Hazardous Speies Mitigation-NASK

Hazardous Species Identification, Attractants, and Mitigations at the Naval Air Station Kingsville, TX

Final Report

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Final Report

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Executive Summary

It is a military aviation facility's priority to provide the safest flying environment possible. Managing habitats on or near military airfields is a key factor in providing this safety margin. The primary military mission of Naval Air Station Kingsville (NASK) is to provide advanced pilot training for future aircraft carrier aviators using T-45 aircraft. Unfortunately, NASK already occurs within a matrix of varying land-uses that may increase avian abundance and use including many large-bodied birds like vultures and other raptors. While it is impossible to keep all birds away from the airfield environment, it is important to determine which species present the greatest risk to aviators, and to manage for those species in ways that keep them away from airfields and flight paths.

Although a large body of research has been conducted relating to bird-aircraft collisions, very few studies have investigated the relationship between bird strikes and activity, weather patterns, and landscape features. Because it was hypothesized that weather patterns and landscape features may be influencing bird strikes and activity at NASK, we (1) monitored avian use of the areas around the airfield by conducting point counts, (2) collected general weather data and micro-site temperature in the areas on and around the airfield, (3) analyzed trends in bird strikes using historic bird/bat-airstrike data, (4) analyzed trends in flight patterns and activity using Doppler radar data collected by the facility, and (5) examined the data for correlations between weather patterns and the flight patterns and activities of birds. We analyzed these data by season and time of day (period), if possible. Below, we report the results of our study and provide recommendations for mitigating the risk of bird-aircraft collisions at NASK.

- *Avian Point Counts* – We conducted avian point count surveys to examine relative abundance of all birds as well as groups of birds (i.e., vultures, other raptors, and other species) by season, period, altitude, and location (agricultural field, riparian area, airfield, other).
    - We observed 73 bird species during our point count surveys. As a group, swallow species were the most detected birds overall. The most detected species in winter were meadowlark spp. (*Sturnella* spp.; 218 detections) and turkey vulture (*Cathartes aura*; 146 detections); in spring were broad-winged hawk (*Buteo platypterus*; 1,229 detections) and swallow spp. (1,187 detections); in summer were swallow spp. (638 detections) and mourning dove (*Zenaida macroura*; 385 detections); and in fall were swallow spp. (500 detections) and blackbird spp. (452 detections).
    - We detected most vultures at 30–100 m (~100–330 ft), most other raptors at >200 m (~650 ft), and most other species at 10–30 m (~30–100 ft).
    - Out of birds that were not flying, most vultures were detected on anthropogenic structures and most other raptors were detected on anthropogenic structures and vegetation. Black vultures (*Coragyps atratus*) and white-tailed hawks (*Geranoaetus albicaudatus*) were usually detected on anthropogenic structures and turkey vultures were rarely detected not flying.
    - Of the flying birds, the majority of vultures were detected over the riparian area, the majority of other raptors were detected over the airfield, and other species were detected mostly over the riparian area.

- Vultures and hawks were most active in the middle of the day during all seasons, except on the agricultural field when vultures were as active or more active compared to other locations during the evenings. Other bird species showed much more variation across and between seasons and locations.

- *Weather Monitoring* – We collected weather data in the riparian area, on the airfield, and in the agricultural field (temperature only).
    - Overall, 2021 was a much wetter and colder year than normal for the Kingsville area. There was an unusually strong cold period in mid-February of 2021 when the temperature repeatedly dropped below 0°C (32°F). From 15 to 19 May, a strong tropical rainfall and wind event occurred at NASK that briefly disabled all weather stations.
    - Average wind gust speeds were highest in spring and during the evening and lowest in fall and during the morning. Winds in spring and summer were mostly out of the east and southeast, respectively. Winds were much more variable in fall and winter and were often out of the southeast like in other seasons.
    - Airfield and agricultural field temperatures were similar across all seasons. The agricultural field was cooler in the summer and warmer in the winter than the riparian area, possibly due to ground cover. The airfield was also warmer in the winter than both the riparian area and agricultural field because it did not cool as much at night.
- *Aircraft Strike Trends* – We used bird/bat-aircraft strike data from October 2010 to September 2021 to examine avian collisions in relation to time (i.e., season and time of day) by species and bird group. We looked at total strikes as well as strikes weighted by respective Relative Hazard Scores (RHSs) which is calculated per species based on percentages of strikes resulting in different levels of damage to fighter aircraft.
    - The species with the highest strike risk scores overall were black vulture, turkey vulture, broad-winged hawk, cliff swallow (*Petrochelidon pyrrhonota*), barn swallow (*Hirundo rustica*), and cave swallow (*Petrochelidon fulva*).
    - The species with the highest strike risk score for winter was black vulture, for spring was broad-winged hawk, for summer was cave swallow, and for fall was turkey vulture.
    - The most-struck species groups were swallows and other songbirds, but when weighted by RHSs, vultures and hawks, kites, owls, and falcons increased in importance.
    - The greatest number of strikes occurred in fall and at night (songbirds), but most strikes with raptors (i.e., vultures and hawks, kites, owls, and falcons) and swallows occurred during the mid-day temporal period.
    - Vulture strike risk was similar across all seasons while strikes with hawks occurred more in spring and fall compared to other seasons.
- *Radar-recorded Bird Movements* – We used data from a MERLIN™ Bird Strike Avoidance Radar System unit to identify temporal trends (i.e., season, period) in overall bird activity (i.e., the number of birds, referred to as targets) and direction of movement from horizontal scanning radar and altitudinal activity under 610 m (2000 ft).

- HSR: Mean targets per hour was greatest in spring and fall, and peak activity during these seasons occurred at night. Target passage rates recorded by the radar were greater for nocturnal than diurnal periods in spring, summer, and fall.
- VSR: Approximately 1/3 of targets occupied the low-altitude class (0–213 m [0–700 ft]), with 13% in the lowest band (i.e., 0–91 m [0–300 ft]) and 22% in the band from 91–213 m (300–700 ft). More than 65% of targets occupied the high-altitude class (213–610 m [700–1,200ft]), with 25% in the 213–366 m (700–1,200 ft) band and 41% in the 366–610 m (1,200–2,000 ft) band.
- The lowest activity below 610 m (2000 ft) occurred in the morning for all seasons and was highest in spring during the night.
- Activity within the lower altitudinal class (VSR) was highest in spring and fall during mid-day or at night. Activity in the morning was low overall but was slightly higher in the lower altitudinal class in spring and fall. The most activity in the evenings occurred in winter within both altitudinal classes.

- *Bird-Weather Trends* – We examined the relationship between bird activity from the scanning radar and weather patterns to determine if they were correlated within seasons and periods. The data allowed us to predict which weather characteristics correlated with high bird activity both overall (HSR) and in the four altitudinal bands (VSR).
  - Spring

	Morning	**Mid-Day**	**Evening**	**Night**
Overall Activity	Higher Temperature & Falling BP	Higher Temperature & Winds out of the WSW, SW, SSW, and S	Higher Temperature, Lower Wind Speeds, SE Winds & Rising BP	Higher Temperature & Lower Wind Speeds
0-91 m (0-300 ft)	-	Southerly Winds	SE Winds	Higher Wind Speeds
91-213 m (300-700 ft)	SE Winds	SW Winds	NW or SE Winds	SE Winds & Rising BP
213-366 m (700-1200 ft)	SE Winds	Southerly Winds	NW Winds	Southerly Winds & Rising BP
366-610 m (1200-2000 ft)	Decreasing Temperature & SE Winds	Higher Temperature & Southerly Winds	Lower Wind Speeds, Winds out of the NW or SE & rising BP	Lower Wind Speeds, SW Winds & Rising BP

  - Summer

	Morning	**Mid-Day**	**Evening**	**Night**
Overall Activity	Higher Temperature & Lower Wind Speed	Lower Wind Speed, Southerly Winds & Rising BP	Lower Wind Speeds & SE Winds	Higher Temperature, Lower Wind Speeds, & Winds out of the N
0-91 m (0-300 ft)	-	Lower Wind Speed	Higher Temperature	Lower Temperature & Falling BP
91-213 m (300-700 ft)	Rising BP	Lower Wind Speed and NW Winds	Lower Temperature & NE Winds	Higher Temperature & Rising BP
213-366 m (700-1200 ft)	Higher Temperature	Higher Temperature, NW Winds & Rising BP	Lower Temperature & NE Winds	Higher Temperature, Lower Wind Speeds, & Rising BP

366-610 m (1200-2000 ft)	Higher Temperature	Higher Temperature & Lower Wind Speeds	Lower Temperature & NE Winds	Higher Temperature, Lower Wind Speeds, Winds out of the N & Rising BP

- Fall

	Morning	**Mid-Day**	**Evening**	**Night**
Overall Activity	Higher Temperature, Lower Wind Speed, Winds out of the N & Falling BP	Higher Temperature, Lower Wind Speed, Winds out of the N & Rising BP	Higher Temperature, Lower Wind Speeds, & Winds NOT out of the SE	Higher Temperature, Lower Wind Speed, Winds NOT out of the SE & Rising BP
0-91 m (0-300 ft)	Lower Temperature & Lower Wind Speeds	Lower Temperature & Lower Wind Speed	Winds NOT out of the SE	Winds NOT out of SW & Rising BP
91-213 m (300-700 ft)	NW Wind & Rising BP	Lower Temperature, Higher Wind Speed & Winds out of the W	Winds NOT out of the SE	Higher Temperature & Rising BP
213-366 m (700-1200 ft)	Higher Temperature, Lower Wind Speed, NW Wind & Rising BP	Higher Wind Speed & Winds NOT out of the NE	Winds NOT out of the SE	Higher Temperature, Lower Wind Speed, & Rising BP
366-610 m (1200-2000 ft)	Higher Temperature, Lower Wind Speed, NW Wind & Rising BP	-	Winds NOT out of the SE	Higher Temperature, Lower Wind Speed & Rising BP

- Winter

	Morning	**Mid-Day**	**Evening**	**Night**
Overall Activity	NW Winds	Higher Temperature & Lower Wind Speed	Higher Temperature & Lower Wind Speed	Higher Temperature, Lower Wind Speed, Winds NOT out of the SE & Rising BP
0-91 m (0-300 ft)	Lower Wind Speed & SE Winds	Higher Temperature, Lower Wind Speed & Winds out of the W	Higher Temperature	Higher Temperature
91-213 m (300-700 ft)	Lower Wind Speed & NW Winds	Higher Temperature, Lower Wind Speed, Winds out of the NW, & Falling BP	Higher Temperature & Lower Wind Speed	Higher Temperature, Winds NOT out of the SE & Rising BP
213-366 m (700-1200 ft)	-	Higher Temperature, Lower Wind Speed, Winds out of the SE & Falling BP	Higher Temperature & Lower Wind Speed	Higher Temperature, Winds NOT out of the SE & Rising BP
366-610 m (1200-2000 ft)	-	Higher Temperature, Lower Wind Speed, Wind out of the SE & Falling BP	Higher Temperature, Lower Wind Speed & Winds out of the NW	Higher Temperature, Winds NOT out of the SE & Rising BP

Factors Associated with Increased Strike Risk

- Several factors are known to increase risk of collisions between birds and aircraft including the makeup of the surrounding landscape, avian species using the airspace, avian abundance, time of year (i.e., migration, breeding, wintering), and weather.

        - Landscape – We conducted a review of the literature to better understand how the area surrounding NASK may be influencing the presence, abundance, and use of the area by vultures, raptors, and birds in general.
        - Seasonal Changes and Weather – We then conducted a review of the literature to better understand how the different seasons, along with migration and weather, can influence the presence and abundance of birds overall in the area as well as at lower altitudes near the airfield.

Summary and Recommendations

- Habitat Management
    - The landscape features surrounding the NASK Main Station, including the city of Kingsville to the west, extensive croplands to the north and east, and the Tranquitas, San Fernando, and Santa Gertrudis creeks that run along the northern, eastern, and southern boundaries of the installation, respectively, all contribute to the high bird activity in the area. Each one of these land uses has been found to increase bird strike risk individually, but research also suggests that this matrix of varying land uses on the landscape elevates the likelihood of bird strikes even higher.
    - Additionally, the arrangement of the airfield, riparian corridors, and croplands may be creating thermal columns that are used by vultures, other raptors, and swallows near the airfield. This effect may be even greater in the winter when the croplands have been plowed.
    - Given the likely contribution of the cropland, cropland edges, and the diversity of the landscape uses in the area to the elevated bird abundance, a potential solution could be to decrease the amount of cropland near the airfield and encourage farmers to plant crops that are less attractive to birds.
    - The role of the landfill that lies ~5 km (2.5 mi) to the south of the airfield in attracting large-bodied birds such as black and turkey vultures is unclear without further research that examines detailed use and movement by the birds in the area.
    - Although we detected more turkey vultures than black vultures during our study, black vultures were struck as often as turkey vultures at NASK. This could be because black vultures use the area within the flight path or fly at the same altitude as NASK aircraft more often than turkey vultures. Furthermore, we detected more black vultures than turkey vultures in the area that were not flying, which may indicate that black vultures are using lower altitudes in the landing path more often than turkey vultures.
    - Reduction in foraging opportunities for vultures and other raptors is critical. Actions to reduce the amount of raptor and vulture food resources in the area will likely further help decrease the abundance of vultures and other raptors near the airfield. This includes removing crops that attract fewer small mammals (e.g., mice, rabbits) to decrease use of the area by hawk spp. and crops that attract fewer large mammals (e.g., wild hogs, deer) that are susceptible to automobile collisions to decrease the use of the area by vultures.

  - A critically important management action to deter vultures would be to promptly remove any road-killed or other dead animals within 3 km of the airfield.
  - Airfield managers can also manipulate woody vegetation located near airstrips. Woody trees and shrubs provide important habitat for birds, and removing or altering this vegetation is recommended to reduce the number of perching, foraging, nesting, and roosting sites available to nuisance species near airfields.
- Seasonal Changes and Weather (Avoidance)
  - The strike risks were multitudes higher during spring and fall migration, when hundreds of thousands of small and large birds move through the region. Under ideal weather conditions for migration, most of the birds that move through the area stay at very high altitudes; however, certain weather conditions cause the birds to move to lower altitudes or remain in the area for a few hours up to several days.
  - At this time, guidelines dictate that flight activity is suspended when HSR TPR is ≥1,160; however, these mitigation strategies are set to soon change. Therefore, we do not provide precise values for when weather conditions will likely cause a cessation of flight activity.
  - Instead, we have provided trends and guidance for weather changes (temperature, wind direction, wind speed, and changes in BP) that indicate when activity in the area overall and within the lower altitudes surrounding the airfield will likely be elevated within a particular season.

Further Research Needs –

- We can provide more detailed recommendations for avoiding bird strikes related to weather to managers once the new mitigation strategy guidelines for suspending flight activity are released and available.
- A more time-intensive research study is needed to better understand why black vultures are being struck so often in the AOC.
- More research is needed to understand if thermal uplift in the area can be reduced through alteration of croplands or the riparian areas, including the AOC, and what those land cover changes should look like.

Purpose

We investigated the relationship between bird strikes and activity, weather patterns, and landscape features at the Naval Air Station Kingsville Main Station to identify factors leading to increased bird-aircraft strike risk within the area of concern (AOC) and provided recommendations for mitigating risk. The objective of this project was to identify attractants and present solutions to decrease strike hazards from large-bodied avian species (vultures and other raptors) that frequent the AOC airspace. To accomplish this goal, we (1) conducted avian point counts, (2) collected and analyzed weather data, (3) identified trends in bird strikes and activity using existing strike and avian-radar datasets, and (4) examined the relationship between bird activity and weather patterns. We conducted our research in coordination with the Naval Facilities Engineering Command, Atlantic and Naval Air Station Kingsville personnel including the USDA-WS Airport Biologist and the Natural Resources Program Manager under Cooperative Agreement #N62470-20-2-2009.

Introduction

It is a military aviation facility's priority to provide the safest flying environment possible. Managing habitats on or near military airfields is a key factor in providing this safety margin. The primary military mission of Naval Air Station Kingsville (NASK) is to provide advanced pilot training for future aircraft carrier aviators using T-45 aircraft (NASK 2018). As such, a major concern for the installation is mitigating the risk of aircraft strikes with birds and other wildlife. NASK has been actively pursuing Restrictive Easements to provide for the necessary protection and safety of airport operations by preventing development and natural growth that are incompatible air operations and security (i.e., Air Installation Compatible Use Zones Program, OPNAV 11010.36.c and DoDI 4165.57). Unfortunately, NASK already occurs within a matrix of varying land-uses that may increase the abundance and use by many large-bodied birds including vultures and other raptors.

Data from Air Operations suggests that aircraft conducting local flight operations encounter large birds disproportionally at the approach to runways 13L and 17R, the area of concern (AOC). There are a number of factors that are suspected to sustain a large local vulture population within close proximity of the airfield, including a local landfill located three miles south and several communication towers that provide roosting habitat. It is likely that a large percentage of the birds responsible for strikes do not reside on the NASK but are transitioning through the AOC. In addition to supporting a large number of wintering and breeding bird species, NASK is located in the main flightpath of the Central Flyway bird migration route. Every spring and fall, hundreds of thousands of birds migrate through the NASK airspace.

While it is impossible to keep all birds away from the airfield environment, it is important to determine which species present the greatest risk to aviators, and to specifically manage those species in ways that keep them away from airfields and flight paths. Military airfield managers can target resources to help decrease problem wildlife by enhancing habitats away from the active airfield area as well as decreasing features near the airfield that attract these species.

Although a large body of research has been conducted relating to bird-aircraft collisions, very few studies have investigated the relationship between bird strikes and activity, weather patterns, and landscape features. Because it was hypothesized that weather patterns and landscape features may be influencing bird strikes and activity at NASK, we (1) monitored avian use of the areas around the airfield by conducting point counts, (2) collected general weather data and micro-site temperature in the areas on and around the airfield, (3) analyzed trends in bird strikes using historical bird/bat-airstrike data, (4) analyzed trends in flight patterns and activity using Doppler radar data collected by the facility, and (5) examined the data for correlations between weather patterns and the flight patterns and activities of birds. Below, we report the results of our study and provide recommendations for mitigating the risk of bird-aircraft collisions at NASK.

Study Area

We conducted our research at the NASK Main Station, an approximately 3,346 ac (1,354 ha) military installation located 43 miles (69 km) southwest of Corpus Christi, Texas and approximately 3 mi (5 km) southeast of Kingsville, Texas in Kleberg County, Texas. The Main Station is located in the Western Gulf Coastal Plain Level III Ecoregion, an area distinguished by its relatively flat topography and grassland potential natural vegetation (Griffith et al. 2007). The climate in the Kingsville area is generally hot and dry (<772 mm [31 in] of rainfall per year) (Vose et al. 2014). The wettest month is typically September (130 mm [5.2 in]), and the driest months are February and December (37 mm [1.5 in]) (Vose et al. 2014). Maximum temperatures in the summer average around 35°C (95°F) while average high winter temperatures are around 21°C (70°F) (Vose et al. 2014). Average temperature lows range from 8°C (46°F) in January to 24°C (75°F) in August (Vose et al. 2014).

The Main Station is comprised mostly of the active airfield and airfield support facilities but also contains a developed area, agricultural outleases, and wooded riparian and hunting areas. The airfield consists of runways oriented in north-to-south (17R) and northwest-to-southeast (13L) directions surrounded by grassy fields. Tranquitas Creek and its associated riparian area lie to the north and northwest of the airfield, and the San Fernando Creek lies to the east and southeast. North of Tranquitas Creek lies an agricultural outlease where cotton was grown in 2021. Beyond the perimeter of the installation, high landscape diversity (e.g., agricultural fields, creeks and associated riparian and wetland areas, a landfill) may be contributing to bird-aircraft strike risk. The main crops grown in the area surrounding NASK include cotton, milo, and corn.

Approach

We conducted avian point counts to identify and examine the relative abundance of bird species using different altitudes and locations in the NASK airspace, particularly in the AOC, by season and time of day. We monitored temperature on the airfield, in the Tranquitas Creek riparian area, and in the agricultural outlease north of the Tranquitas Creek to collect weather data and to identify differential heating and cooling patterns between the three areas that may be influencing airflow and thermal uplift in the NASK airspace. We also collected general weather information by season. We used existing bird-strike records from NASK from the past 10+ years to examine avian collisions and calculate overall and seasonal species-specific strike risk as well as to examine seasonal and temporal patterns in strikes by species group. We also used existing Doppler radar data to examine trends in bird activity both overall and below 610 m (2000 ft) in the NASK airspace. Finally, we examined the relationships and trends between bird activity and weather patterns using the radar and weather data. Unless otherwise indicated, we used the open-source program Rstudio v. 2021.09.0 statistical package (R Core Team, Vienna, Austria) for all statistical analyses and ArcMap v. 10.3.1 (Environmental Systems Research Institute, Redlands, CA) for all spatial analyses and mapping.

Methods

Avian Point Counts

We conducted 30-minute point counts at two locations (Figure 1) three times per day (i.e., period; morning, mid-day, and evening) and two days per month for one year, resulting in 144 total 30-minute point counts. Point 1 at the northwest end of 13L (Figure 1) allowed the observer to see birds within the AOC above the Tranquitas Creek riparian area as well as the agricultural field to the north and on the airfield to the south. Point 2 on the east side of the airfield (Figure 1) allowed the observer to see birds that were using the space in the middle of the airfield. We conducted our first point counts in December 2020 and our last in November 2021. We began morning point counts approximately one hour after sunrise, mid-day point counts at 1230 hours, and evening point counts approximately two hours before sunset. During each point count, a single observer recorded all species detected, the number of individuals of each species, and the altitude (i.e., not flying, 0–2 m, 2–10 m, 10–30 m, 30–100 m, 100–200 m, >200 m) and location of individuals. For birds that were not flying, we recorded location as anthropogenic structure (e.g., utility pole, building), fence, ground, or vegetation, and for birds that were flying, we recorded location as airfield, riparian, agricultural, or other (i.e., the area near Point 2 that is neither a riparian area nor part of the airfield) based on which area the bird was flying over (Figure 1).

We used point count results to examine the relative abundance of all birds, groups of birds (i.e., vultures, other raptors, and other species), and individual species by season, time of day, altitude, and location. When reporting on the location of flying birds, we subset the data to include only detections of birds flying over the riparian area and agricultural field from Point 1 and birds flying over the airfield and other area from Point 2 (Figure 1). The datasheet used to record avian point count data can be found in Appendix A1.

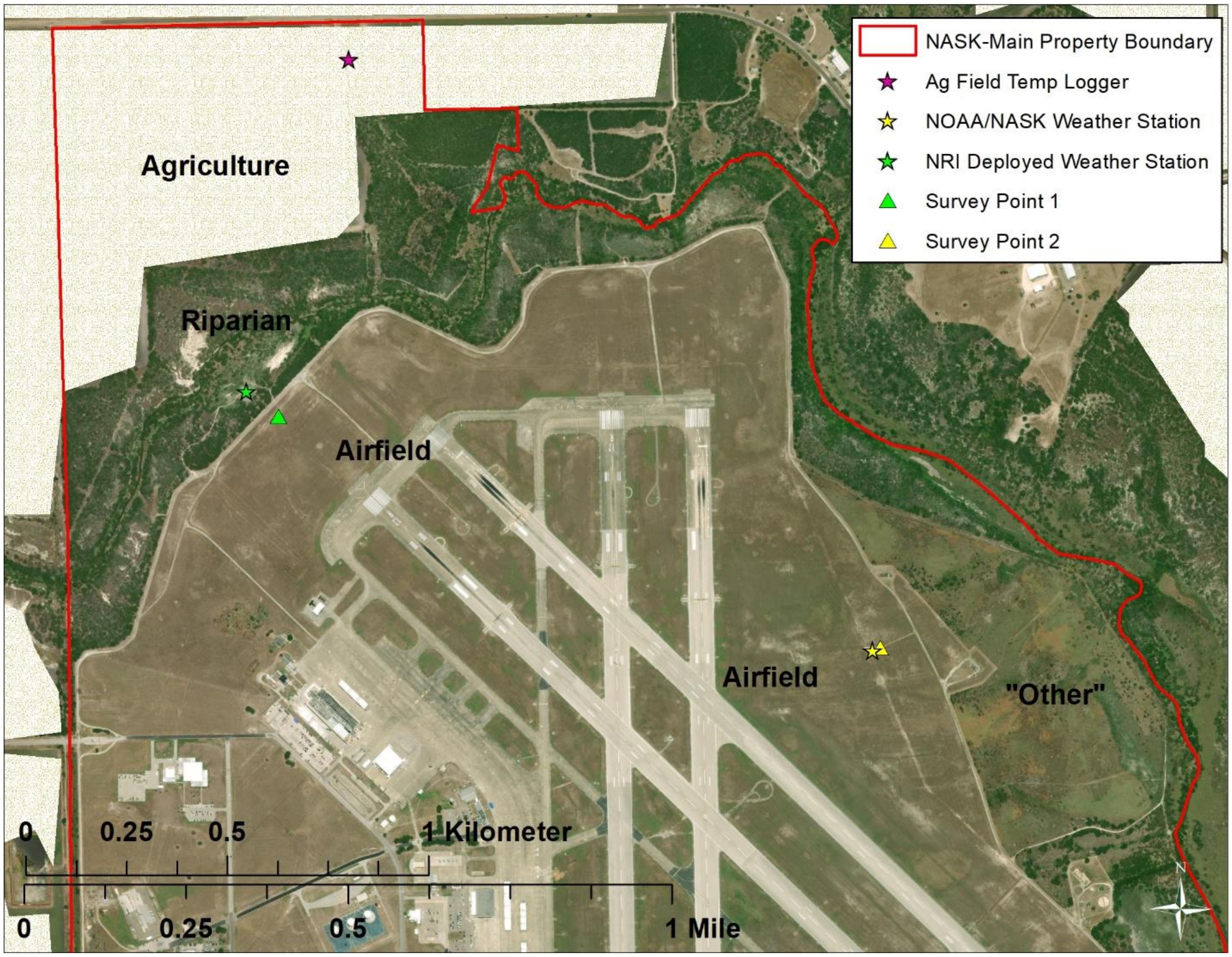


Figure 1. Locations of weather stations, avian point counts, and classifications used during point counts for "location" (agriculture, airfield, riparian, other) at Naval Air Station Kingsville, Texas.

Weather Monitoring

We collected weather data in three locations: (1) near Bird Survey Point 2 (N 27° 30’32.2488 W 97° 48’14.7744), (2) in the riparian area on the northwest end of runway 13L (N 27° 30’53.6832 W 97° 49’11.3628), and (3) on the agricultural field at the north end of the NASK property (N 27° 31’20.3880 W 97° 49’01.7328; Figure 1). The National Oceanic and Atmospheric Administration (NOAA) operates the airfield weather station (hereafter airfield; station id 72251612928), and data for this station was acquired from the NOAA National Centers for Environmental Information dataset (Vose et al. 2014). The data downloaded were from hourly reports of temperature (°Celsius [℃]), precipitation (millimeters [mm]), wind speed (meters per second [m/s]), wind direction (angular degrees), relative humidity (%), and barometric pressure (BP; hectopascals).

On 9 November 2020, we installed a HOBO RX2100 station (Onset Corporation; Figure 2) in the riparian area that used 4G cell transmission, solar charging, and a variety of sensors mounted on a tripod mounting system to upload weather information every five minutes. Data recorded and uploaded included temperature (℃), rainfall (mm), average and gust wind speeds (m/s), wind direction (angular degrees), BP (millibars [mbar]), relative humidity (%), and dew point (℃). The weather station was deployed in an open, unobstructed location away from nearby trees or buildings. The weather station, including sensors, was placed according to deployment guidelines provided by Onset Corporation (https://www.onsetcomp.com/files/Weather_Stations_Guide.pdf).

Figure 2. Riparian weather station deployed by Texas A&M University on the northwest end of the airfield at Naval Air Station Kingsville, Texas.

In addition to the two larger weather stations, we deployed a HOBO MX2300 temperature logger (Onset Corporation) in the agricultural field on 9 December 2020. The temperature logger is a weatherproof stand-alone sensor that uses Bluetooth low energy to allow data downloads directly to a mobile device. We attached the logger to a post in the middle of the agricultural field just to the north of the riparian area (Figure 1). Temperature readings (℃) were recorded every 5 minutes by the data logger and were downloaded monthly. Temperature measurements recorded simultaneously in three locations (airfield, riparian, agricultural field) allowed us to observe and analyze rates of temperature increase or decrease in the three areas.

In May of 2021, a strong tropical system moved through the Kingsville area bringing extreme heavy rainfall and high winds. In addition to the NOAA weather station temporarily going offline, the riparian weather station was flooded and stopped recording on 19 May 2021 at 08:18. A new data logger was installed and deployed on 3 June 2021 at 09:45. However, the wind sensor was no longer communicating with the logger and no wind information was available in the riparian area after that date. The agricultural field temperature logger stopped working for unknown reasons on 5 August 2021 and was not repairable. Therefore, we relied on the NOAA weather station on the airfield for general weather data that was used for general weather summaries and for analyses of avian behavior trends as they related to general weather patterns. Comparisons of temperatures between the three areas were limited to spring and winter although we were able to compare airfield and riparian temperatures for every season.

We summarized and compared weather data (temperature, wind speed, wind direction, BP, and rainfall) by season and time of day. We compared average temperatures for the airfield, riparian area, and agricultural field (when available) and wind speeds for the airfield and riparian area using two-way interactive ANOVA. We then examined pairwise differences post hoc using Tukey's HSD test. We examined directional trends (i.e., wind direction), by calculating the mean direction of wind and the mean resultant length ($\bar{R}$) during each period (i.e., morning, mid-day, evening, night) by season. The mean resultant length is a measure of directional strength with values closer to one indicating strong directionality, with similar angles throughout, and values closer to zero indicating weak directionality. We used a Rayleigh's test to examine the uniformity of directions within seasons and periods. In order to compare heating and cooling differences between the airfield, riparian area, and agricultural field we first calculated change in temperature every hour by season and time of day. We then compared these values using two-way interactive ANOVA to determine if temperature changes were significantly different.

Aircraft Strike Trends

We used NASK strike records obtained from Eddie Earwood, USDA-WS Airport Biologist, to calculate overall and seasonal species-specific strike risk as well as to examine seasonal and temporal patterns in strikes by species group (e.g., pigeons and doves, vultures). For all strike analyses, we only included strikes on birds and bats where the species involved in the strike was identified. For overall strike risk we used strike records from October 2010–September 2021, and for seasonal strike risk we used strike records from winter 2010/2011–summer 2021. We assigned strikes from the months of December, January, and February to the season of winter, strikes from March, April, and May to spring, strikes from June, July, and August to summer, and strikes from September, October, and November to fall. We then used the following equation (identified in DeVault et al. 2018) to calculate overall and seasonal strike risk per species: $RHS^2 \times Strikes^2$. RHS, or relative hazard score, is calculated per species based on percentages of strikes resulting in different levels of damage, and we used the RHSs for fighter aircraft reported in Pfeiffer et al. (2018a). For species not included in Pfeiffer et al. (2018a), we input the body mass of the species into the equation for fighter aircraft identified in Pfeiffer et al. (2018a) to calculate RHS. The strike metric refers to the number of strikes per species, scaled to 100 (DeVault et al. 2018).

To examine seasonal and temporal patterns in strikes, we used strike records from October 2010–September 2021 and looked at total strikes as well as strikes weighted by respective RHSs. We assigned strikes to four temporal periods based on the reported time of strike: morning (sunrise to 3 hours after sunrise), mid-day (3 hours after sunrise to 3 hours before sunset), evening (3 hours before sunset to sunset), and night (sunset to sunrise).

Radar-recorded Bird Movements

A MERLIN™ Bird Strike Avoidance Radar System unit (DeTect Inc., Panama City, FL), located at the NASK Main Station, recorded the number of birds (referred to as targets) passing horizontal and vertical scanning radars at hourly intervals from 10 November 2020–30 November 2021 (9,264 hours; Table 1). The horizontal scanning radar (HSR) tracked low-flying targets within a circle around the unit and recorded the direction of the target's movements. The vertical scanning radar (VSR) tracked the number of targets within four altitudinal bands (i.e., 0–91 m [0–300 ft], 91–213 m [300–700 ft], 213–366 m [700–1,200 ft], 366–610 m [1,200–2,000 ft]) above the unit.

Table 1. Survey effort (hours) by horizontal and vertical scanning radars from 10 November 2020–30 November 2021 at MERLIN™ radar site at Naval Air Station Kingsville, Texas.

Radar	Survey period	No data recorded[a]	Rain[b]	Other excluded[c]	Usable Intervals[d]	% usable intervals[e]	Time recorded[f]	% interpolated[g]
HSR	9,264	83	11	72	9,181	99.1%	9,099.4	<1%
VSR	9,264	514	79	435	8,750	94.5%	8,618.4	<2%

a Number of hour intervals when radars recorded 0 minutes (i.e., downtime).
b Number of hour intervals when rain occurred for >30 minutes.
c Number of hour intervals when <30 minutes recorded or when the number of targets recorded = 0.
d Number of hours when radars recorded ≥30 minutes and rain occurred ≤30 minutes.
e [(Hours with usable data)/(hours in survey period)] * 100
f Total minutes recorded during usable hours/60 min/h.
g Percent data interpolated assuming homogenous detection within each interval = {[(Actual time recorded)/(hours with usable data)] * 100} – 100.

Though the MERLIN™ unit was in place throughout the survey period, there were intervals when the radars were not operational (i.e., hours in which no data were recorded; Table 1) and when data may have been compromised (i.e., hours when rain events lasted ≥60 minutes; Table 1). We removed such intervals from the horizontal and vertical datasets, then we visually examined the remaining intervals to identify any potential errors. We identified 72 intervals when the HSR was not recording and 79 intervals when the VSR was not recording. As many of these intervals were consecutive, we assumed the lack of records represented radar error. Many of these intervals occurred in May 2021 during a tropical weather event. Among the remaining usable intervals were instances wherein the radars did not record continuously for the full 60 minutes. We included these intervals in all analyses but used interpolated target count data provided by DeTect (i.e., the makers of the MERLIN™ system) to represent the unrecorded time assuming a homogenous distribution of targets throughout each interval. We determined the percentage of interpolated data included as the actual time recorded in hours divided by the total number of hours with usable data. Interpolated counts accounted for <2% of the data recorded by the HSR and <1% of the data recorded by the VSR (Table 1).

To identify temporal trends in bird movements, we calculated the mean number of targets recorded per hour, per day by the HSR and VSR throughout the survey period and plotted the daily rates for both radars on the same graph as a time series. We also graphed the predicted number of targets recorded per radar by hour and season. We then collapsed the hourly data into morning, mid-day, evening, and night (nocturnal) periods. We identified the sunrise and sunset times for each day and considered the hours from sunrise to three hours post sunrise as morning, the three hours before sunset as evening, the other daylight hours as mid-day, and the hours from sunset to sunrise as night periods. We used the 30-min mark to represent cutoffs within each interval. For example, we considered 0600–0700 a morning period if sunrise occurred during the first half of the hour and a night period if sunrise occurred in the latter half of the hour. Similarly, we considered the 1800–1900 interval a night period if sunset occurred in the first half of the hour and an evening period if sunset occurred in the latter half of the hour. We calculated the target passage rates (TPRs) for each radar by period for each day by dividing the number of targets recorded by the number of intervals included. We also examined directional trends (i.e., direction of target travel over the airfield) using target data recorded by the HSR. We used these values to calculate the mean TPR for each period for each radar per season and tested for differences in TPR between seasons and periods using a two-way interactive ANOVA. We then examined pairwise differences post hoc using a Tukey's HSD test.

Lastly, we examined altitudinal trends in target movements. Because most bird-aircraft collisions in the United States occur at ≤152 m (500 ft) (Dolbeer 2006), we divided altitudinal bands into two classes representing differences in the risk of strikes and associated damages: low-altitude (0–213 m [0–700 ft]) and high-altitude (213–610 m [700–2000 ft]).We assume the risk of bird strikes is greater in the low-altitude class, based on Dolbeer (2006), but we do not refer to the classes as high (or low) risk because altitude data regarding strikes at NASK were not available to us at the time of writing.

We calculated the mean number of targets recorded per hour, per day in each altitude class throughout the survey period and plotted the daily rates on a graph as a time series. We also graphed the predicted number of targets per altitude class by hour and season. We then collapsed the hourly data into periods as described above. We calculated the TPRs for each altitude class by period for each day by dividing the number of targets recorded by the number of intervals included. We used these values to calculate the mean TPRs within each altitude class for all seasons and periods and tested for differences in TPR between seasons and periods using a two-way interactive ANOVA. We then examined pairwise differences post hoc using a Tukey's HSD test.

Bird-Weather Trends

We examined the relationship between bird activity and weather patterns to determine if they were correlated within seasons and periods. We first examined if one or multiple weather variables correlated with overall bird activity as indicated by TPR from the MERLIN™ HSR. We then examined if one or multiple weather variables correlated with bird activity at the four altitudinal bands (VSR) defined in the previous section (i.e., 0–91 m [0–300 ft], 91–213 m [300–700 ft], 213–366 m [700–1,200 ft], 366–610 m [1,200–2,000 ft]). In order to assess which weather variables correlated with bird activity, we first examined relationships using multiple linear regression with passage rate as the response variable and the weather variables (mean temperature, wind speed, ordinal wind direction [NE, SE, NW, SW] and change in BP) as the potential explanatory variables. We evaluated change in BP by calculating the change over three hours.

Multiple linear regression is used to assess the relationship between two variables while accounting for the effect of other variables. This allowed us to cancel out the effects of other weather variables so we could isolate and measure the relationship between the two variables of interest (passage rate and each individual weather variable). Once we checked that all linear model assumptions were met (i.e., normality of residuals, no multicollinearity, homoscedasticity), we performed a multiple regression test using *lm* function of the *stats* base package. We used stepwise selection in the R package MASS with both forward and backward selection to identify the best model, which we defined as the model with the fewest number of variables with an Akaike Information Criterion (AIC) value within 2 of the lowest AIC value. We then examined the R^2 value (goodness of fit), F statistic (if model is better fit than intercept only), and standard error of the regression to determine how useful the models were for explaining changes in passage rate.

Once we analyzed general trends in weather and bird activity, we analyzed each weather variable individually with more detail to understand any nuance that could be helpful for avoiding bird strikes throughout the year. Each detailed weather variable was analyzed alongside TPR to evaluate overall activity (HSR) and activity in the two lowest altitudes, 0–91 m and 91–213 m (VSR). We used these values to calculate the mean TPRs for each season and period and tested for differences in TPR using a two-way interactive ANOVA. We then examined pairwise differences post hoc using a Tukey's HSD test. We divided wind direction into 16 categories (NNW, NW, WNW, W, WSW, SW, SSW, S, SSE, SE, ESE, E, ENE, NE, NNE, N) instead of the four ordinal directions used for regression modeling. We categorized wind speed on the Beaufort Force scale (Table 2), which is an empirical measure that relates wind speed to visual observations. This allowed us to relate wind speed to what the birds may have been experiencing and reacting to by changing their altitude and behavior. We categorized change in BP over three hours according to meteorological definitions of how much change is considered high, moderate, low, or steady (Table 3Table 2). We evaluated the impact of rainfall by day (i.e., days with measurable rain vs. days with no rain) on passage rate by season. We also plotted daily average temperatures against daily average passage rate.

Table 2. Categories of Beaufort scale and associated speed in meters per second (m/s) and miles per hour (mph) and description of the category.

Beaufort Force	Speed		Description
	m/s	mph	
0	<0.3	0-1	Calm - smoke rises vertically
1	0.3-1.5	1-3	Light Air - direction of wind shown by smoke drift
2	1.6-3.3	4-7	Light Breeze - leaves rustle
3	3.4-5.5	8-12	Gentle Breeze - leaves and small twigs in constant motion
4	5.6-7.9	13-18	Moderate Breeze - raises dust & small branches are moved
5	8.0-10.7	19-24	Fresh Breeze - small trees begin to sway
6	10.8-13.8	25-31	Strong Breeze - large branches in motion
7	13.9-17.1	32-38	Near Gale - whole trees in motion
8	17.2-20.7	39-46	Gale - breaks twigs off trees
9	20.8-24.4	47-64	Sever Gale - slight structural damage occurs
10	24.5-28.4	55-63	Storm - seldom experienced inland; trees uprooted
11	28.5-32.2	64-72	Violent Storm - wide-spread damage
12	32.3-37.1	72-83	Hurricane

Table 3. Categories of change in barometric pressure over three hours.

