NORMANDEAU ASSOCIATES
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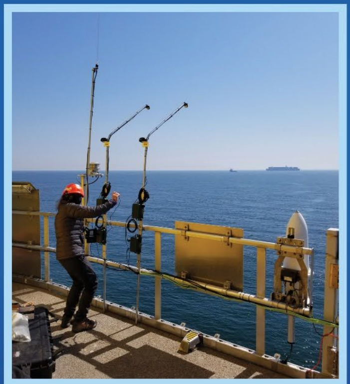
Postconstruction Bird and Bat Monitoring at the Coastal Virginia Offshore Wind Pilot Project

April 2021–March 2024 Final Report

Submitted to
Dominion Energy
600 East Canal Street
Richmond, VA 23219

December 2024



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DISCLAIMER

This report presents the results for 2021–2024 (years 1 through year 3) of the postconstruction bird and bat monitoring at the Coastal Virginia Offshore Wind Pilot Project from April 2021 until March 2024 at Turbine A01 (years 1–3) and Turbine A02 (year 1 only; Motus detections were recorded years 1–3).

REVISIONS

Version	Date	Author	Comment
1.0	December 23, 2024	Normandeau Associates	Initial submission
2.0	January 14, 2025	Normandeau Associates	Address Dominion’s comments

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Acronyms and Abbreviations

AI	artificial intelligence
ATOM	Acoustic and Thermographic Offshore Monitoring
BOEM	Bureau of Ocean Energy Management
CVOW	Coastal Virginia Offshore Wind
Dominion Energy	Virginia Electric and Power Company, d/b/a Dominion Energy Virginia
FAA	Federal Aviation Administration
IR	infrared
kHz	kilohertz
km	kilometers
kV	kilovolt
m	meter
mb	millibars
MHz	megahertz
MW	megawatt
m/s	meters per second
nm	nautical miles
Normandeau	Normandeau Associates, Inc.
RAP	research activities plan
RSZ	rotor swept zone
SSD	solid-state drive
UAS	unmanned aircraft system
USFWS	US Fish and Wildlife Service
VE	Virginia Energy (formerly DMME)
VHF	very high frequency
WTG	wind turbine generators

Executive Summary

Virginia Electric and Power Company, d/b/a Dominion Energy Virginia (Dominion Energy), on behalf of Virginia Energy (VE, formerly Virginia Department of Mines, Minerals and Energy [DMME]), has developed the Coastal Virginia Offshore Wind (CVOW) Pilot Project in federal waters 24 nautical miles (nm) (43 kilometers [km]) off the coast of Virginia. In 2019, Dominion contracted Normandeau Associates, Inc. (Normandeau), to provide postconstruction monitoring for the CVOW Pilot Project. Normandeau's Acoustic and Thermographic Offshore Monitoring (ATOM™) systems can be deployed on platforms underneath offshore wind turbines and collect data within the rotor swept zone (RSZ) and the vicinity of the wind turbine 24/7 during the monitoring period. This postconstruction monitoring final report presents the results from the 3-year study (April 1, 2021–March 15, 2024) at Turbines A01 and A02. During the first year, ATOM was deployed on both A01 and A02, and during years 2 and 3 ATOM was only operating on A01 (during years 2 and 3, A02 only had Motus operating). In addition to presenting results from all 3 years, we also make comparisons of bird and bat abundance among years when meaningful.

The ATOM system represents a collection of multiple sensors designed to collect information about bird and bat activity in the RSZ. Each ATOM system combines four types of wildlife sensors analyzed in combination: thermal cameras operating in stereo, a visible-light camera, acoustic detectors for birds and bats, and a very high frequency (VHF) receiver to detect birds fitted with NanoTags™ or PowerTags™. Data retrieval trips occurred approximately every other month representing a balance between reliable data security and cost control. Each data retrieval trip typically involved one day at each turbine and included the commute time from shore to turbine. In July 2022, the Motus receivers were upgraded from Lotek receivers to dual-band receivers from Cellular Tracking Technologies covering the 166-megahertz (MHz) and the 434-MHz bands. We also upgraded the two Omni antennas originally installed in year 1 to a configuration of four Yagi and two Omni antennas. Turbine A01 uses 434-MHz Yagi antennas and 166-MHz Omni antennas; Turbine A02 uses 434-MHz Omni antennas and 166-MHz Yagi antennas.

No bird or bat collisions were observed during the 3-year study period. Across all ATOM sensors and the entire three-year monitoring period, there were 3,428 detections of birds and bats (1,355 bats [40%], 2,000 birds [58%], and 73 bird/bat [2%]). We observed 82% of bird detections during the day and 18% at night. We observed 37% of bats during the day and 63% at night. Among all detections, 78% were observed in September or October. For birds, 70% were observed in either September or October, while 79% of bats were observed in September alone.

Bat detections include 3 bat species: silver-haired bat (*Lasionycteris noctivagans*), hoary bat (*Lasiurus cinereus*), and eastern red bat (*Lasiurus borealis*). There were 267 (20%) bat detections that could not be identified to species including both video and acoustic detections and 12 unknown low-frequency individuals (<1%). The detections that could be identified to species include silver-haired bat (598; 44%), hoary bat (169; 13%), and eastern red bat (309; 23%). No federally or state-listed bat species were detected during the study.

Bird observations included 1,013 (51%) passerine detections, 392 (20%) gull detections, 314 (16%) unidentified birds, 133 (7%) raptor detections, 50 (3%) shorebird detections, and 30 (2%) tern detections. All other species groups had <1% detections each. Passerines had the most species with 38, followed by 12 shorebird species, 7 gull species, and 5 raptor species; all other species groups had 2 or fewer species. Skuas and corvids were also identified but no individuals from these species groups were identified to species.

Two federally listed bird species (2 Red Knot individuals [*Calidris canutus rufa*] and 4 Piping Plover individuals [*Charadrius melodus*]) were detected by the Motus receivers in 2023. Both species are also state-listed as threatened. Individual Red Knots were detected on May 21, 2023, and June 11, 2023, in wind speeds of 9.1 m/s and 10.7 m/s, respectively.

Two Piping Plovers were detected in July 2023 in wind speeds of 3.6 m/s and 1.6 m/s. A third Piping Plover was recorded on August 5, 2023, in a wind speed of 2.8 m/s. On July 25, 2024, a fourth Piping Plover was detected at A01 and A02 at wind speeds of 2.6 and 2.9 m/s respectively. All piping plovers occurred in wind speeds of 3.6 m/s or less.

Most (57%) bird activity occurred when turbine blades were not spinning; however, it is unknown whether this was a result of the lack of blade motion or because blades are less likely to be spinning at lower wind speeds when birds are more likely to be active. Most (65%) bat detections were recorded while the blades were spinning; however, it is not known if this was attraction to the moving objects or a willingness to forage at higher wind speeds when the blades would normally be spinning.

Bat and bird activity seems to be related to wind speed and wind direction for most species groups. Much of the bird and bat activity observed is likely southbound fall migration given that 78% of the bird and bat detections occurred in September or October. Higher bat and passerine activity during northerly winds during the fall was expected as these winds are favorable to southbound fall migration. A decline in bat and passerine activity above wind speeds of 5 meters per second (m/s) and a further decline above 9 m/s was expected given that bats and passerines are typically more active when wind speeds are low. With only 22% of passerine detections occurring when the wind speed was >5 m/s is notable due to the cut-in speed being 3–5 m/s for the turbines at the CVOW Pilot Project. Less bird and bat activity when blades are spinning could reduce the likelihood of collisions.

Over 7,000 insect detections occurred annually during the 3-year study. Insects included many butterflies, moths, and dragonflies, though only select detections were identified to species. Across the 3-year study, insect activity peaked during September and October and were lower during other periods. Within-day activity showed that insect activity peaked during the early morning hours (6:00–8:00) and then again in the late afternoon (16:00–18:00). There was a moderate correlation between bat and insect activity ($\rho = 0.48$) as well as passerine and insect activity ($\rho = 0.36$). This correlation is not surprising given the high number of aerial foraging behaviors directed at insects observed in the video data. Aerial foraging was the most observed behavior for passerines (53% of observations) and bats (56% of observations), monopole gleaning was the second most common behavior for bats (17% of observations), and perching was the second most common behavior for passerines (14% of observations). Foraging behaviors have implications for collision risk because bats and birds are often distracted while chasing prey (aerial foraging) or looking for prey (monopole gleaning and hawking) and may be less aware of the presence of the blades. However, most bird foraging behavior occurs when the blades are not moving (74% of aerial foraging, 74% of hawking, and 75% of monopole gleaning) so an increase in collision risk could be less than expected while birds are foraging. In contrast, most bat foraging (56% of aerial foraging and 69% of monopole gleaning) occurred when the blades were spinning.

No collisions were observed in the video data. When the turbine blades were moving, all bats and birds avoided collisions while foraging within the RSZ; however, there were air-displacements recorded for birds and bats. Air-displacement occurs when an individual gets displaced by air pressure waves from the passing blades. Bat air-displacements were the following: 1 unidentified bat on 9/29/21, 1 unidentified bat on 8/3/22, and 1 silver-haired bat on 10/27/22. There were four observations of bird air-displacement: 1 unidentified passerine on 10/15/2021, 1 unidentified passerine on 10/28/21, 1 Great Black-backed Gull (*Larus marinus*) on 2/15/2022, and 1 Eastern Phoebe (*Sayornis phoebe*) on 10/23/23. Microavoidance behaviors were observed 45 times for bats and 65 times for birds. Microavoidance reflects last-second action taken to avoid the turbine blades while in proximity to the blade surface. Microavoidance prevents a collision with the blade and is an essential behavior for reducing collision mortality.

Introduction

Offshore wildlife surveys are challenging as conventional methodologies have limitations in adverse weather conditions and low visibility, particularly for gathering species-specific data. A remote operating ATOM™ system (Robinson Willmott and Forcey 2014; Robinson Willmott et al. 2015; Robinson Willmott et al. 2023) for birds and bats coupled with visible-light cameras and a VHF receiver is one solution to this issue. This technology combination provides a cost-effective way to understand bird and bat occurrence within rotor swept altitudes at offshore wind sites. The rationale for this system and sensor selection is simple at its core and consists of four elements that drive the choice of detection equipment.

1. Only acoustic data can provide species-specific information for many bird species during low light or adverse weather conditions. This is also true for bats.
2. Thermal data are a necessary complement to acoustic data for risk studies as microphones cannot record silent birds or calculate flight heights. We use two cameras operating in stereo to calculate flight heights.
3. A visible-light camera can supplement target information from the thermal cameras during daylight. Some species-specific information will be possible at lower altitudes depending on the flight height and size of the target along with available daylight.
4. A VHF receiver and associated antenna system can provide occurrence data on radio-tagged birds as part of the Motus Wildlife Tracking System and is useful for providing information on activity and approximate location of tagged threatened and endangered species such as Roseate Tern (*Sterna dougallii*), Red Knot (*Calidris canutus rufa*), and Piping Plover (*Charadrius melodus*).

Virginia Electric and Power Company, d/b/a Dominion Energy Virginia (Dominion Energy), on behalf of Virginia Energy (VE, formerly DMME) has developed the CVOW Pilot Project in federal waters 27 nm (43 km) off the coast of Virginia (Figure 1). The CVOW Pilot Project is a collaborative effort including DMME as the lease holder, Dominion Energy as the designated operator, and Tetra Tech and Normandeau as the environmental consultants. The CVOW Pilot Project consists of 2 6-megawatt (MW) Siemens Gamesa wind turbine generators (WTGs) and a 34.5-kilovolt (kV) transmission cable through state and federal waters. Dominion Energy received approval from the Bureau of Ocean Energy Management (BOEM) on the most recent research activities plan (RAP) on June 20, 2019, and provisionally accepted the project on October 13, 2020 (Tetra Tech and Normandeau 2020).

Requirements in the RAP state that postconstruction monitoring must include:

- Thermal imaging on both WTGs
- Acoustic monitoring of bat activity on both WTGs
- Boat-based bird surveys

In addition to these requirements, Dominion Energy has added these sensors on each WTG to collect additional data and increase the research value of the project:

- Acoustic sensors for birds
- Backup acoustic detectors for both birds and bats
- A visible-light camera to supplement the thermal cameras during the day
- A VHF receiver to detect animals fitted with NanoTags™ and PowerTags™

In 2019, Dominion Energy contracted Normandeau to provide postconstruction monitoring for the CVOW Pilot Project. Normandeau's ATOM systems can be deployed on platforms underneath offshore wind turbines and collect data within the RSZ and the vicinity of the wind turbine 24/7 during the monitoring period. This postconstruction monitoring final report presents the results of years 1, 2, and 3 of ATOM monitoring (April 1, 2021–March 15, 2024). We also compare results among years when appropriate. Differences between the first and subsequent years include the following:

- Upgraded Motus systems on A01 and A02 using the dual-band Cellular Tracking Technologies receivers were added in July 2022.
- Upgraded Motus antenna arrays at both turbines in July 2022; Turbine A01 uses 434-MHz Yagi antennas and 166-MHz Omni antennas; Turbine A02 uses 434-MHz Omni antennas and 166-MHz Yagi antennas.
- Following completion of the first year of data collection, cameras and acoustics were removed from A02 leaving only a Motus receiver on the platform. A full ATOM system including thermal, visible-light, acoustics, and Motus sensors were only installed on A01.
- Monitoring occurred throughout the year in years 2 and 3 whereas in year 1 monitoring was only done in the spring (April 1–June 15), fall (August 15–October 31), and winter (January 15–March 15) seasons.

