can be extracted together with the same software. We classified software-extracted calls to species categories by visual inspection of spectrographs and made the data available online the next morning. Our intention was to carry out nightly monitoring of the spring and fall migration periods, and our spring monitoring extended through the night of 18-19 June. During the first 18 nights of June, we only logged 2 warbler & sparrow nfcs—a Grasshopper Sparrow *Ammodramus savannarum* on the night of 12-13 June and a call too faint to ID on the night of 17-18 June. Fall migration monitoring began the night of 3-4 July, and on the night of 7 July at 2206 CST we recorded our first warbler nfc of the “fall” migration—a Black-and-white Warbler (Fig. 1).

The nocturnal flight call of the BAWW was determined in 1989 when WRE spectrographically matched diurnal flight calls of visually confirmed BAWWs with a distinctive unidentified night flight call he had recorded. It would then take more than a decade of additional sleuthing in collaboration with Michael O’Brien before flight call examples of all migrant warblers & sparrows in eastern NA

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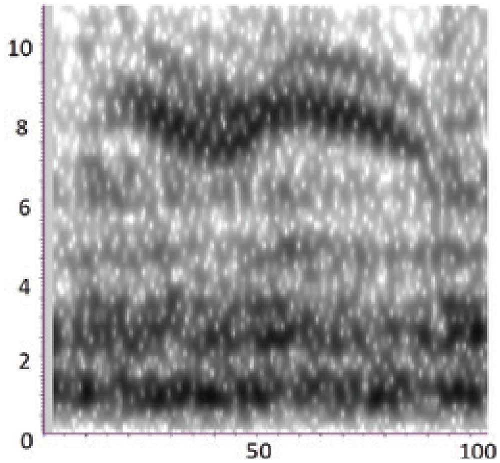


Figure 1. Spectrogram of BAWW nfc recorded 7 July 2012 over Harlingen High School South. Frequency is in kilohertz on the Y-axis and time is in milliseconds on the X-axis. The call is about 80 mS long, a bit less than 1/10 of a second.

were acquired. This was necessary to verify that no other species had a similar flight call to BAWW that needed discrimination. It turned out the nfc of BAWW is one of the more distinctive small passerine nfcs in North America; no other species is remotely similar. The Evans and O'Brien archive of visually confirmed passerine flight call descriptions for eastern NA was published in 2002 and has been an online public resource since 2017 (see link in lit. cited).

By the end of July 2012, our nightly audio recording of the sky over HHSS had resulted in 79 warbler & sparrow nfc detections, 67 identified as BAWW. While we knew BAWW is an early migrant, we did not anticipate it would be the most abundant nfc over HHSS in July. In the BAWW's peak fall migration months (Aug & Sep) in the Upper Midwest and Northeastern U.S., the BAWW nfc is typically no more than 3% of the total composition (WRE, unpubl. data). This is because other species giving nfcs are migrating along with them. In the July 2012 data from HHSS, more than 75% of the total nfcs were BAWW. The 12 non-BAWW calls recorded in July 2012 were identified as 1 Savannah Sparrow *Passerculus sandwichensis*, 3 Grasshopper Sparrows, 1 Yellow Warbler *Setophaga petechia* type, and 7 others too weak in amplitude to classify.

To be clear, the 67 BAWW nfcs do not represent 67 separate birds. Some individuals give more than one call when passing in range of the microphone/detection system. And artificial light, especially during low cloud ceiling or hazy nights, can cause an increase in the calling rate of an individual bird as well as aggregation behavior that may result in the same individual passing through the microphone's call pick-up zone multiple times. Like most high schools in the U.S., the grounds of HHSS are well lit at night. During the period of this study, these lights were brighter than those in the immediate surrounding land and residential area. While there are many bright light sources associated with the municipality of Harlingen, the school lighting produced a relatively bright island of light on the outskirts of the complex lightscape of the city.

Potential light-effected calling rate increases and aggregation phenomenon seemingly confound use of nocturnal flight calls for producing a reliable index to the numbers of birds passing. Evans and Mellinger (1999) suggested a way to counter these and other such variables by deriving an index aimed toward estimating the minimum number of vocal individuals passing. They termed it the "MIP" method. A major component of this method, which can be used alone or with other algorithms, is to estimate the typical time an individual bird of a particular species would take to pass through a microphone's call pickup region. One then lumps all calls of a species occurring within that interval as 1 detected individual. After evaluating tens of hours of nocturnal flight call recordings with a specific microphone, one gets a sense of the typical passage time for different species.

With a similar microphone design as this BAWW study, Evans and Mellinger (1999) used a 1-minute interval to produce a MIP index for Grasshopper and Savannah Sparrow nfcs. Using the same microphone design as this BAWW study, Evans et al. (2017) used a very conservative 15-minute interval to quantify the occurrence of an unknown flight call in southern Mexico. A longer summation interval leads to more certainty in quantifying different individuals, but more likelihood of undercounting. The optimum summation interval depends on the species involved, study site characteristics, and specific goals of a study.

In our 2012 study at HHSS we chose a 1-minute interval. For example, there were 2 nights (21-22, 22-23 July) where a rapid series of BAWW nfcs occurred, sounding like they were from the same individual. Both these nights had periods where the calling pattern suggested birds were disoriented in the light. The first night had 11 BAWW nfcs within 30 seconds just after midnight and a single BAWW nfc at 0110 CST. Using the 1-minute rule, the first bout of calling was interpreted as 1 individual because all the calls occurred within a minute. Counting the isolated BAWW nfc at 0110 as a separate individual, the MIP count for this night was determined to be 2. Applying this method to the whole month of July 2012, 67 individual BAWW nfcs translated to a MIP total of 38. The MIP total is also not the actual number of individuals passing over. It is an estimate of the minimum number of vocal individuals passing that is likely a more accurate passage rate activity index than a total call count, especially when isolated artificial light sources are involved.

METHODS

To investigate whether the 2012 BAWW nfc phenomenon was regular at HHSS, we set out to record nfcs again in the years that followed. As in 2012, we recorded 9 hours of monaural audio per night from 2000-0500 CST (UTC-6) using an Old Bird 21c microphone (Old Bird, Ithaca, NY) aimed at the night sky (Fig. 2). This microphone has a hypercardioid sensitivity pattern and is designed to have acute directional sensitivity in the 2-10 kHz range—for a rough sense of the pickup pattern, imagine a 60-degree cone expanding well up into the sky along with a zone of omnidirectional sensitivity closer to the microphone. The microphone's maximum detection range for warbler and sparrow nfcs is estimated to be roughly 300 m.

We used about 30 m of cable to transfer the audio signal from the microphone to a Turtle Beach Amigo II sound card, which was connected to a PC running Windows 7 in MHC's biology classroom. Audio was automatically recorded to the PC nightly with Easy HiQ software (now obsolete) at 22050 Hz sampling rate and 16-bit resolution in WAV file format. We aimed to begin recording each year in early July.

To extract BAWW nfcs from the all-night audio, we ran Tseep software (Old Bird, Ithaca, NY) either in real-time (2012) or later on the recorded 9-hr audio files to automatically extract short transient sounds in the 6-10 kHz frequency band. WRE then visually analyzed spectrograms of the short clips using GlassOFire software (Old Bird, Ithaca, NY) to separate avian nfcs from non-calls, and to manually classify nfcs to species categories. The GlassOFire spectrograms were computed with a 128-sample Hamming window, a hop size of 1

Figure 2. Old Bird 21c microphone located on the roof of HHSS in spring 2012.

sample, and a DFT size of 256 samples. Evans and O'Brien (2002) served as the basis for assigning calls to species categories. BAWW nfc occurrence data was converted to an estimate of the minimum number of individuals acoustically detected (MIP total) using the 1-minute rule as in 2012.

To explore the possibility of independent ground-truthing, we followed Gyekis et al. (2019) in comparing eBird observations with our nfc data. We downloaded Cameron County TX eBird frequency data for the BAWW from July & August for 2011-2020 (eBird 2021). These eBird data indicate the proportion of checklists with BAWW reports per "eBird week", where a month is divided into 4 weeks, the first 3 are standard weeks with 7 days and the last week contains whatever number of days to finish the month. In our case, the final eBird week of July and August each contained 10 days. We then carried out Pearson product-moment correlation to determine the strength of the linear relationship between weekly changes among our BAWW nfc MIP data and the weekly percentage of eBird checklists with BAWW reports. To account for the different number of days in an eBird week, nfc MIP totals per eBird week were divided by the number of days in an eBird week to come up with a nightly average per eBird week, which was used as the nfc variable.

RESULTS

To augment our 2012 data, we attempted to obtain additional nfc data from early July through August 2013-2017. Technical problems led to incomplete, unusable datasets in 2013 and 2017. We were successful in obtaining three years of additional data (2014-2016), which gave us four total seasons of data for our analysis. For this report, we evaluated continuous nightly recordings from 2000-0500 CST over the dates noted below:

2012: 3 July—1 September
2014: 3 July—1 September
2015: 7 July—1 September
2016: 11 July—1 September

Figure 3 shows the combined-year nightly average BAWW nfc MIP total per eBird week. Table 1 shows the BAWW nfc MIP totals per standard week per year. For a standard week when all 4 years recorded each of the 7 nights, there were 28 station-nights recorded. All combined-year standard weeks in the study had 28 station-nights recorded except the first 2 weeks. In the week of July 1-7, only 11 of 28 potential station nights were recorded, so the bar for that week in Figure 3 may be underrepresented. For the week of 8-14 July, 25 of 28 potential station-nights were recorded, so the bar for that week in Figure 3 may be a bit underrepresented.

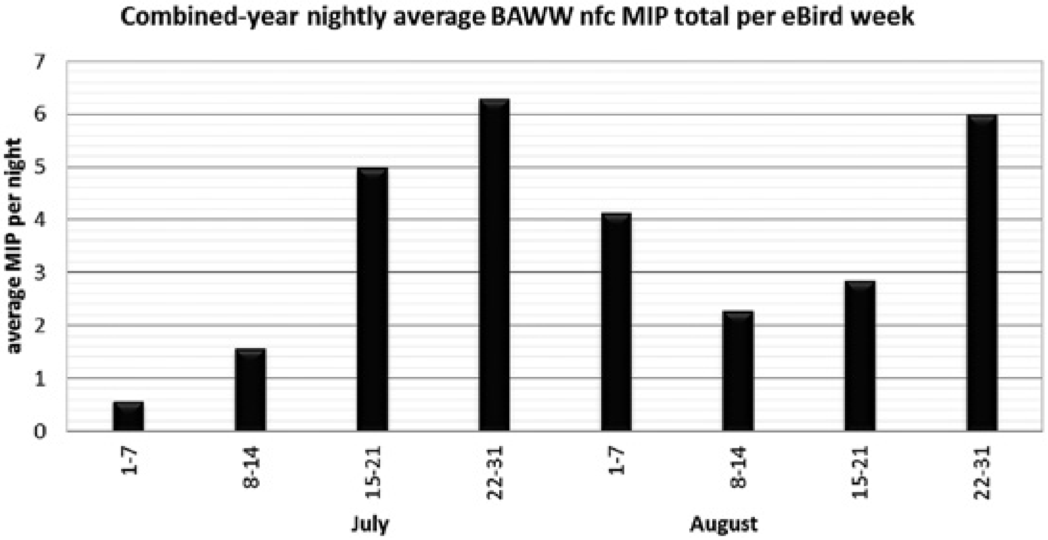


Figure 3. Bars shows the nightly average BAWW nfc MIP total per eBird week for the combined four years of study.

Table 1. BAWW nfc MIP totals per standard week per year (1 July—1 Sep). An asterisk indicates a week with incomplete nightly coverage.

Week dates	2012	2014	2015	2016
1-7*	1	3	0*	nd
8-14*	2	4	5	0*
15-21	17	7	3	8
22-28	14	13	14	7
29-4	3	26	7	10
5-11	4	1	4	6
12-18	4	1	0	5
19-25	5	8	3	42
26-1	1	4	0	12

Over the 4 years of nightly July-August monitoring, 382 BAWW nfcs were detected and a MIP total of 238 was derived, 113 in July and 125 in August. Figure 3 shows a bimodal distribution of the combined-year nightly average nfc MIP total per eBird week over the 2 months, with peaks in the last 10 days of each month and a trough in the middle of August.

The eBird frequency data is based on 169 of 4692 Cameron Co. birding checklists that logged BAWW over 10 years in the July-August period (eBird 2021). Though we did not have nfc data for 6 of these years, 10 years of eBird data was necessary in order to generate a comparable sample size with our nfc data (n= 169 versus n = 238 for nfc) to enable a reasonably robust statistical correlation. Figure 4 shows the percentage of eBird checklists per eBird week reporting BAWWs in July and August of 2011-2020. A bimodal pattern like that shown for BAWW nfc MIP totals in Figure 3 is indicated.

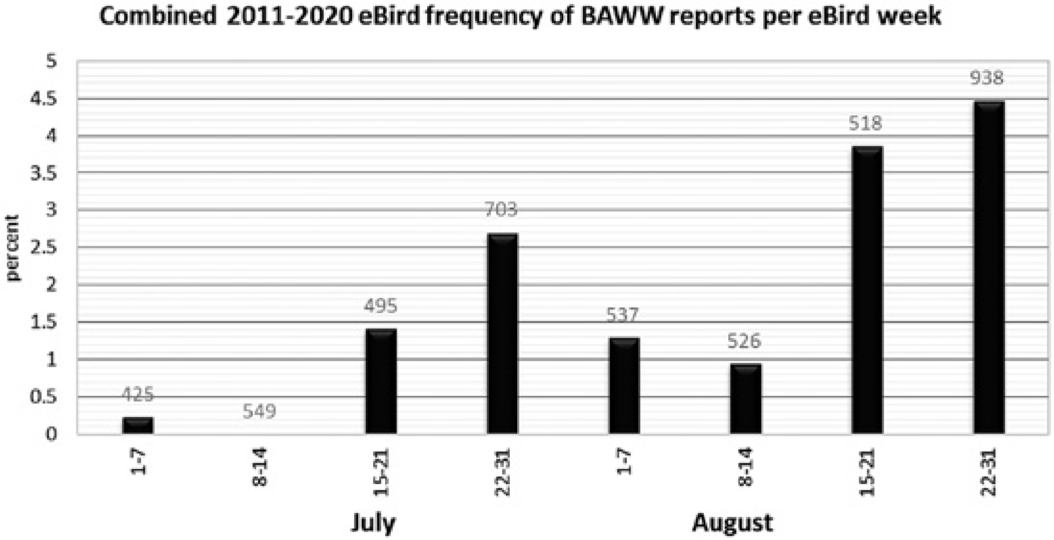


Figure 4. Bars show the percentage of Cameron County, TX eBird checklists from 2011-2020 that reported BAWW in the designated week. The total number of eBird checklists for each week is noted atop the bars.

BAWW nfc MIP data and eBird BAWW frequency data from July & August correlate moderately well (r = 0.66). A much stronger value of r = 0.93 occurs when just the first 6 eBird weeks are correlated.

DISCUSSION

Our BAWW flight call data from birds in active night migration indicates an early wave of migrants passes through Cameron County, TX from July through early August. The nfc data shows the wave begins at least by the first week of July. Inspecting Table 1 reveals that all 4 years show a peak in nfc MIP totals sometime in the week beginning July 15 to the week beginning July 29. The peak varied in being centered in the beginning or end of this period, and in 2016 seems less defined and more protracted. Table 1 indicates that the 2-week dip in nfc MIP totals from 5-18 August that defines the end of the wave is apparent in all 4 years. We show that this pattern of nfc detection from July through mid-August is strongly correlated with BAWW eBird frequency data for Cameron County. The strong positive correlation is benefited somewhat by the fact that both datasets begin in the early portion of fall migration at an accordingly low level.

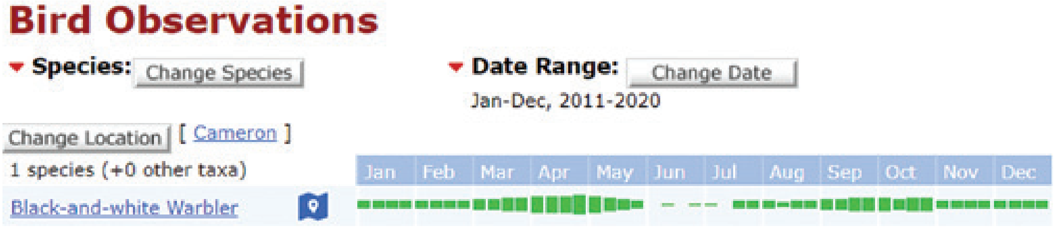
BAWWs that compose the July through early August flight are likely from an early-breeding population in the southern portion of the species' range. The population breeding in the Texas Hill Country west, north, and east of San Antonio is the closest, beginning about 400 km north-northwest of Cameron County (eBird 2021). The southern portion of the continental BAWW breeding population extends in a broad swath northeastward from relatively dense populations in the Texas Hill Country, across lower populations in Eastern TX, toward denser populations from Southeastern Oklahoma through the Ozarks, and then eastward to denser populations in the Appalachians and vicinity (eBird 2021). To what extent these more eastern populations may migrate westward around the Gulf of Mexico and through the LRGV is unknown to us.

Figure 3 shows a steep increase in nfc MIP totals from 22-31 August. Inspection of the data for that time in Table 1 indicates the big increase is due to the high tally in 2016. None of the other 3 years show this increase. One possibility is that in 2016 a typically later arriving wave may have shown up earlier than in the other years. Perhaps this is a wave arriving from the southcentral portion of the BAWW breeding range (i.e., Ozarks, ~1000 km NNE). Based on WRE's experience monitoring BAWW nfcs across the Upper Midwest and Northeastern U.S., late August seems too early for a wave from the northern breeding population (Northern U.S. and Southern Canada) to be passing through the LRGV—in particular, the concentration of birds that was passing on the nights of 21-22 & 22-23 August 2016, which had the highest 2-night total in the 4 complete years of study (MIP total of 27).

The eBird data from 2011-2020 shows a steep increase in BAWW reports in the whole second half of August (Fig. 4). As noted, this was not the case in 3 out of 4 of our nfc monitoring seasons. We can speculate whether this might be due to early flights of a second BAWW wave that may have occurred in the additional 6 years of eBird data included in the comparison for which we have no nfc data. In any case, it makes sense that BAWWs from further away, either the Ozarks or the northern populations in the upper Midwestern US and Canada would be more variable in their time of passage through the LRGV. The further away a population is originating, the greater the time & space for weather variables to impact migration progress. Furthermore, some of these distant populations may cross the Gulf of Mexico when conditions are right or go around the western Gulf when weather is not conducive for crossing. So, the latter half of August has a lot of unknowns and possibilities at play in the timing of later BAWW flights through the LRGV, especially considering tropical storm activity in the northwestern Gulf of Mexico.

The passage of July migrant BAWWs through the LRGV appears to have relatively consistent timing, suggesting these birds are from a closer breeding population like that in the Texas Hill Country. It seems unlikely that the Hill Country population would wholly bypass the LRGV to the west, though a substantial portion may do so. This is an interesting question for future studies.

Looking at the eBird BAWW histogram for Cameron County (Fig. 5), one gets the impression that fall migration does not begin until the week of 15 July. Our nocturnal flight call data indicate there is BAWW migration over the LRGV in the first 2 weeks in July. While we did not monitor for BAWW nfcs in late June, we note that on 29 June 2012 there were 2 eBird checklists reporting BAWW in the LRGV in or close to Cameron County. One was at Resaca de la Palma State Park and the other at Estero Llano Grande State Park (4 km west of Cameron



Bird Observations

Species:

Date Range: Jan-Dec, 2011-2020

[Cameron]

1 species (+0 other taxa)

Black-and-white Warbler

Figure 5. BAWW histogram for Cameron County, TX provided by eBird (www.ebird.org); created 12 Feb 2021.

Co.). We suggest that these birds are likely early fall migrants and that in some years southbound migrant BAWWs are already passing over the lower Rio Grande River into Mexico in late June.

ACKNOWLEDGEMENTS

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WINTERING NON-EASTERN RED-TAILED HAWKS (*BUTEO JAMAICENSIS*) ON THE GREAT PLAINS AND EASTWARD: MOSTLY NORTHERN (*B. J. ABIETICOLA*), NOT WESTERN (*B. J. CALURUS*).

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ABSTRACT.—In 1950, Todd described a new subspecies of Red-tailed Hawk (*B. j. abieticola*) that inhabited the Boreal Forest of northern Canada, but that subspecies was not accepted by the AOU Check-list Committee at that time. It became a forgotten race. Specimens and sight records in winter of more heavily marked non-eastern Red-tailed Hawks (*B. j. borealis*) on the Great Plains and eastward were automatically assigned to western Red-tailed Hawks (*B. j. calurus*) because of their darker markings. In 2014, Ligouri and Sullivan revisited northern Red-tailed Hawks, found that adults were more darkly marked, compared to Eastern Red-tailed Hawks." I examined non-breeding adult specimens labeled as western Red-tailed Hawks that were taken on the Great Plains or otherwise outside the breeding range of that subspecies in 8 museums. Using traits from Liguori and Sullivan, I found that almost all were northern Red-tailed Hawks; only 5 collected in southern Texas had traits of western Red-tailed Hawks. Further, I found that many dark-morph adult specimens from this winter region were not western Red-tailed Hawks but were most likely an undescribed dark-morph of northern Red-tailed Hawk.

Many sight records, photographs, and specimens of heavily marked non-eastern Red-tailed Hawks have been taken in winter within the breeding range of eastern Red-tailed Hawks in central and eastern North America from the Great Plains to the east coast. It was assumed that these were of the western Red-tailed Hawks (*B. j. calurus*), as it was the only subspecies known previously to have heavily marked underparts on adults and rufous and dark color morphs, other than Harlan's Hawk (*B. j. harlani*). (Clark and Wheeler 2001, Liguori 2004). The northern Red-tailed Hawk (*B. j. abieticola*), a forgotten taxon recently revisited by Liguori and Sullivan (2014), is also more heavily marked on adults compared to eastern Red-tailed Hawks (*B. j. borealis*) and Fuertes Red-tailed Hawk (*B. j. fuertesi*), It was described by Todd (1950) as the Northern Red-tailed Hawk (*B. j. abieticola*). This subspecies was never recognized as a valid subspecies by the then AOU Check-list Committee. The AOU ceased listing subspecies after the 5th edition in 1957 until the present. The on-line Birds of the World mentions *B. j. abieticola*, but treats it as "…a matter of debate." (https://birdsoftheworld.org/bow/home). Northern Red-tailed Hawks breed in the boreal forest belt from Alaska to Labrador and winter farther south in much of southern U. S (Todd 1950, Liguori and Sullivan 2014). Based on Liguori and Sullivan (2014), I have determined traits which distinguish the plumages of northern adults from those of adult western and eastern adult Red-tailed Hawks.

Almost all specimens in 8 museums labeled as western Red-tailed Hawks taken on the Great Plains and eastward in winter were judged to be northern Red-tailed Hawks. Fewer than a dozen photographs (Lish 2015) and five specimen records of light-morph western Red-tailed Hawks were from the southern Great Plains, outside the breeding range of western Red-tailed Hawks. And the western specimens were only from southern Texas and photos only from central Oklahoma. Some, but not all, of the records of dark adults from this large area were dark-morph Harlan's Hawks, which can be distinguished from dark adult Red-tailed Hawks by tail color and pattern, as well as other characters (Clark and Wheelers 2001, Liguori 2004, Liguori and Sullivan 2014, Clark 2018). This result suggests that the dark-morph and rufous-morph Red-tailed Hawk specimen records in this region, except for southern

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Texas, and outside the breeding range of the western Red-tailed Hawk, are not of that subspecies. These specimens are most likely an undescribed dark-morph northern Red-tailed Hawks, as suggested by Iron (2012). I found that these dark adult Red-tailed Hawks differed in several characters from dark-morph adult western ones.

METHODS

Seventy-eight light- and 34 dark-morph specimens of adult Red-tailed Hawk were examined in eight museums (Table 1). These specimens had been collected outside the breeding range of western Red-tailed Hawk on the Great Plains and eastward and were labeled as that subspecies. The vast majority were taken in North Dakota and Arkansas, as well as Texas, but also from Michigan, Oklahoma, Louisiana, Saskatchewan, Manitoba, Northwest Territory, Minnesota, Missouri, Kansas, Iowa, West Virginia, Pennsylvania, Maryland, New Jersey, and Georgia (Table 1). I assigned each of the specimens to western, eastern, or northern subspecies, using the characters in Clark and Wheeler (2001), Liguori (2004), and Liguori and Sullivan (2014) and shown in Table 2 and Fig. 1. Figure 20 in Liguori and Sullivan (2014) shows a comparison of adult eastern, western, and northern Red-tailed Hawks. I examined more than 30 photographs of dark-morph Red-tailed Hawks taken outside the breeding range of western Red-tailed Hawk as shown in Preston and Beane (2009).

The bare tarsi of 92 specimens labeled as western, but judged to be northern (n = 62 light morph and n = 30 dark morph), were measured using the criteria described in Clark (2018). I ran two-tailed T-tests comparing the means of bare tarsi of dark- and light-morph western and presumed northern specimens.

In addition to the study skins forty adult Red-tailed Hawks were captured from 2016 to 2021 in winter in southern Texas. They all were judged as to their subspecies.

I examined photos of a dark-morph Red-tailed Hawk adult taken in Madison, Wisconsin by Erik Bruhnke in 2011. I examined photos of three dark-morph Red-tailed Hawks that had been captured for banding in northern Virginia by Paul Napier: two adults in 1996 and 2000, and a juvenile in 1999. I examined photos of three dark-morph Red-tailed Hawks that had been taken in Arkansas for falconry by Cody Fields. I examined photos of a dark-morph Red-tailed Hawk adult taken into a rehabilitation facility in West Virginia

RESULTS

Most, if not all, of the light-morph specimens that were labeled as western Red-tailed Hawks and taken in winter from this vast area had the traits of northern Red-tailed Hawks (n = 73, Table 1) (Table 2) (Fig. 1). Table 3 is a list of 30 dark-morph specimens taken from this area. These are most likely northern Red-tailed Hawks, as no light-morph western Red-tailed Hawk specimens were

Table 1. Museum specimens of adult Red-tailed Hawks taken on the Great Plains and eastward.

Museum	No. light northerns	No. light westerns	No. dark northerns	Collecting States
Texas A & M	5	2	0	TX (7)
Delaware Museum	1	0	1	MO (2)
Heard Museum	4	0	1	TX (5)
Houston MNH	2	1	0	TX (3)
LSU Museum	11	0	1	TX (1), LA (11)
Noble OU Museum	10	0	0	OK (10)
Coven OSU Museum	3	0	1	OK (4)
U. Michigan Museum	31*	2	28	AR (29), KS (1) MB (1), MN (1), MO (1), ND (25) NWT (1)
US National Museum	6	0	2	ND (1), IA (2), OK (1), NJ (1), Mex (1)
TOTAL	73	5	34	

* Only a sample.

Table 2. Plumage traits of adult Red-tailed Hawks by subspecies.

Trait/Subspecies	Eastern	Northern	Western
Throat	Pale	Pale with dark edges or darkly streaked	Dark
Sides of breast	Unmarked	Streaked	Unmarked
Underparts	Buffy	Buffy or whitish	Rufous
Belly band	Few dark streaks	Many dark streaks	Rufous barring
Leg feathers	Unmarked	Whitish to buffy, with spotting	Barred rufous
Scapulars	Whitish	Buffy, reduced	Buffy to rufous
Upper tail coverts	Pale	Pale	Dark
Tail	Only dark subterminal	Extra dark bands	Extra dark bands
Subterminal tail band	Narrow or absent	Wider	Narrow
Outer primary tips	Pale	Pale, with dark bands	Dark

collected in these areas, and they differed from dark westerns in several traits. Note that one of these specimens was collected in June in the Northwest Territory of Canada, suggesting a breeding record. The last six in the list were taken in the same areas as many of the adults in this table and are assumed to represent dark northern juveniles. Fig 2 is a dark-morph northern adult specimen taken in Payne County, Oklahoma on October 11, 1941.

I found only a handful of light-morph western Red-tailed Hawk specimens that had been taken outside of the breeding range of this race; these five taken in southern Texas (Table 1). I found only a few photographs of adult light-morph western Red-tailed Hawks in central Oklahoma (Lish 2015). I conclude that the only valid records of this race on and east of the Great Plains are from southern Texas and central Oklahoma.

I found no statistical difference between the bare tarsi measurements of light-morph (n = 62) (mean = 36.50) and dark-morph (n = 29) (mean = 36.63) putative northern Red-tailed Hawk specimens (T-test: p = 0.719, t = 0.361, df = 89). Bare tarsi lengths of presumed light-morph northern specimens are significantly different from light- morphs of breeding western Red-tailed Hawks (n = 220) (mean = 41.40) (T-test: p 1.04 x e^{27}, t = 1.97, df = 279) (Clark 2018). The bare tarsi lengths of dark-morph northern specimens are also significantly different from the bare tarsi length of dark-morph western Red-tailed Hawks (n = 50) (mean = 42.56) (T-test: p = 1.15 x e^{15}, t = 1.991,

Figure 1. Comparison of adult Eastern (top) (TX), Northern (center) (TX), and Western (Bottom) (CA) Red-tailed Hawk. a. top - ventral. b. bottom - dorsal. Heard Museum. McKinney, TX

Table 3. Dark morph specimens of northern Red-tailed Hawks collected outside range of western subspecies.

State	Museum	No.	Age	Sex	DATE	Location	Bare tarsi
OK	OK State U	522	Adult	M	Nov. 1941	Payne Co.	39.8
NWT	USNM	193557	Adult	U	June 1903	Mackenzie Delta	35.5
ND	USNM	335306	Adult	F	Apr. 1929	Grafton	33.2
ND	U. MI	54845	Adult	F	Sept. 1923	Grafton	35.1
ND	U. MI	58929	Adult	M	Oct. 1927	Grafton	35.8
AR	U. MI	60676	Adult	M	Jan. 1929	Pea Ridge	35.9
AR	U. MI	60677	Adult	M	Dec. 1928	Pea Ridge	39.2
AR	U. MI	60678	Adult	F	Jan. 1929	Pea Ridge	38.7
ND	U. MI	60952	Adult	F	Mar. 1929	Pea Ridge	37.5
ND	U. MI	60956	Adult	M	April 1929	Grafton	38.3
AR	U. MI	62090	Adult	M	Dec. 1925	Pea Ridge	36
AR	U MI	62106	Adult	M	Feb. 1927	Pea Ridge	35.9
AR	U.MI	62113	Adult	M	Jan. 1926	Pea Ridge	33.3
AR	U. MI	62157	Adult	M	Nov. 1926	Pea Ridge	35.9
AR	U. MI	62168	Adult	F	Dec. 1927	Pea Ridge	36.5
AR	U.MI	62178	Adult	M	Dec. 1924	Pea Ridge	34.8
KS	U. MI	62207	Adult	M	Dec. 1924	Greenwood	36
AR	U. MI	67147	Adult	M	Jan. 1926	Pea Ridge	37.3
AR	U. MI	68242	Adult	F	Dec. 1931	Washington	38.5
AR	U. MI	71917	Adult	F	Jan. 1934	Pea Ridge	35.5
ND	U. MI	118545	Adult	F	Sept. 1925	Grafton	35.5
ND	U. MI	121647	Adult	M	Jan. 1935	Pea Ridge	36.8
ND	U. MI	58334	2nd Prebasic	M	June 1927	Grafton	35.9
ND	U. MI	59303	2nd Prebasic	M	April 1923	Grafton	37.2
ND	U. MI	54890	Juvenile	F	Oct. 1922	Grafton	36.1
ND	U. MI	58937	Juvenile	M	Oct. 1927	Grafton	38.8
AR	U. MI	60681	Juvenile	F	Jan, 1929	Pea Ridge	35.5
ND	U. MI	62119	Juvenile	F	Oct. 1927	Grafton	38.1
KS	U. MI	62206	Juvenile	M	Dec. 1924	Greenwood	39.4
ND	U. MI	68284	Juvenile	F	Oct. 1931	Grafton	39.2

df = 76) taken during the breeding season (WSC unpublished data).

The 40 adult Red-tailed Hawks captured for banding by me in southmost Texas were determined to be 13 Northerns, 20 Easterns, 6 Fuertes, and 1 Western, using the traits of Table 2. Figure 4 is a northern adult: a dorsal, and b ventral.

The dark-morph adult reported and depicted in Iron (2012) was most likely a northern Red-tailed Hawk. Two other published records of dark red-tails–from Pennsylvania by Wiltraut (1992) and Floyd (1993) are also likely northern ones. Wiltraut reported that he saw a dark adult in the same place on January19, 1990 and from January-March 1991. A photo of it perched is on page 46 of the same issue of Pennsylvania Birds, vol 5, no. 1, in the account of Northampton Co. Floyd (1993) reported that he and Jeff Hoover saw an all-dark adult Red-tailed Hawk

Figure 2. Dark-morph specimen of adult northern Red-tailed Hawk collected in Oklahoma. Cowen Museum, Oklahoma State U.

on February 23, 1992 in Centre Co, PA. No photos were taken of that adult.

Erik Bruhnke took photos of a dark-morph adult Red-tail on the Capitol grounds in Madison, WI on December 11, 2011. It looks somewhat like a dark-morph western Red-tail but note the noticeably wider dark subterminal band and wingtips that do not reach the tail tip (Fig. 4, a perched, and b. flying).

Steve Baker had taken photos of dark Red-tailed Hawks at the Mackinac Straits Hawk Count in Michigan in the springs of 2008 and 2012-2018. One was banded. We determined that all were northern (Fig. 5 shows a dark adult with two northern light-morph adults.).

The three dark-morph Red-tailed Hawks captured for banding in Virginia by Paul Napier (Adult shown in Fig. 6, a dorsal, b ventral) and three taken for falconry in Arkansas by Cody Fields (One dark adult shown in Fig. 7, a dorsal, b ventral). were also most likely dark northern Red-tailed Hawks The dark-morph Red-tailed Hawk adult in the Rehab facility in West Virginia was likewise most likely a dark northern Red-tailed Hawk (Fig. 8).

DISCUSSION

I found no specimens or photographs of light-morph western Red-tailed Hawks outside of the breeding range of this subspecies on the Great Plains and eastward, except for the 5 specimens from southern Texas, two adults captured for banding in southmost Texas, and photographs from central Oklahoma (Lish 2015). Rather, most of the non-eastern wintering adults in this area had the traits of northern adult Red-tailed Hawks. By logic therefore, the dark-morph and rufous-morph adult Red-tailed Hawk photos, sight records, and specimens reported herein from the Great Plains and eastward are most likely from a subspecies other than western. There are no records of dark-morph or rufous-morph individuals in either the eastern or Fuertes (*B. j. fuertesi*) populations, but there are indications that the northernmost breeding Red-tailed Hawk does have a dark morph (e.g., Table 2 for a specimen collected in the NWT in June during the breeding season). The first published mention of a dark-morph adult northern Red-tailed Hawk is by Townsend (1913) from Labrador. He wrote “A very dark bird of this species [Red-tailed Hawk] was seen for three days near a precipitous hill on the branch river. Only when seen from above could the red tail be distinguished, from below, the tail seemed nearly black”. Iron (2012) reports on a dark-morph adult Red-tailed Hawk from Ontario that she opined might be a northern subspecies. She showed photos of a juvenile dark-morph specimen from the Royal Ontario Museum taken in Toronto, Ontario and thought it might also be a dark northern subspecies.

Lish (2015) has many photos of adult northern Red-tailed Hawks wintering in central Oklahoma (e.g. pp 76-77), including dark- and rufous-morph adults (e.g., pp. 56-57, 60, 78), which are most likely northern Red-tailed Hawks. He also shows photos of adult western Red-tailed Hawks.

Figure 3. Northern light-morph adult Red-tailed Hawk captured in south Texas in November 2011. a. top - ventral. b. bottom -dorsal.

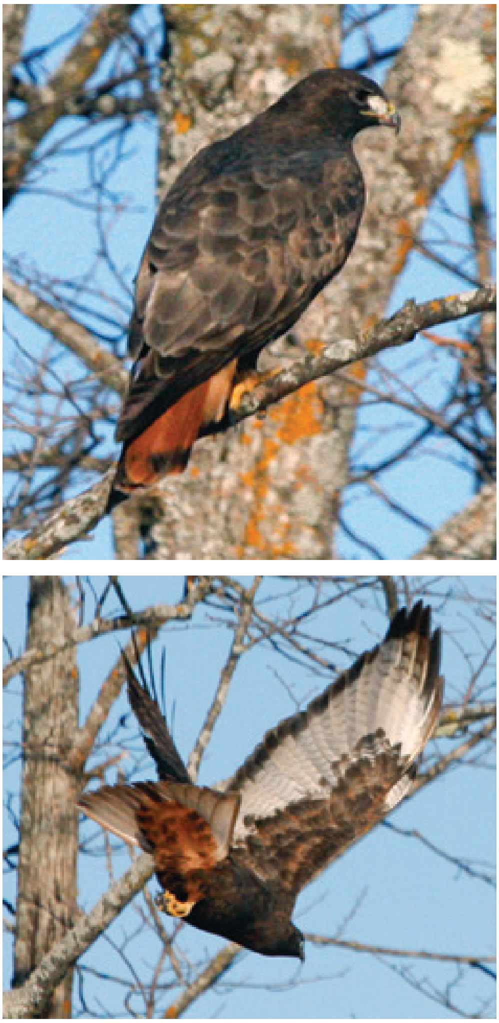

Figure 4. Northern adult dark-morph Red-tailed Hawk, Madison, WI. December 11, 2011. a. top - perched. b. bottom - flying. Photos by Erik Bruhnke.

Figure 5. Northern adult dark-morph Red-tailed Hawk taken at Mackinac Straits, MI in April 2020, with two light-morph northern adults. Photo by Steve Baker.

Figure 6. Northern adult dark-morph Red-tailed Hawk captured in VA in Dec 2000. a. left - ventral. b. right -dorsal. Photos by Paul Napier.

Apparently the AOU Checklist Committee did not consider accepting *B. J. abieticola*, based on Todd (1950), as none of the Annual Supplements published in the Auk in between 1950 and the publication of the Fifth AOU Check-list in 1957 (25th-31st) mentions it. The 1957 Check-list was the last to include subspecies.

A map showing satellite tracks of 31 migrating western Red-tailed Hawks from 1999 to 2003 (Fig. 9, based on Hawk Watch International (HWI) unpublished data) suggests that they tend to move south from their breeding areas into Mexico and Central America, with little indication of eastward movement into the Great Plains. Cartron (2010; p. 42, Fig. 4.2), shows migrating western Red-tailed Hawks moving south, but not east. Oleyar and Watson (2020; p. 29) document only one western Red-tailed Hawk band recovery on the Great Plains; that recovery was in southern Texas. Fig. 5 in Bonerbo and Goodrich (2021) shows band recoveries of western Red-tailed Hawks, with only one east of the breeding range. The above are consistent with the findings herein of few Western

Figure 7. Northern adult dark-morph Red-tailed Hawk captured in winter in AR. Jackson. a. left -ventral. b. right - dorsal. Photos by Cody Fields.

Red-tails on the southern Great Plains. A few of these western migrants could end up in southern Texas and central Oklahoma, as indicated by the five adult western specimens and photos in Lish (2015).

Mitchell and Mitchell (2017) discuss the subspecies of Red-tailed Hawk wintering on the Mississippi Alluvial Valley. They have photos of adult northern Red-tailed Hawks but none of western Red-tailed Hawks.

Figure 8. Northern adult dark-morph Red-tailed Hawk in rehabilitation in WV in Nov. 1999. Photo by Wendy Perrone, Three Rivers Avian Center.

A research team called the Red-tailed Hawk Project is doing field and laboratory work to determine, among other objectives, the origin of non-eastern Red-tailed Hawks wintering on the Great Plains. Go to: https://redtailedhawkproject.org/ for more details and latest results. One of the Projects' techniques is placing GPS transmitters on them in winter to determine their breeding locales. One of the team, Bryce Robinson, will also be using Population Genomics to help determine the relationships among the various taxa of Red- tailed Hawks.

ACKNOWLEDGMENTS

I thank Brian Sullivan for suggesting that I do this study. I thank Dave Oleyar for preparing Fig. 9 from HWI data. I thank Jeff Smith for discussions on Red-tailed Hawk migration and for mentioning the western Red-tailed Hawk migration map in Birds of New Mexico that he had prepared. I thank Jim Lish for discussions on wintering Red-tailed Hawks in central Oklahoma. I thank the curators and collection managers of these museums: Biodiversity Research and Teaching Collections, Birds (Texas A & M); Delaware Museum of

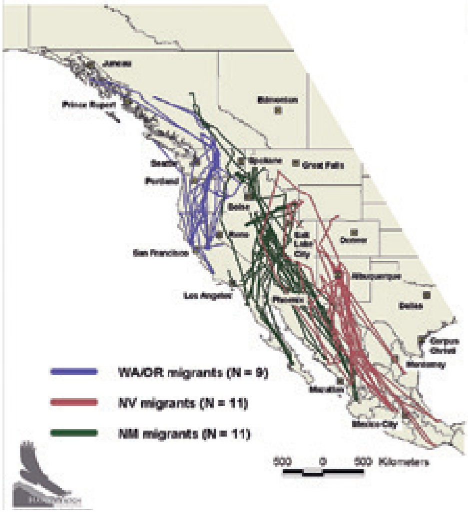

Figure 9. Migration tracking data for western Red-tailed Hawks. Data from Hawk Watch International.

Natural History; Heard Museum of Natural History; Houston Museum of Natural History, Museum of Natural Science, Louisiana State U.; Philadelphia Academy of Natural Sciences; Noble Museum (U. of Oklahoma); Oklahoma State U.; Museum of Zoology, U. Michigan; and U. S. National Museum (Smithsonian Institute). I thank Steve Baker, Erik Bruhnke, Cody Fields, Paul Napier, and Wendy Perrone for permission to use their photographs.

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ACOUSTIC SURVEY OF NOCTURNAL BIRD MIGRATION AT RICE UNIVERSITY IN HOUSTON, TX DURING FALL 2020

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ABSTRACT.—Urban centers are hazardous for migrating birds because of the lack of appropriate stopover habitat and the disorienting effects of light pollution on nocturnal migrants. Low background noise due to the 2020 COVID pandemic allowed for an acoustic survey of fall migration in Houston, Texas (USA), a major metropolitan area located on a critical part of the mid-continent flyway. Nocturnal flight call surveys were conducted each night at a microphone station at Rice University from 7 Jul to 30 Nov. A total of 3799 independent flight calls were detected with sparrows and warblers dominating. For many species, the migration windows established by this study matched those determined from sight surveys over many years, indicating the great potential of nocturnal acoustic monitoring as an accurate and efficient method of studying temporal patterns of bird migration. Nocturnal acoustic surveys may work particularly well for birds that are seldom seen during the day owing to their secretive habits. For example, 67 Grasshopper, 71 LeConte's, and 5 Nelson's Sparrows, which are rarely if ever seen in transit in the study area, were detected. Also noteworthy were numerous detections of thrushes, which are rarely seen in the fall along the upper Texas coast. Broad migratory patterns were also revealed in this study. The highest migrant fluxes as detected by nocturnal flight calls were associated with major cold fronts. During these nights, nocturnal flight calls were detected within an hour after sundown and descended two hours before sunrise. Nocturnal flight call surveys were compared to Doppler radar reflectivity. High flight call fluxes broadly correlated with high radar reflectivity in late fall. On any given night, the decline in flight call detections before dawn was coupled to a decline in radar reflectivity. However, radar reflectivity typically increased an hour before the first detection of flight calls each evening. In late fall (Nov), resurgences in flight call detections were observed at sunrise, invariably accompanied by a resurgence in radar reflectivity as well. This study shows that nocturnal acoustic surveys may provide useful information for reducing the number of nocturnal building collisions of migrating birds and possibly documenting the effects of climate and land-use change on migratory patterns from year-to-year.