Category	Barometric Pressure Change over 3 Hours (mbars)
Rapid Decrease	-10.0 to -6.1
Moderate Decrease	-6.1 to -1.4
Low Decrease	-1.4 to -0.1
Steady	-0.1 to 0.1
Low Increase	0.10 to 1.4
Moderate Increase	1.4 to 6.1
Rapid Increase	6.1 to 10

Results

Avian Point Counts

We observed 73 bird species during our point count surveys (Table B1.1). As a group, swallow species (spp.) were the most detected birds overall (2,328 detections). The most detected species in winter were meadowlark spp. (*Sturnella* spp.; 218 detections) and turkey vulture (*Cathartes aura*; 146 detections). The most detected species in spring were broad-winged hawk (*Buteo platypterus*; 1,229 detections) and swallow spp. (1,187 detections). The most detected species in summer were swallow spp. (638 detections) and mourning dove (*Zenaida macroura*; 385 detections). The most detected species in fall were swallow spp. (500 detections) and blackbird spp. (452 detections). We detected the most vultures and other raptors in spring and during mid-day surveys, while other species were more variable (Figure 3).

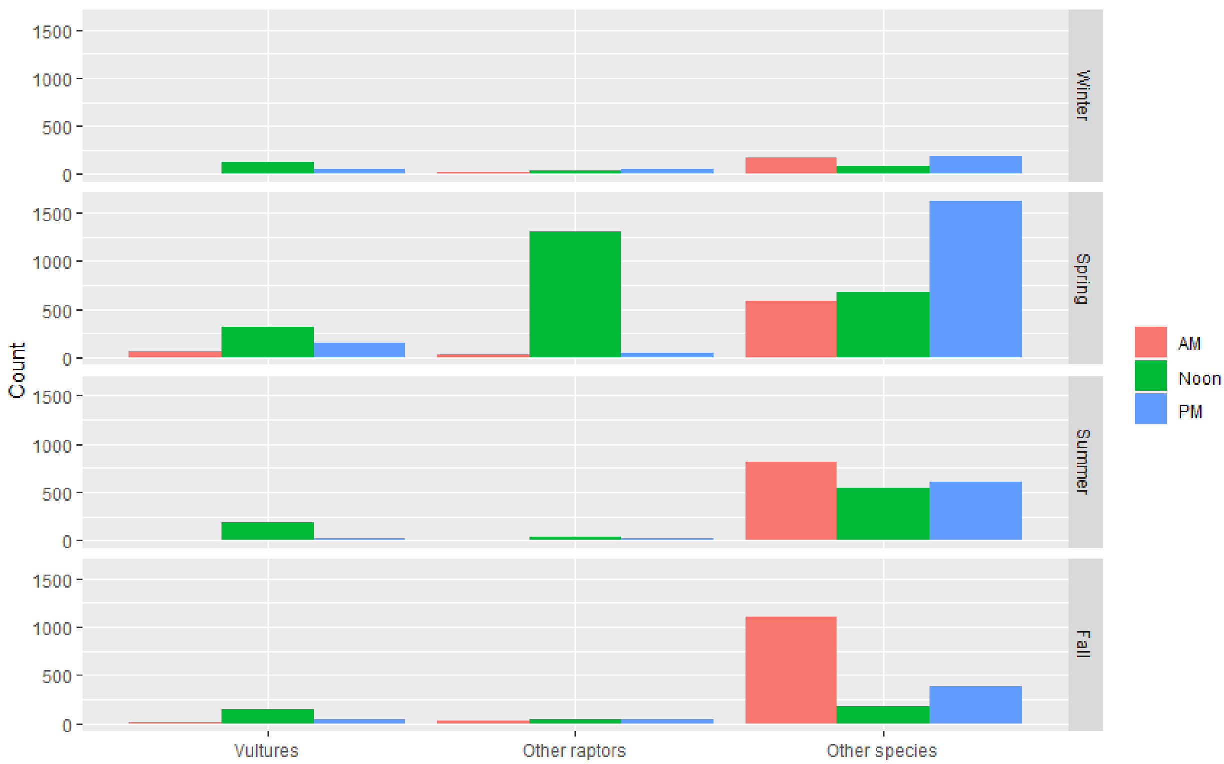


Figure 3. Number of detections of vultures, other raptors, and other species recorded per season during morning (AM), mid-day (Noon), and evening (PM) surveys at Naval Air Station Kingsville, December 2020−November 2021.

We detected most vultures at 30–100 m (~100–330 ft), most other raptors at >200 m (~650 ft), and most other species at 10–30 m (~30–100 ft) (Figure 4). Figure 5 shows the number of detections of five commonly detected species per altitudinal band by season. Out of birds that were not flying, most vultures were detected on anthropogenic structures and most other raptors were detected on anthropogenic structures and vegetation (Figure 6). In winter and fall, most other species that were not flying were detected on the ground, and in spring and summer were detected on fences (Figure 6). Black vultures (*Coragyps atratus*) and white-tailed hawks

(*Geranoaetus albicaudatus*) were usually detected on anthropogenic structures, turkey vultures were rarely detected not flying, crested caracaras (*Caracara plancus*) were usually detected on vegetation, and American kestrels (*Falco sparverius*) were mostly detected on anthropogenic structures and fences (Figure 7).

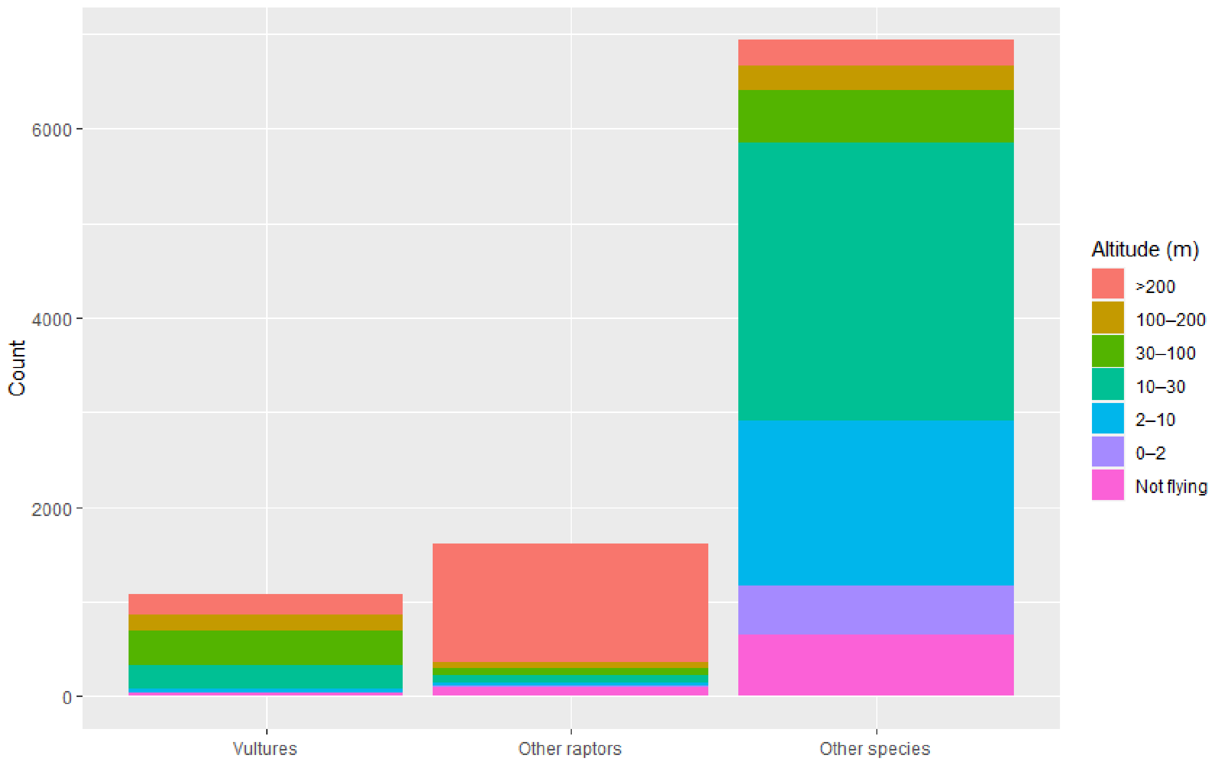


Figure 4. Number of detections of vultures, other raptors, and other species recorded per altitudinal band at Naval Air Station Kingsville, December 2020−November 2021.

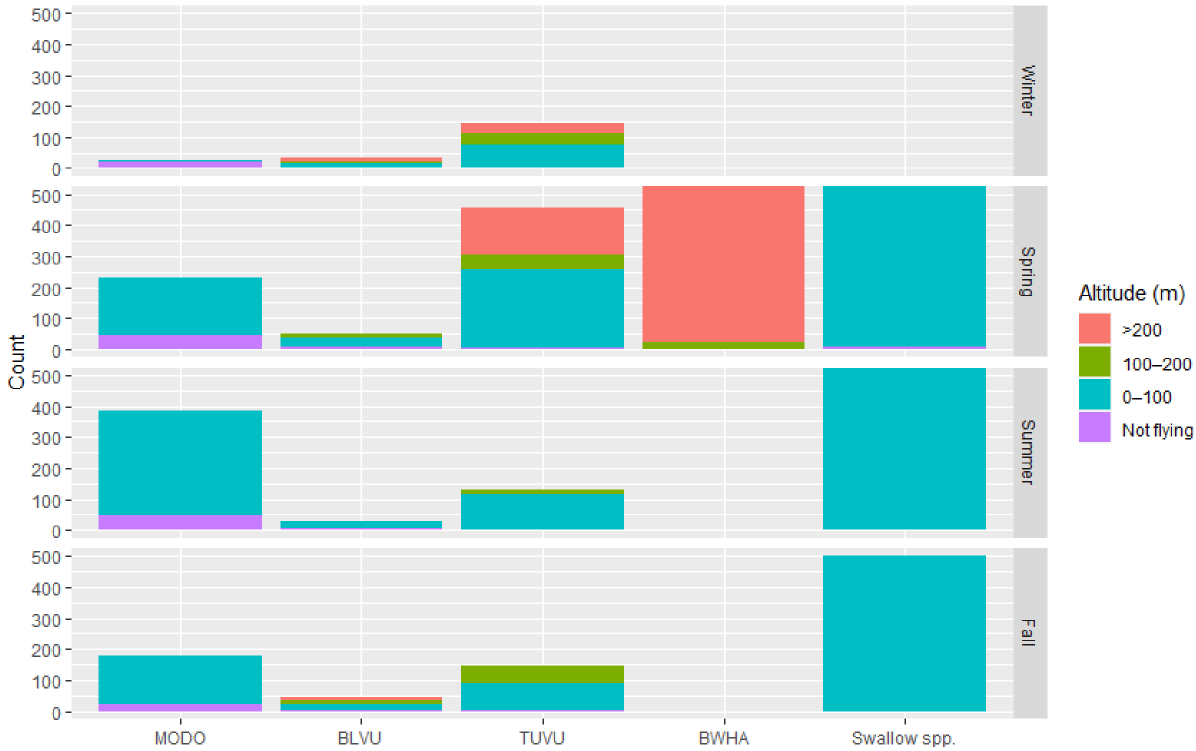


Figure 5. Number of detections of mourning doves (Zenaida macroura; MODO), black vultures (Coragyps atratus; BLVU), turkey vultures (Cathartes aura; TUVU), broad-winged hawks (Buteo platypterus; BWHA), and swallow species recorded per altitudinal band by season at Naval Air Station Kingsville, December 2020−November 2021. Note that the number of detections of BWHA in spring and swallow species in spring and summer exceeded what is shown in the figure.

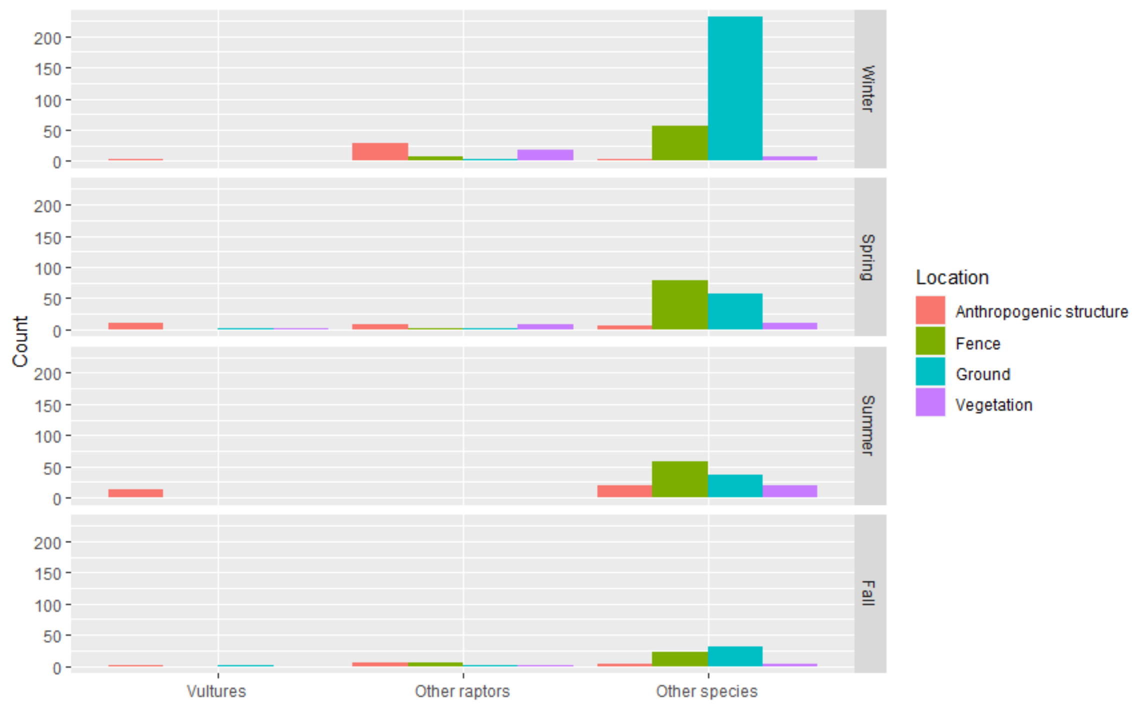


Figure 6. Number of detections of vultures, other raptors, and other species that were not flying by season and location at Naval Air Station Kingsville, December 2020−November 2021.

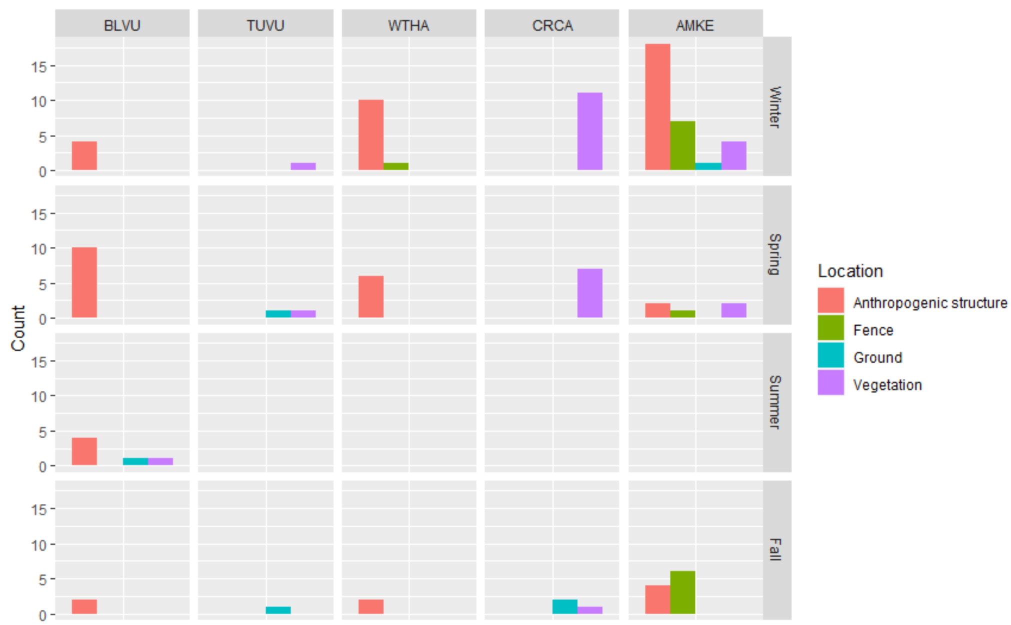


Figure 7. Number of detections of black vultures (Coragyps atratus; BLVU), turkey vultures (Cathartes aura; TUVU), white-tailed hawks (Geranoaetus albicaudatus; WTHA), crested caracaras (Caracara plancus; CRCA), and American kestrels (Falco sparverius; AMKE) that were not flying by season and location at Naval Air Station Kingsville, December −November 2021.

Of the flying birds, the majority of vultures were detected over the riparian area, the majority of other raptors were detected over the airfield, and other species were detected mostly over the riparian area (Figure 8). Vultures and other raptors were most active in the middle of the day during all seasons (Figure 9, Figure 10, and Figure 12), except on the agricultural field when vultures were as active or more active compared to other locations during the evenings (Figure 11). Other bird species showed much more variation across and between seasons and locations (Figure 9, Figure 10, Figure 11, Figure 12). Generally, other species of birds increased use of each area during spring as the day progressed and decreased their use of each area throughout the day in summer. In fall, other species were mostly observed in the mornings.

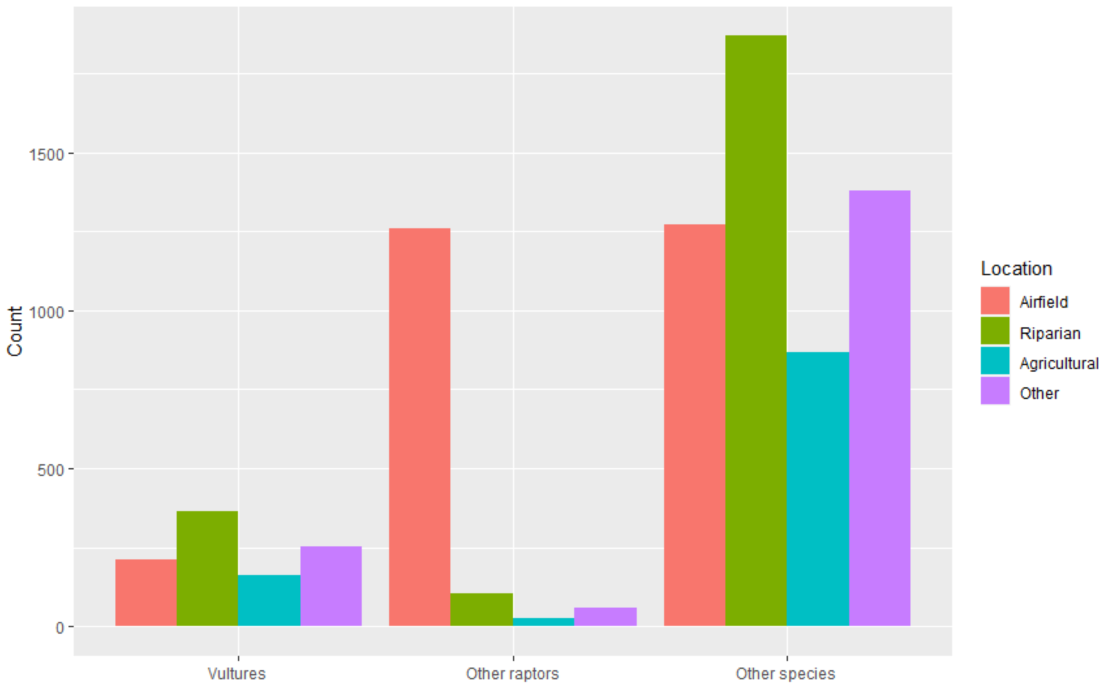


Figure 8. Number of detections of vultures, other raptors, and other species flying over the airfield, riparian area, agricultural field, and other area at Naval Air Station Kingsville, December 2020−November 2021.

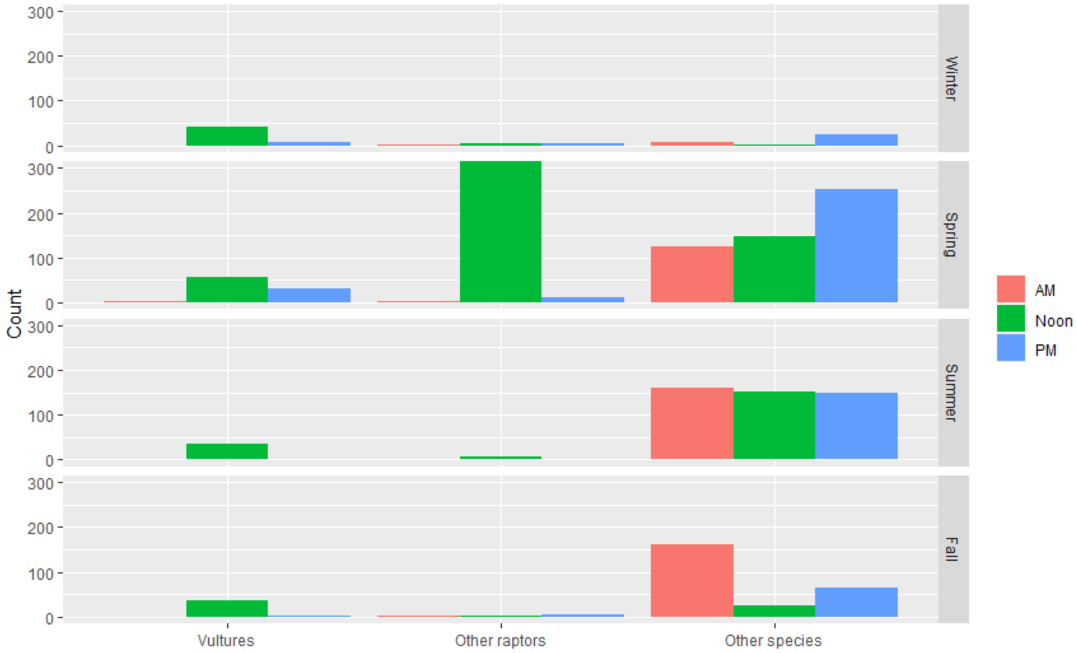


Figure 9. Number of detections of vultures, other raptors, and other species flying over the airfield per season during morning (AM), mid-day (Noon), and evening (PM) surveys at Naval Air Station Kingsville, December 2020−November 2021. Note that the number of detections of other raptors during noon surveys in spring exceeded what is shown in the figure.

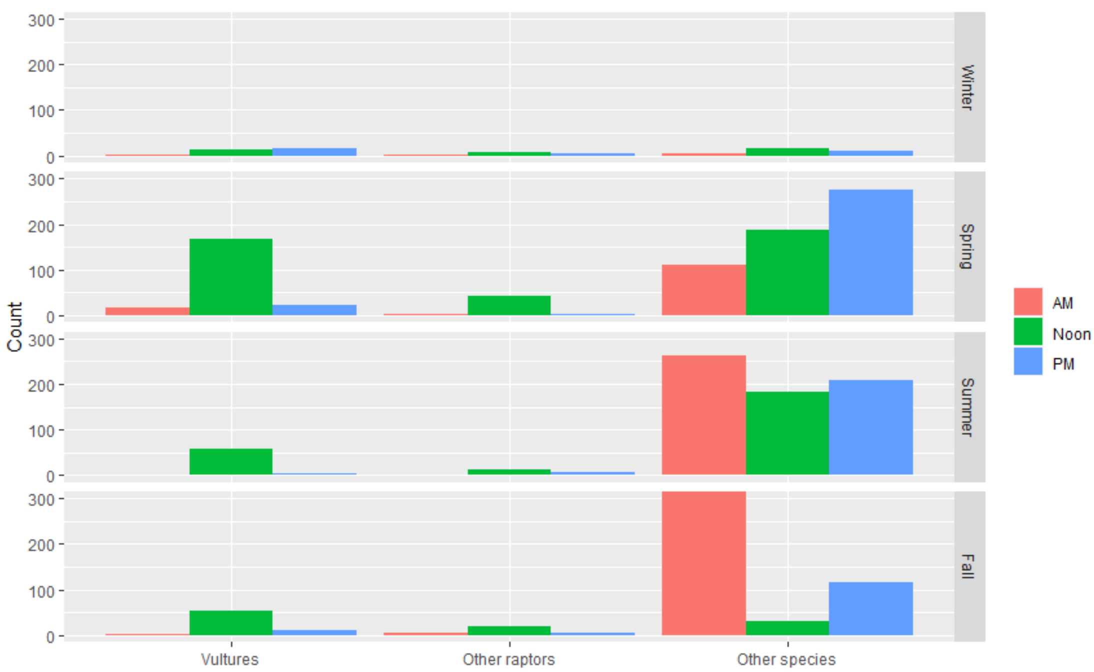


Figure 10. Number of detections of vultures, other raptors, and other species flying over the riparian area per season during morning (AM), mid-day (Noon), and evening (PM) surveys at Naval Air Station Kingsville, December 2020−November 2021. Note that the number of detections of other species during AM surveys in fall exceeded what is shown in the figure.

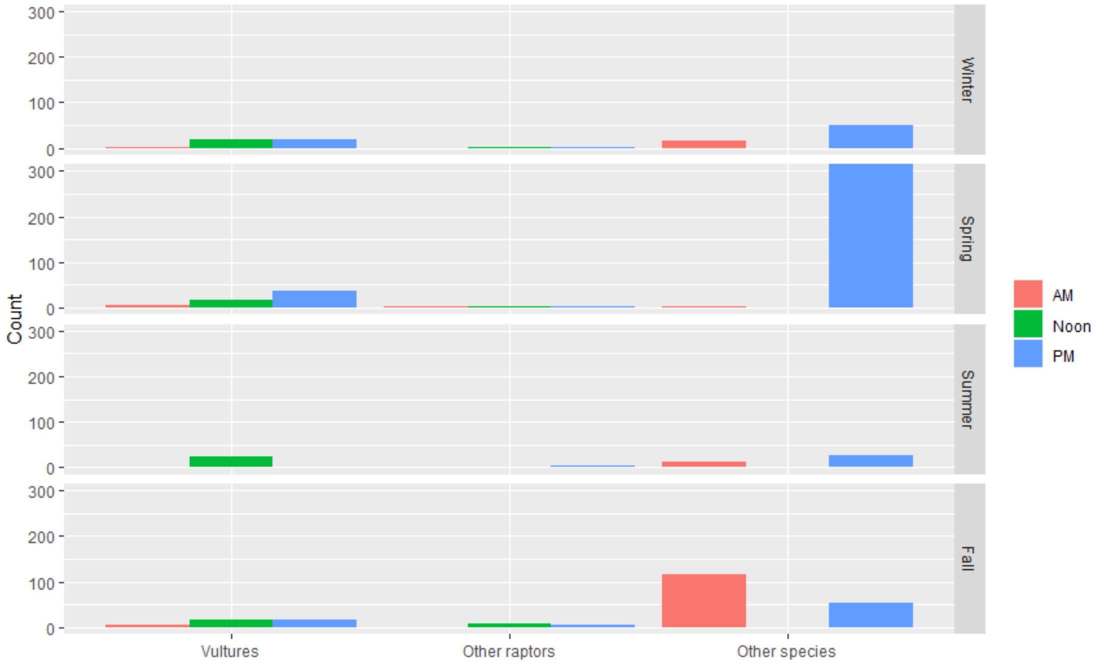


Figure 11. Number of detections of vultures, other raptors, and other species flying over the agricultural field per season during morning (AM), mid-day (Noon), and evening (PM) surveys at Naval Air Station Kingsville, December 2020−November 2021. Note that the number of detections of other species during PM surveys in spring exceeded what is shown in the figure.

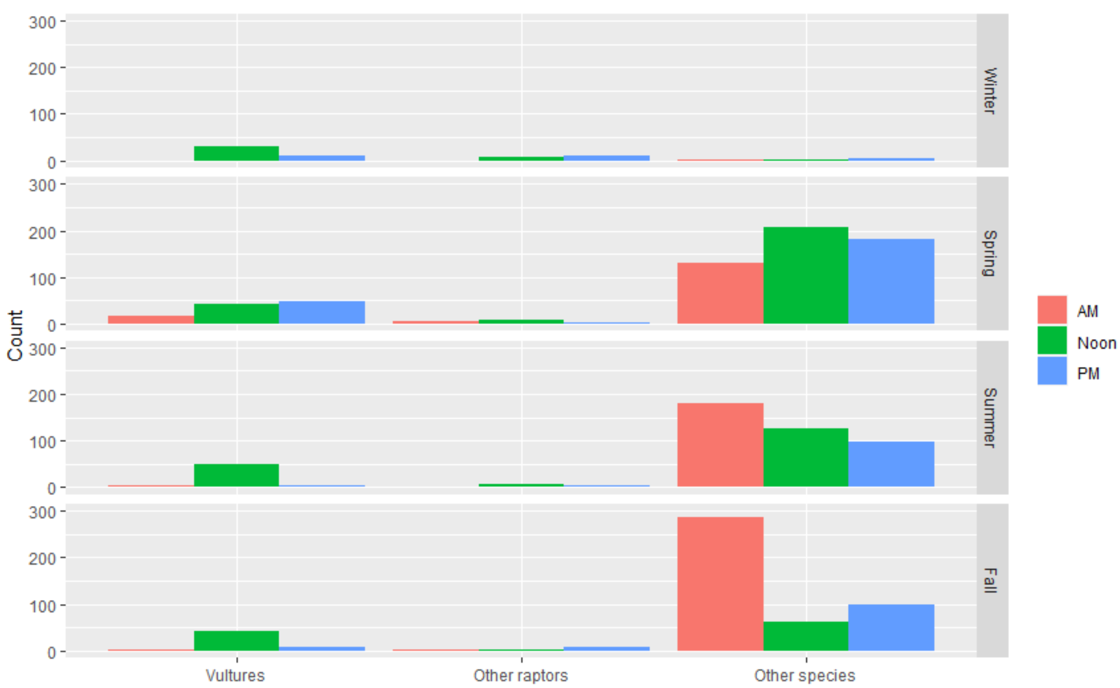


Figure 12. Number of detections of vultures, other raptors, and other species flying over the “other” area per season during morning (AM), mid-day (Noon), and evening (PM) surveys at Naval Air Station Kingsville, December 2020−November 2021.

Weather Monitoring

Overall, 2021 was a much wetter and colder year than normal for the Kingsville area (Vose et al. 2014). Average high temperatures at NASK during our study period ranged from 32°C (90°F) in the summer to 20°C (68°F) in the winter (Figure 13). Average low temperatures ranged from 26°C (79°F) in the summer to 11°C (52°F) in the winter (Figure 13). There was an unusually strong cold period in mid-February of 2021 when the temperature repeatedly dropped below 0°C (32°F; Figure 13).

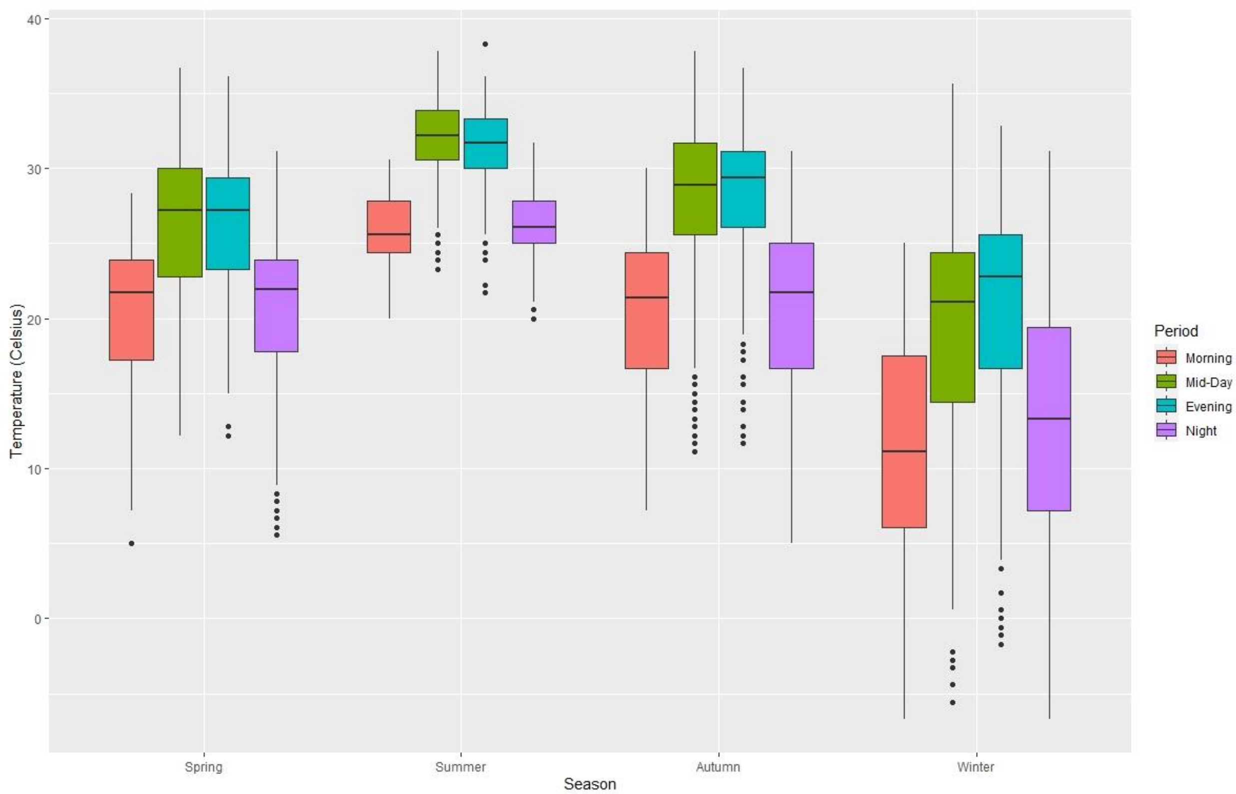


Figure 13. Temperature per period (Morning, Mid-day, Evening, and Night) for each season recorded 10 November 2020 to 30 November 2021 by the NOAA weather station at Naval Air Station Kingsville, Texas.

Rainfall totals were highest in the spring and summer of 2021 (Table 4). From 15 May to 19 May, a strong tropical rainfall event occurred at NASK. The exact amount of rainfall at NASK is difficult to determine because the system caused both the riparian weather station and the NOAA airfield station to become disabled for a period of time. Rainfall totals were estimated to be between 254 and 381 mm (10–15 inches) in the area of NASK over the 3 days.

Table 4. Summary statistics for weather from 10 November 2020 to 30 November 2021 at Naval Air Station Kingsville, Texas.

		Mean Temperature (SD) ℃			Mean Gust Wind Speed (SD) m/s		Mean Barometric Pressure (SD)	Total Rainfall
Season	Period	Airfield	Riparian	Ag Field	Airfield	Riparian	mbar	mm
Spring	Morning	20.5 (4.5)	19.5 (4.4)	20.3 (4.6)	4.0 (2.4)	2.5 (2.1)	1014.7 (6.4)	230.4
	Mid-Day	26.2 (4.8)	26.0 (5.1)	27.0 (5.1)	6.4 (2.3)	3.8 (1.7)	1014.6 (6.4)	
	Evening	26.2 (4.2)	26.9 (4.8)	26.4 (4.2)	7.0 (2.4)	5.3 (1.6)	1012.4 (6.5)	
	Night	20.6 (4.7)	20.0 (5.3)	20.0 (4.8)	4.1 (2.4)	2.7 (2.1)	1014.0 (6.4)	
Summer	Morning	26.0 (2.1)	26.6 (2.6)	25.6 (2.4)	2.5 (2.1)		1014.0 (2.7)	(219.0)[1]
	Mid-Day	32.0 (2.6)	32.6 (2.7)	32.0 (3.0)	4.8 (2.5)		1013.8 (2.9)	
	Evening	31.3 (2.6)	31.7 (2.9)	30.5 (2.9)	5.9 (2.1)		1012.2 (2.7)	
	Night	26.4 (1.9)	25.8 (2.0)	25.0 (1.9)	2.8 (1.9)		1013.4 (2.6)	
Fall	Morning	20.4 (5.2)	20.4 (5.6)		2.7 (1.9)	1.6 (1.6)	1017.2 (5.3)	121.7
	Mid-Day	28.3 (5.1)	28.8 (5.4)		4.6 (2.5)	3.8 (1.7)	1016.5 (5.3)	
	Evening	28.2 (4.7)	28.8 (4.8)		5.6 (2.2)	4.6 (1.4)	1014.6 (5.2)	
	Night	20.8 (5.3)	19.9 (5.7)		2.9 (1.7)	1.7 (1.7)	1016.2 (5.2)	
Winter	Morning	11.4 (7.0)	11.0 (7.4)	11.5 (7.5)	3.4 (2.1)	2.1 (2.1)	1019.6 (6.4)	53.3
	Mid-Day	18.9 (5.1)	19.2 (7.8)	20.6 (8.4)	5.4 (2.6)	4.6 (1.9)	1019.0 (6.4)	
	Evening	20.3 (4.7)	20.6 (7.6)	21.5 (8.2)	5.6 (2.5)	4.7 (2.0)	1016.6 (6.0)	
	Night	12.9 (5.3)	11.1 (7.5)	11.1 (7.4)	3.8 (2.3)	2.1 (2.3)	1018.3 (6.1)	

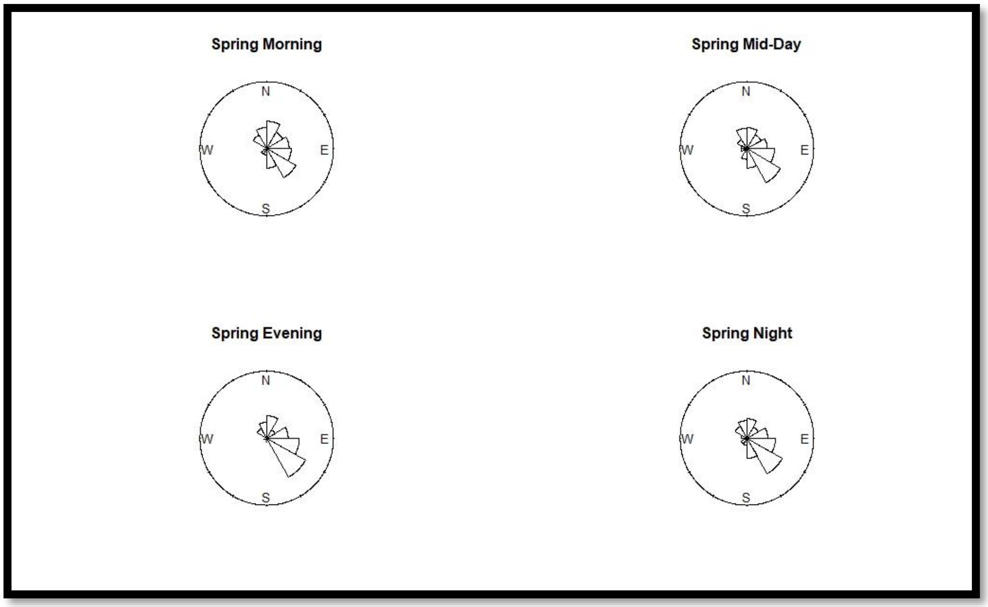
[1]Underestimate due to equipment failure during storm event the night of 19 June 2021.

Average wind gust speeds were highest in spring and during the evening and lowest in fall and during the morning (Table 5). Winds in spring and summer were mostly out of the east and southeast, respectively (Table 5; Figure 14a, b), but were slightly more from the south during summer (Figure 14b). Winds were much more variable in fall and winter and were often out of the southeast like in other seasons (Figure 14c, d). Winds in fall were most often out of the east during all periods except mornings when they were primarily out of the north (Table 5; Figure 14c). Northerly winds occurred more often in the winter during all periods (Figure 14d). Wind speed also differed between the airfield and the riparian area during each season where measurements were available ($F_{51,\ 78100} = 4.33$, $P = 0.01$; Table 5). Wind speeds were always higher on the airfield compared to the riparian area (Table 5).

Table 5. Mean direction of wind (θ) and mean resultant length ($\bar{R}$) by season and period recorded by the NOAA weather station at Naval Air Station Kingsville, Texas from 10 November 2020 to 30 November 2021. Periods with the strongest directionality based on mean resultant length in bold. Also, the results of Rayleigh's test of uniformity (S) and associated p-values.