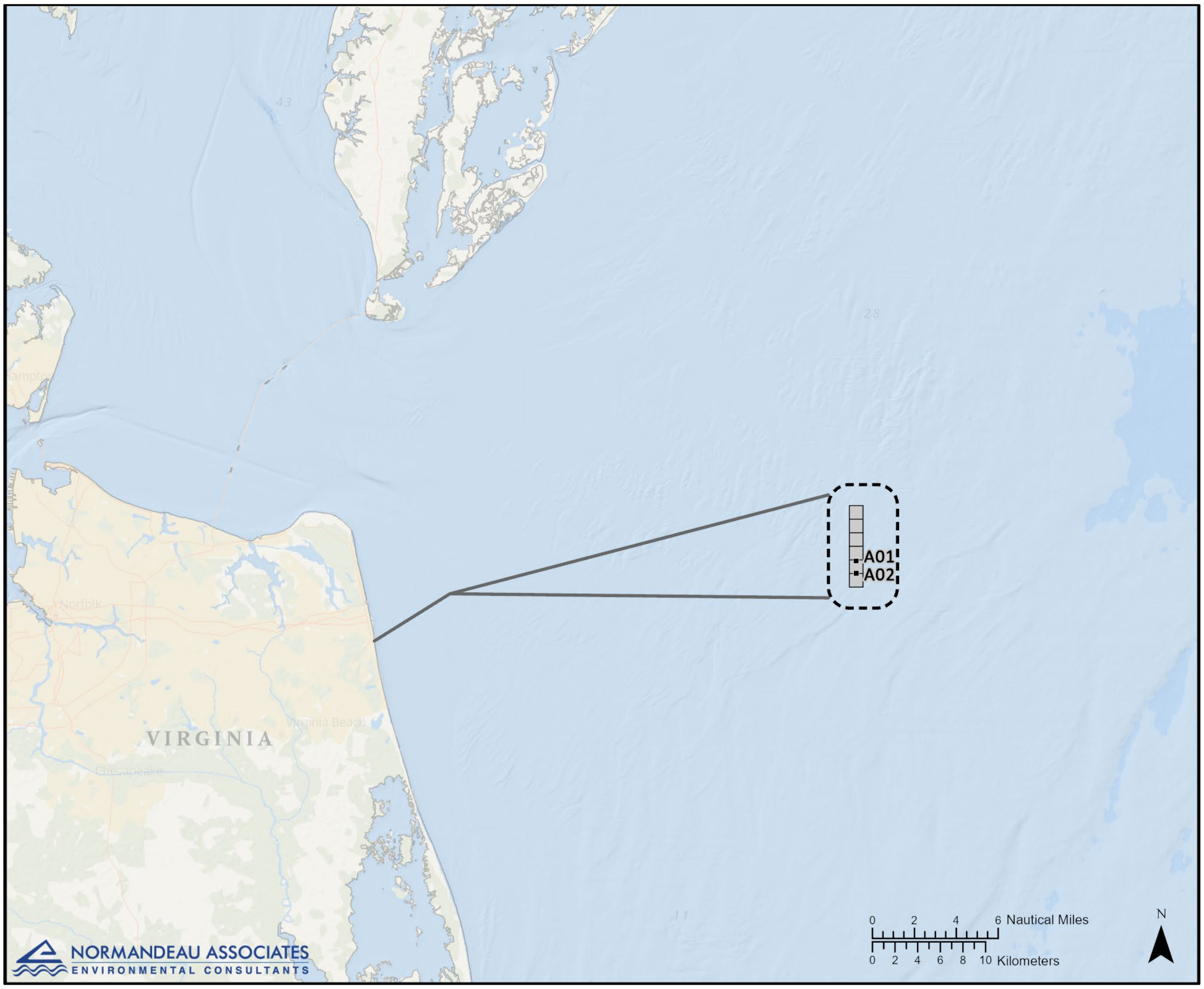


Figure 1. Location of the Coastal Virginia Offshore Wind Pilot Project and turbines.

Methods

Overview

The ATOM system provides critical species-specific, quantitative data on bird and bat occurrence at wind facilities that can fill data gaps for risk and impact studies and regulatory compliance. The ATOM system represents a collection of multiple sensors designed to collect information about bird and bat activity in the RSZ. Multiple sensors ensure comprehensive data collection within the area of interest. ATOM is designed for remote, marine weatherized, self-powered operation at a large marine buoy or fixed platform such as a wind turbine or meteorological tower. This design enables ATOM to collect data on birds and bats continuously for long-term deployments, providing essential information on day/night variation and seasonal variation of bird and bat occurrence at actual or proposed offshore wind facilities with minimum labor. Each ATOM system combines four types of wildlife sensors analyzed in combination:

- Audible sound detectors for bird vocalizations and ultrasonic detectors for bat vocalizations enable species-level identification, which is essential for species-specific regulatory drivers such as the Endangered Species Act and the Migratory Bird Treaty Act. Acoustic data also provide some species-specific identifications to targets detected with thermal cameras that cannot otherwise be identified.

- Thermal cameras provide data to quantify bird and bat passage rates during low visibility or when individuals are not vocalizing; two cameras operating in stereo permit calculation of flight heights and flight speeds.
- A visible-light camera permits some species identification at lower altitudes depending on the size of the target and flight altitude.
- A VHF receiver can detect NanoTagged and PowerTagged animals as part of the Motus network.

The computers that form the central core of the ATOM system are housed inside a custom-fabricated weatherproof container containing the power supply, networking components, and the two thermal cameras. The core ATOM components are mounted to a custom metal chassis attached to the turbine platform (Figure 2). The dimensions of the chassis were constrained to allow transportation in a pickup truck and to be carried by two people.

Acoustic detectors and VHF receivers and antennas are mounted away from the chassis. Location of the chassis on the platform is critical for the thermal and visible-light cameras, so they have an optimal view of the rotor swept area. Based on the available locations, we selected the position that provided the most comprehensive view of the RSZ while still permitting turbine maintenance operations without constraints (Figure 2). During the initial deployment, bird deterrents were installed on the ATOM box to discourage perching; however, these were determined to be a safety hazard and were removed during a subsequent data retrieval trip.

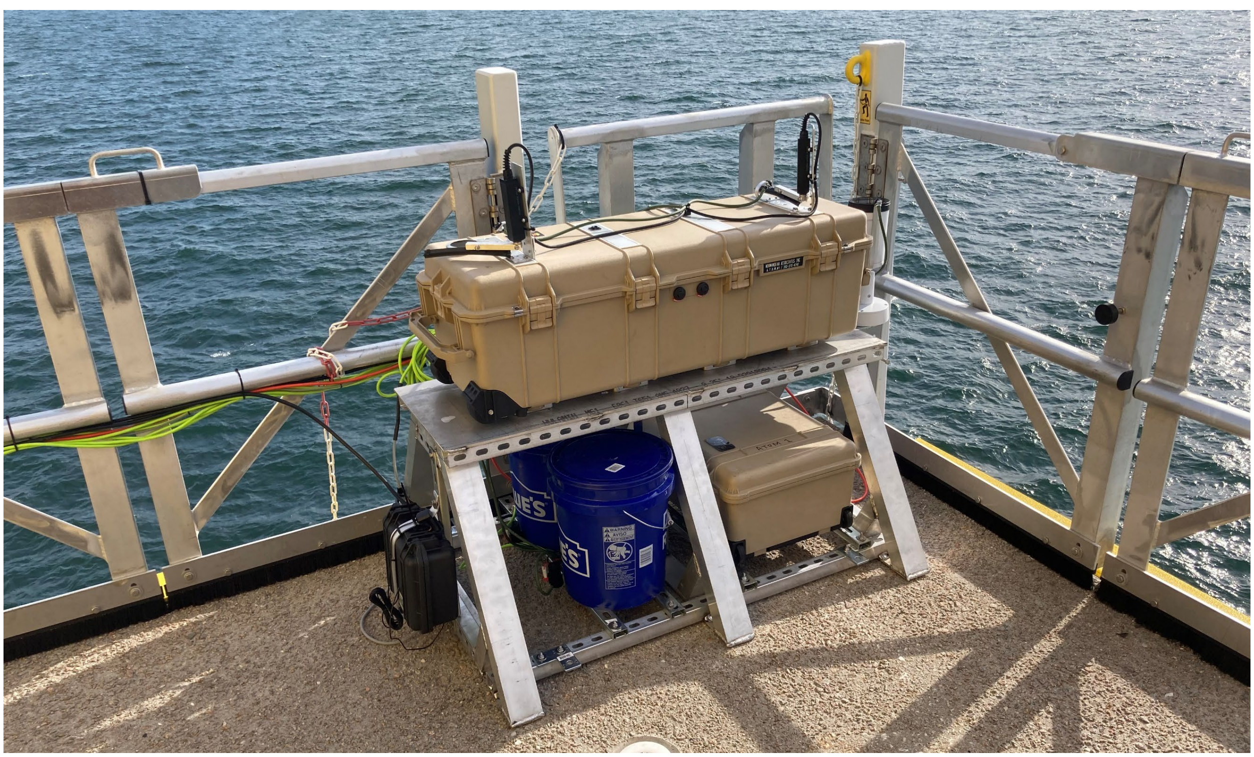


Figure 2. The core ATOM system components installed on the CVOW turbine platform.

The ATOM system operates continuously, and all sensors record information 24/7 throughout the monitoring period. Video data from the thermal and visible-light cameras are stored on the internal drives within the weatherproof container. Data from the bird and bat acoustic detectors are stored internally on the detectors' SD cards. VHF receiver data are stored internally on the VHF receivers' internal storage. Data retrieval trips were performed on each ATOM system during which video drives were swapped with new ones with fresh storage capacity, and data storage cards were swapped out with empty ones on the acoustic and VHF receivers. All data were transferred to network-attached storage for backup, processing, and analysis.

Video

The thermal camera array on the ATOM system consists of two vertically oriented thermal imaging cameras operating in stereo. The camera array was adjusted during the initial setup and calibrated in stereo for an optimal view of the RSZ. Cameras were re-evaluated for quality assurance during the data download trips. To supplement the viewshed surveyed by thermal cameras, each ATOM system also includes one visible-light camera to provide additional data on targets detected during the day. The video collection system sends hourly status reports via satellite modem connection. In addition, the satellite modem connection allows remote inspection of the electronics to ensure proper functioning and data collection. These remote inspections are typically done weekly to ensure the status messages accurately reflect the state of system.

Before video review, all data are cataloged and processed to note any gaps due to turbine power outages, system outages, or corrupted files. Normandeau has developed a process to review video data using automatic target detection software and manual review of potential targets by human analysts. Software performs an initial track detection in 100% of the thermal camera video data and flags all potential movement of interest. Manual review of potential targets is then performed using Normandeau's ReMOTe data portal and analysis tool. Using ReMOTe, analysts can simultaneously review thermal and visible-light video for the periods flagged by the automated software. Human analysts can determine and note the target type (wildlife, airplane, cloud, turbine blade, rain) and have their observations saved automatically into a central database. The results of the manual review are instantly available via the ReMOTe data portal, and wildlife is characterized as bird, bat, or insect. Birds and bats are sent to taxonomic experts (>10 years of experience) for identification when the thermographic track is simultaneously visible in the visible-light video. Identifications are made to the lowest taxonomic level possible. Birds marked as unidentified are birds that either could not be identified because they only appear in the thermographic cameras, key morphological characteristics needed for identification are not apparent in the visible-light camera, or observations lack supporting acoustic data (see next section). During identification, behaviors and whether the turbine blades are moving are noted. Behaviors are described as:

- Attraction (comes to check-out turbine then continues)
- Hawking (sallies from perch on short flights to capture flying insects)
- Microavoidance (blade interactions when blades are moving)
- Perching
- Aerial foraging (prolonged continuous flight capturing prey items)

- Low patrol (direct flight below the RSZ)
- High patrol (direct flight within or above the RSZ)
- Flyover (very high flight visible above turbine, usually large birds that can be detected at longer distances)
- Thermaling (no flapping)
- Monopole gleaning (taking insects off the monopole)

The flight height and speed calculations of targets are based on a track detection and particle analysis process. The track detection process outputs a series of particles with each track. Each particle has a center coordinate that corresponds to the pixel position of the particle within the video frame. Once tracks from the left and right cameras are paired, the distance of the object from the cameras can be determined from the relative position of the object in each camera. Specifically, the distance from the camera will be inversely proportional to the offset of the X coordinates from the full width of the camera frame. Once the distance (D) to an object has been determined, the absolute location of the object can be determined. The X-Y coordinates of the object in the camera frame correspond linearly to the object's location within a plane a distance D to the camera.

Object velocities are determined by comparing the object location in sequential video frames. The object velocity between two video frames is the difference in absolute location multiplied by the video frame rate. To reduce noise in the distance and velocity data, a smoothing filter is applied to particle locations prior to calculations. To improve the accuracy of the calculations, a translation is applied to the particles to account for slight deviations from a perfectly parallel camera alignment. For each system, the coefficients of this translation have been derived from the tracks of airplanes, which fly high enough that they should appear at the same location in each camera. With a large collection of airplane particles distributed across the image field, the difference in relative orientation between the two cameras can be determined.

After tracks have been paired, particle locations have been smoothed and translated, and distance and velocity have been calculated for each video frame, a median distance and velocity are recorded for the track. Note that it is not possible to calculate distance and speed if targets are detected in only one of the cameras in the stereo pair.

Acoustic

Acoustic monitoring of birds and bats on the ATOM system includes four recorders on each turbine platform: two acoustic recorders with microphones to capture bird calls and two full spectrum ultrasonic bat recorders with microphones to capture bat calls. Each pair of bird and bat detectors is sampling the same airspace; the extra detector is for redundancy in case of equipment failure. The acoustic detectors are not capable of remote connection and inspection; however, these systems are inspected during each trip to the turbine when all systems are inspected for physical damage, routine wear and tear, and proper electronic functioning. Repairs and maintenance are conducted as necessary.

Bats

Bat call files were uploaded to the Normandeau ReMOTe server for storage and processing. We ran all .wav files through bat acoustic identification software SonoBat (Arcata, USA). After all .wav files were processed, we manually vetted any call that SonoBat's auto-identification algorithm designated as a potential bat. During the processing of data, any gaps in the data are calculated by automated processing and noted.

Birds

A broad review of the bird acoustic data showed some excessive clipping in many of the call files. This can be due to high amplitude wind, water, or mechanical noise. Data were used to create an automated .wav file clipping check algorithm in MATLAB (Mathworks, Natick, MA). This algorithm was run on data from the CVOW Pilot Project to determine which files contained the least amount of clipping and could be processed. Bird acoustic data were processed with Wildlife Acoustics Kaleidoscope Pro (v 5.4.8) software using automated detection parameters determined for the flight calls of species in Table 1 using flight call audio data in the Cornell Lab of Ornithology Macaulay Library archives (https://search.macaulaylibrary.org/catalog). These species were chosen based on sightings noted in ebird.org for the eastern US region and cross-referenced with the Migratory Bird Treaty Act. Note that detection parameters for the species listed do not necessarily exclude other species or non-bird sounds, so manual auditory (headphones) and visual (spectrogram) review of the detections is necessary to confirm any bird call within or outside the list and to exclude false alarms. Additional bird species were confirmed from any detections not listed in Table 1, focusing on but not limited to gulls, terns, and sandpipers. This species list is not to be taken as exhaustive as the Kaleidoscope settings can also detect species outside this list.