Twice a year, with the changing of the seasons, birds across the planet take to the skies to migrate. In the northern spring, birds migrate north to take advantage of the plethora of sunlight and food in the northern latitudes to breed and rear their young. As fall approaches and the length of daylight shortens in the northern latitudes, these birds migrate south to their wintering grounds near the equator or southern hemisphere, only to repeat this cycle the next spring.

Migration can be perilous as the journey is long and the hazards are many (Able 1999, Robbins et al. 1989). Understanding the timing, magnitude and species composition of migrating birds is critical for bird conservation, particularly when it comes to assessing populations or potential human-made hazards during migration. For example, knowing exactly when and where birds migrate can help assess where wind turbines, a demonstrated hazard for birds, are placed and when they are operated (Howe et al. 2002). Similarly, it is well known that many birds, from shorebirds to songbirds, migrate at night so that they can use daylight hours to find food (Farnsworth et al. 2004, Horton et al. 2015, Larkin et al. 2002, Mabee and Cooper 2004). As such, nocturnal migrants face a unique hazard

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today—light pollution. In urban centers where lights and tall buildings coexist, the disorienting effects of lights can cause birds to collide into buildings or drive them to exhaustion, forcing them to the ground where they become victims to other hazards, such as cats, moving cars, etc. (Cabrera-Cruz et al. 2018, La Sorte et al. 2017, Longcore et al. 2013, Van Doren et al. 2017). Knowing when birds move through in the night would help inform when lights should be turned off or wind turbines shut down.

Most of our understanding of migration patterns comes from visual or audio surveys during daylight hours by field ornithologists or amateur birders. Diurnal surveys, however, produce variable results due to differences in observer skill and the inherent patchiness of how birds move through at a local level, which is strongly influenced by microhabitat variability and local weather. Establishing a generalized picture of migration patterns through diurnal surveys thus requires a big data approach in which surveys over large lengthscales and by many observers are pooled to average out observer bias and local variability. Community science projects, such as eBird, have harnessed the power of big data, revolutionizing our understanding of the geographic distribution and migratory patterns of birds (Sullivan et al. 2009, Walker and Taylor 2017). Many birds, however, migrate in the night (e.g., the "dark migration") and may go undetected during the day if they have secretive habits or if they do not stop in a particular study area. Thus, an open question is how much information regarding bird migration is not observed through diurnal surveys.

Doppler radar provides an essential complement to diurnal surveys because it allows for continuous continental and local scale monitoring and provides a window into "dark migration". There are, of course, challenges in converting bulk radar reflectivity into the numbers and species make-up of birds flying overhead (Farnsworth et al. 2004, Farnsworth et al. 2016, Gasteren et al. 2008, Gauthreaux Jr and Belser 2003). Over the last two decades, nocturnal acoustic surveys focused on detecting nocturnal flight calls (NFCs) have grown as an essential complement to radar studies. NFC surveys have helped to validate radar surveys and remain the only method for identifying nocturnal migrants to species. In particular, the pioneering work of Evans and co-workers (Evans and O'Brien 2002, Evans and Rosenberg 2000), along with community archives of bird calls (macaulay.org, ebird.org, xeno-canto.org), has led to significant advances in our understanding of NFC identification.

In early 2020, the COVID-19 pandemic caused the world to lock down, restricting travel and thereby forcing us to conduct surveys locally. Motivated by the desire to continue observing birds, we decided to monitor NFCs. We took advantage of the reduction in background noise associated with vehicular and aviation traffic. This paper presents the results of NFC surveys conducted by the first author between Aug 1-Nov 30 in urban Houston, TX (USA). Houston is the fourth largest city in the United States and is projected to become the third largest in the next few years. It is centered on one of the major flyways of North America, the mid-continent flyway, and being located on the Gulf of Mexico, it serves as a critical transit point along this flyway (Able 1999, Eubanks et al. 2006, Gauthreaux et al. 2006). In spring and fall, a large proportion of the world's neotropical migrants pass through the Houston area. To date, most NFC surveys have focused on eastern North America (Evans and O'Brien 2002, Evans and Rosenberg 2000, Farnsworth 2005, Farnsworth et al. 2004, Farnsworth and Lovette 2005). Fewer studies have been conducted in the western United States (Mabee and Cooper 2004) and along the Gulf Coast (Evans and Mellinger 1999, Larkin et al. 2002). Almost no NFC or radar studies have been published for fall migration on the Gulf Coast. Here, we present the first continuous NFC survey of fall migration along the Texas coast.

METHODS

Nightly NFC surveys from 7 Jul to 30 Nov, 2020 were conducted. Surveys began at sundown and continued until 2 hours before sunrise. An Olympus ME-31 compact shotgun microphone was attached to an Olympus LS-P4 digital recorder for audio recordings. The recording apparatus was placed inconspicuously at the top of a small lemon tree in the middle of an athletic field (O'Connor Field) on the Rice University campus in Houston, TX (29.718773, -95.404975). This site was chosen because it was the furthest from roads and thus had the lowest traffic noise in this urban area. In addition, the first author has conducted diurnal surveys of this site for the last 20 years.

The shotgun microphone was oriented vertically and unobstructed to the sky. The ME-31 microphone has a frequency response between 70-15,000 Hz and a sensitivity of −36.5 dB. No wind guard was applied to the microphone so as not to suppress high frequencies. Based on diurnal recordings of calling Yellow-rumped Warblers, whose exact distances from the microphone was known, we estimate that the microphone was able to detect overhead warbler flight calls from a distance of 70-100 m. However, because we used a shotgun microphone, we estimated that our cone of detection was approximately <35°, corresponding to a lateral detection radius of 22-32 m at a height of 70100 m above the microphone.

We recognize that our recording set up is less advanced than some existing protocols. Our use of off-the-shelf recording equipment was motivated by convenience. Given the urban nature of our site, its use for athletic activities during the day and evening, and the lack of a plug-in power supply, it was necessary to have a microphone that was of low cost, inconspicuous (to minimize theft or vandalism) and easy to remove every morning so that data could be downloaded and batteries replaed.

Occasionally, we were not able to record. No usable recordings were obtained during nights of heavy rains. On a few occasions, our recording apparatus malfunctioned due to being knocked down by wind or animal, so no data are provided for these nights. There were four nights in early September, where we were unable to record because the authors were not present to install the microphone. These hiatuses are few and should not influence the overall results of this study. The hiatuses are denoted in the data files as well as any figures depicting time series.

Weather data were taken from the University Place KTXHOUST3188 station. We report total daily precipitation and average daily temperatures, dew point, humidity, wind speed, and barometric pressure. We used the base reflectivity data from Houston's Nexrad radar system (KHGX) located in Dickinson, just south of Houston. The base reflectivity data correspond to a base azimuth angle of 0.5°. Historical data were retrieved from the National Centers for Environmental Information from the National Oceanic and Atmospheric Administration (ncdc.noaa.gov).

Recordings were manually processed through Audacity, an open-source signal processing software. Each night's recording was first visually scanned in spectral mode to pick NFCs. Identification or classification of calls was based on listening to and visually analyzing spectrograms. We used our own experience as well as comparisons to existing NFC databases (Macaulay.org, xeno-canto.org) and the oldbird.org archives (Evans and O'Brien 2002) to identify the spectrograms. When in doubt, the identification of an NFC was discussed among the authors as well as with NFC experts in the community. Many NFCs are not identifiable, so we have taken a conservative approach here in reporting our data. For example, we grouped all warblers as "warbler sp." because the great majority of the warbler NFCs were not identifiable. Many of the sparrow NFCs were identifiable, but those that were not identifiable to species have been categorized as "sparrow sp."

Select spectrograms were deposited in the Macaulay bird sound archives and linked to eBird reports. Recordings are all archived under the Rice University, Houston, Texas eBird hotspot under user "Cintylee". Numeric data on the numbers of each species per night are also stored on the eBird archives. More detailed data with exact time stamps within a given night survey can be requested from the first author.

RESULTS

Identification of Nocturnal Flight Calls

The frequency band of most songbirds lie above 5 kHz (warblers between 5-8 kHz and sparrows between 7-10 kHz) while ambient background noise was typically below 2 kHz. No noise corrections were applied to detect and identify calls. However, for archived recordings, a high pass filter was applied to remove low frequency background noise for ease of hearing. We chose a cutoff frequency that would not attenuate calls of interest but removed as much low frequency background noise as possible (typically <2 kHz). In some cases, signals were amplified, but otherwise no other processing was performed. Identification of spectrograms to species was based on the pioneering work of (Evans and O'Brien 2002). Representative spectrograms of NFCs recorded during our surveys are shown in Figure 1a-e (although we did not record any Grey-cheeked Thrushes (*Catharus minimus*) in the fall, we have added a recording from spring 2020 for completeness).

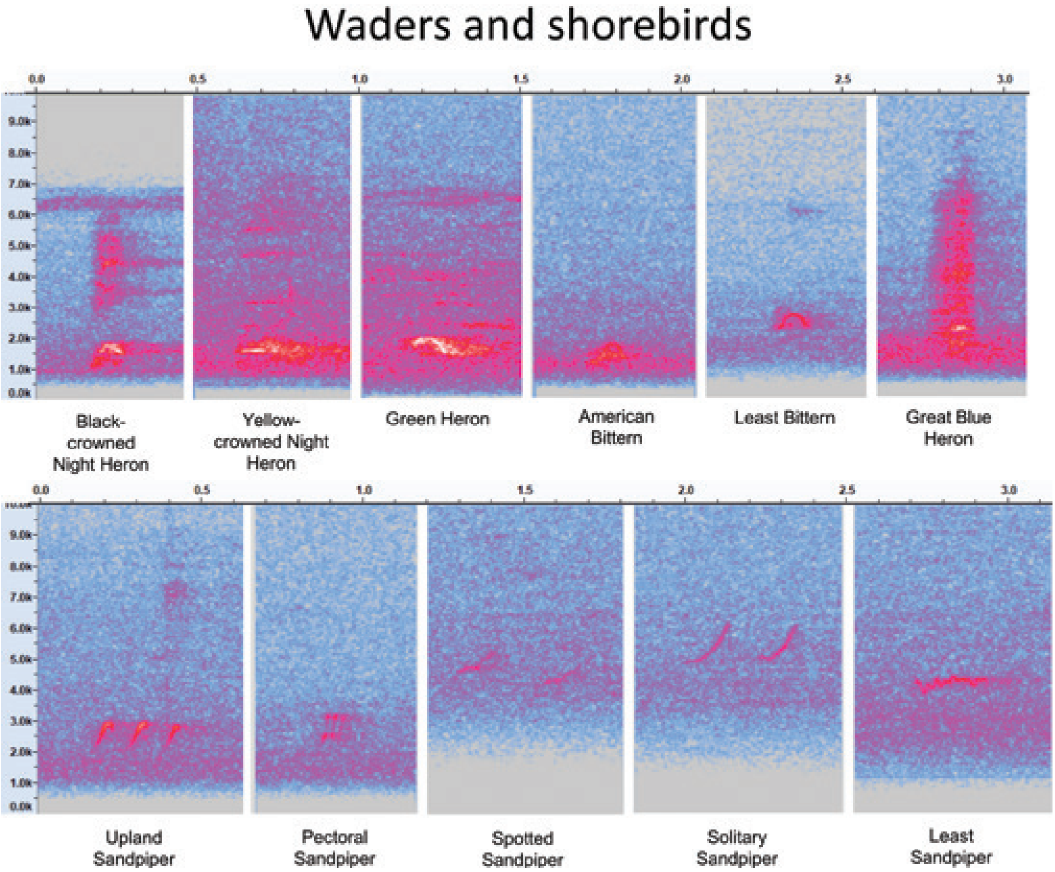

Figure 1A. Representative spectrograms of waders and shorebirds used for classification.

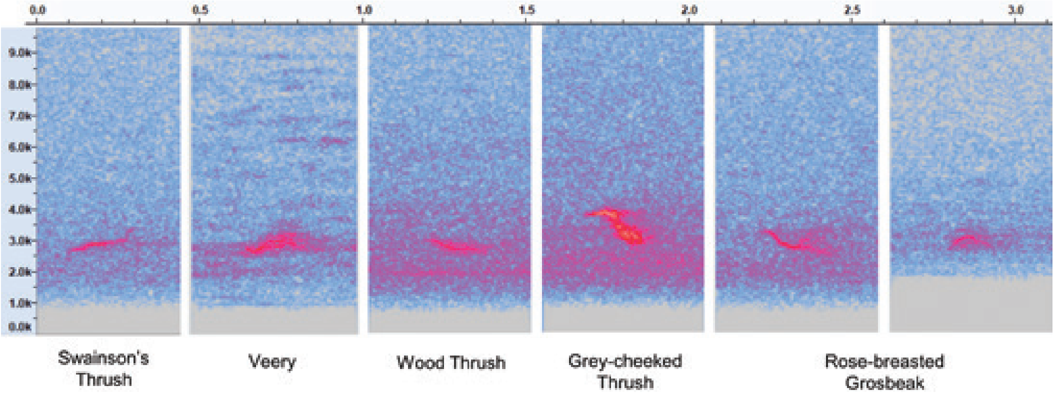

Figure 1B. Representative spectrograms of thrushes and grosbeaks. A Grey-cheeked Thrush from spring has been provided for comparison.

Estimating Numbers of Nocturnal Flight Calls

Although the goal was to estimate the number of birds flying overhead, audio surveys obviously only detect calling birds. Some species never call, but even for those species that give nocturnal flight calls, they must call when they are passing over the

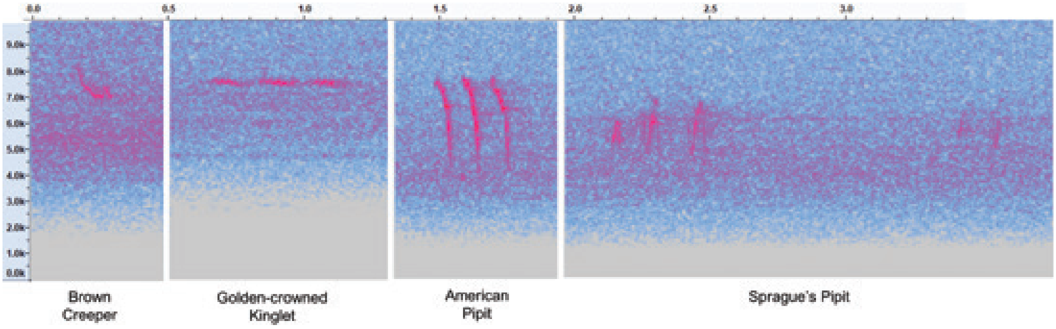

Figure 1C. Representative spectrograms of Brown Creeper, Golden-crowned Kinglet and American and Sprague's Pipits. Pipit spectrograms were recorded at dawn.

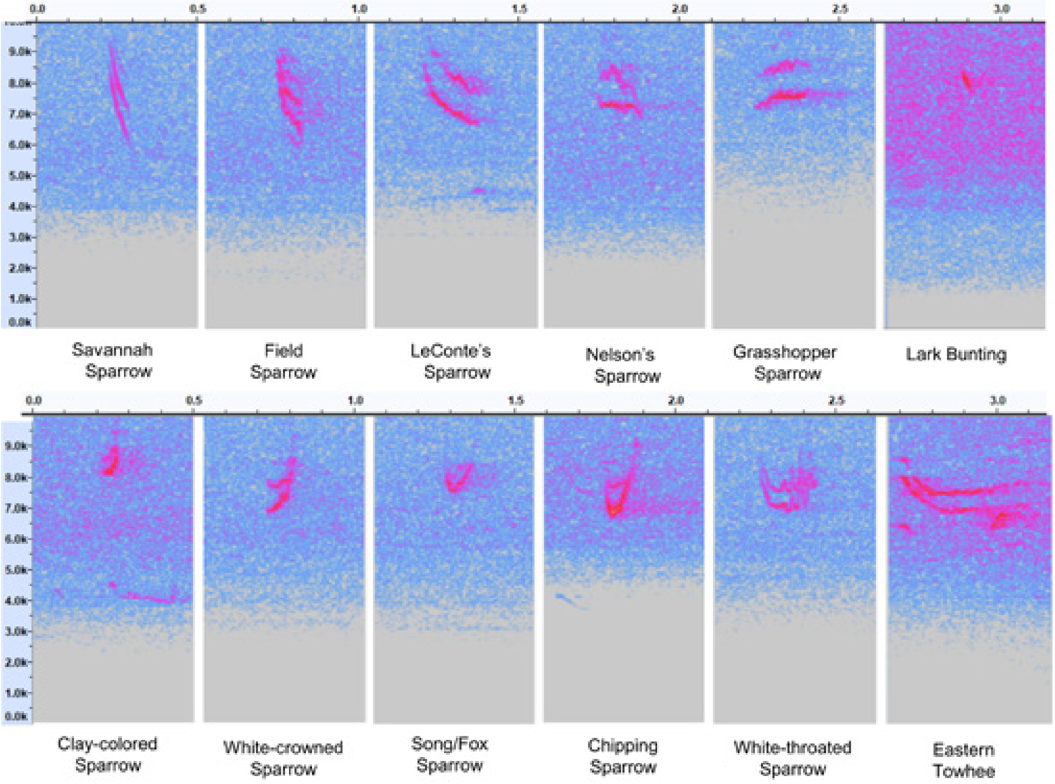

Figure 1D. Representative spectrograms of nocturnal flight calls of sparrows and related species.

microphone to be detected. The ability to detect calls also depends on how high a bird is flying above the microphone. Flying level, however, may differ between species or vary depending on weather conditions or time during the night. Numbers of NFC picks no doubt severely under-estimate the total numbers of birds flying over. Regardless of these uncertainties, numbers of NFCs should still provide valuable data on spatial and temporal patterns of migration for a given species. Assessing relative abundances between different species is made challenging by the species-specific behaviors described above.

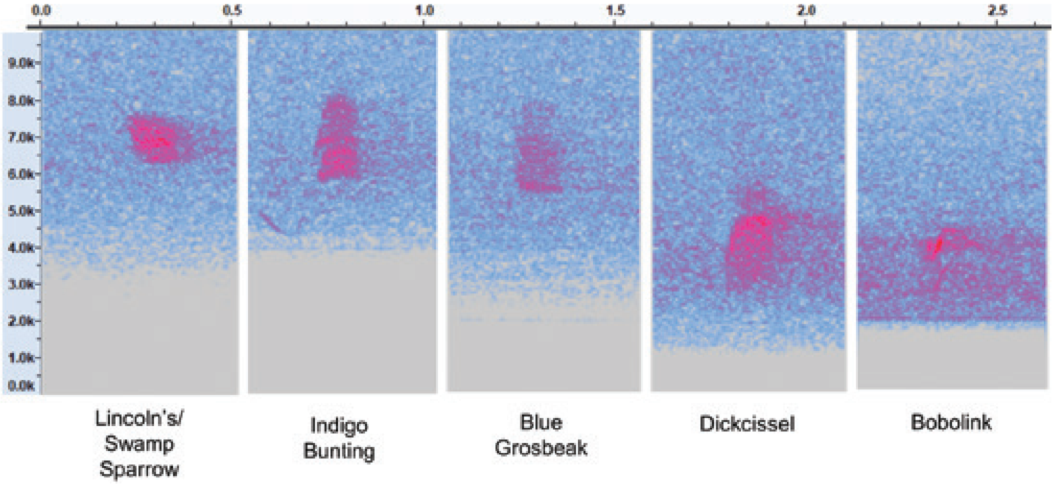

Figure 1E. Representative spectrograms of buzzy nocturnal flight calls. Lincoln's and Swamp Sparrows were not separable.

Our aim was to determine the number of unique NFCs. In general, we counted calls outside of a 15 second window to be independent. Individual birds flying overhead passed over within this time window based on our analysis of call series that show increasing and then decreasing amplitude with time, which we interpret to represent the approach to and the retreat of the bird from our microphone. Most NFCs recorded during our fall survey, however, were single calls separated by much longer timescales than 15 seconds, so the problem of over-counting was generally not an issue. Nevertheless, we attempted to count multiple birds within 15 second windows when possible. Series showing increasing followed by decreasing amplitudes of calls were designated as one bird. Calls with different amplitudes within a 3 second window were designated as different birds. For most bird species, we never had to apply these protocols because the number of migrants per unit time was low. However, these protocols had to be adopted for Yellow-rumped Warblers, which often displayed high flight call fluxes at dawn, making it difficult to distinguish between unique individuals. There is thus considerable uncertainty in our reported Yellow-rumped Warbler numbers. We do not report numbers of species that have both a migratory and resident population (e.g., American Robin, American Crow, Blue Jay) as we were unable to distinguish between migrants and residents from flight calls alone.

Migratory Patterns

A total of 3799 presumed independent NFCs were recorded between 1 Aug-30 Nov, 2020. Most NFCs were recorded between 15 Oct-15 Nov, with sparrows (*Passerellidae*), warblers (*Parulidae*) and buntings (*Passerina*) making up >90% of all calls. Although we lumped all warbler calls into one generalized warbler sp., most of the warbler calls represent morning flight Yellow-rumped Warblers (*Setophaga coronata*). Sparrows and buntings were primarily nocturnal. Total number of birds without warblers was 1773. Figure 2 shows the species breakdown of the dominant nocturnal migrants.

Where data were available, we compared our NFC results to 20 years of diurnal surveys conducted at Rice University. These data were primarily collected by the first author and are archived and publicly available in eBird under the Rice University eBird Hotspot. We chose not to compare to eBird data for larger regions, such as Harris county or the upper Texas coast because regional eBird data do not always distinguish between birds that both migrate and winter in the region. For example, regional eBird data for all sparrows on the upper Texas coast blend migrants with wintering birds so that only first arrivals in the fall and last departures in the early spring can be determined. The lack of habitat at Rice University makes the campus unfavorable for wintering or summering birds. Rice University is thus strictly a migratory stopover, making it

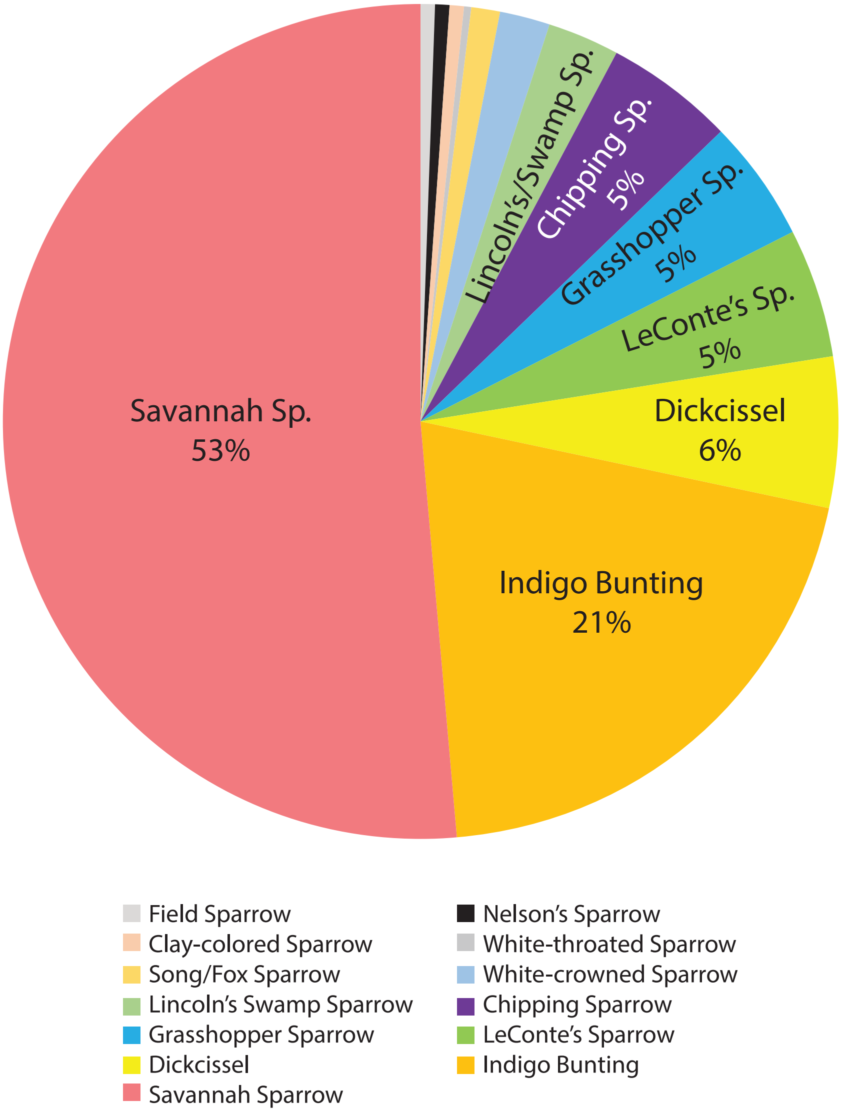

Figure 2. Pie chart showing the species breakdown of sparrows, Dickcissels and Indigo Buntings over the course of the fall survey.

an ideal location to compare diurnal surveys of migration with NFC data.

As discussed below in more detail, the NFC-based temporal patterns match those established from 20 years of diurnal surveys at Rice for most species (Figs. 3 and 4). In Figures 3 and 4, we show migration windows inferred from combining 20 years of diurnal surveys at Rice University. For a number of species, many years of diurnal surveys are needed to establish the migration window. This is particularly so for secretive birds or those that may primarily fly over the study site rather than stop. Diurnal surveys are also heavily dependent on observer skill as well as the presence of appropriate microhabitats for certain species. The distribution of microhabitats may change from year to year or even disappear due to changes in land use and development. The consistency of our NFC results with our two decades of diurnal surveys shows that continuous NFC monitoring over just one season is likely sufficient to define the migration window for many species. For very secretive birds, such as

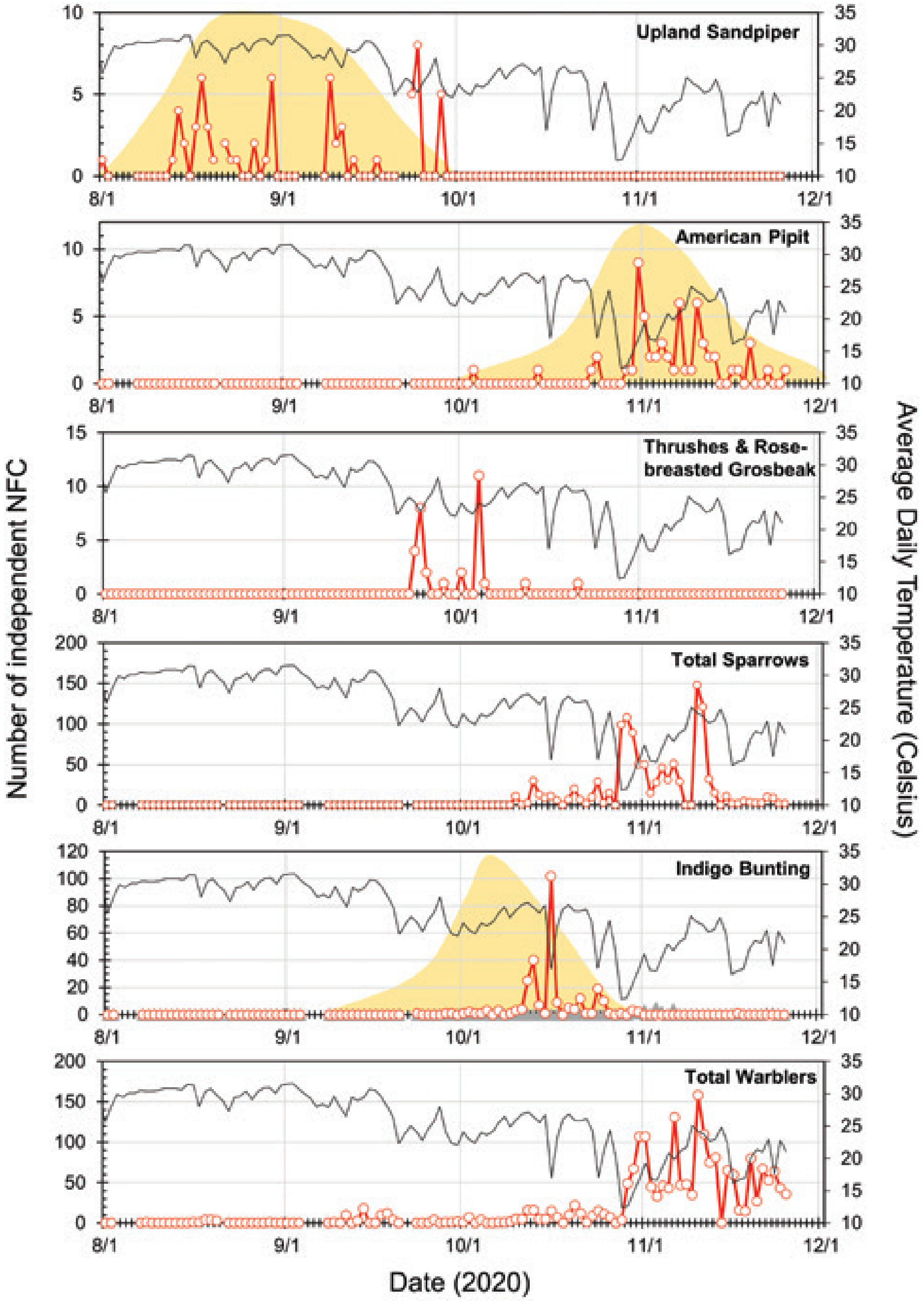

Figure 3. NFC detections as a function of calendar date (red lines). From top to bottom: Upland Sandpiper, American Pipit, thrushes and Rose-breasted Grosbeak, total sparrows, Indigo Bunting, and total warblers. Most of the warbler detections pertain to morning flight Yellow-rumped Warblers. Thin black line corresponds to 24-hr average temperature. Yellow shaded regimes correspond to the diurnal record, which was approximated from 20 years of diurnal observations conducted in the same location. Yellow-shaded regime is not drawn to scale and is only meant to represent relative variations, not absolute numbers. Diurnal observations not shown for thrushes and grosbeaks because none have been recorded in the fall. Diurnal observations not shown for total sparrows and total warblers.

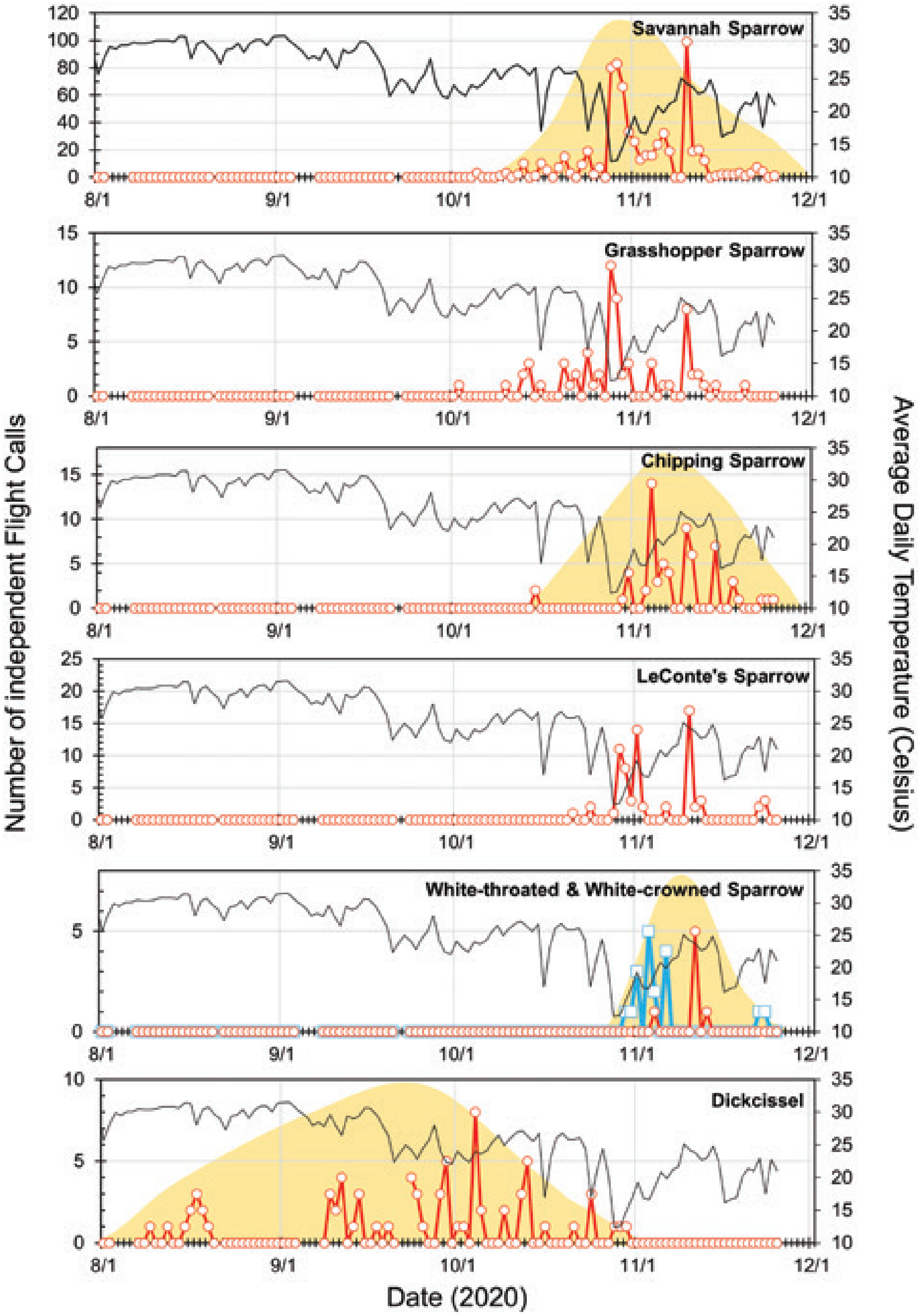

Figure 4. Number of independent NFC detections as a function of calendar date (red lines). From top to bottom: Savannah, Grasshopper, Chipping, LeConte's, White-throated, and White-crowned Sparrows (blue) and Dickcissel. Thin black line corresponds to 24-hr average temperature. Yellow shaded regimes correspond to trends inferred from 20 years of diurnal observations conducted in the same location. Yellow-shaded regime is not drawn to scale and is only meant to represent relative variations, not absolute numbers.

some grassland sparrows, the number of diurnal sightings over two decades was too low to even establish a migration window.

Shorebirds

Shorebirds (primarily *Scolopacidae*) were recorded from 1 Aug to 15 Oct. Upland Sandpipers (*Bartramia longicauda*) dominated with 65 recorded between 1 Aug-28 Sep (Fig. 3). Upland Sandpipers were the most frequently detected shorebird although this is likely because they are highly vocal during migration and their calls are loud. Numbers of Uplands increased abruptly in mid-August and continued until the end of September, after which there was a rapid drop off in detections.

Spotted (*Actitis macularius*) and Solitary Sandpipers (*Tringa solitaria*) were the only other regularly recorded nocturnal shorebird migrants with 9 (15 Aug-14 Sep) and 8 recorded (17 Aug-20 Oct), respectively. We detected surprisingly few other shorebirds. Additional shorebirds included 1 Greater Yellowlegs (*Tringa melanoleuca*; 15 Oct), 1 Whimbrel (*Numenius hudsonicus*; 22 Aug), 4 Least Sandpipers (*Calidris minutilla*; 2 on 17 Aug; one on 12, 13 and 15 Sep), and 2 Pectoral Sandpipers (*Calidris melanotos*; 24 and 28 Sep), all between mid-Aug and mid-Sep.

Except for Upland, Spotted and Solitary Sandpipers, the general paucity of other species is curious given that large numbers of shorebirds undoubtedly pass through our region in the fall. One explanation is that most shorebirds do not call when migrating. Another possibility is that most shorebirds fly too high to be detected.

Waders

A few waders were detected. Green Heron (*Butorides virescens*) was detected 14 times between 1 Aug-4 Oct with most in the last half of September and early October. We also detected 2 Great Blue Herons (*Ardea herodia*s; 13 and 28 Oct), 2 Least Bitterns (*Ixobrychus exilis*; 15 Aug and 11 Sep), 2 American Bitterns (*Botaurus lentiginosus*; 28 Sep and 16 Nov), and 11 Black-crowned Night-Herons (*Nycticorax nycticorax*; 9 Jul-2 Oct). No Yellow-crowned Night Herons (*Nyctanassa violacea*) were detected nocturnally in the fall.

Waterfowl

The only waterfowl detected during our nocturnal surveys were Black-bellied Whistling Ducks (*Dendrocygna autumnalis*) and a small flock of Snow Geese (*Anser caerulescens*) on 13 Nov.

Thrushes

Thrushes are generally thought to be rare fall migrants in Texas based on diurnal observations. We were thus surprised to detect numerous thrushes in the night (Fig. 3): 13 Swainson's Thrushes (*Catharus ustulatus*) were detected between 24 Sep-4 Oct with a total of 6 detected during the night of 24-25 Sep; 13 Veeries (*Catharus fuscescens*) were detected between 23 Sep-4 Oct with 7 recorded on 4 Oct, and 6 Wood Thrushes (*Hylocichla mustelina*) were detected between 4-20 Oct with 4 on 4 Oct.

We detected more Veeries and Swainson's and Wood Thrushes during our nocturnal fall surveys than the total recorded with visual surveys over the last 20 fall seasons at Rice. Although these species are abundant spring migrants in central and east Texas, they are considered rare during fall migration as their fall migration paths are thought to lie further east of their spring migration paths (Eubanks et al. 2006). Only one or two thrushes are detected in any given night during fall migration compared to hundreds per night during spring migration. While our results are consistent with the general understanding that fall migrants are rare, our results suggest that thrushes may be more regular migrants through east Texas than currently recognized.

Thrushes may be too secretive, especially in the fall, to detect with visual surveys. Fall migrants may also fly over the region without stopping and thus go undetected during the day. Recent work on Veery and Wood Thrush flight paths using GPS tracking confirms that small numbers of these thrushes indeed go through east Texas and Louisiana in the fall (Hobson and Kardynal 2015, Kardynal and Hobson 2017, Stanley et al. 2015).

Creepers and kinglets

We recorded one Brown Creeper (*Certhia americana*) (20 Nov) and one Golden-crowned Kinglet (*Regulus satrapa*) (10 Nov) several hours before sunrise. Golden-crowned Kinglets are known to occasionally call in the night, but Brown Creepers are generally not thought to call in the night, making our creeper nocturnal flight call noteworthy.

Pipits

We detected 59 American Pipits (*Anthus rubescens*). Most American pipits were detected from late October (23 Oct) to the end of November, with a high of 9 on 31 Oct (Fig. 3). Single birds on 4 and 14 Oct were early arrivals. Pipits were detected only after sunrise. Three Sprague's Pipits (*Anthus spragueii*) were detected (19 and 30 Oct, 24 Nov), all just before sunrise.

Grosbeaks, Dickcissels, Buntings and Bobolinks

We detected 266 Indigo Buntings (*Passerina cyanea*) with >95% occurring within a narrow window of time between 11-25 Oct (Figs. 3, 5). Most Indigo Buntings passed through between 11-17 Oct with a peak of 102 (38% of the total) on

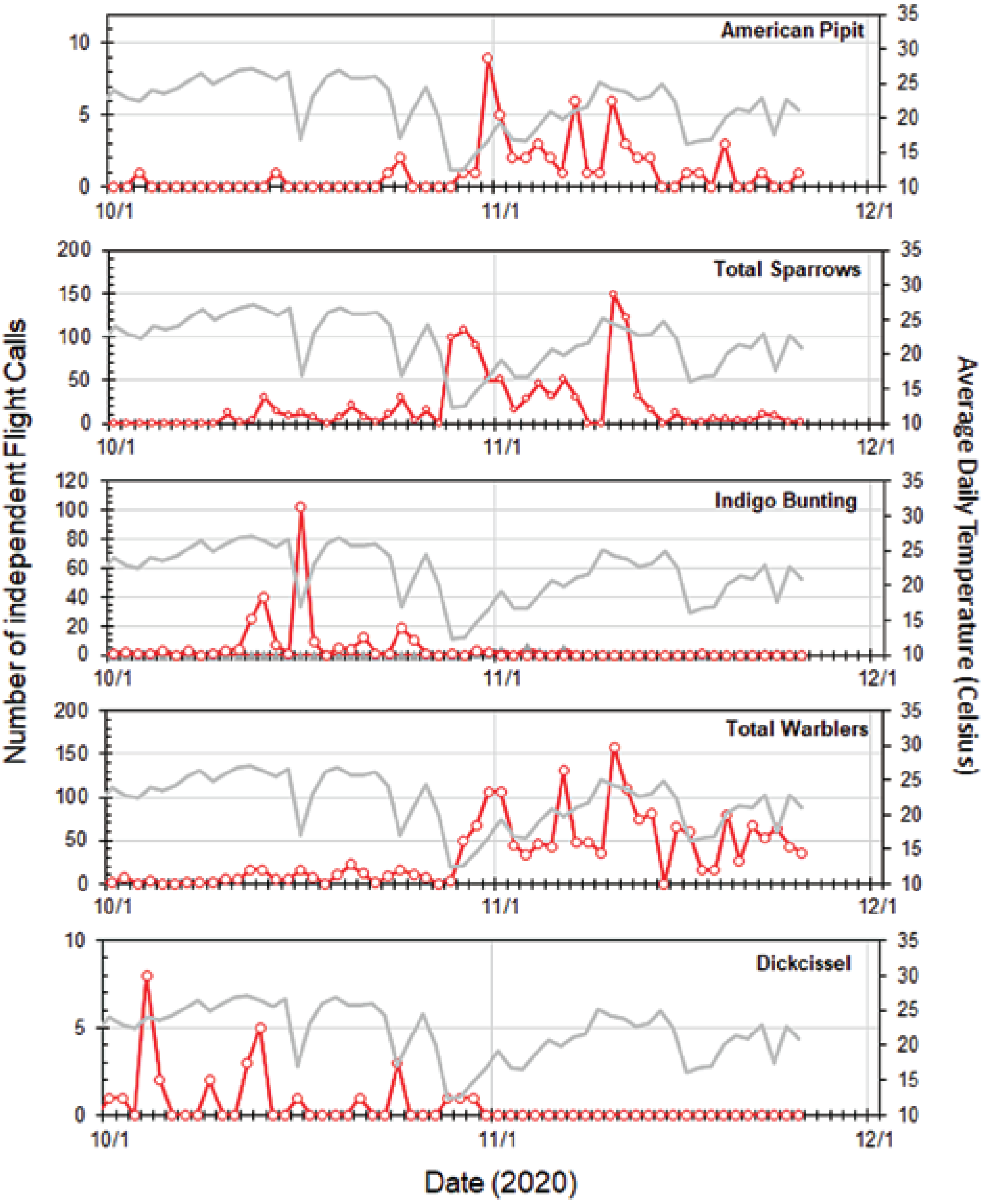

Figure 5. Number of independent NFC detections as a function of calendar date (red lines) zoomed in to include only Oct and Nov. From top to bottom: American Pipit, total sparrows, Indigo Bunting, total warblers, and Dickcissel. Thin black line corresponds to 24-hr average temperature.