Season	Period	n	θ[a]	$\bar{R}$	S[b]	P-value
Spring	Morning	239	85 (E)	0.5	0.477	<0.01
	Mid-Day	554	109 (E)	0.5	0.532	<0.01
	Evening	252	109 (E)	**0.7**	0.671	<0.01
	Night	799	114 (E)	0.6	0.579	<0.01
Summer	Morning	207	125 (SE)	0.4	0.399	<0.01
	Mid-Day	579	143 (SE)	**0.7**	0.690	<0.01
	Evening	260	133 (SE)	**0.9**	0.913	<0.01
	Night	796	140 (SE)	**0.7**	0.734	<0.01
Fall	Morning	278	26 (N)	0.4	0.384	<0.01
	Mid-Day	511	111 (E)	0.3	0.327	<0.01
	Evening	317	110 (E)	0.6	0.621	<0.01
	Night	1193	97 (E)	0.4	0.358	<0.01
Winter	Morning	230	13 (N)	0.3	0.310	<0.01
	Mid-Day	415	93 (E)	0.1	0.085	0.05
	Evening	247	69 (E)	0.3	0.257	<0.01
	Night	1074	68 (E)	0.2	0.238	<0.01

[a] General cardinal or ordinal direction in parentheses: north (N), northeast (NE), east (E), southeast (SE), southwest (SW), west (W), and northwest (NW).


Spring Morning
N
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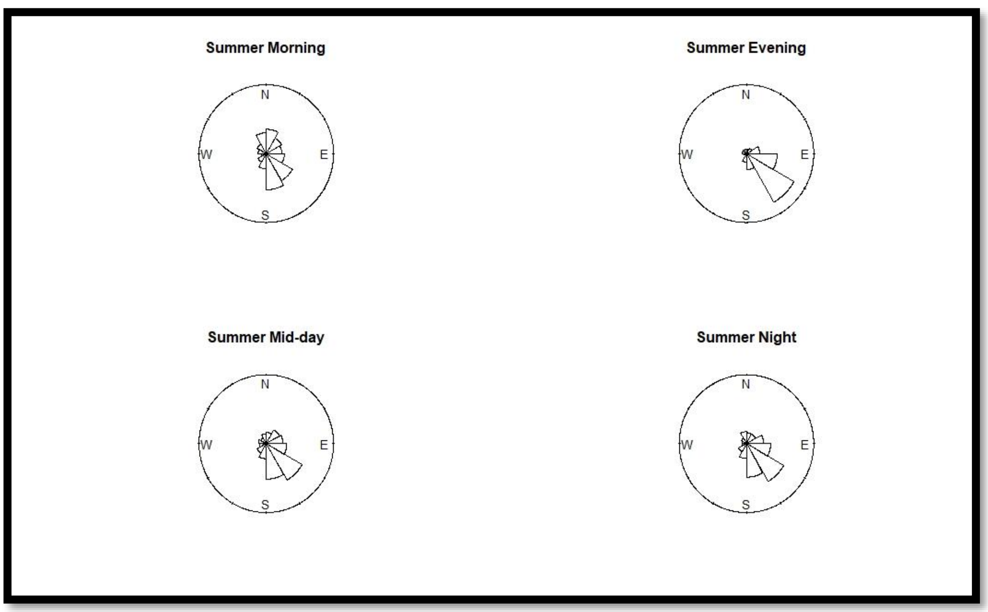
a.


Summer Morning
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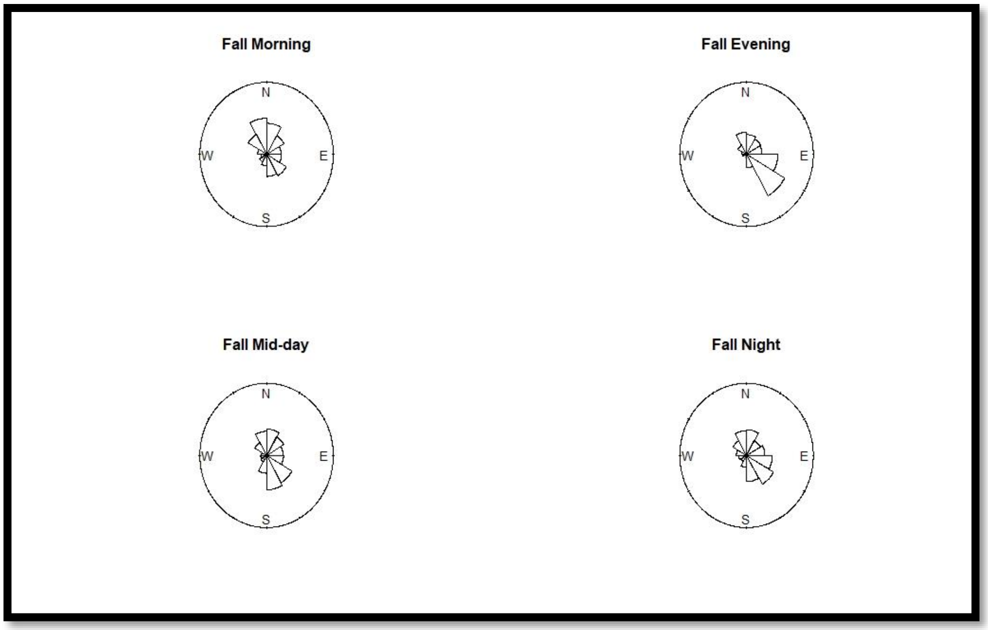

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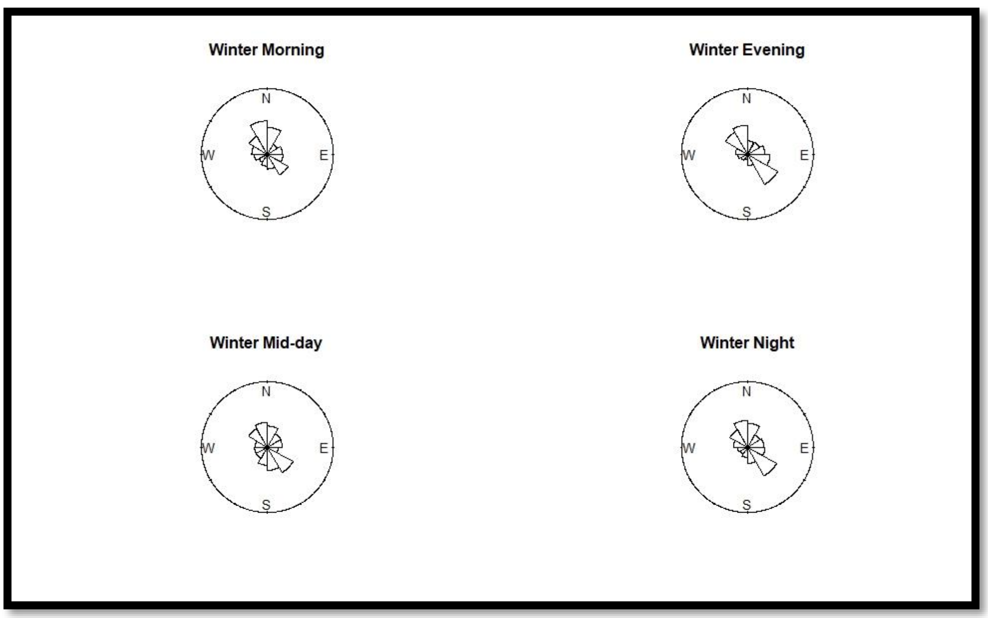


d.

Figure 14. Wind direction in a) spring, b) summer, c) fall, and d) winter in the morning, mid-day, evening, and night hours at Naval Air Station Kingsville, Texas.

Air temperatures differed by location in some seasons ($F_{1381, 988543} = 6.64$, $P \leq 0.01$; Table 6). Airfield and agricultural field temperatures were similar across all seasons. The agricultural field was cooler in the summer and warmer in the winter than the riparian area, possibly due to ground cover (Table 6). The airfield was also warmer in the winter than both the riparian area and agricultural field because it did not cool as much at night (Table 6). Observations of temperature change every hour on the airfield, within the riparian area, and in the agricultural field indicated that these areas heat and cool at different rates in the morning ($F_{5, 2541} = 2.78$, P = 0.02) and evening ($F_{5, 2426}$ = 2.98, P = 0.01), respectively, depending on season (Table 6). Temperature change was not different between locations during the mid-day hours ($F_{5, 5060}$ = 1.30, P =0.26) or when all night hours were combined ($F_{5, 10163}$ = 0.386, P = 0.86) during any season (Table 6). The riparian area heated significantly faster than the airfield during the morning hours in summer, fall, and winter but not in spring (Table 6). The agricultural field also heated faster than the airfield in the winter during the morning hours (Table 6). The agricultural field cooled much faster than the airfield and the riparian area during the evening hours in spring and winter (Table 6). It is possible that it also cooled faster in summer and fall, but there is no data available for those seasons due to equipment failure. The riparian and airfield cooled at similar rates during all seasons (Table 6).

Table 6. Mean and standard deviation (SD) for change in hourly temperature by season and period near the airfield, in the riparian area, and in the agricultural field. Bold indicates increases or decrease in temperature is significantly different between locations.

		Mean (SD) Hourly Temperature Change		
Season	Period	Airfield	Riparian	Ag Field
Spring	Morning	0.78 (1.54)	0.69 (2.02)	1.07 (1.79)
	Mid-Day	1.16 (1.69)	1.45 (1.76)	1.37 (1.99)
	Evening	**-0.79 (1.21)**	**-0.68 (1.52)**	**-1.29 (1.30)**
	Night	-0.61 (1.06)	-0.76 (1.33)	-0.66 (1.17)
Summer	**Morning**	**1.09 (1.42)**	**1.69 (1.70)**	-
	Mid-Day	0.83 (1.55)	0.72 (1.78)	-
	Evening	-0.89 (1.19)	-0.96 (1.37)	-
	Night	-0.58 (0.75)	-0.68 (0.84)	-
Fall	**Morning**	**1.03 (1.82)**	**1.62 (2.75)**	-
	Mid-Day	1.74 (2.35)	1.70 (2.35)	-
	Evening	-1.20 (1.26)	-1.15 (1.57)	-
	Night	-0.76 (0.98)	-0.89 (1.29)	-
Winter	**Morning**	**0.52 (2.12)**	**1.25 (2.22)**	**1.16 (2.08)**
	Mid-Day	2.05 (2.46)	2.04 (2.33)	2.31 (2.64)
	Evening	**-0.54 (1.15)**	**-0.80 (1.38)**	**-1.46 (1.67)**
	Night	-0.81 (1.71)	-0.94 (1.81)	-0.93 (1.58)

Aircraft Strike Trends

The species with the highest strike risk scores overall were black vulture, turkey vulture, broad-winged hawk, cliff swallow (*Petrochelidon pyrrhonota*), barn swallow (*Hirundo rustica*), and cave swallow (*Petrochelidon fulva*) (Table B2.1). The species with the highest strike risk score for winter was black vulture (Table B2.2), for spring was broad-winged hawk (Table B2.3), for summer was cave swallow (Table B2.4) and for fall was turkey vulture (Table B2.5). The most-struck species groups were swallows and other songbirds, but when weighted by RHSs, vultures and hawks, kites, owls, and falcons increased in importance (Figure 15). The greatest number of strikes occurred in fall (Figure 15 and Figure 17) and at night (Figure 16 and Figure 17), but most strikes with raptors (i.e., vultures and hawks, kites, owls, and falcons) and swallows occurred during the mid-day temporal period (Figure 16).

Vulture strike risk was similar across all seasons while strikes with hawks, kites, owls, and falcons occurred more in spring and fall compared to other seasons (Figure 15). Strikes with swallows were notably higher in summer and fall compared to other seasons (Figure 15) and consistently occurred in the middle of the day (Figure 16). Other songbirds were struck most often in spring or fall (Figure 15) and were struck largely during the night (Figure 16).

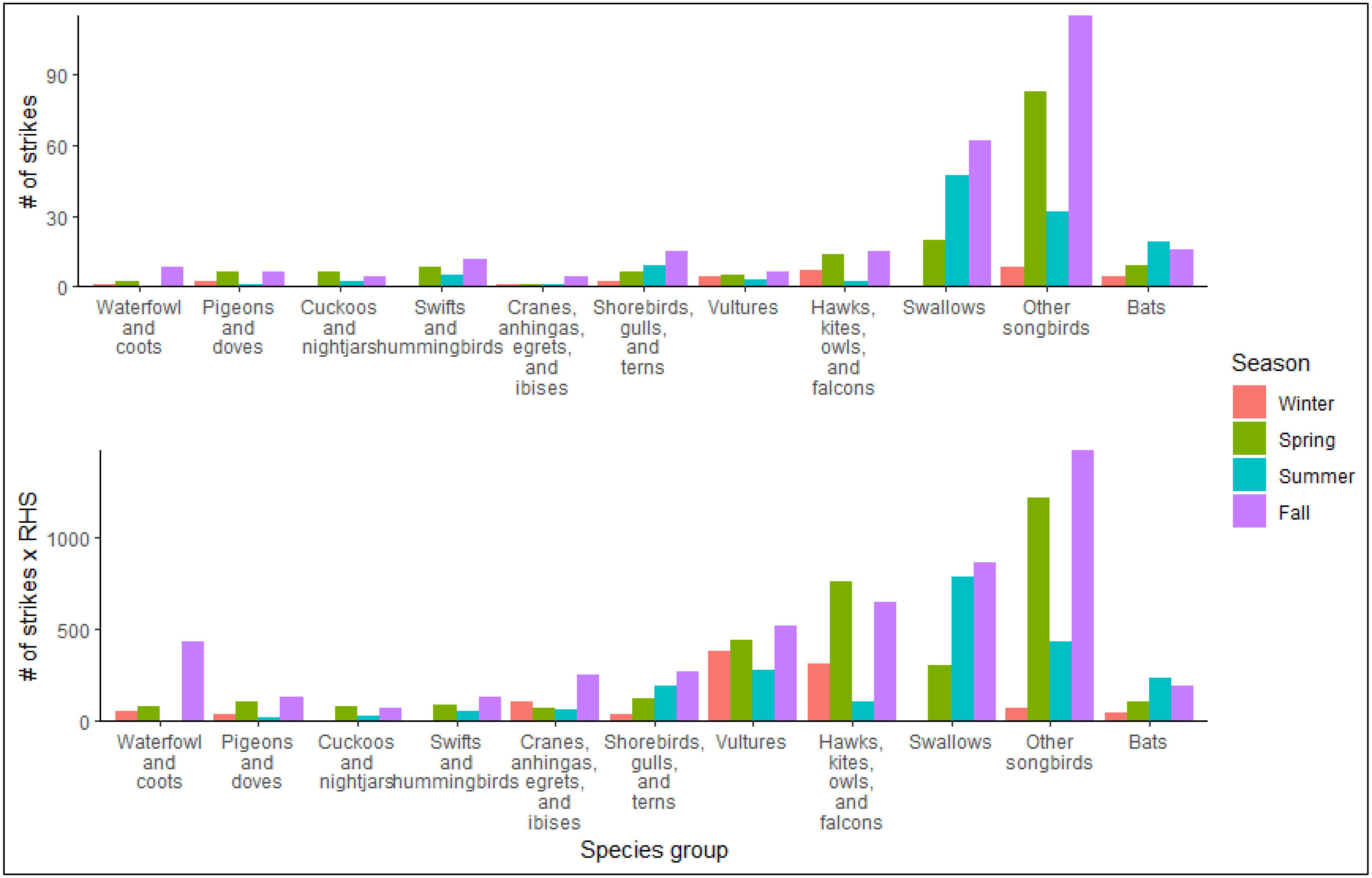


Figure 15. Number of strikes per species group by season (top) and number of strikes weighted by respective relative hazard scores (RHS) per species group by season (bottom) for all identified bird and bat species struck from October 2010–September 2021.

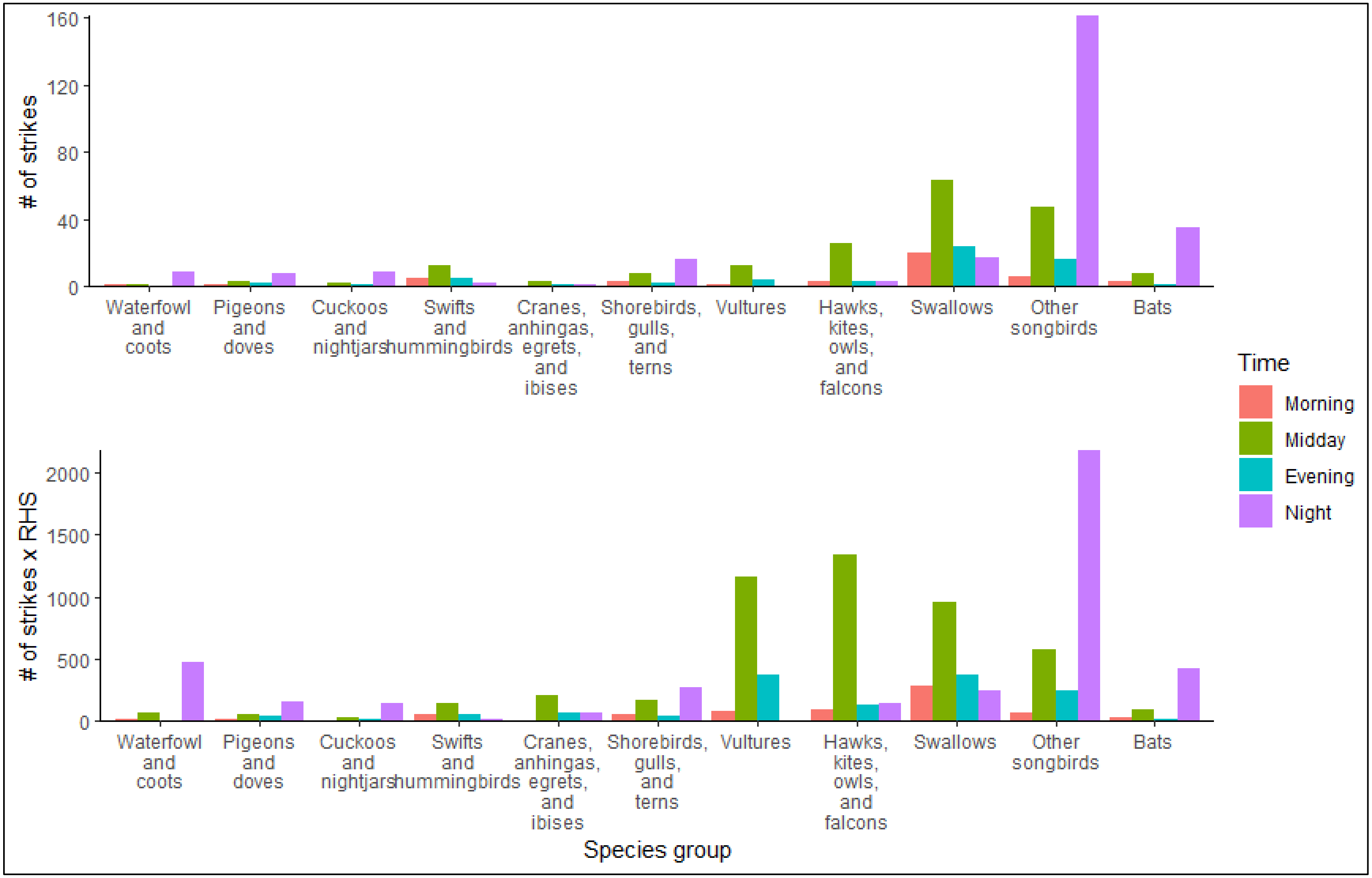


Figure 16. Number of strikes per species group by time of day (top) and number of strikes weighted by respective relative hazard scores (RHS) per species group by time of day (bottom) for all identified bird and bat species struck from October 2010–September 2021

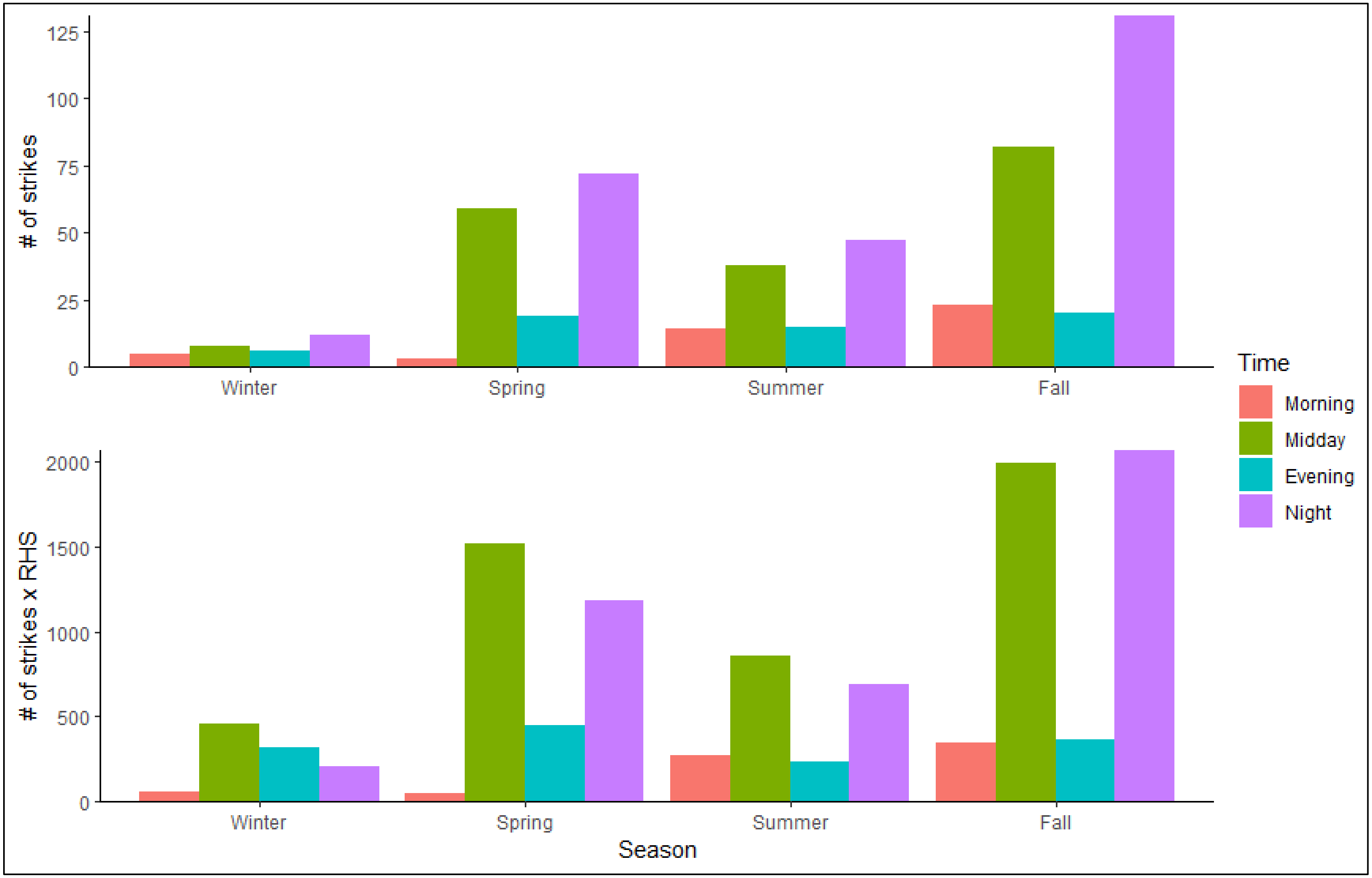


Figure 17. Number of strikes per season by time of day (top) and number of strikes weighted by respective relative hazard scores (RHS) per season by time of day (bottom) for all identified bird and bat species struck from October 2010–September 2021.

Radar-recorded Bird Movements

Mean targets per hour was greatest in spring and fall (Figure 18), and peak activity during these seasons occurred at night (Figure 19). There was a significant interaction between period (i.e., morning, mid-day, evening, and night) and season on overall activity ($F_{3,9} = 41.4$, $P \leq 0.01$). Target passage rates recorded by the radar were greater for nocturnal than diurnal periods in spring, summer, and fall (Table 7; Figure 19), likely corresponding to increased numbers of migratory birds moving through the area at night in spring and fall. Pairwise tests of the HSR data indicated that TPR did not vary by period in winter and was the lowest compared to all other seasons (Table 7; Figure 19). Additionally, overall activity was similar among 1) summer and fall evenings, which were times when TPR was lowest for those seasons, 2) spring and fall mornings, and 3) mid-day and evenings in summer. TPR was highest during spring and fall nights (Table 7; Figure 19).

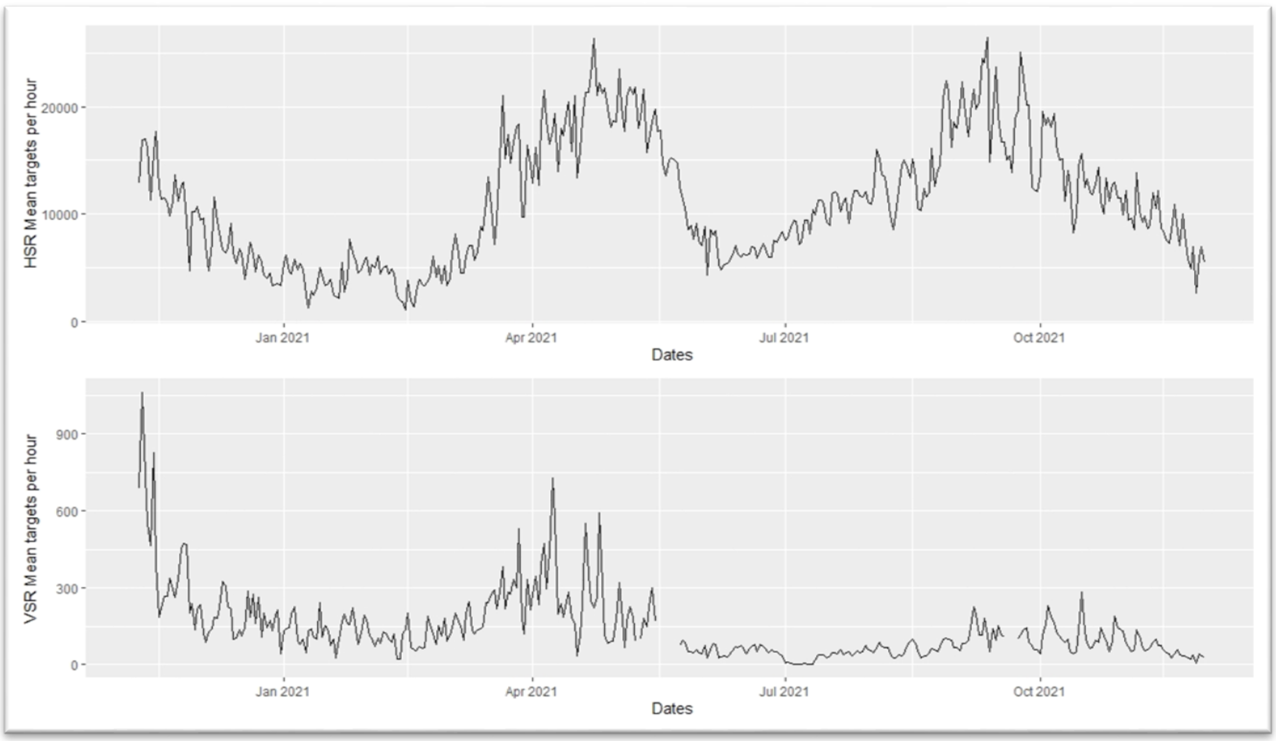


Figure 18. Mean targets per hour per day recorded by the MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars from 10 November 2020 to 30 November 2021 at Naval Air Station Kingsville.

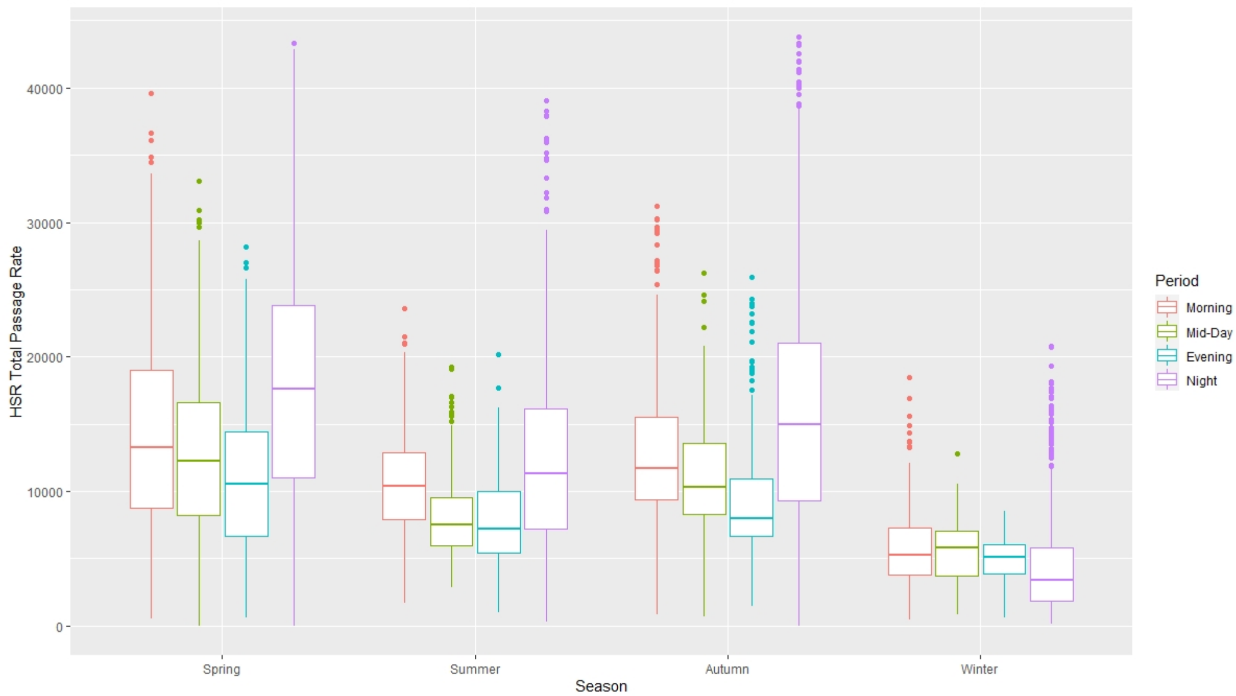


Figure 19. Mean targets per hour per period (Morning, Mid-day, Evening, and Night) for each season recorded 10 November 2020 to 30 November 2021 by the MERLIN^{TM} horizontal scanning radar (HSR) at Naval Air Station Kingsville.

Table 7. Mean (and standard deviation [SD]), minimum, and maximum target passage rates (TPR) recorded by the MERLIN™ horizontal scanning radar at Naval Air Station Kingsville by season and period from 10 November 2020 to 30 November 2021. Units are the number of targets per number of hourly intervals.

Season	Period	Mean (SD)	Min	Max
Spring	Morning	14,324 (7,397)	524	39,574
	Mid-Day	12,796 (5,836)	0	33,051
	Evening	11,125 (5,544)	568	28,175
	Night	17,405 (8,525)	0	43,342
Summer	Morning	10,762 (3,991)	1,679	23,561
	Mid-Day	8,040 (2,841)	2,884	19,260
	Evening	7,884 (3,196)	1,026	20,175
	Night	12,467 (6,605)	323	39,057
Fall	Morning	13,028 (5,735)	873	31,248
	Mid-Day	10,926 (3,770)	650	26,209
	Evening	9,350 (4,349)	1450	25,935
	Night	15,746 (8,530)	0	43,795
Winter	Morning	5,764 (2,896)	466	18,453
	Mid-Day	5,468 (2,144)	841	12,834
	Evening	4,888 (1,616)	640	8,511
	Night	4,423 (3,578)	114	20,798

*All values rounded to the nearest whole number.

Direction of travel was not uniform within seasons or seasonal periods (Figure 20) and differed between seasons (F_{21}= 984.2, $P \leq 0.01$). In spring, the direction of travel was generally north/northwest while the general direction of travel in summer and fall was south/southwest (Figure 20). Periods also differed within spring (F_{21} = 67.85, $P \leq 0.01$), summer (F_{21} = 44.17, $P \leq 0.01$), fall (F_{21} = 45.41, $P \leq 0.01$), and, to a lesser extent, winter (F_{21} = 19.75, $P \leq 0.01$) (Fig. X). Most northern movement in summer, fall, and winter occurred at night while southern movements in fall occurred throughout the day and night (Figure 20).

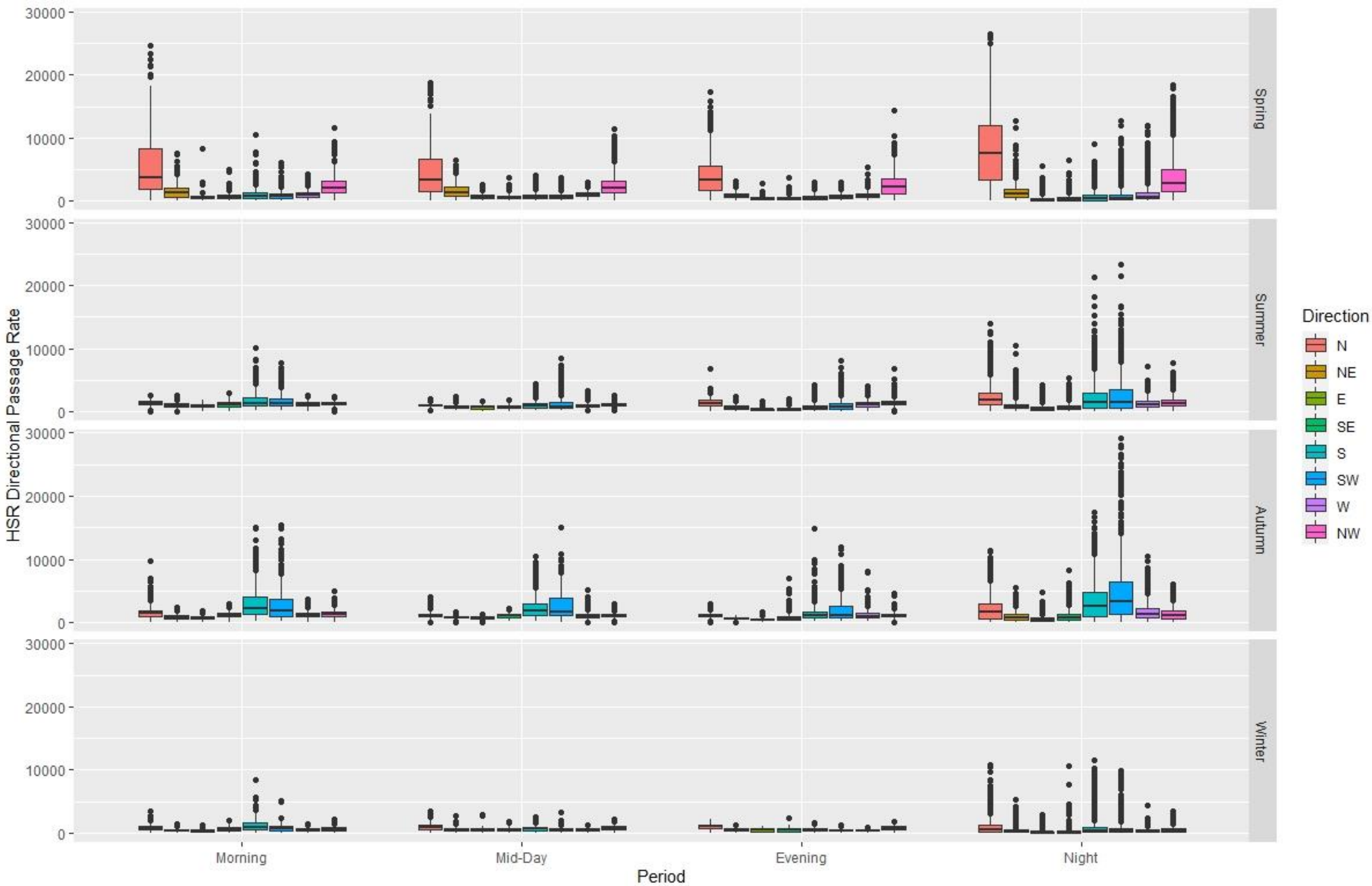


Figure 20. Mean targets per hour per period (Morning, Mid-day, Evening, and Night) for each season and period recorded 10 November 2020 to 30 November 2021 by the MERLIN^{TM} horizontal scanning radar (HSR) at Naval Air Station Kingsville.

The MERLIN™ VSR recorded flight activity in all four altitudinal bands (Figure 21). Approximately 1/3 of targets occupied the low-altitude class (0–213 m [0–700 ft]), with 13% in the lowest band (i.e., 0–91 m [0–300 ft]) and 22% in the band from 91–213 m (300–700 ft). More than 65% of targets occupied the high-altitude class (213–610 m [700–1,200ft]), with 25% in the 213–366 m (700–1,200 ft) band and 41% in the 366–610 m (1,200–2,000 ft) band. Mean targets per hour in all altitude classes were greatest in spring while fall and winter had similar distributions (Figure 22). There was a significant interaction between period (i.e., morning, mid-day, evening, night) and season on TPR for all altitudinal bands (0–91 m: $F_{9,9249} = 10.13$, $P \leq 0.01$; 91–213 m: $F_{9,9249} = 13.85$, $P \leq 0.01$; 213–366 m: $F_{9,9249} = 11.53$, $P \leq 0.01$; 366–610 m: $F_{9,9249} = 32.84$, $P \leq 0.01$). Target passage rates recorded at each altitudinal band were greater for nocturnal than diurnal periods in all seasons (Figure 22). The lowest activity occurred in the morning for all seasons (Figure 22).

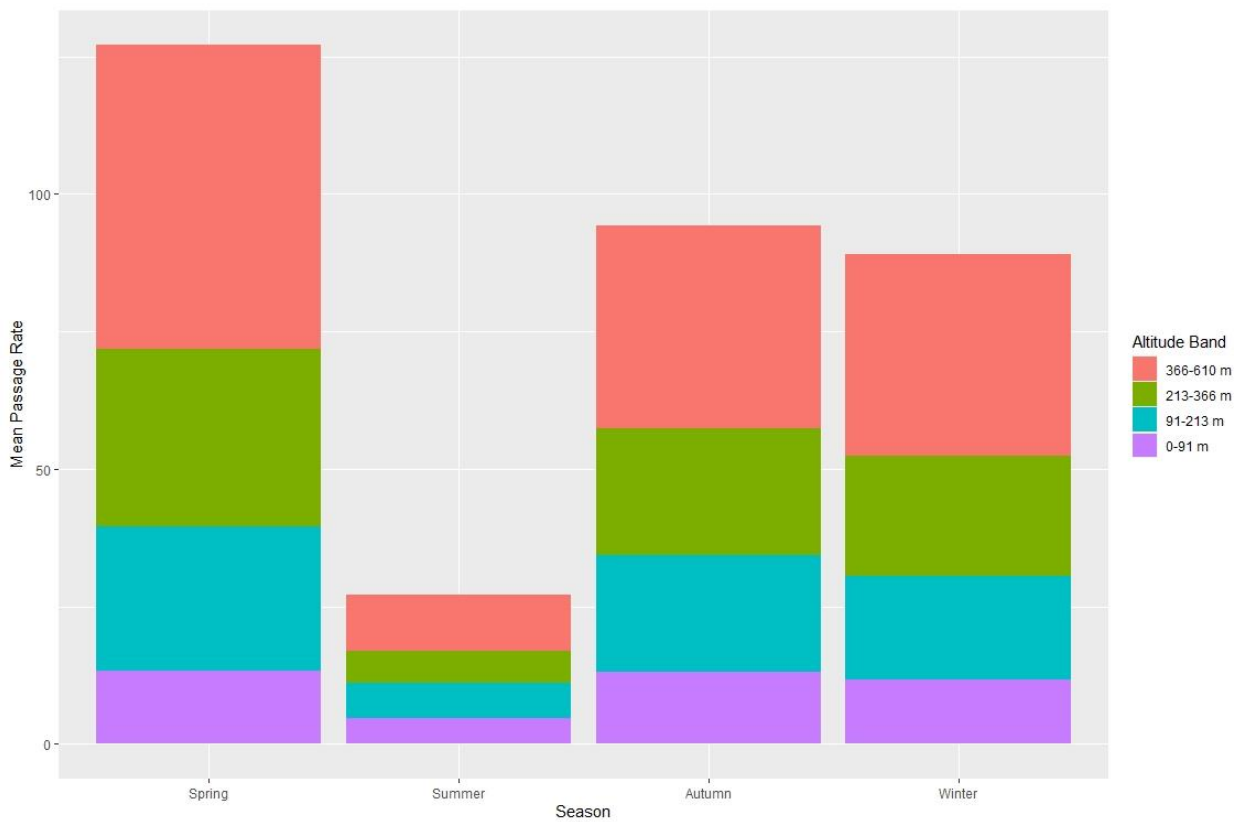


Figure 21. Number of targets recorded by the MERLIN™ vertical scanning radar by altitudinal band and season at Naval Air Station Kingsville, Texas, from 10 November 2020 to 30 November 2021. Altitudinal bands listed by the ranges in meters above ground level.