Manual auditory (headphones) and visual (spectrogram) review was conducted on every detection generated by the Kaleidoscope Pro software auto-detection cluster analysis. Any detections that were not birds are not listed. For this analysis, one call corresponds to at least one confirmed detection within any 1-minute span. Two calls from the same species within the same minute are counted as one occurrence.

Table 1. Bird Species Whose Flight Calls were Used for Automatic Detection Parameter Selection

Cape May Warbler	Northern Parula	Bobolink
Ovenbird	American Redstart	Palm Warbler
Gray-cheeked Thrush	Black-throated Blue Warbler	Black-and-white Warbler
Blackpoll Warbler	Common Yellow Throat	Bay-breasted Warbler
Least Bittern	Green Heron	Veery
Swainson's Thrush	Wood Thrush	Northern Waterthrush
Magnolia Warbler	Blackburnian Warbler	Yellow Warbler
Chestnut-sided Warbler	Yellow-rumped Warbler	Savannah Sparrow
White-throated Sparrow	Blue Grosbeak	Indigo Bunting

VHF Receivers and Antennas

Each ATOM system includes a VHF receiver and associated antennas to detect Motus-tagged birds as they fly near the wind turbine. During year 1, the Motus setup included two omnidirectional whip antennas positioned on opposite sides of the monopole to maximize range and address signal interference and a Lotek SRX800-D1 receiver configured to detect NanoTagged wildlife flying near the turbines. These two components have been able to detect a beacon test tag up to 1.25 miles (2 km) from the turbine platform.

In July 2022, the Motus receivers were upgraded to dual-band SensorStations manufactured by Cellular Tracking Technologies capable of detecting tags using the 166-MHz and the 434-MHz bands. In addition, antenna arrays at both turbines were upgraded to include 4 Yagi antennas and 2 Omni antennas. Turbine A01 uses 434-MHz Yagi antennas and 166-MHz Omni antennas; Turbine A02 uses 434-MHz Omni antennas and 166-MHz Yagi antennas. Antenna arrays used a split mast design where two Yagi antennas and one Omni antenna were on opposite sides of the monopole to minimize signal interference as much as possible.

The Motus receiver on A01 was calibrated in October 2022 and the receiver on A02 was calibrated in December 2022. Both Motus receivers were calibrated via boat, where test tags were placed on top of a 2-meter (m) mast on a boat while the boat traveled outward from the turbines in concentric transects until reaching 5 km from the wind turbine. Receiver detections of both 166-MHz and 434-MHz test tags were overlaid on the boat’s tracklog to understand how signal strength varied as distance from the receiver increased. In addition, the acoustic and Motus equipment clocks are checked for accuracy to ensure they are synchronized during each data retrieval trip.

Tag data from the VHF receivers were uploaded to the Motus website (motus.org). These data are processed on the Motus webserver, and the tag identifications are determined by matching any tags detected to tag deployments in the Motus database. Once data processing was complete, species identifications were determined by querying the Motus database using the R package *motus* or by manually reviewing the detections at each receiver location (Motus 2021).

ATOM Operation

The ATOM systems were deployed on Turbines A01 and A02 during the second week of March 2021 to allow adequate commissioning and testing before the beginning of the spring monitoring period on April 1, 2021. During year 1, data retrieval trips occurred approximately monthly and approximately every 2–3 months in years 2 and 3. Each data retrieval trip typically involved one day at each turbine and included the commute time from shore to turbine. Following completion of year 1, the acoustic and video sensors were decommissioned on Turbine A02, leaving only the Motus system operating; the full ATOM system continued to operate on Turbine A01 (Table 2).

Table 2. Schedule of Deployment, Data Retrieval, and Decommissioning of ATOM Throughout the Three-Year Study Period

Year / Season	Turbine Visit Week	Purpose of Visit
1 / Spring	Mar 8, 2021	Deployment week for spring
1 / Spring	Apr 11, 2021	Data retrieval
1 / Spring	May 10, 2021	Data retrieval
1 / Spring	Jun 14, 2021	Data retrieval / Decommissioned until fall
1 / Fall	Jul 12, 2021	Deployment week for fall
1 / Fall	Aug 16, 2021	Data retrieval
1 / Fall	Sep 13, 2021	Data retrieval
1 / Fall	Nov 15, 2021	Data retrieval
1 / Winter	Jan 17, 2022	Data retrieval
1 / Winter	Feb 14, 2022	Data retrieval
1 / Winter	Mar 28, 2022	Data retrieval / Video and acoustics decommissioned on ATOM 2
2 / Spring	Jun 12, 2022	Data retrieval
2 / Summer	Jul 24, 2022	Motus upgrade to CTT receivers on A01 and A02 / Data retrieval
2 / Fall	Oct 9, 2022	Data retrieval
2 / Winter	Dec 2, 2022	Data retrieval
2 / Winter	Feb 6, 2023	Data retrieval
3 / Spring	Apr 2, 2023	Data retrieval
3 / Summer	Jun 18, 2023	Data retrieval
3 / Summer	Sep 4, 2023	Data retrieval
3 / Fall	Nov 5, 2023	Data retrieval
3 / Winter	Jan 28, 2024	Data retrieval
3 / Summer	Aug 4, 2024	Data retrieval / Decommission video and acoustics on A01, leaving only Motus at A01 and A02

Data Analysis

Behavioral observations were categorized for all bats and birds observed in video. As no collisions were observed, none are reported here. Analyses focused on microavoidance events when animals interacted with moving blades, foraging strategies, perching observed, attraction, and if animals flying over the turbine showed evidence of attraction or distraction caused by the turbine structure.

Insect detections were quantified along with bat and bird activity for the monitoring period. We examined relationships of insect detections with bird and bat detections by using Spearman's rank correlations to look for associations.

To relate bat and bird activity to weather variables, we used modeled wind speed and wind direction data from StormGeo. StormGeo is a weather forecasting service that provides route planning, operational, and risk assessment services to the offshore wind sector. Weather variables were related to the bird and bat call data by matching the animal detection timestamps to the closest value found in the weather data. Data from StormGeo were available hourly for year 1 and every 3 hours for years 2 and 3. For each weather variable, we examined relationships between variability in weather variables with bird and bat activity by examining frequency histograms of detections with the range of values for each weather variable.

Results

Video

Across years, video sensor uptime ranged from 90 to 98% (Figure 3). Most downtime occurred in year 1:

- Downtime of ATOM 2 (Turbine A02) from April 20 to May 12, 2021, was due to a wiring fault in the system; this was repaired during a data retrieval trip.
- Visible-light video was only recorded during the day from April 1 to 7, 2021, on ATOM 2 due to a storage system wiring problem, which was corrected during a subsequent data retrieval trip.
- Thermal data from ATOM 1 (Turbine A01) was missing from May 29 to June 1, 2021, due to a software issue that was patched when the system came back online after power was cycled at the turbines (Appendix A).
- During winter, damage to the satellite modem prevented a remote fix during a 15-day period (January 26 to February 9, 2022) when ATOM 1 (Turbine A01) recorded data but did not save it to the drives.

Other periods of downtime in year 1 were minor and could be attributed to turbine maintenance (Appendix A). Uptime in years 2 and 3 exceeded 95% for all video sensors (Figure 3).

Results of the calibration testing showed that a large bird should be detected out to 280 m (drone size) while a small bird (tennis ball size) should be detected out to 130–144 m (Appendix B).

Across all 3 years, there were 2,142 bird and bat detections in the video with 1,731 birds (81%), 338 bats (16%), and 73 detections designated as bird/bat (3%). Of the 338 bat detections in video, only 72 (21%) were identified to species due to the difficulty of identifying visual field marks on bats. Bats accounted for 16% of all video detections (including bird/bats) (Table 3); however, video data were still useful for characterizing bat behaviors including blade interactions and microavoidance. These discussions are presented later in the report.

Individuals from 16 bird species groups were identified including cuckoos, nightjars, swifts, corvids, shorebirds, gulls, terns, shearwaters, skuas, gannets, anhingas, pelicans, raptors, woodpeckers, hirundines (swallows), and passerines. While swallows and corvids are passerines, they are treated here separately given their different natural history and foraging behavior compared to other passerines. Fifty-seven species-level identifications were possible: 1 species of cuckoo, 1 species of nightjar, 1 species of swift, 3 species of shorebirds, 6 species of gulls, 1 species of tern, 1 species of shearwater, 1 species of gannet, 1 species of anhinga, 1 species of pelican, 4 species of raptors, 1 species of woodpecker, 1 species of Hirundine (swallow), and 34 species of passerines. No skuas or corvids were able to be identified to species. Passerines (940) accounted for 54% of the birds detected in the video, unidentified birds (314) were 18%, gulls

(288) were 17%, and raptors (130) were 8% of the observations. Other species groups were <1% of the observations (Table 3).

In addition, we performed a second review of 10% of the observations initially classified as a bird/bat/insect to determine if additional time and experience with the data could improve identification rates: 86% were insects, 7% were unidentified birds/bats, 5% were unidentified birds, and 2% were unidentified bats. None of the initially identified bird/bat/insects could be identified to species.

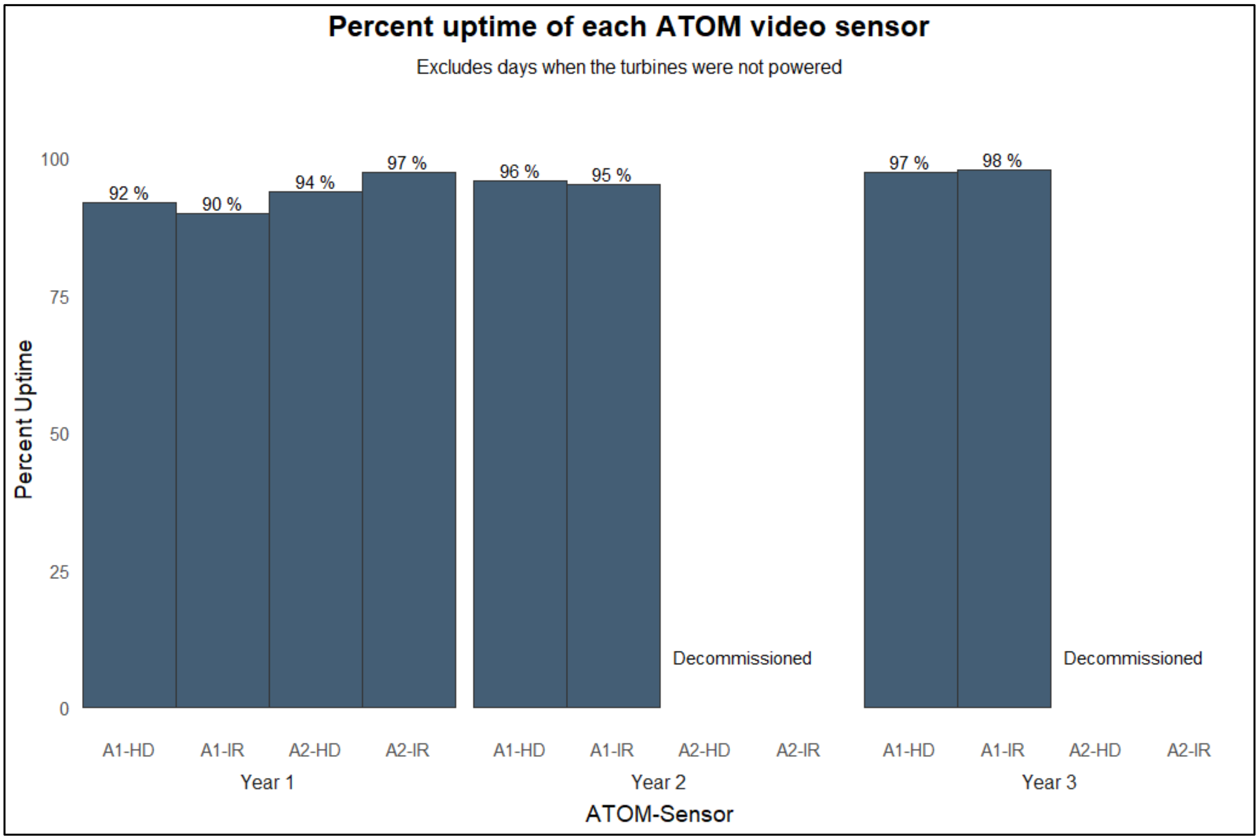


Figure 3. Uptime of the video sensors on the two ATOM systems over the 3-year monitoring period.

Downtime due to a power outage on the turbines is not included in the calculations.