Table 1. Season totals (Aug-Nov, 2020)

Species		total	Noc/ Dawn*	First	Peak	Last
Black-bellied Whistling Duck	*Dendrocygna autumnalis*	16	Noc	thru		thru
Snow Goose	*Anser caerulescens*	1	Noc		11/13	
Upland Sandpiper	*Bartramia longicauda*	65	Noc	8/1		9/28
Whimbrel	*Numenius hudsonicus*	1	Noc		8/22	
Least Sandpiper	*Calidris minutilla*	5	Noc	8/17		9/15
Pectoral Sandpiper	*Calidris melanatos*	2	Noc		9/24, 9/28	
Spotted Sandpiper	*Actitis macularius*	9	Noc	7/31		9/14
Solitary Sandpiper	*Tringa solitaria*	7	Noc	8/17		10/20
Greater Yellowlegs	*Tringa melanoleuca*	1	Noc		10/15	
American Bittern	*Botaurus lentiginosus*	2	Noc		9/28, 11/16	
Least Bittern	*lxobrychus exilis*	2	Noc		8/15, 9/11	
Great Blue Heron	*Ardea herodias*	2	Noc		10/01, 10/28	
Green Heron	*Butorides virescens*	14	Noc	7/29	9/15	10/21
Black-crowned Night Heron	*Nycticorac nycticorax*	12	Noc	7/9	9/28	10/2
Barn Owl	*Tyto alba*	19	Noc	10/13	11/17	11/19
Golden-crowned Kinglet	*Regulus satrapa*	1	Noc		11/10	
Brown Creeper	*Certhia americana*	1	Noc		11/20	
Veery	*Catharus fuscescens*	13	Noc	9/23		9/25
Swainson's Thrush	*Catharus ustulatus*	13	Noc	9/24		10/4
Wood Thrush	*Hylocichla mustelina*	6	Noc	10/4		10/10
Cedar Waxwing	*Bombycilla cedrorum*	30	Dawn	10/29		thru
American Pipit	*Anthus rubescens*	59	Dawn	10/1		12/7
Sprague's Pipit	*Anthus spragueii*	3	Dawn	10/19		12/24
Pine Siskin	*Spinus pinus*	93	Dawn	10/19		thru
American Goldfinch	*Spinus tristis*	40	Dawn	11/3		thru
Grasshopper Sparrow	*Ammodramus savannarum*	67	Noc	10/2	10/28	11/20
Chipping Sparrow	*Spizella passerina*	64	Noc	10/10	11/4	11/24
Clay-colored Sparrow	*Spizella pallida*	6	Noc	9/26		10/29
Field Sparrow	*Spizella pusilla*	3	Noc	10/28		10/31
Lark Bunting	*Calamospiza melanocorys*	1	Noc		10/28	
White-crowned Sparrow	*Zonotrichia leucophrys*	18	Noc	10/31	11/6	11/22
White-throated Sparrow	*Zonotrichia albicollis*	7	Noc	11/1	11/11	11/13
LeConte's Sparrow	*Ammospiza leconteii*	71	Noc	10/21	11/10	11/23
Nelson's Sparrow	*Ammospiza nelsoni*	5	Noc	10/7		10/29
Savannah Sparrow	*Passerculus sandwichensis*	681	Noc	10/5	11/10	11/30
Song/Fox Sparrow	*Melospiza melodia/Passerella iliaca*	7	Noc			
Lincoln's/Swamp Sparrow	*Melospiza lincolnii/Melospiza georgiana*	26	Noc	10/26	10/29	11/24
Sparrow Sp.	*Passerellidae*	99	Noc			
Total sparrow	*Passerellidae*	1055	Noc	10/10	11/10	11/25
Eastern Towhee	*Pipilo erythrophthalmus*	2	Dawn		11/22, 11/24	
Yellow-breasted Chat	*lcteria virens*		Noc		10/19	
Bobolink	*Dolichonyx oryzivorus*		Noc		10/20	
Eastern Meadowlark	*Sturnella magna*		Noc		10/28	
Total warblers	*Parulidae*	1970	Noc	9/11	11/10	11/25
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	14	Noc	9/23	10/4	10/21
Indigo Bunting	*Passerina cyanea*	266	Noc	9/23	10/16	11/17
Dickcissel	*Spiza americana*	72	Noc	8/16	10/4	11/22
Total individuals		3799				

*Noc = detected nocturnally, Dawn = detected at sunrise

Dates of passage bracketed by first and last arrival as detected by NFCs. Peak passage in NFC surveys are noted. If numbers of detections are low, no peak passage or first/last arrivals shown. Where only one or two NFCs were detected, exact dates of detection are shown under peak passage column.

the night of 16 Oct after a major cold front. A total of 72 Dickcissels (*Spiza americana*) were detected between 9 Aug-30 Oct. Dickcissel passage appears to occur in two stages: a brief pulse in mid-Aug and a protracted passage between mid-Sep and late Oct (Fig. 4, 5). Peak Dickcissel passage appears to be in early October. A Bobolink (*Dolichonyx oryzivorus*), rarely ever detected in the fall during diurnal surveys, was detected on 20 Oct just before dawn. Five Rose-breasted Grosbeaks (*Pheucticus ludovicianus*) were detected between 23 Sep-21 Oct. We note that no Rose-breasted Grosbeaks were ever reported from diurnal surveys at Rice University in the last twenty years. Rose-breasted Grosbeak is also considered to be an uncommon fall migrant on the Texas coast, so our results suggest that fall migrants may be more regular in east Texas than currently appreciated.

New World Sparrows

Sparrows represented the largest number of migrants detected by nocturnal flight calls (Fig. 2). A total of 1065 sparrows was detected, with most in late fall from 9 Oct-15 Nov (Figs. 4, 5). Sparrow numbers begin building in the 2nd week of October and increase substantially in late October to mid-November. The largest fluxes appear to occur immediately after the passage of cold fronts and then decline rapidly in the days afterward. Warm, humid days just before the arrival of a cold front show highly reduced numbers.

Savannah Sparrows (*Passerculus sandwichensis*) were by far the most abundant species with a total of 681 detected between 5 Oct-30 Nov. The next most abundant sparrow species detected were LeConte's Sparrows (*Ammospiza leconteii*) with 71 between 21 Oct-23 Nov, Grasshopper Sparrows (*Ammodramus savannarum*) with 67 between 2 Oct-20 Nov, and Chipping Sparrows (*Spizella passerina*) with 64 between 10 Oct-24 Nov. We were not able to confidently distinguish between the flight calls of Lincoln's (*Melospiza lincolnii*) and Swamp Sparrows (*Melospiza georgiana*); 26 Lincoln's/Swamp Sparrows were detected between 26 Oct-24 Nov. We also recorded 14 White-crowned Sparrows (*Zonotrichia leucophrys*) between 31 Oct-22 Nov), 7 White-throated Sparrows (*Zonotrichia albicollis*) between 1-13 Nov, 3 Field Sparrows (*Spizella pusilla*) between 28-31 Oct, 6 Clay-colored Sparrows (*Spizella pallida*) between 26 Sep-29 Oct, 5 Nelson's Sparrows (*Ammospiza nelsoni*) between 7-29 Oct and 7 Song/Fox Sparrows (*Melospiza melodia/Passerella iliaca*) between 30 Oct-11 Nov (Song and Fox calls were indistinguishable). One Lark Bunting (*Calamospiza melanocorys*) was detected on 28 Oct.

The NFC surveys revealed new migratory information about sparrows, which are either secretive or require highly specific habitat to be found during the day. For example, over 20 years of surveying at Rice University, no more than a total of 10 Grasshopper and LeConte's Sparrows each were observed, too few to establish an accurate migratory window. The fact that we recorded more than 60 independent NFCs of these two species in one season underscores the power and efficiency of using NFCs to study the migration of certain sparrow species. Nelson's Sparrows are almost never seen during the day along the Gulf coast except in coastal salt marsh habitats, so our NFC surveys provide a rare glimpse of their migration window. We also note that Clay-colored Sparrows, which are generally considered rare along the upper Texas coast, have shown up in diurnal surveys at Rice University, making our study site somewhat of an anomaly. The multiple Clay-colored Sparrow NFC detections suggest that this species is a regular fall migrant in our region, but rarely detected during diurnal surveys.

Finally, the number of NFC detections of Zonotrichia sparrows, such as White-crowned and White-throated, seemed to be far lower than their abundances in visual surveys. White-throated Sparrows are common fall migrants at Rice University, but the fact that only 7 NFCs were detected during this study suggests that White-throated Sparrows may not call as frequently as many of the grassland sparrows. White-crowned Sparrows are common along the Texas coast, but only a handful of sight records exist for our study site, so it is unclear if the lack of NFC detections of White-crowned Sparrows represents rarity or under-detection.

Warblers

We were unable or hesitant to identify most warbler flight calls to species. Only a few species were confidently identified: American Redstart (*Setophaga ruticilla*), Black-and-white Warbler (*Mniotilta varia*), Ovenbird (*Seiurus aurocapilla*), Mourning Warbler (*Geothlypis Philadelphia*), and Northern Waterthrush (*Parkesia noveboracensis*).

Because of the difficulty in identifying warbler flight calls, we lumped all warblers together for the purposes of this paper. In late fall, most of the warblers detected were most likely Yellow-rumped (*Setophaga coronate*) and Orange-crowned Warblers (*Leiothlypis celata*), but we did not attempt to separate them.

Warbler NFCs were detected in early fall (before late Oct), but typically only a few per night. This contrasts with spring migration, when hundreds of calls are detected on some nights. We do not know if this reflects just a lower intensity of warbler migrants in the fall due to a more protracted fall migration window. A more likely possibility is that warblers typically fly at elevations too high for their low amplitude calls to be detected. In the spring, low hanging clouds associated with cold fronts may force warblers down to lower elevations, allowing their flight calls to be detected. With the exception of Yellow-rumped and Orange-crowned Warblers, the bulk of fall warbler migration may pass through in late Aug to late Sep, before the arrival of strong cold fronts.

Interestingly, Yellow-rumped and Orange-crowned Warblers were often not detected in the night, but instead during a large pulse from sunrise to 1-2 hours after sunrise, almost all between late Oct and late Nov (Figs. 4, 5). The numbers of independent flight calls reported for these two species is highly uncertain and the uncertainty itself is difficult to quantify due to the challenge of separating multiple calls when there are numerous birds. Our approach, however, should be a lower bound on the number of independent flight calls. We interpret these early morning pulses of flight call activity to be related to highly active morning flights. As we discuss below, these morning flights detected through flight calls appear to coincide with a morning resurgence in base radar reflectivity, suggesting that large numbers of migrating birds, after settling down in pre-dawn hours, take to the skies again in the early morning hours.

Relationship With Cold Fronts

The first major cold fronts appeared in mid-October. From mid-October through the end of November, 7 cold fronts passed through: 16, 24, and 28 Oct; 3, 6, 10 and 14 Nov (Figs. 3-5). These early cold fronts resulted in an influx of Indigo Buntings, but only moderate influxes of sparrows. Sparrow passage did not escalate until the passage of a major cold front in late October (28 Oct), which saw the drop to the lowest temperature over the entire fall survey. Sparrow flux increased only modestly after the passage of a moderate cold front on 6 Nov. However, another moderate cold front immediately afterwards (10 Nov) resulted in a major flux of sparrows. Sparrow numbers decreased rapidly after this front. A major front on 14 Nov produced almost no sparrows, indicating that the passage of sparrows was largely complete by 11 Nov. After the initial pulse of sparrows immediately following a cold front, numbers declined within the following 2-3 days as temperatures warmed back up. In some cases, numbers decline to zero the night before the arrival of a cold front.

Dickcissels, thrushes, shorebirds and waders mostly pass through before mid-Oct and hence before the arrival of major cold fronts, so these birds do not appear to be influenced by cold fronts. Most warblers, with the exception of Yellow-rumped Warblers, also pass through before mid-Oct and are also not influenced by cold fronts. Yellow-rumped Warblers, however, arrive late in the fall and appear to follow the patterns of sparrows in responding to cold fronts.

To more objectively evaluate the link between cold fronts and the passage of birds, it was necessary to develop a quantitative way to identify "cold" days. To do this, we reasoned that the baseline climate in Houston was subtropical with "cold" days defined as deviations away from this warm, subtropical baseline. We regressed a polynomial function through the temperature maxima in our time series. The deviation of temperatures from this warm baseline represents cold fronts or the aftermath of a cold front. The polynomial function adopted is given by T_{base} (°C) $= -2.557\times10^{-7}d^4 + 8.461\times10^{-5}d^3 - 9.837\times10^{-3}d^2 + 3.717\times10^{-1}d + 27.310$, where d represents the number of days after an arbitrary start date, which in this case was 7/25/2020.

Using the above approach in defining cold temperature swings we find that 54% of Upland Sandpiper, 88% of American Pipit, 71% of sparrow and 78% of Indigo Bunting abundance peaks coincided with low temperatures. To make these calculations, we only considered the days within the migration window of the relevant species. These results indicate that late fall migrants, that is, those that pass through primarily in Oct and Nov are strongly influenced by cold fronts. We note that the percentage of cold temperatures, which also coincided with high NFC counts tend to be lower (Table 2). Only 30%, 27% and 45% of temperature lows were associated with high counts of Upland Sandpipers, American Pipits, and Indigo Buntings, indicating that although high counts of NFCs may correlate with low temperatures, low temperatures alone do not always yield high NFCs. Only in the case of sparrows is the percentage of temperature drops associated with high sparrow counts similar to the percentage of high sparrow counts associated with low temperatures. This indicates that the influx of sparrows is linked to low temperatures. These effects can be seen in Figure 6. These results confirm that the flux of migrants is highest immediately after a cold front, but numbers decrease rapidly in the days after the cold front.

Night Schedule

From 16 Oct-25 Nov, we noted the times of every nocturnal flight call detected. For surveys conducted before 16 Oct, total numbers of flight calls were noted, but we unfortunately did not record the times of every call at that time. Fortunately, our records for 16 Oct-25 Nov coincide with peak intensity of fall migrants. With the exception of warblers, nocturnal migrants begin to be detected between 2-4 hours after sunset (Figs. 7 and 8). Detections continue until 3 to 0 hours before sunrise although, in most cases, nocturnal flight calls declined significantly by 2 hours before sunrise.

Warbler flight calls between 16 Oct-25 Nov were mostly unidentified, but undoubtedly dominated by Yellow-rumped Warblers and to a lesser extent Orange-crowned Warblers, both of which are terminal migrants. In almost all cases, most of the warbler flight calls occurred within the hour before and after sunrise, with peak detection occurring within 30 minutes before sunrise. We consider the bulk of these flight calls to be associated with morning flights of Yellow-rumped and Orange-crowned Warblers on the "ground", that is, flying from tree to tree or just above the canopy (<50 m). Only small numbers of warbler flight calls were detected during the night, perhaps because they fly too high for their faint calls to be detected.

Comparisons to Radar

We also compared our results to the base radar reflectivity each night. We considered two quantities. We first determined the average base reflectivity for each night by taking the average reflectivity over the city of Houston at midnight. We also determined base reflectivity over our monitoring station at Rice University each night as a function of time (Fig. 9).

Nights with high counts of Upland Sandpipers, sparrows, Indigo Buntings and Dickcissels appear to be accompanied by high radar reflectivity as shown in Table 2 and Fig. 6, confirming that high radar reflectivity in the night most likely represents birds. However, we note that high radar reflectivity itself is not always accompanied by high NFC detections, suggesting that birds flying overhead might not always be detected from recording stations either because they fly too high or are not calling.

Comparisons of radar and NFC time series through a given night was particularly interesting (Figs. 7 and 8). Radar intensity picks up rapidly after sundown (within a half hour after sundown), but NFC intensity appears to be delayed, picking up 2 hours after sunset. By contrast, the decline in radar and NFC intensity in the 1-2 hours before sunrise are coupled. Assuming that radar indeed represents flying birds, these results indicate that fall migrating birds, represented in this study mostly

Table 2. Associations between migratory pulses with radar and temperature

		# bird peaks associated with a radar peak	# radar peaks associated with a bird peak	# bird peaks associated with a temperature lows	# temperature lows associated with bird peaks
		%	%	%	%
Upland Sandpiper	*Bartramia longicauda*	80	53	54	30
American Pipit	*Anthus rubescens*	55	38	88	27
Sparrows	*Passerellidae*	71	62	71	72
Indigo Bunting	*Passerina cyanea*	83	75	78	45

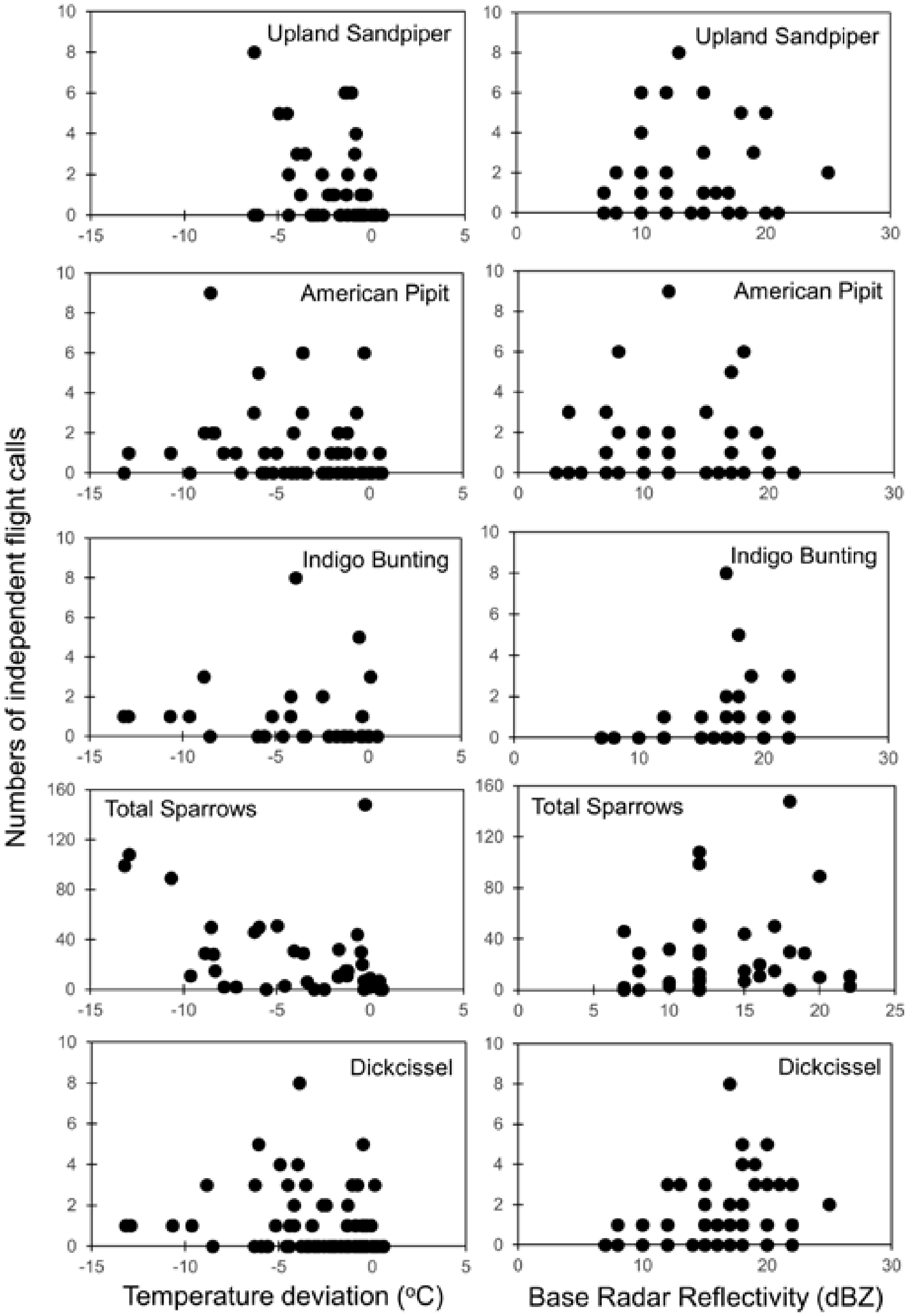

Figure 6. Numbers of NFCs for various species as a function of negative temperature deviations (left column) and base radar reflectivity (right column). Temperature deviation is referenced to an upper envelope of average daily temperature from Aug to Nov, 2020.

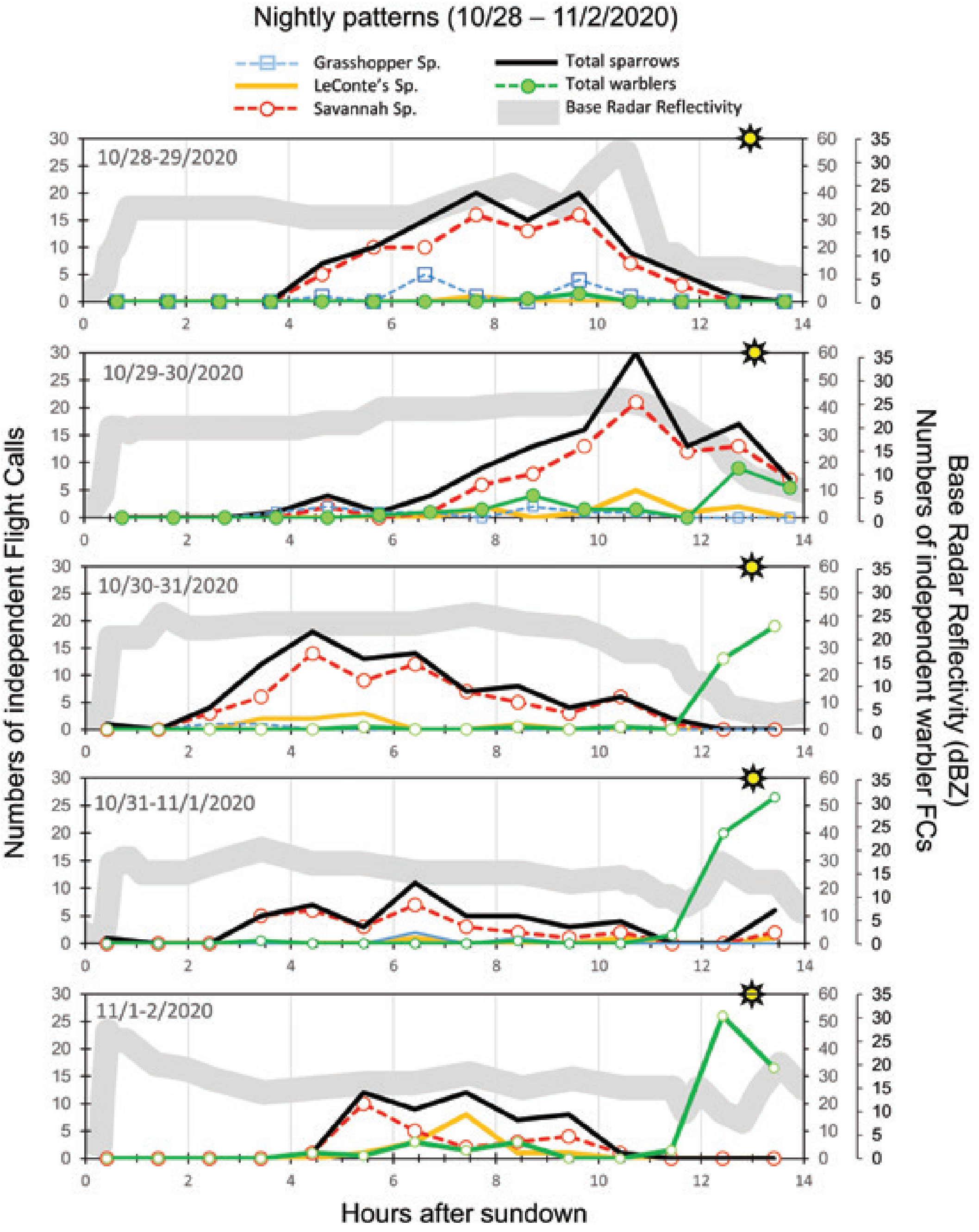

Figure 7. Numbers of independent NFC detections versus hours after sunset from 28 Oct-2 Nov. This range in dates corresponds to the aftermath of a major cold front that passed through on 28 Oct during the day. Sun symbol shows the time of sunrise. Data were binned in 1-hour intervals. Data are shown for Grasshopper, LeConte's and Savannah Sparrows, along with total sparrows and warblers. Warblers pertain to morning flights of Yellow-rumped and Orange-crowned Warblers, which may represent local movements of birds that arrived for the winter rather than transients.

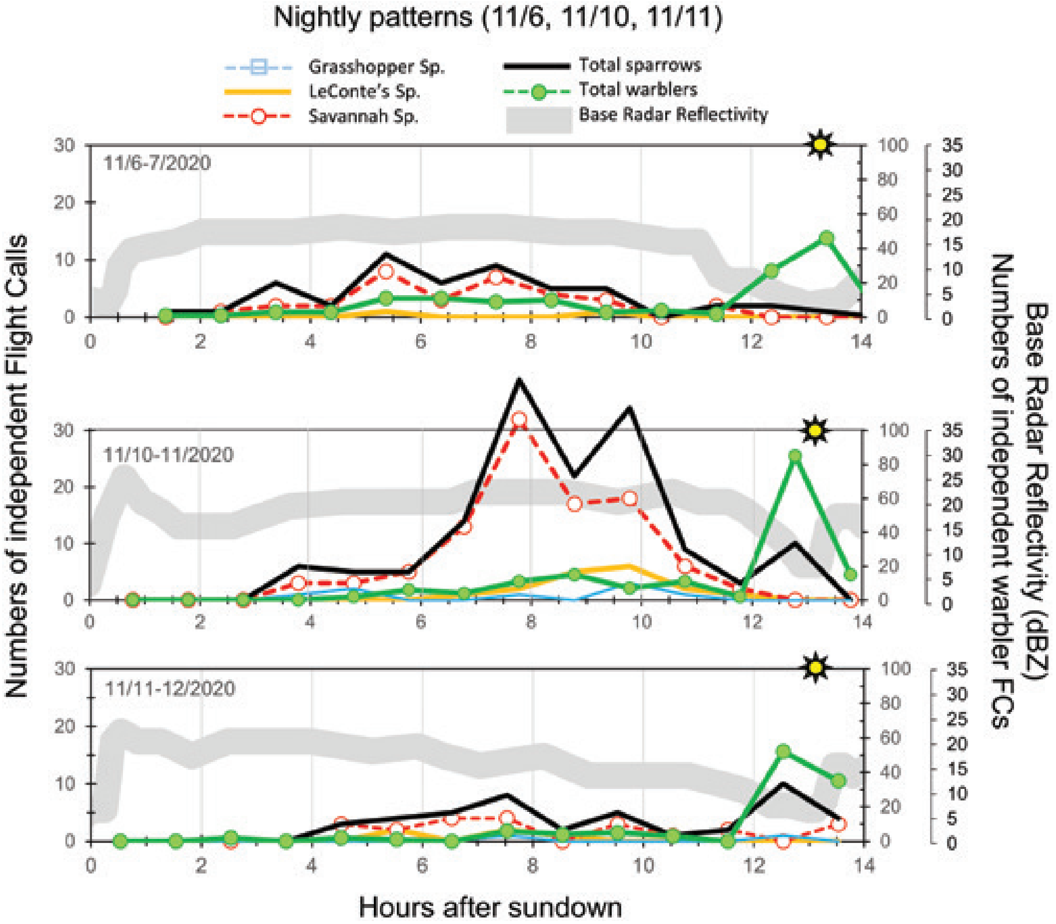

Figure 8. Numbers of independent NFC detections versus hours after sunset from three different nights in which birds were detected. These dates immediately follow the passage of moderate cold fronts. Sun symbol shows the time of sunrise. Data were binned in 1-hour intervals. Data are shown for Grasshopper, LeConte's and Savannah Sparrows, along with total sparrows and warblers. Warblers pertain to morning flights of Yellow-rumped and Orange-crowned Warblers, which may represent local movements of birds that arrived for the winter rather than transients.

by sparrows, do not call during take-off. Sparrows appear to primarily call after they have reached their migrating elevations. Sparrow NFCs decrease in the 1-2 hours before sunrise, but the synchronous decline in radar picks suggests that this decrease in overhead NFCs is simply due to sparrows landing 1-2 hours before sunrise.

In late fall (early Nov), we recorded large numbers of warbler flight calls at dawn. As noted above, these are dominated by Yellow-rumped Warblers. From flight calls alone, it was not clear if these represented local movements of terminal migrants. However, these dawn influxes of NFCs are often associated with a brief resurgence in radar intensity (Figs. 7 and 8), suggesting that these warblers are flying back up high into the sky, perhaps to explore immediate surroundings for better habitats to settle down in for the day.

DISCUSSION AND CONCLUSIONS

Our results have several implications. First, our study demonstrates that NFC surveys robustly define the timing of migration in one season unlike visual surveys, which may take years or decades,

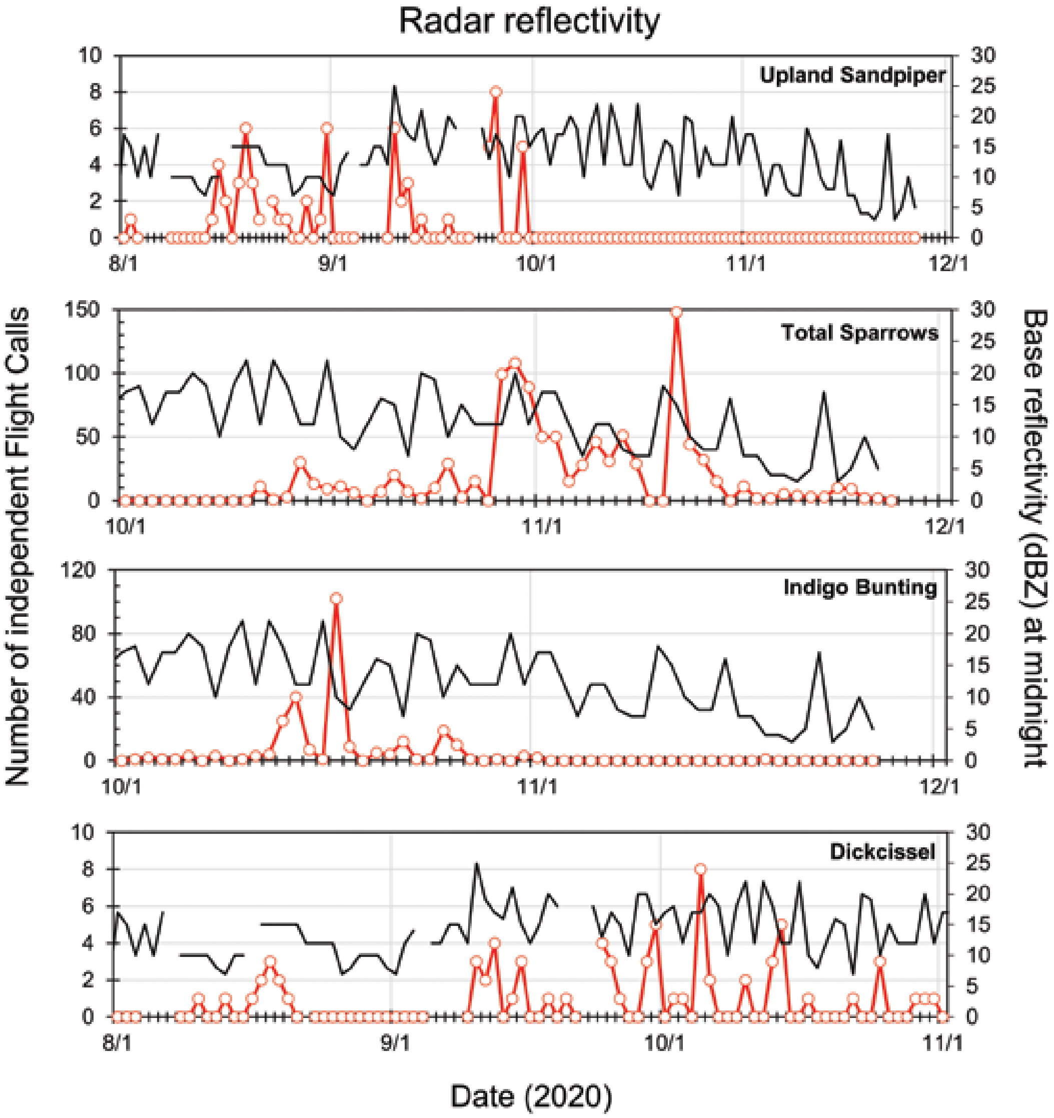

Figure 9. Nightly radar (base reflectivity) at midnight over the study site versus number of independent NFCs.

to establish migration windows especially for more secretive species. The advantage of NFC surveys is that they offer the ability for continuous monitoring over a large area, whereas the human-hours needed to conduct continuous visual surveys would be cost-prohibitive. NFC surveys may thus be the ideal method for objectively documenting annual or decadal changes in the timing of migration due to climate or other environmental change.

Our results also have implications for minimizing building strike mortality. Our NFC and radar observations indicate that the main movements of fall songbird migration in Houston, TX happens between mid-Sep and the end of Nov. This is the window of time that songbird migrants face the greatest threats from building collisions. The most vulnerable time for night-time strikes is between sunset and two hours before sunrise. The largest flights occur immediately after the passage of cold fronts. The associations between high NFC fluxes and high radar intensity further suggests that migration forecasts based on radar (e.g., Cornell Laboratory of Ornithology's Birdcast) should predict well whether a given night will have a high flux of migrants. These migration forecasts, however, do not have the resolution to predict the temporal pattern of migrants within a given night, so radar-based forecasts need to be complemented with empirical NFC data.

Similar studies like ours should be conducted in spring and fall for every major metropolitan area to establish peak migration windows. We also suspect that the timing of flights during the night may also be site-dependent owing to changes in land use. For example, because of lack of extensive sparrow habitat in the immediate area of our monitoring station, these sparrows presumably took to the skies from less developed areas to the north. With urban development projected to expand northward in the next decade (Hakkenberg et al. 2018), habitats for birds will be pushed farther away from urban Houston. The time it takes for southbound songbirds to arrive over Houston from these retreating habitats will thus increase, which would mean that by the time these birds encounter the light-polluted urban center of Houston and the Texas coast, they could be more exhausted and more likely to experience higher mortality. Annual NFC surveys are needed to track the effects of land use change to the arrival time of migrating birds over urban centers.

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ABUNDANCE, SPECIES RICHNESS, AND DEMOGRAPHICS OF WINTERING NEARCTIC-NEARCTIC MIGRANTS FROM A LONG-TERM BIRD BANDING STATION IN NORTH TEXAS

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ABSTRACT.—Long-term bird banding efforts contribute valuable data to understanding changes in populations of short-distance Nearctic-Nearctic migrants due to changes at different spatiotemporal scales. My objective was to use 38 seasons of bird banding data to examine changes in abundance, species richness, and demographics of wintering Nearctic-Nearctic migrants at a long-term bird banding station in North Texas. 11,374 individuals of 49 Nearctic-Nearctic migrant species were banded in a fragmented landscape from 1978-2014 along the Central Flyway at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas. The three most frequently captured species, Lincoln's Sparrow (*Melospiza lincolnii*), White-throated Sparrow (*Zonotrichia albicollis*), and Ruby-crowned Kinglet (*Regulus calendula*), accounted for 41.5% of all banded individuals and 18 species accounted for 94% of all banded individuals. Among 18 species with substantial sample size, 13 species exhibited decreasing annual abundance over the banding period, whereas only five species demonstrated increasing annual abundance. Annual species richness declined from 1980-2014; however, the number of netting days per year declined during the last eight years of banding. 16 species demonstrated age ratios favoring more adults than hatch year birds and two species exhibited age ratios favoring more hatch year birds than adults. Three species exhibited sex ratios favoring more males than females, three species exhibited sex ratios favoring more females than males, and two species exhibited balanced sex ratios. Data for several species supported conclusions related to age- and sex-based differential migration. Data from this study provides a baseline for comparison to future population changes among wintering Nearctic-Nearctic migrants in the North Texas zone of the Central Flyway.

Large-scale winter survey efforts, like the National Audubon Society's Christmas Bird Counts, provide short- and long-term abundance and species richness indices; however, there is a lack of long-term, regional studies focused on wintering Nearctic-Nearctic species' population metrics and demography using bird banding data. Nearctic-Nearctic migrants are species that nest in the northern U.S. or Canada, then migrate a relatively short distance to the southern U.S. and Mexico. Long-term bird banding efforts contribute a wide variety of population data at different spatiotemporal scales (Karr 1990, Wang and Finch 2002, Dunn and Ralph 2004, Ruiz-Gutiérrez et al. 2012). In Alaska, Bailey (1974) used short-term banding data to document passerine species richness and abundance in spring migration. Similarly, in southern Michigan, Dunn et al. (1997) used longer-term banding data to examine population changes relative to population index methods such as the U. S. Fish and Wildlife Service's Breeding Bird Survey (hereafter BBS). In Massachusetts, Lloyd-Evans and Atwood (2004) used long-term spring and fall migration banding data to demonstrate significant population declines among migrant bird species. Ballard et al. (2003) documented similar long-term declines in resident and migrant birds using constant effort mist-netting in coastal California. Many published studies focused on coastal migration stopover sites (Ballard et al. 2003, Lloyd-Evans and Atwood 2004, Osenkowski et al. 2012); however, Rimmer et al. (2004) compared a coastal site to an inland site in New England because inland sites and sub-regional sites are often understudied. Wood (2020) documented long-term declines in abundance and species richness with

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greater abundance and species richness during spring migration for Nearctic-Neotropical migrants at an inland stopover site in North Texas.

Other long-term banding studies focused on avian demographics. Using long-term banding data, Confer et al. (2014) documented low recruitment rates and shifting proportions of hatch year Northern Saw-whet Owls (*Aegolius acadicus*) in the central and eastern U. S. In North Texas, Wood (2020) used bird banding data for Nearctic-Nearctic migrants to demonstrate differential migration with higher sex ratios of males in both spring and fall migrations and higher proportions of adult birds versus hatch year birds in fall migration.

Long-term banding studies also contribute to understanding site fidelity. Somershoe et al. (2009) studied philopatry for Nearctic-Nearctic migrants wintering in Florida over a 6-year period. Some species were recaptured during spring and fall migration annually such as Yellow-rumped Warbler (*Setophaga coronata*), whereas species such as Gray Catbird (*Dumatella carolinensis*) overwintered annually. In Oaxaca Mexico, Monroy-Ojeda et al. (2013) documented strong site fidelity of wintering passerines including Warbling Vireo (*Vireo gilvus*) and Yellow-rumped Warbler in an urban botanical garden, whereas nomadic species such as Cedar Waxwing (*Bombycilla cedrorum*) exhibited little winter site fidelity.

Bird banding data also can be used to examine the impacts of anthropogenic climate change. In China, Jiao et al. (2016) utilized banding data from two banding stations to document declines in passerine populations related to increasing annual temperatures. Bird banding data also can be used to examine the impacts of sprawl on wintering passerine use of urban habitat patches. In an isolated urban habitat patch in Louisiana, Wolfe et al. (2013) used bird banding data to demonstrate that Carolina Wren (*Thryothorus ludovicianus*), Tufted Titmouse (*Baeolophus bicolor*), and White-eyed Vireo (*Vireo griseus*) had comparable survival rates to Monitoring Avian Productivity and Survivorship (MAPS) program regional survival estimates. Conversely, Brown Thrasher (*Toxostoma rufum*), Carolina Chickadee (*Poecile carolinensis*), and Northern Cardinal (*Cardinalis cardinalis*) exhibited lower survival rates than regional survival estimates from MAPS data.

In the 2010s, the Prairie and Timbers Audubon Society brought to the author's attention that they collected 38 winter seasons of bird banding data at the Heard Natural Science Museum & Wildlife Sanctuary (hereafter referred to as the Heard) in North Texas. This data set included substantial information about Nearctic-Nearctic migrants using the Heard as a stopover or wintering site. This bird banding data offered an opportunity to examine various aspects of population metrics and demographics of Nearctic-Nearctic migrants over a long temporal scale. Similar to Wolfe et al. (2013), the Heard data are from an isolated habitat patch within an urban context adjacent to urban sprawl. Baseline data from the Heard can be used to examine species-level responses to local landscape changes due to encroachment from sprawl or large-scale factors such as anthropogenic climate change in the Central Flyway in North Texas.

This study addressed the lack of published studies of long-term changes in abundance, species richness, and species-level demographics for Nearctic-Nearctic migrants in the North Texas zone of the Central Flyway. My objectives were to 1) summarize bird banding data from a long-term mist netting effort, 2) examine trends in winter abundance and species richness, 3) and 4) examine trends in species-level demographics.

METHODS

Study Site

All banding occurred at the Heard located in the city of McKinney, Collin County in North Texas (33° 09'N, 96° 36'W; elevation 192 m) from 1978-2014. Birds were netted in a variety of habitats within the 117-ha site. Habitats included: mid-successional prairie grassland, green ash (*Fraxinus pennsylvanica*)-black willow (*Salix nigra*) forest, and intermittently flooded mid-successional forest with sugarberry (*Celtis laevigata*), Osage orange (*Maclura pomifera*), cedar elm (*Ulmus crassifolia*), and honey locust (*Gleditsia triacanthos*). Open forests of scattered pecan (*Carya illinoinensis*) and escarpment live oaks (*Quercus fusiformis*) interspersed with Bermuda grass (*Cynodon dactylon*) also were sampled. Successional habitat changes including species composition and physical structure occurred at the Heard during the netting period, which could influence capture rates for different species (Remsen and Good 1996).

Field Methods

Volunteer banders operated 10 to 25 12-m nylon mist nets (2.6-m height, 36-mm mesh size) depending on the number of volunteers available. Nets were only placed in the understory, therefore netting efforts likely under-sampled mid- and high-canopy species (Mallory et al. 2004). Netting and handling protocols followed Ralph et al. (1993) and Gustafson et al. (1997). All birds received a uniquely numbered band; aging and sexing criteria followed Pyle (1997). Table 1 includes all species in the study by common and scientific name.

Each banding year consisted of birds banded from July of one year through May of the following year, which encompassed both migratory and wintering Nearctic-Nearctic migrant use at the Heard. For logistical reasons, no banding occurred in fall 1978, 1979, and 2004. Data analysis occurred through December 31, 2014. 1312 banding days were achieved over the course of the study (Fig. 1). The mean number of banding days per winter was 34.2 (range = 4-77) and the number of banding days annually declined over the course of the study, especially in the 2010s (Fig. 1).

Descriptive Analysis

Species abundance results include initial capture for individual birds plus any interannual recaptures. Intraseasonal recaptures were omitted from analysis due to redundancy. No records of recaptures were available prior to 1994, so recapture data were only included post-1994; thus, abundance data are underestimated from the early period of the study. For some species, small sample sizes hindered abundance analysis; however, they were included in species richness analysis. Abundance, age, and sex data were examined for each species. Age categories included Unknown (U), Hatch Year (HY), Second Year (SY), After Hatch Year (AHY), and After Second Year (ASY), and Third Year (TY) that could be examined independently or combined with sex. Sexes included male (M), female (F), and unknown (U). U individuals were excluded from sex ratio analysis.