Activity within the lower altitudinal class was highest in spring and fall (Figure 21) during mid-day or at night (Figure 22). Activity within lower altitudinal class was highest at night during the fall (Figure 21). Activity within the higher altitudinal class was highest at night in spring and fall (Figure 22). Activity in the morning was low overall but was slightly higher in the lower altitudinal class in spring and fall (Figure 22). The most activity in the evenings occurred in winter within all altitudinal bands (Figure 22).

Figure 22. Number of targets recorded by the MERLIN™ vertical scanning radar by altitudinal band, season, and period (i.e., day, night) at Naval Air Station Kingsville, Texas, from 10 November 2020 to 30 November 2021. Altitudinal bands listed by the ranges in meters above ground level.

Bird-Weather Trends

Because weather and bird activity differed by season (see above sections), bird-weather trends are discussed below by each season separately to better convey within-season differences in bird activity and passage rates.

Spring

Multiple linear regression was used to test if temperature, wind speed, wind direction, or change in barometric pressure over the previous 3 hours significantly predicted horizontal and vertical passage rates for each period (i.e., morning, mid-day, evening, night) in spring. Wind direction correlated with passage rates during each period (Table 8). Southerly winds, particularly from the southeast, correlated with higher passage rates in the morning, mid-day, evening, and at night from 0 to 610 m (0 to 2000 ft) as well as in the mid-day and evenings for overall activity (Table 8). Winds out of the northwest in the evenings also correlated with higher activity from 91 to 610 m (300 to 2000 ft) (Table 8c). Warmer temperatures correlated with higher overall activity in the area for each period (Table 8). Lower wind speeds correlated with higher activity above 366 m (1200 ft) in the evenings (Table 8c). Falling BP correlated with higher HSR TPR in the mornings (Table 8a) while rising BP correlated with higher HSR TPR in the evenings (Table 8c). Rising BP at night also correlated with more bird activity from 91 to 610 m (300 to 2000 ft) (Table 8d).

Table 8. Results of multiple linear regression for total passage rate for MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars in spring of 2021 for (a) mornings, (b) mid-day, (c) evenings, and (d) nights. Altitudinal bands listed by the ranges in meters above ground level.

a) Morning	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Change in BP	Wind Direction	Wind Direction	Wind Direction	Temperature + Wind Direction
Intercept	8755.44 (2171.87)***	12.49 (1.98)***	23.19 (4.46)***	17.52	34.63 (9.34)***
Temperature	368.98 (99.94)***				-0.97 (0.47)*
Wind Speed					
Wind Direction		SE 4.64 (2.54)	SE 14.30 (5.71)*	SE 11.58 (5.09)*	SE 9.59 (4.63)*
Change in Barometric Pressure	-1354.42 (297.05)***				
R-squared	0.15	0.02	0.05	0.05	0.04
Adjusted R-squared	0.14	0.01	0.04	0.04	0.02
Standard Error	6852	15.23	34.22	30.54	25.38
F-statistic	18.82	1.38	3.34	3.42	2.00
Significance F	<0.01	0.25	0.02	0.02	0.10
Observations	182	182	182	182	182

b) Mid-day	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Direction	Wind Direction	Wind Direction	Wind Direction	Wind Direction
Intercept	3963.03 (1542.39)*	12.58 (2.28)***	29.86 (4.18)***	29.29 (4.99)***	10.94 (16.04)
Temperature	299.67 (59.97)***				0.82 (0.63)

Wind Speed					
Wind Direction	NW -2337.77 (905.87)*; SE 1836.97 (681.38)**; SW 4259.02 (1205.61)***	SE 8.72 (2.68)**; SW 28.06 (5.03)***	SW 50.50 (9.21)***	SE 16.27 (5.86)**; SW 56.20 (11.00)***	SE 27.61 (7.14)***; SW 80.88 (13.31)***
Change in Barometric Pressure					
R-squared	0.21	0.09	0.08	0.08	0.14
Adjusted R-squared	0.20	0.08	0.07	0.07	0.14
Standard Error	5309.00	21.03	38.51	45.96	53.27
F-statistic	28.25	12.60	10.51	10.99	16.01
Significance F	<0.01	<0.01	<0.01	<0.01	<0.01
Observations	383	383	383	383	383

c) Evening	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed + Wind Direction + Change in BP	Wind Direction	Wind Direction	Wind Direction	Wind Direction + Wind Speed + Change in BP
Intercept	-41.02	7.60 (2.03)***	9.75 (3.36)**	10.38 (3.95)**	28.40)8.51)**
Temperature	629.26 (84.88)***				
Wind Speed	-942.78 (173.64)***				-2.62 (1.13)*
Wind Direction	SE 4373.86 (986.68)***	SE 4.89 (2.26)*	NW 17.54 (6.25)**; SE 9.36 (3.75)*	NW 21.22 (7.36)**	NW 35.32 (10.09)***; SE 24.58 (6.75)***
Change in Barometric Pressure	582.26 (253.84)*				3.47 (1.72)*
R-squared	0.33	0.02	0.05	0.04	0.09
Adjusted R-squared	0.32	0.01	0.04	0.03	0.07
Standard Error	4689.00	12.33	20.41	24.03	32.43
F-statistic	17.95	2.47	4.80	4.38	4.97
Significance F	<0.01	0.09	0.01	0.01	<0.01
Observations	202	202	202	202	202

d) Night	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed	Wind Speed	Wind Direction + Change in BP	Wind Direction + Change in BP	Wind Direction + Wind Speed + Change in BP
Intercept	8237.18 (1310.79)***	10.78 (1.29)***	22.07 (2.93)***	27.88 (4.50)***	70.61 (12.34)***
Temperature	600.09 (67.94)***				
Wind Speed	-819.51 (133.35)***	1.04 (0.27)***			-3.92 (2.01)
Wind Direction			SE 11.15 (3.27)***	SE 20.66 (5.02)***; SW 25.27 (2.34)*	SE 42.20 (11.74); SW 118.86 (24.60)***
Change in Barometric Pressure			2.41 (0.76)**	4.40 (1.16)***	11.04 (2.67)***
R-squared	0.11	0.02	0.03	0.05	0.07
Adjusted R-squared	0.11	0.02	0.03	0.05	0.06
Standard Error	8203.00	16.76	30.64	47.03	107.00

F-statistic	43.86	14.74	5.54	8.71	9.19
Significance F	<0.01	<0.01	<0.01	<0.01	<0.01
Observations	726	677	677	628	628

*P = 0.01
**P = 0.001
***P = 0.00

When wind direction and TPR were assessed alone, TPRs differed among directions in spring for overall activity ($F_{15, 1823} = 11.34$, $P < 0.01$) as well as for 0–91 m ($F_{15, 1679} = 5.17$, $P < 0.01$) and 91–213 m ($F_{15,1679} = 4.76$, $P < 0.01$). In spring, the highest activity occurred when winds were generally from the S and W (Figure 23). The highest activity overall occurred at night when winds were from the S and SSW as well as in the morning when winds were from the SE (Figure 23). At low altitudes, the highest activity occurred at night when winds were from the W and WNW and activity was higher during the morning and mid-day when winds were generally from the W (Figure 23).

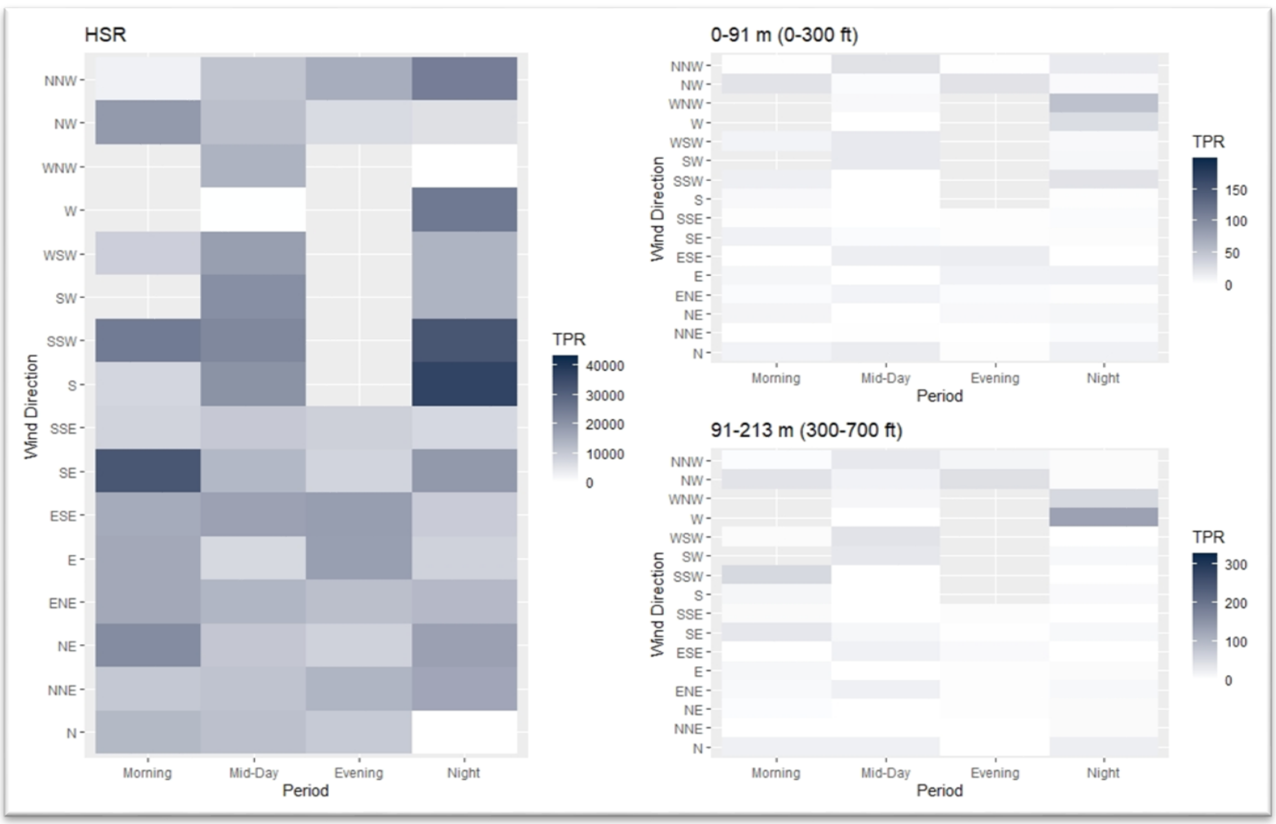


Figure 23. Heatmaps showing spring hourly total passage rate (TPR) indicated by the MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radars (0–91 m and 91–213 m) and direction of wind in spring 2021 at Naval Air Station Kingsville.

When categorized on the Beaufort Scale (BF), impact of wind speeds in spring on TPR differed significantly for overall activity ($F_{6, 1926} = 15.17$, $P < 0.01$). Overall activity decreased steadily with increasing wind speed (Figure 24). Wind speeds did not impact vertical radar passage rates for the lower altitudes (0–91 m: $F_{6,\ 1764}$ = 2.19, P = 0.04; 91–213 m = $F_{6,1764}$ = 15.17, P = 0.22) in spring when no other weather variables were considered.

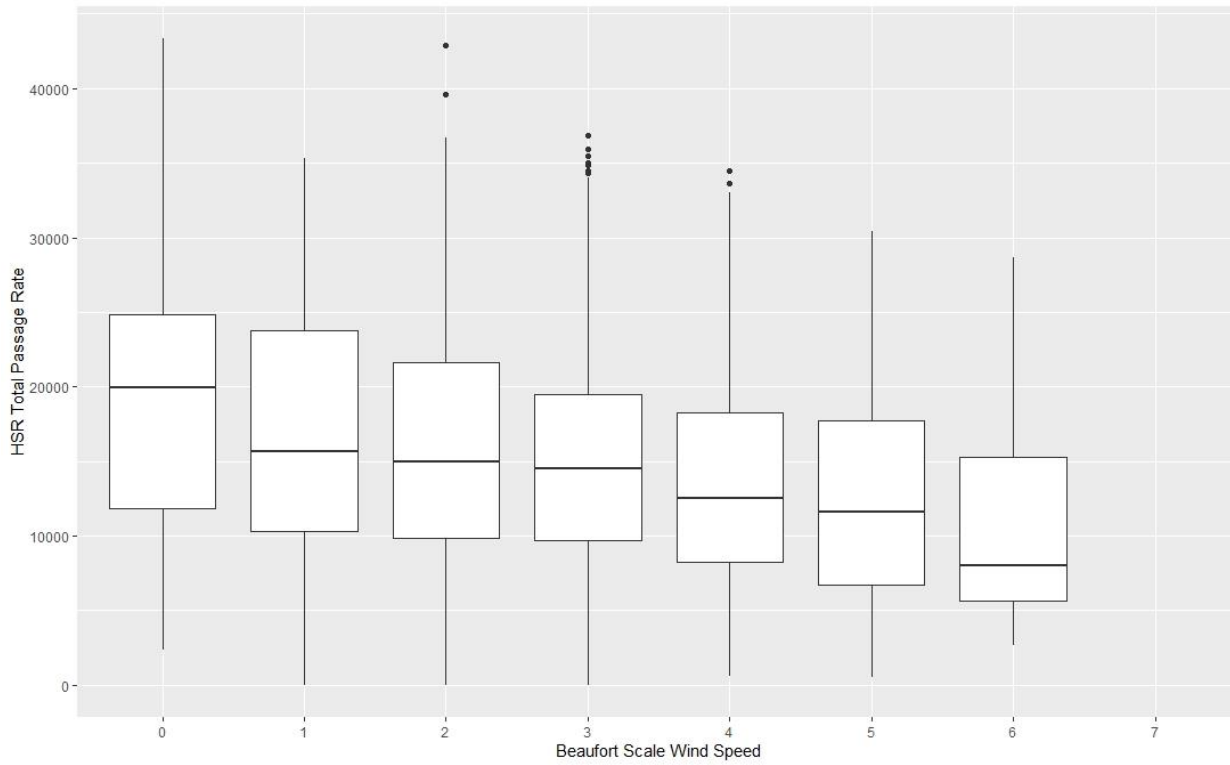


Figure 24. Mean targets per hour in spring 2021 by the MERLIN^{TM} horizontal scanning radar (HSR) at Naval Air Station Kingsville.

Decreasing barometric pressure (BP) was correlated with higher HSR mean passage rates in the mornings and evenings in spring (Figure 25). In the lower altitudes, VSR mean passage rates were generally higher in the mornings and evenings when BP was decreasing. During the mid-day period, VSR mean passage rate was much higher when BP was rapidly increasing (Figure 25). Barometric pressure activity did not correlate with HSR mean passage rate, but steady BP correlated with lower VSR mean passage rate in the 91–213 m (300–700 ft) altitude compared to times when BP was rising or falling (Figure 25).

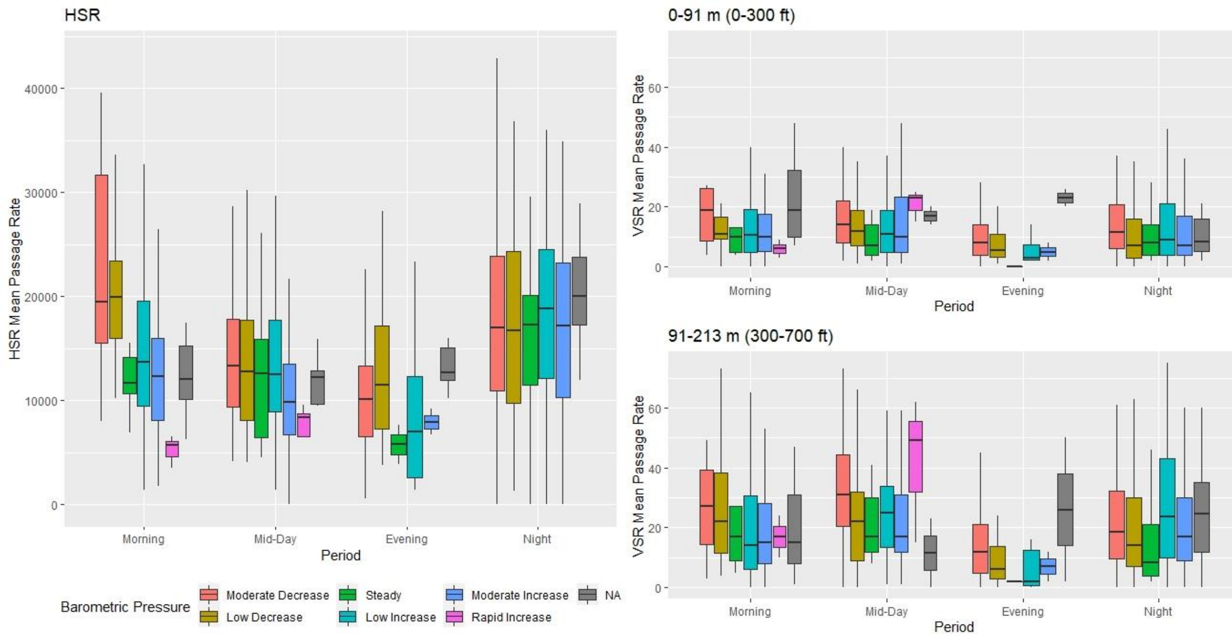


Figure 25. Boxplots showing spring total passage rate (TPR) indicated by the MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radars (0–91 m and 91–213 m) and change in barometric pressure over three hours in spring 2021 at Naval Air Station Kingsville.

Higher average daily temperature corresponded with higher overall daily activity but not at lowest altitudes (0–213 m [0–700 ft]; Figure 26) when all periods were combined. However, differences in temperature between the agricultural field and the riparian area during the mid-day and evening corresponded to higher activity below 213 m (700 ft) (Figure 27b, c).

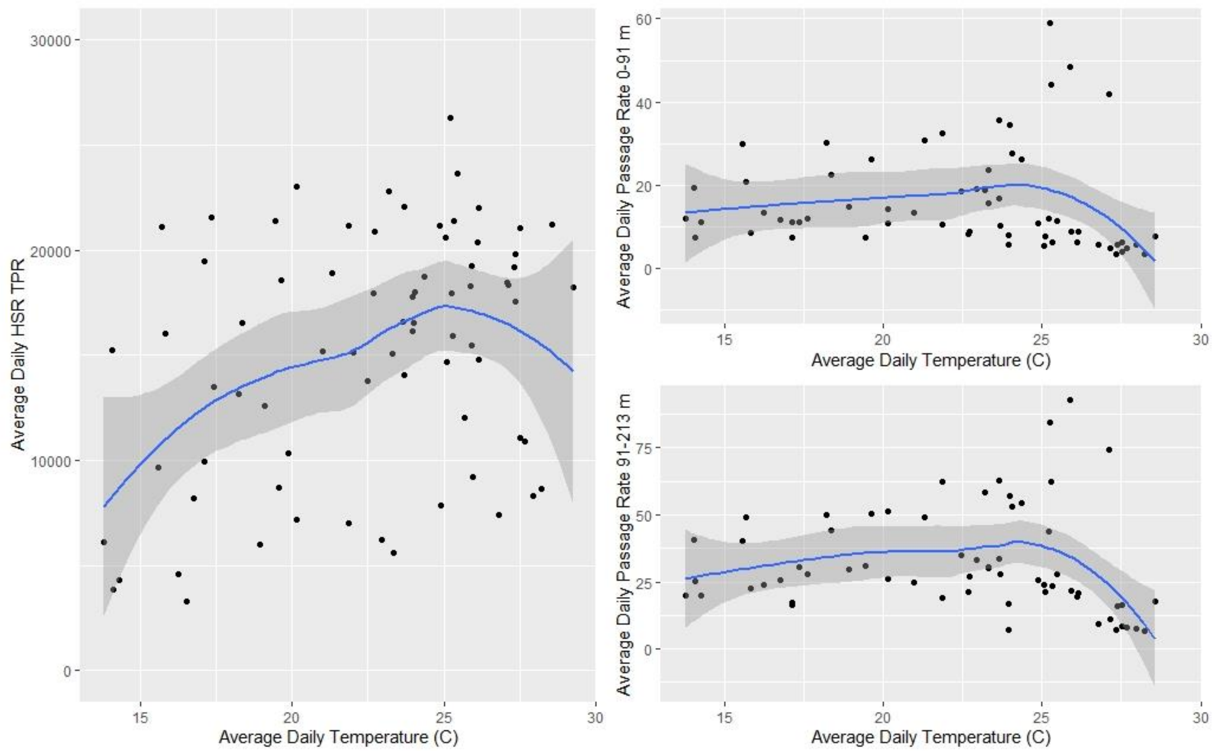
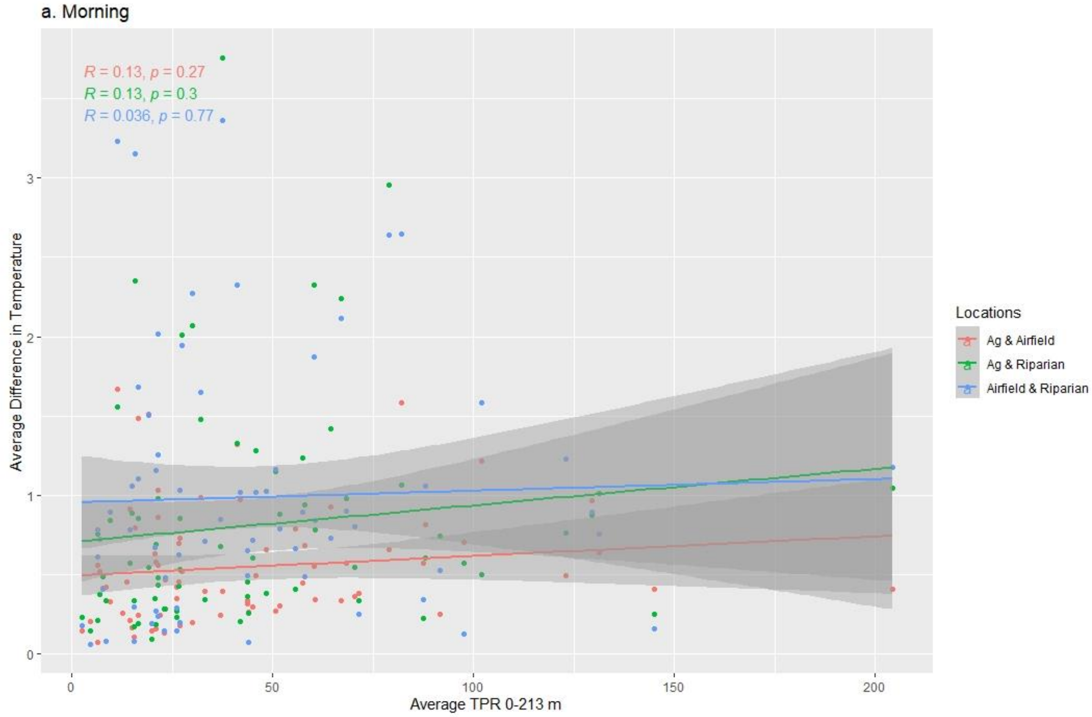
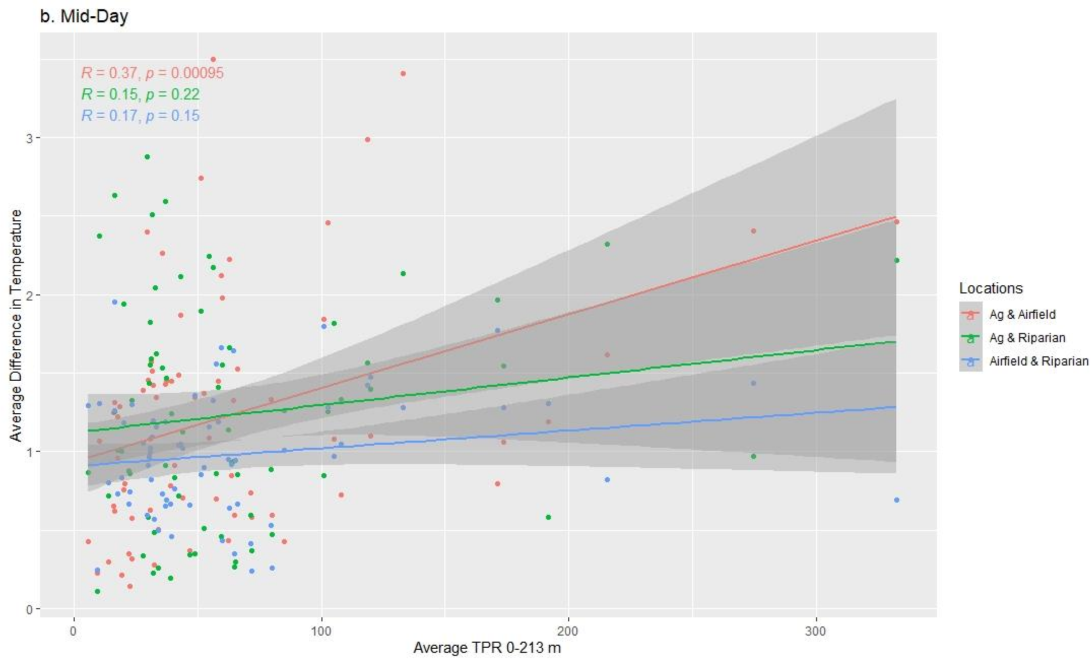
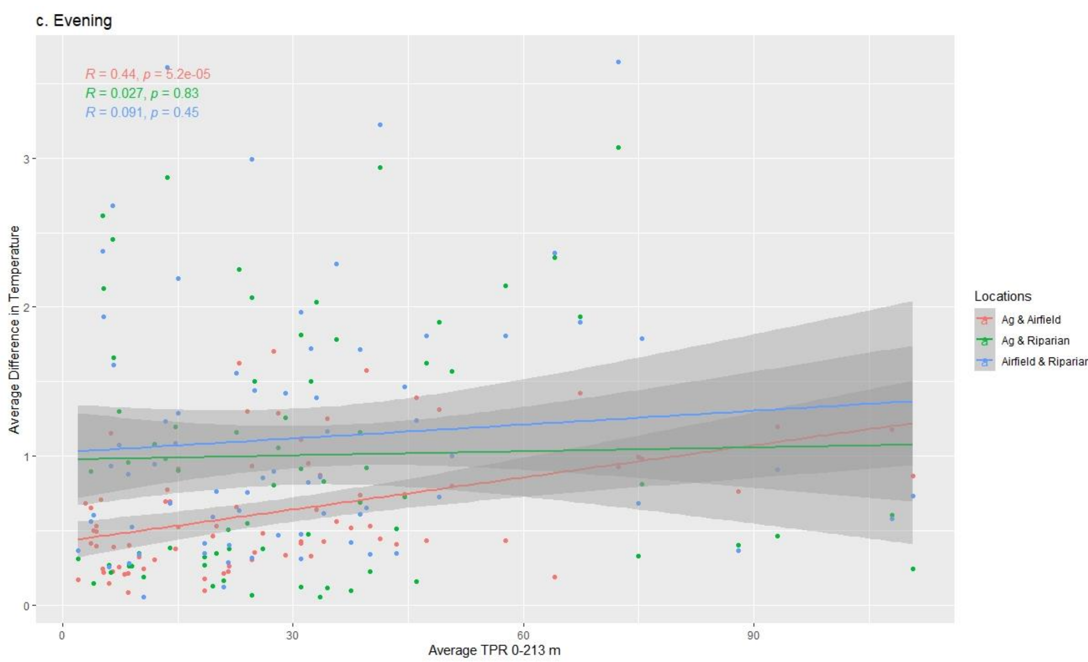


Figure 26. Average daily temperatures and MERLIN™ horizontal (HSR) and vertical (VSR) scanning radar total passage rates in spring of 2021.

a. Morning




b. Mid-Day
R = 0.37, p = 0.00095
R = 0.15, p = 0.22
R = 0.17, p = 0.15
Average Difference in Temperature
Average TPR 0-213 m
Locations
Ag & Airfield
Ag & Riparian
Airfield & Riparian


c. Evening
R = 0.44, p = 5.2e-05
R = 0.027, p = 0.83
R = 0.091, p = 0.45
Average Difference in Temperature
Average TPR 0-213 m
Locations
Ag & Airfield
Ag & Riparian
Airfield & Riparian

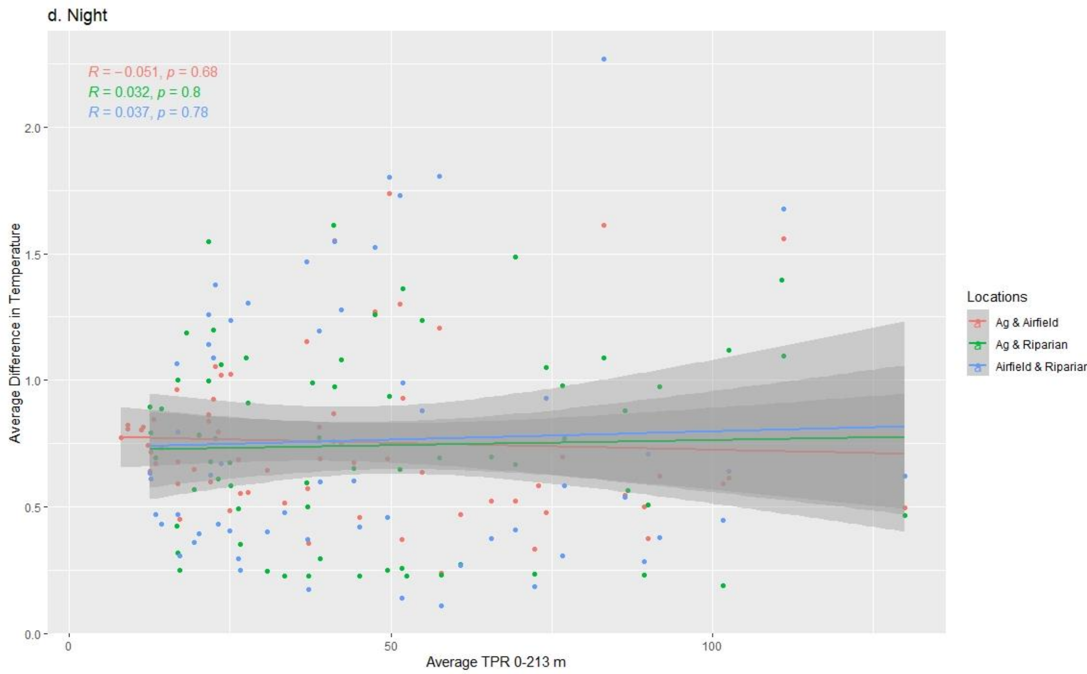


Figure 27. Average temperature difference and MERLIN^{TM} vertical scanning radar (VSR) average passage rate from 0 to 213 m during a) mornings, b) mid-day, c) evenings, and d) nights at Naval Air Station Kingsville, Texas in spring of 2021.

Summer

When analyzed using multiple linear regression, wind had no influence on passage rates in the mornings during the summer (Table 9). During mid-day, winds out of the northwest correlated with lower passage rates from 91 to 366 m (300 to 1200 ft) while winds out of the south during that period correlated with higher general bird activity (HSR; Table 9b). Winds out of the northeast consistently correlated with higher passage rates in the evening hours from 91 to 610 m (300 to 2000 ft) and passage rates were higher above 610 m (2000 ft) when winds were out of the SE (Table 9c). At night, southerly winds correlated with lower activity at higher altitudes (d). Cooler temperatures correlated with more activity from 213 to 610 m (700 to 2000 ft) during all periods while warmer temperatures correlated with more activity from 0 to 213 m (0 to 700 ft) (Table 9). Higher overall activity (HSR) at night also occurred when temperatures were warmer (Table 9d). Lower wind speeds generally correlated with higher activity overall (Table 9). Change in BP influenced bird activity at night (Table 9d); falling BP correlated with increased night time activity at the lowest altitudinal band but rising BP correlated with higher activity above 91 m (300 ft).

Table 9. Results of multiple linear regression for total passage rate for MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radars in summer of 2021 for (a) mornings, (b) mid-day, (c) evenings, and (d) nights. Altitudinal bands listed by the ranges in meters above ground level.

a) Morning	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed	Intercept only	Change in BP	Temperature	Temperature
Intercept	8724.20 (2973.70)**	5.88 (0.31)***	6.50 (0.76)***	-21.56 (4.63)***	-24.65 (7.04)***
Temperature	149.50 (118.0)			1.06 (0.18)***	1.27 (0.27)***
Wind Speed	-789.70 (119.70)***				
Wind Direction					
Change in Barometric Pressure			1.71 (0.68)*		
R-squared	0.15		0.02	0.12	0.08
Adjusted R-squared	0.14		0.02	0.12	0.07
Standard Error	3588	5.08	8.07	5.96	9.06
F-statistic	23.01		6.34	36.01	22.3
Significance F	<0.01		0.01	<0.01	<0.01
Observations	264	268	265	267	267

b) Mid-day	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Wind Direction + Wind Speed + Change in BP	Temperature + Wind Speed	Wind Speed + Wind Direction	Temperature + Wind Direction + Change in BP	Temperature + Wind Speed
Intercept	8955.10 (407.48)***	3.36 (2.74)	14.42 (1.48)***	-3.93 (4.71)	-7.94 (6.65)
Temperature		0.09 (0.09)		0.43 (0.15)**	0.84 (0.21)***
Wind Speed	-460.45 (59.46)***	-0.20 (0.09)*	-0.72 (0.21)***		-1.04 (0.21)***

Wind Direction	SE 1306.48 (398.23)**; SW 2282.59 (453.40)***		NW '-9.24 (2.35)***	NW -6.40 (1.90)***	
Change in Barometric Pressure	149.52 (106.64)			0.87 (0.32)**	
R-squared	0.16	0.01	0.06	0.05	0.06
Adjusted R-squared	0.16	0.01	0.05	0.04	0.06
Standard Error	2497.00	4.82	8.85	7.12	11.70
F-statistic	17.96	2.69	6.75	4.76	16.51
Significance F	<0.01	0.07	<0.01	<0.01	<0.01
Observations	462	531	460	459	531

c) Evening	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Wind Speed + Wind Direction	Temperature	Temperature + Wind Direction	Temperature + Wind Direction	Temperature + Wind Direction
Intercept	6712.60 (1273.30)***	-3.19 (3.01)	28.62 (5.15)***	41.52 (8.45)***	70.89 (17.98)***
Temperature		0.22 (0.10)*	-0.43 (0.15)**	-0.68 (0.24)**	-1.27 (0.52)*
Wind Speed	-371.20 (110.70)***				
Wind Direction	SE 3459.80 (1229.60)**		NW -13.69 (4.04)***; SE -11.89 (2.01)***; SW -15.29 (2.80)***	NW -17.27 (6.63)**; SE -16.05 (3.29)***; SW -20.25 (4.59)***	NW -28.36 (14.09)*; SE -22.09 (7.00)**; SW - 30.59 (9.76)**
Change in Barometric Pressure					
R-squared	0.07	0.02	0.15	0.12	0.06
Adjusted R-squared	0.05	0.02	0.14	0.10	0.05
Standard Error	3146.00	3.75	4.85	7.95	16.91
F-statistic	4.35	5.46	10.83	7.80	3.95
Significance F	<0.01	0.02	<0.01	<0.01	<0.01
Observations	244	256	242	242	242

d) Night	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed + Wind Direction	Temperature + Change in BP	Temperature + Change in BP	Temperature + Wind Speed + Change in BP	Temperature + Wind Direction + Wind Speed + Change in BP
Intercept	-14547.69 (4060.50)	16.23 (1.96)***	2.04 (2.39)	-9.58 (2.94)**	-26.05 (6.21)***
Temperature	1198.60 (166.90)***	-0.45 (0.07)***	0.50 (0.17)	0.62 (0.12)***	1.57 (1.92)***
Wind Speed	-1020.40 (183.3)***			-0.73 (0.12)***	-1.07 (0.27)***
Wind Direction	SE -2349.70 (824.3)**				SE -4.48 (1.21)***; SW -3.62 (1.42)*
Change in Barometric Pressure		-0.59 (0.14)***	0.50 (0.17)**	0.42 (0.16)*	1.29 (0.33)***
R-squared	0.09	0.08	0.02	0.06	0.07
Adjusted R-squared	0.08	0.08	0.01	0.06	0.07

Standard Error	5892.00	3.98	4.85	4.71	8.51
F-statistic	13.61	36.95	7.11	16.96	9.19
Significance F	<0.01	<0.01	<0.01	<0.01	<0.01
Observations	701	859	859	823	695

*P = 0.01
**P = 0.001
***P = 0.00

When analyzed on its own, TPR were different among wind directions for overall activity ($F_{15, 1816}$ = 1.99, P = 0.01) as well as for 0-91 m ($F_{15, 1804}$ = 3.45, P < 0.01) and 91-213 m ($F_{15, 1804}$ = 3.12, P < 0.01). The highest HSR TPR occurred when winds were generally from northerly directions during the morning and night hours (Figure 28). The highest TPR occurred at night when the winds were from the north or WSW (Figure 28). At low altitudes, the highest TPR occurred during morning hours when winds were out of the NNE (Figure 28). Nighttime TPR at lower altitudes was elevated for most wind directions (Figure 28).

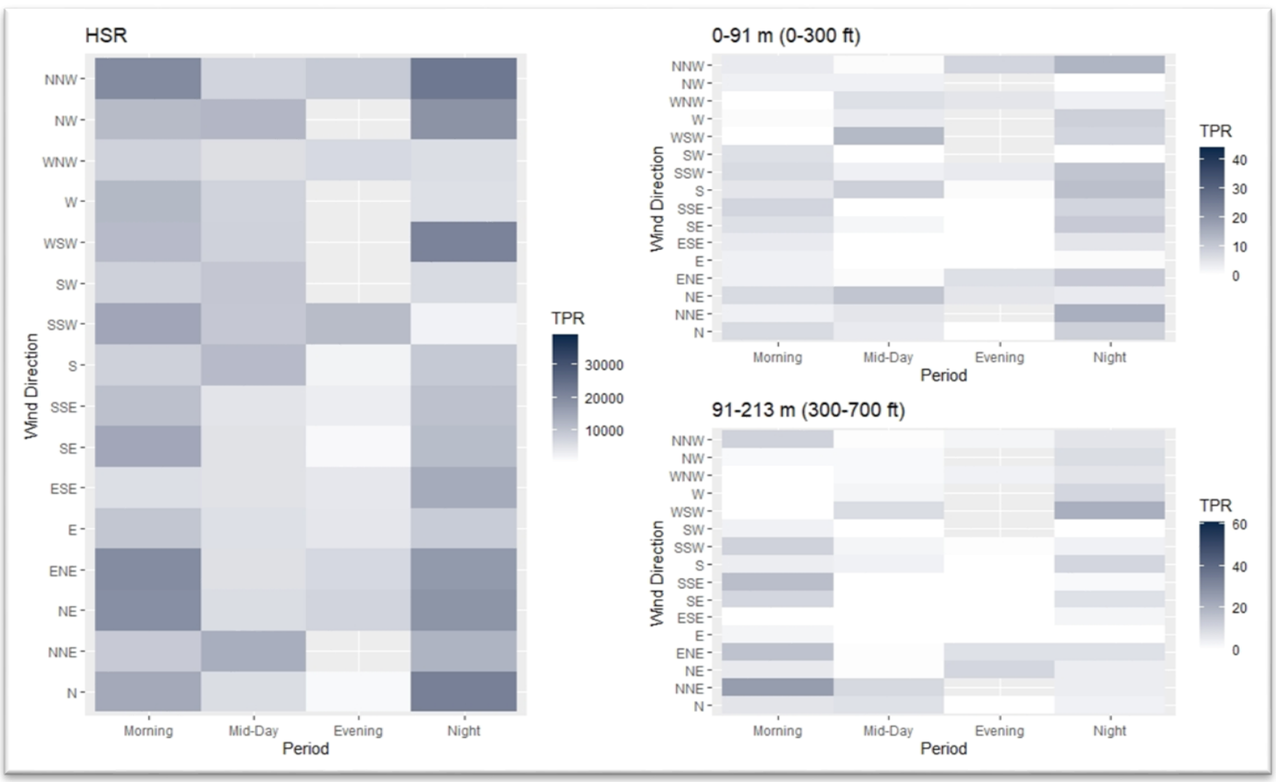


Figure 28. Heatmaps showing summer total passage rate (TPR) indicated by the MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars (0-91 m and 91-213 m) and direction of wind in summer 2021 at Naval Air Station Kingsville.