A1 = ATOM 1, A2 = ATOM 2, HD = HD Visible-light Camera, IR = Thermal Camera Pair

Table 3. Bird and Bat Observations Recorded Using a Combination of Thermal and Visible-light Video Sensors During the 3-Year Study

Type	Subtype	Common Name	Year 1	Year 2	Year 3	Total
Bird	Cuckoo	Yellow-billed Cuckoo	0	0	3	3
Bird	Nightjar	Common Nighthawk	0	0	4	4
Bird	Swift	Chimney Swift	0	2	0	2
Bird	Shorebird	Whimbrel	0	1	0	1
Bird	Shorebird	White-rumped Sandpiper	0	0	1	1
Bird	Shorebird	Shorebird species	3	2	10	15
Bird	Skua	Skua species	1	0	0	1
Bird	Gull	Bonaparte's Gull	0	1	0	1
Bird	Gull	Laughing Gull	10	11	7	28
Bird	Gull	Franklin's Gull	0	0	1	1
Bird	Gull	Herring Gull	8	68	8	84
Bird	Gull	Great Black-backed Gull	3	8	16	27
Bird	Gull	Lesser Black-backed Gull	0	1	1	2
Bird	Gull	Large Gull species	27	32	32	91
Bird	Gull	Small Gull species	4	7	0	11
Bird	Gull	Gull species	10	13	20	43
Bird	Tern	Royal Tern	0	0	1	1
Bird	Shearwater	Cory's Shearwater	0	2	0	2
Bird	Gannet	Northern Gannet	0	0	1	1
Bird	Anhinga	Anhinga	0	0	1	1
Bird	Pelican	American White Pelican	0	0	15	15
Bird	Raptor	Osprey	8	1	29	38
Bird	Raptor	Mississippi Kite	0	1	1	2
Bird	Woodpecker	Northern Flicker	1	0	0	1
Bird	Raptor	Merlin	1	0	0	1
Bird	Raptor	Peregrine Falcon	53	30	0	83
Bird	Raptor	Raptor species	3	3	0	6
Bird	Passerine	Eastern Phoebe	0	0	2	2
Bird	Passerine	Red-eyed Vireo	0	0	1	1
Bird	Corvid	Corvid species	2	0	0	2
Bird	Hirundine	Cliff Swallow	0	0	1	1
Bird	Hirundine	Hirundine species	3	5	0	8
Bird	Passerine	Brown Creeper	10	0	3	13
Bird	Passerine	Winter Wren	17	1	1	19
Bird	Passerine	Wren species	1	6	0	7
Bird	Passerine	Gray-cheeked Thrush	0	1	0	1
Bird	Passerine	American Robin	2	0	2	4

Type	Subtype	Common Name	Year 1	Year 2	Year 3	Total
Bird	Passerine	American Pipit	1	0	0	1
Bird	Passerine	House Finch	0	1	0	1
Bird	Passerine	Snow Bunting	0	4	0	4
Bird	Passerine	Dark-eyed Junco	0	0	1	1
Bird	Passerine	White-throated Sparrow	0	2	0	2
Bird	Passerine	Bobolink	0	0	1	1
Bird	Passerine	Orchard Oriole	0	18	0	18
Bird	Passerine	Brown-headed Cowbird	0	5	0	5
Bird	Passerine	Common Grackle	0	0	1	1
Bird	Passerine	Golden-winged Warbler	0	0	1	1
Bird	Passerine	Blue-winged Warbler	1	0	0	1
Bird	Passerine	Black-and-white Warbler	13	0	3	16
Bird	Passerine	Prothonotary Warbler	0	4	0	4
Bird	Passerine	Hooded Warbler	0	1	0	1
Bird	Passerine	American Redstart	3	3	1	7
Bird	Passerine	Kirtland's Warbler*	1	0	0	1
Bird	Passerine	Cape May Warbler	119	3	2	124
Bird	Passerine	Northern Parula	1	0	0	1
Bird	Passerine	Magnolia Warbler	4	1	0	5
Bird	Passerine	Bay-breasted Warbler	7	0	0	7
Bird	Passerine	Blackburnian Warbler	5	0	0	5
Bird	Passerine	Yellow Warbler	0	0	9	9
Bird	Passerine	Chestnut-sided Warbler	0	0	1	1
Bird	Passerine	Blackpoll Warbler	0	4	0	4
Bird	Passerine	Palm Warbler	13	5	2	20
Bird	Passerine	Pine Warbler	27	1	2	30
Bird	Passerine	Yellow-rumped Warbler	16	15	7	38
Bird	Passerine	Setophaga species	184	10	3	197
Bird	Passerine	Parulidae species	6	0	0	6
Bird	Passerine	Rose-breasted Grosbeak	11	0	0	11
Bird	Passerine	Passerine species	285	57	28	370
Bird	Unid. Avian	Unidentified bird species	161	106	47	314
Bat	Bat	Silver-haired bat	1	32	4	37
Bat	Bat	Hoary bat	2	11	3	16
Bat	Bat	Eastern Red bat	4	14	1	19
Bat	Bat	Bat species	104	113	49	266
Bird/Bat	Bird/Bat	Bird/Bat	49	9	15	73

* State-listed as endangered with a probable identification

Acoustic

The acoustic detectors produce a summary file that keeps a running log for every minute that the detector is functioning. There were 128 summary files from 8 detectors (A1-Bat-Left, A1-Bat-Right, A1-Bird-Left, A1-Bird-Right, A2-Bat-Left, A2-Bat-Right, A2-Bird-Left, A2-Bird-Right). These files were compiled for each turbine and detector type (A1-Bat, A1-Bird, A2-Bat, A2-Bird) resulting in millions of records. The left and right detectors served as redundant backups in case one malfunctioned, so any duplicate minutes between the left and right detectors were reduced to one record, and the minutes were summarized by day. The percentage uptime was then calculated for each day considering 1,440 minutes per day and then averaged for the study years (Figure 4).

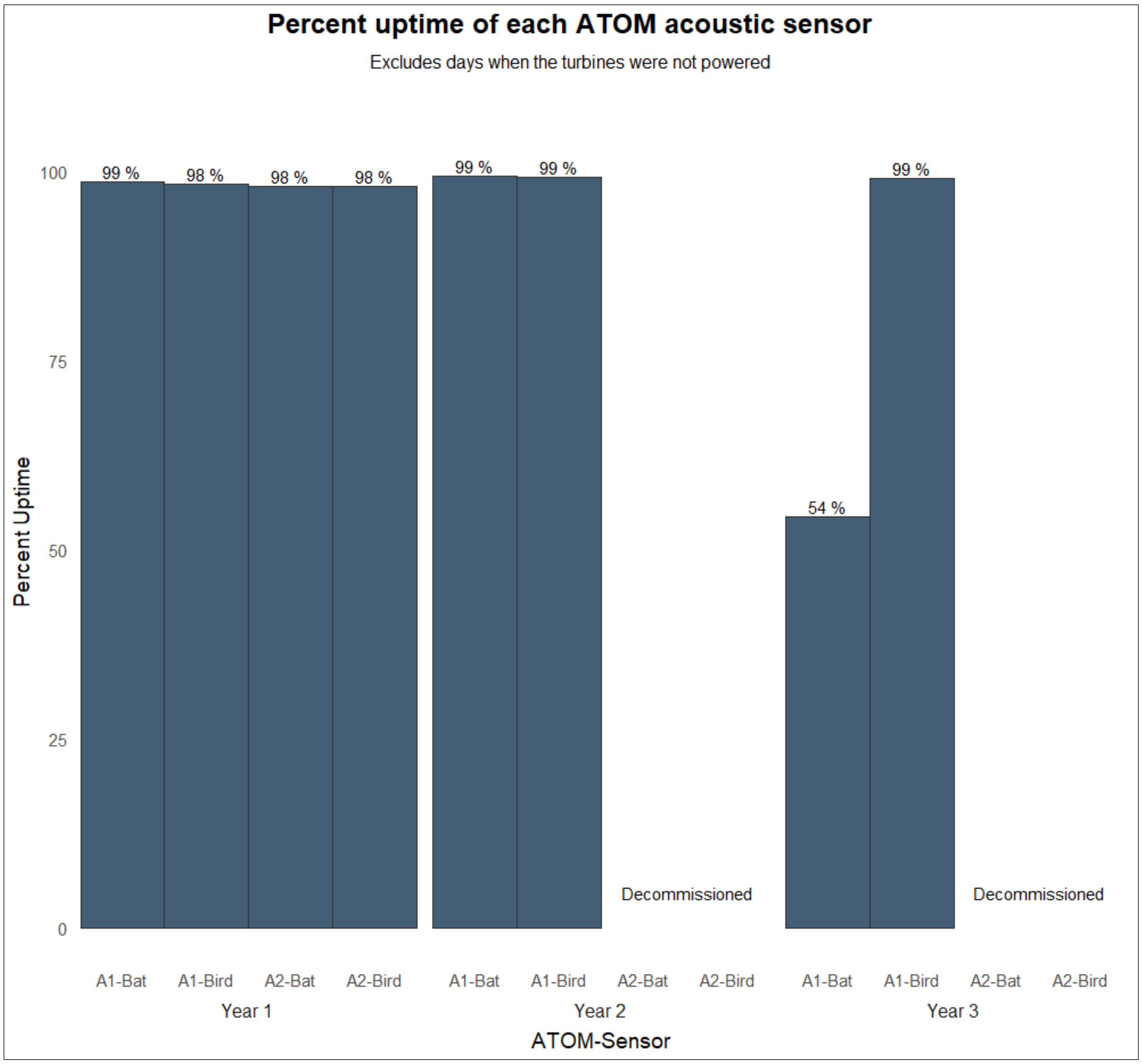


Figure 4. Uptime of the bird and bat acoustic sensors on the two ATOM systems over the 3-year monitoring period.

Downtime due to a power outage on the turbines is not included in the calculations

A1 = ATOM 1, A2 = ATOM 2

During the 3-year study period there were 1,016 acoustic bat detections among 3 species: silver-haired bat, hoary bat, and eastern red bat (Table 4). Silver-haired bats were detected 561 (55%) times, hoary bats 153 (15%) times, and eastern red bats 290 (29%) times. There were also 12 (1%) unidentified low-frequency species recorded. Bat abundance peaked in September when 875 (86%) of all detections occurred. September and October contained 93% of all bat detections (Figure 5). During fall, silver-haired bats generally showed up before hoary bats and eastern red bats. Hoary bats generally occurred later in the season while eastern red bats occurred throughout much of the fall period (Figure 6). Of the 1,016 bat calls, 403 (40%) were detected during the day (sunrise–sunset) and 613 (60%) were recorded at night (sunset–sunrise).

A lightning strike on June 23, 2023, damaged the bat acoustic sensors (Figure 7) and much of the summer and fall season in 2023 was missed. Consequently, we present year 4 bat acoustic data up until ATOM was decommissioned in August 2024 (Figure 5).

Table 4. Acoustic Calls from Birds and Bats Identified During the 3-Year Study

Type	Subtype	Common Name	Year 1	Year 2	Year 3	Total
Bird	Duck	Northern Shoveler	0	0	4	4
Bird	Duck	Black Scoter	0	0	2	2
Bird	Shorebird	Upland Sandpiper	3	0	0	3
Bird	Shorebird	Spotted Sandpiper	1	0	3	4
Bird	Shorebird	Solitary Sandpiper	2	6	0	8
Bird	Gull	Laughing Gull	1	4	15	20
Bird	Gull	Ring-billed Gull	0	0	2	2
Bird	Gull	Herring Gull	5	23	52	80
Bird	Gull	Great Black-backed Gull	0	2	0	2
Bird	Tern	Sandwich Tern	0	0	5	5
Bird	Tern	Royal Tern	1	5	17	23
Bird	Loon	Common Loon	0	1	4	5
Bird	Storm-petrel	Wilson's Storm-Petrel	0	2	0	2
Bird	Pelican	Brown Pelican	0	0	3	3
Bird	Ardeidae	Green Heron	0	1	0	1
Bird	Ardeidae	Great Blue Heron	0	0	1	1
Bird	Passerine	Gray-cheeked Thrush	0	14	0	14
Bird	Passerine	Swainson's Thrush	0	1	0	1
Bird	Passerine	American Robin	2	0	0	2
Bird	Passerine	White-throated Sparrow	0	2	0	2
Bird	Passerine	Savannah Sparrow	0	0	1	1
Bird	Passerine	Ovenbird	0	0	1	1
Bird	Passerine	Northern Waterthrush	1	9	0	10
Bird	Passerine	Black-and-white Warbler	2	0	2	4
Bird	Passerine	American Redstart	1	4	3	8

Type	Subtype	Common Name	Year 1	Year 2	Year 3	Total
Bird	Passerine	Northern Parula	2	1	2	5
Bird	Passerine	Magnolia Warbler	1	0	0	1
Bird	Passerine	Bay-breasted Warbler	2	1	1	4
Bird	Passerine	Chestnut-sided Warbler	0	1	0	1
Bird	Passerine	Blackpoll Warbler	0	1	0	1
Bird	Passerine	Palm Warbler	1	1	0	2
Bird	Passerine	Yellow-rumped Warbler	0	0	2	2
Bird	Passerine	Rose-breasted Grosbeak	12	0	0	12
Bat	Bat	Silver-haired bat	238	320	3	561
Bat	Bat	Hoary bat	86	66	1	153
Bat	Bat	Eastern Red bat	96	191	3	290
Bat	Bat	Unknown low-frequency species	12	0	0	12

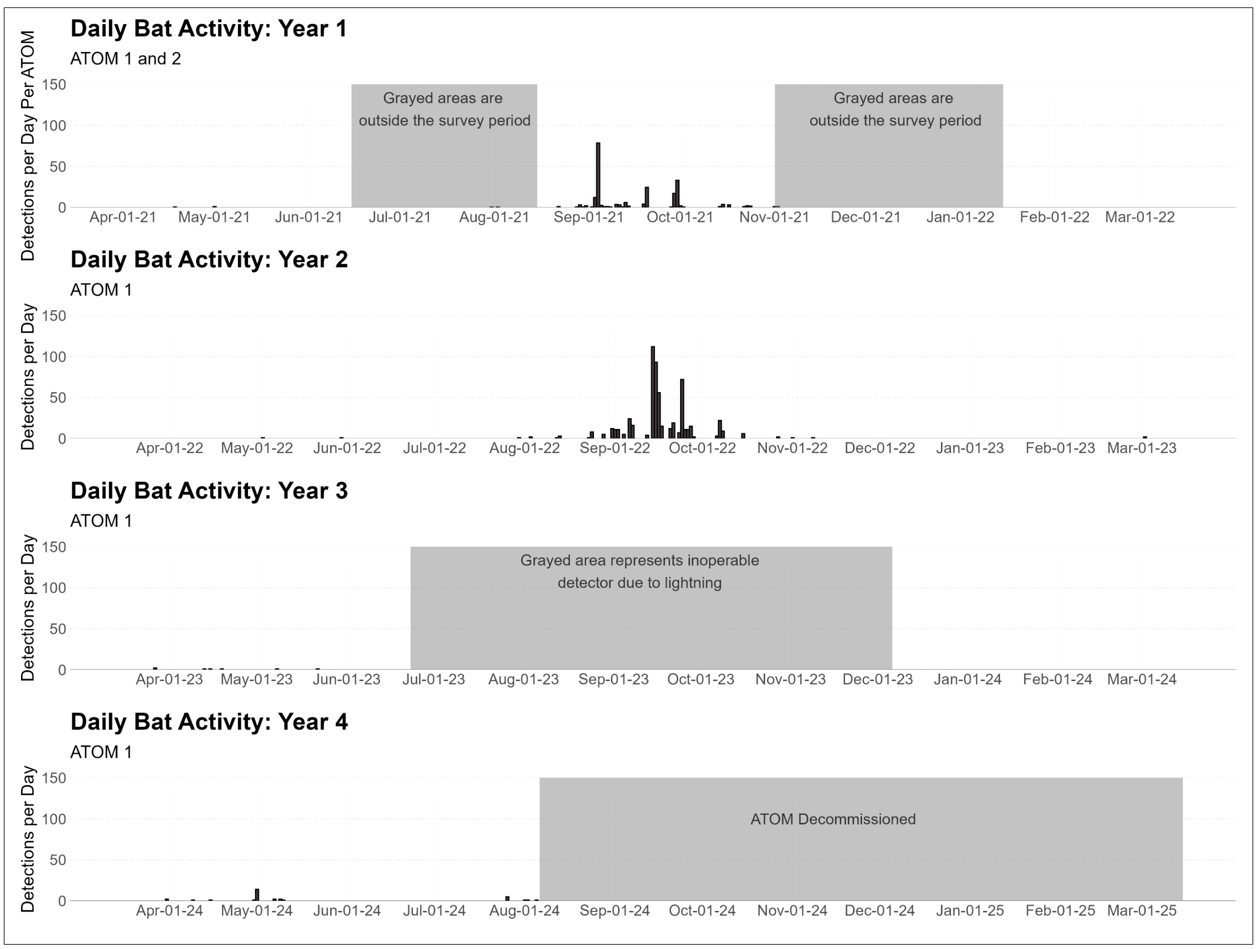


Figure 5. Number of bat calls per day during years 1-4 of the study.