RESULTS AND DISCUSSION

Species Richness

From 1978-2014, 49 Nearctic-Nearctic species were banded at the Heard (Table 1). Species richness varied annually but exhibited a declining trend post-1980 at the Heard (Fig. 2). The decline in species richness was more pronounced in the

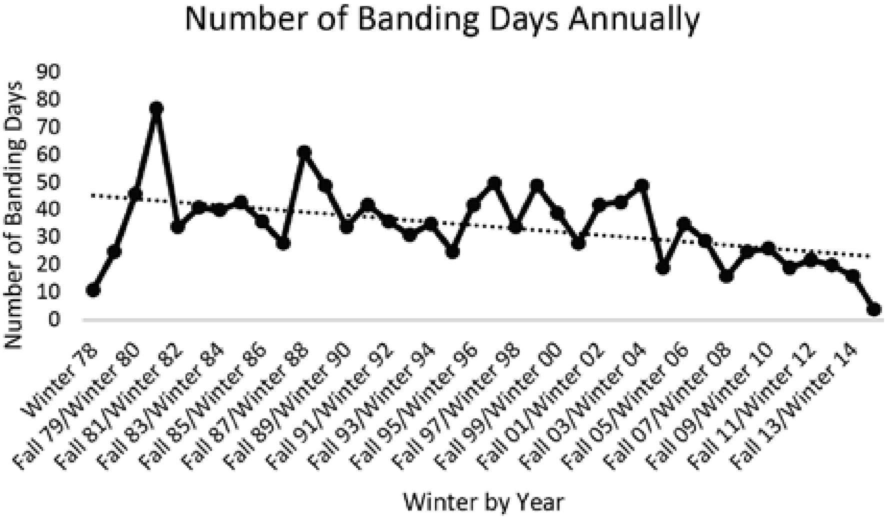

Figure 1. Number of winter banding days annually from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

Table 1. Common name, scientific name, total captures, and number seasons of captures for wintering Nearctic-Nearctic migrants at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas from 1978-2014.

Common Name	Scientific Name	Total Captures	# Seasons Captured
Lincoln's Sparrow	*Melospiza lincolnii*	2128	38
White-throated Sparrow	*Zonotrichia albicollis*	1528	38
Ruby-crowned Kinglet	*Regulus calendula*	1060	37
Song Sparrow	*Melospiza melodius*	718	35
Yellow-rumped Warbler	*Setophaga coronata*	641	33
Dark-eyed Junco	*Junco hyemalis*	624	35
American Goldfinch	*Spinus tristis*	496	32
Orange-crowned Warbler	*Leiothlypis celata*	489	37
Field Sparrow	*Spizella pusilla*	471	36
Fox Sparrow	*Passerella iliaca*	471	35
Harris's Sparrow	*Zonotrichia querula*	345	25
Swamp Sparrow	*Melospiza georgiana*	344	30
Brown-headed Cowbird	*Molothrus ater*	310	13
Brown Thrasher	*Toxostoma rufum*	285	36
Hermit Thrush	*Catharus guttatus*	262	33
White-crowned Sparrow	*Zonotrichia leucophrys*	221	33
Golden-crowned Kinglet	*Regulus satrapa*	160	26
Eastern Phoebe	*Sayornis phoebe*	152	31
Brown Creeper	*Certhia americana*	83	23
Winter Wren	*Troglodytes hiemalis*	79	21
American Robin	*Turdus migratorious*	57	18
Eastern Bluebird	*Sialia sialis*	46	13
Chipping Sparrow	*Spizella passerina*	43	19
Eastern Towhee	*Pipilo erythrophthalamus*	37	15
Bewick's Wren	*Thryomanes bewickii*	32	16
Savannah Sparrow	*Passerculus sandwichensis*	32	16
LeConte's Sparrow	*Ammospiza leconteii*	30	8
Yellow-bellied Sapsucker	*Sphyrapicus varius*	28	21
Northern Flicker	*Colaptes auratus*	26	17
Red-winged Blackbird	*Agelaius phoeniceus*	26	8
Clay-colored Sparrow	*Spizella pallida*	22	17
Sharp-shinned Hawk	*Accipiter striatus*	21	17
Loggerhead Shrike	*Lanius ludovicianus*	19	12
Pine Siskin	*Spinus pinus*	19	4
Spotted Towhee	*Pipilo maculatus*	18	11
Cedar Waxwing	*Bombycilla cedrorum*	17	10
Grasshopper Sparrow	*Ammodramus savannarum*	7	6
Marsh Wren	*Cistothorus palustris*	6	3
Sedge Wren	*Cistothorus platensis*	3	3
Lark Sparrow	*Chondestes grammacus*	3	3
Rusty Blackbird	*Euphagus carolinus*	3	3
Red-headed Woodpecker	*Melanerpes erythrocephalus*	2	2
Cactus Wren	*Campylorhynchus brunneicapillus*	2	1
Purple Finch	*Haemorhous purpureus*	2	1
Cassin's Sparrow	*Peucaea cassinii*	2	1
Red-breasted Nuthatch	*Sitta canadensis*	1	1
Vesper Sparrow	*Pooecetes gramineus*	1	1
Henslow's Sparrow	*Centronyx henslowii*	1	1
Western Meadowlark	*Sturnella neglecta*	1	1

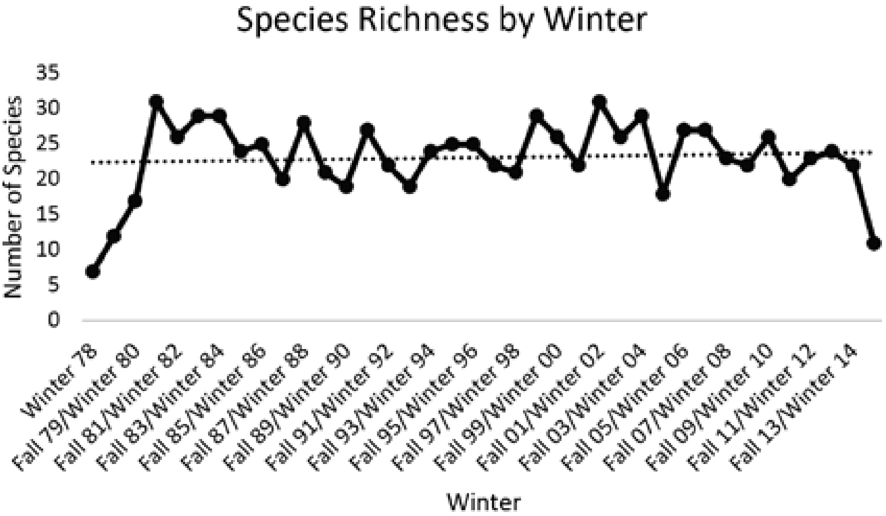

Figure 2. Annual species richness from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

2010s when the number of banding days decreased (Fig. 2). 30.6% (15/49) of species were banded in ≥30 seasons with Lincoln's Sparrow and White-throated Sparrow the only species banded every season. 26.5% (13/49) of species were banded in 15-26 years and 42.9% (21/49) of species were captured in ≤14 years at the Heard (Table 1).

Abundance

11,374 individuals of 49 Nearctic-Nearctic species were banded at the Heard over 38 banding seasons (Table 1). The three most abundant species banded (Lincoln's Sparrow, White-throated Sparrow, and Ruby-crowned Kinglet accounted for 41% (4716/11,374) of all individuals banded at the Heard. 18 species accounted for 94% (10,705/11,374) of all banded individuals. For 18 species with substantial sample size (≥152 individuals), 13 species exhibited decreasing annual abundance trends and 5 species demonstrated increasing annual abundance trends during the banding period.

Demographic Trends

For the 18 species with substantial sample size, 16 species exhibited age ratios with more adults than HY birds (Table 2). This result is interesting in that post-breeding there could be a larger cohort of HY birds in fall migration and overwintering populations. Two species (American Goldfinch, Field Sparrow) exhibited age ratios in which HY birds outnumbered adults (Table 2). Two species (Golden-crowned Kinglet, Yellow-rumped Warbler) exhibited balanced sex ratios and three species (Brown-headed Cowbird, Ruby-crowned Kinglet, White-throated Sparrow) exhibited sex ratios in which males outnumbered females (Table 2). Conversely, three species (American Goldfinch, Dark-eyed Junco, Orange-crowned Warbler) had sex ratios favoring more females than males (Table 2).

Species-Specific Analysis

Lincoln's Sparrow (n = 2128) was banded in all 38 seasons and exhibited a 1.4 adult:1 HY age ratio (Table 2). At the Heard, Lincoln's Sparrow exhibited annual variation in abundance but an overall decreasing abundance trend (Fig. 3). This trend differed from the BBS +0.1%/year survey-wide increasing population trend for Lincoln's Sparrow (Sauer et al. 2019). The high abundance of this species at the Heard reaffirms this area as a significant wintering site for this species. Similarly, Root (1988) cited Texas as the site with the highest winter density for Lincoln's Sparrow, although little is known about winter demographics for this species (Ammon 2020).

White-throated Sparrow (n = 1528) was banded in all 38 seasons and demonstrated a 1.6 adult:1 HY age ratio and 7.6 male:1 female sex ratio (Table 2). At the Heard, White-throated Sparrow abundance peaked in the late 1980s-early 1990s, then declined

Table 2. Age and sex combinations for wintering Nearctic-Nearctic migrants at the Heard Natural Science Museum & Sanctuary in North Texas from 1978-2014.

Species	Age-Sex	Number
American Goldfinch		
	ASY-F	11
	ASY-M	14
	AHY-F	60
	AHY-M	49
	SY-F	16
	SY-M	19
	SY-U	1
	HY-F	149
	HY-M	120
	HY-U	29
	U-F	17
	U-M	5
	U-U	6
	Total	496
American Robin		
	ASY-F	1
	ASY-M	1
	ASY-U	6
	AHY-F	4
	AHY-M	3
	AHY-U	24
	SY-M	2
	SY-U	7
	HY-U	5
	U-F	1
	U-U	3
	Total	57
Bewick's Wren		
	ASY-U	1
	AHY-U	12
	HY-U	6
	U-U	13
	Total	32
Brown Creeper		
	AHY-F	1
	AHY-U	19
	HY-U	22
	U-U	41
	Total	83
Brown-headed Cowbird		
	ASY-F	2
	ASY-M	8
	AHY-F	81
	AHY-M	179
	AHY-U	18
	SY-F	1
	SY-M	3
	HY-F	1
	HY-M	7
	HY-U	10

Table 2. (*Continued*).

Species	Age-Sex	Number
	Total	310
Brown Thrasher		
	ASY-F	1
	ASY-U	27
	AHY-F	2
	AHY-M	1
	AHY-U	170
	SY-M	3
	SY-U	10
	HY-U	39
	U-U	32
	Total	285
Cactus Wren		
	AHY-U	1
	HY-U	1
	Total	2
Cassin's Sparrow		
	AHY-F	1
	HY-M	1
	Total	2
Cedar Waxwing		
	ASY-F	1
	ASY-M	4
	AHY-F	3
	AHY-M	1
	AHY-U	1
	SY-F	3
	SY-M	2
	HY-M	1
	U-M	1
	Total	17
Chipping Sparrow		
	ASY-U	1
	AHY-U	7
	SY-U	7
	HY-U	20
	U-U	8
	Total	43
Clay-colored Sparrow		
	AHY-U	8
	SY-U	4
	HY-U	7
	U-U	3
	Total	22
Dark-eyed Junco		
	ASY-U	1
	ASY-M	1
	AHY-F	62
	AHY-M	74
	AHY-U	166
	SY-F	11

Table 2. (*Continued*).

Species	Age-Sex	Number
	SY-M	1
	SY-U	21
	HY-F	44
	HY-M	25
	HY-U	115
	U-F	40
	U-M	21
	U-U	42
	Total	624
Eastern Bluebird		
	ASY-F	7
	ASY-M	8
	AHY-F	2
	AHY-M	9
	SY-F	3
	SY-M	3
	SY-U	4
	HY-M	5
	HY-U	3
	U-F	1
	U-M	1
	Total	46
Eastern Phoebe		
	ASY-F	3
	ASY-U	10
	AHY-F	6
	AHY-M	2
	AHY-U	52
	SY-F	3
	SY-U	5
	HY-U	53
	U-U	18
	Total	152
Eastern Towhee		
	AHY-F	12
	AHY-M	8
	AHY-U	1
	SY-F	2
	SY-M	4
	HY-F	6
	HY-M	2
	U-F	2
	Total	37
Field Sparrow		
	ASY-U	9
	AHY-U	146
	SY-M	1
	SY-U	14
	HY-M	1
	HY-U	201
	U-M	1

Table 2. (*Continued*).

Species	Age-Sex	Number
	U-U	98
	Total	471
Fox Sparrow		
	ASY-U	10
	AHY-F	1
	AHY-M	1
	AHY-U	171
	SY-U	11
	HY-U	148
	U-F	2
	U-M	7
	U-U	120
	Total	471
Golden-crowned Kinglet		
	ASY-F	1
	ASY-M	2
	AHY-F	22
	AHY-M	36
	SY-F	1
	HY-F	5
	HY-M	4
	HY-U	1
	U-F	49
	U-M	39
	Total	160
Grasshopper Sparrow		
	ASY-U	1
	AHY-U	4
	U-U	2
	Total	7
Harris's Sparrow		
	ASY-U	9
	AHY-F	1
	AHY-M	2
	AHY-U	177
	SY-U	7
	HY-M	1
	HY-U	6
	U-M	1
	U-U	141
	Total	345
Henslow's Sparrow		
	AHY-U	1
	Total	1
Hermit Thrush		
	ASY-M	1
	ASY-U	31
	AHY-F	3
	AHY-U	119
	SY-U	16
	HY-U	85
	U-U	7
	Total	262

Table 2. (*Continued*).

Species	Age-Sex	Number
Lark Sparrow		
	AHY-M	3
	Total	3
LeConte's Sparrow		
	AHY-U	11
	HY-U	13
	U-U	6
	Total	30
Lincoln's Sparrow		
	ASY-U	47
	AHY-M	4
	AHY-U	876
	SY-M	1
	SY-U	118
	HY-F	1
	HY-U	733
	U-U	348
	Total	2128
Loggerhead Shrike		
	AHY-U	3
	HY-U	6
	U-U	10
	Total	19
Marsh Wren		
	AHY-U	1
	HY-U	2
	U-U	3
	Total	6
Northern Flicker		
	ASY-F	5
	ASY-M	2
	AHY-F	5
	AHY-M	5
	SY-F	3
	SY-M	3
	HY-F	1
	U-F	1
	U-U	1
	Total	26
Orange-crowned Warbler		
	ASY-F	8
	ASY-M	17
	ASY-U	1
	AHY-F	74
	AHY-M	44
	AHY-U	91
	SY-F	16
	SY-M	14
	SY-U	10
	HY-F	66
	HY-M	25
	HY-U	64
	U-F	22

Table 2. (*Continued*).

Species	Age-Sex	Number
	U-M	18
	U-U	19
	Total	489
Pine Siskin		
	AHY-F	1
	AHY-M	3
	AHY-U	3
	HY-U	6
	U-M	1
	U-U	5
	Total	19
Purple Finch		
	AHY-F	2
	Total	2
Red-breasted Nuthatch		
	AHY-U	1
	Total	1
Red-headed Woodpecker		
	ASY-U	1
	SY-U	1
	Total	2
Ruby-crowned Kinglet		
	ASY-F	4
	ASY-M	35
	ASY-U	3
	AHY-F	193
	AHY-M	214
	SY-F	7
	SY-M	29
	SY-U	1
	HY-F	75
	HY-M	44
	HY-U	6
	U-F	195
	U-M	244
	U-U	10
	Total	1060
Red-winged Blackbird		
	ASY-F	1
	ASY-M	7
	AHY-F	3
	AHY-M	10
	AHY-U	1
	SY-M	2
	U-M	1
	U-U	1
	Total	26
Rusty Blackbird		
	AHY-F	1
	SY-M	1
	U-M	1

Table 2. (*Continued*).

Species	Age-Sex	Number
	Total	3
Savannah Sparrow		
	AHY-U	10
	SY-U	6
	HY-U	8
	U-U	8
	Total	32
Sedge Wren		
	AHY-U	1
	HY-U	1
	U-M	1
	Total	3
Sharp-shinned Hawk		
	AHY-M	3
	SY-M	5
	HY-M	8
	HY-U	3
	U-U	2
	Total	21
Song Sparrow		
	ASY-U	7
	AHY-M	1
	AHY-U	327
	SY-U	28
	HY-U	265
	U-U	90
	Total	718
Spotted Towhee		
	ASY-M	2
	ASY-U	1
	AHY-M	6
	AHY-U	1
	HY-F	6
	U-F	2
	Total	18
Swamp Sparrow		
	ASY-F	1
	ASY-U	30
	AHY-F	1
	AHY-U	114
	SY-M	1
	SY-U	30
	HY-U	111
	U-U	56
	Total	344
Vesper Sparrow		
	HY-U	1
	Total	1
Western Meadowlark		
	U-F	1
	Total	1

Table 2. (*Continued*).

Species	Age-Sex	Number
White-crowned Sparrow		
	ASY-U	15
	AHY-M	2
	AHY-U	63
	SY-U	43
	HY-F	1
	HY-M	1
	HY-U	91
	U-U	5
	Total	221
White-throated Sparrow		
	ASY-M	4
	ASY-U	33
	AHY-F	13
	AHY-M	217
	AHY-U	489
	SY-F	3
	SY-M	15
	SY-U	98
	HY-F	26
	HY-M	109
	HY-U	398
	U-F	5
	U-M	10
	U-U	108
	Total	1528
Winter Wren		
	AHY-U	17
	SY-U	1
	HY-F	1
	HY-U	30
	U-U	30
	Total	79
Yellow-bellied Sapsucker		
	TY-M	1
	ASY-F	2
	AHY-F	2
	AHY-M	1
	SY-F	1
	SY-M	3
	SY-U	1
	HY-F	7
	HY-M	6
	HY-U	3
	U-F	1
	Total	28
Yellow-rumped Warbler		
	ASY-F	46
	ASY-M	51
	ASY-U	2
	AHY-F	66

Table 2. (*Continued*).

Species	Age-Sex	Number
	AHY-M	58
	AHY-U	84
	SY-F	74
	SY-M	69
	SY-U	14
	HY-F	33
	HY-M	35
	HY-U	63
	U-F	1
	U-U	45
	Total	641

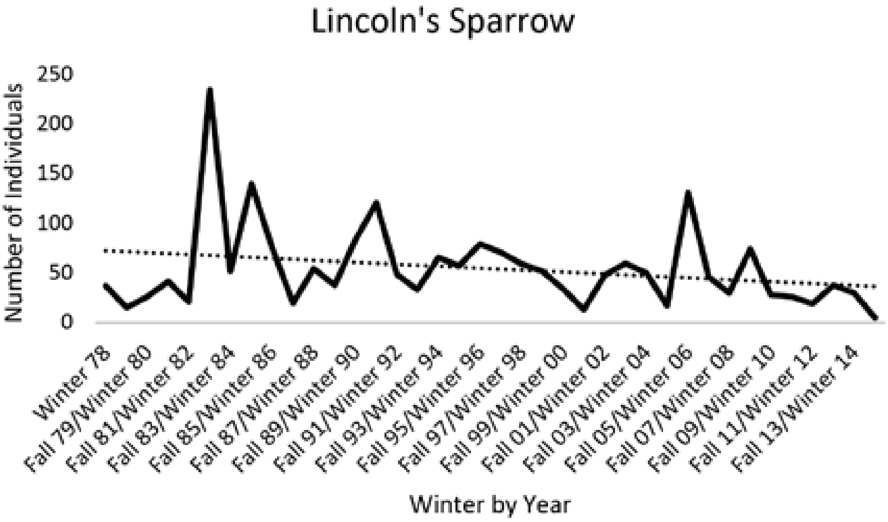

Figure 3. Lincoln's Sparrow winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

for the remainder of the study (Fig 4). Heard data paralleled the BBS −0.8%/year survey-wide decreasing population trend for White-throated Sparrow (Sauer et al. 2019). The 1.6 adult:1 HY age ratio for this species was greater than the 1:1 age ratio suggested by other studies (Piper 1995). Piper and Wiley (1990) documented that adult White-throated Sparrows (45-50%) exhibited higher winter site fidelity than HY birds (30-39%). The skewed 7.6 male:1 female sex ratio follows previously published studies showing White-throated Sparrows exhibit differential latitudinal migration during winter (Jenkins and Cristol 2002, Mazerolle and Hobson 2007). Interestingly, the Heard is near the southern end of the White-throated Sparrow's winter distribution, which suggests females in this zone of the Central Flyway winter deeper in South-Central Texas (Falls and Kopachena 2020).

Ruby-crowned Kinglet ($n = 1060$) was banded in 37 seasons and demonstrated a 3.9 adult:1 HY age ratio and a 1.2 male:1 female sex ratio (Table 2). Ruby-crowned Kinglet at the Heard exhibited two peaks in abundance in the late 1980s and early 2000s but declined rapidly thereafter (Fig 5). Heard data paralleled a similar set of two peaks in BBS data, although the declining abundance trend at the Heard differed from the BBS +0.7%/year survey-wide increasing population trend for Ruby-crowned Kinglet (Sauer et al. 2019). Laurenzi et al. (1982) documented decreased winter survival due to extreme cold, but mild winters at the Heard likely helped Ruby-crowned Kinglet survival.

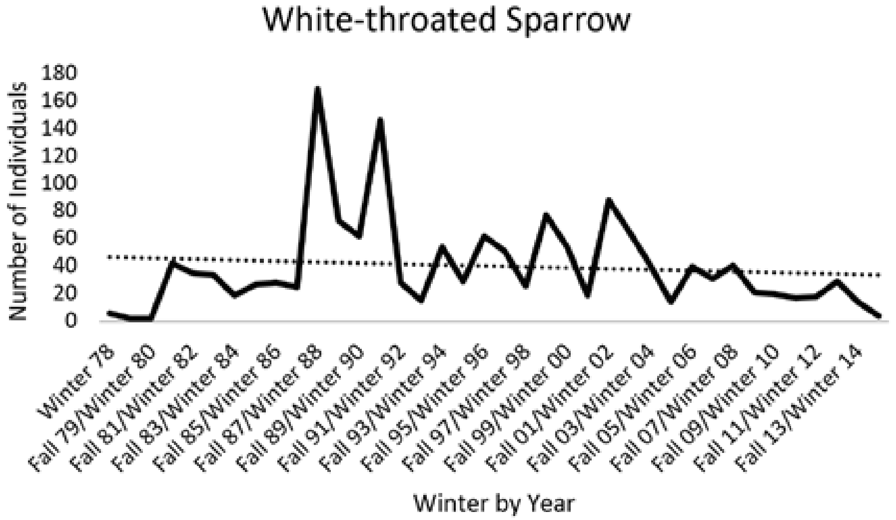

Figure 4. White-throated Sparrow winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

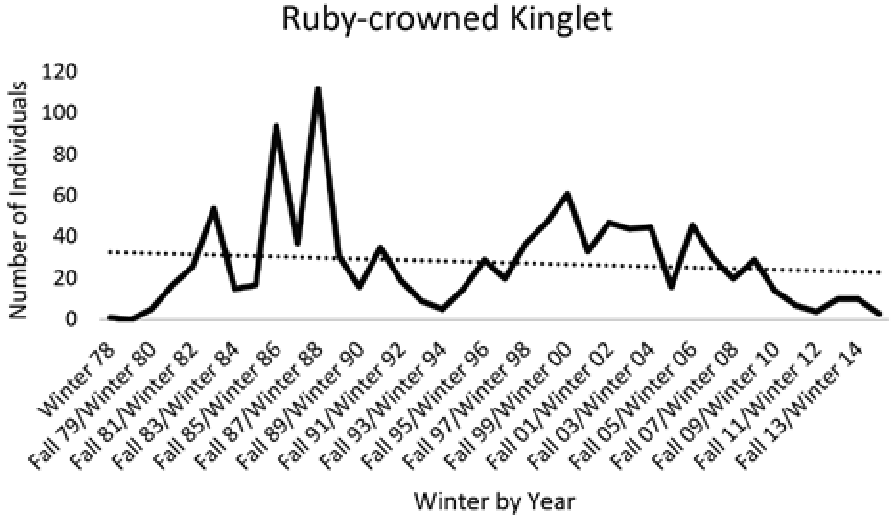

Figure 5. Ruby-crowned Kinglet winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

Latitudinal differential migration by age may occur in Ruby-crowned Kinglet (Swanson et al. 2020b). The 3.9 adult:1 HY age ratio indicates a high proportion of adults wintered at the Heard, which is in the northern third of the Ruby-crowned Kinglet's winter range (Swanson et al. 2020b). Heard data corresponded to other studies showing HY Ruby-crowned Kinglets migrating earlier than adults and farther south during winter (Benson and Winker 2001).

Song Sparrow (n = 718) was banded in 35 seasons and exhibited a 1.4 adult:1 HY age ratio (Table 2). Song Sparrow abundance peaked in the early 1980s, then steadily declined thereafter (Fig. 6). Heard data followed the BBS −0.6%/year survey-wide population trend (Sauer et al.

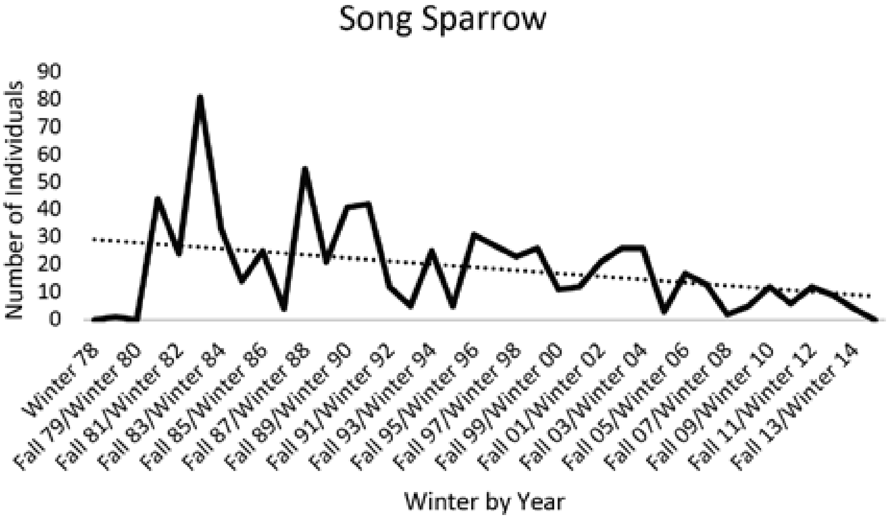

Figure 6. Song Sparrow winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum Wildlife Sanctuary in North Texas.

2019). Little is known about migrant Song Sparrow demographics (Arcese et al. 2020).

Yellow-rumped Warbler (*n* = 641) was banded in 33 seasons and exhibited a 3.5 adult:1 HY age ratio and 1 male:1 female sex ratio (Table 2). At the Heard, Yellow-rumped Warbler annual abundance increased, but was generally low except for two significant peaks in the early and late 2000s. Yellow-rumped Warbler abundance trends at the Heard generally followed the BBS +0.2%/year survey-wide trend for this species (Sauer et al. 2019). Yellow-rumped Warblers exhibit unusual patterns of latitudinal differential migration in which HY males winter farther north than adult males and HY females winter farther south than adult females, with adults more abundant in the middle latitudes of the species' winter range (Hunt and Flaspohler 2020). The 3.5 adult:1 HY age ratio indicates the Heard is in the middle of the Yellow-rumped Warblers' winter range in the Central Flyway. Although a balanced sex ratio was observed at the Heard for this species, Hunt and Flaspohler (2020) suggest Yellow-rumped Warbler exhibits latitudinal differential migration with males wintering farther north than females.

Dark-eyed Junco (*n* = 624) was banded in 35 seasons and demonstrated a 1.8 adult:1 HY age ratio and a 1.3 female:1 male sex ratio (Table 2). At the Heard, Dark-eyed Juncos exhibited three significant peaks in the early 1980s, late 1980s, and early 1990s followed by a rapid decline in abundance thereafter (Fig 7). Heard data paralleled the steady decline of Dark-eyed Juncos demonstrated by the BBS −0.7%/year survey-wide decreasing population trend (Sauer et al. 2019). Dark-eyed Junco exhibited a 1.8 adult:1 HY age ratio during winter at the Heard, which is in the southern tier of the winter distribution for this species. In Indiana, Ketterson and Nolan (1982) showed latitudinal differential migration based on age for Dark-eyed Junco with adults migrating farther south than HY birds. Similarly, Dark-eyed Juncos at the Heard showed a sex ratio biased towards females, which corresponded to a similar pattern of latitudinal differential migration based on sex with females more likely to occur in the southern portion of the winter range for this species (Ketterson and Nolan 1976).

American Goldfinch (*n* = 496) was banded in 32 seasons and demonstrated a 1.8 HY:1 adult age ratio and a 1.2 female:1 male sex ratio (Table 2). American Goldfinch annual abundance declined slightly and was bimodal with captures >25 or 0-5 per winter (Fig. 8). American Goldfinch abundance at the Heard contrasted sharply with the BBS -0.6%/year survey-wide decreasing population trend (Sauer et al. 2019). American Goldfinches at the Heard exhibited an age ratio skewed in favor of HY birds, which contradicted Prescott and Middleton's (1990) data which suggested adult goldfinches

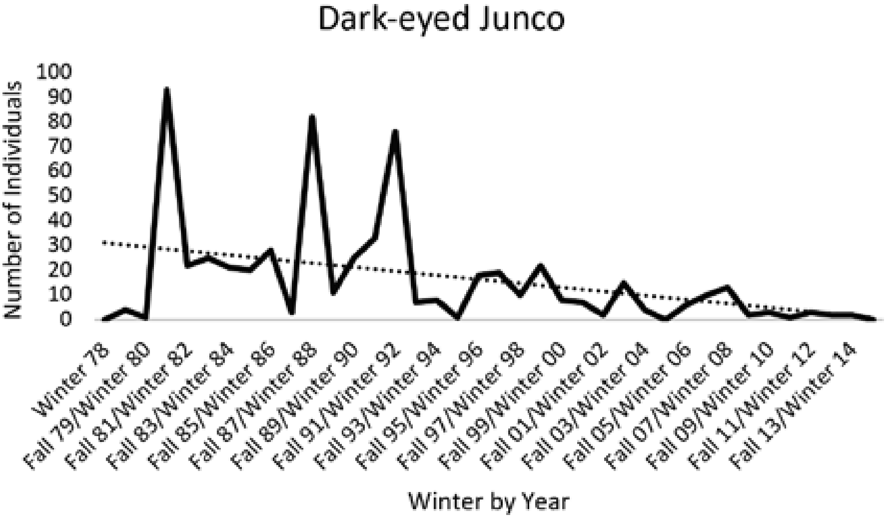

Figure 7. Dark-eyed Junco winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

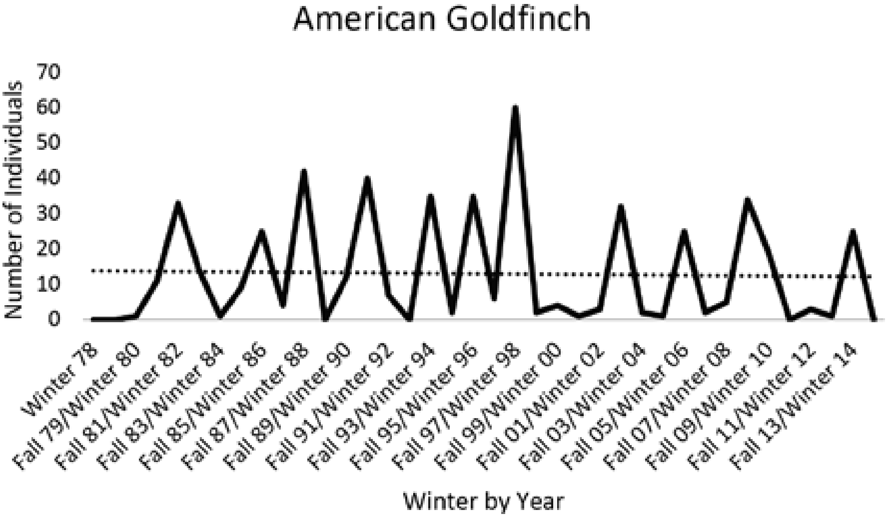

Figure. 8. American Goldfinch winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

wintered farther south. American Goldfinches at the Heard exhibited a sex ratio favoring females, which corresponded to other studies showing latitudinal differential migration based on sex for this species (Prescott and Middleton 1990). Little information is available regarding age ratios of American Goldfinch during winter (McGraw and Middleton 2020).

Orange-crowned Warbler ($n = 489$) was banded in 37 seasons and demonstrated a 1.8 adult:1 HY age ratio and a 1.6 female:1 male sex ratio (Table 2). At the Heard, Orange-crowned Warbler abundance steadily declined over the course of banding. Heard data paralleled the BBS −0.6%/year survey-wide decreasing population trend for this species (Sauer et al. 2019). Orange-crowned Warblers exhibited a 1.8 adult:1 HY age ratio during winter at the Heard, which differed markedly from the 6.3 HY:1 adult ratio for this species during autumn migration in coastal California (Taylor et al. 1994). The low proportion of HY Orange-crowned Warblers at the Heard suggested this species may exhibit latitudinal differential migration based on sex during winter (Gilbert et al. 2020).

Field Sparrow (*n* = 471) was banded in 36 seasons and exhibited a 1.2 HY:1 adult age ratio (Table 2). Field Sparrow abundance showed a slightly decreasing abundance trend with one exceptional peak in the late 1980s. The decline in Field Sparrow abundance at the Heard was not as steep as the BBS −2.2%/year survey-wide decreasing population trend for this species (Sauer et al. 2019). Carey et al. (2020) documented high abundance and density of Field Sparrow in Texas (Carey et al. 2020), although little demographic data has been published for this species.

Fox Sparrow (*n* = 471) was banded in 35 seasons and exhibited a 1.3 adult:1 HY age ratio (Table 2). Fox Sparrow abundance showed a slightly decreasing abundance trend with wide annual variation over the banding period, although this species is known to be abundant in the Red River region of North Texas (Root 1988). The decline in Fox Sparrow abundance at the Heard was similar to the BBS −0.4%/year survey-wide decreasing population trend for this species (Sauer et al. 2019). Little is known about wintering Fox Sparrow age and sex ratios (Weckstein et al. 2020).

Harris's Sparrow (*n* = 345) was banded in 25 seasons and exhibited a highly skewed 28 adult:1 HY age ratio (Table 2). This species exhibited peak abundance in the late 1970s-early 1980s but plummeted thereafter. BBS data was not available for a population trend comparison (Sauer et al. 2019). Harris's Sparrow is known to exhibit strong winter site fidelity (Harkins 1937 Graul 1967), although little demographic data exists for wintering Harris's Sparrows (Norment et al. 2020).

Swamp Sparrow (*n* = 344) was banded in 30 seasons and exhibited a 1.6 adult:1 HY age ratio (Table 2). Swamp Sparrow abundance increased over the banding period with two significant peaks in the mid-1990s and early 2000s. Heard data paralleled the BBS +0.8%/year survey-wide increasing population trend for this species (Sauer et al. 2019). Swamp Sparrows prefer marshes and riparian vegetation adjacent to open water (Root 1988, Herbert and Mowbray 2020), which were present at the Heard. Encroachment due to sprawl over the banding period may have concentrated Swamp Sparrows in the remaining suitable habitat at the Heard; thus, increasing annual abundance for this species at the site. A scarcity of demographic information exists for wintering Swamp Sparrows (Herbert and Mowbray 2020).

Brown-headed Cowbird (*n* = 310) was banded in only 13 seasons and exhibited a highly skewed 16.2 adult:1 HY age ratio and 2.3 male:1 female sex ratio (Table 2). Abundance data was limited for this species as almost all individuals were banded during only two winters (1979-1980 and 1983-1984). Although Brown-headed Cowbirds exhibit a 1 male:1 female sex ratio during the breeding season (Teather and Robertson 1986), sex ratio was skewed towards males at the Heard. Brown-headed Cowbird flocks are often segregated by sex during winter and likely explains the skewed sex ratio for this species at the Heard (Lowther 2020).

Brown Thrasher (*n* = 285) was banded in 36 seasons and exhibited a skewed 5.5 adult:1 HY age ratio (Table 2). Brown Thrasher demonstrated steadily increasing abundance over the banding period (Fig. 9). The increasing abundance trend at the Heard strongly contrasted with the steep BBS −0.9%/year survey-wide decreasing population trend for Brown Thrasher (Sauer et al. 2019). Sauer et al. (1996) documented high winter abundance and density for Brown Thrasher in Texas (Sauer et al. 1996), although little is known about winter demographics for this species (Cavitt and Haas 2020).

Hermit Thrush (*n* = 262) was banded in 33 seasons and exhibited a 2 adult:1 HY age ratio (Table 2). Hermit Thrush abundance trended upwards throughout the banding period driven by two significant peaks in the late 1980s and 1990s. Although Hermit Thrush abundance increased annually, it differed from the flat BBS 0.0%/year survey-wide population trend for this species (Sauer et al. 2019). The 0.0%/year trend is somewhat misleading as this species demonstrated a rapid population increase in the early 2000s followed by a sudden decrease in the last 10 years (Sauer et al. 2019). The 2 adult:1 HY age ratio for Hermit Thrush at the Heard contrasted sharply with Brown et al. (2002) which documented a 1.7 HY: 1 adult age ratio for wintering Hermit Thrushes in southeastern Louisiana. Dwyer (1998) reported a 1.3 female:1 male sex ratio for Hermit Thrushes wintering in Louisiana, although sex ratio was balanced for Hermit Thrushes wintering at the Heard.

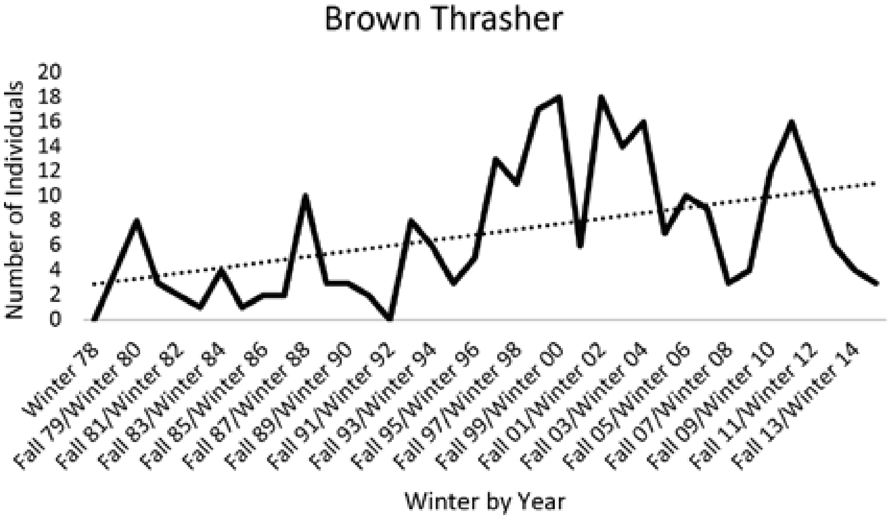

Figure 9. Brown Thrasher winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

White-crowned Sparrow ($n = 221$) was banded in 30 seasons and exhibited a 1.3 adult:1 HY age ratio (Table 2). White-crowned Sparrow abundance declined over the banding period, although three significant spikes occurred during winter 1983-1984, 1989-1991, and 1999-2000. Heard data paralleled the BBS −0.2%/year survey-wide population decline for White-crowned Sparrow (Sauer et al. 2019). Chilton et al. (2020) suggested extensive interannual variation exists for White-crowned Sparrow age and sex ratios but did not provide specific data.

Golden-crowned Kinglet ($n = 160$) was banded in 26 seasons and exhibited a skewed 6.2 adult:1 HY age ratio, but a balanced 1:1 sex ratio (Table 2). Golden-crowned Kinglet abundance declined over

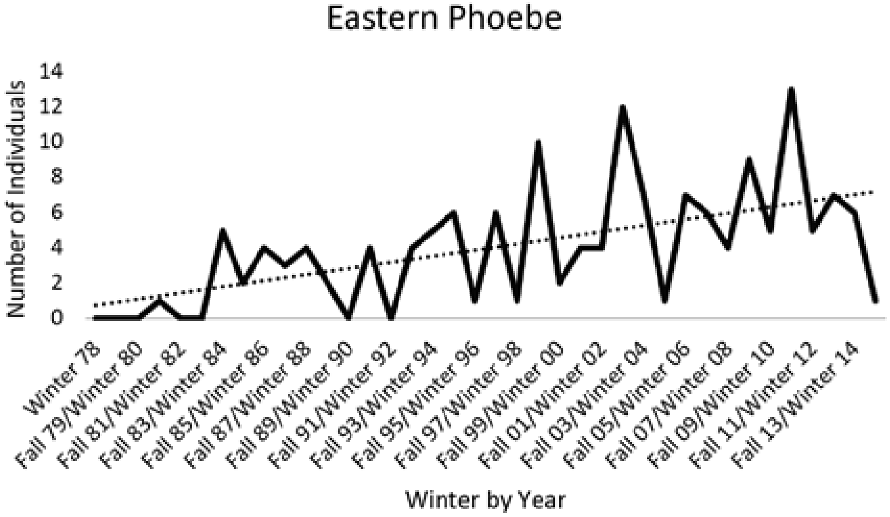

Figure 10. Eastern Phoebe winter abundance and trend line from 1978-2014 at the Heard Natural Science Museum & Wildlife Sanctuary in North Texas.

the banding period, although there was a significant spike during winter 1987-1988 and a surge in the late 1990s-early 2000s. Decreasing abundance of Golden-crowned Kinglet at the Heard was similar to the BBS -0.2%/year survey-wide population decline for this species, with a steeper decline in the 2000s (Sauer et al. 2019). Little demographic information exists for Golden-crowned Kinglet in winter (Swanson et al. 2020a).

Eastern Phoebe (n = 152) was banded in 31 seasons and exhibited a 1.5 adult:1 HY age ratio (Table 2). Eastern Phoebe abundance steadily increased with peak abundance during winter 2010-2011 (Fig. 10). Increasing abundance of Eastern Phoebe at the Heard strongly corresponded to the BBS $+0.4\%$/year survey wide population increase, with strong increases from the 1980s to early 2000s (Sauer et al. 2019). Root (1988) documented the highest winter densities for Eastern Phoebe in East Texas, although a scarcity of winter demographic information exists for this species (Weeks 2020).

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ECOLOGY, BEHAVIOR, AND REPRODUCTION OF INTRODUCED MUTE SWANS (*CYGNUS OLOR*) IN TEXAS

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ABSTRACT.—Natural history of the Mute Swan (*Cygnus olor*) in Texas is lacking. A citizen-science invasive bird project was developed to collect observational data on the ecology, behavior, and reproduction of the Mute Swan in Texas. The highest frequency of Mute Swan sightings occurred in San Antonio, Austin, Dallas-Fort Worth metroplex, Tyler metropolitan area, and Houston. The most frequently reported habitat was freshwater lakes, wetlands and other water bodies, with most swans found in water. Swimming and foraging were the most common behaviors. Swans were sympatric with other aquatic bird species in nearly one-fourth of all observations. Mean flock size was 3.0 (mode = 1-2, range = 1-15). Some swans were permanent residents while others displayed short, seasonal movements. Swans commonly re-nested in previous locations, and cygnets hatched between early May - June. Very limited information is also provided on the Black Swan (*C. atratus*) in Texas. We compare and contrast our finding with other studies of Mute Swans, both in their native and invasive ranges, and also discuss whether they are currently an environmental threat in Texas.

Invasive species pose potential threats to native ecosystems, and an understanding of their natural and life histories is needed for effective conservation (Blackburn et al. 2014). Given the potentially volatile nature of the effects of invasive species, such populations should be managed properly, and this requires working knowledge of the life history and ecological niche of introduced species (Clout and Williams 2013).