Impact of wind speeds in summer on TPR differed for overall activity ($F_{6, 2124} = 41.38$, $P < 0.01$) as well as at the lower altitudes (0-91 m: $F_{6, 2110} = 3.36$, $P < 0.01$; 91-213 m = $F_{6, 2110} = 5.13$, $P < 0.01$). Like spring, mean targets per hour decreased with increasing wind speeds (Figure 29), with largest decreases occurring when winds were > 8.0 m/s (18 mph) for altitudes above 91 m (300 ft) (Figure 29). Despite the statistical significance for mean targets in the lowest altitude (0-91 m [0-300 ft]) by wind speed, the Tukey Test did not indicate actual differences between individual wind speeds at that altitude (Figure 29).

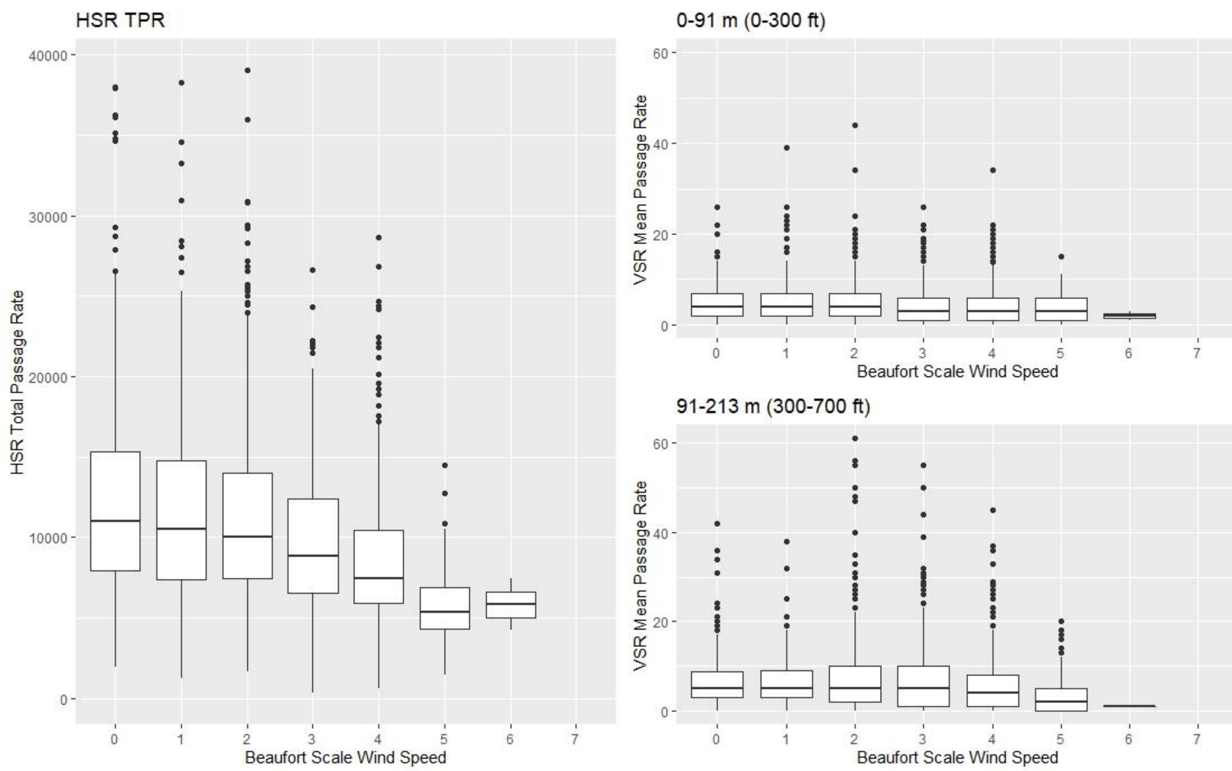


Figure 29. Mean targets per hour in summer 2021 by the MERLIN^{TM} horizontal scanning radar (HSR) and vertical scanning radar (VSR) at the two lowest altitudes (0-91 m and 91-213 m) for each Beaufort Scale wind speed at Naval Air Station Kingsville.

Days with rainfall in summer had the same HSR mean passage rate as days without rainfall ($F_{3, 370} = 1.85$, $P = 0.99$). The same was true at the two lowest altitudes (0-91 m: $F_{3, 357} = 0.56$, $P = 0.99$; 91-213 m: $F_{3, 357} = 0.77$, $P = 0.99$). Changes in barometric pressure had little correlation to mean passage rates during the summer (Figure 30).

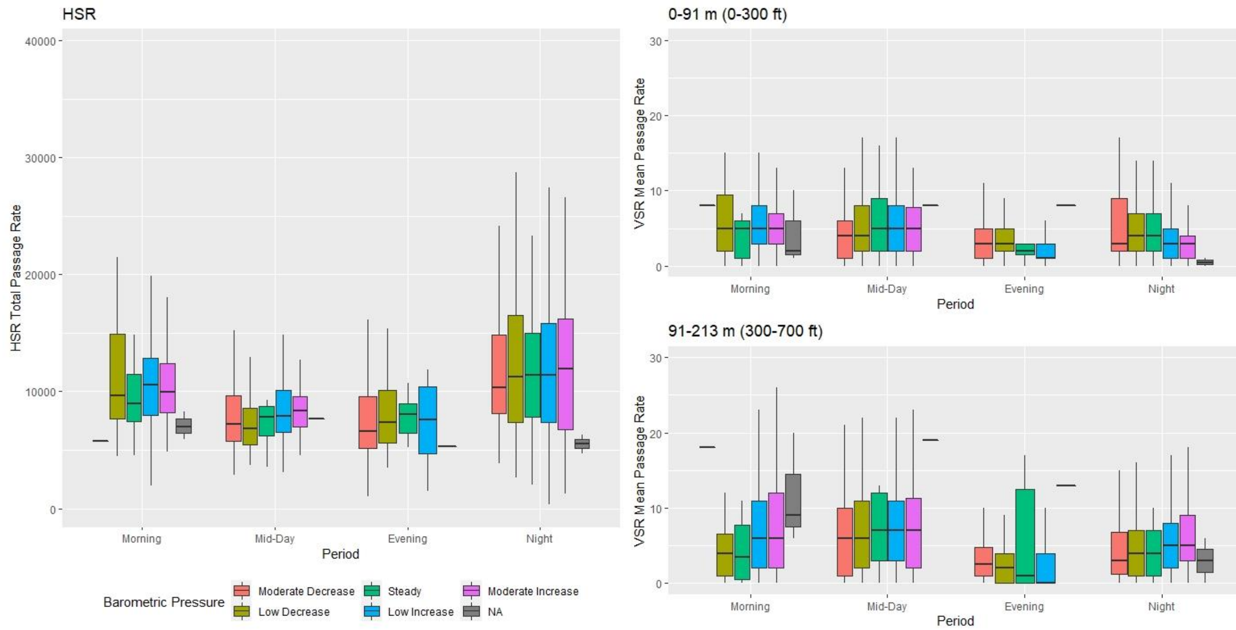


Figure 30. Boxplots showing summer total passage rate (TPR) indicated by the MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars (0-91 m and 91-213 m) and change in barometric pressure over three hours in summer 2021 at Naval Air Station Kingsville.

Average daily temperature had little correlation with average passage rates in summer when all periods are grouped together (Figure 31). However, mornings and mid-day hours during the summer correlated with higher passage rates at the lowest altitudes when the agricultural field and the riparian areas heat differently (Figure 32a, b).

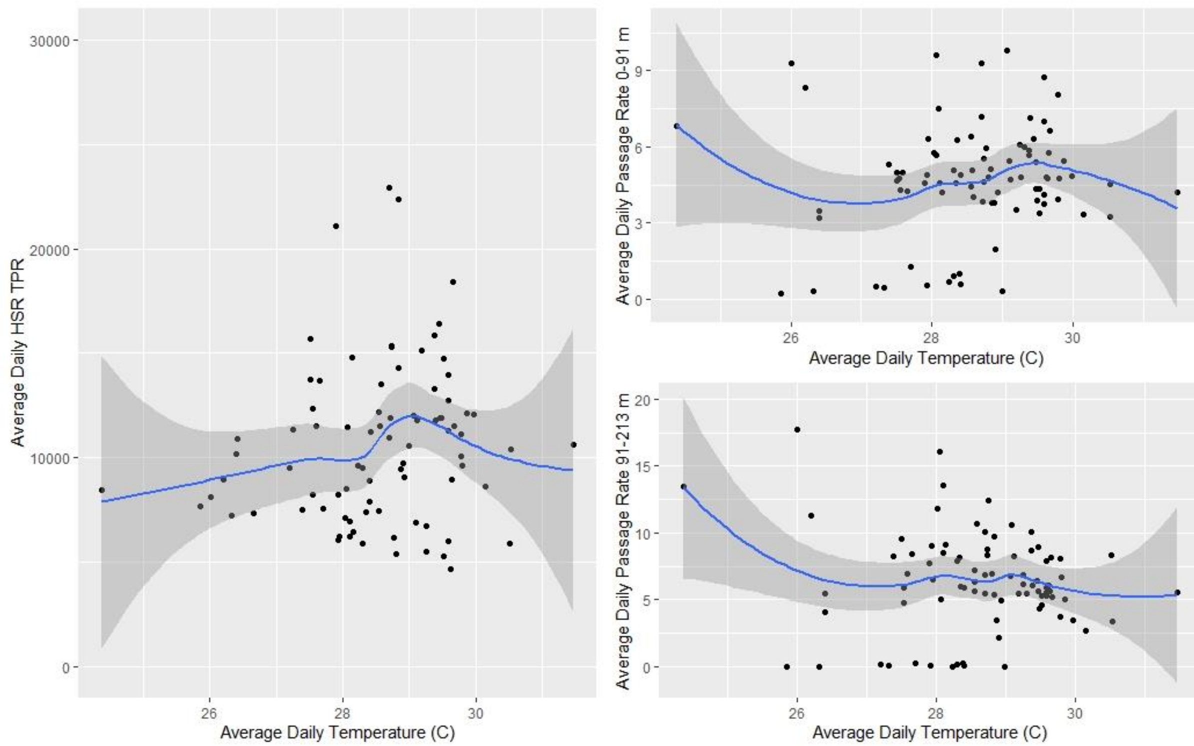
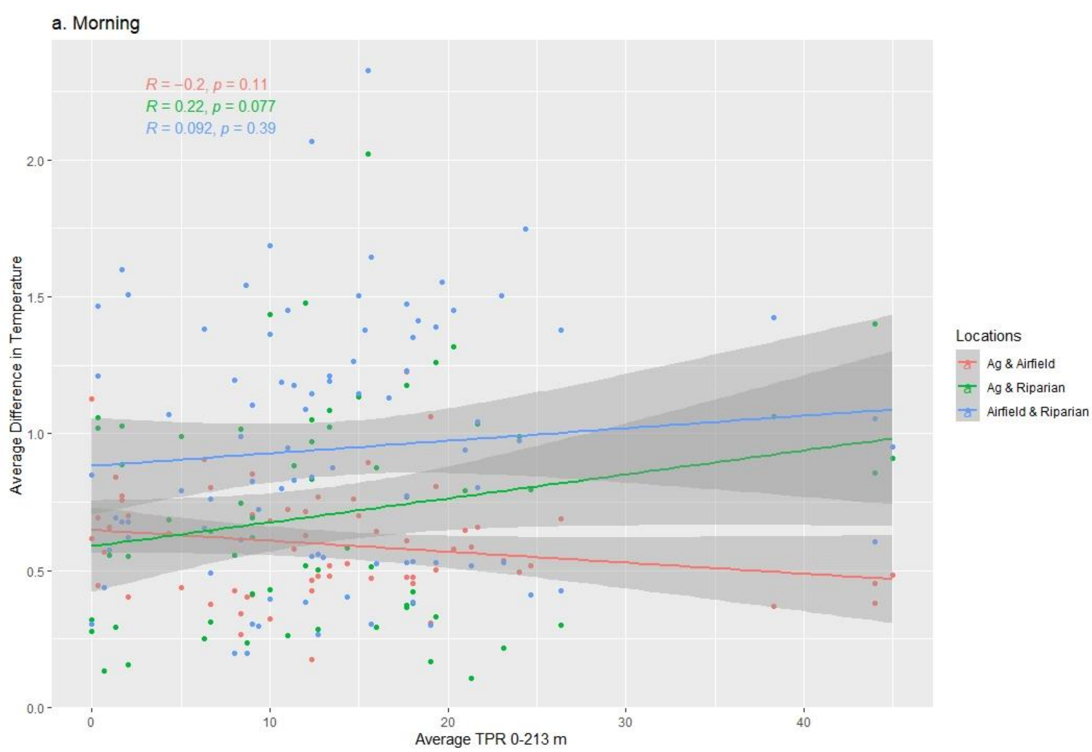
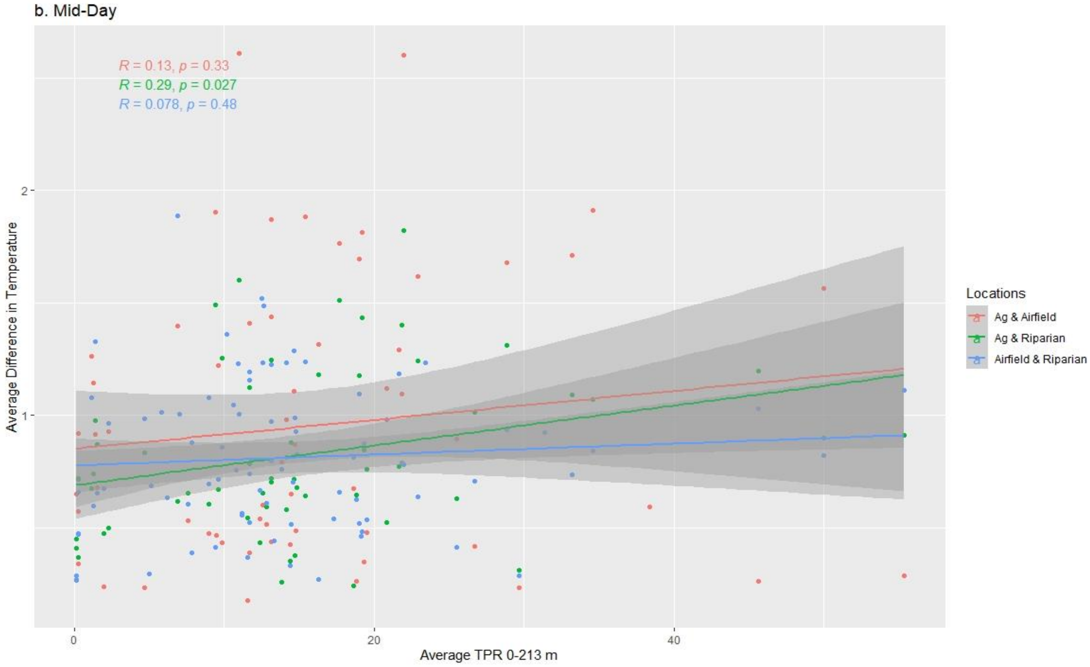


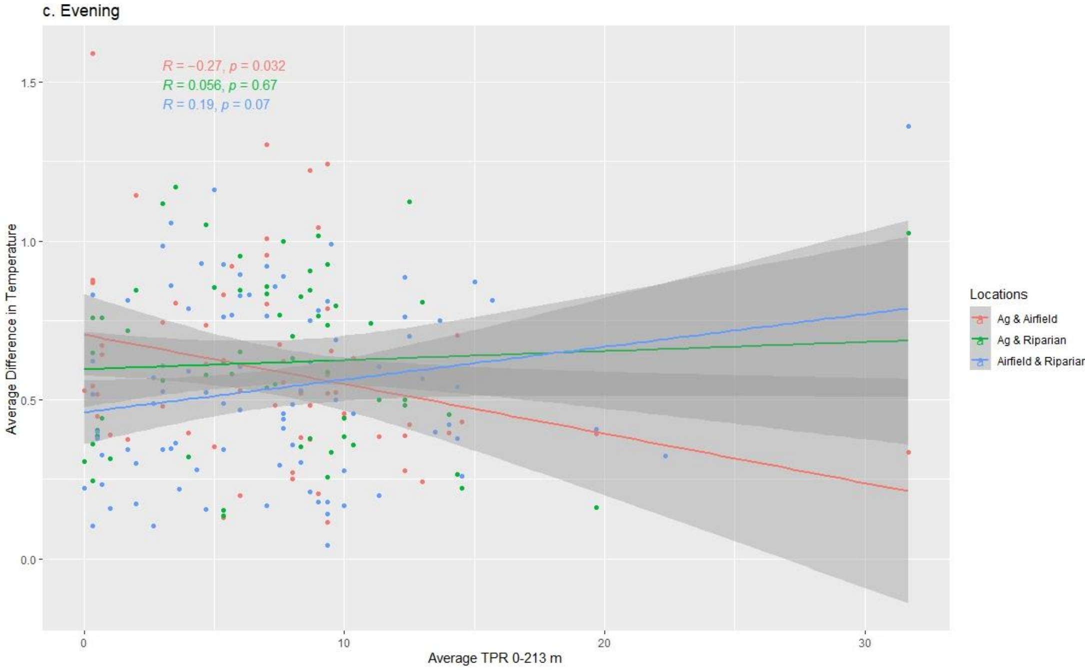
Figure 31. Average daily temperatures and MERLIN™ horizontal (HSR) and vertical (VSR) scanning radar total passage rates in summer of 2021.



b. Mid-Day



c. Evening



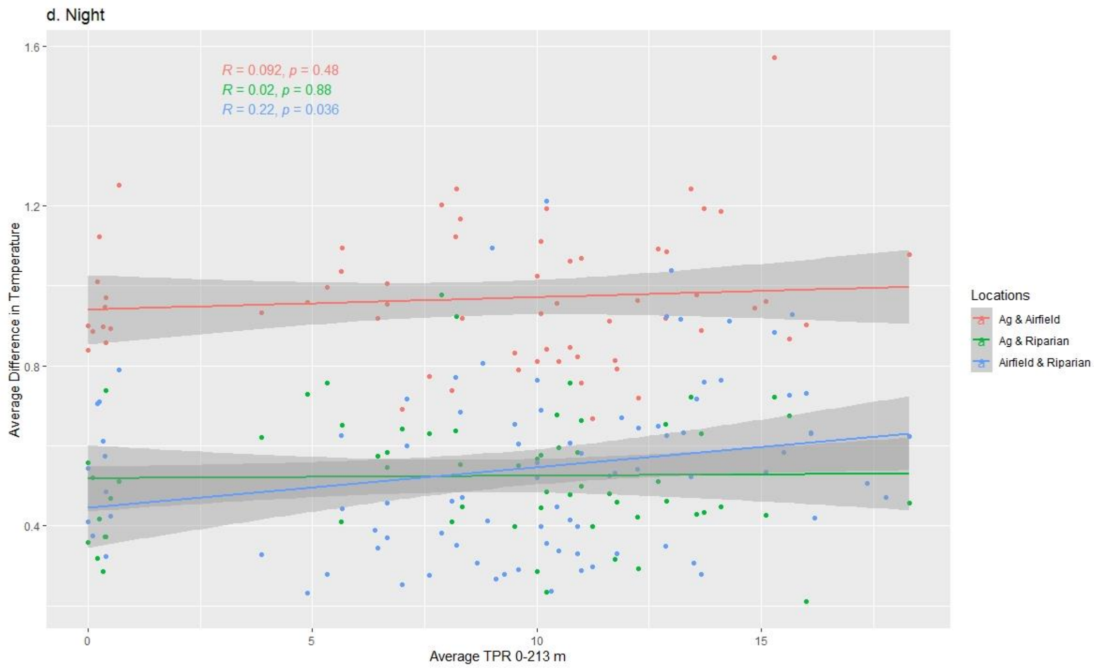


Figure 32. Average temperature difference and MERLIN^{TM} vertical scanning radar (VSR) average passage rate from 0 to 213 m during a) mornings, b) mid-day, c) evenings, and d) nights at Naval Air Station Kingsville, Texas in summer of 2021.

Fall

Like in spring, wind direction in the fall strongly correlated with bird activity above 91 m (300 ft). In the mornings, winds out of the NW correlated with higher bird activity from 91 to 610 m (300 to 2000 ft) while winds out of the southeast correlated with lower general activity (HSR) Table 10a). During mid-day, winds out of the west correlated with higher activity from 91 to 366 m (300 to 1200 ft) while winds out of the south correlated with lower overall activity (HSR) (Table 10b). Southeasterly winds were consistently correlated lower activity for all altitudes in the evenings (Table 10c) and with HSR TPR at night (Table 10d). Lower wind speed correlated with higher activity in general for all periods (Table 10) except during mid-day hours from 91 to 366 m (300 to 1200 ft; Table 10b). Rising BP correlated with higher activity overall (Table 10) except during morning hours when fall BP correlated with significantly higher passage rates (Table 10a).

Table 10. Results of multiple linear regression for total passage rate for MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radars in fall months for (a) mornings, (b) mid-day, (c) evenings, and (d) nights. Altitudinal bands listed by the ranges in meters above ground level.

a) Morning	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Direction x Wind Speed + Change in BP	Temperature + Wind Speed	Wind Direction + Change in BP	Temperature + Wind Speed + Wind Direction + Change in BP	Temperature + Wind Speed + Wind Direction + Change in BP
Intercept	3723.97 (1959.41)	22.15 (3.03)***	7.41 (2.00)***	-7.38 (5.94)	-6.62 (8.21)
Temperature	663.39 (75.56)***	-0.47 (0.14)***		0.82 (0.24)***	1.08 (0.35)**
Wind Speed	-339.66 (342.72)	-0.92 (0.41)*		-1.65 (0.76)*	-3.26 (1.04)**
Wind Direction	SE -3918.41 (1956.74)*		NW 5.93 (2.12)**	NW 7.40 (2.88)*	NW 8.48 (3.97)*
Change in Barometric Pressure	-1261.32 (399.59)**		3.03 (0.99)**	4.39 (1.32)**	7.87 (1.82)***
R-squared	0.35	0.06	0.09	0.13	0.16
Adjusted R-squared	0.32	0.06	0.07	0.11	0.14
Standard Error	5026	11.89	12.91	16.83	23.25
F-statistic	12.39	8.44	4.82	5.21	6.69
Significance F	<0.01	<0.01	<0.01	<0.01	<0.01
Observations	221	253	211	211	211

b) Mid-day	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed + Wind Direction + Change in BP	Temperature + Wind Speed	Temperature + Wind Speed x Wind Direction	Wind Speed x Wind Direction	Wind Direction
Intercept	2886.07 (867.17)***	39.18 (7.75)***	27.49 (16.70)	-7.50 (11.14)	36.82 (4.15)***
Temperature	432.78 (29.67)***	-0.63 (0.26)*	-1.07 (0.44)*		
Wind Speed	-424.55 (64.00)***	-1.48 (0.55)**	5.19 (2.14)*	6.99 (2.22)***	
Wind Direction	SE -3544.99 (361.81)***; SW -3631.19 (452.91)***		NW 48.93 (16.94)**; SW 40.05 (16.06)*	NW 60.91 (17.44)***; SE 34.36 (14.55)*; SW 47.47 (16.82)**	SE -9.24 (5.21)

Change in Barometric Pressure	404.37 (69.77)***				
R-squared	0.42	0.03	0.05	0.04	0.02
Adjusted R-squared	0.42	0.02	0.03	0.03	0.01
Standard Error	2801.00	29.19	41.25	43.20	42.32
F-statistic	52.34	6.57	2.82	2.67	2.59
Significance F	<0.01	<0.01	<0.01	0.01	0.05
Observations	434	485	413	413	413

c) Evening	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed + Wind Direction + Change in BP	Wind Direction	Wind Direction	Wind Direction	Wind Direction
Intercept	126.07 (1598.80)	13.20 (2.18)***	19.86 (3.82)***	22.79 (4.32)***	30.43 (4.64)***
Temperature	363.75 (54.82)***				
Wind Speed	-837.82 (127.33)***				
Wind Direction	SE -2572.31 (678.48)***	SE -5.54 (2.44)*	SE -12.04 (4.26)**	SE -14.80 (4.82)**	SE -16.08 (5.18)**
Change in Barometric Pressure	905.71 (189.18)***				
R-squared	0.44	0.02	0.04	0.04	0.04
Adjusted R-squared	0.43	0.01	0.03	0.04	0.03
Standard Error	3547.00	13.64	23.83	26.95	28.96
F-statistic	36.21	2.58	4.97	5.16	4.86
Significance F	<0.01	0.08	0.01	0.01	0.01
Observations	234	223	223	223	223

d) Night	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed x Wind Direction + Change in BP	Wind Direction + Change in BP	Temperature + Change in BP	Temperature + Wind Speed + Change in BP	Temperature + Wind Speed + Change in BP
Intercept	3141.61 (1609.76)	15.63 (1.90)***	11.69 (5.03)*	14.24 (5.97)*	30.89 (8.06)***
Temperature	955.69 (56.68)***		0.54 (0.24)*	0.91 (0.29)**	1.61 (0.39)***
Wind Speed	-1720.93 (344.96)***			-2.36 (0.90)**	-6.02 (1.22)***
Wind Direction	SE -3294.06 (1375.84)*	SW -9.48 (4.09)*			
Change in Barometric Pressure	539.53 (194.61)**	1.40 (0.73)	3.67 (1.05)***	4.95 (1.24)***	8.21 (1.67)***
R-squared	0.29	0.01	0.02	0.03	0.05
Adjusted R-squared	0.28	0.01	0.02	0.02	0.05
Standard Error	7411.00	28.75	43.47	50.64	68.36
F-statistic	46.97	3.15	9.95	10.30	19.21
Significance F	<0.01	0.01	<0.01	<0.01	<0.01
Observations	1047	1014	1175	1145	1145

*P = 0.01

**P = 0.001
***P = 0.00

TPR only differed significantly by wind direction for overall activity in fall ($F_{15, 2270}$ = 6.07, P < 0.01), but not at the lower altitudes (0-91 m: $F_{15,2179}$ = 1.17, P = 0.29; 91-213 m: $F_{15, 2179}$ = 0.91, P = 0.55). The highest overall HSR TPR occurred at night when winds were from the WSW, SSW, SSE, and ENE as well as in the mornings when winds were out of the north (Figure 33). TPR was also high in the evenings when winds were out of the east (Figure 33). At low altitudes, the highest TPR occurred during the mid-day and evening hours when winds were out of the W and WNW, but were not significantly different from other directions (Figure 33).

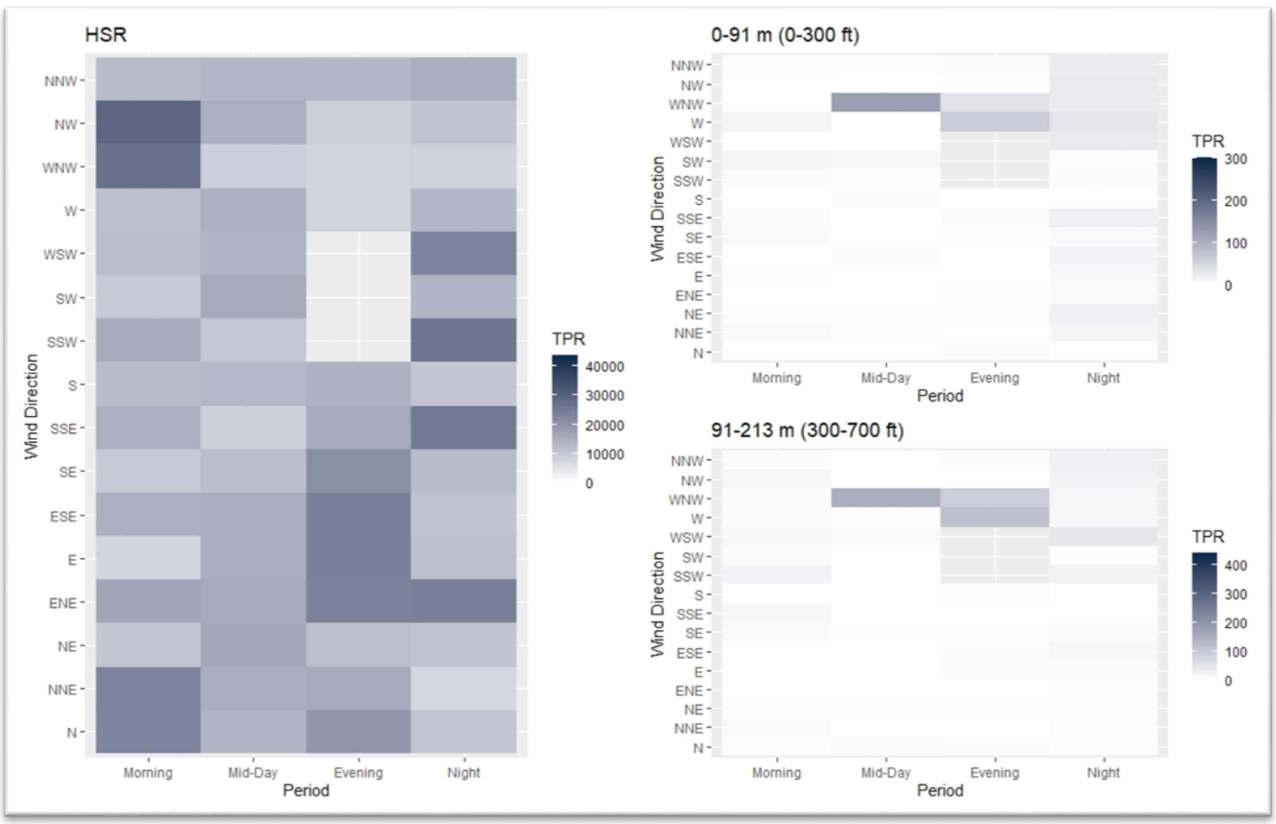


Figure 33. Heatmaps showing fall total passage rate (TPR) indicated by the MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radars (0-91 m and 91-213 m) and direction of wind from in fall 2020 and 2021 at Naval Air Station Kingsville.

Impact of wind speeds in fall on passage rate differed for overall activity ($F_{6, 2574}$ = 45.83, P < 0.01) as well as at the lower altitudes (0-91 m: $F_{6, 2473}$ = 4.77, P < 0.01; 91-213 m = $F_{6, 2473}$ = 2.78, P < 0.01). Like spring and summer, passage rates decreased with increasing wind speeds (Figure 34). The biggest decrease in mean passage rate for all altitudes combined occurred when winds were above 3.4 m/s (~ 8 mph) and there was an increase in mean passage rate for the lowest altitude (0-91 m [0-300 ft]) when winds were between 10.8 and 13.8 m/s (25 and 30 mph) (Figure 34).

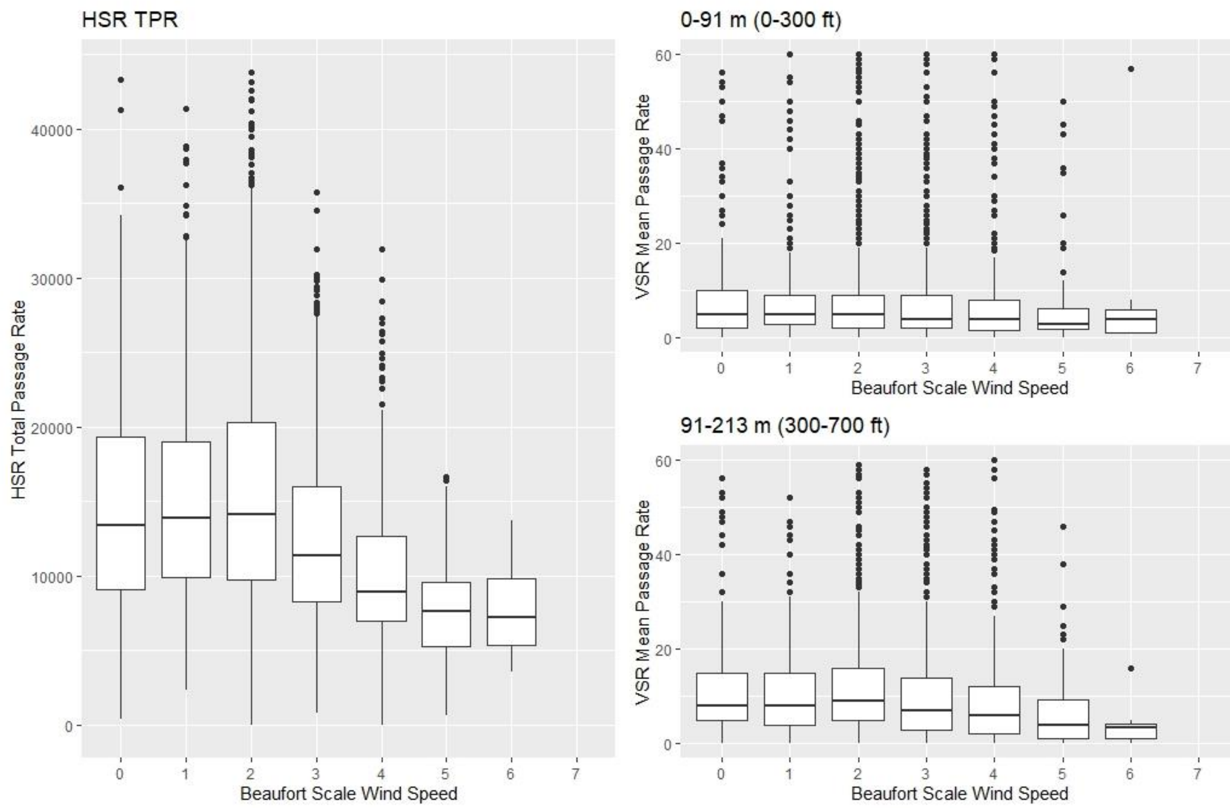


Figure 34. Mean targets per hour in 10 November 2020 to 30 November 2020 and 1 September 2021 to 30 November 2021 by the MERLIN™ horizontal scanning radar (HSR) and vertical scanning radar (VSR) at the two lowest altitudes (0-91 m and 91-213 m) for each Beaufort Scale wind speed at Naval Air Station Kingsville, Texas.

Increasing BP at night correlated with higher HSR mean passage rates and rapid increases in BP at night significantly increased VSR mean passage rates at the lowest two altitudes during the fall (Figure 35). A moderate decrease in BP at night during the fall months correlated with the lowest mean passage rate for all altitudes combined and the two lowest (0-91 m [0-300 ft]; 91-213 m[300-700 ft]) (Figure 35). Rapid increases in BP during the mid-day hours also correlated with low mean passage rate (Figure 35).

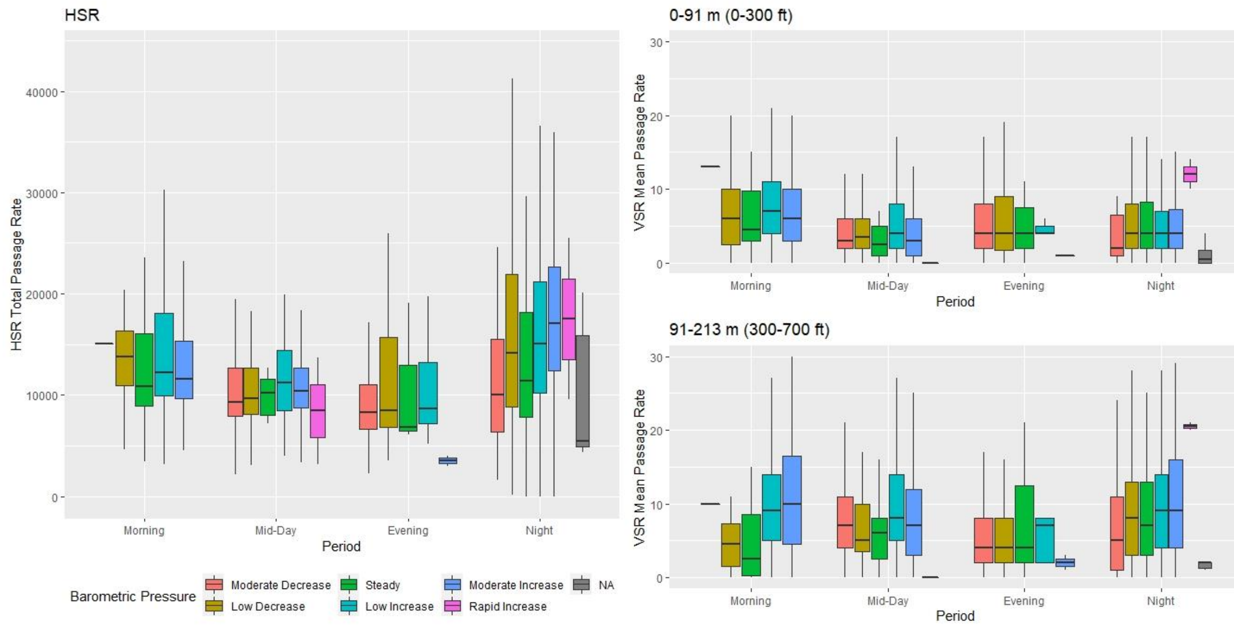


Figure 35. Boxplots showing fall total passage rate (TPR) indicated by the MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radars (0-91 m and 91-213 m) and change in barometric pressure over three hours on fall 2020 and 2021 at Naval Air Station Kingsville, Texas.

Higher temperatures correlated with more activity during each period for all altitudes except the lowest where higher activity was correlated with lower temperatures in the morning and mid-day (Table 10). Overall activity was higher when average daily temperatures were higher but not at lower altitudes (Figure 36). Increasing differences in temperature between the airfield and riparian areas (no agriculture temperature available for fall), corresponded with more activity at the lowest altitudinal bands during mid-day and evening hours during the fall (Figure 37b, c).