Detections for year 1 are normalized per turbine to be comparable to subsequent years when data was only collected at one turbine. Data from year 4 represents the period outside the official study timeframe, but when equipment was still operating.

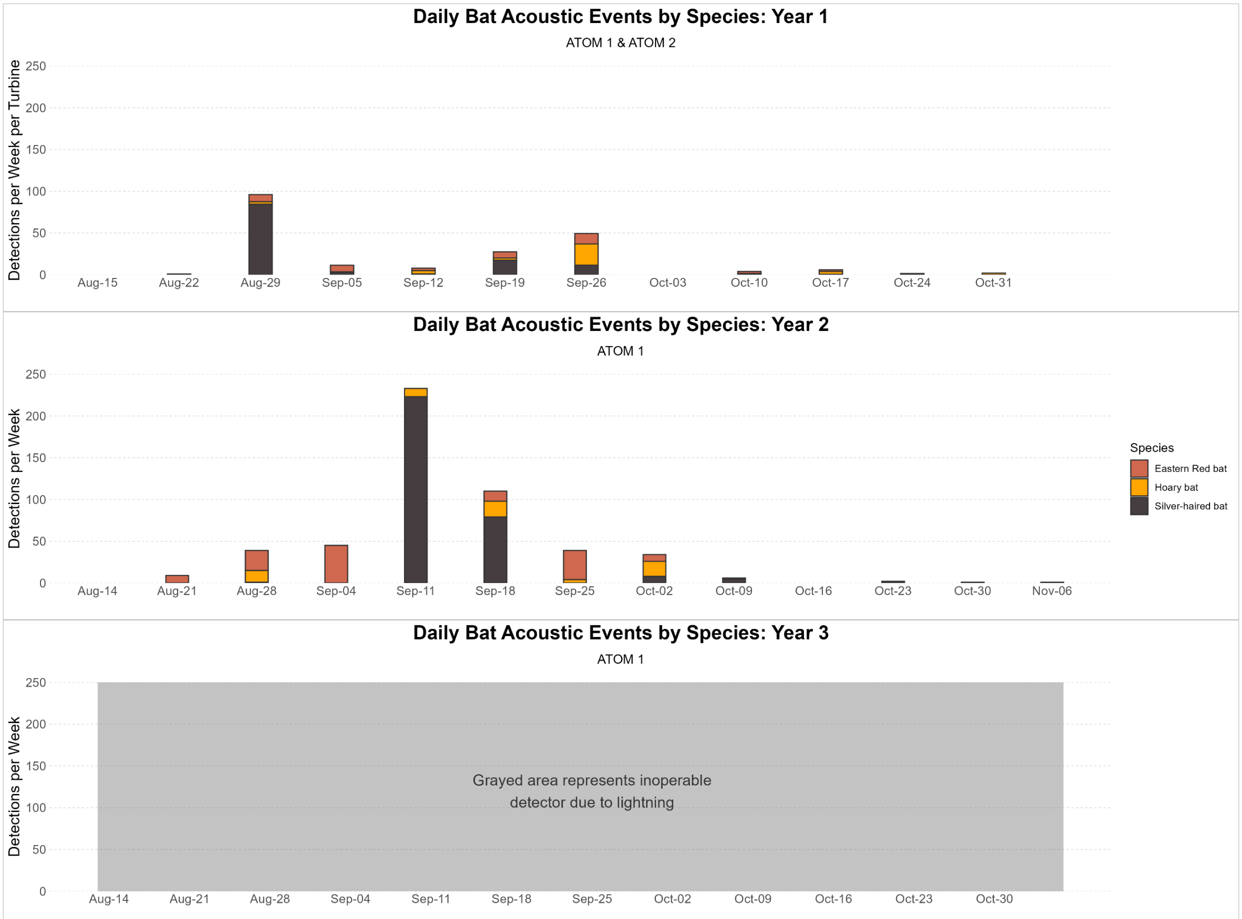


Figure 6. Temporal distribution of bat species occurrence in the fall monitoring period for years 1-3.

Detections for year 1 are normalized per turbine to be comparable to subsequent years when data were only collected at one turbine. Detections from year 3 are unavailable for the fall because of a lightning strike on June 23, 2023, that damaged bat acoustic sensors.

Figure 7. Lightning strike recorded on June 23, 2023, that damaged bat acoustic sensors.

There were 236 bird detections across 9 species groups and 33 species that occurred during acoustic surveys across the 3-year study period. The most frequently detected species was Herring Gull (*Larus argentatus*) with 80 detections followed by Royal Tern (*Thalasseus* *maximus*) with 23 detections (Table 4). On a monthly level, 47% of all bird acoustic detections occurred in August, 11% occurred in September, and 21% occurred in October (Figure 8). Of the 236 bird calls, 201 (85%) were detected during the day (sunrise–sunset) and 35 (15%) were recorded at night (sunset–sunrise).

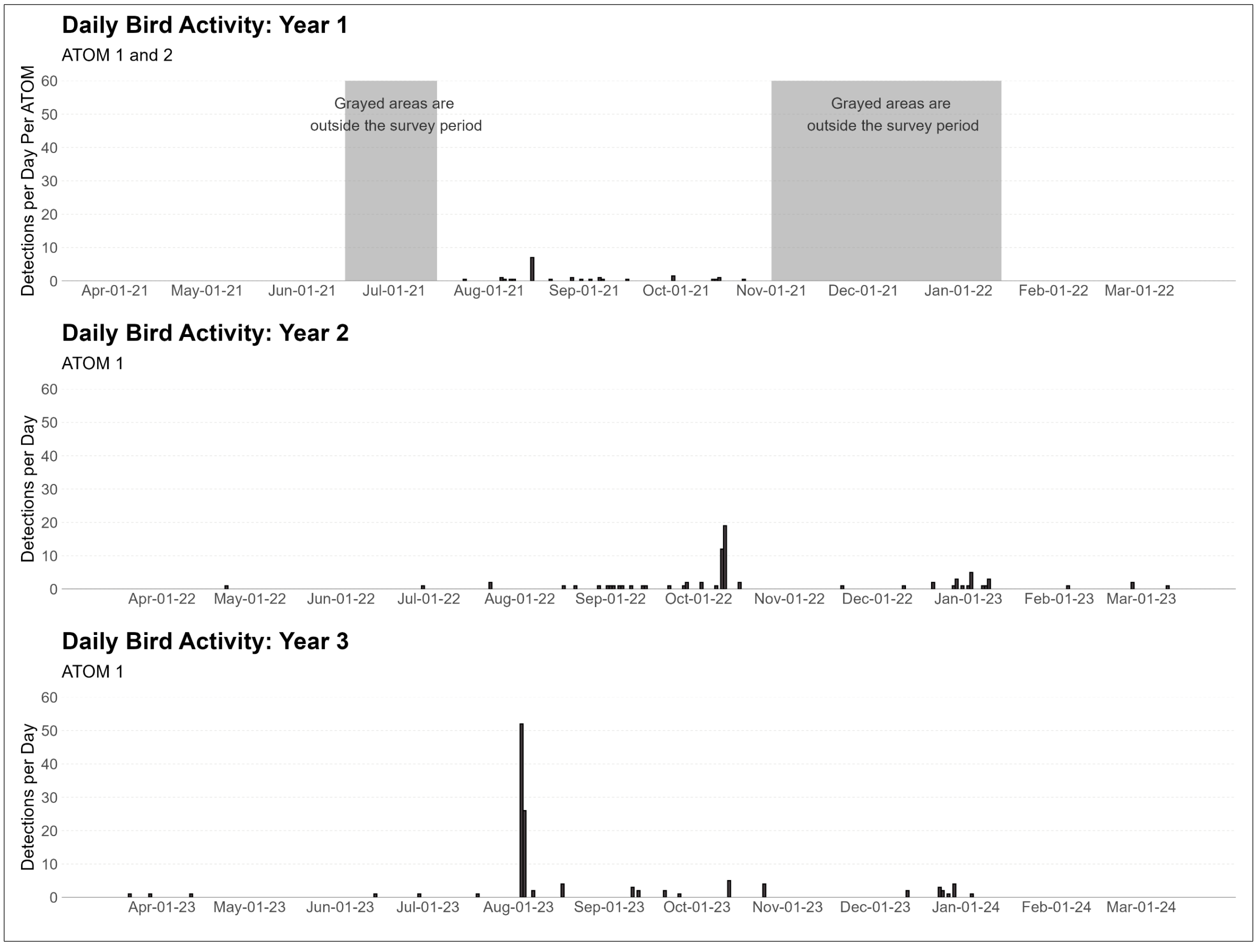


Figure 8. Number of birds calls per day during years 1-3 of the study.

Detections for year 1 are normalized per turbine to be comparable to subsequent years when data were only collected at one turbine.

Motus

Calibration results showed good detection ranges at both Turbine A01 (Figure 9) and Turbine A02 (Figure 10). Signal strength was stronger at longer distances from Turbine A01 compared to A02. This was likely the result of the better distance performance of the 434-MHz Yagi antennas on A01 combined with the better performance and lower noise offshore compared to the 166-MHz band.

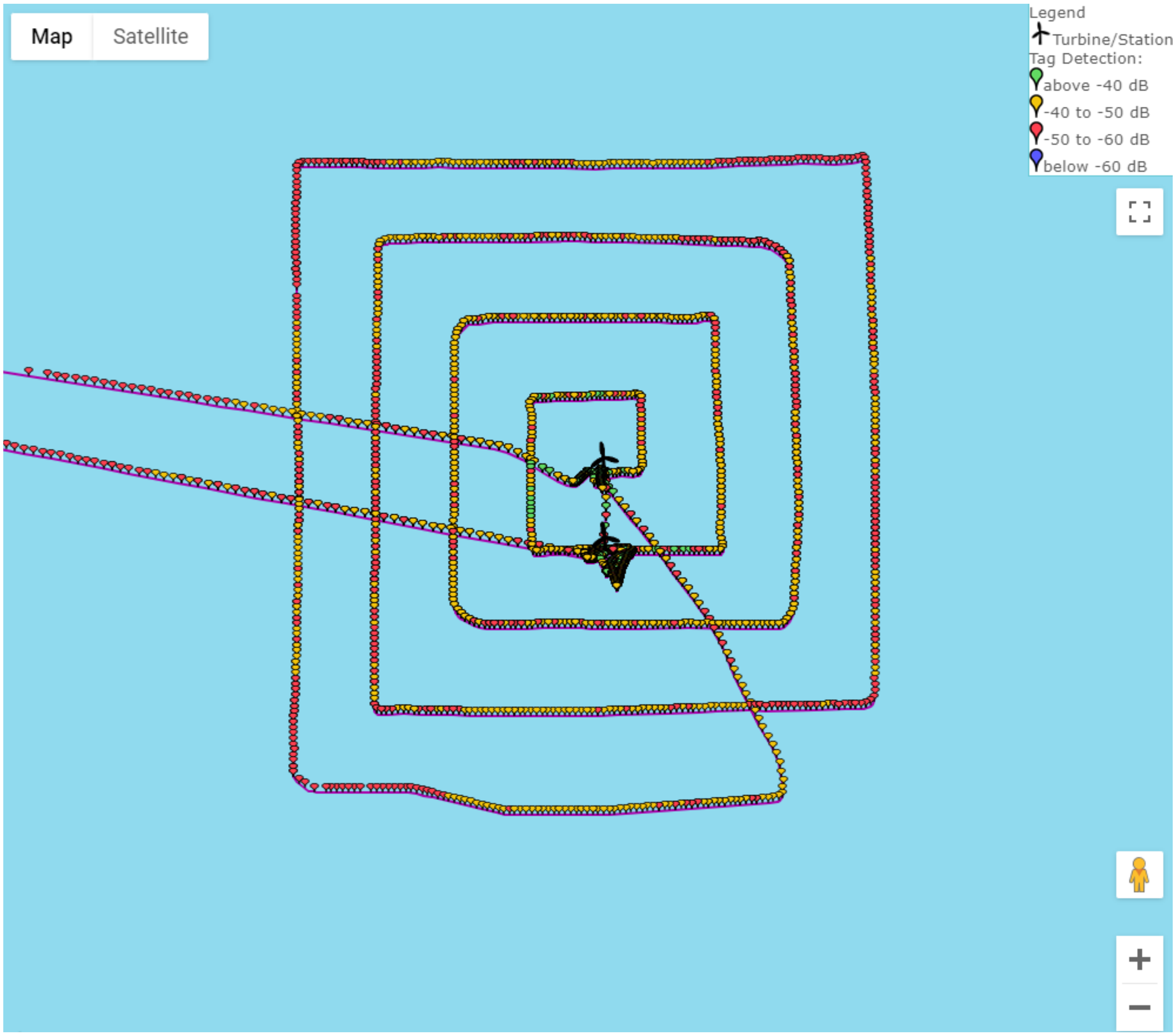


Figure 9. Results of Motus receiver calibration on Turbine A01 conducted in October 2022.