The Mute Swan (*Cygnus olor*) is native to Eurasia, ranging from the British Isles to Inner Mongolia (Cramp and Simmons 1977), with considerable expansion since the early twentieth century (Gayet et al. 2020). It is an invasive species to North America from multiple introductions, inhabiting coastal ponds, slow-moving rivers (Kear 2005), and an increasing number of artificial waterbodies in residential areas (Gayet et al. 2020).

There are a variety of factors responsible for the successful invasion of Mute Swans. With the ability to upend in deeper water than other waterfowl (O'Brien and Askins 1985), the Mute Swan has a distinct foraging advantage over many native species. Overgrazing (Cobb and Harlan 1980) and subsequent abandonment of foraging sites by native species (Allin et al. 1987) have become concerns. Furthermore, the Mute Swan is known to graze agricultural lands (Sears 1989) and is thus a potential nuisance to farming activity. Due to its potential effects on recreational and natural landscapes, further study on the behavior and environmental impacts of the Mute Swan is required. For populations in Texas, much of this information is still unexplored. Herein we document natural and life history aspects of the Mute Swan in Texas, specifically the ecology, behavior, and reproduction of this species.

METHODS

A questionnaire was designed to gather data on Mute Swans. The questionnaire was posted on the website of the Houston Museum of Natural Science (hmns.org/files/invasivebirds.doc) and internet list-servs, and was also distributed to local birdwatching clubs and annual birdwatching festivals. The questions were straightforward, requiring only minimal knowledge on Mute Swans to answer them. The front page of the questionnaire also included images of the invasive species to aid in identification.

The collected email responses to the questionnaire varied in detail. Some responses were

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Mute Swans at Barton Creek. Photo Vincent O'Brien

complete, while others had many questions unanswered. Responses with multiple missing components were considered incomplete and were not included in the analyses. Photographs documenting the specimen and surroundings of the sighting were often attached along with the returned questionnaires. To ensure accuracy, responses were reviewed by checking photographs and ground-truthing certain sites before they were entered into a database.

In addition to the responses for the questionnaire, publicly available data sets from eBird (i.e., Texas sightings, 1988-2020) were also included for the distribution analysis of this study. Data that were not complete with locality or known to have non-flighted swans (pinioned, tendon- or wing-clipped) were discarded. For multiple sightings at the same location, only the earliest sighting was included.

Data for White Rock Lake (Dallas) were excluded from mean flock size computation because the number of swans was a strong outlier in the normalized distribution of the data points.

RESULTS

Distribution

Breeding Mute Swans, initially established for ornamental purposes, were first recorded in the United States along the lower Hudson River in 1910 (Baldassarre 2014). Mute Swans were later imported for recreational activities, zoos, and as a potential deterrent towards Canada Geese, with the population in Texas likely being established by swan escapes or releases after such introductions.

Mute Swans were observed in 736 unique locations in Texas (Fig. 1). Distribution was clustered around Austin (n = 239), Houston (n = 142), Dallas-Fort Worth metroplex (n = 105), San Antonio (n = 61), and Tyler metropolitan area (n = 25). Approximately one-half of all sightings at unique locations before 2000 were reported in Austin (n = 8). Although the exact source of introduction remains unknown, it was likely around Austin, where the highest frequency of sightings occurred before (and after) 2000. Several recent sightings after 2013 were reported west of all five distribution

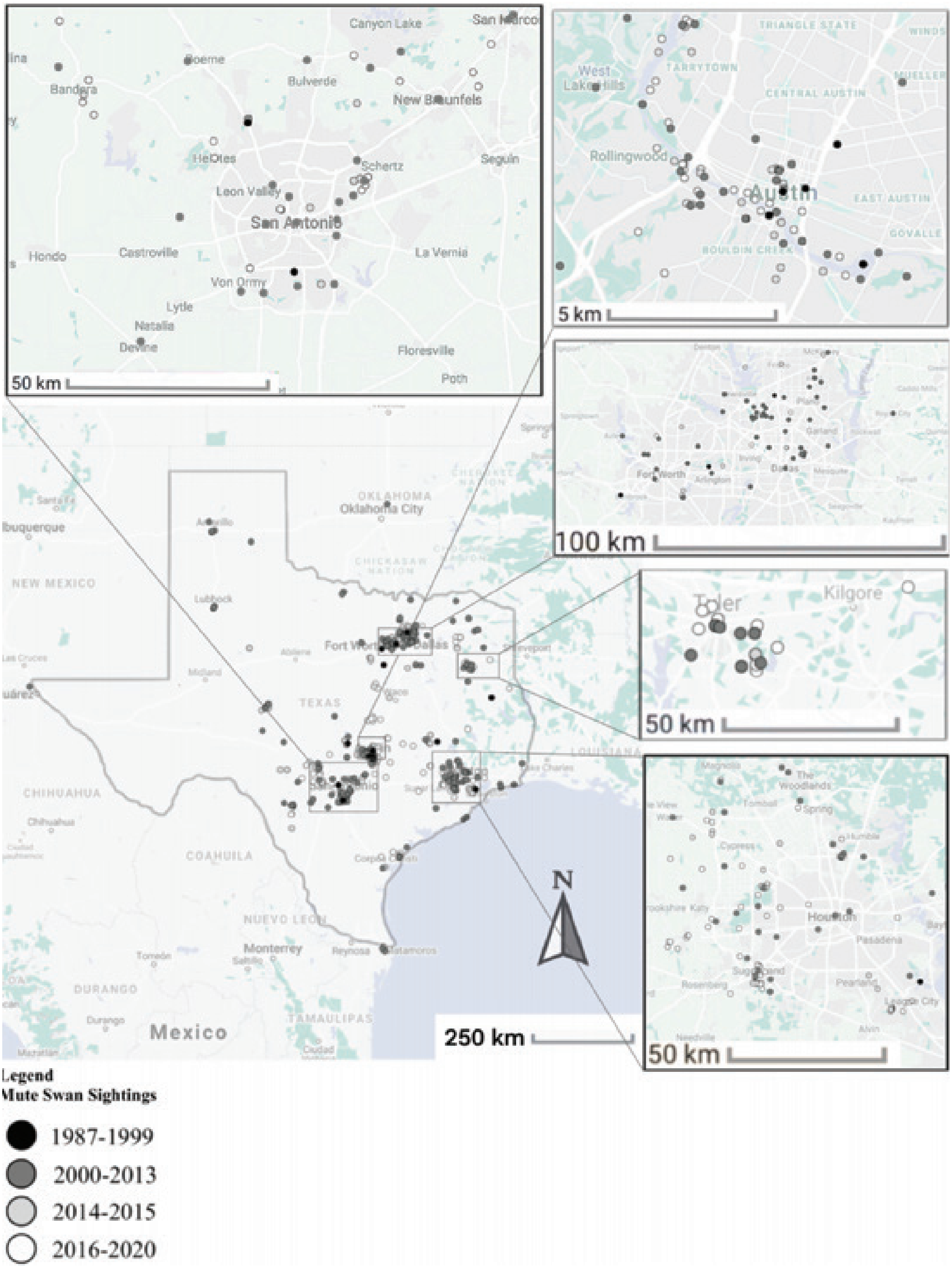

Figure 1. Distribution of Mute Swans in Texas.

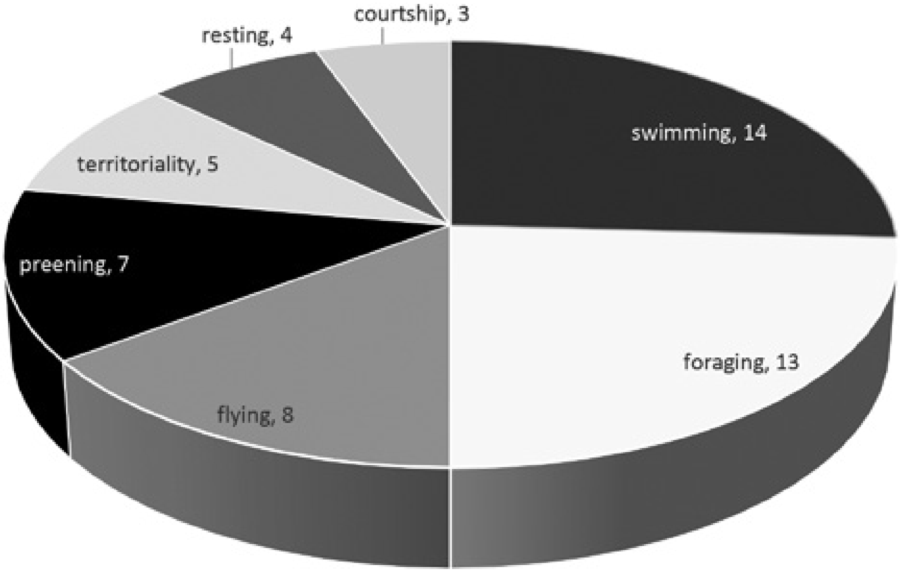

Figure 2. The most common behaviors of Mute Swans in Texas. Numbers represent # of records of each respective behavior.

clusters, suggesting that Mute Swans are expanding in the state. For example, approximately 50% and 72% of all reported sightings in San Angelo and Kerrville, respectively, occurred after 2015.

Habitat

All habitats were comprised of large freshwater bodies of water (n = 30), these were primarily freshwater lakes and wetlands (80%, n = 24), or similar habitats, including (n = 1 each): water treatment plants, bayou oxbows, flooded gravel pits, flooded pastures, reservoirs, and canals connecting two lakes. Water bodies varied from pristine and spring fed, to next to a major construction zone with illegal dumping of trash (e.g., old furniture).

Vegetation ranged from little with vast open water, to areas with punctuated aquatic vegetation, including reed beds (n = 5) containing rushes, grasses, sedges, Cattails (*Typha sp.*; n = 4), emergent Seep (*Baccharis salicifolia*) and Button willow (*Cephalanthus occidentalis*; n = 2), dead trees (n = 1), and islands with Sycamore (*Platanus occidentalis*) and Willow (*Salix sp.*) trees (n = 2). Water bodies were surrounded by irrigated farmland, park, grassland, brushland, or woodland. Swans were most often recorded in the water (79%) as opposed to on land (6%), with 15% of the cases on both land and water during the observation.

Behavior

Swan behaviors (Fig. 2; from most to least frequently recorded) included: swimming (26%), foraging (24%), flying (15%), preening (13%), territoriality (9%), resting (7%), and courtship (6%).

Very little information was recorded regarding diet. Swans ate algae (n = 1), fed on vegetation at the bottom of a lake (n = 1), and ate bread and grain products when offered supplemental food by humans in 17% of reports.

Interspecific interactions

Swans were sympatric with other aquatic bird species in nearly one-fourth (23%, n = 11) of all observations, including White Pelicans (*Pelecanus erythrorhynchos*), several species of cormorants, herons, egrets and ibis, seven species of wild ducks, several breeds of introduced and domestic ducks, American Coots (*Fulica americana*), and Forster's Terns (*Sterna forsteri*). However, in most cases these species were not necessarily in close association with the swans. Swans did coexist with Black-bellied Whistling Ducks (*Dendrocygna autumnalis*; n = 4) and invasive Egyptian Geese (*Alopochen aegyptiaca*; n = 2), but would become aggressive towards whistling ducks and large catfish when food was being provided by humans (n = 1).

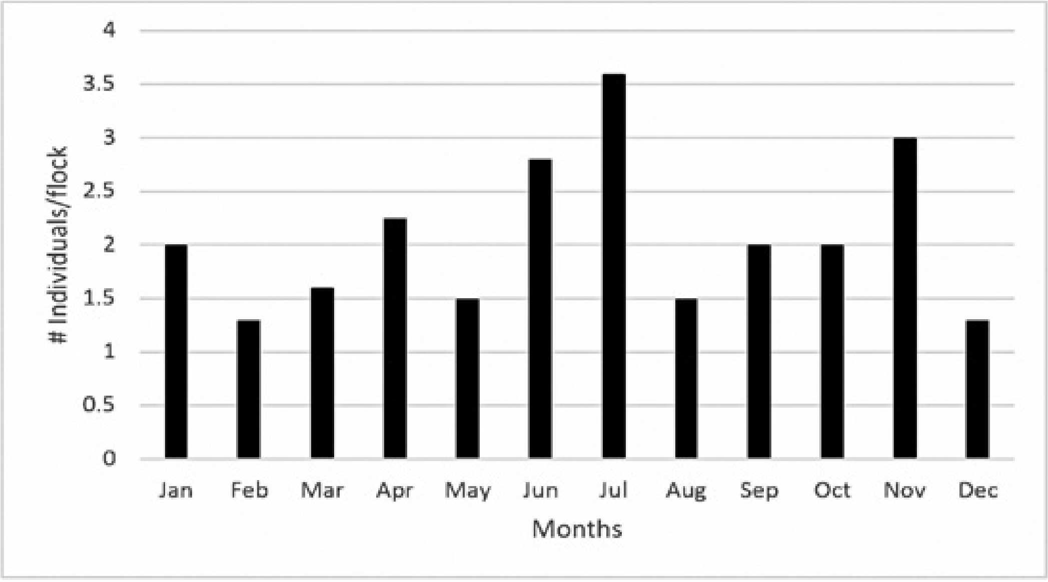

Figure 3. Mean flock size of Mute Swans in Texas per month.

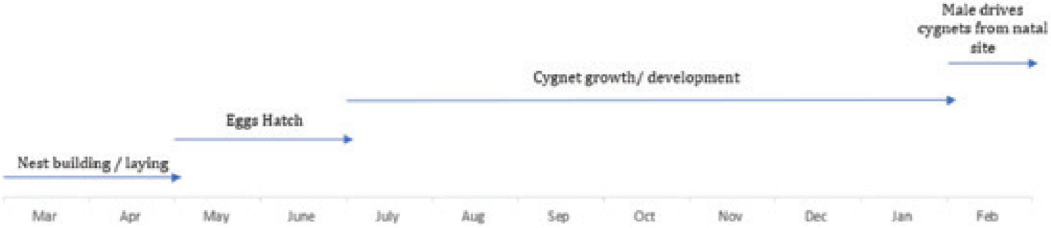

Figure 4. Annual reproductive cycle of Mute Swans in Texas.

Flock dynamics

Overall mean flock size was 3.0 (mode = 1-2, range = 1-15, n = 43). Much larger populations were found at White Rock Lake (Dallas), with 30-40 birds typically present, and a peak Christmas Bird Count (CBC) in December of 61 birds. The highest flock sizes occurred during summer (June-July) reflecting the addition of offspring, and the lowest occurred during the winter (December, February; Fig. 3).

Seasonality and movements

Some populations of swans display short, seasonal migrations, and others (primarily solitary individuals) were permanent residents, as swans were observed throughout the calendar year (Fig. 3). Local seasonal migration was apparent because certain populations in the same region were present only at a certain site October - February, and present at two other sites February/March–October. Swans left at least one site during a drought in 2011 that rendered their pond uninhabitable.

Reproduction and life cycle

Courtship of bonded male-female pairs involves head-bobbing and intertwined necks (n = 1). Nest building takes place from early March–April (n = 4; Fig. 4). Parents attempt to re-nest annually in the same vicinity, as long as the nesting area is not flooded (n = 3). For example, a 2013 nest was built 27 m from the 2012 nest because the old nesting ground was flooded. At the same site in 2016, the first nest built in March was flooded, so the second nest was built the following month 30 m from the first attempted site. The nest is 2.5 m in diameter, located on shore 3 m from water (n = 3), and is made of long, dead grasses and tall reeds, often built on top of short grass (n = 2).

Clutches of 4-8 eggs (mean = 5.6, n = 3) are typically laid an average of 1.5 days apart, with incubation commencing upon completion of the clutch (n = 1), by both parents (n = 2), from March–April (n = 7; Fig. 4). Non-developing eggs are rolled out of the nest by the parents (n = 1).

The number of cygnets hatching ranges 1-8 (mode = 2-3, mean = 3.4, n = 7) between early May (n = 5)–June (n = 5; Fig. 4). Newly hatched cygnets remain in the nest up to three days, whereupon the parents take them to the water to drink, returning to the nest nightly to sleep for the first week of life (n = 1).

Males with nests/cygnets are aggressive to intruders (n = 2). For example, when people approach the bank with a nest/cygnets, the male swims over quickly and leaps onto the bank, vocalizing and wing-flapping (n = 3), while the female stays in the water feeding with the cygnets (n = 1). Although cygnets are full-sized beginning in July (n = 1), they remain grey in color until post-winter molt to white plumage (n = 4).

Survivorship data was provided for 2012-17 at Converse North Park. Cygnet survivorship was 100% during 2012-14, and in 2017 a single cygnet disappeared at three weeks of age, probably due to predation. Although eight cygnets hatched in 2013, five had injuries due to fishing hooks/line. None hatched despite three attempts during 2015-16 due to heavy rains (see above); adults aborted attempts and abandoned the inundated nest after 3 weeks.

Males drive offspring from the natal site in February (n = 3; Fig. 4) to prepare for the breeding season, as a territory of ~1.25 Ac. (0.50 Ha) is required for a breeding pair (n = 1). The young typically range within 1.5 km of their natal pond when dispersing, and individuals flying further often return to the natal area ultimately (n = 1).

Mortality is due to vehicular collision (n = 2 adults), utility line electrocution (1 adult), coyote (1 adult female incubating eggs), and unknown predators (3 cygnets, 1/night serially). Raccoons (*Procyon lotor*) predated 1-2 eggs from nests (n = 1). One adult flew to a new residential pond, where a dog (*Canis familiaris*) attacked it and broke its wing (n = 1).

Black Swans (*Cygnus atratus*)

Black Swans were reported at three locations: 15 May 2010 in Bacliff (north of highway 646), 17 and 24 March 2005 in Beaumont (Highway 69 @ Washington), and 12 October 2017 in La Vernia. In all three cases they were also associated with freshwater bodies (e.g., lake or drainage ponds with numerous canals), were swimming (n = 2) or flying over (n = 2, probably the same individual in Beaumont), and were in groups ranging 1-3. Reports from eBird appear to be captive birds without flying ability, rather than the feral situations mentioned above.

DISCUSSION

Comparisons with Mute Swans in their native range.

Throughout their native range in north and central Eurasia (Cramp and Simmons 1977), Mute Swans are described as having high ecological plasticity (Fouque et al. 2007) due to their lax habitat, breeding, and dietary requirements. In their native range Mute Swans occupy a wide variety of wetland habitats, frequently making use of artificial bodies of water. They have flexible requirements for nesting sites (Gayet et al. 2011), eat a wide range of plant material (Berglund et al. 1963), and supplement their feeding by grazing on agricultural crops and habituating to artificial food (Bailey et al. 2008), sometimes leading to competition among conspecifics (Sears 1989). Although fully wild populations are mainly migratory, particularly in areas with colder winters, regions of their native range with partial migrants or sedentary populations experience higher population growth (Snow and Perrins 1998).

Plasticity in Mute Swans was also observed in this study. In Texas, habitats varied in water quality, vegetation, and level of human development, with only a large body of water being the main requirement. Mute Swans were commonly found coexisting with humans, as 17% of the reports documented supplemental feeding, with swans even occasionally becoming aggressive towards other species while being fed. Any migration observed was limited to short and local seasonal movements and only seen in some populations.

Within their native range, Mute Swans are also gregarious outside of the breeding season, particularly during fall and winter. However, the smallest flock sizes in the Texas study occurred during the winter, with most winter months averaging ≤ 2 birds/flock. Conversely, the largest flocks in Texas occurred in the summer and reflected the addition of offspring. Similar to their native range, nesting commenced in early March, and territorial behavior during the breeding season was also observed. In some areas of Europe, Mute Swans do not exhibit breeding aggression, believed to be due to their recolonization of previous habitats and occupation of once-vacant niches (Posya and Sorjonen 2000). Similarly, some Mute Swans in the Texas study lacked agonistic behavior when sympatric with other species.

Although there is a potential for overgrazing in locations with high densities of Mute Swans within their native range, flock sizes in Texas averaged three birds and generally did not suggest such ecological impacts.

Comparisons with Mute Swans in their invasive range.

Mute Swans have successfully established populations outside of Europe in Japan, Morocco, South Africa, Australia, and New Zealand (Lever 1987), in addition to North America. In North America, Mute Swans occur most frequently in British Columbia, California, and Michigan (Baldassarre 2014), with significant increases occurring within the Atlantic Flyway (Allin 1993), lower Great Lakes, and Atlantic and Pacific Coasts (Petrie and Francis 2003). Overall, the trends of Mute Swans in Texas are similar to those of other introduced populations, with smaller populations and flock sizes in Texas.

Within much of their invasive range, Mute Swans are non-migratory, prefer to remain on their breeding grounds throughout the year (Snow and Perrins 1998), and tend to form multiple local populations, as they do not disperse widely. This explains the visible population clusters around five locations in Texas (Fig 1), with individual sightings more dispersed outside of these clusters. Invasive Mute Swans are generally either sedentary or short-distance migrants as dictated by weather severity, and occasionally migrate within their breeding range (Brewer et al. 1991), similar to our findings in Texas.

In North America dominant predators of Mute Swans include raccoons and dogs, both documented in this study. Although predation is a driving cause for population declines in New Zealand (Seabrook-Davidson 2013), the numerous sightings in Texas suggest that predation did not contribute to population decline in this study.

In Japan and Australia, Mute Swan numbers are low and there are no recorded negative impacts (Rees et al. 2019). In those areas and other regions of North America with smaller populations of Mute Swans (e.g., Texas), the potential for overgrazing is also low. Conversely, in Connecticut (Chasko 1986), certain locations within the Chesapeake Bay (Tatu et al. 2006), and some mid-continental American wetlands (Stafford et al. 2012), Mute Swans had significant impacts on plant communities by either reducing plant cover or below-ground biomass. A source for the high magnitude of grazing is high density of birds (Wood et al. 2012), with overgrazing also being more pronounced in smaller ponds (Chasko 1986). Thus, given that Texas Mute Swans occupy larger bodies of water with a low mean flock size, overgrazing is not currently an issue in Texas.

Are invasive Mute Swans a threat to the environment in Texas?

Mute Swans raise many potential and realized environmental and socioeconomic concerns within their invasive range. Ecological concerns include overgrazing and reduction of plant biomass (Stafford et al. 2012), competition with native species (Gyimesi et al. 2011), and their ability to transport avian influenza viruses (EFSA Panel on Animal Health and Welfare 2017). Socioeconomic effects also exist, including but not limited to crop damage (Rowell and Spray 2004) and reduction in the quality of recreational areas from swan feces and territorial attacks (Hindman and Tjaden 2014).

Among these concerns, small flock and population sizes in Texas limit overgrazing potential and fecal contamination, although large flocks of up to 61 individuals have been recorded at White Rock Lake (1.93 mi.^{2}/5 km^2) and are a potential source of concern if populations continue to grow.

Aggression to humans remains a potential concern, and agonistic behavior exhibited by male swans towards humans has been documented in Texas, although not frequently and with no serious injury. Mute Swans were also aggressive towards other waterfowl and fish species; however, this was restricted to a single circumstance during supplemental feeding. As such, agonistic and territorial behavior are potential threats in Texas and may increase in frequency should populations expand.

CONCLUSION

Holistically, given their high ecological plasticity, abundance of well-suited habitats, and trends of increased sightings in recent years, Mute Swan numbers will likely continue to grow and thrive in Texas. Moreover, the observed interactions between this species and humans in their invasive range raises questions about the potential for more frequent and aggressive encounters. As such, further study on the expanding ranges and flocks of Mute Swans is warranted, with an emphasis on the increasing numbers in current population clusters. We document the life history of Mute Swans in Texas and compare our observations with studies conducted in both the natural and invasive range of this species. Although few harmful ecological or environmental effects have been observed currently, the potential for greater impacts and exacerbated threats posed by Mute Swans is a cause for concern in Texas and North America.

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GOLDEN-CHEEKED WARBLER DETECTIONS IN AN URBAN SETTING REMAIN STABLE FOR 17 YEARS

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ABSTRACT.—Golden-cheeked Warbler (*Setophaga chrysoparia*) habitat includes urban and rural areas and population dynamics differ in urban areas. Barton Creek Habitat Preserve is an urban preserve where surveys for Golden-cheeked Warblers have been conducted since 2001. Each spring point counts were conducted at 43 sites, with surveys repeated 1-3 times per season. The warbler population at the preserve appears to be stable with a mean occupancy of 0.65 ± 0.08 (95% confidence intervals), despite notable droughts during 2003, 2005, 2008, and 2011 and a 46% increase in the human population of Travis County (2001-2012). Number of Brown-headed Cowbird (*Molothrus ater*) and Woodhouse's Scrub-jay (*Aphelocoma woodhouseii*) detections did not significantly affect warbler detections ($F_{1,645} = 0.34$ and 0.78, $p = 0.56$ and 0.78, respectively). Overall, the preserve continues to provide suitable habitat for Golden-cheeked Warblers.

The Golden-cheeked Warbler (*Setophaga chrysoparia*, hereafter warbler) is a Federally endangered neotropical migrant that nests only in central Texas. Breeding habitat consists exclusively of a mix of mature Ashe juniper (*Juniperus asheii*), oak species (*Quercus* spp.), and other various hardwood species (Ladd and Gass 1999, Campbell 2003). The warbler was listed as an endangered species in 1990 due to habitat destruction, habitat modification and predation (U.S. Fish and Wildlife Service 1990). Clearing of juniper woodlands for agriculture practices and urbanization has led to significant population reductions, especially around Travis, Williamson, and Bexar counties where rapid suburban expansion has occurred (U.S. Fish and Wildlife Service 1992).

The warbler breeding range spans an urban to rural gradient and warbler population dynamics may differ between urban and rural sites. Fragmentation of habitat is higher in urban areas which can have negative consequences for warbler populations at urban sites. Robinson et al. (2018) found that size and distance to nearest habitat patch influenced patch occupancy and territory establishment. Larger habitat patches and habitat patches of closer proximity were more likely to be occupied by warblers. Seasonal productivity, nest success, and bird density were also negatively influenced by increasing amounts of edge within the landscape (Peak and Thompson 2013, Peak and Thompson 2014, Reidy et al. 2009, Reidy et al. 2018). Additionally, warblers at urban sites have shorter dispersal distances of males and greater variance in survival across years compared to those in rural areas (Jette et al. 1998, Duarte et al. 2014, Reidy et al. 2018).

The Balcones Canyonlands Conservation Plan was developed as a conservation cooperative between the U.S. Fish and Wildlife Service, the City of Austin, and Travis County, TX, in 1996. The plan established a preserve system in western Travis County, the Balcones Canyonlands Preserve (BCP), to protect endangered species and species of concern that may be displaced by urban development (City of Austin and Travis County 1996). Although the BCP network protects 12,800 hectares of habitat, it is unclear how their population dynamics will be affected by Austin's projected annual rate of 1.9% through 2040 (Imagine Austin 2016).

Since 2001, annual surveys of Golden-Cheeked Warbler and other breeding birds have been conducted at The Nature Conservancy's Barton Creek Habitat Preserve, part of the BCP and located in a rapidly urbanizing area near Austin. Surveys were conducted during peak breeding months using trained volunteers. Here, we summarize

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survey efforts and provide detection probability and occupancy trends for Golden-cheeked Warblers, Brown-headed Cowbirds (*Molothrus ater*), and Woodhouse's Scrub-jay (*Aphelocoma woodhouseii*) from 2001-2017 at Barton Creek Habitat Preserve.

METHODS

Barton Creek Habitat Preserve (30° 17' 14" N, 97° 54' 38" W), owned since 1994 by The Nature Conservancy, protects 1,653 hectares of undeveloped land and is located in Travis County, west of Austin, TX, in the Edwards Plateau ecoregion. The landscape in this area is characterized by rugged limestone hills and shallow soils. The vegetation community is influenced by a topographic gradient. Upland hilltops support a mix of grasslands, savannas and early successional woodlands. Dominant plant species include live oak (*Quercus fusiformis*), Ashe juniper, honey mesquite (*Prosopis glandulosa*), little bluestem (*Schizachyrium scoparium*) and sideoats grama (*Bouteloua curtipendula*). Hillside slopes are typically closed canopy woodlands dominated by Ashe juniper, live oak, Texas red oak (*Quercus buckleyi*), cedar elm (*Ulmus crassifolia*), Texas persimmon (*Diospyros texana*), Texas mountain laurel (*Sophora secundiflora*), and Texas wintergrass (*Nassella leucotricha*). Riparian sites are dominated by pecan (*Carya illinoensis*), hackberry (*Celtis laevigata*), and cedar elm. General management of the preserve consists of deer population control, occasional prescribed fire in grasslands, and removal of Ashe juniper from grasslands. Brown-headed Cowbirds (*Molothrus ater*), an obligate nest parasite, are present but not abundant on the preserve, thus low intensity efforts to remove cowbirds from the preserve have been implemented. Although Barton Creek Habitat Preserve provides suitable nesting habitat for the warbler, the preserve is surrounded by urban development. The preserve is further fragmented into three tracts separated by two major highways.

Volunteers were recruited to carry out surveys based on their ability to correctly identify songbirds, with an emphasis on visual and aural identification of Golden-cheeked Warblers. Fixed point count locations (n = 43), approximately 250-300 meters apart, were established along existing roads and trails in closed-canopy oak-juniper woodland (Fig. 1). These areas were specifically chosen because they represented high-quality warbler habitat.

Volunteers conducted five-minute point counts one to four times between April and early June every spring from 2001-2017 (Table 1). Observers recorded weather conditions and time of surveys. All species detected within 150 meters were recorded and observations were assigned one of two distance bins: less than 50 meters or greater than 50 meters. Surveys began at sunrise and ended five hours after sunrise (typically between 06:30 and 11:30). Surveys did not take place during unfavorable weather conditions where precipitation was more than a light drizzle or winds exceeded 25 mph.

We calculated occupancy and detection probability estimates of Golden-cheeked Warblers in R 3.5 (R Core Team 2019) using the "unmarked" package (Fiske et al. 2011) for each year that had two or more survey replicates. We used single season occupancy models with no covariates because number of survey replicates and individual observers varied across years, with 22 observers during the study. We also calculated mean number of detections per year with 95% confidence intervals for the Golden-cheeked Warbler, Brown-headed Cowbird, and Woodhouse's Scrub-jay. Again, because number of survey replicates varied each year, mean detections were scaled by number of surveys at each point for each year. Finally, We used a linear mixed-effects model ('lme4' package, Bates et al. 2015), with survey point as a random factor, to assess the effects of Brown-headed Cowbird and Woodhouse's Scrub-jay detections on number of Golden-cheeked Warbler detections.

RESULTS

Golden-cheeked Warblers were detected at least once at 42 of 43 survey points. Detection probability pooled across all years was 0.47 (SD 0.12) with the highest detection probabilities in 2003 (mean = 0.68 [SD 0.08]) and the lowest in 2017 (mean = 0.22 [SD 0.18]; Fig. 2). Mean occupancy pooled across all years was 0.65 [SD 0.17] with the highest occupancy estimates in 2006 (mean = 0.88 [SD 0.33]) and the lowest in 2004 (mean = 0.39 [SD 0.10]; Fig. 3). Detection probabilities and occupancy estimates are not reported for 2001 or 2016 because surveys were only conducted once in those years.

The highest number of warbler detections per point was 0.80 (95% CI = 0.21) in 2003, with 2017 having the lowest number of detections per

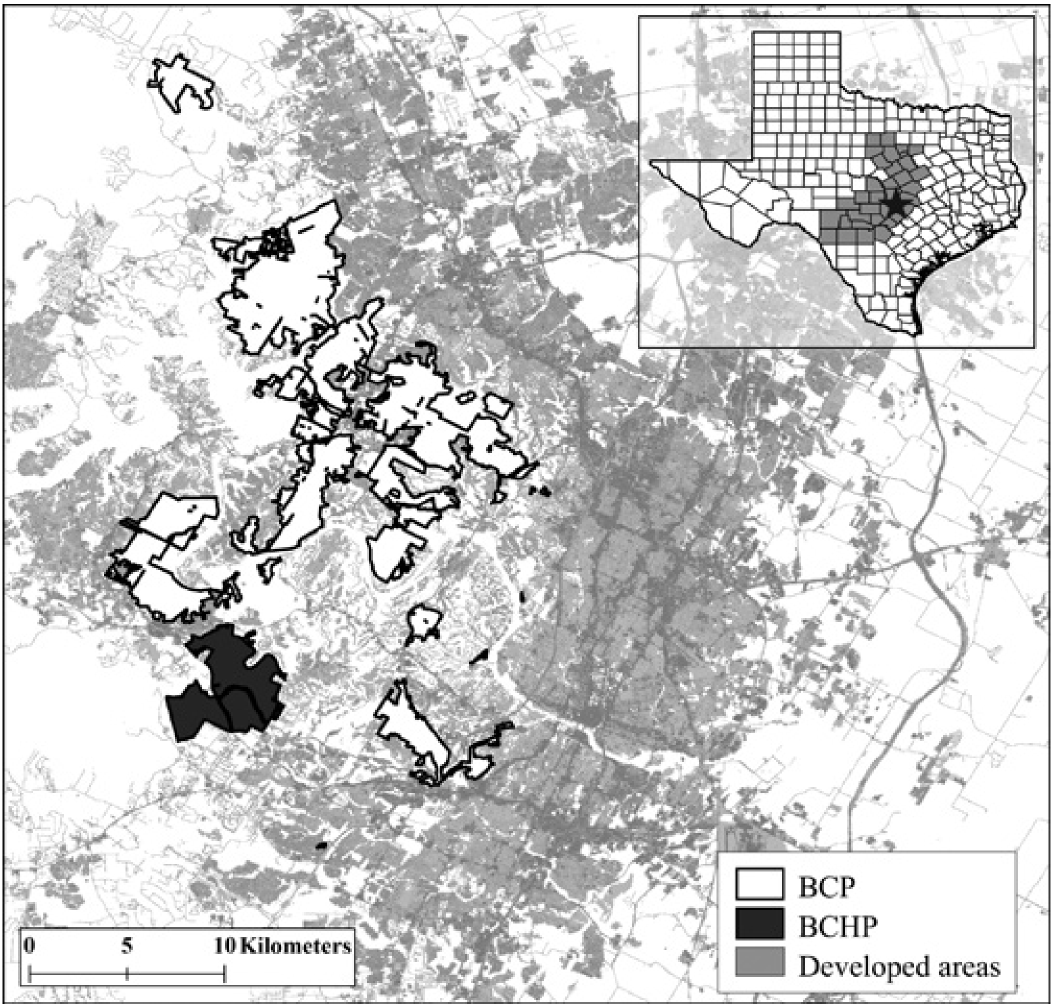

Figure 1. Golden-cheeked warbler (*Setophaga chrysoparia*) breeding range and location of Barton Creek Habitat Preserve (BCHP) where annual point counts were conducted from 2001 – 2017. BCHP is in Travis County and part of the Balcones Canyonland Preserve system (BCP) that protects habitat for warblers and other endangered species in an area with expanding development.

point (mean = 0.13 [95% CI = 0.08]; Fig. 4). Brown-headed Cowbird detections per point were also highest in 2003 (mean = 0.15 [95% CI = 0.09]) while no cowbirds were detected in 2006, 2008, 2009, and 2016. Woodhouse's Scrub-jay detections were highest in 2006 (mean = 0.33 [95% CI = 0.19]) and lowest in 2016 (mean = 0.07 [95% CI = 0.13]). Neither cowbird or scrub-jay detections had a significant effect on warbler detections ($F_{1,645} = 0.34$, $P = 0.56$ and $F_{1,645} = 0.08$, $P = 0.78$, respectively).

DISCUSSION

This study provides information on population dynamics for an endangered songbird, the Golden-cheeked Warbler, in a woodland largely surrounded by urban development. Analysis of volunteer-based monitoring efforts at Barton Creek Habitat Preserve (BCHP) indicate this property continues to provide habitat for the warblers as well as many other woodland species (mean species richness was 45). Occupancy estimates from this 17-year data set can be used as a metric for reporting population trends and habitat suitability at this preserve.

Table 1. Point counts conducted from 2001-2017 at Barton Creek Habitat Preserve, Travis County, Texas. Number of points surveyed and number of surveys completed varied by year based on available resources.

Year	No. Points surveyed	No. Survey events	Survey date range
2001	43	43	5/05 – 5/28
2002	43	78	5/05 – 5/25
2003	43	82	5/03 – 5/25
2004	43	82	4/04 – 5/25
2005	42	94	4/15 – 6/05
2006	43	69	4/15 – 5/27
2007	43	84	4/14 – 5/19
2008	42	84	4/19 – 6/01
2009	42	125	4/19 – 5/31
2010	42	103	4/17 – 6/01
2011	42	81	4/02 – 5/22
2012	42	112	4/23 – 5/05
2013	42	93	4/07 – 5/11
2014	42	124	4/05 – 5/19
2015	42	79	4/11 – 5/31
2016	30	40	4/03 – 4/16
2017	42	83	4/08 – 5/20

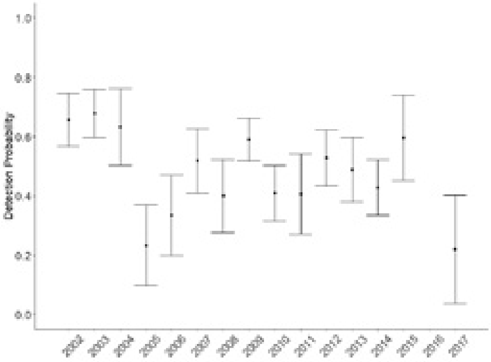

Figure 2. Detection probabilities (± standard errors) of golden-cheeked warblers (*Setophaga chrysoparia*) at Barton Creek Habitat Preserve in Travis County, TX, from 2002 – 2017. Detection probabilities for 2001 and 2016 are not included because sample size was too low for reliable estimates.

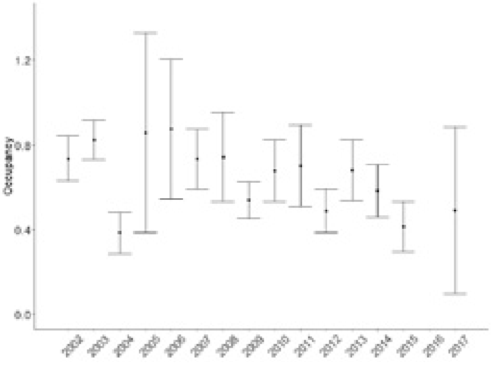

Figure 3. Occupancy estimates (± standard errors) for golden-cheeked warblers (*Setophaga chrysoparia*) at Barton Creek Habitat Preserve in Travis County, TX, from 2002 – 2017. Occupancy estimates for 2001 and 2016 are not included because sample size was too low for reliable estimates.

Habitat fragmentation and adjacent urban development likely has a negative impact on warbler population dynamics on BCHP. Mean occupancy (0.65) and detection probability (0.47) were lower at BCHP compared to the overall Balcones Canyonland Preserve system estimates (0.83 and 0.56, respectively; Reidy et al. 2016, Reidy et al. 2017). Our detection probability estimate was also lower than the range-wide estimate (0.70; Collier et al. 2012). Warbler occupancy has been shown to decrease as fragmentation increases (Collier et al. 2012, Peak and Thompson 2013, Peak and

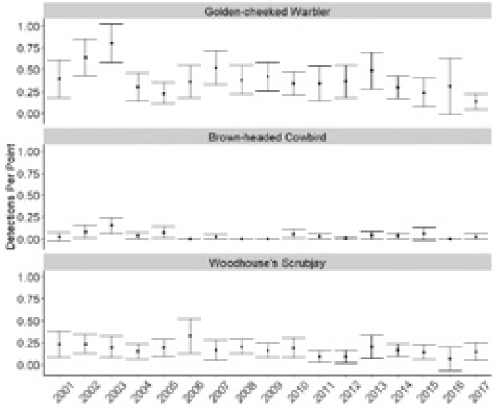

Figure 4. Mean number of birds detected per point (± 95 % confidence intervals) at 43 point count locations from 2001 – 2017 at Barton Creek Habitat Preserve, Travis County, TX.

Thompson 2014, Reidy et al. 2016). Barton Creek Habitat Preserve is divided by two major highways and almost completely surrounded by housing developments. These results suggest that although the preserve provides suitable habitat and is part of a network of protected lands, warbler occupancy at the preserve may be relatively low as a result of nearby urban activity.

Across most years, occupancy did not vary significantly. The years with lowest occupancies (i.e. 2004, 2012 and 2015) may be a result of non-anthropogenic environmental stressors like drought and food availability. The Austin area experienced extreme drought conditions during 2003, 2008, and 2011 (Weather Underground). Prolonged drought conditions can negatively impact songbird reproductive success through decreased food availability and increased pressure from predators (Langin et al. 2009, Colón et al. 2017, Vernasco et al. 2018). While occupancy at the preserve may be low, the number of birds per point appears to remain mostly stable. Continuation of the annual surveys will be important for monitoring future population trends.

Two avian predators of warbler nests, Brown-headed Cowbird and Woodhouse's Scrub-jay, are found on BCHP. Despite previous studies showing a positive relationship between cowbirds and urban-adjacent habitat (Kluza et al. 2000, Chace et al. 2002, Burhans et al. 2006), average number of Brown-headed Cowbird detections per point at the preserve was only 0.04. In the past, cowbird trapping was implemented as part of management on the preserve and on average approximately 10 cowbirds per year were removed from the preserve (Brandon Crawford, personal communication). Preserve staff stopped trapping in 2010. The low presence of cowbirds is likely a reflection of habitat suitability; the preserve is primarily dense woodland and the nearest ranch with more open habitat and cattle is approximately 3 miles away. Woodhouse's Scrub-jay, another documented nest predator of Golden-cheeked Warblers (Reidy et al. 2008), were detected in low numbers, on average 0.17 detections per point. Reidy et al. (2008) report Woodhouse's Scrub-jays were responsible for 75% of avian predation of Golden-cheeked Warbler nests at urban sites and only 13% at rural. Avian nest predators do not appear to be a major threat to the warbler population at BCHP.

The city of Austin has experienced substantial urban growth in the last few decades. From 2002-2012, the population of Travis County increased by 23% (Texas Water Resources Institute 2019) and is projected to nearly double again by 2040 (Imagine Austin Year 5 Progress Report 2017). As urbanization increases, protected green spaces will increasingly become the only habitat for wildlife species. This is especially true for habitat specialists like the Golden-cheeked Warbler. The surveys from Barton Creek Habitat Preserve show that Golden-cheeked Warblers can persist in urban preserves, but at lower densities than in more rural habitat. Protection of large, unfragmented sites will be critical to the long-term survival of the species.

ACKNOWLEDGMENTS

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THE EARLY HISTORY OF ORNITHOLOGY IN TARRANT COUNTY, TEXAS

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ABSTRACT.—Data on the occurrence, distribution and nesting of birds in an area is usually gathered over an extended period of time and, as new accounts are published, the names and accomplishments of earlier workers are seldom cited. An example of this reality is the work of the first individuals to study the birds of Tarrant County, Texas. Only by working back through the literature and consulting seldom-cited sources can their contributions be fully appreciated. This paper presents short biographies of those early collectors and naturalists who contributed to the development of ornithology in Tarrant County.

THE MISSISSIPPI VALLEY MIGRATION STUDY OF 1884-1885

There were 13 stations in Texas with designated observers during the first year of the migration study sponsored by the American Ornithologists' Union (Casto 1992). A new station was added in 1885 with Nathaniel Porter Ball (1862-1929) named as the observer from Fort Worth, Texas (Cooke 1885).