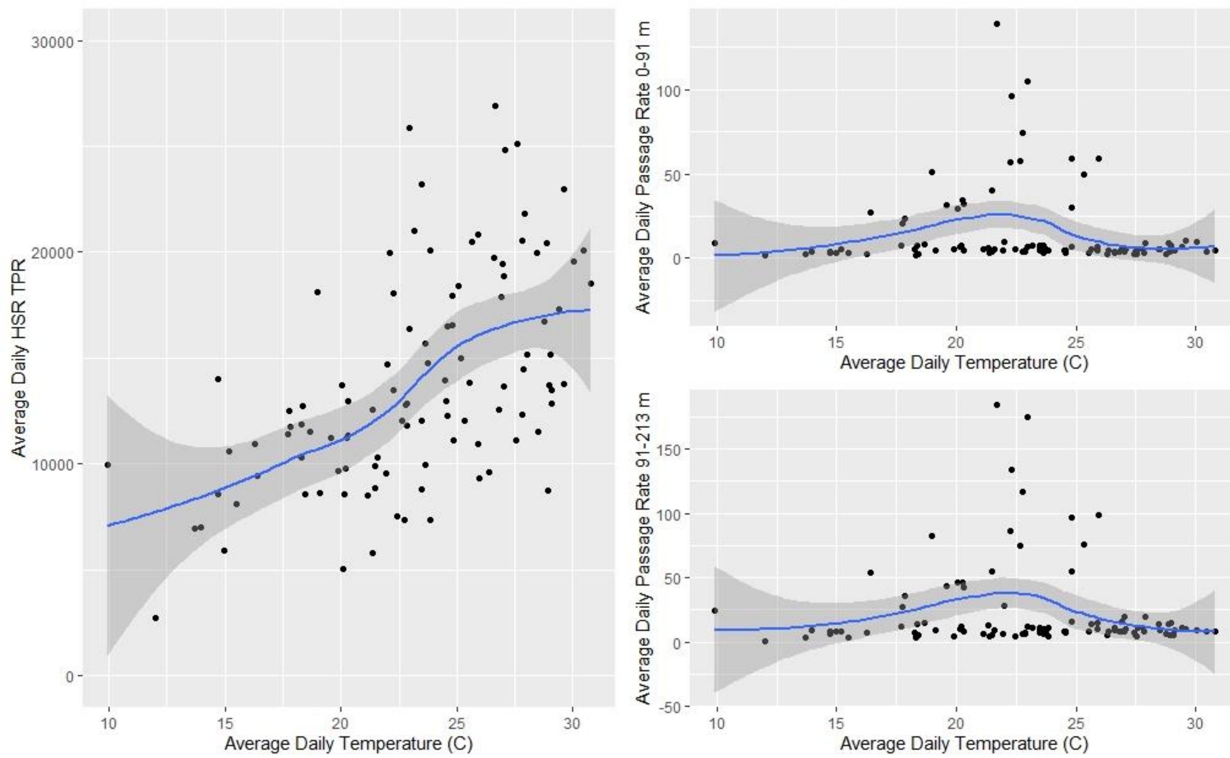
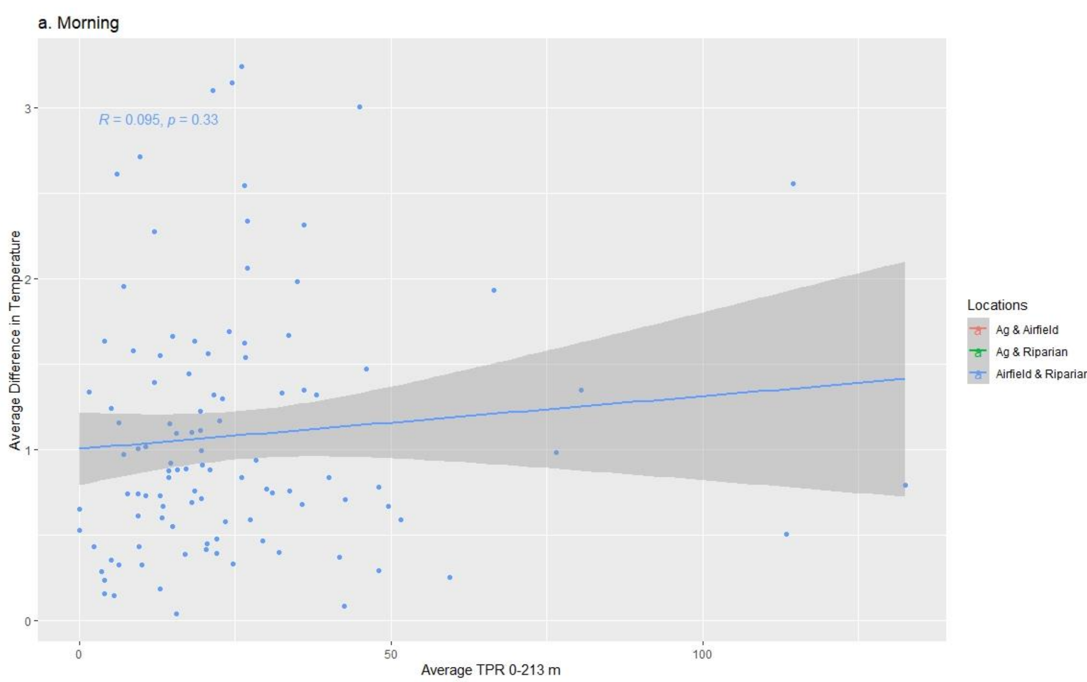
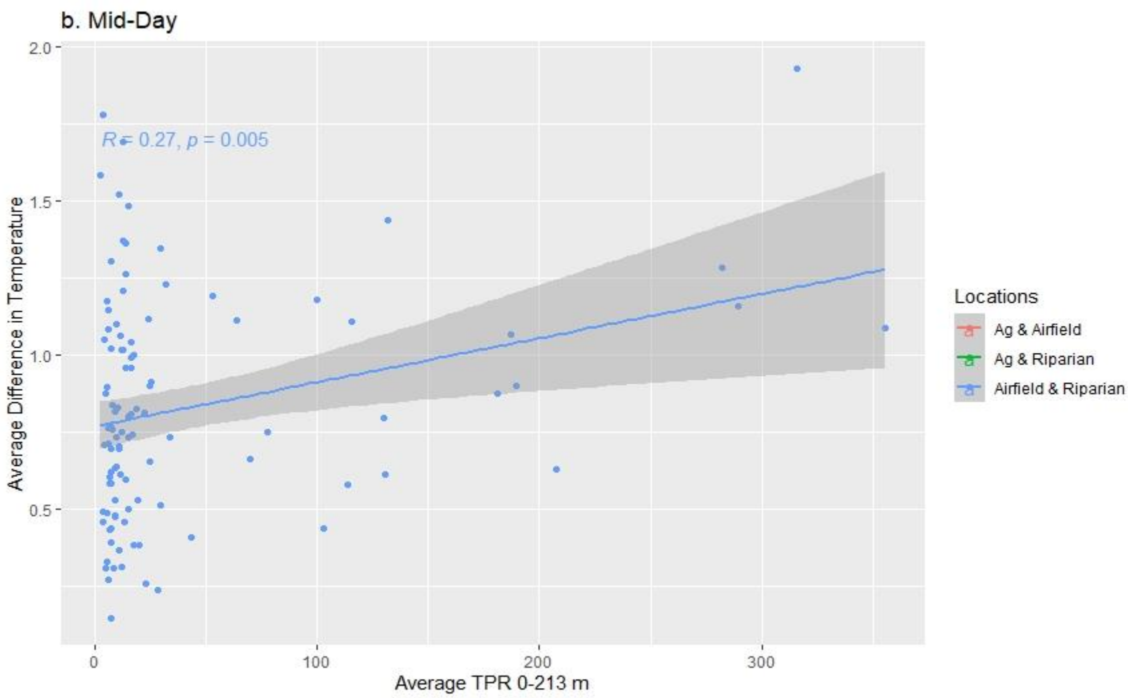
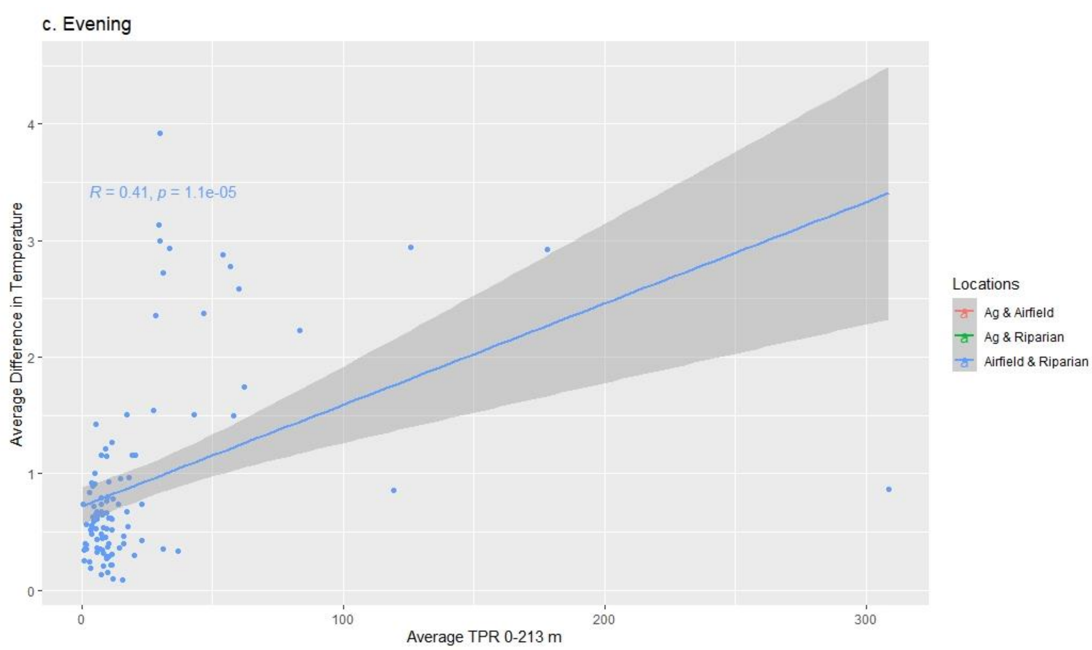


Figure 36. Average daily temperatures and MERLIN™ horizontal (HSR) and vertical (VSR) scanning radar total passage rates 10 November 2020 to 30 November 2020 and 1 September 2021 to 30 November 2021 at Naval Air Station Kingsville, Texas.





b. Mid-Day
R = 0.27, p = 0.005
Average Difference in Temperature
Average TPR 0-213 m
Locations
Ag & Airfield
Ag & Riparian
Airfield & Riparian



c. Evening
R = 0.41, p = 1.1e-05
Average Difference in Temperature
Average TPR 0-213 m
Locations
Ag & Airfield
Ag & Riparian
Airfield & Riparian

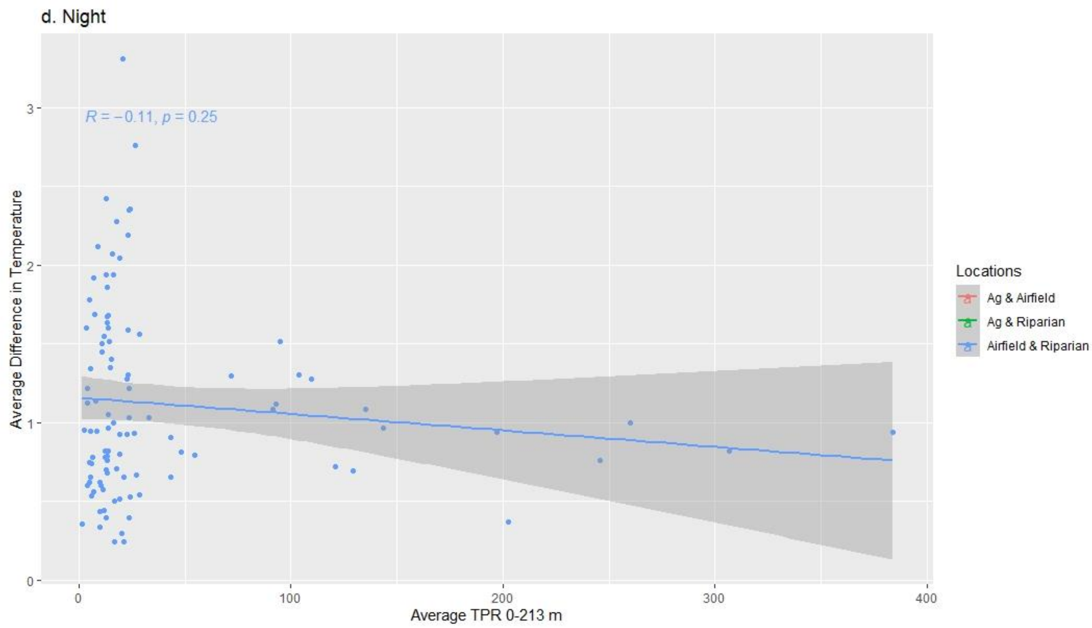


Figure 37. Average temperature difference and MERLIN^{TM} vertical scanning radar (VSR) average hourly passage rate from 0 to 213 m during a) mornings, b) mid-day, c) evenings, and d) nights at Naval Air Station Kingsville, Texas in fall of 2021.

Winter

Wind direction during the winter did not influence activity as strongly or as consistently as in other seasons (Table 11). However, higher temperatures correlated strongly with higher activity overall in the mid-day, evening, and night hours (Table 11). Like in other seasons, lower wind speed correlated with more activity as well during all periods and all altitudes, but to a lesser magnitude at the lowest altitude (0-91 m [0-300 ft]) (Table 11). BP had little influence on activity except at night when it was positively correlated with higher passage rates above 91 m (300 ft) (Table 11d).

Table 11. Results of multiple linear regression for total passage rate for MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars in winter months for (a) mornings, (b) mid-day, (c) evenings, and (d) nights. Altitudinal bands listed by the ranges in meters above ground level.

a) Morning	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Wind Direction + Wind Speed	Wind Direction + Wind Speed	Temperature + Wind Speed + Wind Direction	Intercept only	Intercept only
Intercept	6452.73 (497.14)***	8.35 (1.41)***	8.23 (2.23)***	0.01 (0.59)***	21.46 (1.54)***
Temperature			0.17 (0.12)		
Wind Speed	-352.33 (92.33)	-0.61 (0.26)*	-0.78 (0.37)*		
Wind Direction	NW 1074.93 (434.83)*	SE 4.42 (1.31)***	NW 5.68 (1.76)**		
Change in Barometric Pressure					
R-squared	0.14	0.10	0.09		
Adjusted R-squared	0.12	0.08	0.06		
Standard Error	2080	6.01	8.57	8.39	22.1
F-statistic	6.28	4.62	3.20		
Significance F	<0.01	<0.01	0.01		
Observations	161	177	177	205	205

b) Mid-day	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed	Temperature + Wind Speed + Wind Direction	Temperature + Wind Speed + Wind Direction + Change in BP	Temperature + Wind Speed x Wind Direction + Change in BP	Temperature + Wind Speed x Wind Direction + Change in BP
Intercept	4170.80 (306.38)***	6.76 (2.73)*	13.49 (4.27)**	-4.07 (9.45)	5.35 (11.30)

	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Temperature	132.66 (11.71)***	1.00 (2.73)***	1.63 (0.18)***	1.74 (0.19)***	2.07 (0.22)***
Wind Speed	-226.92 (36.61)***	-1.93 (0.33)***	-3.00 (0.51)***	-0.32 (1.90)	-1.14 (2.27)
Wind Direction		NW 5.09 (2.10)*; SW 6.11 (2.65)*	NW 12.03 (3.27)***	SE 22.75 (10.53)*	SE 23.97 (12.59)*
Change in Barometric Pressure			-1.17 (0.49)*	-2.11 (0.48)***	-3.27 (0.57)***
R-squared	0.29	0.31	0.29	0.36	0.38
Adjusted R-squared	0.29	0.30	0.28	0.34	0.37
Standard Error	1834.00	13.76	21.35	20.64	24.67
F-statistic	82.94	32.47	24.97	21.92	24.59
Significance F	<0.01	<0.01	<0.01	<0.01	<0.01
Observations	405	369	368	368	368

c) Evening	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m
Best Model	Temperature + Wind Speed	Temperature	Temperature + Wind Speed	Temperature + Wind Speed	Temperature + Wind Speed + Wind Direction
Intercept	4592.61 (284.08)***	0.58 (2.75)	12.62 (6.13)*	13.57 (8.28)	8.76 (16.36)
Temperature	95.10 (10.27)***	0.52 (0.13)***	0.83 (0.22)***	0.96 (0.30)**	1.72 (0.54)**
Wind Speed	-305.55 (30.86)***		-2.16 (0.67)**	-2.35 (0.90)**	-3.85 (1.77)*
Wind Direction					NW 30.11 (12.45)*
Change in Barometric Pressure					
R-squared	0.50	0.08	0.12	0.08	0.12
Adjusted R-squared	0.49	0.07	0.11	0.07	0.10
Standard Error	1060.00	13.53	22.87	30.89	48.59
F-statistic	92.67	16.34	12.44	8.59	4.69
Significance F	<0.01	<0.01	<0.01	<0.01	<0.01
Observations	189	192	189	189	176

d) Night	HSR TPR	0-91 m	91-213 m	213-366 m	366-610 m

Best Model	Temperature + Wind Speed x Wind Direction + Change in BP	Temperature + Wind Speed	Temperature + Wind Speed x Wind Direction + Change in BP	Temperature + Wind Speed x Wind Direction + Change in BP	Temperature + Wind Speed x Wind Direction + Change in BP
Intercept	3856.17 (601.64)***	-0.07 (0.76)	1.20 (3.46)	4.22 (4.73)	24.13 (7.63)**
Temperature	96.93 (18.66)***	0.75 (0.05)***	0.76 (0.11)***	0.95 (0.14)***	1.50 (0.23)***
Wind Speed	-410.47 (141.42)**	0.21 (0.17)	-0.01 (0.83)	-0.14 (1.13)	-2.41 (1.83)
Wind Direction	SE -1360.91 (684.19)*		SE '-1.17 (3.89)*	SE 0.57 (5.32)*	SE -12.75 (8.57)*
Change in Barometric Pressure	621.35 (49.54)***		1.01 (0.38)**	1.42 (0.52)**	2.23 (0.84)**
R-squared	0.18	0.19	0.23	0.20	0.14
Adjusted R-squared	0.17	0.19	0.23	0.19	0.13
Standard Error	3126.00	11.83	17.40	23.80	38.37
F-statistic	21.10	220.90	29.72	24.77	15.23
Significance F	<0.01	<0.01	<0.01	<0.01	<0.01
Observations	896	968	887	887	887

*P = 0.01
**P = 0.001
***P = 0.00

TPR were different between wind directions for overall activity ($F_{15, 1936} = 5.74$, $P < 0.01$) as well as for 0-91 m ($F_{15, 1909} = 11.52$, $P < 0.01$) and 91-213 m ($F_{15, 1909} = 10.74$, $P < 0.01$). Overall activity was well distributed across all wind directions during the winter (Figure 38). Overall activity was also high in the evenings when winds were out of the east (Fig. X). At low altitudes, the highest TPR in winter occurred during the mid-day and evening hours when winds were out of the W and SW (Figure 38).

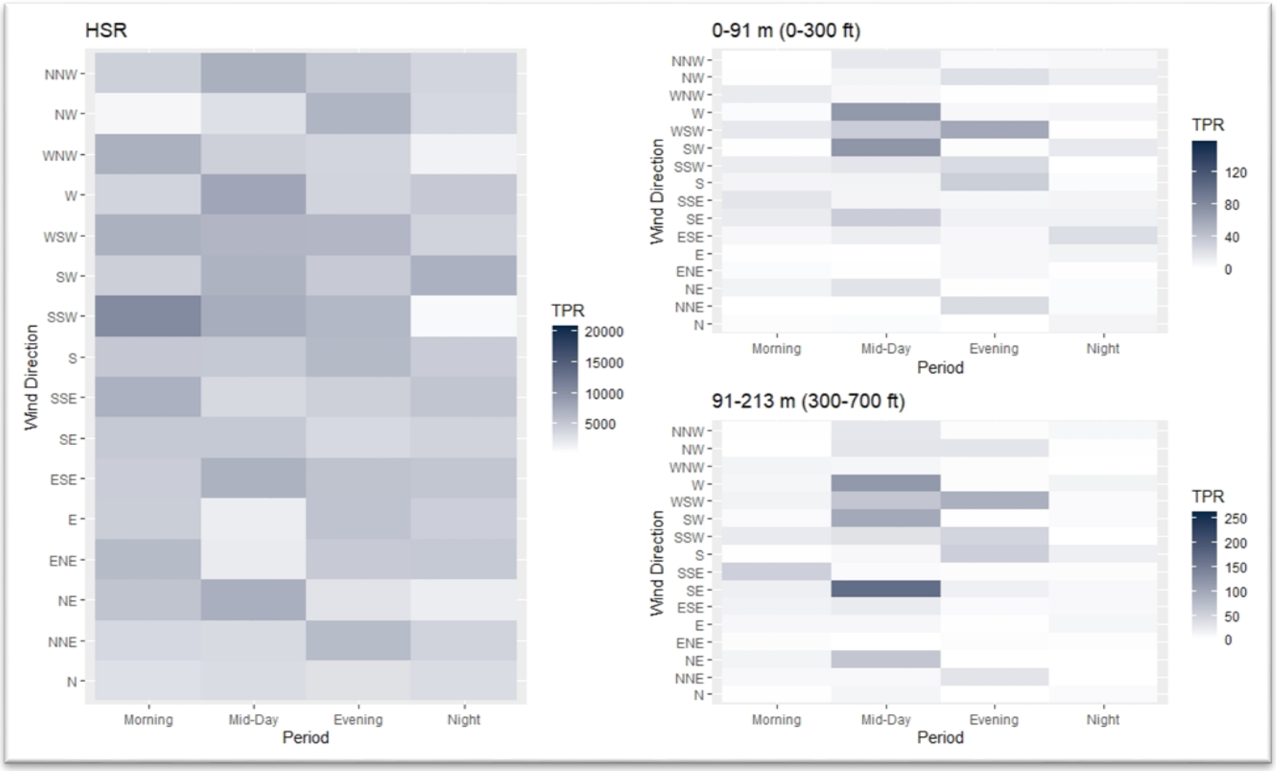


Figure 38. Heatmaps showing winter total passage rate (TPR) indicated by the MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars (0-91 m and 91-213 m) and direction of wind in winter 2021 at Naval Air Station Kingsville, Texas.

Impact of wind speeds in winter on TPR differed for overall activity ($F_{6, 2116} = 4.11$, $P < 0.01$) as well as at the lower altitudes (0-91 m: $F_{6, 2088} = 2.86$, $P = 0.01$; 91-213 m = $F_{6, 2088} = 5.58$, $P < 0.01$); however, trends for increasing wind speeds and passage rates were not the same for overall activity and for the two lowest altitudes (Figure 39). Passage rate was lower for all altitudes combined when there was no wind (Figure 39). Mean passage rate increased with the higher wind speeds at the lowest altitude (0-91 m [0-300 ft]). Mean passage rate was higher when winds were 0 m/s (0 mph) than the next two Beaufort Scale categories and then rises again when winds were between 3.4 and 7.9 m/s (8 and 17 mph) at the 91-213 m (300-700 ft) altitude (Figure 39).

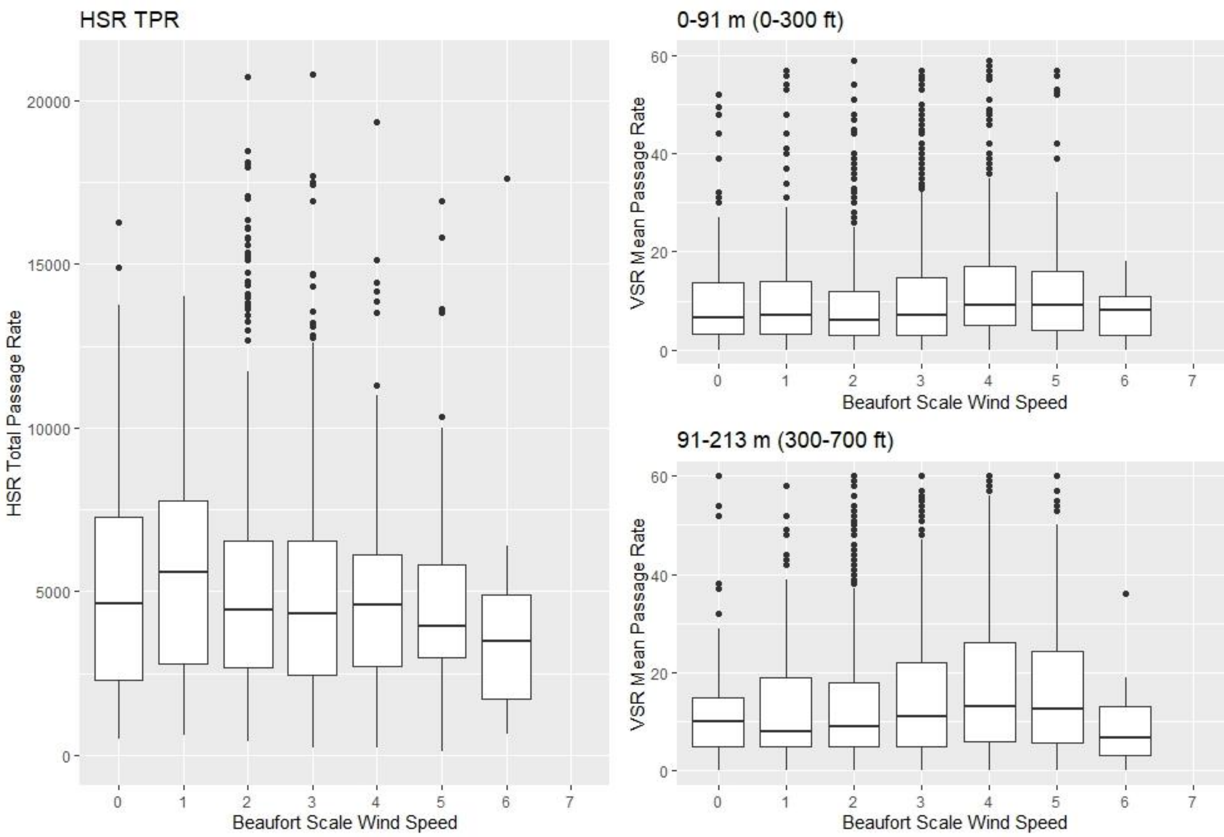


Figure 39. Mean targets per hour from 01 December 2020 to 28 February 2021 by the MERLIN[TM] horizontal scanning radar (HSR) and vertical scanning radar (VSR) at the two lowest altitudes (0-91 m and 91-213 m) for each Beaufort scale wind speed at Naval Air Station Kingsville, Texas.

Days with rainfall in winter had the same HSR mean passage rate (all altitudes) as days without rainfall ($F_{3, 370} = 1.85$, P = 0.85). The same was true at the two lowest altitudes (0-91 m: $F_{3, 357} = 0.56$, P = 0.98; 91-213 m: F3, 357 = 0.77, P = 0.87). A moderate decrease in BP in the morning correlated with higher mean passage rates for the HSR (all altitudes) as well as for the lowest altitude (0-91 m [0-300 ft]) (Figure 40). In the evenings, mean passage rate was lower when BP was increasing for HSR and the two lowest VSR altitudes (Figure 40). At night, mean passage rate was higher according to the HSR the more rapidly the BP climbed, but there was no observed impact of BP at the two lowest altitudes during that those hours (Figure 40).

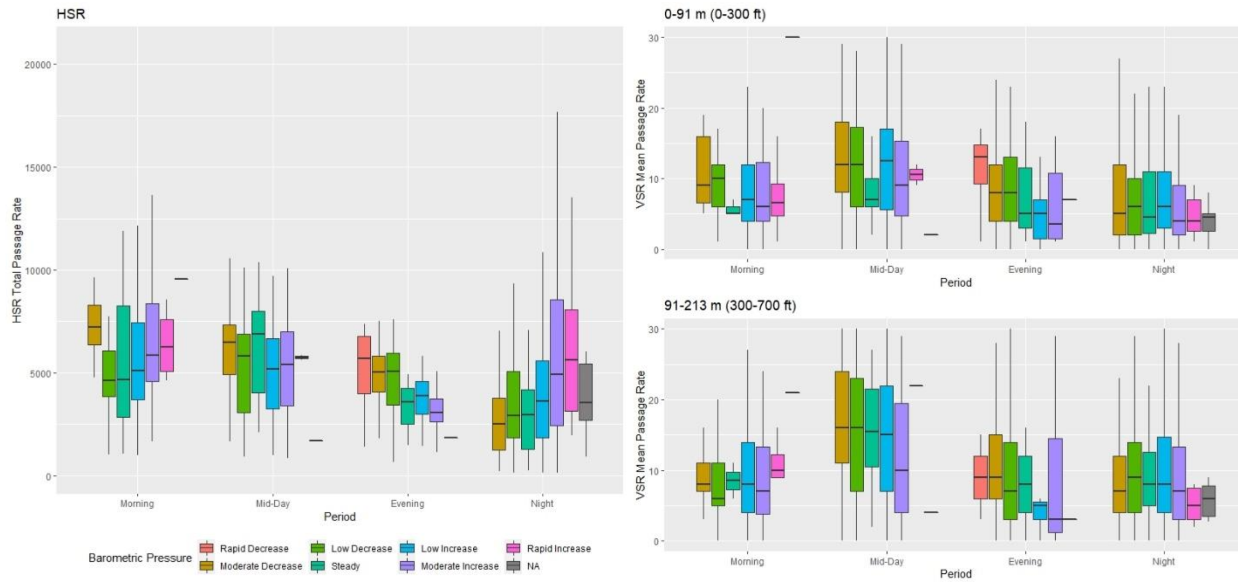


Figure 40. Boxplots showing winter total passage rate (TPR) indicated by the MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radars (0-91 m & and 91-213 m) and change in barometric pressure over three hours in winter 2021 at Naval Air Station Kingsville, Texas.

Average daily TPR for overall activity and the two lowest altitudes were higher when average daily temperatures were warmer (Figure 41). Hourly activity was positively correlated with differences in temperature between all areas during the mid-day hours at the lowest altitudinal bands (Figure 42b). Increasing differences in temperature between the agricultural field and the airfield as well as the agricultural field and the riparian area also corresponded with higher use of the lower altitudes during the evening hours in winter (Figure 42c).

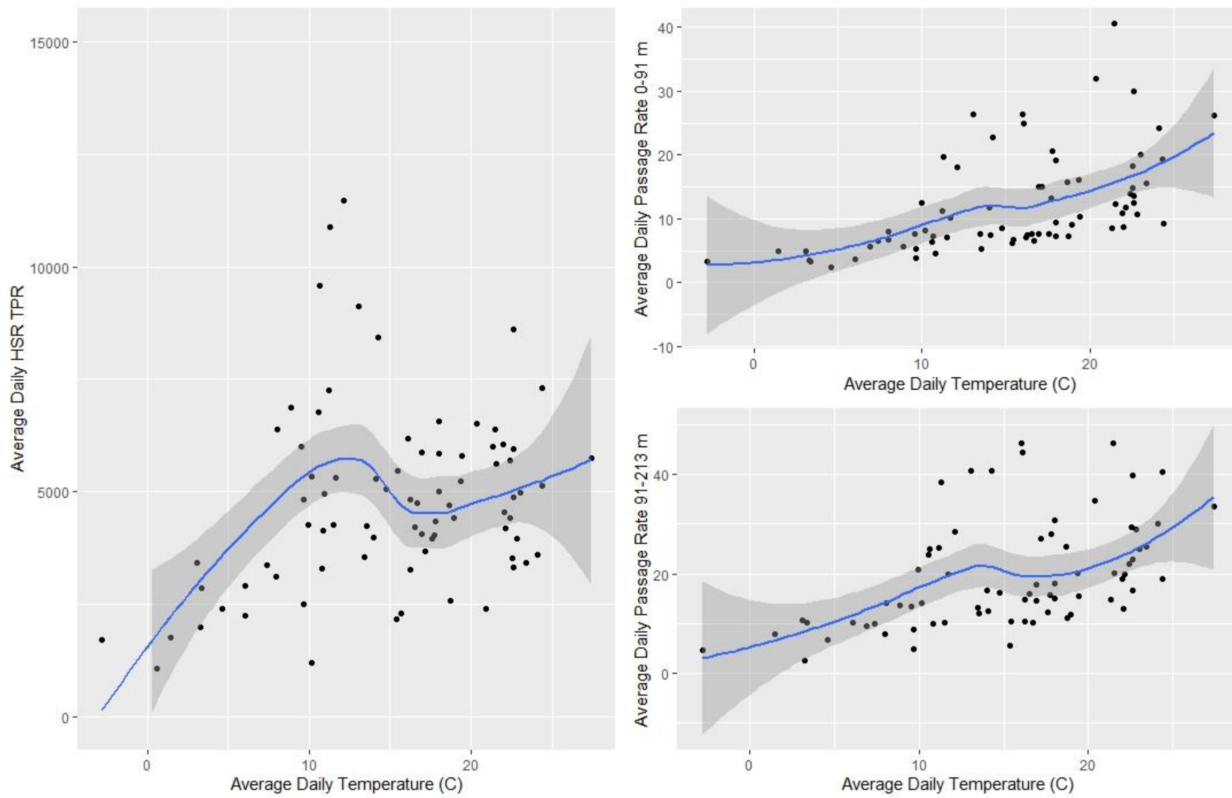
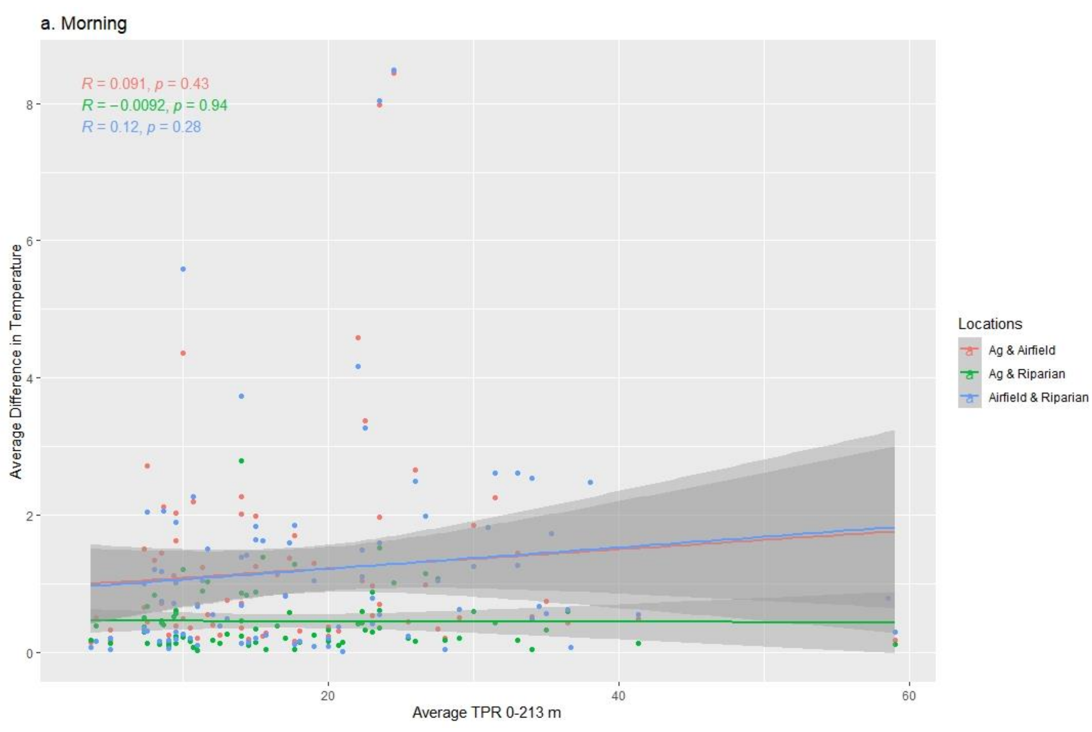
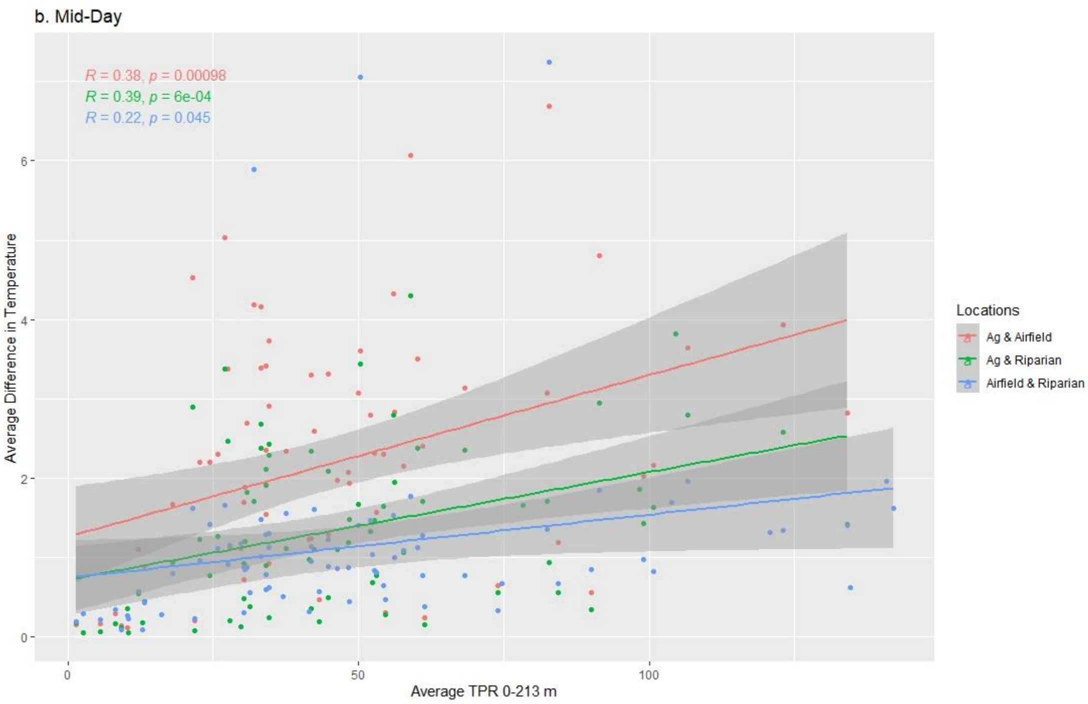
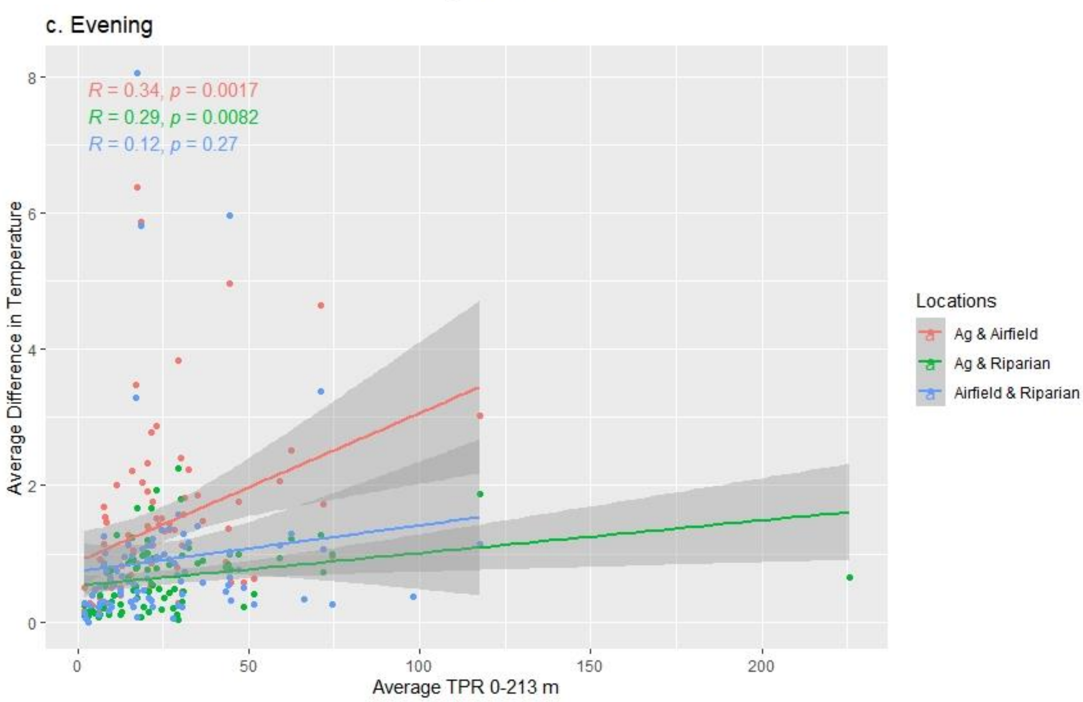


Figure 41. Average daily temperatures and MERLIN^{TM} horizontal (HSR) and vertical (VSR) scanning radar total passage rates 01 December 2020 to 28 February 2021 at Naval Air Station Kingsville, Texas.




b. Mid-Day
R = 0.38, p = 0.00098
R = 0.39, p = 6e-04
R = 0.22, p = 0.045
Average Difference in Temperature
Average TPR 0-213 m
Locations
Ag & Airfield
Ag & Riparian
Airfield & Riparian


c. Evening
R = 0.34, p = 0.0017
R = 0.29, p = 0.0082
R = 0.12, p = 0.27
Average Difference in Temperature
Average TPR 0-213 m
Locations
Ag & Airfield
Ag & Riparian
Airfield & Riparian

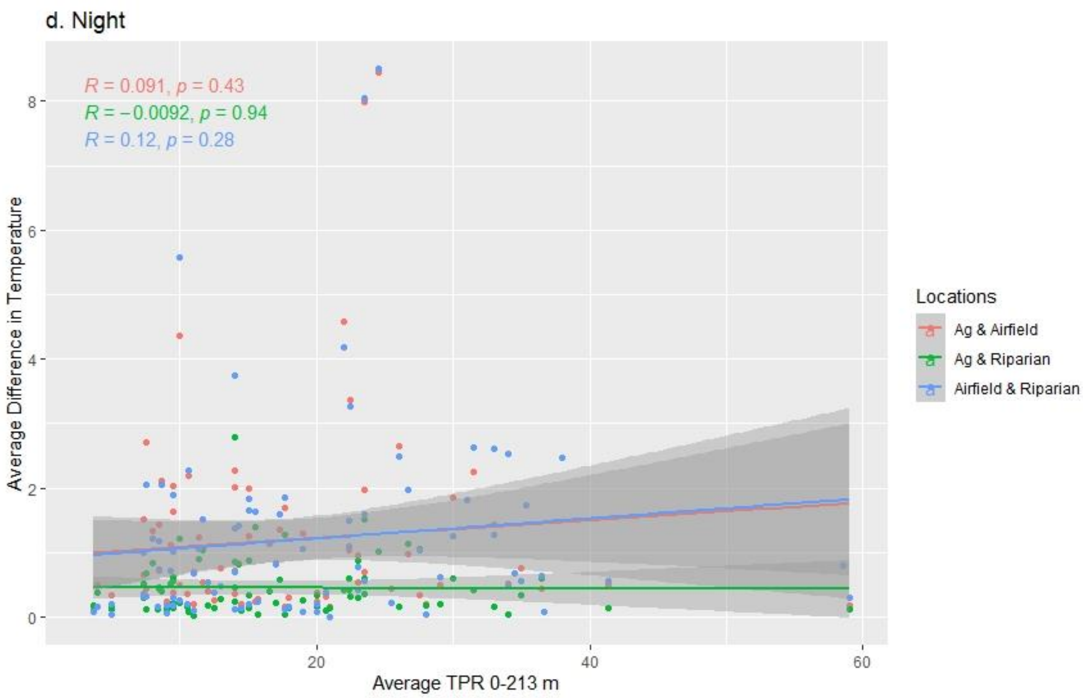


Figure 42. Average temperature difference and MERLIN^{TM} vertical scanning radar (VSR) average passage rate from 0 to 213 m during a) mornings, b) mid-day, c) evenings, and d) nights at Naval Air Station Kingsville, Texas in winter of 2020 and 2021.