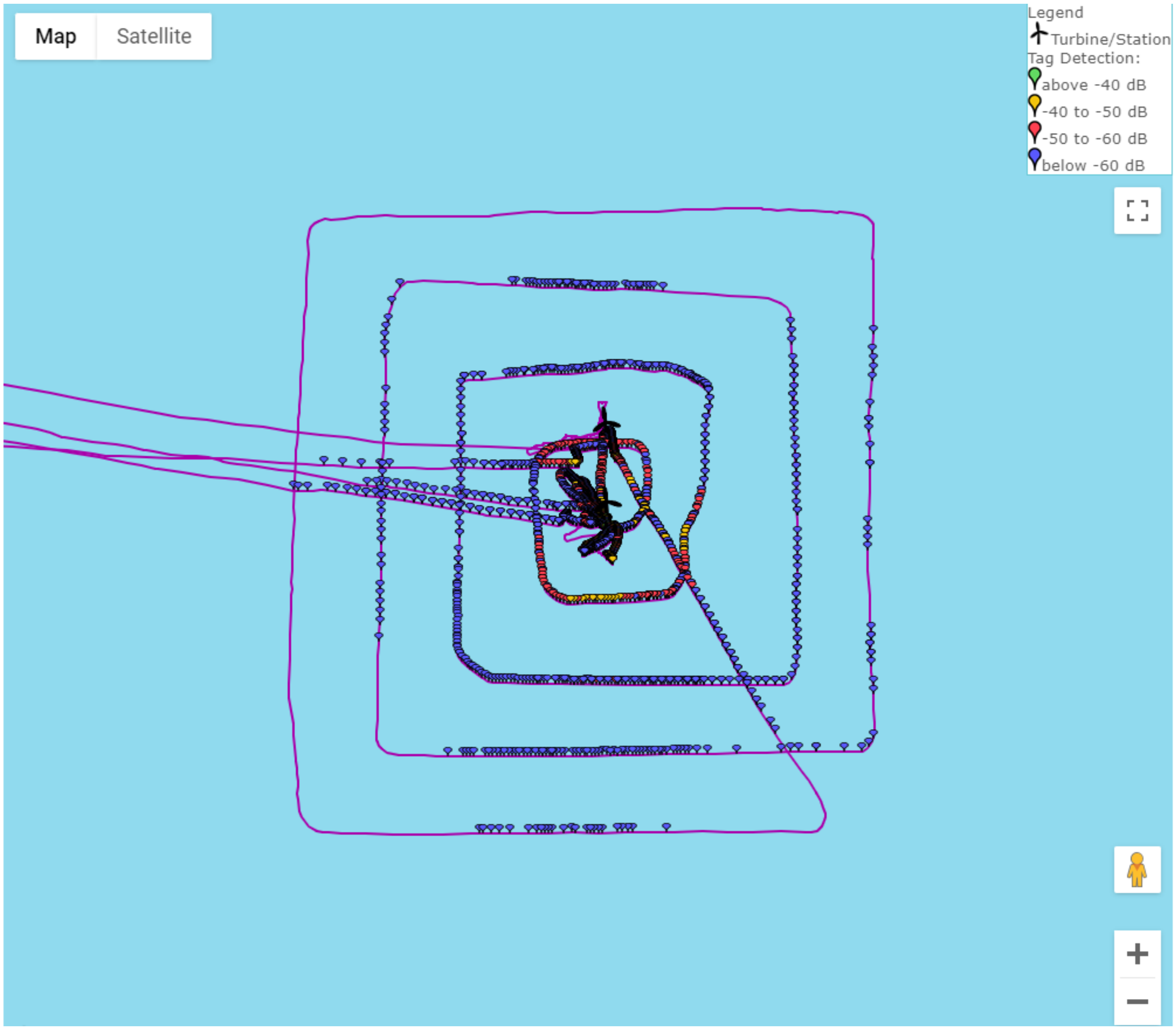


Figure 10. Results of Motus receiver calibration on Turbine A02 conducted in December 2022.

There were 31 bird detections and 1 bat detection recorded by the Motus systems during the 3-year study. Year 1 had 3 detections, year 2 had 9 detections, and year 3 had 20 detections.

Shorebirds were the most frequently recorded species group with 18 observations followed by swallows with 7 observations. Two Red Knots and four Piping Plovers were detected as part of a Dominion Energy tagging study. More information on the Red Knot and Piping Plover detections can be found in Table 8. Other shorebirds recorded include a Semipalmated Plover (*Charadrius semipalmatus*), which was detected on August 8, 2021, in a wind speed from the south of 2.8 m/s. A Semipalmated Sandpiper was detected at both turbines on September 24, 2021, at 18:00 near A01 and at 19:00 at A02 suggesting the bird flew around the area for an hour. During this time the wind was from the northeast with a mean wind speed of 7.3 m/s. A Black-bellied Plover (*Pluvialis squatarola*) was detected May 16, 2022, in a wind speed from the southwest of 8.8 m/s. A Sanderling (*Calidris alba*) was in the vicinity of the turbines on September 18, 2022, in a wind speed from the east-southeast of 2.7 m/s. Two Short-billed

Dowitchers (*Limnodromus griseus*) were reported: one on May 9, 2024, and one on July 19, 2024. We do not have the wind-resource information for this period (Table 5).

Of other species detected by Motus, several individual Purple Martins (*Progne subis*) remained in the vicinity of the turbines for multiple days. One individual was recorded between August 12 and August 15, 2022, encountering winds from the north to northeast between 4.9 and 9.1 m/s. Another Purple Martin remained in the vicinity of the turbines between September 7 and September 9, 2022, in wind speeds between 6.3 and 11.8 m/s from the northeast and northwest. The only other individual Purple Martin was detected only once on August 25, 2022, in a wind speed from the south-southeast of 2.6 m/s (Table 5).

A Common Nighthawk (*Chordeiles minor*) was detected on September 12, 2023, in wind speeds from the west of 4.1 m/s (Table 5).

American Kestrel (*Falco sparverius*) was the only raptor species in the Motus data. Two individuals (one on September 15, 2022, and one on October 3, 2023) were recorded. The 2022 individual was active in a wind speed from the north-northeast of 8.4 m/s and the 2023 individual was active in a wind speed from the north of 7 m/s (Table 5).

Two passerines were detected; both were Bobolink (*Dolichonyx oryzivorus*). One was detected on September 14, 2023, and one was detected on October 2, 2023. The first detection was in a wind speed from the north of 6.8 m/s and the latter in a wind speed from the north-northwest of 4.4 m/s (Table 5).

A single bat was detected by the Motus stations, but all data including species identification, date of detection, and broader locations of other Motus detections of the same individual have been withheld on motus.org (Table 5).

One benefit of Motus tracking is it provides broader context for the species being detected at the turbine locations. While we might surmise the migratory strategy being employed by the species we detect (see Discussion), we see within the Motus tracking data the paths used by these tagged individuals. Maps of the flight paths that are broadly interpreted from Motus receiver locations are provided in Appendix C.

Table 5. Motus Tag Detections (Excluding Red Knots and Piping Plovers) Recorded During the 3-Year CVOW Pilot Project Bird and Bat Postconstruction Monitoring Study.

Common Name	Date/time (Local)	Tag ID	Wind Direction	Wind Speed	Temp	Visibility
Common Nighthawk	09/12/2023 00:10	71189	159	3.5	26.5	10
Common Nighthawk	09/12/2023 00:10	71189	159	3.5	26.5	10
Black-bellied Plover	05/16/2022 00:45	82326	227	8.8	15.6	5
Semipalmated Plover	08/08/2021 22:45	45368	181	2.8	23.8	10
Short-billed Dowitcher	05/09/2024 11:45	883380	Data not available			
Short-billed Dowitcher	05/09/2024 11:30	883380				
Short-billed Dowitcher	7/19/2024	888298				
Short-billed Dowitcher	7/19/2024	888298				
Sanderling	09/18/2022 01:30	61422	111	2.7	23.5	10
Semipalmated Sandpiper	09/24/2021 18:00	55948	35	7.5	20.8	10
Semipalmated Sandpiper	09/24/2021 19:00	55948	22	7.1	21.4	10
American Kestrel	09/15/2022 14:15	67435	20	8.4	22.9	10
American Kestrel	10/03/2023 13:00	76334	13	7	20.8	10
Purple Martin	08/12/2022 14:00	60790	11	9.1	24.3	10
Purple Martin	08/14/2022 07:00	60790	55	4.9	24.6	10
Purple Martin	08/15/2022 07:00	60790	38	6.9	24.5	10
Purple Martin	09/07/2022 13:15	61221	344	6.3	25	10
Purple Martin	09/09/2022 06:30	61221	34	11.8	23.3	10
Purple Martin	08/25/2022 12:50	66283	159	2.6	25.3	10
Purple Martin	09/11/2023 14:50	69626	291	4.2	25.8	10
Bobolink	10/02/2023 03:10	75424	375	2.2	25.4	10
Bobolink	09/14/2023 00:15	75566	5	6.8	25.8	10
Bat species	NA	47349	Data not available			

Sensor Comparison

Across bats and birds and all sensor types, acoustic sensors found 1,252 (37%) detections and video found 2,142 (63%) detections. Motus had 32 detections (<1%) (Table 6). Acoustic sensors detected 75% of all bat detections but only 12% of bird detections. Video sensors found 87% of bird detections but only 25% of bat detections. Most bat species identifications would not have occurred without the acoustic sensors as bat identification by sight alone is difficult.

There were 59 bird and bat species found in video, 36 species found in acoustics, and 10 species found with Motus. There were 39 species found in the video that were not found in other sensors, while acoustic sensors detected 16 species that were not found in other sensors. Motus receivers detected 9 species that were not found in other sensors (Table 7).

Terns, waterfowl, storm-petrels, and herons were only found using the acoustic sensors, suggesting these species groups avoided the area immediately around the turbine and were not in the video viewshed. Other than White-rumped Sandpiper (*Calidris fuscicollis*) and Whimbrel (*Numenius phaeopus*), all shorebird species were found either in the acoustics or Motus data, which also suggests some level of mesoavoidance for this species group.

Table 6. Sensor Comparison Among Acoustic, Motus, Anecdotal Photos, and Video Sensors During the 3-Year Study

Subtype	Common Name	Scientific Name	Acoustic	Video	Motus	Photo	Total
Duck	Northern Shoveler	*Spatula clypeata*	4	0	0	0	4
Duck	Black Scoter	*Melanitta americana*	2	0	0	0	2
Cuckoo	Yellow-billed Cuckoo	*Coccyzus americanus*	0	3	0	0	3
Nightjar	Common Nighthawk	*Chordeiles minor*	0	4	2	0	6
Swift	Chimney Swift	*Chaetura pelagica*	0	2	0	0	2
Shorebird	Black-bellied Plover	*Pluvialis squatarola*	0	0	1	0	1
Shorebird	Semipalmated Plover	*Charadrius semipalmatus*	0	0	1	0	1
Shorebird	Piping Plover	*Charadrius melodus*	0	0	7	0	7
Shorebird	Upland Sandpiper	*Bartramia longicauda*	3	0	0	0	3
Shorebird	Whimbrel	*Numenius phaeopus*	0	1	0	0	1
Shorebird	Short-billed Dowitcher	*Limnodromus griseus*	0	0	4	0	4
Shorebird	Spotted Sandpiper	*Actitis macularius*	4	0	0	0	4
Shorebird	Solitary Sandpiper	*Tringa solitaria*	8	0	0	0	8
Shorebird	Red Knot	*Calidris canutus*	0	0	2	0	2
Shorebird	Sanderling	*Calidris alba*	0	0	1	0	1
Shorebird	White-rumped Sandpiper	*Calidris fuscicollis*	0	1	0	0	1
Shorebird	Semipalmated Sandpiper	*Calidris pusilla*	0	0	2	0	2
Shorebird	Shorebird species		0	15	0	0	15
Skua	Skua species		0	1	0	0	1
Gull	Bonaparte's Gull	*Chroicocephalus philadelphia*	0	1	0	0	1
Gull	Laughing Gull	*Leucophaeus atricilla*	20	28	0	0	48
Gull	Franklin's Gull	*Leucophaeus pipixcan*	0	1	0	0	1
Gull	Ring-billed Gull	*Larus delawarensis*	2	0	0	0	2
Gull	Herring Gull	*Larus argentatus*	80	84	0	0	164
Gull	Great Black-backed Gull	*Larus marinus*	2	27	0	0	29
Gull	Lesser Black-backed Gull	*Larus fuscus*	0	2	0	0	2

Subtype	Common Name	Scientific Name	Acoustic	Video	Motus	Photo	Total
Gull	Large Gull species		0	91	0	0	91
Gull	Small Gull species		0	11	0	0	11
Gull	Gull species		0	43	0	0	43
Tern	Sandwich Tern	*Thalasseus sandvicensis*	5	0	0	0	5
Tern	Royal Tern	*Thalasseus maximus*	23	1	0	1	25
Loon	Common Loon	*Gavia immer*	5	0	0	0	5
Storm-petrel	Wilson's Storm-Petrel	*Oceanites oceanicus*	2	0	0	0	2
Shearwater	Cory's Shearwater	*Calonectris diomedea*	0	2	0	0	2
Gannet	Northern Gannet	*Morus bassanus*	0	1	0	0	1
Anhinga	Anhinga	*Anhinga anhinga*	0	1	0	0	1
Pelican	American White Pelican	*Pelecanus erythrorhynchos*	0	15	0	0	15
Pelican	Brown Pelican	*Pelecanus occidentalis*	3	0	0	0	3
Ardeidae	Green Heron	*Butorides virescens*	1	0	0	0	1
Ardeidae	Great Blue Heron	*Ardea herodias*	1	0	0	0	1
Raptor	Osprey	*Pandion haliaetus*	0	38	0	0	38
Raptor	Mississippi Kite	*Ictinia mississippiensis*	0	2	0	0	2
Woodpecker	Northern Flicker	*Colaptes auratus*	0	1	0	0	1
Raptor	American Kestrel	*Falco sparverius*	0	0	2	0	2
Raptor	Merlin	*Falco columbarius*	0	1	0	0	1
Raptor	Peregrine Falcon	*Falco peregrinus*	0	83	0	1	84
Raptor	Raptor species		0	6	0	0	6
Passerine	Eastern Phoebe	*Sayornis phoebe*	0	2	0	0	2
Passerine	Red-eyed Vireo	*Vireo olivaceus*	0	1	0	0	1
Corvid	Corvid species		0	2	0	0	2
Hirundine	Purple Martin	*Progne subis*	0	0	7	0	7
Hirundine	Cliff Swallow	*Petrochelidon pyrrhonota*	0	1	0	0	1
Hirundine	Hirundine species		0	8	0	0	8