Nathaniel Ball originally lived on a farm near Reeds, Missouri, where he served as an observer during 1884. Ball moved to Fort Worth in 1885 where he worked as an attorney until at least 1899. At the time of the 1900 census he was again living in Missouri but later moved to Colton, San Bernardino County, California. Ball is cited eight times in the final migration report for observations made at Reeds, Missouri, but there is no mention of observations made by him at Fort Worth. Ball's contribution, if any, to the migration study is questionable.

EARLIEST COLLECTION OF EGGS 1885-1886

The eggs of a Blue Grosbeak were collected on 29 May 1885 at Fort Worth by "S. Woodworth." These eggs were later obtained through purchase or exchange by Richard Magoon Barnes (1862-1945, Fig. 1) an attorney living in Lacon, Illinois. In 1922, Barnes donated his entire collection of nearly 39,000 eggs, including the set from Tarrant County, to the Chicago Museum [now Field Museum] of Natural History (FMNH 13898). Barnes was the publisher and editor of The Oologist from 1909 until 1941 during which time over 100 articles by collectors and observers from Tarrant County were published in his journal.

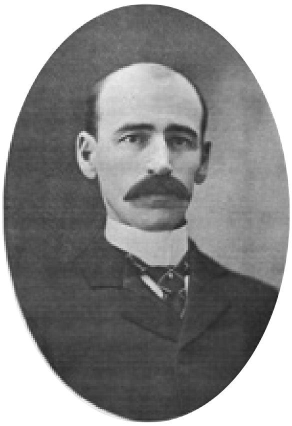

Figure 1. Richard Magoon Barnes. Member of the A.O.U., Cooper Ornithological Club, National Audubon Society, National Geographic Society and the Illinois Academy of Science. Photograph from The Oologist 26(4):50 [1909].

Woodworth was also the collector of a set of Mississippi Kite eggs taken at Fort Worth on 25 May 1886. This set was originally acquired by the Academy of Natural Sciences of Philadelphia but later transferred to the Western Foundation of Vertebrate Zoology (WFVZ 117873) in Camarillo, California.

The identity of S. Woodworth is unknown. His name is not found in any of the early oology trade journals, and he is not included in the list of Texas collectors compiled by Oberholser (1974) or in Davis' Standard Collectors Directory (Davis 1896)

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or any of the other directories of pre-1900 collectors. His collection of eggs during the consecutive years 1885 and 1886 suggests that Woodworth was resident of Tarrant County.

BIRDS COLLECTED IN TARRANT COUNTY DURING 1887

Charles Barney Cory (1857-1921, Fig. 2) from Boston, Massachusetts, was a member of the Nuttall Ornithological Club and a founding member of the American Ornithologists' Union. He was independently wealthy and devoted his life to the study of ornithology (Osgood 1922). Cory employed George Armstrong during April and May 1887 to collect in the vicinity of Fort Worth where 153 specimens representing 33 species and subspecies were taken. Cory later donated his entire collection of over 19,000 specimens, including those taken in Tarrant County, to the Field Museum of Natural History (FMNH).

Figure 2. Charles B. Cory, distinguished ornithologist who commissioned the first collection of birds from Tarrant County. Photograph from Osgood (1922).

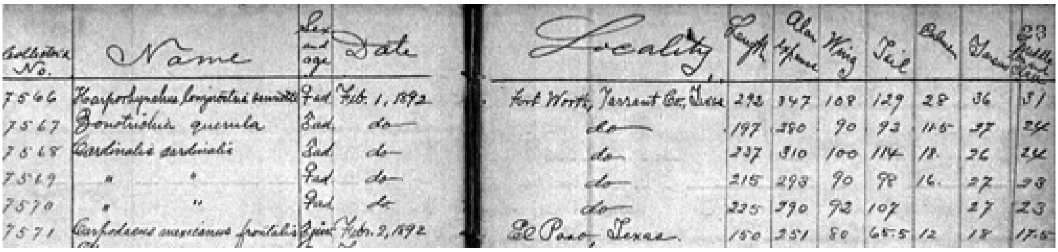
Very little is known of George Armstrong other than that he collected for C. B. Cory. Oberholser (1974) lists Armstrong as a collector of birds in Tarrant, El Paso and Calhoun counties. Although Oberholser knew of the specimens taken at Fort Worth, most ornithologists were not aware of their existence. As a result, this important assemblage of bird skins, taken 134 years ago, is not mentioned by any of the individuals who worked in Tarrant County following their collection by Armstrong in 1887.

WORK OF FIELD NATURALISTS 1892 AND 1894

Edgar Alexander Mearns (1856-1916), Captain and Assistant Surgeon in the United States Army, was ordered to report to El Paso, Texas, on 1 February 1892 to begin work as the medical officer and naturalist with the Mexican-United Sates International Boundary Commission (Richmond 1918). He did not arrive at El Paso on the appointed date as evidenced by two Northern Cardinals and a Brown Thrasher taken by him at Fort Worth on 1 February 1892. These specimens are now in United States National Museum (USNM 125794, 125865, 125756). The co-collector of these specimens was Frank Xavier Holzner (1864-1920), an immigrant from Germany, who was employed by the Boundary Commission as an assistant field naturalist. Holzner later settled in San Diego, California, where at various times he worked as a bath house operator and taxidermist.

In addition to the two Northern Cardinals and Brown Thrasher mentioned above, Mearns' catalogue of specimens records and gives measurements for a Long-billed Thrasher, a Harris's Sparrow and a third Northern Cardinal collected at Fort Worth on 1 February 1892 (Mearns 1892, Fig. 3). The present location of these specimens is unknown. Mearns left Fort Worth immediately following the above-mentioned collections and the next entry in his field book is dated 2 February 1892 at El Paso, Texas.

Field agents of the Bureau of the Biological Survey also spent short periods of time in Tarrant County. Vernon Orlando Bailey (1864-1942) was appointed in 1890 as the Chief Field Naturalist of the Bureau and, for the next several years, the naturalists working under him were dispatched across the United States to inventory and report on the birds and other animals observed or collected. Between 1890 and 1911, several of these naturalists visited Texas and mailed their reports to Bailey. However, only two of the survey naturalists are known to have visited Tarrant County. Basil Hicks Dutcher recorded six species of birds at Saginaw, a suburb of Fort Worth, during 16-17 August 1892 (Dutcher 1892) whereas John Alden Loring reported 34 species while traveling from Troupe



Collector's No.	Name	Sex and age	Date	Locality	Length	Alar expanse	Wing	Tail	Culmen	Tarsus	Middle toe
7566	Harporhynchus longirostris sennetti	♀ ad.	Feb. 1, 1892	Fort Worth, Tarrant Co., Texas	292	347	108	129	28	36	31
7567	Zonotrichia querula	♂ ad.	do	do	197	280	90	93	11.5	27	24
7568	Cardinalis cardinalis	♂ ad.	do	do	237	310	100	114	18.	26	24
7569	" "	♀ ad.	do	do	215	293	90	98	16.	27	23
7570	" "	♀ ad.	do	do	225	290	93	107		27	23
7571	Carpodacus mexicanus frontalis	♂ juv.	Feb. 2, 1892	El Paso, Texas	150	251	80	65.5	12	18	17.5

Figure 3. Pages from the specimen catalogue of E. A. Mearns listing the birds collected at Fort Worth, Texas, on 1 February 1892.

to Fort Worth during the last week of March and early April 1894 (Loring 1894). These unpublished records contributed little to the knowledge of Tarrant County birds.

GEORGE SUTTON'S WORK IN TARRANT COUNTY 1911-1914

George Miksch Sutton (1898-1982) arrived in Fort Worth in 1911 when his father accepted a position teaching at Texas Christian University. Although only 13 years old at this time, George had already acquired a deep interest in nature, particularly birds. The family remained in Fort Worth for only three years but, during this time, George roamed the countryside taking notes and collecting birds and their eggs while also maintaining a small aviary. Seventeen sets of eggs collected at Fort Worth by Sutton during 1913 and 1914 are at the Carnegie Museum of Natural History (CM) in Pittsburgh, Pennsylvania.

Sutton's first publications, written soon after his arrival at Fort Worth, dealt with the behavior of a Painted Bunting and the description of an albino Burrowing Owl (Sutton 1912a,b). A Greater Roadrunner (Fig. 4) he had domesticated was the

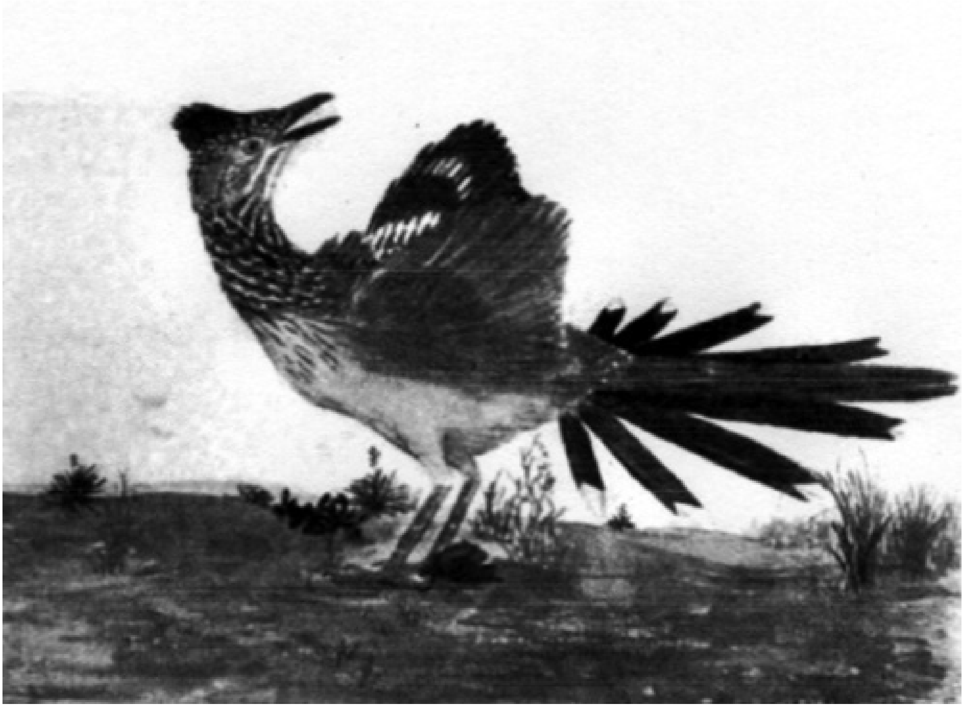


Figure 4. Sutton's pet roadrunner in an attitude of fright. The primary and secondary feathers of the wings are still not fully developed. Drawn by Sutton when he was 17 years old (Sutton 1915).

focus of a study of the growth and development of this species (Sutton 1913, Jackson 2007). In later years, Sutton continued studying roadrunners and providing additional details of his experience with this bird at Fort Worth (Sutton 1915, 1922).

Sutton moved from Texas in 1914 but his continuing interest in the birds of Tarrant County became manifest years later in the publication of a carefully annotated list of the breeding birds of Tarrant County (Sutton 1938). Cited in this paper are the publications and observations of several of the young collectors with whom Sutton became acquainted with while living in Fort Worth.

SUTTON'S TARRANT COUNTY FRIENDS

Listed first among those individuals with whom Sutton established a continuing relationship was Ramon Graham who, according to Sutton, was "an enthusiastic oologist and capable taxidermist … who has published many notes on the birds of the region." Sutton was taking mail-order taxidermy lessons when his family moved to Fort Worth in 1911 (Jackson 2007, p. 19), and it was perhaps because of his interest in this subject that he became acquainted with Ramon Graham. Other individuals acknowledged by Sutton in his 1938 paper include Jake Zeitlin, Charles McClendon and Millard Chandler.

Raymond 'Ramon' Graham (1893-1969, Fig. 5), son of William M. and Carrie Shepherd Graham, was born in Greenville, Texas, where the family lived before moving to Fort Worth in 1902. His family and friends began calling him "Ramon" at an early age, and this was the name he used for the rest of his life. His fascination with nature began at an early age, and it was said that he terrorized every girl in the 3rd grade with lizards, horned toads and baby snakes (Anon. 1920a).

Ramon was an 18 year-old practicing taxidermist when the Sutton family arrived in Fort Worth. George Sutton, then only 13 years old, most likely visited Graham's shop where he watched Graham make taxidermy mounts and drill and blow birds' eggs. Years later, Sutton told how he had obtained skins of a grackle and White-breasted Nuthatch from his "friend" Ramon Graham for which he had promised to pay when he had earned enough money. His parents were quite concerned when they learned of this arrangement and, to avoid their scolding, he lied and burned the note detailing the transaction, an action for which he later expressed regret (Sutton 1980, p. 32).

Graham was a poor student who disliked arithmetic and English grammar. As a result, he quit school at age sixteen to study taxidermy and open a shop advertising himself as a "taxidermist, naturalist and zoologist" (Anon. 1920a). In 1916, he moved his shop to "Camp Live Oak" at Williams Spring near Lake Worth where he could live in close contact with nature. His dislike for the city was so intense that he did not go into town for months at a time. In his self-imposed isolation, he took up writing short stories and poems (Anon. 1920a). These stories were undoubtedly the numerous articles that he submitted to The Oologist (Appendix 1.)

One of Graham's stories described the tribulations that he and two of his friends experienced while camped in the brush between Carrizo Springs and Eagle Pass. During the night pack rats chewed up their leather harness, carried off much of their smaller camp equipment and, most significantly, their egg blow pipe. The next morning, after destroying numerous dens and killing over forty rats, their equipment and the precious blow pipe were recovered and, after repairing their harness, they rode on to the Rio Grande (Graham 1925).

Graham's dwelling at Camp Live Oak, aka "Camp Graham," was littered with examples of his taxidermy work and photographs taken during a trek along the Texas border while working on a government biological survey. This survey, according to Graham, lasted a little over seven months during which time he traveled, perhaps with exaggeration, 1,170 miles on horseback and 1,000 miles in Mexico on burros (Anon.1920a,b). The nature of this survey is unknown but, based on Graham's mention of collecting along the Mexican border (Graham 1920b), the survey may have taken place sometime during 1919. Graham also submitted reports on migratory birds to the Bureau of the Biological Survey for which he was credited as having the "most accurate and complete observations" received from the area (Anon.1920a).

Graham was not a hermit and, in spite of his isolation, he often gave parties for "real girls and office-bound men and women to see life through his eyes…" (Anon. 1920a). One of the girls who attended his parties was Luella Dunn who shared his interest in outdoor life and birds and would later publish a few articles under her own name (Appendix 1.). Drawn together by shared interests, Ramon and Luella were married on 31 May 1920.

Ramon Graham published 85 short articles in The Oologist between 1912 and 1931 (Appendix 1). Seventy-four of these notes mention birds occurring in Tarrant County. Significantly, 41 of these articles are cited in Sutton's 1938 paper. Sutton and Graham remained in contact over the years as evidenced by several mentions that "Mr. Graham writes me" regarding such and such species (Sutton 1938).

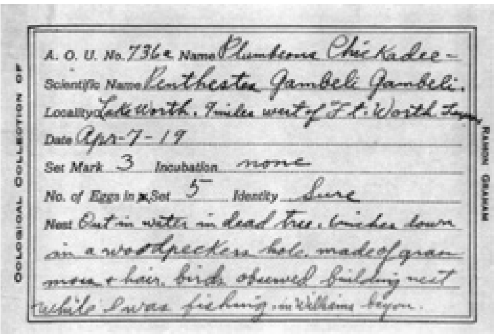
Figure 5. Ramon Graham from a photograph in the Fort Worth Star-Telegram, 8 February 1920.

Ramon Graham was an avid hunter and on a trip to Menard County numerous deer and turkeys were killed and the skins of eight armadillos made into baskets (Graham 1917). Graham was, however, cognizant of the need to protect birds. As early as 1919, he noted the decrease of several local species and advocated for a 10-year closed season for all water birds (Graham 1919b). He also strongly believed that vultures, hawks, owls, nighthawks, roadrunners and yellow-billed cuckoos should be protected. Furthermore, birds were to be killed only for food or in the interest of science (Graham 1920a). Collectors should not take more eggs or birds than needed and violators of this rule should not have their collecting permit renewed (Graham 1924). Graham was in favor of autos and good roads but was also of the opinion that autos were fast killing out the game birds and other animals of Texas (Graham 1922).

Figure 6. Photograph of the nest and eggs of a Blue Grosbeak taken by Ramon Graham at his camp on Lake Worth and published in The Oologist 37(9):106 [1920].

Graham (1913) collected eggs and prepared bird skins for exchange with other collectors. His specialty seems to have been the eggs of owls, hawks and vultures (Graham 1914). Skins of a Dickcissel and a Northern Mockingbird are in the James R. Slater Museum of Natural History (PSM). None of his taxidermy mounts have been located. However, fifteen egg sets collected by Graham in Tarrant County are at the Western Foundation for Vertebrate Zoology (WFVZ). The data cards for these eggs indicate that Graham exchanged eggs with individuals and organizations in distant parts of the United States who eventually donated them to the WFVZ. Donors for Graham's egg sets at the WFVZ include the well-known oologists Lyle D. Miller, Ed Harrison, Sidney B. Peyton, and Walter G. Goelitz. Organizations identified as donors of egg sets collected by Graham include the Academy of Natural Sciences of Philadelphia (ANSP), Oregon State University (OSU), Massachusetts Audubon Society (MAS), San Diego Natural History Museum (SDNHM), and Cumberland Science Museum (CSM). Seven sets of eggs collected by Graham are at the FMNH (#s 10900, 10920, 12443, 13803, 18977, 14232, 10288), six sets of eggs at Yale Peabody Museum (YPM) and one set, respectively, at Humboldt State University (HSU) and Chicago Academy of Sciences (CHAS). It is also worth noting that Graham was a member of the International Museum of Comparative Oology in Santa Barbara, California (Dawson 1924).

Ramon and Luella were both working as taxidermists in 1930 although the census of that year lists him as a brick layer, a skill that he probably learned from his father who was in construction work. During the next several years



OOLOGICAL COLLECTION OF

A. O. U. No. 736a Name Plumbeous Chickadee –
Scientific Name Penthestes Gambeli Gambeli.
Locality Lake Worth. 9 miles west of Ft. Worth Tex.
Date Apr-7-19
Set Mark 3 Incubation none
No. of Eggs in Set 5 Identity Sure
Nest Out in water in dead tree, 6 inches down in a woodpeckers hole. made of grass moss + hair. bird observed building nest while I was fishing in Williams bayou.

RAMON GRAHAM

Figure 7. Egg data card, Western Foundation of Vertebrate Zoology. Graham had a camp at Williams Spring near Lake Worth and many of his records are of birds observed or eggs collected in this locality. The “Plumbeous Chickadee” is today known as the Carolina Chickadee.

he collected various animals and, in the summer of 1939, launched the Tex-Mex Scientific Exposition or Graham’s Kiddie Circus as it was popularly called (North 1939). The variety of animals in Graham’s “kiddie circus” demonstrates that he was experienced in wildlife husbandry, and that he was a showman with a desire to educate children about the animals of the local area.

The exposition consisted of 68 miniature circus wagons, a trained armadillo, 100 snakes of various species, around 60 horned lizards, as well as every small animal found in Tarrant County and a cast of 26 children. The exposition played at several locations before the children went back to school. Plans were made to perform again during the following summer but this did not happen since the 1940 census lists Graham as a “brick manager,” a trade that he followed for the remainder of his work life.

Jacob Israel ‘Jake’ Zeitlin (1902-1989, Fig. 8), the son of Russian immigrants, was born in Wisconsin but his family moved to Fort Worth in 1905 (Chernofsky 1987). Zeitlin was eight years younger than Graham and, although the details of the relationship are unknown, Zeitlin perhaps worked as an assistant or accompanied Graham on collecting expeditions for the adventure of being outdoors. Together, Graham and Zeitlin co-authored a “List of Breeding Birds in Tarrant County” based on observations during the years 1915 to 1919 (Graham and Zeitlin 1921). Zeitlin and George Sutton corresponded after Sutton left Fort Worth as evidenced by a letter dated 28 January 1922 in which Zeitlin related the breeding of Northern Shovelers at Lake Worth (Sutton 1938, p. 174).

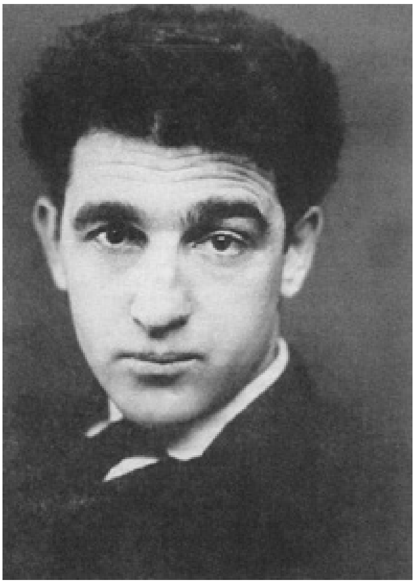


Figure 8. Jacob Israel ‘Jake’ Zeitlin as a young man. Zeitlin was described by Graham (1919b) as an “enthusiastic ornithologist.” Photograph from Ancestry.com

Jake Zeitlin became a legend in his later years. According to one account, he went to Austin, Texas, as a 14-year old hobo and spent the night in jail because he had no place to stay (Anon. 1961). Four years later, Zeitlin made a second trip to Austin where he met with William Green Sterrett, Texas Game, Fish and Oyster Commissioner, James William Neill, Director of the Division of Farmers’ Institutes and George Finlay Simmons, professor of zoology at the University of Texas, for discussions of the birdlife of Texas and its protection (Zeitlin 1920). Zeitlin soon became an advocate for conservation and, in later years, he and William Rounds, a local physician and naturalist, gave weekly lectures to Fort Worth civic groups promoting the protection of birds (Graham 1924). Zeitlin later served as director of the field study of birds at the annual meeting of the North Texas Biological Society held on Lake Worth in May 1925. The newspaper reporter covering the event described Zeitlin as a “poet and naturalist” (Benson 1925) whereas Zeitlin described himself as being a “Scientific Collector and Naturalist” (Barnes 1922). No record of specimens collected by Zeitlin has been found.

In 1925, Zeitlin moved from Fort Worth to Los Angeles, California, where he opened a store specializing in rare books and manuscripts. His influence in this field developed rapidly, and in the following years he became a significant force in the cultural and intellectual life of Southern California (Wikipedia). Zeitlin never again studied or wrote about birds but, in 1927, he published a book of poems, Whispers and Chants, the foreword of which was written by his friend and renowned poet, Carl Sandburg (Chernofsky 1987). He later authored a book on the writings of the British philosopher Aldous Huxley, as well as books and articles on a variety of subjects. Zeitlin's personal and business papers, 1920-1987, are archived in the Library Special Collections at the University of California at Los Angeles.

Charles Rogers McLendon (1896-1955) was a childhood friend of George Sutton. Years later, Sutton (1980, p. 39) recalled that McLendon had stirred his imagination with "glowing accounts of the ducks he had shot at Katy Lake." Sutton also named McLendon as the source regarding the occurrence of the Western Kingbird in Tarrant County (Sutton 1938, p. 188).

McLendon was an advocate of hunting, and he claimed that hawks were slaughtering the quail in Texas, and that they were the cause of the demise of quail rather than hunters, cats and boys with B-B guns (McLendon 1916). McLendon served with the Texas National Guard on the Rio Grande where he and George Maxon collected together (Maxon 1916). He was later sent to France where he served during World War I (Maxon 1918). Following his discharge, he worked as a newspaper reporter in Fort Worth and an assistant city editor in New York City. He later moved to San Diego California, but is buried in Ulster County, New York. Six sets of eggs collected by McLendon in Tarrant County are at the WFVZ.

Millard Hunter Chandler (1897-1955) was also a childhood friend to whom Sutton (1938, p. 182) credited collection of a Long-eared Owl in Tarrant County during the autumn of 1912. Chandler was working for McGee Rubber Company in Fort Worth at the time of his registration for World War I. He served as a pilot in France during the war, and in 1921 opened a radio and service shop in Fort Worth that he operated until his retirement. No articles written or specimens collected by Chandler have been found, and his relationship with Sutton seems to have been of a personal nature.

OTHER EARLY TARRANT COUNTY COLLECTORS

Earl Edwin Moffat, George Emmitt Maxon and Verlaine Daniel were friends of Ramon Graham. None of these men are known to have had a relationship with Sutton although they are cited in his 1938 paper on the birds of Tarrant County.

Earl Edwin Moffat (1894-1974) was from Marshall, Harrison County, Texas. How he began collecting with Ramon Graham is unknown. From 1915 through 1921, Moffat published 13 notes in The Oologist but only two of these papers dealt with birds in Tarrant County. The first of these papers reported the rare sighting on Lake Worth of an Osprey from the deck of Ramon Graham's sailboat (Moffat 1916a). The second paper was a humorous account of Moffat and Graham's collection of the eggs of a Barred Owl from a hollow in a partially submerged tree in Lake Worth (Moffat 1916b). A few eggs collected by Moffat in Tarrant and Harrison counties are now at the WFVZ, HSU, USNM and University of Michigan Museum of Zoology (UMMZ).

At the time of the 1920 census, Moffat was working as a railroad clerk. He later moved to California where he worked at various times as a grocer, custodian, painter and cabinet maker. In his later years, he returned to Marshall, Texas, where he is buried.

George Emmitt Maxon (1894-1957, Fig. 9) was perhaps Graham's earliest egg-collecting companion. Both were about the same age and had probably known one another since childhood (Casto and Burke 2009). They were particularly active during spring 1915, publishing their observations on the first eggs of the season in Texas (Graham and Maxon 1915).

Maxon served in the Texas National Guard from 1911 until June 1918 before enlisting in the 90th Infantry Division and being deployed to France. Following his discharge in 1919, he returned to Fort Worth where he worked as a Deputy United States Game Warden at Lake Worth and again began to collect with Ramon Graham. Maxon's experiences as a game warden apparently changed his outlook on the practice of oology and, in following years, he spoke against the indiscriminate collecting of eggs. His dedication to conservation is also shown by his service as president of the Fort Worth Chapter of the Izaak Walton League from 1925 until 1927. Maxon is also known to have invented the "swimming mouse" bass lure (Sorrells 2021). He continued to operate his flower shop in Fort Worth until around 1927 when he moved to Vernon, Wilbarger County, Texas, at the invitation of Robert Lee More, to run a plant nursery (Casto and Burke 2009).

Figure 9. George Maxon and his wife, Florence, taken at Maxon's camp on Lake Worth while he was serving as a United States Deputy Game Warden. The man in the car is believed to be Florence's uncle, Earnest Elmer Pearce. Photograph posted by Kerrlita Westrick on Ancestry.com.

Maxon collected with R. L. More after moving to Vernon and most of his eggs were later incorporated into More's collection (Casto and Burke 2009). Between 1916 and 1922, Maxon published 13 articles in The Oologist, three of which are cited by Sutton (1938) as pertaining to the birds of Tarrant County. Small numbers of egg sets collected by Maxon are found in the Museum of Vertebrate Zoology (MVZ), University of Washington Burke Museum (UWBM), Texas A&M University Biodiversity, Research and Teaching Collections (TCWC), WFVZ, HSU, and YPM. Maxon is also acknowledged by John Kern Strecker of Baylor University for observations on the amphibians and reptiles of Tarrant and Wilbarger counties (Strecker 1929).

Verlaine Daniel (1893-1955, Fig. 10), son of James Buchanan Daniel, was born in Memphis, Hall County, Texas, but by 1901 the family was living in Fort Worth where James worked in real estate. Little is known of Verlaine's early life other than that he attended college for three years and that he worked in the meat-packing industry for Swift & Company and later as a salesman for Wilson and Company (Anon. 1955a,b). His two short notes published in The Oologist were based on observations made at Ramon Graham's Camp on Lake Worth (Daniels 1921, 1926). A set of Black Vulture eggs taken on 18 April 1920 is at the University of Kansas Biodiversity Institute (KU) and a second set of this same species taken on 15 April 1934 is at the WFVZ. Verlaine's name is often misspelled in the literature as "Verlain Daniels."

Figure 10. Verlaine Daniel. Photograph from the Fort Worth Star-Telegram, 20 July 1955, p. 9.

Two other collectors from Fort Worth – Rufus Lackland and Woodruff Yeates – are not cited in Sutton's 1938 paper on the birds of Tarrant County. They are, however, mentioned in articles written by Ramon Graham.

Rufus Jefferson Lackland, Jr. (1896-1960) was born in Waxahachie, Texas, and his family moved to Fort Worth when he was a child. Graham (1919a) mentions him as a fellow collector serving as a soldier in France. Lackland was working as a bookkeeper at the time of the 1920 census. He later obtained a law degree from the University of Texas and by 1930 was working in the office of the district attorney in Fort Worth. In his later years, Lackland worked as a lawyer for Gulf Oil Corporation in Houston. No record has been found of eggs collected or publications by Lackland.

Elijah Woodruff Yeates, Jr. (1894-1987) was born in Mansfield, Tarrant County, Texas, but his family moved to Fort Worth when he was a young child. His earliest records are of eggs collected in 1911.

Yeates (1914) advertised that he had eggs of Turkey and Black Vultures, Barn and Screech Owls and Red-tailed Hawk for exchange. Some of the vulture eggs were probably collected by Graham and Yeates during a joint outing to a nesting area about 20 miles from Fort Worth (Graham 1912). Yeates was also credited with having collected an unusually large set of 10 eggs of a Greater Roadrunner (Graham 1915).

Yeates joined the army during World War I and attended officer's training school (Graham 1919a). Following his discharge, he returned to Fort Worth where he worked as a foreman in a packing house and continued to collect eggs until at least 1924. Yeates was living in San Francisco, California, when he applied in 1925 for membership in the Cooper Ornithological Club (Grinnell and Ellis 1925). In later years, he worked as a secretary in a brokerage house and later as an executive in the lumber and door industry.

Around 40 of Yeates' egg sets from Tarrant County and 13 from Amarillo, Potter County, are found in the TCWC at Texas A&M University. Two sets are at the WFVZ and one set at the Carnegie Museum of Natural History (CM). A set of Pyrrhuloxia eggs (Fig. 11) collected by Yeates had three different owners before being acquired by the WFVZ. No record has been found that Yeates published any of his collection data.

Figure 11. Pyrrhuloxia eggs collected in Tarrant County by Woodruff Yeates on 28 June 1916. These eggs were exchanged or sold to Earnest H. Short of Rochester, NY, before being passed to W. A. Strong in San Jose, CA, and eventually to Pomona College in Claremont, CA, before being acquired in 1970 by the WFVZ (EN-86622).

John Bigger Litsey, Jr. (1894-1964) was a contemporary of George Sutton, Ramon Graham and George Maxon but there is no evidence that they knew one another or that they collected together. Litsey published notes on the nesting of the Scissor-tailed Flycatcher and the occurrence of the Townsend Solitaire in Tarrant County (Litsey 1911, 1918). Nine sets of eggs collected by Litsey in Tarrant County during 1910-1911 are at the Oklahoma Museum of Natural History (OMNH), four sets at the WFZV, three sets at the FMNH (#s, 10228, 10229, 19230) and two sets at the YPM. Litsey also exchanged eggs with Ralph Handsaker of Zearing, Iowa (Henderson 2007).

In 1911, at the age of 17, Litsey became an active member of the Cooper Ornithological Club. Advertisements in The Condor for 1918 indicate that he wanted skins of Pectoral, Least and Semipalmated Sandpipers in winter plumage for which he offered choice sets of eggs in exchange. Litsey later moved to Dallas where, at the time of the 1930 census, he was working as a curator at the zoo. Litsey was active as a field observer and a contributor to the checklist of the birds of Dallas County (Stillwell 1939). His report of Starlings in Dallas County during the winter of 1930-1931 represents the first record of this species for northcentral Texas. Litsey also collected fossils. Twenty specimens of fossil invertebrates collected by Litsey in the vicinity of Fort Worth are in the Museum of Comparative Zoology at Harvard (MCZ Database).

LEGACY OF THE EARLY TARRANT COUNTY COLLECTORS AND NATURALISTS

Neither George Sutton, Ramon Graham, George Maxon nor any of the other early collectors, other than E. A. Mearns and the agents working for the Biological Survey, had any formal training in ornithology or the natural sciences. All of the post-1900 collectors belonged to the same age cohort having been born between 1893 and 1898. Although Sutton lived in Fort Worth for only a brief period of time, it was through his later work as a professional ornithologist that the observations of earlier collectors was passed to Warren M. Pulich, Sr. (1919-2010) and incorporated into his book Birds of Tarrant County (Pulich 1979).

Ramon Graham published all of his records in The Oologist which went out of business in 1941. Very few libraries subscribed to the journal thus ensuring that later investigators would have only limited access to copies. Harry Oberholser, however, kept an annotated and chronological list of all articles published in The Oologist and other early journals that mentioned the birds of Texas. However, the detailed bibliography of Oberholser's typescript of The Bird Life of Texas was edited before publication and most of the articles by Graham and George Maxon were deleted. Fortunately, the early issues of The Oologist have been scanned and are available at the Hathi Trust Digital Library. Just as important, the records of specimens collected by Graham and the other collectors noted in this study are accessible on VertNet.

The collection of birds' eggs was viewed by many ornithologists as having little or no scientific value. Collectors were often referred to as "nest robbers" and accused of adversely affecting bird populations. Ramon Graham, Jake Zeitlin and George Maxon responded to this criticism by recommending that no more eggs should be taken than necessary and that most species of birds should be protected. Graham (1920a) was particularly adamant that vultures were a beneficial species and not carriers of anthrax as was believed by many cattlemen during the early 1900s (Casto 1988).

While living at Fort Worth, George Sutton collected 17 sets of eggs that are now at the Carnegie Museum. It is likely that Sutton learned the techniques of drilling and blowing eggs from Ramon Graham. Sutton later denounced the practice of "egg-hoarding" and "egg-exchanging" while advancing the viewpoint that "sincere ornithologists want living birds to see and study, not stuffed skins and egg shells" (Sutton 1939). Sutton was, however, a member of the International Museum of Comparative Oology (Dawson 1924), and the Delaware Museum of Natural History (DMNH) contains the skins of 86 birds collected in Texas by Sutton between the years 1935 and 1956.

Two features of Ramon Graham's work are significant. He believed in sharing his observations, and he did so by publishing them in The Oologist which was read not only by amateur collectors but also by many serious ornithologists. Secondly, as a bird census taker for the Bureau of the Biological Survey, he recognized the value of enumerating the numbers of breeding birds in a particular area as a factor in judging the effectiveness of state and federal laws designed to protect them. The bird census began in 1914 (Anon. 1914, Nelson 1915), and it is likely that Graham began submitting observations soon thereafter. In 1919, he was the director of the bird census for Fort Worth (Anon. 1919). His reports and those of other census takers are most likely archived with the Bureau of Biological Survey but they were not consulted for this study.

The early collectors in Tarrant County left not only a written record of their field observations but also a physical legacy in the many sets of eggs and study skins that are now in museums throughout the United States. These physical remains, most of which are over 100 years old, are not just relics of a bygone age but objects for further research made possible by advances in chemistry and other scientific disciplines. The potential use of museum specimens in research was clearly recognized by Ramon Graham who claimed to have killed only a few birds whose skins he prepared for future study so that they would be of "some benefit" to the world (Graham 1919b). The estimated five million birds' eggs in museums throughout the world, of which those taken in Tarrant County are a minor component, are now considered to be an "invaluable and underused resource" (Marini, et al. 2020).

The individuals who contributed to the early development of ornithology in Tarrant County have been largely forgotten. The list of Texas collectors compiled by Oberholser (1974) does not include the names of George Sutton, Ramon Graham, George Maxon, Earl Moffat or John Litsey even though specimens collected by them are found in major museums. In contrast, Woodruff Yeates (misspelled as Yates) and Jake Zeitlin are included in Oberholser's list even though no record has been found of specimens taken by Zeitlin. It is, however, worthy of note that Rylander (1962) cited the publications of Graham, Zeitlin, Maxon, Moffat and Daniel in his thesis on the bird life of adjacent Denton County, Texas.

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Appendix 1. Articles that mention Texas birds published in The Oologist by Ramon and Louella Dunn Graham.

Ramon Graham was a strong supporter of The Oologist. The editor of the journal, Richard Magoon Barnes, suggested in 1915 that subscribers purchase extra copies to send to their friends as a Christmas present or to encourage them in the study of birds. It was later reported that Ramon Graham of Fort Worth, Texas, was the leader in this effort (Barnes 1915).

The articles listed below were taken from H. C. Oberholser's chronological bibliography of Texas birds found in the typescript of The Bird Life of Texas at the Briscoe Center for American History, University of Texas at Austin. Copies of The Oologist in which these articles were published can be viewed at the website of the Hathi Trust Digital Library. Graham also published several articles in The Oologist that did not mention birds and are, therefore, not included in the following list.

1912. The Black and Turkey Vulture. Oologist 29(3):334.

1914. Hints on hawk, owl, and vulture. Oologist 31(2):30-31; First sets taken of this season, 31(7):138-139.

1915. North Texas bird notes. Oologist 32(6):102-103; A White-eyed Vireo's misfortune, 32(6):104; (with George Emmett Maxon), First eggs of the season in Texas, 32(7):118; A freak set of cardinals, 32(9):153; Roadrunner, 32(11):182; Birds that nest in Tarrant Co., Texas, and notes, 32(4):191; Belted Kingfisher, 32(11):191; The accidental finds of Cassin's sparrows, 32(11):191-192; Texas bobwhite, 32(11):192; How did this Turkey Vulture live?, 32(11):192; Mourning Dove notes, 32(12):211.

1916. A Krider's Hawk trick, 33(2):31-32; The Scissor-tailed Flycatcher, 33(2):33-34, Notes [Fort Worth, Texas], 33(2):34; Painted Bunting, 33(4):76; Nesting dates of Texas birds, 33(4):81-82; Notes from Camp Graham at Lake Worth, nine miles northwest of Fort Worth, Texas, 33(7):137-139; Texas bird notes, 33(10):170-171; Carolina Rail accidently killed, 33(11):187-188; Vulture conditions in North Texas, 33(11):187-188; The water bound chickadee, 33(11):189.

1917. Fishing for Barn Owls in Lake Worth, 34(1):18; Mockingbird and green snake, 34(33; Tufted Titmouse found at night, 34(3):58; Plumbeous Chickadees are not afraid, 34(5):84; Horned Owls not collected, 34(5):90; Eagles, 34(5):94; The belled buzzard, 34(6):111; Notes from Camp Graham, Fort Worth, Texas, 34(11):187-189.

1918. Ducks and other water birds of Lake Worth, Texas, 35(2):29-30; Notes, 35(10):140-141.

1919. Fall migration, 36(4):69; Ducks are scarce this year, 36(5):88-89; Notes from Camp Graham, 36(5):89-90; Bird note from Lake Worth, Tarrant Co., Texas, 36(6):97; The Plumbeous Chickadee, 36(6):127-128; My first find of Blue Grosbeaks, 36(8):133; Tarrant County, Texas breeders, 36(10):187-188; Bird notes, 36(10):188; Birds observed from train, from Austin, Texas, to Burnet, Texas, 36(11):196; The curiosity of the wood ducks, 36(11):202; Texas bird notes, 36(11):203; Humming bird joke, 36(11):206.

1920. A beautiful sight, 37(1):5-6; Texas migration notes, 37(3):34; “Spring’s awakening”, 37(3):36-37; Vulture times, 37(6):68; Bird travel notes, 37(11):129; Texas ducks migration notes, No. 1, 37(11):130-131; Texas bird migration notes, No. 3, 37(11):131.

1921. Texas notes, 38(4):41-42; Corpus Christi Bay bird life, 38(4):46-47; List of the breeding birds of Tarrant County, Texas (with Jake Zeitlin), 38 (7):93; Texas duck migration notes, No. 2, 38(10):133; “Sense or Instinct”, 38(10):135; Texas notes for 1921, 38(12):176-177; The road runner’s curiosity, 38(10):135.

1922. The Blue Grosbeak in Tarrant County, Texas, 39(2):25-27; Eagle tricks [Young County], 39(3):43; What the auto kills, 39(3):46; Eagle and fox terrier, 39(5):80; Note book notes, 39(5):83; An Easter egg hunt, 39(6):89-90; Backyard birds [San Antonio, TX], 39(7):109-110; Glossy Ibis observed and killed near Fort Worth, Texas, 39(7):110; Many pelicans killed and wounded [Erath County], 39(10):149; Texas bird notes 1922, 39(11);158; Canada Goose migration, 39(11):167; Carolina Wren building material, 39(12):175-176.

1923. Just as the sun went down, 40(2):34-35; Plumbeous Chickadee, 40(4):58; Timing a screech owl, 40(5):79; Will woodpeckers flush by pounding tree?, 40(6):110; The meeting tree, 40(6):111; A tree of mystery, 40(9):150-151.

1924. Nature studies, 41(7):88; A 1909 wonder, 41(7):89; The armadillo and wild turkey, 41(7):90; A plea for bird protection, 41(7):151-152; A hunt in Texas, 41(8):104-106.

1926. Indian Creek, Texas [Kerr County], 43(3):92; Texas bird notes, 43(8):116; In camp near San Antonio, 43(10):140.

1927. Texas trails – Gentry Creek [near Handley, TX], 44(8):102-103.

1928. Walnut Creek trails, Kimble County, Texas, 45(8):116-120.

1929. A Texas general mixture, 46(4):57; Texas trails [Devil’s River], 46(6):76.

Articles by Mrs. Ramon (Louella Dunn) Graham

1921. The road runner’s curiosity, 38(10):135.

1922. A devoted father, 39(11):155.

1925. Back yard bird notes [Handley, TX] 42(2):27.

1925. Bird notes taken while butterfly chasing [Arlington, TX], 42(6):94.

1931. An Easter day walk in Fort Worth neighborhood, 48(4):53-54; Chimney Swift breeding in Fort Worth, Texas, 48(11):157-158.

1932. Nature observations at Lake Worth, Fort Worth, Texas, 49(7):74-77.

1937. Woodcock killed in Texas, 54(2):53.

TEXAS BIRD RECORDS COMMITTEE REPORT FOR 2021

Eric Carpenter[1]

674 Goodnight Trail, Dripping Springs, Texas 78620

The Texas Bird Records Committee (hereafter "TBRC" or "committee") of the Texas Ornithological Society requests and reviews documentation on any record of a TBRC Review List species (see TBRC web page at http://www.texasbirdrecordscommittee.org). Annual reports of the committee's activities have appeared in the Bulletin of the Texas Ornithological Society since 1984. For more information about the Texas Ornithological Society or the TBRC, please visit www.texasbirds.org. The committee reached a final decision on 156 records during 2021: 143 records of 48 species were accepted and 13 records of 12 species were not accepted, an acceptance rate of 91.7% for this report. A total of 259 observers submitted documentation (to the TBRC or to other entities) that was reviewed by the committee during 2021.

The TBRC accepted 2 first state records in 2021: Limpkin and Steller's Sea-Eagle. These two additions bring the official Texas State List to 657 species in good standing. This total does not include the 5 species on the Presumptive Species List, nor the 2 species on the Supplemental List.

In addition to the review of previously undocumented species, any committee member may request that a record of any species be reviewed. The committee requests written descriptions as well as photographs, video, and audio recordings if available. Information concerning a Review List species may be submitted to the committee secretary, Eric Carpenter, 674 Goodnight Trail, Dripping Springs, Texas 78620 (email: ecarpe@gmail.com). Guidelines for preparing rare bird documentation can be found in Dittmann and Lasley (1992) How To Document Rare Birds. Online submission forms can be found at https://www.texasbirdrecordscommittee.org/home/forms.