Factors Associated with Increased Strike Risk

Several factors are known to increase risk of collisions between birds and aircraft including the makeup of the surrounding landscape (Coccon et al. 2015, Andersson et al. 2017, Pfeiffer et al. 2018b), avian species using the airspace (Pfeiffer et al. 2018a), avian abundance (DeVault et al. 2018), time of year (i.e., migration, breeding, wintering), and weather (Pennycuick 1972). Below we first discuss how the area surrounding NASK may be influencing the presence, abundance, and use of the area by vultures, raptors, and birds in general. Then we discuss how the different seasons, along with migration and weather, can influence the presence and abundance of birds overall in the area as well as at lower altitudes near the airfield. Finally, we give some concluding remarks and recommendations for habitat management and training scheduling that will likely help reduce the incidence of bird strikes as well as future research that could help refine these guidelines more and further decrease strike risk in the future.

Landscape

Landscape features that are correlated with increased bird strike rates include wetlands or water sources (Fox et al. 2013, Andersson et al. 2017, Pfieffer et al. 2018b), cultivated crops (DeVault et al. 2009, Pfieffer et al. 2018b), and urban areas (Pfeiffer et al. 2018b). Pfieffer et al. (2018b) found that fragmentation (i.e., diversity of land uses) within a 3-km (~2-mile [mi]) radius was a strong predictor of higher bird strike rates. They also found that cultivated crop areas, regardless of type, surrounding the airfield and large wetlands were among the strongest predictors of strike rates within 8-km (~5 mi) with the presence of corn patches being a very strong predictor of higher strike rates (Pfieffer et al. 2018b). Similarly, Coccon et al. (2015) found that agricultural fields within a 13-km (~8-mi) buffer attracted several avian groups, including hawk spp., who exploit the fields to feed, shelter, and rest during all seasons of the year. Additionally, carrion in open habitats such as along roads and in crop fields may be easier for vultures and other carrion eaters (e.g., crested caracara) to find (Coleman and Fraser 1989).

Black and turkey vultures are present year-round at NASK. Black vultures are resident and occur in lower numbers than turkey vultures, as turkey vultures are both resident and migratory. Despite their obvious similarities in life histories and behaviors (e.g., soaring, diet of carrion), black vultures and turkey vultures are different. They have different habitat preferences and behaviors because they evolved to forage in different ways. For example, turkey vultures, which are more solitary, have an excellent sense of smell and can find food by soaring higher in the sky (Cornell Lab of Ornithology 2019). Conversely, black vultures have a poor sense of smell, tend to occur in groups, and often monitor turkey vultures and other black vultures for cues as to where to find food or hunt in open habitats (Cornell Lab of Ornithology 2019).

Black vultures tend to fly slightly higher than turkey vultures (Coleman and Fraser 1989, DeVault et al 2005, Avery et al. 2011), possibly to monitor turkey vultures and follow them to food (Buckley 1996). Flying altitude varies by time of day. Most vulture flight in the morning is low, below 50 m (164 ft), while mid-day flights typically range above 150 m (492 ft) for black vultures and between 50–100 m (164–328ft) for turkey vultures, except during the summer when they tend to be higher (100–150 m [328 –492 ft]) (Avery et al. 2011). Black vultures are known to spend significantly less time flying than turkey vultures, as turkey vultures spend much more time searching for fresh carrion (Coleman and Fraser 1989, Buckley 1997, DeVault et al 2004, Avery et al. 2011). However, actual flight times for both species vary considerably between locations in the United States likely because of variation in food availability and landscape composition.

Despite turkey vultures being in much higher in abundance in the Kingsville region than black vultures (Oleyar and Watson 2020, Pardieck et al. 2020) and turkey vultures spending more time in flight, black vultures are involved in strikes as often as turkey vultures at NASK. This may be partially due to soaring height preferences discussed previously. Another reason may be that black vultures around NASK have established their home ranges surrounding the airfield, which are considerably smaller than turkey vulture home ranges (Coleman and Fraser 1989, Avery et al. 2011). Thus, black vultures are not traveling out of the area as often as turkey vultures in search of food. This is because turkey vultures prefer to feed on small carcasses that tend to be dispersed and unpredictable on the landscape (Kirk and Mossman 1998) while black vultures like to re-use previous feeding sites that are typically larger carcasses (Buckley 1996) given that they rely on sight rather than smell. Thus, black vultures spend less time searching for food compared to turkey vultures (Coleman and Fraser 1989, Holland et al. 2017). In addition, when pilots are more likely to encounter black vultures in groups (higher density), unlike turkey vultures that are most often alone, thus making it more likely for a strike to occur.

Vultures and other large soaring birds may prefer roads and forested areas because of the updrafts, or thermals, they produce (Pennycuick 1972, Coleman and Fraser 1989). Thermals, defined as upward currents of warm air, are often used by birds to gain height and soar. Thermals are caused by an unstable vertical distribution of temperature in the atmosphere resulting from uneven heating of the air near the ground due to differences in land cover (Figure 43). This effect may be enhanced when a nearby crop field has been plowed under, exposing bare soil that is more conducive to solar heating. Days with higher temperatures tend to have higher thermal column development, decreasing the energy cost of soaring flight for vultures and other raptor species (Kerlinger 1989).

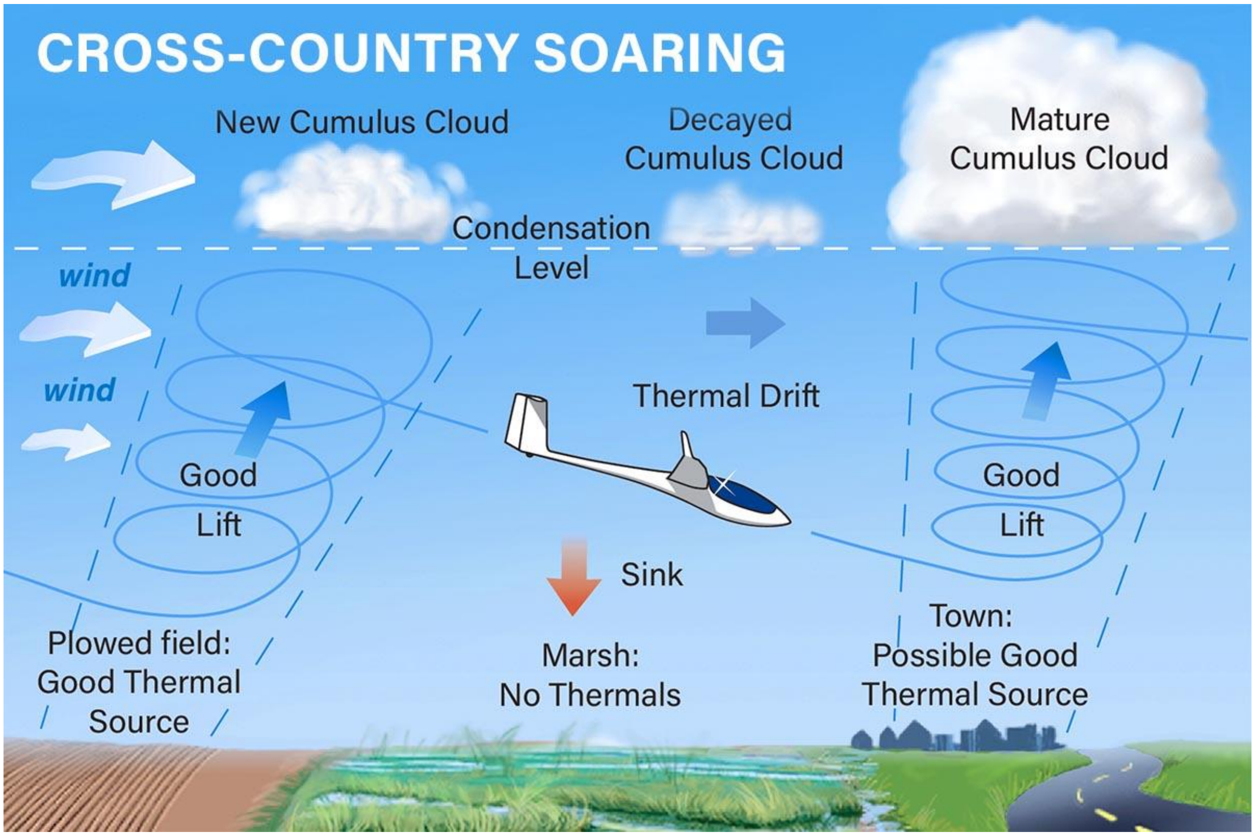


Figure 43. Illustrated diagram showing how thermal lift is created (credit: Soaring Society of America).

Black and turkey vultures are communal roosters (Buckley 1998). Examples of roosting locations often utilized by vultures include power line transmission support structures (Buckley 1998), large trees (Buckley 1996, Coleman and Fraser 1989), and communication towers (Avery et al. 2002). Vulture communal roosting sites are believed to function as a place for social interaction and information exchange (e.g., food/foraging) (Buckley 1996). Man-made or natural roosting sites near the NASK airfield could be attracting vultures to the area. Novaes and Cintra (2013) found that black vulture roosting sites were highly correlated with distance to feeding sites within urban areas in Brazil, but little more is currently known about vulture roost-site selection criteria (Kluever et al. 2020), especially in more rural landscapes, such as those found in South Texas.

Bird groups such as vultures, gulls, and corvids (i.e., crows) may be attracted to the landfill located near NASK (Coccon et al. 2015, Moreno-Opo and Margalida 2017). Landfills in northeast Italy were found to be very attractive to birds, particularly gulls and corvids (i.e., crows, ravens) but only during winter when food was scarcer (Coccon et al. 2015). In contrast, Pfieffer et al. (2020) found that abundance or density of landfills was not associated with bird strikes. However, they analyzed strikes at civilian airports where aircraft were typically not remaining within bird-rich altitudes (~0–1,067 m) for extended periods, unlike aircraft at NASK. They also did not address seasonal effects or landscape effects, which may have been significant given most of the airports included in their study occurred in areas that were more urbanized than Kingsville. It is not clear whether the landfill located near NASK is causing an increased abundance of either species of vulture in the NASK airspace, but it is very likely that resident and migrating vultures utilize the landfill for foraging (T. McFarland, pers. obs.), and the home range sizes of both species are large enough to encompass both the landfill and the NASK airfield (Coleman and Fraser 1989). A more localized study of vulture movement, habitat use, and foraging behavior is needed to understand if the landfill near NASK is contributing to higher vulture abundance in the area compared to areas further away from the landfill.

Seasonal Changes and Weather

The Kingsville area lies within the Central Flyway of ~380 species of birds migrating in spring and fall each year. Millions of birds from South and Central America migrate to North America and back each year. Bird species that "hug" the coastline from Mexico through Texas during migration include turkey vultures and many species of hawks, flycatchers, swallows, warblers, and sparrows. Particularly notable are the number of vultures and hawks that move through the region. HawkWatch, an organization that counts migrating raptors every year, in Corpus Christi counted 96,288 turkey vultures, 16,015 Mississippi kites, and 484,082 *Buteo* species (primarily broad-winged hawks) in 2019 during fall migration (Oleyar and Watson 2020). These same birds moved through the Kingsville area.

Migration patterns and how they relate to weather are still not fully understood, likely because there are so many variables at play including how each individual species is adapted to migrate most efficiently. For example, Beauchamp (2011) found that species that migrate during the day tend to be more social and travel in larger flocks than their nocturnal counterparts. Predation risk also plays an important role in migratory behavior (Alerstam 2011). As such, differences in migration patterns are based not just on the physiology and anatomy of birds but also on behavioral traits and risk avoidance. In addition, weather and foraging conditions at breeding and wintering sites as well as along migration routes influence bird migration behaviors, including when and where birds stop to forage or rest (Alerstam 2011). However, hawks and other migratory birds typically remain at high altitudes but will drop down into lower altitudes to travel, forage, and rest, depending on weather conditions (Alerstam 1979, Haest et al. 2019). Birds that are not migrating also change their behaviors based on weather (Wolf and Walsberg 1996, Alerstam 2011). Below we discuss some of these behaviors and weather conditions and relate them to what we observed at NASK.

Different species of birds adapted for migration in diverse ways with evolution favoring individuals who expended the least amount of energy possible. In general, passerines (songbirds) depart when there is a tail wind shortly after dusk (Åkesson and Hedenström 2000) and fly mainly at night (Alerstam 2009, Beauchamp 2011). Larger birds like raptors, storks, and cranes mainly migrate during the day to take advantage of thermals to reduce flapping (Alerstam 2009, Beauchamp 2011). Additionally, birds will adjust their migratory behavior based on environmental conditions (winds, precipitation, foraging areas) they encounter while migrating (Alerstam 2009, Calvert et al. 2009, Mallon et al. 2021). A "stopover" occurs when birds stop migrating and remain in an area for a few hours or days. Mallon et al. (2021) found that both the onset and duration of stopovers by turkey vultures were influenced by weather variables with precipitation inducing the stopover. They also observed that activity during a stopover was promoted by higher temperatures and thermal soaring (Mallon et al. 2021). Indeed, thermal development is important in determining migration behavior for large-bodied migratory birds (Leshem and Yom-Tov 1996, Dodge et al. 2014, Duerr et al. 2015). For songbirds, precipitation and strong winds are the best predictors of increased stopover length (Calvert et al. 2009). However, cooler temperatures in spring may also reduce migratory activity of smaller birds (Metcalfe et al. 2013) and increasing air pressure (BP) hasten timing of departure in migrating birds (Sapir et al. 2011, Sjöberg et al. 2018).

Wind has long been understood to play a dominant role in when and at what altitude birds migrate (Throwbridge 1902, Liechti and Bruderer 1998, Liechti 2006, Haest et al. 2019). Wind speeds are usually much lower at low altitudes than high due to friction. As such, it was long believed that migrating birds fly at lower altitudes when wind direction is not favorable to increase energy efficiency (Alerstam 1979). However, it is now understood that the role of wind speed and direction in relation to migration is more complicated (Alerstam 2009, 2011). Regardless, favorable tailwinds during migratory flight are very important for birds due to the large increase in energy efficiency (Liechti and Bruderer 1998). Further, migrating birds will fly at the altitude that maximizes wind support (Bruderer et al. 1995). Ambient temperature plays a role in migration as well (Heast et al. 2019). For example, Wikelski et al. (2003) found that two thrush species used twice as much energy during stopovers as during migratory flight because of the need for temperature regulation. This could mean that smaller birds wait for warmer weather conditions to stop and refuel.

Non-migrating birds, both large and small, are also known to respond to weather conditions. High temperatures were highly correlated with black vulture soaring in South Carolina, but wind speed was not a significant contributor to black or turkey vulture flight behavior (DeVault et al. 2005). A large-scale study of turkey vultures also concluded that higher temperature and corresponding thermal uplifts coincided with more movement during all times of the year, including migration (Dodge et al. 2014). Thermal uplifts have also been shown to affect the altitude and behavior of smaller avian species like purple martins (*Progne subis*) and tree swallows (*Tachycineta bicolor*) (Dreelin et al. 2018). Birds also have the ability to use changes in barometric pressure to detect changes in the weather and adjust their behavior accordingly. For example, a sharp drop in pressure has been shown to increase avian activity and increase foraging during the winter (Carey and Dawson 1999, Metcalfe et al. 2013). Birds that forage on flying insects also change their flight altitude and behavior based on the local weather and time of day (Dreelin et al. 2018, Winkler et al. 2013).

Summary and Recommendations

Habitat Management

The landscape features surrounding the NASK Main Station include the city of Kingsville to the west, extensive croplands to the north and east, and the Tranquitas, San Fernando, and Santa Gertrudis creeks that run along the northern, eastern, and southern boundaries of the installation, respectively, all contribute to the high bird activity in the area (Figure 44). Each one of these land uses has been found to increase bird strike risk individually, but research also suggests that this matrix of varying land uses on the landscape elevates the likelihood of bird strikes even higher (Pfeiffer et al. 2018b). Additionally, the arrangement of the airfield, riparian corridors, and croplands may be creating thermal columns that are used by vultures, other raptors, and swallows near the airfield. This effect may be even greater in the winter when the croplands have been plowed. The role of the landfill that lies ~5 km (2.5 mi) to the south of the airfield (Figure 44) in attracting large-bodied birds such as black and turkey vultures is unclear without further research that examines detailed use and movement by the birds in the area.

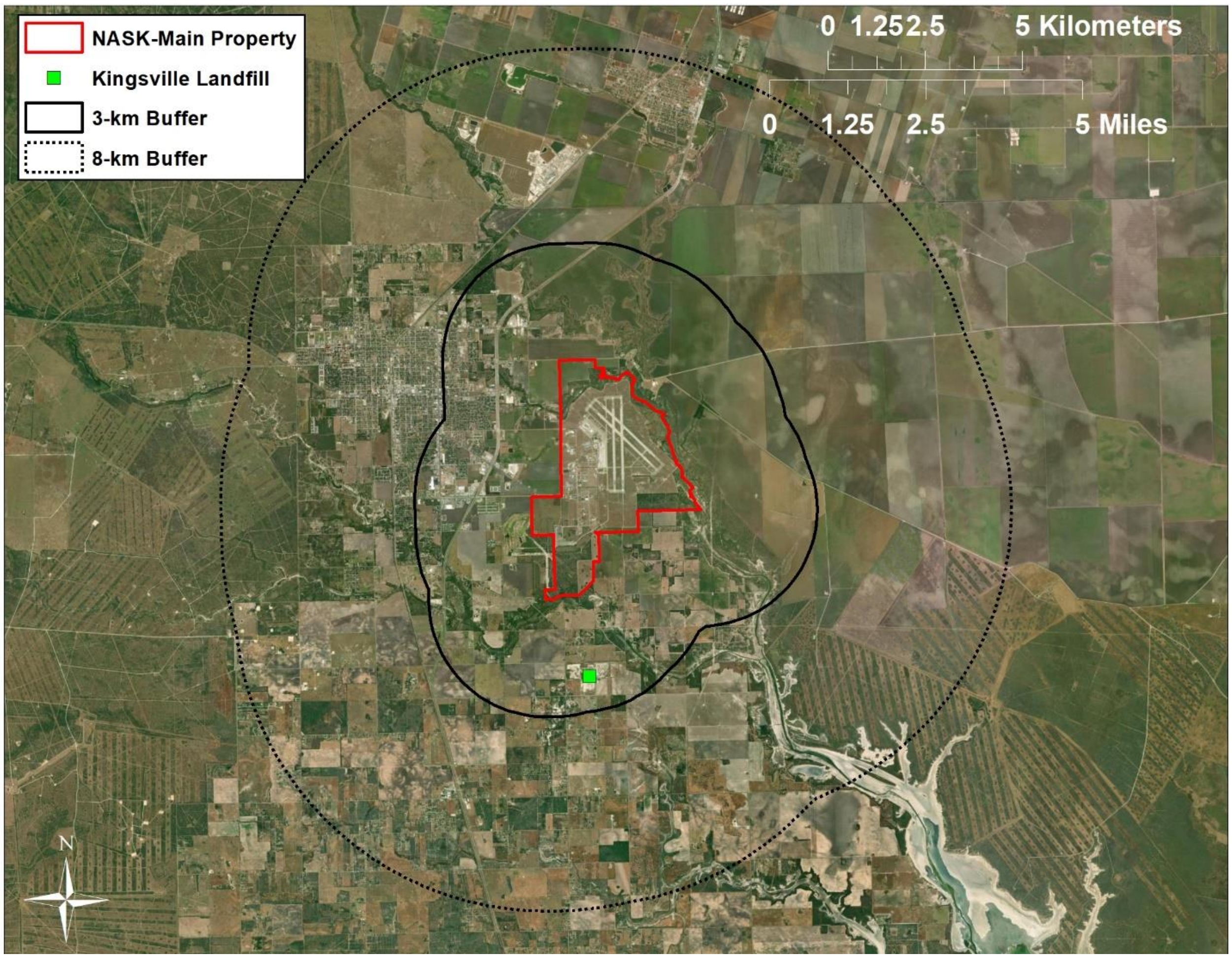


Figure 44. Naval Air Station Kingsville, Texas with 3-kilometer (2.5-mile) and 8-kilometer (~5-mile) buffers.

Although we detected more turkey vultures than black vultures during our study, black vultures were struck as often as turkey vultures at NASK from October 2010–September 2021. This could be because black vultures use the area within the flight path or fly at the same altitude as NASK aircraft more often than turkey vultures. Furthermore, we detected more black vultures than turkey vultures in the area that were not flying, which may indicate that black vultures are using lower altitudes in the landing path more often than turkey vultures.

Given the likely contribution of the cropland, cropland edges, and the diversity of the landscape uses in the area to the elevated bird abundance, a potential solution could be to decrease the amount of cropland near the airfield, particularly within 3 km (~2 mi) (Figure 44). There are numerous agricultural crops and land covers that are less attractive to birds (DeVault et al. 2013). The planting of year-round vegetation within this zone would not only decrease landscape diversity, but would also decrease differential heating, thus reducing thermal lift around the airfield.

Reduction in foraging opportunities for vultures and other raptors is critical. Actions to reduce the amount of raptor and vulture food resources in the area will likely further help decrease the abundance of vultures and other raptors near the airfield (Coleman and Fraser 1987, DeVault et al. 2003, Cleary and Dolbeer 2005). Crops that attract fewer small mammals (e.g., mice, rabbits) may decrease use of the area by hawk spp. while crops that attract fewer large mammals (e.g., wild hogs, deer) that are susceptible to automobile collisions may decrease the use of the area by vultures. Given the daily diet preferences, foraging strategies, and home ranges of vultures that likely currently overlap with the airfield (Colemand and Fraser 1989, DeVault et al. 2005), a critically important management action to deter vultures would be to promptly remove any road-killed or other dead animals within 3 km of the airfield.

Other techniques that have proven effective at reducing bird-aircraft strikes include maintaining specific grass heights or types, reducing woody cover, removing standing water, modifying anthropogenic structures, and manipulating food resources. Initially, some habitat management actions can be expensive, but if properly executed, the limited follow up requirements reduce the long-term costs when compared with other management options (MacKinnon et al. 2001, Cleary and Dickey 2010). The FAA suggests extending management techniques and reducing land uses that attract hazardous birds to an 8-km (~5-mi) buffer from the farthest edge of an airport's operating area to further reduce risk (FAA 2007); however, this large of an area may be difficult to manage, especially given that the city of Kingsville is within 8 km of the NASK Main Station (Figure 44).

Airfield managers can also manipulate woody vegetation located near airstrips. Woody trees and shrubs provide important habitat for birds, and removing or altering this vegetation is recommended to reduce the number of perching, foraging, nesting, and roosting sites available to nuisance species near airfields (e.g., Blokpoel 1976, Buckley and McCarthy 1994). For example, removal of northern bayberry (*Myrica pensylvanica*), a woody shrub, at John F. Kennedy International Airport resulted in a 75% reduction in the number of aircraft strikes by tree swallows that foraged on bayberry fruits (Bernhardt et al. 2009). Similarly, direct reduction of roosting or perching locations through tree pruning or removal can potentially result in quick reductions in perching species including blackbirds, hawks, and vultures (Good and Johnson 1976, Burger 1985, Blackwell and Wright 2006). Avery et al. (2002) reported up to 5 months of deterring black and turkey vultures from using communication towers by suspending vulture carcasses or taxidermic effigies in Florida. As with any management action, modification of woody vegetation should be implemented on a case-by-case basis because management actions may be expensive with limited benefits (Blackwell et al. 2009) and may come with unintended consequences (e.g., public disapproval, reduced cooling benefits, replacement of one undesired bird species for another).

Seasonal Changes and Weather (Avoidance)

The strike risks were multitudes higher during spring and fall migration, when hundreds of thousands of small and large birds move through the region. Under ideal weather conditions for migration, most of the birds that move through the area stay at very high altitudes; however, certain weather conditions cause the birds to move to lower altitudes or remain in the area for a few hours up to several days. When this happens, strike risk is elevated even more. At this time, guidelines dictate that flight activity is suspended when HSR TPR is ≥1,160; however, these mitigation strategies are set to soon change (E. Earwood, pers. comm.). Therefore, we do not provide precise values for when weather conditions will likely cause a cessation of flight activity. We have, however, provided trends and guidance for weather changes (temperature, wind direction, wind speed, and changes in BP) that indicate when activity in the area overall and within the lower altitudes surrounding the airfield will likely be elevated within a particular season.

Spring

A large number of birds migrate through southeast Texas in the spring which greatly increases likelihood of strikes on all bird species, especially during peak migration times. Most of the birds observed during the spring point counts were migratory including hawk spp, swallow spp., and vulture spp. Both black and turkey vultures migrate but are also found year round in south Texas. Hawks and vultures were observed most often in the middle of the day during all seasons, including spring. Other species of birds were observed most often during the evening point counts, but were seen being active throughout the day. Most costly bird strikes happen during mid-day or at night with vultures spp., hawk spp., and swallow spp. being struck at mid-day and other songbird spp. being struck during the night in the spring.

The weather during peak migration (i.e., highest number of birds moving through the area) included days with higher temperatures, lower wind speeds, and when the wind was generally out of the south and west (Table 12). These weather characteristics were also correlated with increased bird activity at lower altitudes with a few exceptions. For example, higher wind speeds at night correlated with higher activity below 90 m (300 ft) (Table 12). Rising BP at night was also correlated with higher bird activity below 610 m (2000 ft). In addition, winds out of the northwest correlated with more bird activity from 91 to 610 m (300 to 2000 ft) in the evenings (Table 12). This data suggests that the migrating birds are descending to wait for more favorable winds for migrating north during the evenings and nights during spring.

Table 12. Weather characteristics correlated with higher total passage rate (TPR) indicated by the MERLIN[TM] horizontal (HSR) and vertical (VSR) scanning radars during spring of 2021 at Naval Air Station Kingsville, Texas.

	Morning	Mid-Day	Evening	Night
Overall Activity	Higher Temperature & Falling BP	Higher Temperature & Winds out of the WSW, SW, SSW, and S	Higher Temperature, Lower Wind Speeds, SE Winds & Rising BP	Higher Temperature & Lower Wind Speeds
0-91 m (0-300 ft)	-	Southerly Winds	SE Winds	Higher Wind Speeds
91-213 m (300-700 ft)	SE Winds	SW Winds	NW or SE Winds	SE Winds & Rising BP
213-366 m (700-1200 ft)	SE Winds	Southerly Winds	NW Winds	Southerly Winds & Rising BP
366-610 m (1200-2000 ft)	Decreasing Temperature & SE Winds	Higher Temperature & Southerly Winds	Lower Wind Speeds, Winds out of the NW or SE & rising BP	Lower Wind Speeds, SW Winds & Rising BP

Summer

Although there are much fewer birds migrating through the area in summer, there are a large number of birds utilizing the area especially during morning hours and at night. The most common species seen during the summer were swallow spp. and mourning doves. Hawk spp. were observed occasionally during mid-day and evening in the riparian area. Vulture spp. were observed across all areas during the mid-day hours of summer; however, summer was the season when vulture and hawk spp. were least likely to be involved in strikes. However, swallow spp. combined strike risk in summer was higher than the strike risk for hawks or vultures, suggesting that swallows are extremely active and abundant around NASK in during the summer. Most swallow strikes occur during mid-day but are also common during all other periods. Mourning doves were also very common on summer point counts, particularly in the morning and evenings but were not often involved in strikes.

Most bird activity during the summer occurs at night; however, most of the activity during all periods stays above 610 m (2000 ft). The weather associated with the highest overall activity in the morning and at night was higher temperatures and lower wind speeds (Table 13). Weather variables correlated with higher overall activity in the mid-day and evening was lower wind speeds and southerly winds (Table 13). Activity below 610 m (2000 ft) during mid-day (when most strikes happen in summer) was correlated with winds out of the northwest and rising BP (213-366 m [300-700 ft] only). Activity at night below 91 m (300 ft) was correlated with lower temperatures and falling BP and above 91 m (up to 610 m [2000 ft]) was higher temperatures and rising BP (Table 13). This indicates that the birds are dropping down as low as possible when temperature are low and BP is falling.

Table 13. Weather characteristics correlated with higher total passage rate (TPR) indicated by the MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars during summer of 2021 at Naval Air Station Kingsville, Texas.

	Morning	Mid-Day	Evening	Night
Overall Activity	Higher Temperature & Lower Wind Speed	Lower Wind Speed, Southerly Winds & Rising BP	Lower Wind Speeds & SE Winds	Higher Temperature, Lower Wind Speeds, & Winds out of the N
0-91 m (0-300 ft)	-	Lower Wind Speed	Higher Temperature	Lower Temperature & Falling BP
91-213 m (300-700 ft)	Rising BP	Lower Wind Speed and NW Winds	Lower Temperature & NE Winds	Higher Temperature & Rising BP
213-366 m (700-1200 ft)	Higher Temperature	Higher Temperature, NW Winds & Rising BP	Lower Temperature & NE Winds	Higher Temperature, Lower Wind Speeds, & Rising BP
366-610 m (1200-2000 ft)	Higher Temperature	Higher Temperature & Lower Wind Speeds	Lower Temperature & NE Winds	Higher Temperature, Lower Wind Speeds, Winds out of the N & Rising BP

Fall

Like spring, a large number of migrants move through the study area during the fall with the bulk of the activity occurring at night. Below 610 m (2000 ft), most of the fall activity occurs at night and during the mid-day hours. Consequently, that is when the vast majority of strikes happen in the fall. The most common birds observed during fall point counts were dove spp., blackbird spp., and swallow spp. Like in the other seasons, vultures spp. were commonly seen during mid-day hours over the riparian area and the airfield. Other raptor spp. were not seen very often in fall on point counts. Despite this, raptor spp. had a large strike risks during fall months, second only slightly to spring. Strike risk for vulture spp., swallows spp., and other songbirds have been higher during the fall than another season.

Overall bird activity in fall was higher when the temperature was warmer, wind speeds were lower, and winds were out of the north. Higher bird activity in the morning corresponded with rising BP for altitudes below 610 m (2000 ft) and when winds were out of the northwest for altitudes from 91 to 610 m (300 to 2000 ft). This could be indicating that migrating birds are moving through the area in the mornings when winds are out of the north. Despite higher temperatures being correlated with higher overall bird activity, bird activity at the lowest altitudinal bands was highest when temperatures were colder. Anytime the winds were not out of the southeast in the evenings during the fall, bird activity was high below 610 m (2000 ft). Rising BP and warmer temperatures corresponded to high bird activity at all altitudes during the night in the fall (Table 14).

Table 14. Weather characteristics correlated with higher total passage rate (TPR) indicated by the MERLIN[TM] horizontal (HSR) and vertical (VSR) scanning radars during fall of 2021 at Naval Air Station Kingsville, Texas.

	Morning	**Mid-Day**	**Evening**	**Night**
Overall Activity	Higher Temperature, Lower Wind Speed, Winds out of the N & Falling BP	Higher Temperature, Lower Wind Speed, Winds out of the N & Rising BP	Higher Temperature, Lower Wind Speeds, & Winds NOT out of the SE	Higher Temperature, Lower Wind Speed, Winds NOT out of the SE & Rising BP
0-91 m (0-300 ft)	Lower Temperature & Lower Wind Speeds	Lower Temperature & Lower Wind Speed	Winds NOT out of the SE	Winds NOT out of SW & Rising BP
91-213 m (300-700 ft)	NW Wind & Rising BP	Lower Temperature, Higher Wind Speed & Winds out of the W	Winds NOT out of the SE	Higher Temperature & Rising BP
213-366 m (700-1200 ft)	Higher Temperature, Lower Wind Speed, NW Wind & Rising BP	Higher Wind Speed & Winds NOT out of the NE	Winds NOT out of the SE	Higher Temperature, Lower Wind Speed, & Rising BP
366-610 m (1200-2000 ft)	Higher Temperature, Lower Wind Speed, NW Wind & Rising BP	-	Winds NOT out of the SE	Higher Temperature, Lower Wind Speed & Rising BP

Winter

Winter is the season with the least amount of overall bird activity within the study area. The species that are struck the most in winter are black vultures, American kestrels, white-tailed hawks, Brazilian free-tailed bats (*Tadarida brasiliensis*), and Savannah Sparrows (*Passerculus sandwichensis*). However, hawk spp. and vulture spp. activity is similar to summer and fall. Like other seasons, vulture activity is highest during mid-day but vultures also use all of the areas other than airfield in the evening. Other raptor spp. are active in the study area in the morning, mid-day, and evenings in low numbers. Most strikes in winter on vultures and other raptor spp. occur during the mid-day followed closely by the evening. Unlike the other three seasons, overall bird activity is lowest at night; however, winter bird activity below 610 m at night is actually higher than springtime bird activity during the middle of the day. This means that the small amount of activity that is occurring at night is occurring below 610 m (2000 ft). Unlike summer, which also has low overall bird activity, a large proportion of the activity occurs below 610 m (2000 ft) during the winter.

Overall activity in the morning was higher if winds were out of the northwest. General bird activity during the other periods (mid-day, evening, and night) was higher when temperatures were higher and the wind speed was low. Lower wind speed commonly correlated with more bird activity both overall and below 610 m (2000 ft) (Table 15). Overall activity at night was also higher if winds were not out of the SE and BP was rising (Table 15). Winds out of the southeast in the morning increased activity below 91 m (300 ft). During the mid-day, winds out of the west and northwest correlated with higher activity below 213 m (700 ft) while winds out of the southeast correlated with more activity from 213 to 610 m (700 to 2000 ft). This suggest that birds are reacting differently to the wind direction depending on the time of day.

Table 15. Weather characteristics correlated with higher total passage rate (TPR) indicated by the MERLIN™ horizontal (HSR) and vertical (VSR) scanning radars 10 November 2020-28 February 2021 and 01 November 2021-30 November 2021 at Naval Air Station Kingsville, Texas.

	Morning	Mid-Day	Evening	Night
Overall Activity	NW Winds	Higher Temperature & Lower Wind Speed	Higher Temperature & Lower Wind Speed	Higher Temperature, Lower Wind Speed, Winds NOT out of the SE & Rising BP
0-91 m (0-300 ft)	Lower Wind Speed & SE Winds	Higher Temperature, Lower Wind Speed & Winds out of the W	Higher Temperature	Higher Temperature
91-213 m (300-700 ft)	Lower Wind Speed & NW Winds	Higher Temperature, Lower Wind Speed, Winds out of the NW, & Falling BP	Higher Temperature & Lower Wind Speed	Higher Temperature, Winds NOT out of the SE & Rising BP
213-366 m (700-1200 ft)	-	Higher Temperature, Lower Wind Speed, Winds out of the SE & Falling BP	Higher Temperature & Lower Wind Speed	Higher Temperature, Winds NOT out of the SE & Rising BP
366-610 m (1200-2000 ft)	-	Higher Temperature, Lower Wind Speed, Wind out of the SE & Falling BP	Higher Temperature, Lower Wind Speed & Winds out of the NW	Higher Temperature, Winds NOT out of the SE & Rising BP

Further Research Needs

We can provide more detailed recommendations for avoiding bird strikes related to weather to managers once the new mitigation strategy guidelines for suspending flight activity are released and available. For example, we could provide temperature or wind speeds on a given day during the seasons that will likely lead to a suspension of flight activity. This would allow flight activity managers to plan ahead and avoid last-minute changes. In addition, these potentially more precise recommendations could be improved in accuracy if more years of data, both avian radar and weather, were used to model weather and bird activity. This is because normal variation in bird activity occurs within and between years due to variations in long-term precipitation patterns and other factors outside of the NASK area. A more comprehensive analysis of historical data would capture the range of variation in bird activity in the area during all seasons. This data already exists and would be relatively easy to pull together and analyze.

More research is needed to better understand why black vultures are being struck so often in the AOC. A vulture-centered research study at NASK would elucidate the behaviors and activity that occurs in the area including when and where vultures forage within their home ranges. This includes the use of the landfill to the south of NASK as well as the cropland and roads in the area. It is also critical to understand where the vultures are roosting. Removal of roosting perches or repelling vulture use of those structures would decrease overall vulture activity in the area and likely decrease strike rates.

Finally, more research is needed to understand if thermal uplift in the area can be reduced through alteration of croplands or the riparian areas, including the AOC. It is possible that the matrix of land uses in the area will always be conducive to thermals during daytime heating, especially during certain times of year (i.e., winter). However, some land covers may reduce the differential heating. Research on which land covers, whether they be crops or native vegetation, would work best to reduce heating differences and to what extent they need to be implemented (i.e., distance from the airfield) is needed to make the best recommendations before changes are made. These changes in land cover would also need to beneficial for reducing overall bird abundance, particularly raptor and vulture abundance, due to foraging and other life history needs.

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Appendix A1 Point Count Spreadsheet

POINT COUNT DATASHEET

Date: ________ StudyLoc: ________ Point 1 Sky Code: ________ Observer: ________

Start: ________ AM Noon PM Point 2

Birds not flying

Species	Count	Location	Comments

Birds flying 0–2 m

Species	Count	Location	Bearing	Comments

Birds flying 2–10 m

Species	Count	Location	Bearing	Comments

Birds flying 10–30 m

Species	Count	Location	Bearing	Comments

Birds flying 30–100 m

Species	Count	Location	Bearing	Comments

Birds flying 100–200 m

Species	Count	Location	Bearing	Comments

Birds flying >200 m

Species	Count	Location	Bearing	Comments

Appendix B1. Avian Point Counts

Table B1.1 Number of detections recorded per bird species per season during morning (AM), mid-day (Noon), and evening (PM) surveys at Naval Air Station Kingsville, December 2020−November 2021. Stars indicate Texas Species of Greatest Conservation Need.