Subtype	Common Name	Scientific Name	Acoustic	Video	Motus	Photo	Total
Passerine	Brown Creeper	*Certhia americana*	0	13	0	0	13
Passerine	Winter Wren	*Troglodytes hiemalis*	0	19	0	0	19
Passerine	Wren species		0	7	0	0	7
Passerine	Gray-cheeked Thrush	*Catharus minimus*	14	1	0	0	15
Passerine	Swainson's Thrush	*Catharus ustulatus*	1	0	0	0	1
Passerine	American Robin	*Turdus migratorius*	2	4	0	0	6
Passerine	American Pipit	*Anthus rubescens*	0	1	0	0	1
Passerine	House Finch	*Haemorhous mexicanus*	0	1	0	0	1
Passerine	Snow Bunting	*Plectrophenax nivalis*	0	4	0	0	4
Passerine	Dark-eyed Junco	*Junco hyemalis*	0	1	0	0	1
Passerine	White-throated Sparrow	*Zonotrichia albicollis*	2	2	0	0	4
Passerine	Savannah Sparrow	*Passerculus sandwichensis*	1	0	0	0	1
Passerine	Bobolink	*Dolichonyx oryzivorus*	0	1	2	0	3
Passerine	Orchard Oriole	*Icterus spurius*	0	18	0	0	18
Passerine	Brown-headed Cowbird	*Molothrus ater*	0	5	0	0	5
Passerine	Common Grackle	*Quiscalus quiscula*	0	1	0	0	1
Passerine	Ovenbird	*Seiurus aurocapilla*	1	0	0	0	1
Passerine	Northern Waterthrush	*Parkesia noveboracensis*	10	0	0	0	10
Passerine	Golden-winged Warbler	*Vermivora chrysoptera*	0	1	0	0	1
Passerine	Blue-winged Warbler	*Vermivora cyanoptera*	0	1	0	0	1
Passerine	Black-and-white Warbler	*Mniotilta varia*	4	16	0	0	20
Passerine	Prothonotary Warbler	*Protonotaria citrea*	0	4	0	0	4
Passerine	Hooded Warbler	*Setophaga citrina*	0	1	0	0	1
Passerine	American Redstart	*Setophaga ruticilla*	8	7	0	0	15
Passerine	Kirtland's Warbler*	*Setophaga kirtlandii*	0	1	0	0	1
Passerine	Cape May Warbler	*Setophaga tigrina*	0	124	0	0	124
Passerine	Northern Parula	*Setophaga americana*	5	1	0	0	6

Subtype	Common Name	Scientific Name	Acoustic	Video	Motus	Photo	Total
Passerine	Magnolia Warbler	*Setophaga magnolia*	1	5	0	0	6
Passerine	Bay-breasted Warbler	*Setophaga castanea*	4	7	0	0	11
Passerine	Blackburnian Warbler	*Setophaga fusca*	0	5	0	0	5
Passerine	Yellow Warbler	*Setophaga petechia*	0	9	0	0	9
Passerine	Chestnut-sided Warbler	*Setophaga pensylvanica*	1	1	0	0	2
Passerine	Blackpoll Warbler	*Setophaga striata*	1	4	0	0	5
Passerine	Palm Warbler	*Setophaga palmarum*	2	20	0	0	22
Passerine	Pine Warbler	*Setophaga pinus*	0	30	0	0	30
Passerine	Yellow-rumped Warbler	*Setophaga coronata*	2	38	0	0	40
Passerine	Setophaga species		0	197	0	0	197
Passerine	Parulidae species		0	6	0	0	6
Passerine	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	12	11	0	0	23
Passerine	Passerine species		0	370	0	0	370
Unid. Avian	Unidentified bird species		0	314	0	0	314
Bat	Silver-haired bat	*Lasionycteris noctivagans*	561	37	0	0	598
Bat	Hoary bat	*Lasiurus cinereus*	153	16	0	0	169
Bat	Eastern Red bat	*Lasiurus borealis*	290	19	0	0	309
Bat	Unknown low-frequency species		12	0	0	0	12
Bat	Bat species		0	266	1	0	267
Bird/Bat	Bird/Bat		0	73	0	0	73

* State-listed as endangered with a probable identification

Table 7. Species Found Uniquely in One Sensor Type Throughout the 3-Year Study

Species Found Only in Video	Species Found Only in Acoustics	Species Found Only in Motus
Yellow-billed Cuckoo	Northern Shoveler	Black-bellied Plover
Common Nighthawk	Black Scoter	Semipalmated Plover
Chimney Swift	Upland Sandpiper	Piping Plover
Whimbrel	Spotted Sandpiper	Red Knot
White-rumped Sandpiper	Solitary Sandpiper	Semipalmated Sandpiper
Bonaparte's Gull	Ring-billed Gull	Sanderling
Franklin's Gull	Sandwich Tern	Short-billed Dowitcher
Lesser Black-backed Gull	Common Loon	American Kestrel
Cory's Shearwater	Wilson's Storm-Petrel	Purple Martin
Northern Gannet	Brown Pelican	
Anhinga	Green Heron	
American White Pelican	Great Blue Heron	
Osprey	Swainson's Thrush	
Mississippi Kite	Savannah Sparrow	
Northern Flicker	Ovenbird	
Merlin	Northern Waterthrush	
Peregrine Falcon		
Eastern Phoebe		
Red-eyed Vireo		
Cliff Swallow		
Brown Creeper		
Winter Wren		
American Pipit		
House Finch		
Snow Bunting		
Dark-eyed Junco		
Bobolink		
Orchard Oriole		
Brown-headed Cowbird		
Common Grackle		
Golden-winged Warbler		
Blue-winged Warbler		
Prothonotary Warbler		
Hooded Warbler		
Kirtland's Warbler*		
Cape May Warbler		
Blackburnian Warbler		
Yellow Warbler		
Pine Warbler		

* State-listed as endangered with a probable identification

Combined Sensors

Across all ATOM sensors and the entire monitoring period, there were 3,428 detections of birds and bats (1,355 bats [40%], 2,000 birds [58%], and 73 bird/bat [2%]) (Table 10). We observed 82% of bird detections during the day and 18% at night. We observed 37% of bats during the day and 63% at night (Table 10). Among all detections, 78% were observed in September or October. For birds, 70% were observed in September or October, while 79% of bats were observed in September alone. No bird or bat collisions were observed during the 3-year study period.

Bat detections include 3 bat species: silver-haired bat, hoary bat, and eastern red bat. There were 267 (20%) bat detections that could not be identified to species including from both video and acoustic detections. The detections that could be identified to species include silver-haired bat (598; 44%), hoary bat (169; 13%), and eastern red bat (309; 23%) (Table 10). No federal or state listed bat species were detected during the study.

Bat activity was most frequent during the nighttime hours though activity was recorded throughout the day, most frequently with acoustics (Figure 11a). Bat activity was the highest in year 2 with the blades spinning (Figure 11b), although malfunctioning detectors in year 3 limited our ability to characterize activity during this time. Overall, 65% of bat activity was observed with the blades spinning and 35% of activity was observed when the blades were stationary. Bat activity was common out to 6–9 m/s wind speed, and bats were active at these moderate wind speeds more in the early daylight hours compared to late at night (Figure 11c). Bat activity was associated with northly winds likely due to favorable migratory conditions (Figure 12). The percentage of foraging behaviors also declined as wind speed increased, especially in wind speeds above 12 m/s (Figure 13). Bat behavior at wind turbines consisted mostly of foraging behaviors including aerial foraging (189 occurrences) and monopole gleaning (58 occurrences). Microavoidance of the turbine blades was also observed 45 times during the 3-year study (Figure 11d). There were three observations of air-displacement when a bat appeared to be pushed off course from the turbine blade by the force of the air movement and started to fall, but the bat recovered and continued flying. The bat revisited the blades before eventually leaving the turbine (Figure 14). Bat air-displacements were: 1 unidentified bat on 9/29/21, 1 unidentified bat on 8/3/22, and 1 silver-haired bat on 10/27/22.

Bird observations included 1,013 (51%) passerine detections, 392 (20%) gull detections, 314 (16%) unidentified birds, 133 (7%) raptor detections, 50 (3%) shorebird detections, and 30 (2%) tern detections (Table 10). All other species groups had <1% detections each. Passerines had the most species with 38, followed by 12 shorebird species, 7 gull species, and 5 raptor species; all other species groups had 2 or fewer species (Table 10). Skuas and corvids were also identified but no individuals from these species groups were identified to species. Skuas, storm-petrels, anhinga, herons, ducks, gannets, loons, pelicans, shearwaters, swifts, and woodpeckers were only observed during the day (Table 10). There were 88% of gulls, 94% of raptors, 97% of terns, and 90% of passerines observed during the day; 66% of shorebirds were observed at night (Table 10). Median flight heights were highest for shorebirds and gulls and lowest for swifts. Median flight speeds were highest for skuas and lowest for shorebirds, swifts, and passerines; the limited sample size for skua (n=1) limits the ability to generalize this finding (Table 11).

Birds were most frequently recorded in the video sensors and were most active between 7:00 and 18:00 local time (Figure **15**a). Across the three years, 57% of birds were observed when the blades were not spinning, and 43% of observations occurred when blades were moving (Figure **15**b). During the peak activity period (7:00–18:00), birds were generally more active at lower wind speeds (<6 m/s) compared to bats; however, during the night, activity was stratified more evenly among wind speeds (Figure **15**c). The percentage of foraging behaviors also declined as wind speed increased, especially in wind speeds above 9 m/s (Figure 16). Bird behavior at wind turbines was dominated by foraging behaviors (aerial foraging, monopole gleaning, hawking, and perching) with 57% of observations involving one of these behaviors (Figure **15**d). Similar to bats, there were 4 bird observations of air-displacement (Figure 17): 1 unidentified passerine on 10/15/2021, 1 unidentified passerine on 10/28/21, 1 Great Black-backed Gull on 2/15/2022, and 1 Eastern Phoebe on 10/23/23.

Federally and State Threatened and Endangered Species

Two federally listed bird species (2 Red Knot individuals [*Calidris canutus rufa*] and 4 Piping Plover individuals [*Charadrius melodus*]) were detected by the Motus receivers in 2023. Both species are also state-listed as threatened. Individual Red Knots were detected at A02 on May 21, 2023, at 07:00 local time in a wind speed from the north of 9.1 m/s and a temperature of 16.8°C and June 11, 2023, at 00:15 local time in a wind speed from the south-southwest of 10.7 m/s and a temperature of 20.4°C.

One Piping Plover individual was detected at A01 on July 21, 2023, at 21:30 local time in a wind speed from the northwest of 3.6 m/s and a temperature of 27.2°C. One individual was detected on July 22, 2023, at both A01 at 23:10 local time and at A02 at 23:00 local time, both events in a wind speed from the east-southeast of 1.6 m/s and a temperature of 26.3°C. A third Piping Plover was recorded at A02 on August 5, 2023, for a period of 15 minutes between 19:45 and 20:00 local time in a northeast wind speed of 2.8 m/s and a temperature of 26.3°C. On July 25, 2024, a fourth Piping Plover was detected at both A01 at 23:10 local time and at A02 at 23:15 local time. Both detections occurred in wind directions from the south-southeast and wind speeds of 2.6 and 2.9 m/s respectively (Table 8). All piping plovers occurred in wind speeds of 3.6 m/s or less. Tracks for these individuals can be found in Appendix C.

State-listed birds detected by ATOM video sensors include 84 observations of Peregrine Falcon (*Falco peregrinus*) (Figure 18). This species is state-listed as threatened by the Virginia Department of Wildlife Resources; all detections of this species were in the fall in 2021 and 2022. This likely represents prolonged foraging at the turbine by no more than 4 or 5 individuals as birds were observed on 19 distinct dates and there were unique plumage characteristics including juvenile plumage and distinct tail-wear and molt observable from the visible-light camera images. Peregrine Falcon detections occurred in wind speeds between 1 m/s and 15.6 m/s with 35% occurring when blades were moving (Table 9). In 29% of observations, the individuals were perching on or near the camera.

Table 8. Wind Resource and Temperature Information Associated with Motus Tag Identifications for Red Knots and Piping Plovers During the 3-Year Bird and Bat Study at the CVOW Pilot Project

Wind speed ranges are provided if wind speed data timestamps occurred more than 1 hour from the bird observation and reflect the wind speed before and after the bird was observed.