The records in this report are arranged taxonomically following the AOS Check-list of North American Birds (AOU 1998) through the 62nd supplement (Chesser et al. 2021). A number in parentheses after the species name represents the total number of accepted records in Texas for that species at the end of 2021. Species added to the Review List because of population declines or dwindling occurrence in recent years do not have the total number of accepted records denoted as there are many documented records that were not subjected to review (e.g. Brown Jay, Pinyon Jay, Tamaulipas Crow, and Evening Grosbeak). All observers who submitted written documentation or photographs/recordings of accepted records are acknowledged by initials. If known, the initials of those who discovered a particular bird are in boldface but only if the discoverer(s) submitted supporting documentation. The TBRC file number of each accepted record will follow the observers' initials. If photographs or video recordings are on file with the TBRC, the Texas Photo Record File (TPRF) (Texas A&M University) number is also given. Specimen records are denoted with an asterisk (*) followed by the institution where the specimen is housed and the catalog number. The information in each account is usually based on the information provided in the original submitted documentation; however, in some cases this information has been supplemented with a full range of dates the bird was present if that information was made available to the TBRC. All locations in italics are counties. Please note that the county designations of offshore records are used only as a reference to the nearest point of land.

TBRC Membership -- Members of the TBRC during 2021 who participated in decisions listed in this report were: Tony Frank, Chair; Keith Arnold, Academician; Eric Carpenter, (non-voting) Secretary; Sheridan Coffey, Greg Cook, Mel Cooksey, Steve Glover, Mary Gustafson, Dan Jones, Stephan Lorenz, Arman Moreno, Chris Runk, and Willie Sekula.

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Additional Abbreviations – AOS = American Ornithologists' Society; AOU = American Ornithologists' Union; BBNP = Big Bend National Park; GMNP - Guadalupe Mountains National Park; NP = National Park; NWR = National Wildlife Refuge; SHS = State Historic Site; SNA = State Natural Area; SP = State Park; WMA = Wildlife Management Area.

ACCEPTED RECORDS

Garganey (Spatula querquedula) (7). One at Village Creek Drying Beds, Arlington, Tarrant on 12 November 2020 (**KN**; 2021-15; TPRF 3885). One at Sabal Palm Sanctuary, Cameron on 3 April 2021 (**CD, ER**, BM; 2021-39; TPRF 3839).

Eurasian Wigeon (Mareca penelope) (62). One at Balmorhea Lake, Reeves on 26 December 2020 - 5 January 2021 (**JM**, EA; 2021-23; TPRF 3807). One at Lubbock, Lubbock on 3 January - 15 February 2021 (**PK**, JC, JeM, ML, JoM, JB, PeK, EC, GK; 2021-01; TPRF 3828). One at Waco Wastewater Treatment ponds, McLennan on 5-9 March 2021 (**FR**, EW, EC, TF; 2021-30; TPRF 3838).

Red-necked Grebe (Podiceps grisegena) (32). One at Lake Tawakoni, Hunt on 7 February 2021 (**RS**; 2021-32; TPRF 3822).

Ruddy Ground Dove (Columbina talpacoti) (30). One at Bentsen-Rio Grande Valley SP, Hidalgo on 15 November 2020 - 5 February 2021 (BM, JH, JB, EC, DA, JoM, FrR; 2020-106; TPRF 3825). One to two at El Paso, El Paso on 21 November - 16 December 2020 (**BZ**; 2020-117; TPRF 3790). Two at west El Paso, El Paso on 29 November 2020 - 10 May 2021 (**JP**, JG; 2020-123; TPRF 3857). One at Davis Mtns. SP, Jeff Davis on 4 December 2020 - 7 January 2021 (**TM**, KZ, CO; 2020-150; TPRF 3803). One at Lajitas, Brewster on 12-13 December 2020 (**SF**, BS; 2020-145; TPRF 3798). One north of Three Rivers, Live Oak on 18-22 December 2020 (**WS**, JF; 2020-134). One at El Paso, El Paso on 3-18 March 2021 (**BZ**; 2021-36; TPRF 3837).

Mexican Violetear (Colibri thalassinus) (98). One southeast of Calaveras Lake, Bexar on 22-24 May 2021 (**LM**; 2021-58; TPRF 3880). One northeast of Leakey, Real on 17-18 June 2021 (**MW, PW**, TG; 2021-80; TPRF 3883). One at Boerne, Kendall on 24-25 June 2021 (DP; 2021-74; TPRF 3896). One at Mission, Hidalgo on 18 July 2021 (JoM; 2021-84; TPRF 3900).

Green-breasted Mango (Anthracothorax prevostii) (25). One at Calallen, Nueces on 6-16 July 2021 (JoM, RP, JH, MT; 2021-78; TPRF 3897).

Costa's Hummingbird (Calypte costae) (48). One at Alpine, Brewster on 5 September - 13 October 2020 (**TZ**, DS, PS, CO, LS; 2020-85; TPRF 3768). One at west El Paso, El Paso on 27-28 March 2021 (JG, JK; 2021-70; TPRF 3868).

Violet-crowned Hummingbird (Leucolia violiceps) (27). One at San Angelo, Tom Green on 14 November 2020 (**CL**; 2020-143; TPRF 3785).

Spotted Rail (Pardirallus maculatus) (3). One at Calliham Unit, Choke Canyon SP, McMullen on 19 December 2020 - 23 January 2021 (**MB, DB**, JoM, JR, CG, DS, EC, EW, RP, JaP, ToF, PF, PG, PI, SL, KY, JS; 2020-136; TPRF 3806).

Limpkin (Aramus guarauna) (7). Up to five at Brazos Bend SP and vicinity, Fort Bend on 6 May+, birds still present as of 31 Dec 2021 (**ChG**, JoM, MC, RP, EC, DeS, EW, JH, NB, LT, RR, HJ, JoB, AM, JL; 2021-53; TPRF 3886). One at Sherman, Grayson on 3-4 June 2021 (**DM, JMc**; 2021-62; TPRF 3887). One at Garner, Parker on 4-5 June 2021 (**JuH**; 2021-61; TPRF 3888). One near Shoveler Pond, Anahuac NWR, Chambers on 9 July - 23 August 2021 (**TiF**, RM; 2021-86; TPRF 3890). At least four at Sheldon Lake, Harris on 17 July+, birds still present as of 31 Dec 2021 (**TR**, DD, LeS, PM, SR, CTL, KB, OJ, PI; 2021-100; TPRF 3891). One west of Sugar Land, Fort Bend on 19 August 2021 (**CCP**; 2021-91; TPRF 3892). One at Champion Lake, Trinity River NWR, Liberty on 28 August 2021 (CP; 2021-94; TPRF 3893). These seven records represents the first seven documented records for Texas.

Purple Sandpiper (Calidris maritima) (29). One at Bolivar Flats, Galveston on 11 December 2020 (**ClL**; 2020-142). One at Surfside Jetty, Brazoria on 14 December 2020 (**JF**; 2020-140).

Red Phalarope (Phalaropus fulicarius) (52). One at Rio Bosque Wetlands Park/Jonathon Rogers Wastewater Treatment ponds, El Paso on 7-8 November 2020 (**PH**, JG, JS; 2020-101; TPRF 3783).

Heermann's Gull (Larus heermanni) (6). One at Lake Kirby, Taylor on 21-22 November 2020 (**JaC**; 2020-115; TPRF 3791).

Short-billed Gull (Larus brachyrhynchus) (46). One at Benbrook Lake/Lake Arlington, Tarrant on 25 November 2020 - 1 January 2021 (**JA**, EW, BC, KY, CA, TF, GC, PC; 2020-118; TPRF 3826). One at Abilene, Taylor on 3 January 2021 (**JaP**; 2021-10; TPRF 3801).

Great Black-backed Gull (Larus marinus) (64). One at Lewisville, Denton on 14-23 December 2020 (**CW**, BrS, EW, DoS, KY, JaS; 2020-126; TPRF 3817). One at San Luis Pass, Galveston on 23 March - 5 April 2021 (**AS**, JoM, DC; 2021-40; TPRF 3875).

Elegant Tern (Thalasseus elegans) (11). One at Bolivar Ferry landing, Galveston on 15 April 2021 (**EC**; 2021-54; TPRF 3871). One at Magnolia Beach, Calhoun on 10 July 2021 (**JMa**; 2021-85; TPRF 3898).

Yellow-billed Loon (Gavia adamsii) (8). One at Balmorhea Lake, Reeves on 28 October - 5 November 2020 (**SF**, RP, DS, PS, EC, JS; 2020-97; TPRF 3775). One at Ascarate Lake, El Paso, El Paso on 8-18 May 2021 (JG, JoM; 2021-55; TPRF 3878).

Great Shearwater (Ardenna gravis) (31). One ~21 miles southeast of Port Aransas, Nueces on 13 December 2020 (**JoM**; 2020-125; TPRF 3804). One near Surfside Jetties, Brazoria on 14 July 2021 (**JSt**; 2021-83; TPRF 3899). One near Galveston Jetties, Galveston on 19 July 2021 (**SC**; 2021-89; TPRF 3901).

Red-footed Booby (Sula sula) (7). One at Padre Is. Nat'l Seashore, Kleberg on 18 February 2021 (**JoM**; 2021-16; TPRF 3823).

Steller's Sea-Eagle (Haliaeetus pelagicus) (1). One at Coleto Creek Reservoir, Victoria on 7 March 2021 (**KG, SaR**; 2021-33; TPRF 3894). This represents the first documented record for Texas.

Short-tailed Hawk (Buteo brachyurus) (62). One at Estero Llano Grande SP, Hidalgo on 24 April 2021 (**DSm**; 2021-50; TPRF 3872).

Northern Saw-whet Owl (Aegolius acadicus) (36). One at Forney, Kaufman on 20-21 December 2020 (**BL, JeL**, TH; 2021-35; TPRF 3818). One west of Fort Davis, Jeff Davis on 19 May 2021 (**RP, BeM**; 2021-59).

Elegant Trogon (Trogon elegans) (8). One at Estero Llano Grande SP, Hidalgo on 23 November 2020 - 5 May 2021 (**TH, MH**, GC, DJ, WS, SK, JoM, DR, RP, PV; 2020-127; TPRF 3856).

Rose-throated Becard (Pachyramphus aglaiae) (81). One at Falfurrias, Brooks on 20 November 2020 - 30 January 2021 (**WS**, ShC, EC, IS, TZ; 2020-113; TPRF 3816). One at Santa Ana NWR, Hidalgo on 22 November 2020 (**GB**; 2020-116; TPRF 3792). One at Salineno, Starr on 28 November 2020 - 13 February 2021 (**GC**, StL, JaH, WB; 2020-133; TPRF 3845). One at Sabal Palm Sanctuary, Cameron on 15-31 January 2021 (**KR**, ME, BSh; 2021-12; TPRF 3820). One at Quinta Mazatlan SP, Hidalgo on 26 January - 9 March 2021 (JeF, MBS, KR, DaP; 2021-71; TPRF 3863). One at Resaca de la Palma SP, Cameron on 26-27 February 2021 (**BM**, ME; 2021-27; TPRF 3824). One at Santa Ana NWR, Hidalgo on 24-26 March 2021 (**ST**; 2021-34; TPRF 3867). One at Mission, Hidalgo on 22 May 2021 (**PR**, MG; 2021-60; TPRF 3881).

"Lawrence's" Dusky-capped Flycatcher (Myiarchus tuberculifer [lawrenceii group]) (30). One at Estero Llano Grande SP, Hidalgo on 12 November 2020 - 9 February 2021 (**HH**, BF, TJA, GC, MBS, RD; 2020-146; TPRF 3840). One at National Butterfly Center near Mission, Hidalgo on 16 November 2020 - 7 February 2021 (**TiF**, LF, MG; 2020-157; TPRF 3841). One at Quinta Mazatlan SP, Hidalgo on 27 November 2020 - 16 March 2021 (**NA**, DJ, RT, JoM, EC, PR, TK; 2020-147; TPRF 3843). At least one at Bentsen-Rio Grande Valley SP, Hidalgo on 29 November 2020 - 17 February 2021 (**KrB**, DaM, DJ, AB; 2020-120; TPRF 3847). One at Santa Ana NWR, Hidalgo on 3 December 2020 - 9 March 2021 (**StL**, KM, DaB, SK; 2020-131; TPRF 3848). One at McAllen Nature Center, Hidalgo on 10 December 2020 - 15 January 2021 (**MM**, NK, RyR; 2020-148; TPRF 3851). One at Resaca de la Palma SP, Cameron on 16 December 2020 - 16 March 2021 (**RG**, AO, JoM, EG, BE; 2020-149; TPRF 3852). One at San Juan Wetlands, Hidalgo on 4 January 2021 (**JuC**; 2021-76; TPRF 3861).

Gray Kingbird (Tyrannus dominicensis) (17). One at South Padre Is., Cameron on 20-23 May 2021 (ME, JoM, JaG; 2021-56; TPRF 3879).

Fork-tailed Flycatcher (Tyrannus savana) (52). Three south of Arroyo City, Cameron on 5 February 2019 (**JB**; 2021-09; TPRF 3779). One ~2 miles west of Santa Ana NWR, Hidalgo on 9 November 2019 (**MaB**; 2020-102; TPRF 3767). One at Eagle Lake, Colorado on 4 November 2020 (**SM**; 2020-109; TPRF 3777). One ~5 miles southwest of Edna, Jackson on 11-12 November 2020 (**BF**, RW; 2020-104; TPRF 3784). One at Texas City, Galveston on 29 December 2020 - 19 January 2021 (**NG**, KOH, ToF, JoM; 2020-155; TPRF 3809).

Greater Pewee (Contopus pertinax) (36). One at Boot Canyon, BBNP, Brewster on 11 June 2021 (**JiC**; 2021-79; TPRF 3889).

Pacific-slope Flycatcher (Empidonax difficilis) (12). One to two at Southside Lions Park, San Antonio, Bexar on 16 October 2020 - 9 January 2021 (**BW**, ShC, MR, AC, ED, DeM; 2020-114; TPRF 3855). One to two at Falls City, Karnes on 8 November 2020 - 1 January 2021 (**WS**, ShC, MR, JT, DA; 2020-103; TPRF 3814). One at Goliad, Goliad on 14-25 November 2020 (**WS**, EC, GP, JaB; 2020-108; TPRF 3815). One at Quinta Mazatlan SP, Hidalgo on 28 November 2020 - 13 February 2021 (**TM**, JiH, JB, BiS, DJ, JoM, DJ, KA, LL; 2020-156; TPRF 3846). One at Santa Ana NWR, Hidalgo on 3 December 2020 - 17 January 2021 (**StL**, PeH, PaV, DaM, RyR; 2020-139; TPRF 3849). One at Daniel's Ranch, Rio Grande Village, Brewster on 8 December 2020 (**EC**; 2020-128; TPRF 3797). One in west Houston, Harris on 8-21 December 2020 (**DiS**, CTL, AW; 2021-72; TPRF 3858). One northeast of Sargent, Matagorda on 18 December 2020 (**MaH, SH, BF**; 2021-20; TPRF 3805). One at Bentsen-Rio Grande Valley SP, Hidalgo on 19 December 2020 (**PeH**; 2020-138). One at Brazos Bend SP, Fort Bend on 19 December 2020 - 4 January 2021 (**MS**, JBe, BiS, GH; 2020-135; TPRF 3859). Two to three near Eagles Nest Lake, Brazoria on 2 January - 13 February 2021 (**RoS**, RW, RoM; 2021-73; TPRF 3860).

Black-whiskered Vireo (Vireo altiloquus) (47). One near Jamaica Beach, Galveston on 5 May 2021 (**GM**; 2021-66; TPRF 3874). One at South Padre Is., Cameron on 5-7 May 2021 (JoM, AgS, EA, CJ; 2021-51; TPRF 3877).

Pinyon Jay (Gymnorhinus cyanocephalus) (5). One at Thompson Grove, Rita Blanca National Grasslands, Dallam on 4 October 2020 (**JB**; 2020-96; TPRF 3769). One 10 miles southeast of Alpine, Brewster on 5-9 November 2020 (**JoS**, SF, JS; 2020-100; TPRF 3782).

Clark's Nutcracker (Nucifraga columbiana) (26). One at Alpine, Brewster on 29 November - 6 December 2020 (**BoS**, PS, DS, RP, CO; 2020-121; TPRF 3793).

Tamaulipas Crow (Corvus imparatus) (21). Up to nine at Brownsville Landfill, Cameron on 12 April - 19 June 2021 (**BB**, DR, JoM, TrG, BeF, TH, MBS, JD; 2021-45; TPRF 3895).

American Dipper (Cinclus mexicanus) (10). One at McKittrick Canyon, Culberson on 7-9 February 2021 (**MiH**, StL; 2021-14; TPRF 3830).

Rufous-backed Robin (Turdus rufopalliatus) (28). One at Mountain View Park, El Paso, El Paso on 31 December 2020 - 19 January 2021 (**BZ**, JoM, TJ; 2021-02; TPRF 3810).

Varied Thrush (Ixoreus naevius) (52). One at Surfside, Brazoria on 13-29 October 2020 (**QT**, ToF, DS, RP, AN; 2020-87; TPRF 3772).

Evening Grosbeak (Coccothraustes vespertinus) (31). One at Dalhart, Hartley/Dallam on 19 October 2020 (**CW**; 2020-91; TPRF 3774). One ~15 miles south of Robert Lee, Coke on 14 November 2020 (**DW**; 2020-110; TPRF 3787). One at Pine Springs, GMNP, Culberson on 17-21 November 2020 (**MiG**, MHa; 2020-112; TPRF 3788). One at White River Lake, Crosby on 2 January 2021 (**PK**; 2021-11; TPRF 3811). One at Plainview, Hale on 16-18 February 2021 (**MO**, NP; 2021-41; TPRF 3832). Up to eighteen at Palo Duro Canyon SP, Randall on 26 February - 18 March 2021 (**RB**, DSm, JoM, EC, MP; 2021-28; TPRF 3835). One at White River Lake, Crosby on 1-8 April 2021 (**ML**; 2021-38; TPRF 3870).

Lawrence's Goldfinch (Spinus lawrencei) (22). One at Franklin Mtns. SP, El Paso on 22-26 October 2020 (**ElD**, JG, ElW, JK; 2020-92; TPRF 3781). One ~20 miles south of Van Horn, Culberson on 14 November 2020 (**BD**; 2020-111; TPRF 3786).

(Slate-colored) Fox Sparrow (Passerella iliaca [schistacea Group]) (6). One at El Paso, El Paso on 7-9 October 2020 (**JK**, JG; 2020-90; TPRF 3770). One west of Fort Davis, Jeff Davis on 8-9 October 2020 (**LoL**; 2020-93; TPRF 3771). One west of Fort Davis, Jeff Davis on 18-20 October 2020 (**MaE, MEa**; 2020-95; TPRF 3773). Two at El Paso, El Paso on 31 October 2020 (**DS**; 2020-98; TPRF 3776). One at Pine Springs, GMNP, Culberson on 6 November 2020 (**JS**; 2020-105; TPRF 3884).

Yellow-eyed Junco (Junco phaeonotus) (11). One at El Paso, El Paso on 17 October - 15 November 2020 (**JG**, DS, EC, AK; 2020-89; TPRF 3780). One at Boot Canyon, BBNP, Brewster on 30 March 2021 (**LH**; 2021-69; TPRF 3869).

Golden-crowned Sparrow (Zonotrichia atricapilla) (48). One at Balmorhea Lake, Reeves on 15 January 2021 (**DL**; 2021-24; TPRF 3812).

Streak-backed Oriole (Icterus pustulatus) (3). One at Arlington, Tarrant on 14-27 February 2021 (**PaS**, EC, EW, PC, GC; 2021-25; TPRF 3831).

Rufous-capped Warbler (Basileuterus rufifrons) (39). One at Del Rio, Val Verde on 27 November 2020 - 4 January 2021 (**EC, WS**, MC, JoM, BrC; 2020-119; TPRF 3802). Two southeast of San Ygnacio, Zapata on 29 May 2021 (**EH**; 2021-63; TPRF 3882).

Golden-crowned Warbler (Basileuterus culicivorus) (31). One at Gladys Porter Zoo, Brownsville, Cameron on 27 November 2020 - 17 March 2021 (**DE**, JoM, DR, DG; 2021-07; TPRF 3827). One at Resaca de la Palma SP, Cameron on 25 February - 1 March 2021 (**ME**, SS; 2021-26; TPRF 3834).

Flame-colored Tanager (Piranga bidentata) (16). One at South Padre Is., Cameron on 2-8 May 2021 (**BH**, JoM, JS; 2021-52; TPRF 3876).

Crimson-collared Grosbeak (Rhodothraupis celaeno) (60). One at Port Aransas, Nueces on 17-20 November 2020 (**ScH**; 2020-107; TPRF 3789). One to two at Estero Llano Grande SP, Hidalgo on 25 November 2020 - 25 March 2021 (**GC**, DaW, HH, JoM, DR, NF, TK; 2020-152; TPRF 3842). Up to three at Quinta Mazatlan SP, Hidalgo on 27 November 2020 - 17 February 2021 (**NA**, MBS, StL, JiH, RyR, JoM, KA; 2020-154; TPRF 3844). One at Salineno, Starr on 6 December 2020 (**JoC**; 2020-132; TPRF 3795). One at Frontera, Weslaco, Hidalgo on 17 December 2020 - 8 January 2021 (**FA**, AV; 2020-153; TPRF 3853). One at South Padre Is., Cameron on 20-22 December 2020 (**BM**, JMo; 2020-158; TPRF 3799). One at Corpus Christi, Nueces on 25 December 2020 (**RA**; 2020-144; TPRF 3800). One at Portland, San Patricio on 27 December 2020 - 2 January 2021 (**DL**, AnO, MC, KC; 2020-159; TPRF 3808). One at Alamo, Hidalgo on 28 December 2020 - 1 February 2021 (**PaH**; 2021-77). One at Corpus Christi, Nueces on 4-27 January 2021 (**JaL, LaL**, JoM, MC, BrW; 2021-03; TPRF 3819). One at Santa Ana NWR, Hidalgo on 17 January - 12 April 2021 (**RyR**, NL, MBS, JoM, ToH; 2021-06; TPRF 3862). One at Harlingen, Cameron on 2 February 2021 (**DoM**; 2021-13; TPRF 3821). One at Resaca de la Palma SP, Cameron on 21 February - 19 March 2021 (RH, JoM, DR, BE; 2021-18; TPRF 3854). One at McAllen, Hidalgo on 26 February 2021 (**StH**; 2021-29; TPRF 3836).

Blue Bunting (Cyanocompsa parellina) (63). One at South Padre Is., Cameron on 4 November 2020 (**JaG**; 2020-99; TPRF 3778). One at Estero Llano Grande SP, Hidalgo on 2 December 2020 (DeR; 2020-130; TPRF 3794). One at Longoria Unit, Las Palomas WMA, Cameron on 6 December 2020 (**MaC**; 2020-124; TPRF 3796). One at Quinta Mazatlan SP, Hidalgo on 9 December 2020 - 9 January 2021 (**PR**, BrB, SL, RyR, HH; 2020-151; TPRF 3850). One at Bentsen-Rio Grande Valley SP, Hidalgo on 19 December 2020 (**PeH**; 2020-137). One at Quinta Mazatlan SP, Hidalgo on 6-7 January 2021 (**RyR**, BeM, JoM; 2021-04; TPRF 3829). One ~20 south-southwest of Victoria, Victoria on 21 January 2021 (**BF**; 2021-05; TPRF 3813). One at Resaca de la Palma SP, Cameron on 22 February - 18 April 2021 (JoM, DR, RP, JaM; 2021-17; TPRF 3865). One at San Antonio, Bexar on 24 February - 26 March 2021 (**ShC, MR**, JH; 2021-19; TPRF 3864). One at Estero Llano Grande SP, Hidalgo on 31 March 2021 (**RyR**; 2021-37). One at Laguna Vista, Cameron on 30 April 2021 (**SW**; 2021-49; TPRF 3873).

Yellow-faced Grassquit (Tiaris olivaceus) (6). One at Resaca de la Palma SP, Cameron on 22 February 2021 (**JY, RG**; 2021-42; TPRF 3833). One at Estero Llano Grande SP, Hidalgo on 8-29 March 2021 (**DPe, CH**, JdL, DH, JoM; 2021-31; TPRF 3866).

NOT ACCEPTED

A number of factors may contribute to a record being denied acceptance. It is quite uncommon for a record to not be accepted due to a bird being obviously misidentified. More commonly, a record is not accepted because the material submitted was incomplete, insufficient, superficial, or just too vague to properly document the reported occurrence while eliminating all other similar species. Also, written documentation or descriptions prepared entirely from memory weeks, months, or years after a sighting are seldom voted on favorably. It is important that the simple act of not accepting a particular record should by no means indicate that the TBRC or any of its members feel the record did not occur as reported. The non-acceptance of any record simply reflects the opinion of the TBRC that the documentation, as submitted, did not meet the rigorous standards appropriate for adding data to the formal historical record. The TBRC makes every effort to be as fair and objective as possible regarding each record. If the committee is unsure about any particular record, it prefers to err on the conservative side and not accept a good record rather than validate a bad one. All records, whether accepted or not, remain on file and can be re-submitted to the committee if additional substantive material is presented.

Garganey (Spatula querquedula). One at Bolivar Peninsula, Galveston on 15 December 1988 (2020-160).

Ruddy Ground Dove (Columbina talpacoti). One ~8 miles northeast of Van Horn, Culberson on 30 May 2021 (2021-65).

Curlew Sandpiper (Calidris ferruginea). One at North Padre Is., Kleberg on 15 December 1997 (2021-08).

Purple Sandpiper (Calidris maritima). One at Mustang Is., Nueces on 17 April 2021 (2021-47).

Little Gull (Hydrocoloeus minutus). One at Lake Tawakoni, Van Zandt on 21 January 2012 (2020-80).

Great Black-backed Gull (Larus marinus). One at Bryan Beach, Freeport, Brazoria on 30 March 2015 (2020-74). One at Quintana, Brazoria on 6 December 2020 (2020-141).

Sooty Shearwater (Ardenna grisea). Three offshore 80 miles, Galveston on 21 December 2020 (2021-21).

"Lawrence's" Dusky-capped Flycatcher (Myiarchus tuberculifer [lawrenceii group]). One at Pedernales Falls SP, Blanco on 25 October - 30 November 2014 (2020-48).

Gray Silky-flycatcher (Ptiliogonys cinereus). One at Rio Grande Village, BBNP, Brewster on 5 May 2021 (2021-64).

Eastern Yellow Wagtail (Motacilla tschutschensis). One at Santa Elena Canyon, Brewster on 13 April 2021 (2021-46).

Rufous-capped Warbler (Basileuterus rufifrons). One at Christmas Mtns., Brewster on 16 April 2021 (2021-48).

Golden-crowned Warbler (Basileuterus culicivorus). One at Laguna Atascosa NWR, Cameron on 26 December 2020 (2021-22).

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Steller's Sea-Eagle. Photographed on 07 March 2021 by Sandi Roesler.

VARIABILITY IN THE B SONG OF THE GOLDEN-CHEEKED WARBLER (*SETOPHAGA CHRYSOPARIA*)

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ABSTRACT—The Golden-cheeked Warbler (*Setophaga chrysoparia*) (GCWA) uses a two-category song system consisting of type A and B song. While the A song is relatively static and exhibits minimal variation, the type B song is more malleable and can change over both time and space. Here we report A and B songs recorded during 2009-2011 from 42 males across 7 counties in Texas and compare these songs to recordings made in 1993-1994. Broadly, the B song consists of 4 syllables, denoted here as a, b, c*, and d. In the 1993-1994 data, the B song exhibited maximum energy around 4600 Hz (the modal frequency). In our data the B song exhibited a significant shift in the modal frequency downwards to about 4000 Hz. Further, three syllables (a, b, and d) retained similarities in their spectrograms to the earlier data, with the shift in the modal frequency being entirely due to a modified c* syllable. This syllable has elements that are tonal or rich in frequency modulations although they are variable across birds and counties. The A song recorded in 1993-1994 exhibited a modal frequency around 4800 Hz, while in our data it was around 4600 Hz. Although there is a slight lowering of the modal frequency in the A song in our data, the shift is not significant leading us to conclude that the A song may not have changed significantly over time. While we could not identify clear patterns of differences between songs across the seven counties in our data, we note the most significant differences in the modal frequency of the B song occurred at the two ends of the data range (Bexar CO in 2009-2011 and Bell CO in 1993-1994). Further studies are needed to determine the cause of these changes and their likely effect on the status of the GCWA.

In the over hundred species of wood-warblers in the Parulidae family, most have a two-category song system (Spector 1992; Bolsinger 1997; Bolsinger 2000). This song system is used for different purposes and appears to have patterns shared by related species (Spector 1992; Bolsinger 1997; Stacier 1996). The Golden-cheeked Warbler (GCWA) (*Setophaga chrysoparia*), a type of wood-warbler that is the subject of this work, also uses this song system. As with other Parulids (wood-warblers), the GCWA's first category, referred to as 'A song', is simple, sung at low rates, and is a stereotyped song that undergoes minimal variation over time (Bolsinger 1997; Bolsinger 2000; Kroodsma 1988). This song is used during daylight hours, early in the spring when males are unmated, and during intersexual interactions (Demko and Mennill 2018; Stacier 1996; Bolsinger 1997; Spector 1992; Kroodsma 1981). However, the second category song, called the 'B song', is more common later in the spring during nesting. This song is used in male-male interactions and during conflicts with neighboring males (Demko and Mennill 2018; Bolsinger 1997; Bolsinger 2000; Stacier 1996). It functions as a territorial defense song where neighboring males counter-sing to match the opponent's song (Demko and Mennill 2018; Bolsinger 1997). The potential for song variation in B song is therefore greater than in the A song where variability may have deleterious

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consequences for mating success (Krebs et al 1981; Armstrong 1973; Molles and Vehrencamp 1999). Indeed, it has been shown that the B song tends to be dynamic and can undergo variation over time and breeding range (Leonard et al. 52 2010; Bolsinger 1997; Stacier 1996; Finn 2020).

There is limited research on the variation of the GCWA's B song. In the period 1993-1994, Bolsinger (1997, 2000) carried out a detailed study of the GCWA's song system in the Fort Hood Military Reservation (Bell and Coryell COs, Texas). In the same period, Bolsinger (1997) covered additional areas within the GCWA's breeding range in Central Texas. Bolsinger found only a few variants of the A song (Bolsinger 1997). However, he found more variants of the B song, with each type being highly variable and possibly geographically distinctive (Bolsinger 1997). All the B songs had the same basic "elements" but there were variations in each of the elements with respect to duration, frequency, form, and occurrence among individual males (Bolsinger 1997). He found that each male sang only one type of A song that was shared with a neighbor, but some males sang more than one type of B song. These song variants were not shared with the neighbors. For each bird, one song among the variants was its primary B song but individuals sang other variants of the B song less frequently (Bolsinger 1997). Bolsinger also documented the use of a C song and hypothesized that this song could be a variant of the B song. However, he did not obtain sufficient recordings to make statistical comparisons (Bolsinger 1997, 2000). Further, Bolsinger obtained fewer recordings from counties in the southwestern edge of the GCWA's range, particularly in Bexar CO (TX).

In a 2009 study in Bexar CO, two of us (WJL and RR) reported B songs with a variable syllable (Leonard et al 2010). Bolsinger (1997, 2000) too reported variations in this syllable between birds, but our recordings exhibited prominent frequency modulations (both up and down slurs) not seen in Bolsinger's recording either in Fort Hood or Bexar CO. We could not carry out a detailed analysis of the song modification due to the small sample size (6 birds). Here we report a larger study with more birds over three breeding seasons covering the period 2009-2011. We cover Bexar and surrounding counties in the southwestern portion of the GCWA's breeding range in central Texas. More recently, a study conducted by Finn (2020), suggests that there are geographic variations in both the A and B songs across the breeding range and the B song has undergone more variation than the A song.

Here, we examine the A and B songs of GCWA, focusing particularly on variations in the B song in Bexar and neighboring counties. We compare the A and B song to songs recorded by Bolsinger 15 years prior to our study (1993-1994). We hypothesize that the B song undergoes more variation than the A song, both over time and geographic breeding range. This would be consistent with the observations made by Bolsinger (1997, 2000), Leonard et al (2010), and Finn (2020) and the use of a two-category song system by other wood warblers. Further, we hypothesize that a specific song feature has been modified significantly between the two study periods, namely the frequency with highest song energy (modal frequency, Bolsinger 1997, 2000; Leonard et al. 2010).

METHODS

We recorded Golden-cheeked Warbler songs in the spring of 2009, 2010, and 2011 from seven counties in central Texas (Fig. 1). We collected songs from publicly managed wildlife parks and from private properties partnering with the Texas Ecological Laboratory (Austin, TX). Thus, the sampling of birds across counties relied on access and was non-uniform. There were three recording sites in Travis (labeled 1-3 in Fig. 1), two in Hays (4-5), two in Blanco (6-7), 25 in Bexar (8-32), six in Kerr (33-38), two in Bandera (39-40), and one in Real County (41). Recordings were identified as being separate males only if more than one male was counter singing at the same location. Two of us (WJL and JLMC) recorded songs starting at dawn. Additionally, we used an autonomously deployed recorder that switched on and off automatically for four hours after dawn. The details of the recording instruments are as follows: 1) WJL used an omnidirectional microphone (MKE 2, 0.02-20 kHz, Sennheiser Electric Corporation) connected to a high-resolution digital audio recorder (Model 722T, Sound Devices LLC) (Leonard et al 2010), 2) JLMC used a super-cardioid shotgun microphone (MKE 600, 0.04-20 kHz, Sennheiser Electric Corporation) connected to a handheld solid state recorder

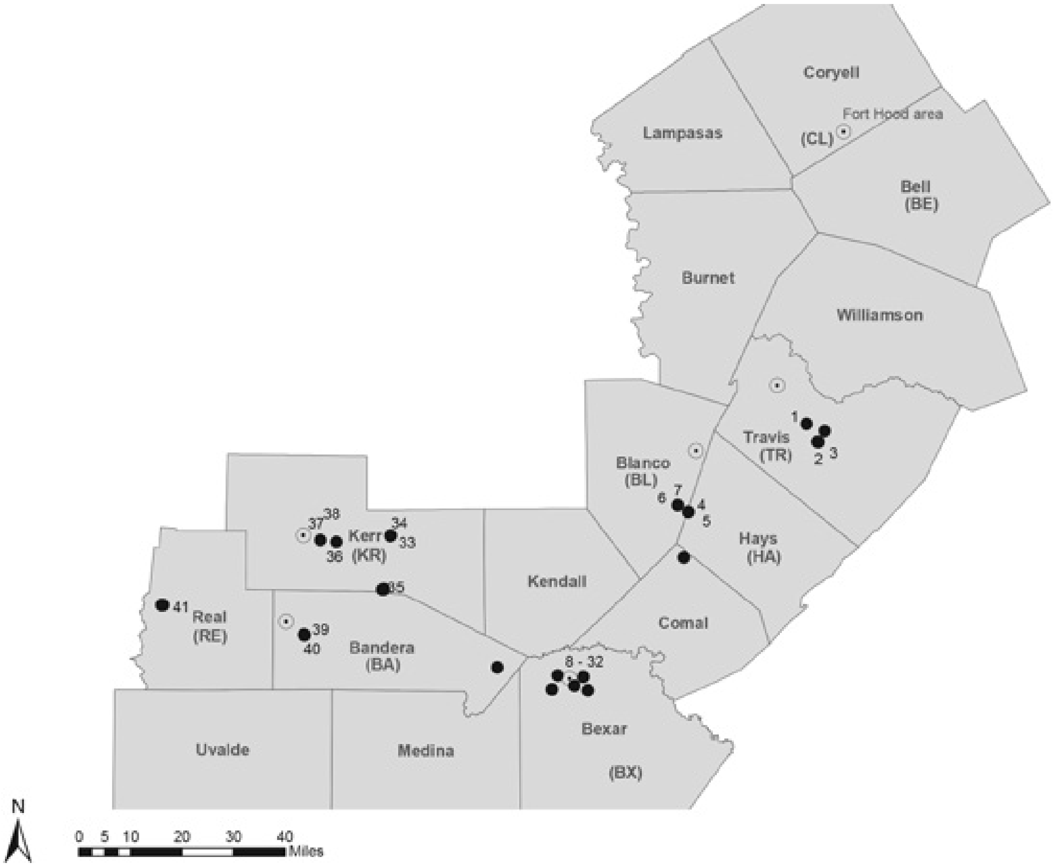

Figure 1. Range map of counties in the Edwards plateau region (Texas). Only southernmost counties in the region are depicted. Locations (GPS) where Golden-cheeked Warbler was surveyed in 2009-2011 are shown in filled black circles with numbers referencing the birds. A number followed by the two-letter code for the county serves as the unique bird ID (e.g., 36:KR refers to bird 36 surveyed in Kerr CO.) Open circles with a dot at the center depict locations of birds surveyed by Bolsinger (1997) in 1993-94. See Table 1 and 2 for additional information.

(Marantz PMD661MK11). While surveying in the field, WJL and JLMC used a parabolic reflector (Sony PBR-330) with windscreens on their microphones. 3) Songs were collected from one remote site located in Real County using an autonomous recorder (Song Meter SM2 Terrestrial autonomous recording unit, Wildlife Acoustics). Recordings were made until males were no longer audible. All songs were sampled at 44.1 kSamples/s and stored as PCM (WAV) files in the hard disk of the Sound Devices recorder, or the Flash (SD) cards of the Marantz recorder, or the SM2 recorder. Raw sound files were initially analyzed using Adobe Audition (Adobe Inc.) by filtering with a band-pass filter (sixth order, Type II Chebychev, 2.5 - 10.5 kHz passband) to reduce noise outside the GCWA's song frequency band (Leonard et al 2010). Individual songs were visually isolated, segmented, and saved as WAV files for further analysis (detailed further below).

We obtained A and B songs recorded by Bolsinger in the period 1993-1994 (Bolsinger 1997, 2000) from Cornell Laboratory of Ornithology's Macaulay Library of Sound. Bolsinger made analog recordings which were converted to digital format at Macaulay Library (our recordings are completely digital). In 1993, Bolsinger used a Marantz PMD cassette recorder with a Dan Gibson parabolic microphone. In 1994-1995, he used Nagra IV-L open reel recorder with a Sennheiser 816 shotgun microphone (Bolsinger 1997). He started recording at dawn on each recording day and recorded until he was unable to find singing males (Bolsinger 1997). Exemplar A and B songs were cut from these recordings for comparative analysis with data from this study. Every effort was made to classify the birds as separate individuals based on the banding identification provided by Bolsinger in his accompanying field notes. Macaulay Library at the Cornell Lab of Ornithology has listed field notes regarding bird ID under the heading "media notes" in their database. A complete list of birds used from their catalog is provided in Table 2. Bolsinger's A and B songs were extracted using Adobe Audition as described above.

We generated sound spectrograms using custom-written MATLAB (The Mathworks Inc.) scripts. Briefly, we obtained the short-time Fourier transform of the song using a 20 ms sliding window or frame (882 samples). This window duration was selected because it provided a good compromise between time and frequency resolution. Each 20 ms frame was Hanning windowed, and Fourier transformed, and then advanced with an overlap of 80%. Magnitude of the short-time Fourier transform was computed, converted to decibels (dBV, re: 1 volt), and normalized so that the maximum magnitude across frequency and time was 0 dBV. Resulting magnitudes were clipped (set at -30 dBV if they fell below −30 dBV) so that the range of the magnitudes in the spectrogram plot was restricted between 0 and −30 dBV. This scaled, clipped, short-time Fourier transform is the spectrogram, with the magnitude depicted in grayscale (Fig. 2a).

The modal frequency is defined as the "frequency of modal intensity" (Bolsinger 2000), i.e., the frequency (*f*m) with the greatest power in the song spectrum. First, for each bird and each song type (A or B), we visually examined the spectrograms of all recorded songs. Then we selected an exemplar song with the clearest spectrogram (i.e., where song features were clearly delineated, and where there was either no interference or minimum interference from other sound sources). Thus, for each bird we had one exemplar A song and one B song. We obtained the modal frequency from the exemplar spectrogram by summing the power at each frequency over the duration of the song. This was repeated for each bird in the database (in both study periods). We chose not to average over all songs for a given bird because the number of recorded songs per bird was variable, the song was stereotypical and unchanged for each bird, and the modal frequency tended to be stable for a bird. At the end of the above analysis each bird had a modal frequency value for it's a song and a modal frequency value for its B song.

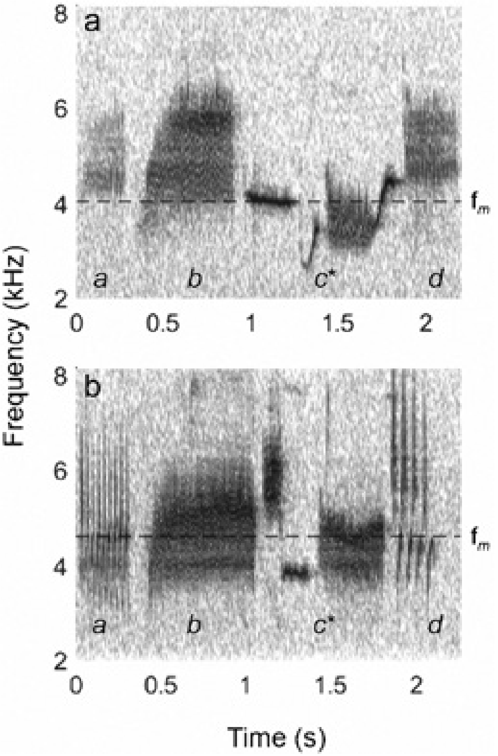

Figure 2. Example B song spectrograms from a) 2009-2011 (current study), and b) 1993-1994 (Bolsinger 1997, 2000) illustrating the analysis method. Spectrograms of the B song are divided into four syllables designated a, b, c*, and d. The frequency at which the song has maximum energy, called the modal frequency or f*m* (dashed line), is selected visually from the song spectrum (Bolsinger 1997).

To minimize the effect of outliers, and because we did not know the underlying probability distribution, we report median values and interquartile range (IQR) for the modal frequency rather than mean and standard deviation. We test the null hypothesis that the two populations of modal frequency observed in 2009-2011 and 1993-1994 are equal. The hypothesis is tested using the Wilcoxon rank sum test of modal frequencies for A and B songs (exact *p*-values are reported). We use this test although it is less powerful than a parametric test (for example, a t-test). Further, even though the modal frequency is well-defined, the presence of noise can cause small shifts in the modal frequency, making a direct comparison of median (or mean) value using a t-test less reliable. Finally, the non-parametric rank sum test is robust in the presence of outliers.

RESULTS

In the spring of 2009, 2010, and 2011 we recorded a total of 1734 B songs from 42 males across 7 counties in Texas (Table 1). We collected

Table 1. B Song recordings from the current study.