Species	Winter				Spring				Summer				Fall				Total
	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	
Black-bellied whistling-duck (*Dendrocygna autumnalis*)	-	-	-	-	6	-	13	19	13	7	11	31	20	-	-	20	70
Duck spp.	-	-	-	-	-	-	-	-	11	2	2	15	12	-	-	12	27
Inca dove (*Columbina inca*)	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	3
White-winged dove (*Zenaida asiatica*)	-	-	-	-	3	1	-	4	21	-	3	24	194	-	-	194	222
Mourning dove (*Zenaida macroura*)	8	1	18	27	94	18	116	228	147	75	163	385	82	19	78	179	819
Dove spp.	-	-	-	-	12	-	-	12	-	-	-	-	-	-	-	-	12
Yellow-billed cuckoo (*Coccyzus americanus*)	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	1
Common nighthawk (*Chordeiles minor*)	-	-	-	-	-	-	3	3	16	5	46	67	-	-	-	-	70
Chimney swift (*Chaetura pelagica*)	-	-	-	-	3	3	-	6	3	-	-	3	20	-	-	20	29
Hummingbird spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2
Sandhill crane (*Antigone canadensis*)	16	-	-	16	-	-	-	-	-	-	-	-	3	-	3	6	22
Black-necked stilt (*Himantopus mexicanus*)	-	-	-	-	-	-	-	-	2	-	6	8	-	-	-	-	8
Killdeer (*Charadrius vociferus*)	1	-	-	1	1	3	-	4	5	3	2	10	2	-	2	4	19
Long-billed curlew (*Numenius americanus*)*	-	1	-	1	-	-	-	-	2	-	2	4	2	-	-	2	7
Long-billed dowitcher (*Limnodromus scolopaceus*)	-	-	-	-	-	-	-	-	-	-	-	-	7	25	-	32	32
Wilson's snipe (*Gallinago delicata*)	-	2	1	3	-	-	-	-	-	-	-	-	-	-	-	-	3
Sandpiper spp.	-	-	-	-	8	4	-	12	48	21	16	85	-	6	-	6	103
Shorebird sp.	-	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	4
Laughing gull (*Leucophaeus atricilla*)	-	-	-	-	1	-	6	7	29	20	2	51	4	-	-	4	62
Franklin's gull (*Leucophaeus pipixcan*)*	-	-	-	-	-	105	650	755	-	-	-	-	-	-	-	-	755
Gull spp.	-	-	-	-	6	1	31	38	-	1	-	1	40	-	2	42	81
Tern spp.	-	-	-	-	3	-	-	3	1	-	6	7	-	-	-	-	10
Anhinga (*Anhinga anhinga*)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1

Species	Winter				Spring				Summer				Fall				Total
	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	
Double-crested cormorant (*Nannopterum auritum*)	-	-	-	-	-	-	1	1	6	1	-	7	1	-	-	1	9
Great blue heron (*Ardea herodias*)	-	1	1	2	-	-	-	-	3	-	1	4	2	-	-	2	8
Great egret (*Ardea alba*)	1	-	-	1	2	-	3	5	1	1	2	4	6	1	2	9	19
Snowy egret (*Egretta thula*)*	-	-	-	-	-	-	-	-	1	14	1	16	-	-	-	-	16
Little blue heron (*Egretta caerulea*)*	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	2
Tricolored heron (*Egretta tricolor*)*	-	-	-	-	-	-	-	-	1	-	-	1	2	-	-	2	3
Cattle egret (*Bubulcus ibis*)	-	-	-	-	-	-	-	-	67	-	-	67	16	-	-	16	83
Green heron (*Butorides virescens*)*	-	-	-	-	1	-	-	1	2	1	-	3	-	-	-	-	4
Heron spp.	-	-	-	-	2	-	6	8	-	-	2	2	1	-	-	1	11
White ibis (*Eudocimus albus*)	-	-	7	7	9	1	3	13	14	-	-	14	2	-	-	2	36
White-faced ibis (*Plegadis chihi*)*	-	-	-	-	9	-	-	9	-	-	-	-	-	-	-	-	9
Ibis spp.	-	1	-	1	-	-	4	4	-	-	-	-	-	-	-	-	5
Roseate spoonbill (*Platalea ajaja*)	-	-	-	-	-	-	-	-	1	-	-	1	1	-	-	1	2
Black vulture (*Coragyps atratus*)	2	23	8	33	10	25	14	49	1	28	-	29	1	40	3	44	155
Turkey vulture (*Cathartes aura*)	2	98	46	146	46	281	131	458	3	119	10	132	11	101	36	148	884
Vulture spp.	-	-	-	-	-	-	-	-	-	38	2	40	-	4	-	4	44
Osprey (*Pandion haliaetus*)	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Mississippi kite (*Ictinia mississippiensis*)*	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	1
Northern harrier (*Circus hudsonius*)*	4	4	8	16	1	1	1	3	-	-	-	-	2	-	6	8	27
Sharp-shinned hawk (*Accipiter striatus*)	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Cooper's hawk (*Accipiter cooperii*)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1
Accipiter sp.	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Harris's hawk (*Parabuteo unicinctus*)*	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1
White-tailed hawk (*Geranoaetus albicaudatus*)*	4	11	10	25	3	12	6	21	-	2	5	7	2	13	9	24	77
Broad-winged hawk (*Buteo platypterus*)	-	-	-	-	-	1,222	7	1,229	-	-	-	-	-	-	-	-	1,229
Swainson's hawk (*Buteo swainsoni*)*	-	-	-	-	2	12	3	17	-	11	3	14	-	10	3	13	44

Species	Winter				Spring				Summer				Fall				Total
	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	
Red-tailed hawk (*Buteo jamaicensis*)	2	4	1	7	2	3	1	6	-	-	-	-	-	1	-	1	14
Hawk spp.	-	4	3	7	4	46	10	60	-	1	3	4	-	4	-	4	75
Belted kingfisher (*Megaceryle alcyon*)	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Woodpecker spp.	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	1	2
Crested caracara (*Caracara plancus*)	7	5	6	18	8	7	7	22	2	13	5	20	8	5	4	17	77
American kestrel (*Falco sparverius*)*	10	13	15	38	3	2	3	8	-	-	-	-	4	3	9	16	62
Eastern phoebe (*Sayornis phoebe*)	9	4	2	15	-	-	-	-	-	-	-	-	-	-	-	-	15
Myiarchus spp.	-	-	-	-	-	1	-	1	-	1	3	4	-	-	-	-	5
Great kiskadee (*Pitangus sulphuratus*)	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Couch's kingbird (*Tyrannus couchii*)	-	-	-	-	2	1	-	3	-	-	-	-	-	-	-	-	3
Western kingbird (*Tyrannus verticalis*)	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	1
Eastern kingbird (*Tyrannus tyrannus*)	-	-	-	-	1	1	-	2	-	-	-	-	-	-	-	-	2
Kingbird spp.	-	-	-	-	-	-	-	-	1	-	-	1	-	-	1	1	2
Scissor-tailed flycatcher (*Tyrannus forficatus*)*	-	-	-	-	16	9	6	31	7	14	10	31	2	7	2	11	73
Loggerhead shrike (*Lanius ludovicianus*)*	6	4	5	15	-	1	1	2	-	-	-	-	3	3	2	8	25
Northern rough-winged swallow (*Stelgidopteryx serripennis*)	-	-	-	-	-	-	-	-	-	40	4	44	-	3	-	3	47
Purple martin (*Progne subis*)	-	-	-	-	1	-	1	2	-	-	-	-	-	-	-	-	2
Tree swallow (*Tachycineta bicolor*)	-	-	-	-	6	72	1	79	3	-	-	3	17	-	-	17	99
Bank swallow (*Riparia riparia*)	-	-	-	-	-	-	10	10	-	-	-	-	-	-	-	-	10
Barn swallow (*Hirundo rustica*)	-	-	-	-	59	68	111	238	19	58	22	99	25	43	38	106	443
Cliff swallow (*Petrochelidon pyrrhonota*)	-	-	-	-	3	11	9	23	2	3	-	5	2	-	-	2	30
Cave swallow (*Petrochelidon fulva*)	-	3	-	3	5	-	10	15	-	-	-	-	-	-	-	-	18
Cliff/Cave swallow	-	-	-	-	13	8	-	21	11	29	28	68	6	-	27	33	122
Swallow spp.	-	-	-	-	92	339	368	799	40	205	174	419	182	54	103	339	1,557
Blue-gray gnatcatcher (*Polioptila caerulea*)	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
European starling (*Sturnus vulgaris*)	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	3

Species	Winter				Spring				Summer				Fall				Total
	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	AM	Noon	PM	Total	
Northern mockingbird (*Mimus polyglottos*)	6	5	9	20	7	4	-	11	11	7	7	25	3	1	-	4	60
Sprague's pipit (*Anthus spragueii*)*	4	-	-	4	-	-	-	-	-	-	-	-	3	3	-	6	10
Botteri's sparrow (*Peucaea botterii*)*	-	-	-	-	-	-	-	-	1	-	1	2	-	-	-	-	2
Lark sparrow (*Chondestes grammacus*)*	-	-	-	-	5	-	-	5	8	-	9	17	-	-	-	-	22
Savannah sparrow (*Passerculus sandwichensis*)	6	1	24	31	1	-	-	1	-	-	-	-	5	3	5	13	45
Sparrow spp.	-	-	-	-	16	1	1	18	24	1	4	29	58	1	40	99	146
Eastern meadowlark (*Sturnella magna*)*	-	-	-	-	10	5	8	23	13	3	9	25	2	-	-	2	50
Meadowlark spp. (*Sturnella* spp.)	105	51	62	218	7	4	3	14	-	-	-	-	-	-	2	2	234
Red-winged blackbird (*Agelaius phoeniceus*)	2	-	1	3	7	3	5	15	97	-	17	114	44	-	1	45	177
Bronzed cowbird (*Molothrus aeneus*)	-	-	-	-	3	1	10	14	22	12	37	71	-	1	-	1	86
Great-tailed grackle (*Quiscalus mexicanus*)	-	-	-	-	56	-	1	57	51	10	3	64	-	-	-	-	121
Blackbird spp.	5	14	53	72	91	2	234	327	96	5	2	103	328	-	74	402	904
Northern cardinal (*Cardinalis cardinalis*)	-	-	-	-	4	-	-	4	1	1	2	4	-	-	-	-	8
Painted bunting (*Passerina ciris*)*	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1
Passerine spp.	-	-	-	-	15	-	10	25	6	-	-	6	-	-	-	-	31
Bird spp.	-	-	-	-	-	-	-	-	-	-	-	-	188	1	-	189	189
Total	202	251	284	737	659	2,280	1,811	4,750	816	753	632	2,201	1,316	353	454	2,123	9,811

Appendix B2. Aircraft Strike Trends

Table B2.1 Risk rank, species group, total number of strikes, strikes scaled to 100, relative hazard scores (RHS), and risk estimates for all identified bird and bat species struck from October 2010–September 2021. Stars indicate Texas Species of Greatest Conservation Need.

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
1	Black vulture (*Coragyps atratus*)	Vultures	9	20	100	4,183,884
2	Turkey vulture (*Cathartes aura*)	Vultures	9	20	80	2,677,686
3	Broad-winged hawk (*Buteo platypterus*)	Hawks, kites, owls, and falcons	13	30	51	2,270,501
4	Cliff swallow (*Petrochelidon pyrrhonota*)	Swallows	44	100	13	1,690,000
5	Barn swallow (*Hirundo rustica*)	Swallows	40	91	14	1,619,835
6	Cave swallow (*Petrochelidon fulva*)	Swallows	28	64	19	1,461,901
7	Blue-gray gnatcatcher (*Polioptila caerulea*)	Other songbirds	22	50	13	422,500
8	Swainson's hawk (*Buteo swainsoni*)*	Hawks, kites, owls, and falcons	5	11	56	404,959
9	Redhead (*Aythya americana*)	Waterfowl and coots	4	9	67	370,992
9	White-tailed hawk (*Geranoaetus albicaudatus*)*	Hawks, kites, owls, and falcons	4	9	67	370,992
11	Swainson's thrush (*Catharus ustulatus*)	Other songbirds	10	23	26	349,174
12	Brazilian free-tailed bat (*Tadarida brasiliensis*)	Bats	21	48	12	328,017
13	Great crested flycatcher (*Myiarchus crinitus*)	Other songbirds	12	27	19	268,512
13	Mourning dove (*Zenaida macroura*)	Pigeons and doves	12	27	19	268,512
15	Anhinga (*Anhinga anhinga*)	Cranes, anhingas, egrets, and ibises	3	7	72	240,992
16	Ruby-throated hummingbird (*Archilochus colubris*)	Swifts and hummingbirds	19	43	11	225,625
17	Evening bat (*Nycticeius humeralis*)	Bats	17	39	12	214,959
18	Dickcissel (*Spiza americana*)*	Other songbirds	11	25	16	160,000
19	Lincoln's sparrow (*Melospiza lincolnii*)	Other songbirds	10	23	17	149,277
20	Laughing gull (*Leucophaeus atricilla*)	Shorebirds, gulls, and terns	4	9	41	138,926
21	Bank swallow (*Riparia riparia*)	Swallows	9	20	16	107,107
21	Savannah sparrow (*Passerculus sandwichensis*)	Other songbirds	16	36	9	107,107
23	American kestrel (*Falco sparverius*)*	Hawks, kites, owls, and falcons	7	16	20	101,240
24	Snowy plover (*Charadrius nivosus*)*	Shorebirds, gulls, and terns	9	20	15	94,137
25	Traill's flycatcher (*Empidonax alnorum/trallii*)	Other songbirds	11	25	12	90,000

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
26	White ibis (*Eudocimus albus*)	Cranes, anhingas, egrets, and ibises	2	5	63	82,004
27	Red-tailed hawk (*Buteo jamaicensis*)	Hawks, kites, owls, and falcons	2	5	61	76,880
28	Yellow warbler (*Setophaga petechia*)	Other songbirds	10	23	12	74,380
29	Grasshopper sparrow (*Ammodramus savannarum*)*	Other songbirds	7	16	17	73,146
30	Upland sandpiper (*Bartramia longicauda*)	Shorebirds, gulls, and terns	7	16	16	64,793
31	Sandhill crane (*Antigone canadensis*)	Cranes, anhingas, egrets, and ibises	1	2	107	59,137
32	Yellow-breasted chat (*Icteria virens*)	Other songbirds	8	18	13	55,868
33	Red-shouldered hawk (*Buteo lineatus*)*	Hawks, kites, owls, and falcons	2	5	51	53,740
34	Nashville warbler (*Leiothlypis ruficapilla*)	Other songbirds	7	16	14	49,607
35	Purple martin (*Progne subis*)	Swallows	4	9	24	47,603
36	Meadowlark spp. (*Sturnella* spp.)*	Other songbirds	5	11	19	46,617
37	Least flycatcher (*Empidonax minimus*)	Other songbirds	7	16	13	42,774
38	Common nighthawk (*Chordeiles minor*)	Cuckoos and nightjars	6	14	15	41,839
39	White-eyed vireo (*Vireo griseus*)	Other songbirds	4	9	21	36,446
40	Mississippi kite (*Ictinia mississippiensis*)*	Hawks, kites, owls, and falcons	2	5	40	33,058
41	Northern yellow bat (*Lasiurus intermedius*)*	Bats	6	14	13	31,426
42	Great horned owl (*Bubo virginianus*)	Hawks, kites, owls, and falcons	1	2	75	29,055
43	Wilson's warbler (*Cardellina pusilla*)	Other songbirds	5	11	14	25,310
44	Chimney swift (*Chaetura pelagica*)	Swifts and hummingbirds	6	14	11	22,500
45	Black-bellied whistling-duck (*Dendrocygna autumnalis*)	Waterfowl and coots	1	2	62	19,855
46	Northern pintail (*Anas acuta*)*	Waterfowl and coots	1	2	60	18,595
46	Orchard oriole (*Icterus spurius*)*	Other songbirds	5	11	12	18,595
46	Yellow-bellied flycatcher (*Empidonax flaviventris*)	Other songbirds	5	11	12	18,595
49	Baird's sandpiper (*Calidris bairdii*)	Shorebirds, gulls, and terns	3	7	19	16,782
50	American wigeon (*Mareca americana*)	Waterfowl and coots	1	2	53	14,509
50	Blue-winged teal (*Spatula discors*)	Waterfowl and coots	1	2	53	14,509
52	Chuck-will's-widow (*Antrostomus carolinensis*)*	Cuckoos and nightjars	2	5	26	13,967
52	Gray-cheeked thrush (*Catharus minimus*)	Other songbirds	2	5	26	13,967
52	Hoary bat (*Aeorestes cinereus*)*	Bats	4	9	13	13,967

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
55	Cooper's hawk (*Accipiter cooperii*)	Hawks, kites, owls, and falcons	1	2	51	13,435
56	Barn owl (*Tyto alba*)	Hawks, kites, owls, and falcons	1	2	48	11,901
57	Cattle egret (*Bubulcus ibis*)	Cranes, anhingas, egrets, and ibises	1	2	42	9,112
57	Sora (*Porzana carolina*)	Waterfowl and coots	2	5	21	9,112
57	Warbling vireo (*Vireo gilvus*)	Other songbirds	2	5	21	9,112
60	Gray catbird (*Dumetella carolinensis*)	Other songbirds	2	5	20	8,264
61	Sprague's pipit (*Anthus spragueii*)*	Other songbirds	3	7	13	7,856
62	Red-eyed vireo (*Vireo olivaceus*)	Other songbirds	2	5	19	7,459
63	Black-bellied plover (*Pluvialis squatarola*)	Shorebirds, gulls, and terns	1	2	36	6,694
63	Scissor-tailed flycatcher (*Tyrannus forficatus*)*	Other songbirds	2	5	18	6,694
63	White-winged dove (*Zenaida asiatica*)	Pigeons and doves	1	2	36	6,694
63	Mourning warbler (*Geothlypis philadelphia*)	Other songbirds	3	7	12	6,694
63	Ruby-crowned kinglet (*Corthylio calendula*)	Other songbirds	3	7	12	6,694
63	Yellow-rumped warbler (*Setophaga coronata*)	Other songbirds	6	14	6	6,694
69	Clay-colored sparrow (*Spizella pallida*)	Other songbirds	2	5	17	5,971
70	Indigo bunting (*Passerina cyanea*)	Other songbirds	8	18	4	5,289
71	Baltimore oriole (*Icterus galbula*)	Other songbirds	5	11	6	4,649
72	American redstart (*Setophaga ruticilla*)	Other songbirds	2	5	14	4,050
72	Black-throated green warbler (*Setophaga virens*)	Other songbirds	2	5	14	4,050
72	Canada warbler (*Cardellina canadensis*)	Other songbirds	2	5	14	4,050
72	Common ground dove (*Columbina passerina*)	Pigeons and doves	2	5	14	4,050
72	Chestnut-sided warbler (*Setophaga pensylvanica*)	Other songbirds	2	5	14	4,050
77	American coot (*Fulica americana*)	Waterfowl and coots	1	2	26	3,492
77	Eastern wood-pewee (*Contopus virens*)	Other songbirds	2	5	13	3,492
77	Tree swallow (*Tachycineta bicolor*)	Swallows	2	5	13	3,492
80	House wren (*Troglodytes aedon*)	Other songbirds	2	5	12	2,975
80	Least sandpiper (*Calidris minutilla*)	Shorebirds, gulls, and terns	2	5	12	2,975
80	Northern rough-winged swallow (*Stelgidopteryx serripennis*)	Swallows	2	5	12	2,975
80	Painted bunting (*Passerina ciris*)*	Other songbirds	2	5	12	2,975

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
80	Sedge wren (*Cistothorus stellaris*)*	Other songbirds	2	5	12	2,975
80	Wilson's snipe (*Gallinago delicata*)	Shorebirds, gulls, and terns	1	2	24	2,975
86	Lesser nighthawk (*Chordeiles acutipennis*)	Cuckoos and nightjars	2	5	11	2,500
87	Blue-headed vireo (*Vireo solitarius*)	Other songbirds	1	2	21	2,278
88	Long-billed thrasher (*Toxostoma longirostre*)	Other songbirds	1	2	20	2,066
89	Bronzed cowbird (*Molothrus aeneus*)	Other songbirds	1	2	19	1,865
90	Eastern whip-poor-will (*Antrostomus vociferus*)	Cuckoos and nightjars	1	2	18	1,674
90	Stilt sandpiper (*Calidris himantopus*)*	Shorebirds, gulls, and terns	1	2	18	1,674
90	Wilson's phalarope (*Phalaropus tricolor*)	Shorebirds, gulls, and terns	1	2	18	1,674
90	Cedar waxwing (*Bombycilla cedrorum*)	Other songbirds	3	7	6	1,674
94	Lark sparrow (*Chondestes grammacus*)*	Other songbirds	1	2	17	1,493
94	LeConte's sparrow (*Ammospiza leconteii*)*	Other songbirds	1	2	17	1,493
96	Common yellowthroat (*Geothlypis trichas*)*	Other songbirds	4	9	4	1,322
96	Least tern (*Sternula antillarum*)*	Shorebirds, gulls, and terns	1	2	16	1,322
98	Red-winged blackbird (*Agelaius phoeniceus*)	Other songbirds	1	2	15	1,162
99	Magnolia warbler (*Setophaga magnolia*)	Other songbirds	1	2	14	1,012
99	Northern waterthrush (*Parkesia noveboracensis*)	Other songbirds	1	2	14	1,012
99	Tennessee warbler (*Leiothlypis peregrina*)	Other songbirds	1	2	14	1,012
102	Eastern kingbird (*Tyrannus tyrannus*)	Other songbirds	1	2	13	873
102	Horned lark (*Eremophila alpestris*)	Other songbirds	1	2	13	873
102	Semipalmated sandpiper (*Calidris pusilla*)	Shorebirds, gulls, and terns	1	2	13	873
105	Kentucky warbler (*Geothlypis formosa*)	Other songbirds	1	2	12	744
105	Killdeer (*Charadrius vociferus*)	Shorebirds, gulls, and terns	1	2	12	744
105	Marsh wren (*Cistothorus palustris*)	Other songbirds	1	2	12	744
108	American pipit (*Anthus rubescens*)	Other songbirds	1	2	7	253
109	Yellow-billed cuckoo (*Coccyzus americanus*)	Cuckoos and nightjars	1	2	6	186
110	Ovenbird (*Seiurus aurocapilla*)	Other songbirds	6	14	0	0

Table B2.2 Risk rank, species group, total number of strikes, strikes scaled to 100, relative hazard scores (RHS), and risk estimates for all identified bird and bat species struck in the winter from winter 2010/2011–winter 2020/2021. Stars indicate Texas Species of Greatest Conservation Need.

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
1	Black vulture (*Coragyps atratus*)	Vultures	3	75	100	56,250,000
2	White-tailed hawk (*Geranoaetus albicaudatus*)*	Hawks, kites, owls, and falcons	3	75	67	25,250,625
3	Sandhill crane (*Antigone canadensis*)	Cranes, anhingas, egrets, and ibises	1	25	107	7,155,625
4	Turkey vulture (*Cathartes aura*)	Vultures	1	25	80	4,000,000
5	American kestrel (*Falco sparverius*)*	Hawks, kites, owls, and falcons	3	75	20	2,250,000
6	American wigeon (*Mareca americana*)	Watefowl and coots	1	25	53	1,755,625
7	Brazilian free-tailed bat (*Tadarida brasiliensis*)	Bats	4	100	12	1,440,000
7	Barn owl (*Tyto alba*)	Hawks, kites, owls, and falcons	1	25	48	1,440,000
9	Mourning dove (*Zenaida macroura*)	Pigeons and doves	2	50	19	902,500
10	Savannah sparrow (*Passerculus sandwichensis*)	Other songbirds	4	100	9	810,000
11	Wilson's snipe (*Gallinago delicata*)	Shorebirds, gulls, and terns	1	25	24	360,000
12	Grasshopper sparrow (*Ammodramus savannarum*)*	Other songbirds	1	25	17	180,625
13	Snowy plover (*Charadrius nivosus*)*	Shorebirds, gulls, and terns	1	25	15	140,625
14	Yellow-rumped warbler (*Setophaga coronata*)	Other songbirds	2	50	6	90,000
15	Cedar waxwing (*Bombycilla cedrorum*)	Other songbirds	1	25	6	22,500

Table B2.3 Risk rank, species group, total number of strikes, strikes scaled to 100, relative hazard scores (RHS), and risk estimates for all identified bird and bat species struck in the spring from spring 2011–spring 2021. Stars indicate Texas Species of Greatest Conservation Need.

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
1	Broad-winged hawk (*Buteo platypterus*)	Hawks, kites, owls, and falcons	6	67	51	11,560,000
2	Swainson's hawk (*Buteo swainsoni*)*	Hawks, kites, owls, and falcons	5	56	56	9,679,012
3	Turkey vulture (*Cathartes aura*)	Vultures	3	33	80	7,111,111
4	Swainson's thrush (*Catharus ustulatus*)	Other songbirds	9	100	26	6,760,000
5	Black vulture (*Coragyps atratus*)	Vultures	2	22	100	4,938,272
6	Dickscissel (*Spiza americana*)*	Other songbirds	7	78	16	1,548,642
7	Barn swallow (*Hirundo rustica*)	Swallows	7	78	14	1,185,679
8	Cave swallow (*Petrochelidon fulva*)	Swallows	4	44	19	713,086
8	Mourning dove (*Zenaida macroura*)	Pigeons and doves	4	44	19	713,086
10	Great horned owl (*Bubo virginianus*)	Hawks, kites, owls, and falcons	1	11	75	694,444
11	Anhinga (*Anhinga anhinga*)	Cranes, anhingas, egrets, and ibises	1	11	72	640,000
11	Yellow warbler (*Setophaga petechia*)	Other songbirds	6	67	12	640,000
11	Brazilian free-tailed bat (*Tadarida brasiliensis*)	Bats	6	67	12	640,000
14	Lincoln's sparrow (*Melospiza lincolnii*)	Other songbirds	4	44	17	570,864
15	Cliff swallow (*Petrochelidon pyrrhonota*)	Swallows	5	56	13	521,605
16	Red-tailed hawk (*Buteo jamaicensis*)	Hawks, kites, owls, and falcons	1	11	61	459,383
17	Common nighthawk (*Chordeiles minor*)	Cuckoos and nightjars	4	44	15	444,444
17	Northern pintail (*Anas acuta*)*	Waterfowl and coots	1	11	60	444,444
19	Meadowlark spp. (*Sturnella* spp.)*	Other songbirds	3	33	19	401,111
20	Gray-cheeked thrush (*Catharus minimus*)	Other songbirds	2	22	26	333,827
20	Blue-gray gnatcatcher (*Polioptila caerulea*)	Other songbirds	4	44	13	333,827
22	Chimney swift (*Chaetura pelagica*)	Swifts and hummingbirds	4	44	11	239,012
22	Ruby-throated hummingbird (*Archilochus colubris*)	Swifts and hummingbirds	4	44	11	239,012
24	Gray catbird (*Dumetella carolinensis*)	Other songbirds	2	22	20	197,531
24	Mississippi kite (*Ictinia mississippiensis*)*	Hawks, kites, owls, and falcons	1	11	40	197,531

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
26	Least flycatcher (*Empidonax minimus*)	Other songbirds	3	33	13	187,778
27	Baird's sandpiper (*Calidris bairdii*)	Shorebirds, gulls, and terns	2	22	19	178,272
27	Red-eyed vireo (*Vireo olivaceus*)	Other songbirds	2	22	19	178,272
29	Black-bellied plover (*Pluvialis squatarola*)	Shorebirds, gulls, and terns	1	11	36	160,000
29	Yellow-bellied flycatcher (*Empidonax flaviventris*)	Other songbirds	3	33	12	160,000
31	Upland sandpiper (*Bartramia longicauda*)	Shorebirds, gulls, and terns	2	22	16	126,420
32	Black-throated green warbler (*Setophaga virens*)	Other songbirds	2	22	14	96,790
32	Common ground dove (*Columbina passerina*)	Pigeons and doves	2	22	14	96,790
32	Chestnut-sided warbler (*Setophaga pensylvanica*)	Other songbirds	2	22	14	96,790
32	Nashville warbler (*Leiothlypis ruficapilla*)	Other songbirds	2	22	14	96,790
36	Eastern wood-pewee (*Contopus virens*)	Other songbirds	2	22	13	83,457
36	Tree swallow (*Tachycineta bicolor*)	Swallows	2	22	13	83,457
38	Evening bat (*Nycticeius humeralis*)	Bats	2	22	12	71,111
38	Purple martin (*Progne subis*)	Swallows	1	11	24	71,111
38	Traill's flycatcher (*Empidonax alnorum/trallii*)	Other songbirds	2	22	12	71,111
41	Lesser nighthawk (*Chordeiles acutipennis*)	Cuckoos and nightjars	2	22	11	59,753
42	Blue-headed vireo (*Vireo solitarius*)	Other songbirds	1	11	21	54,444
42	Sora (*Porzana carolina*)	Waterfowl and coots	1	11	21	54,444
42	Warbling vireo (*Vireo gilvus*)	Other songbirds	1	11	21	54,444
45	Great crested flycatcher (*Myiarchus crinitus*)	Other songbirds	1	11	19	44,568
46	Scissor-tailed flycatcher (*Tyrannus forficatus*)*	Other songbirds	1	11	18	40,000
47	Grasshopper sparrow (*Ammodramus savannarum*)*	Other songbirds	1	11	17	35,679
47	LeConte's sparrow (*Ammospiza leconteii*)*	Other songbirds	1	11	17	35,679
49	Least tern (*Sternula antillarum*)*	Shorebirds, gulls, and terns	1	11	16	31,605
50	Red-winged blackbird (*Agelaius phoeniceus*)	Other songbirds	1	11	15	27,778
51	American redstart (*Setophaga ruticilla*)	Other songbirds	1	11	14	24,198
51	Magnolia warbler (*Setophaga magnolia*)	Other songbirds	1	11	14	24,198
51	Tennessee warbler (*Leiothlypis peregrina*)	Other songbirds	1	11	14	24,198
51	Wilson's warbler (*Cardellina pusilla*)	Other songbirds	1	11	14	24,198

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
55	Northern yellow bat (*Lasiurus intermedius*)*	Bats	1	11	13	20,864
56	Baltimore oriole (*Icterus galbula*)	Other songbirds	2	22	6	17,778
56	Cedar waxwing (*Bombycilla cedrorum*)	Other songbirds	2	22	6	17,778
56	Mourning warbler (*Geothlypis philadelphia*)	Other songbirds	1	11	12	17,778
56	Northern rough-winged swallow (*Stelgidopteryx serripennis*)	Swallows	1	11	12	17,778
56	Orchard oriole (*Icterus spurius*)*	Other songbirds	1	11	12	17,778
56	Painted bunting (*Passerina ciris*)*	Other songbirds	1	11	12	17,778
56	Yellow-rumped warbler (*Setophaga coronata*)	Other songbirds	2	22	6	17,778
56	Indigo bunting (*Passerina cyanea*)	Other songbirds	3	33	4	17,778
64	Common yellowthroat (*Geothlypis trichas*)*	Other songbirds	2	22	4	7,901
65	Ovenbird (*Seiurus aurocapilla*)	Other songbirds	3	33	0	0

Table B2.4 Risk rank, species group, total number of strikes, strikes scaled to 100, relative hazard scores (RHS), and risk estimates for all identified bird and bat species struck in the summer from summer 2011–summer 2021. Stars indicate Texas Species of Greatest Conservation Need.

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
1	Cave swallow (*Petrochelidon fulva*)	Swallows	22	100	19	3,610,000
2	Black vulture (*Coragyps atratus*)	Vultures	2	9	100	826,446
3	Cliff swallow (*Petrochelidon pyrrhonota*)	Swallows	14	64	13	684,380
4	Blue-gray gnatcatcher (*Polioptila caerulea*)	Other songbirds	9	41	13	282,831
5	Evening bat (*Nycticeius humeralis*)	Bats	8	36	12	190,413
6	Barn swallow (*Hirundo rustica*)	Swallows	6	27	14	145,785
7	Laughing gull (*Leucophaeus atricilla*)	Shorebirds, gulls, and terns	2	9	41	138,926
8	Turkey vulture (*Cathartes aura*)	Vultures	1	5	80	132,231
9	Purple martin (*Progne subis*)	Swallows	3	14	24	107,107
10	White-tailed hawk (*Geranoaetus albicaudatus*)*	Hawks, kites, owls, and falcons	1	5	67	92,748
11	Northern yellow bat (*Lasiurus intermedius*)*	Bats	5	23	13	87,293
12	Upland sandpiper (*Bartramia longicauda*)	Shorebirds, gulls, and terns	4	18	16	84,628
13	White ibis (*Eudocimus albus*)	Cranes, anhingas, egrets, and ibises	1	5	63	82,004
14	Traill's flycatcher (*Empidonax alnorum/trallii*)	Other songbirds	5	23	12	74,380
15	Brazilian free-tailed bat (*Tadarida brasiliensis*)	Bats	4	18	12	47,603
16	Ruby-throated hummingbird (*Archilochus colubris*)	Swifts and hummingbirds	4	18	11	40,000
17	Mississippi kite (*Ictinia mississippiensis*)*	Hawks, kites, owls, and falcons	1	5	40	33,058
18	Least flycatcher (*Empidonax minimus*)	Other songbirds	3	14	13	31,426
19	Meadowlark spp. (*Sturnella* spp.)*	Other songbirds	2	9	19	29,835
20	Orchard oriole (*Icterus spurius*)*	Other songbirds	3	14	12	26,777
20	Yellow warbler (*Setophaga petechia*)	Other songbirds	3	14	12	26,777
22	Bank swallow (*Hirundo rustica*)	Swallows	2	9	16	21,157
23	Common nighthawk (*Chordeiles minor*)	Cuckoos and nightjars	2	9	15	18,595
24	Hoary bat (*Aeorestes cinereus*)*	Bats	2	9	13	13,967
25	Baird's sandpiper (*Calidris bairdii*)	Shorebirds, gulls, and terns	1	5	19	7,459
25	Bronzed cowbird (*Molothrus aeneus*)	Other songbirds	1	5	19	7,459

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
25	Great crested flycatcher (*Myiarchus crinitus*)	Other songbirds	1	5	19	7,459
25	Mourning dove (*Zenaida macroura*)	Pigeons and doves	1	5	19	7,459
29	Wilson's phalarope (*Phalaropus tricolor*)	Shorebirds, gulls, and terns	1	5	18	6,694
30	Grasshopper sparrow (*Ammodramus savannarum*)*	Other songbirds	1	5	17	5,971
31	Dickcissel (*Spiza americana*)*	Other songbirds	1	5	16	5,289
32	Yellow-breasted chat (*Icteria virens*)	Other songbirds	1	5	13	3,492
32	Horned lark (*Eremophila alpestris*)	Other songbirds	1	5	13	3,492
34	Least sandpiper (*Calidris minutilla*)	Shorebirds, gulls, and terns	1	5	12	2,975
34	Yellow-bellied flycatcher (*Empidonax flaviventris*)	Other songbirds	1	5	12	2,975
36	Chimney swift (*Chaetura pelagica*)	Swifts and hummingbirds	1	5	11	2,500

Table B2.5 Risk rank, species group, total number of strikes, strikes scaled to 100, relative hazard scores (RHS), and risk estimates for all identified bird and bat species struck in the fall from fall 2011–fall 2020. Stars indicate Texas Species of Greatest Conservation Need.

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
1	Turkey vulture (*Cathartes aura*)	Vultures	4	18	80	2,115,702
2	Barn swallow (*Hirundo rustica*)	Swallows	22	100	14	1,960,000
3	Broad-winged hawk (*Buteo platypterus*)	Hawks, kites, owls, and falcons	6	27	51	1,934,628
4	Cliff swallow (*Petrochelidon pyrrhonota*)	Swallows	22	100	13	1,690,000
5	Black vulture (*Coragyps atratus*)	Vultures	2	9	100	826,446
6	Great crested flycatcher (*Myiarchus crinitus*)	Other songbirds	10	45	19	745,868
7	Anhinga (*Anhinga anhinga*)	Cranes, anhingas, egrets, and ibises	2	9	72	428,430
8	Ruby-throated hummingbird (*Archilochus colubris*)	Swifts and hummingbirds	11	50	11	302,500
9	Snowy plover (*Charadrius nivosus*)*	Shorebirds, gulls, and terns	8	36	15	297,521
10	Blue-gray gnatcatcher (*Polioptila caerulea*)	Other songbirds	9	41	13	282,831
11	Bank swallow (*Riparia riparia*)	Swallows	7	32	16	259,174
12	Red-shouldered hawk (*Buteo lineatus*)*	Hawks, kites, owls, and falcons	2	9	51	214,959
13	Mourning dove (*Zenaida macroura*)	Pigeons and doves	5	23	19	186,467
14	Yellow-breasted chat (*Icteria virens*)	Other songbirds	7	32	13	171,095
15	Savannah sparrow (*Passerculus sandwichensis*)	Other songbirds	10	45	9	167,355
16	Lincoln's sparrow (*Melospiza lincolnii*)	Other songbirds	5	23	17	149,277
17	White-eyed vireo (*Vireo griseus*)	Other songbirds	4	18	21	145,785
17	Evening bat (*Nycticeius humeralis*)	Bats	7	32	12	145,785
19	Laughing gull (*Leucophaeus atricilla*)	Shorebirds, gulls, and terns	2	9	41	138,926
20	American kestrel (*Falco sparverius*)*	Hawks, kites, owls, and falcons	4	18	20	132,231
21	Brazilian free-tailed bat (*Tadarida brasiliensis*)	Bats	6	27	12	107,107
22	Nashville warbler (*Leiothlypis ruficapilla*)	Other songbirds	5	23	14	101,240
23	White ibis (*Eudocimus albus*)	Cranes, anhingas, egrets, and ibises	1	5	63	82,004
24	Red-tailed hawk (*Buteo jamaicensis*)	Hawks, kites, owls, and falcons	1	5	61	76,880
25	Wilson's warbler (*Cardellina pusilla*)	Other songbirds	4	18	14	64,793
26	Blue-winged teal (*Spatula discors*)	Waterfowl and coots	1	5	53	58,037

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
27	Chuck-will's-widow (*Antrostomus carolinensis*)*	Cuckoos and nightjars	2	9	26	55,868
28	Cooper's hawk (*Accipiter cooperii*)	Hawks, kites, owls, and falcons	1	5	51	53,740
29	Dickcissel (*Spiza americana*)*	Other songbirds	3	14	16	47,603
30	Sprague's pipit (*Anthus spragueii*)*	Other songbirds	3	14	13	31,426
31	Cave swallow (*Petrochelidon fulva*)	Swallows	2	9	19	29,835
32	White-winged dove (*Zenaida asiatica*)	Pigeons and doves	1	5	36	26,777
32	Ruby-crowned kinglet (*Corthylio calendula*)	Other songbirds	3	14	12	26,777
32	Traill's flycatcher (*Empidonax alnorum/trallii*)	Other songbirds	3	14	12	26,777
35	Clay-colored sparrow (*Spizella pallida*)	Other songbirds	2	9	17	23,884
36	Canada warbler (*Cardellina canadensis*)	Other songbirds	2	9	14	16,198
37	Swainson's thrush (*Catharus ustulatus*)	Other songbirds	1	5	26	13,967
38	House wren (*Troglodytes aedon*)	Other songbirds	2	9	12	11,901
38	Sedge wren (*Cistothorus stellaris*)*	Other songbirds	2	9	12	11,901
40	Sora (*Porzana carolina*)	Waterfowl and coots	1	5	21	9,112
40	Warbling vireo (*Vireo gilvus*)	Other songbirds	1	5	21	9,112
42	Long-billed thrasher (*Toxostoma longirostre*)	Other songbirds	1	5	20	8,264
42	Indigo bunting (*Passerina cyanea*)	Other songbirds	5	23	4	8,264
44	Eastern whip-poor-will (*Antrostomus vociferus*)	Cuckoos and nightjars	1	5	18	6,694
44	Scissor-tailed flycatcher (*Tyrannus forficatus*)*	Other songbirds	1	5	18	6,694
44	Stilt sandpiper (*Calidris himantopus*)*	Shorebirds, gulls, and terns	1	5	18	6,694
47	Grasshopper sparrow (*Ammodramus savannarum*)*	Other songbirds	1	5	17	5,971
47	Lark sparrow (*Chondestes grammacus*)*	Other songbirds	1	5	17	5,971
49	Upland sandpiper (*Bartramia longicauda*)	Shorebirds, gulls, and terns	1	5	16	5,289
50	American redstart (*Setophaga ruticilla*)	Other songbirds	1	5	14	4,050
51	Eastern kingbird (*Tyrannus tyrannus*)	Other songbirds	1	5	13	3,492
51	Least flycatcher (*Empidonax minimus*)	Other songbirds	1	5	13	3,492
51	Semipalmated sandpiper (*Calidris pusilla*)	Shorebirds, gulls, and terns	1	5	13	3,492
54	Killdeer (*Charadrius vociferus*)	Shorebirds, gulls, and terns	1	5	12	2,975
54	Least sandpiper (*Calidris minutilla*)	Shorebirds, gulls, and terns	1	5	12	2,975

Risk rank	Species	Species group	Total strikes	Scaled strikes	RHS	Risk
54	Marsh wren (*Cistothorus palustris*)	Other songbirds	1	5	12	2,975
54	Mourning warbler (*Geothlypis philadelphia*)	Other songbirds	1	5	12	2,975
54	Northern rough-winged swallow (*Stelgidopteryx serripennis*)	Swallows	1	5	12	2,975
54	Orchard oriole (*Icterus spurius*)*	Other songbirds	1	5	12	2,975
54	Painted bunting (*Passerina ciris*)*	Other songbirds	1	5	12	2,975
54	Yellow-bellied flycatcher (*Empidonax flaviventris*)	Other songbirds	1	5	12	2,975
54	Yellow warbler (*Setophaga petechia*)	Other songbirds	1	5	12	2,975
54	Yellow-rumped warbler (*Setophaga coronata*)	Other songbirds	2	9	6	2,975
64	Common yellowthroat (*Geothlypis trichas*)*	Other songbirds	2	9	4	1,322
65	American pipit (*Anthus rubescens*)	Other songbirds	1	5	7	1,012
66	Baltimore oriole (*Icterus galbula*)	Other songbirds	1	5	6	744
66	Yellow-billed cuckoo (*Coccyzus americanus*)	Cuckoos and nightjars	1	5	6	744
68	Ovenbird (*Seiurus aurocapilla*)	Other songbirds	3	14	0	0