Bird ID#	Number of songs	Year	County	Coordinates (N, W)
1	4	2011	Travis	30.35, −97.81
2	58	2011	Travis	30.32, −97.84
3	9	2011	Travis	30.32, −97.84
4	130	2011	Hays	30.13, −98.26
5	17	2011	Hays	30.13, −98.26
6	20	2011	Blanco	29.78, −99.50
7	18	2011	Blanco	29.78, −99.50
8	27	2011	Bexar	29.57, −98.70
9	98	2010	Bexar	29.63, −98.65
10	11	2010	Bexar	29.63, −98.64
11	23	2010	Bexar	29.63, −98.64
12	19	2010	Bexar	29.63, −98.64
13	78	2010	Bexar	29.63, −98.64
14	50	2010	Bexar	29.63, −98.71
15	33	2010	Bexar	29.63, −98.71
16	35	2010	Bexar	29.60, −98.66
17	14	2010	Bexar	29.60, −98.66
18	39	2010	Bexar	29.60, −98.66
19	9	2010	Bexar	29.61, −98.66
20	10	2010	Bexar	29.61, −98.62
21	21	2010	Bexar	29.61, −98.67
22	136	2010	Bexar	29.61, −98.67
23	209	2010	Bexar	29.62, −98.66
24	165	2010	Bexar	29.62, −98.67
25	3	2010	Bexar	29.64, −98.64
26	48	2010	Bexar	29.64, −98.64
27	95	2010	Bexar	29.64, −98.64
28	28	2009	Bexar	29.64, −98.64
29	29	2009	Bexar	29.63, −98.70
30	17	2009	Bexar	29.64, −98.64
31	56	2009	Bexar	29.62, −98.59
32	7	2010	Bexar	29.62, −98.62
33	60	2011	Kerr	30.06, −99.22
34	25	2011	Kerr	30.06, −99.22
35	18	2011	Kerr	29.91, −99.25
36	14	2011	Kerr	30.05, −99.46
37	70	2011	Kerr	30.04, −99.40
38	19	2011	Kerr	30.04, −99.40
39	1	2011	Bandera	29.61, −99.50
40	5	2011	Bandera	29.78, −99.50
41	10	2011	Real	29.86, −99.96
TOTAL	1734			

fewer A songs (from 12 birds) because the B song was the focus of this study. From Bolsinger's data we obtained a total of 261 B songs cut from 23 recordings (Table 2), and 11 A songs cut from 17 recordings. In our data, in almost all cases, we recorded males using a single A and a single B song.

The spectrogram of an exemplar B song recorded in the current study (Fig. 2a) and Bolsinger's 1993-1994 study (Fig. 2b) demonstrate the song and its syllables. The notation is almost the same as the notation employed in Leonard et al (2010) with some differences. The song spectrogram shows four distinct syllables with clear boundaries and structure. These syllables are depicted in the spectrogram (a, b, c*, d). The syllables a, b, and d were trills (a, and d) or a buzz (b). The c* syllable has a complex sequence of elements that are not always the same in all birds, and which are detailed further below. The spectrogram additionally depicts the modal frequency, $f\mathrm{m}$ (horizontal dashed line).

Modal frequencies of B songs are reported in Table 3 for data from the current study (2009-2011) and Bolsinger's study (1993-1994), with median values, quartiles, and interquartile range (IQR). Data within these year ranges were further subdivided into "All counties" and Bexar CO

Table 2. B Song recordings from Bolsinger's 1993-1994 study.[a]

Bird ID#	Number of songs	Year	County	Coordinates (N, W)	Macaulay Library Catalog #
1	24	1994	Bell	31.15, −97.58	ML109421
2	35	1994	Bell	31.15, −97.58	ML109414
3	30	1994	Bell	31.15, −97.58	ML109336
4	35	1994	Bell	31.15, −97.58	ML109415
5	5	1994	Bell	31.15, −97.58	ML109370
6	20	1994	Bell	31.15, −97.58	ML109378
7	11	1994	Bell	31.15, −97.58	ML109399
8	6	1994	Bell	31.15, −97.58	ML109388
9	8	1994	Bell	31.15, −97.58	ML109389
10	1	1994	Bell	31.15, −97.58	ML109391
11	11	1994	Bell	31.15, −97.58	ML109392
12	1	1994	Bell	31.15, −97.58	ML109398
13	5	1994	Bell	31.15, −97.58	ML109402
14	5	1994	Bell	31.15, −97.58	ML109409
15	3	1994	Travis	30.48, −97.97	ML109445
16	2	1994	Travis	30.48, −97.97	ML109445
17	10	1994	Travis	30.48, −97.97	ML109451
18	8	1994	Blanco	30.3, −98.23	ML109703
19	10	1994	Blanco	30.3, −98.23	ML109698
20	6	1994	Bexar	29.63, −98.62	ML109750
21	10	1995	Kerr	33.5, −99.0	ML110125
22	10	1994	Kerr	33.5, −99.0	ML109632
23	5	1994	Bandera	29.85, −99.58	ML109502
TOTAL	261				

[a] Bolsinger (1997) carried out his study in 1993-1994. Although the recordings here may have a different date, in the text we refer to the date of the study rather than the date of the recordings.

(2009-2011, rows one and two, respectively), and "All Counties" and Bell CO (1993-1994, rows three and four, respectively). A Wilcoxon rank sum test showed that modal frequencies over all counties for 2009-2011 were significantly less than the modal frequencies for 1993-1994 ($p = 3.5 \times 10^{-4}$). Further, modal frequencies for Bexar CO (2009-2011) were significantly less than the modal frequencies for Bell CO (1993-1994) ($p = 6 \times 10^{-5}$). There is considerable separation in the distribution of modal frequencies in the two periods 2009-2011 and 1993-1994 (Table 3, see Q1 and Q3) with almost no overlap in their interquartile ranges (frequencies between Q1 and Q3).

Modal frequencies of A song are reported in Table 4 for data from the current study (2009-2011) and Bolsinger's study (1993-1994). The median value for modal frequency from 2009-2011 is lower than the median modal frequency from 1993-1994, however, the difference is not significant. There is little separation in the distributions of modal frequencies observed in these two periods (Table 4, see Q1 and Q3), with considerable overlap in their interquartile range (frequencies between Q1 and Q3).

In our data, the c* syllable (inset, Fig. 3a) is a complex of several elements, each of which has strong frequency modulations (FMs) or tonal components. The syllable is shifted downwards to lower frequencies in most of the birds (re: 1993-1994) (inset, Fig. 3a, see another exemplar in Fig. 2a) and it is the dominant contributor to the observed modal frequency (Table 3). We show later that this syllable exhibits greatest variability between birds. The terminal element of the c*syllable, usually the third element, is a buzz. In the earlier B song data

Table 3. Modal frequencies for B songs. 1) 2009-2011, current study with all birds from seven counties on first row, and only Bexar CO birds on second row. 2) 1993-1994, Bolsinger (1997, 2000) study with a subset of birds from six counties on third row, and only Bell CO (Fort Hood) birds on fourth row. Q1: 25th percentile (in Hz), Q3: 75th percentile (in Hz), IQR: inter-quartile range (in Hz).

	B song modal frequency (Hz).				
	N	Median	Quartile		IQR
	(birds)		Q1	Q3	
1) 2009-2011					
All counties	41	4094[1]	3950	4569	619
Bexar CO only	25	4097[2]	4006	4455	449
2) 1993-1994					
All counties	23	4649[1]	4515	4942	427
Bell CO only	14	4644[2]	4503	4800	297

[1] All counties: Comparison between 2009-2011 and 1993-1994 are significantly different (Wilcoxon rank sum test, $p = 3.5 \times 10^{-4}$)

[2] Bexar CO and Bell CO: Comparison between 2009-2011 and 1993-1994 are significantly different (Wilcoxon rank sum test, $p = 6 \times 10^{-5}$)

Table 4. Modal frequency for A songs. 1) 2009-2011, current study. 2) 1993-1994, Bolsinger(1997, 2000) study. Q1: 25th percentile (in Hz), Q3: 75th percentile (in Hz), IQR: inter-quartile range (in Hz).

	A song modal frequency (Hz)				
	N	Median	Quartile		IQR
	(Birds)		Q1	Q3	
1) 2009-2011	12	4610	4441	4899	458
2) 1993-1994	11	4811	4537	4902	365

No significant difference in modal frequency between 2009-2011and 1993-1994.

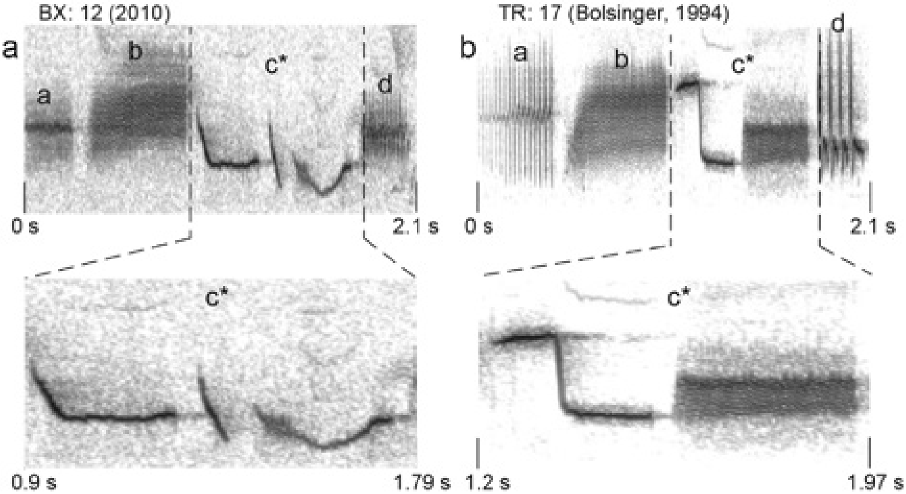

Figure 3. Change in B songs recorded a) in this study, in comparison with b) B songs from Bolsinger (1997). Upper row shows the song spectrogram with four syllables a, b, c*, and d. The inset (bottom row) shows the c* syllable in greater detail. In both the study periods the c* syllable is a complex of elements. a) The c* syllable observed in the current study is shifted downwards as a whole with respect to the c* syllable observed in the 1993-1994 study. Further, it includes complex frequency modulations (up and down slurs).

reported by Bolsinger (top, Fig. 3b) the c* syllable is also made up of multiple elements of which the first two are temporally and spectrally non-overlapping, each of almost constant frequency. These elements are separated widely in frequency space, with the higher frequency element transitioning to the lower frequency element with an abrupt downward FM sweep (inset, Fig. 3b). In some birds the FM sweep is not as pronounced (Fig. 2b) or it may be absent. These two elements are followed by a buzzy note that terminates the c* syllable. The terminal element seems to be present in almost all birds in both study periods (Fig. 2) but may be omitted (Fig. 3a). In general, the c* syllable reported by Bolsinger has energy distributed over a wider frequency band than the c* syllable observed in our study. As with our study, the c* syllable in Bolsinger's study also demonstrates variability between birds.

To determine B song variation across the observed range, and to examine individual song differences, we looked at the spectrograms and modal frequencies of exemplar B songs collected from six of the seven counties in our study (Fig. 4), and six counties from Bolsinger's study (Fig. 5). We excluded Bandera Co. from our data because one of the birds produced songs that were similar to bird 41 from Real Co. (Fig. 4, 41: RE), and recordings of a second bird were not of high quality. Each exemplar spectrogram shown in Figs. 4 and 5 shows the modal frequency for that song (dashed line). The spectrograms support the observation that the modal frequency in the B song of birds recorded in this study are significantly shifted downward to lower frequencies in comparison with the B song recorded in 1993-1994 (see Table 3).

It is possible to determine the likely source of the reduction in modal frequency observed in the study. Unlike the a, b, and d syllables, the c* syllable was much more variable across birds in the current study and in Bolsinger's study (Bolsinger 1997, 2000). Except for three birds in our data (one exemplar of which is shown in Fig. 4, 41: RE), there are typically three elements in the c* syllable. The first element (Fig 2a) is largely intact across birds and is the main contributor to the observed power in the modal frequency. In the Bolsinger data (Fig 2b), this element is concentrated at a higher frequency and contributes to an increase in the modal frequency. The remaining two elements in the c* syllable are more variable in our data especially in Bexar, Real, and Kerr counties due to the presence of complex frequency modulations and buzzes (Fig. 4, except 41:RE). The terminal or third element of the c* syllable observed in the 1993-1994 data is intact in most birds observed in the current study (except Fig. 4, 12:BX). Thus, the higher modal frequency

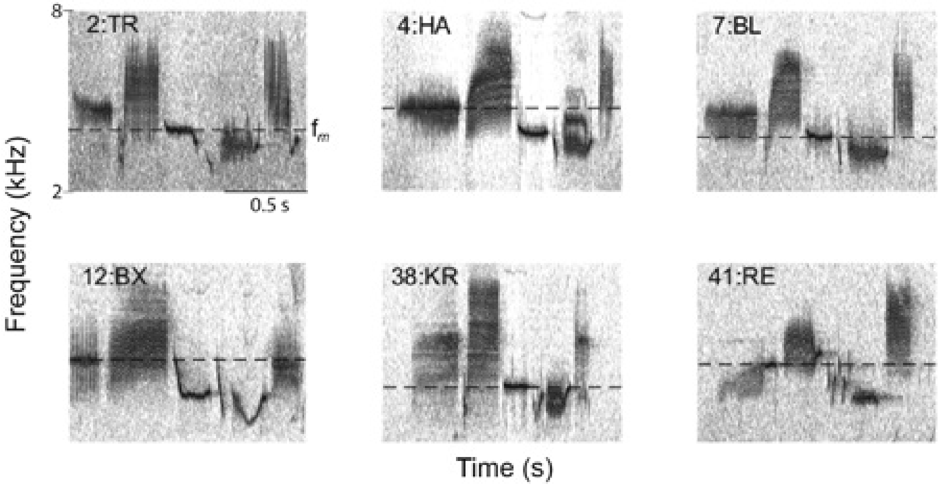

Figure 4. Exemplar B song spectrograms from 6 representative birds, one from each county (except Bandera Co.), surveyed in the current study. Bird IDs and county abbreviations are as in Fig. 1, and "2:TR" means Bird #2 from Travis CO. Modal frequency f*m* is depicted as a dashed line.

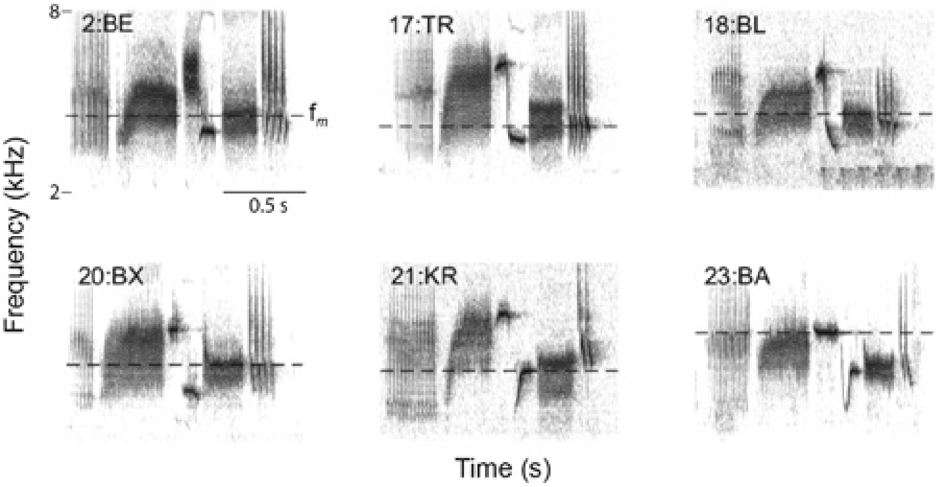

Figure 5. Exemplar B song spectrograms from 6 representative birds surveyed by Bolsinger (1997). The counties either matched the locations reported in Fig. 6 or were taken from counties closest to those studied here. Bird IDs and county abbreviations are as stated in Fig. 4. Modal frequency f_m is depicted as a dashed line.

observed in 1993-1994 (Fig. 5) is partly due to the higher frequency of the initial element in the c* syllable. This high-frequency element is not observed in the recordings made in the current study (Fig. 4). There are some exceptions to the number of elements in c* syllable. We observed three birds whose c* syllable had more than 3 elements (e.g., Fig. 4, 41: RE), with the initial portion of the syllable consisting of rapid sequence of alternating up and down slurs. We did not see this particular syllable element in Bolsinger's recordings. Finally, there are likely differences in the d note seen as an increase in the trill-rate in the current study (re: 1993-1994). However, we did not have sufficient data to confirm whether this was a feature in all the observed B songs.

Due to the small sample size in each county (except Bexar CO), we could not determine any clear spatial differences in the B song structure of the birds. The Real County data (Fig. 4, 41: RE) is similar to one of the birds observed in Bandera County (40: BA, not shown). These songs were recorded at the extreme western edge of their county range (Fig. 1) and demonstrated complex frequency modulations in the first sub-note of the c* syllable.

Exemplars from Bolsinger's study (1993-1994) share similarities but demonstrate notable differences in the structure of the c* syllable (Fig. 5). In addition to the higher frequency of the first element in Bolsinger's c* syllable songs (Figs. 2b and 5), this element is more variable. It is either narrowband (i.e., concentrated in a narrow range of frequencies, Fig. 3b, Fig. 5), or it is a brief buzzy note (Fig. 5, 2:BE). The second element follows an abrupt transition to a constant frequency note that occurs at or around the lower modal frequency (Fig. 3b). This transition may be a rapid downward frequency modulation (FM) sweep or down slur (Fig. 3b, Fig. 5, 18: BL) or an abrupt transition with no FM component present (Fig. 5, 2:BE, 20:BX, 21:KR). Almost invariably, the first two elements in the c* syllable in Bolsinger's data are followed by a third element which is a broadband buzz that seems to contribute significant energy to the modal frequency in most cases (Fig. 5). The bandwidth of this buzzy sub-note was generally smaller than that of the b note, with approximately similar lower frequency limit, but with smaller upper frequency limit. As noted above, the third element is largely intact in our study except in some cases. Overall, there is considerable variability in the c* syllable within the study period considered here, and in the period reported by Bolsinger (1997, 2000).

DISCUSSION

Numerous theories on the reason for song variation exist and most of these theories vary with species. Researchers have proposed the acoustic adaptation hypothesis in areas experiencing urban noise (Patricelli and Blickley 2006). Birds can increase call frequency, duration, and amplitude of their songs to avoid having their songs masked by low-frequency anthropogenic noise (Patricelli and Blickley 2006; Slabbekoorn and Peet 2003; Baker and Gammon 2008). Likewise, song variation can be a direct result of the habitat and, as the habitat changes, so does the song (Baptista and Kroodsma 2001; Wiley 1991; Bowman 1979; Gish and Morton 1981). Alternate theories for geographic variation of songs include the genetic adaptation hypothesis (Nottebohm 1972; Baptista and Kroodsma 2001) and social adaptation theory (Baptista and Kroodsma 2001; Trainer 1983). Here we focus on the acoustic adaptation hypothesis and do not consider alternate theories as they are outside the scope of this study.

The acoustic adaptation hypothesis would predict that the GCWA would increase its modal frequency. However, GCWAs recorded in 2009-2011 exhibited a significant reduction in the modal frequency in the B song compared to the B songs recorded in 1993-1994. This reduction may be a consequence of both temporal and spatial factors (see Table 3). The A song does not change its modal frequency across the two study periods (see Table 4). Thus, the reason for the shift in modal frequency of the B song may not be a result of anthropogenic noise. However, we did not make detailed recordings of background noise and, therefore, more work is needed to determine the cause of this reduction in modal frequency in B song.

The variation of songs in the current study can be attributed to the c* syllable. This syllable has three elements of which the first two are more variable in the current study (Fig. 4) than in 1993-1994 study (Fig. 5). The third element is intact in most birds across the two studies, albeit with some modifications. While there are qualitative differences in the c* syllable in the two studies, a clear quantitative difference is a shift in the modal frequency across the two study periods. This shift could be dependent on spatial and temporal factors. For example, the shift is significant when the B song modal frequency of all birds are pooled together (i.e., we discard any spatial effect) (see Table 3, the rows marked "All counties"). However, when we consider two ends of the range (Bexar CO in the 2009-2011 study versus Bell CO in the 1993-1994 study) the difference is even stronger as seen in the smaller *p*-value (see Table 3). This is because the interquartile range (IQR, Table 3) for a single county is smaller than the IQR for all counties indicating that there may be some spatial effect within each study period. While we conclude that the variability within Bexar CO (and Bell CO) is smaller than the variability observed across all counties within the relevant study period, we cannot conclude that there is a spatial effect when comparing across the two studies. This is because the data were collected at two different time points and so any observed change could be temporal rather than spatial. To fully determine spatial effects, new data must be collected from Bell CO and Bexar CO within the same time-period. This is the aim of a future study.

For many wood-warblers using this two-category song system, the type A song is more stereotyped and undergoes minimal variation (Spector 1992; Bolsinger 1997). For GCWA's, the simple A song is sung at low rates and is directed towards the females allowing for the comparisons of male songs (Bolsinger 1997; Bolsinger 2000; Kroodsma 1988; Demko and Mennill 2018; Price 2013). As with Bolsinger's A song (Bolsinger 1997) we observed some variation in the A song, specifically a small reduction in the modal frequency at the lower end of the frequency range (see Q1 and IQR in Table 4). This reduction does not lead to a significant difference in A song modal frequency between the current study and the 1993-1994 study (Table 4). Thus, the A song appears far less malleable than the B song. In Blue-winged Warblers as well, Kroodsma (1988) found that the A song undergoes minimal variation throughout the geographic range (Kroodsma 1981). He hypothesized that this could be a result of the female's response to singing males and thus could be female driven (Kroodsma 1988; Kroodsma 1981; Janes and Ryker 2006). Therefore, there could be strong selective pressure to maintain A song with minimum variation.

Although the A song was not the focus of our study, we note that the A song recorded by Bolsinger appeared to have little variation, but he did note 4 variations across 13 sites (Bolsinger 1997; Morrison et al 2010). The two main variants, A1 and A2, appeared in the northern and eastern part of the breeding range and the southwestern part of the breeding range, respectively (Bolsinger 1997).

The use of a two-category song system in wood-warblers makes them a good candidate for studying the "micro-geographical variations" in songs (Kroodsma 1981). The variation in the A and B song could indicate the presence of several subpopulations of breeding individuals (Bolsinger 1997). This study provides additional support for this idea and suggests that the song used in male-male interactions (B song) varies more than the song in male-female interactions (A song) (Kroodsma 1981; Bolsinger 1997). We demonstrate a significant shift in modal frequency when comparing songs from 2009-2011 with songs from 1993-1994 (i.e., a temporal change in song frequency), but we could not determine conclusively whether there was a spatial (i.e., geographical) component to these differences. While we have focused more on the B song than the A song in this work, future studies will focus on both songs to assess geographical variations. This will require a large-scale effort to record both A and B songs throughout the breeding range.

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SHORT COMMUNICATIONS

WHITE-TAILED KITES BREEDING DURING WINTER IN THE LOWER RIO GRANDE VALLEY

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White-tailed Kite (*Elanus leucurus*) is a resident of the lower Rio Grande Valley (LRGV) of Texas, their status is listed as uncommon to common (Tweit 2007). Oberholser (1974) lists March–September as the breeding timeframe for these kites in Texas, but beginning a month earlier in San Diego County, CA, with the first eggs laid there by 6 February (Dunk 2020). Prior to 2016 we could find no documented breeding outside of these months, with Marsden et al. (2016) having the only documented occurrence of winter breeding, when they reported an active nest in Cameron County on 3 January 2015.

On 3 February 2021, we captured and banded a White-tailed Kite in juvenile plumage along Louisiana Road (26° 14’ 08” N, 97° 50’ 07” W) in Santa Rosa, Cameron County, TX 78593, with a second juvenile sighted nearby twice the following week, both times in the presence of one or more adults, along Sesso Road (26° 16’ 56” N, 97° 50’ 22” W), also in Santa Rosa. The second juvenile was approximately 5.2 kilometers NNW of the first juvenile and most unlikely to be a sibling. We captured and banded another juvenile kite, the third encountered, on 3 March 2021 along Rabb Road (26° 14’ 37.6” N, 97° 50’ 13.1” W) in Santa Rosa, Cameron County, TX 78593. This juvenile was approximately 940 m from the first kite banded and most likely a sibling. Both kites were captured using a bal chatri with house mouse (Mus musculus) as the lure animal (Bloom et al. 2007).

White-tailed Kite juveniles have a dusky crown and nape, with cinnamon fringing. The back feathers are brownish gray with cinnamon tips, and the breast feathers have a cinnamon wash (Pyle 2008). Their white tails show an incomplete dusky subterminal band. This plumage is shown in figure 2[d]. plate 4 in Clark and Wheeler (2001). The two kites captured (Fig. 1) were still in fresh juvenile plumage, a plumage that would normally be encountered only from June–November (Clark and Wheeler 2001, Pyle 2008). Juvenile White-tailed Kites undergo a complete body molt during the pre-formative molt about three months after fledging, replacing juvenile body feathers with adult-like ones (Pyle 2005).

Based on an incubation period of 30-32 d, and fledging occurring 4-5 wk after hatching (Dunk 2020), we estimate the adults began nesting sometime around the beginning of December. Prior to the observation of an active nest in January by Marsden et al. (2016), the latest date White-tailed Kites in Texas would have eggs is August (Oberholser 1974).

White-tailed Kites (*Elanus leucurus*)

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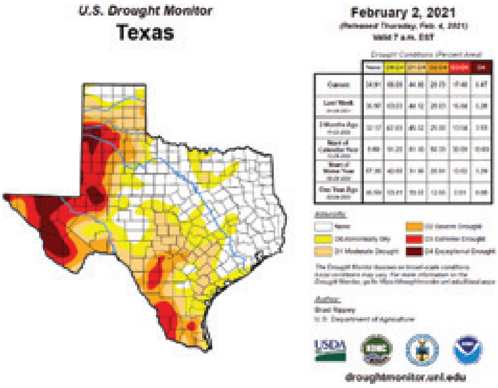
Brush (2005) suggested breeding numbers vary from year to year, corresponding to rainfall. In 2015 when the active kite nest was located, the LRGV had above average rainfall for the past two years, which broke a long period of drought (Marsden et al. 2016). We had assumed White-tailed Kite prey abundance would be tied to rainfall, and with above normal amounts of rain there would be abundant prey that could lead to opportunistic breeding attempts outside their normal breeding season. However, as Figure 2 shows, the area where the juvenile kites were encountered is experiencing severe drought.



From 3 January 2021 to 4 March 2021, we captured and banded six adult female White-tailed Kites, all with brood patches. These may not all have been developing for the upcoming breeding season, especially the female captured on 21 January who could have been the mother of the juvenile sighted along Sesso Road, as she was banded approximately 500 m to the east. It is possible the abundance of White-tailed Kite prey is not dependent upon rainfall. Prey abundance may remain constant or, as Prugh et al. (2018) found, some plant and animal species may experience a population increase in response to drought. We recommend further study of White-tailed Kite winter breeding attempts in the LRGV as its regularity and causes are not currently understood.

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EXTRALIMITAL BREEDING OF RED-EYED VIREO (*VIREO OLIVACEOUS*) AND CAROLINA CHICKADEE (*POECILE CAROLINENSIS*) IN SAN PATRICIO COUNTY, TEXAS

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Red-eyed Vireos (*Vireo olivaceous*) and Carolina Chickadees (*Poecile carolinensis*) are widespread and familiar oscine Passerine (songbird) species that occur throughout much of eastern North America. Red-eyed Vireos are at times abundant, seemingly ever-present denizens of eastern North American woodlands during the breeding season (spring and summer, exact time frame dependent upon latitude). They range from the Atlantic coast and south-central Florida in the east (Stevenson -and Anderson 1994), to central Texas (Benson and Arnold 2001), and north into the Maritime provinces and south-central Canada (Stewart et al. 2015, Cimprich et al. 2020). In the more northerly latitudes, their range extends locally across northern Oregon (Gilligan et al. 1994), much of Washington (Wahl et al. 2005), and well into Canada (Godfrey 1986; Cimprich et al. 2020).

Carolina Chickadees are endemic to the southeastern continental United States and largely nonmigratory. Familiar “backyard birds” to many, this species breeds in a wide array of forested (Hamel 1992) and suburban habitats (Hadidian 1997, Mostrom et al. 2020). They range from western Oklahoma (Mostrom et al. 2020) east to the Atlantic coast and north to northern Indiana (Keller and Castrale 1998) and Ohio (Peterjohn and Rice 1991). Carolina Chickadees range as far south as central Florida (Florida Fish and Wildlife Conservation Commission 2003) and the central Texas coast (Lockwood and Freeman 2014, Mostrom et al. 2020).

Both Carolina Chickadees (BirdLife International, 2016) and Red-eyed Vireos (BirdLife International, 2019) are Species of Least Concern on the IUCN Red List. According to recent Breeding Bird Survey data, Red-eyed Vireos are experiencing slight and broad population increases range-wide with some locally negative trends in the southern and western portions of their breeding range (Sauer et al. 2017). Carolina Chickadees on the other hand have been exhibiting weakly negative population trends across much of their range (Sauer et al. 2001). Neither species is a focus of much direct conservation concern (Cimprich et al. 2020; Mostrom et al. 2020).

In Texas, Red-eyed Vireos breed throughout much of the eastern and central part of the state, west to the Edwards Plateau and south to central Coastal Bend region (Benson and Arnold, 2001). Carolina Chickadees exhibit a similar, but slightly more widespread breeding range in Texas, extending west to the Edwards Plateau and north to the Panhandle region of north Texas (Benson and Arnold 2001). Birds at these locations are largely resident since this species is nonmigratory (Mostrom et al. 2020). The previously known southern extent of the breeding range of Red-eyed Vireo in Texas is the San Antonio River in Victoria County (Lockwood and Freeman, 2014). Carolina Chickadees are known to be common year-round residents south to northern Live Oak and Aransas Counties on the Coastal Bend (Lockwood & Freeman, 2014). In the southern portions of their range, they are localized and found primarily along riparian drainages (Lockwood and Freeman, 2014).

In this article, I report the confirmed breeding of Red-eyed Vireos and Carolina Chickadees at the Welder Wildlife Refuge in San Patricio County, Texas. The Welder Wildlife Refuge is a privately owned and operated 7800-acre wildlife refuge that is managed by the Rob and Bessie Welder Wildlife Foundation. The observations detailed in this article represent the most southerly known confirmed breeding records of both these avian species in Texas.

OBSERVATIONS

Red-eyed Vireo and Carolina Chickadee were confirmed breeding in an area of the Welder Wildlife Refuge commonly referred to as “Hackberry Mott” (28° 6’ 47” N, -97° 24’ 24.18” W). This section of

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the refuge encompasses an area of approximately 40 acres (as calculated through Google Earth) of mature riparian floodplain forest along the south banks of the Aransas River. Overstory is dominated by hackberry (Celtis occidentalis) and cedar elm (Ulmus crassifolia). This habitat type is consistent with the broad, preferred breeding habitats of Red-eyed Vireos (Cimprich et al. 2020) and Carolina Chickadee (Mostrom et al. 2020), and also consistent with the preference of Carolina Chickadees for riparian drainages in the southern part of their range in Texas (Lockwood and Freeman, 2014).

Linear Transects and Nest Searching (2021)

I conducted thirteen stationary point counts on 2 June 2021 along a linear transect in Hackberry Mott along with a separate area to the east, of similar habitat, along the Aransas River (28° 6' 60" N, −97° 24' 0" W). Point counts were six minutes in length, conducted between 0645 0930 h CDT to target the period of traditionally higher bird activity. They were spaced between 200-250 m apart to minimize multiple detections of the same individual. Nine different singing Red-eyed Vireos were present in Hackberry Mott, and an additional three at the nearby area. Several hours later I observed an adult Red-eyed Vireo in Hackberry Mott carrying food to an obscured portion of a hackberry canopy about 10-15 m high, followed by auditory chick begging calls. Shortly thereafter I witnessed the same individual engage in territorial defense by aggressively attacking a Green Jay (Cyanocorax yncas) that approached too close to the presumed nest location. On 3 June 2021, an adult female Red-eyed Vireo was captured at Hackberry Mott as part of an ongoing Monitoring Avian Productivity and Survivorship (MAPS) banding operation. This individual had a well-developed brood patch, indicating nesting in the immediate vicinity.

I detected four individual Carolina Chickadees in Hackberry Mott during the point count surveys. Two were singing, one was calling, and one was only visually observed. The calling individual was also visually observed and was a young juvenile, suggesting a successful nearby nesting attempt by this species.

Prior reports

The majority of Red-eyed Vireo observations were by song (MWDM, pers. obs.), and frequently of multiple individuals. Repeated song is commonly an indication of a territorial male [although a multitude of research has been conducted on the role of female song too (Odom et al. 2014)], indicating a high likelihood of a breeding pair. Notable summer (June and July) eBird records (Ebird, 2021) include four singing individuals on 6 June 2018 (Michael McCloy), three singing individuals on 2 July 2019 (Brandon Baker, Derek Malone, Michael McCloy), and four singing individuals on 7 July 2019 (Michael McCloy). Seasonally earlier and later records were not included here because this species is a neotropical migrant that is known to be common in the immediate region during migration. Also notable was a nonbreeding (lacking a visible brood patch or cloacal protuberance) adult (After Hatch Year, AHY) Red-eyed Vireo that was captured on 7 June 2007 at Hackberry Mott as part of the MAPS banding operation.

Numerous presence records of Carolina Chickadee exist on eBird for the WWR dating back to 1966 (Gene Blacklock, eBird 2021), many of which are during the summer months. This suggests that Carolina Chickadees are not at the WWR due to a recent range expansion and may in fact have bred here in previous years and decades. One AHY and one Hatch Year (HY, juvenile or immature) Carolina Chickadee were captured together at the Hackberry Mott MAPS banding station on 28 May 2008. The presence of a HY bird at this date indicate that the species likely bred in the immediate vicinity. This timing is consistent with literature that states that eggs of the first brood of this species are typically laid in late March or April, with hatching occurring approximately two weeks later and fledging from 16-19 days after that (Mostrom et al. 2020). Additionally, chick begging was reported from around the WWR Headquarters area (28° 6' 46" N, -97° 25' 2" W) on 13 May 2021 (Joseph Di Liberto, eBird 2021) which is consistent timing with the observation of a young juvenile nearby on 2 June 2021 (Michael McCloy).

IMPLICATIONS

The Aransas River is located at a unique biogeographical cross-section in the Texas Coastal Bend region. It is near the northerly range limits of species such as White-tipped Dove (*Leptotila verreauxi*), Green Jay, Long-billed Thrasher (*Toxostoma longirostre*), and Olive Sparrow (*Arremonops rufivirgatus*), in addition to these aforementioned southerly breeding range limits of species such as Red-eyed Vireo and Carolina Chickadee. Long-term monitoring of the avian populations in this immediate region may therefore provide early insights into range shifts and localized changes in biodiversity that are being experienced due to land use change, climate change, other anthropogenic causes, or a combination thereof. Additionally this highlights the importance of riparian corridors in this region, particularly in the context of avian conservation. This is Welder Wildlife Foundation Contribution number 735

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AMERICAN KESTRELS (*FALCO SPARVERIUS*) WITH ABERRANT PLUMAGE

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We document 2 nestling female American Kestrels (*Falco sparverius*) with aberrant plumage consisting of diminished brown, grey, and black colors with normal rufous pigmentation. Both aberrant kestrels hatched in the same nest box during 2 different years, have the same mother, and presumably inherited the same genetic condition that diminishes eumelanin pigmentation in plumage. We hypothesize these kestrels are either "brown" mutants with incompletely oxidized eumelanin or they express a type of dilute plumage called "isabel", defined as a quantitative reduction of eumelanin.

Avian plumage colors and hues are created by combinations of pigment granules embedded in various arrays within feathers (Lovette and Fitzpatrick 2016). Eumelanin produces black, dark brown, and gray feather colors depending on the density, and distribution (van Grouw 2021). Phaeomelanin (pheomelanin) pigmentation is reddish brown and buff; and carotenoids produce yellow, orange, and red colors. Structural colors are specific arrangements of keratin, pigments and air that refract light to produce blue and iridescent hues (Fox 1976).

Aberrant plumage in wild birds is not uncommon and can arise from several causes: genetic mutations (van Grouw 2021), environmental contaminants (Bortolotti et al. 2003), age (van Grouw 2021), stress, disease, parasites, or injury (Guay et al. 2012), and radiation (Møller and Mousseau 2001). Few accounts of aberrantly plumaged American Kestrels (hereafter "kestrel") are published: a dark melanistic male kestrel (Carpenter and Carpenter 1988), a kestrel with sexually mosaic plumage (Parrish et al. 1987), a male kestrel with random white feathers (Kolodzinski 2020), and an aberrant female kestrel we captured in Texas that shares some characteristics with the kestrels described herein (Morrow and Morrow 2014).

In one of our study area nest boxes, we documented 2 nestling female kestrels with aberrant plumage in 2 separate broods in 2019 and 2021; both kestrels have pale to silvery brownish feathers instead of black and dark brown (Figs. 1a and b). Between 2017 and 2021 we monitored an average of 81 kestrel nest boxes that produce an average of 259 nestlings annually within the Shenandoah Valley Raptor Study Area. A comprehensive description of the study area, our methodology, and productivity is detailed in our paper (Morrow and Morrow 2021). On 19 May 2019, during routine banding of nestlings, we documented the first aberrant female kestrel and photographed her next to her normal plumaged sister (Fig. 1a). Two years later, on 17 May 2021 while banding nestlings at 17 d of age in the same nest box, we identified the second similarly aberrant female. At 97 d of age the 2021 aberrant kestrels' tail feathers (Fig. 1b) had barring that was pale brown to silvery gray interspersed with rufous. By comparison, normal juvenile female kestrel rectrices are barred blackish with rufous (Fig. 1c). Malar stripes and other normally dark feathers of the head and neck were grayish in both aberrant birds, but their eyes, cere, legs and orbital skin were normal, as described by Smallwood and Bird (2020). Overall, both aberrant kestrels' plumage had normal feather patterns, but of a different hue in which the dark colors appear as "washed out" or diluted in intensity.

We confirmed both aberrant kestrels have the same mother, by recapturing the same USGS-banded breeding female in the same box over each of 5 consecutive years (2017-2021). We did not capture a breeding male kestrel during either year that aberrant females hatched. All kestrels observed near the nest box during the past five breeding seasons (presumably the parents) had normal plumage.

Our premise is that both aberrant kestrel nestlings have a genetic condition that alters either

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Figure 1. (a) Comparison of plumage of female American Kestrel siblings: on left is the aberrant female; on the right is her sister with normal plumage 19 May 2019. Photo courtesy of B. Spory; (b) Rectrices of aberrant juvenile female American Kestrel at 97 d on 20 July 2021; (c) rectrices of a normal juvenile female kestrel from the same study area. Photos 1b & 1c by L. Morrow.

production or expression of eumelanin in their plumage; however, we cannot know definitively without genetic or chemical analysis. Many studies have shown there are numerous genes encoding melanic coloration in birds and melanin-based color phenotypes are often associated with inherited mutations of these various melanogenic genes (Roulin and Ducrest 2013). The aberration is likely genetic because the same mother produced both aberrant kestrel chicks and a sibling female chick from the 2019 clutch had normal plumage (Fig. 1a), arguing against an environmental or diet-related cause. First, we hypothesized that these nestling kestrels could be ‘brown’ mutants based on their pale plumage and the fact that only females express altered plumage because of the brown mutation. ‘Brown’ is the most common heritable color aberration in birds and is documented in many avian species (van Grouw 2013). The brown encoding allele is sex-linked recessive in birds, which means that a ‘brown’ individual produced by normal-plumaged parents is always a female (van Grouw 2021). Chemically, the brown mutation is a single point mutation in the tyrosinase-related protein-1 gene (TYRP1) (Kuzumaki et al. 1993), resulting in incomplete oxidation of eumelanin. In brown mutants the density and distribution of eumelanin granules in feathers normal but, since the eumelanin granules are not fully oxidized, plumage looks aberrant with the normally black feathers appearing gray or brown and overall dark colors are less intense (van Grouw 2013). In addition, the abnormal melanin causes brown mutants’ feathers to be more prone to breakage and wear; plus “brown” birds are overly sensitive to sunlight and can bleach to a whitish color within months, causing misidentification of older bleached-out brown mutants (van Grouw 2021).

Figure 2. Aberrant plumage of a female American Kestrel captured in Texas; note overall pale and faded brown spots and barring of plumage, whitish stripe across tail, excessive feather wear and breakage. Photo by L. Morrow.

The aberrant female kestrels from our nest box study in Virginia have similar, but not identical aberrant plumage as the female kestrel we captured in Texas 23 January 2003 (Fig. 2). In our paper about the Texas kestrel's aberrant plumage, we describe her as "dilute" (Morrow and Morrow 2014) even though she had some features of a brown mutant (less intense dark colors faded to white with excessive wear and a broken primary). We did not identify this aberrant Texas kestrel as a brown mutant because several plumage features did not match van Grouw's definition (2013); specifically, she had black malar stripes, a normal (dark) subterminal band and a wide whitish stripe across all her tail feathers. It is probable that the Texas kestrel was indeed a brown mutant who also experienced extraneous influences that further affected her uniquely aberrant plumage.

Our alternate hypothesis is that the 2 aberrant kestrels in Virginia express dilute plumage which is a quantitative reduction of one or both types of melanin pigments (van Grouw 2013). Dilute birds appear paler overall due to one or more mutations of various genes involved in the complex processes of melanin distribution in feathers (Van Grouw 2021). In the 'isabel' form of dilution only eumelanin pigmentation is decreased, causing black and dark brown feathers to be appear pale while reddish (phaeomelanin) colors are unaffected (Van Grouw 2021). Isabel dilution aptly describes the 2 aberrant kestrels' appearance. Inheritance of dilution mutations in kestrels is unclear, but further genetic, chemical, spectrophotometric analysis, or selective breeding could clarify the cause of aberrant plumage in these kestrels.

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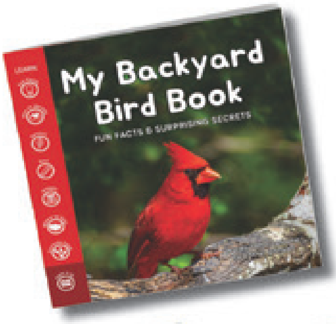

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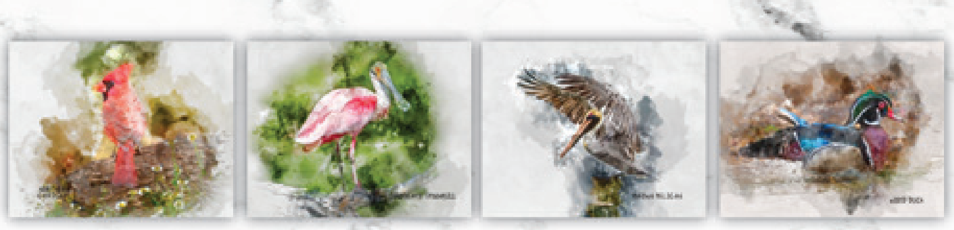

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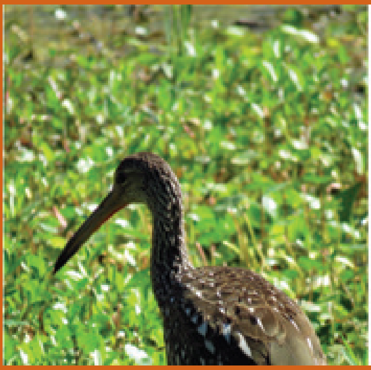
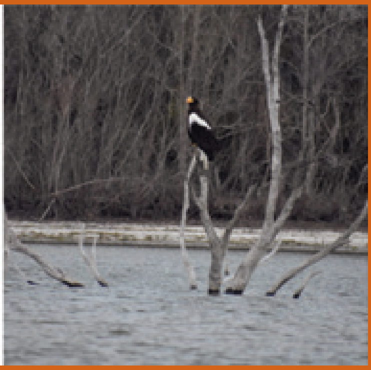


Limpkin



Steller's Sea-Eagle

The TBRC has officially added **Steller's Sea-Eagle** and **Limpkin** to the state list. The acceptance of these species brings the State List to **657** in good standing.

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