Common Name	Date/time (Local)	Tag ID	Wind Direction (decimal degrees)	Wind Speed (m/s)	Wind Speed Range (m/s)	Temperature (°C)
Red Knot	05/21/2023 07:00	63590	4	9.1	5.3–9.1	16.8
Red Knot	06/11/2023 00:15	64686	190	10.7	10.7–8.6	20.4
Piping Plover	07/21/2023 21:30	75074	313	3.6	3.8–3.6	27.2
Piping Plover	07/22/2023 23:00	75080	118	1.6		26.3
Piping Plover	07/22/2023 23:10	75080	118	1.6		26.3
Piping Plover	08/05/2023 19:45	75094	32	2.8		25
Piping Plover	08/05/2023 20:00	75094	32	2.8		25
Piping Plover	07/25/2024 23:10	86469	150	2.6		23
Piping Plover	07/25/2024 23:15	86469	160	2.9		23

Table 9. Wind Resource and Temperature Information Associated with Observations of Peregrine Falcon During the 3-Year Bird and Bat Study at the CVOW Pilot Project

Common Name	Date/time (Local)	Wind Direction (Decimal Degrees)	Wind Speed (m/s)	Temperature (°C)
Peregrine Falcon	9/30/2021 16:19	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:19	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:20	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:20	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:20	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:20	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:20	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:20	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:20	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:21	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:21	312	1.9	21.1
Peregrine Falcon	9/30/2021 16:21	312	1.9	21.1
Peregrine Falcon	10/2/2021 14:14	189	5.3	20.9
Peregrine Falcon	10/6/2021 9:06	72	5.7	22.8
Peregrine Falcon	10/6/2021 9:06	72	5.7	22.8
Peregrine Falcon	10/6/2021 9:06	72	5.7	22.8
Peregrine Falcon	10/6/2021 12:00	91	3.1	23.1
Peregrine Falcon	10/16/2021 12:01	194	10.8	21.8

Common Name	Date/time (Local)	Wind Direction (Decimal Degrees)	Wind Speed (m/s)	Temperature (°C)
Peregrine Falcon	10/16/2021 12:01	194	10.8	21.8
Peregrine Falcon	10/22/2021 8:46	224	11.9	20.1
Peregrine Falcon	10/22/2021 8:55	224	11.9	20.1
Peregrine Falcon	10/22/2021 8:55	224	11.9	20.1
Peregrine Falcon	10/22/2021 11:18	231	9.7	19.6
Peregrine Falcon	10/23/2021 9:29	357	4.9	18.6
Peregrine Falcon	10/23/2021 9:29	357	4.9	18.6
Peregrine Falcon	10/23/2021 9:29	357	4.9	18.6
Peregrine Falcon	10/23/2021 10:19	11	3.5	18.7
Peregrine Falcon	10/23/2021 10:20	11	3.5	18.7
Peregrine Falcon	10/23/2021 10:20	11	3.5	18.7
Peregrine Falcon	10/23/2021 10:46	11	3.5	18.7
Peregrine Falcon	10/23/2021 10:46	11	3.5	18.7
Peregrine Falcon	10/23/2021 10:57	11	3.5	18.7
Peregrine Falcon	10/23/2021 11:35	345	3.5	18.8
Peregrine Falcon	10/23/2021 11:36	345	3.5	18.8
Peregrine Falcon	10/23/2021 12:03	327	4.4	18.8
Peregrine Falcon	10/23/2021 12:25	327	4.4	18.8
Peregrine Falcon	10/23/2021 13:45	320	4.4	18.8
Peregrine Falcon	10/23/2021 15:18	301	5.3	19.3
Peregrine Falcon	10/24/2021 8:54	71	7.3	19.1
Peregrine Falcon	10/24/2021 8:54	71	7.3	19.1
Peregrine Falcon	10/24/2021 8:54	71	7.3	19.1
Peregrine Falcon	10/24/2021 8:58	71	7.3	19.1
Peregrine Falcon	10/24/2021 10:07	88	8	19
Peregrine Falcon	10/25/2021 10:25	173	8.8	22
Peregrine Falcon	10/25/2021 10:54	173	8.8	22
Peregrine Falcon	10/25/2021 10:55	173	8.8	22
Peregrine Falcon	10/25/2021 12:22	170	9.3	22.2
Peregrine Falcon	10/26/2021 13:51	295	15.6	18.4
Peregrine Falcon	10/30/2021 15:04	214	9.6	18.5
Peregrine Falcon	10/30/2021 15:07	214	9.6	18.5
Peregrine Falcon	10/30/2021 15:10	214	9.6	18.5
Peregrine Falcon	10/30/2021 15:18	214	9.6	18.5
Peregrine Falcon	10/30/2021 15:22	214	9.6	18.5
Peregrine Falcon	10/31/2021 6:55	252	10.9	15.7
Peregrine Falcon	8/27/2022 13:53	274	2	24.8

Common Name	Date/time (Local)	Wind Direction (Decimal Degrees)	Wind Speed (m/s)	Temperature (°C)
Peregrine Falcon	8/27/2022 13:53	274	2	24.8
Peregrine Falcon	10/2/2022 12:32	263	5.5	20.1
Peregrine Falcon	10/2/2022 12:34	263	5.5	20.1
Peregrine Falcon	10/2/2022 12:37	263	5.5	20.1
Peregrine Falcon	10/2/2022 12:37	263	5.5	20.1
Peregrine Falcon	10/2/2022 12:49	263	5.5	20.1
Peregrine Falcon	10/2/2022 13:06	263	5.5	20.1
Peregrine Falcon	10/2/2022 13:16	263	5.5	20.1
Peregrine Falcon	10/2/2022 14:19	295	7.5	20.2
Peregrine Falcon	10/2/2022 14:24	295	7.5	20.2
Peregrine Falcon	10/2/2022 14:25	295	7.5	20.2
Peregrine Falcon	10/2/2022 14:27	295	7.5	20.2
Peregrine Falcon	10/2/2022 14:30	295	7.5	20.2
Peregrine Falcon	10/2/2022 14:31	295	7.5	20.2
Peregrine Falcon	10/2/2022 15:31	295	7.5	20.2
Peregrine Falcon	10/7/2022 12:47	267	5.3	18.4
Peregrine Falcon	10/7/2022 19:04	161	3.3	20
Peregrine Falcon	10/10/2022 13:06	300	1	17.2
Peregrine Falcon	10/10/2022 13:06	300	1	17.2
Peregrine Falcon	10/11/2022 8:01	13	3.5	17.9
Peregrine Falcon	10/11/2022 8:02	13	3.5	17.9
Peregrine Falcon	10/21/2022 12:26	350	3.9	16.1
Peregrine Falcon	11/22/2022 10:38	351	5.4	11.9
Peregrine Falcon	11/22/2022 10:38	351	5.4	11.9
Peregrine Falcon	11/22/2022 10:39	351	5.4	11.9
Peregrine Falcon	11/22/2022 10:39	351	5.4	11.9
Peregrine Falcon	11/22/2022 10:40	351	5.4	11.9
Peregrine Falcon	11/22/2022 10:43	351	5.4	11.9
Peregrine Falcon	11/22/2022 10:43	351	5.4	11.9

The Kirtland’s Warbler (*Setophaga kirtlandii*) is listed as state endangered in Virginia. This species is highly range restricted and breeds in jack pines in Michigan and winters in the Bahamas. This species was observed flying over the camera and below the RSZ on October 1, 2021, at 13:27 local time in a wind speed of 7.3 m/s. The identification was given a confidence level of “probable” as the lack of a sharp image precluded us from giving the confidence level of “definite.” (Figure 19). The following field marks led to this identification:

- Light speckling along flanks and creating a light necklace
- Clean yellow throat and center of belly
- Whitish undertail coverts
- White edging to outer tail feathers fitting Kirtland's Warbler

Table 10. Bird and Bat Species Recorded During the 3-Year Postconstruction Bird and Bat Study at the CVOW Pilot Project

Subtype	Common Name	Scientific Name	Year 1		Year 2		Year 3		Total
			Day	Night	Day	Night	Day	Night	
Duck	Northern Shoveler	*Spatula clypeata*	0	0	0	0	4	0	4
Duck	Black Scoter	*Melanitta americana*	0	0	0	0	2	0	2
Cuckoo	Yellow-billed Cuckoo	*Coccyzus americanus*	0	0	0	0	3	0	3
Nightjar	Common Nighthawk	*Chordeiles minor*	0	0	0	0	2	4	6
Swift	Chimney Swift	*Chaetura pelagica*	0	0	2	0	0	0	2
Shorebird	Black-bellied Plover	*Pluvialis squatarola*	0	0	0	1	0	0	1
Shorebird	Semipalmated Plover	*Charadrius semipalmatus*	0	1	0	0	0	0	1
Shorebird	Piping Plover	*Charadrius melodus*	0	0	0	0	2	5	7
Shorebird	Upland Sandpiper	*Bartramia longicauda*	1	2	0	0	0	0	3
Shorebird	Whimbrel	*Numenius phaeopus*	0	0	1	0	0	0	1
Shorebird	Short-billed Dowitcher	*Limnodromus griseus*	0	0	0	0	2	2	4
Shorebird	Spotted Sandpiper	*Actitis macularius*	0	1	0	0	3	0	4
Shorebird	Solitary Sandpiper	*Tringa solitaria*	1	1	5	1	0	0	8
Shorebird	Red Knot	*Calidris canutus*	0	0	0	0	1	1	2
Shorebird	Sanderling	*Calidris alba*	0	0	0	1	0	0	1
Shorebird	White-rumped Sandpiper	*Calidris fuscicollis*	0	0	0	0	1	0	1
Shorebird	Semipalmated Sandpiper	*Calidris pusilla*	1	1	0	0	0	0	2
Shorebird	Shorebird species		3	0	2	0	0	10	15
Skua	Skua species		1	0	0	0	0	0	1
Gull	Bonaparte's Gull	*Chroicocephalus philadelphia*	0	0	1	0	0	0	1
Gull	Laughing Gull	*Leucophaeus atricilla*	10	1	15	0	21	1	48
Gull	Franklin's Gull	*Leucophaeus pipixcan*	0	0	0	0	1	0	1
Gull	Ring-billed Gull	*Larus delawarensis*	0	0	0	0	2	0	2
Gull	Herring Gull	*Larus argentatus*	12	1	80	11	58	2	164
Gull	Great Black-backed Gull	*Larus marinus*	3	0	10	0	15	1	29

Subtype	Common Name	Scientific Name	Year 1		Year 2		Year 3		Total
			Day	Night	Day	Night	Day	Night	
Gull	Lesser Black-backed Gull	*Larus fuscus*	0	0	1	0	1	0	2
Gull	Large Gull species		25	2	27	5	21	11	91
Gull	Small Gull species		2	2	7	0	0	0	11
Gull	Gull species		9	1	9	4	15	5	43
Tern	Sandwich Tern	*Thalasseus sandvicensis*	0	0	0	0	5	0	5
Tern	Royal Tern	*Thalasseus maximus*	1	1	5	0	18	0	25
Loon	Common Loon	*Gavia immer*	0	0	1	0	4	0	5
Storm-petrel	Wilson's Storm-Petrel	*Oceanites oceanicus*	0	0	2	0	0	0	2
Shearwater	Cory's Shearwater	*Calonectris diomedea*	0	0	2	0	0	0	2
Gannet	Northern Gannet	*Morus bassanus*	0	0	0	0	1	0	1
Anhinga	Anhinga	*Anhinga anhinga*	0	0	0	0	1	0	1
Pelican	American White Pelican	*Pelecanus erythrorhynchos*	0	0	0	0	15	0	15
Pelican	Brown Pelican	*Pelecanus occidentalis*	0	0	0	0	3	0	3
Ardeidae	Green Heron	*Butorides virescens*	0	0	1	0	0	0	1
Ardeidae	Great Blue Heron	*Ardea herodias*	0	0	0	0	1	0	1
Raptor	Osprey	*Pandion haliaetus*	8	0	1	0	26	3	38
Raptor	Mississippi Kite	*Ictinia mississippiensis*	0	0	1	0	1	0	2
Woodpecker	Northern Flicker	*Colaptes auratus*	1	0	0	0	0	0	1
Raptor	American Kestrel	*Falco sparverius*	0	0	1	0	1	0	2
Raptor	Merlin	*Falco columbarius*	1	0	0	0	0	0	1
Raptor	Peregrine Falcon	*Falco peregrinus*	53	1	29	1	0	0	84
Raptor	Raptor species		3	0	2	1	0	0	6
Passerine	Eastern Phoebe	*Sayornis phoebe*	0	0	0	0	2	0	2
Passerine	Red-eyed Vireo	*Vireo olivaceus*	0	0	0	0	1	0	1
Corvid	Corvid species		1	1	0	0	0	0	2
Hirundine	Purple Martin	*Progne subis*	0	0	5	1	1	0	7

Subtype	Common Name	Scientific Name	Year 1		Year 2		Year 3		Total
			Day	Night	Day	Night	Day	Night	
Hirundine	Cliff Swallow	*Petrochelidon pyrrhonota*	0	0	0	0	1	0	1
Hirundine	Hirundine species		3	0	5	0	0	0	8
Passerine	Brown Creeper	*Certhia americana*	10	0	0	0	3	0	13
Passerine	Winter Wren	*Troglodytes hiemalis*	17	0	0	1	1	0	19
Passerine	Wren species		1	0	5	1	0	0	7
Passerine	Gray-cheeked Thrush	*Catharus minimus*	0	0	15	0	0	0	15
Passerine	Swainson's Thrush	*Catharus ustulatus*	0	0	1	0	0	0	1
Passerine	American Robin	*Turdus migratorius*	4	0	0	0	2	0	6
Passerine	American Pipit	*Anthus rubescens*	1	0	0	0	0	0	1
Passerine	House Finch	*Haemorhous mexicanus*	0	0	1	0	0	0	1
Passerine	Snow Bunting	*Plectrophenax nivalis*	0	0	4	0	0	0	4
Passerine	Dark-eyed Junco	*Junco hyemalis*	0	0	0	0	1	0	1
Passerine	White-throated Sparrow	*Zonotrichia albicollis*	0	0	3	1	0	0	4
Passerine	Savannah Sparrow	*Passerculus sandwichensis*	0	0	0	0	0	1	1
Passerine	Bobolink	*Dolichonyx oryzivorus*	0	0	0	0	1	2	3
Passerine	Orchard Oriole	*Icterus spurius*	0	0	18	0	0	0	18
Passerine	Brown-headed Cowbird	*Molothrus ater*	0	0	5	0	0	0	5
Passerine	Common Grackle	*Quiscalus quiscula*	0	0	0	0	1	0	1
Passerine	Ovenbird	*Seiurus aurocapilla*	0	0	0	0	0	1	1
Passerine	Northern Waterthrush	*Parkesia noveboracensis*	1	0	5	4	0	0	10
Passerine	Golden-winged Warbler	*Vermivora chrysoptera*	0	0	0	0	1	0	1
Passerine	Blue-winged Warbler	*Vermivora cyanoptera*	1	0	0	0	0	0	1
Passerine	Black-and-white Warbler	*Mniotilta varia*	13	2	0	0	5	0	20
Passerine	Prothonotary Warbler	*Protonotaria citrea*	0	0	4	0	0	0	4
Passerine	Hooded Warbler	*Setophaga citrina*	0	0	1	0	0	0	1
Passerine	American Redstart	*Setophaga ruticilla*	3	1	4	3	1	3	15

Subtype	Common Name	Scientific Name	Year 1		Year 2		Year 3		Total
			Day	Night	Day	Night	Day	Night	
Passerine	Kirtland's Warbler*	*Setophaga kirtlandii*	1	0	0	0	0	0	1
Passerine	Cape May Warbler	*Setophaga tigrina*	117	2	3	0	2	0	124
Passerine	Northern Parula	*Setophaga americana*	2	1	1	0	1	1	6
Passerine	Magnolia Warbler	*Setophaga magnolia*	4	1	1	0	0	0	6
Passerine	Bay-breasted Warbler	*Setophaga castanea*	7	2	0	1	0	1	11
Passerine	Blackburnian Warbler	*Setophaga fusca*	5	0	0	0	0	0	5
Passerine	Yellow Warbler	*Setophaga petechia*	0	0	0	0	9	0	9
Passerine	Chestnut-sided Warbler	*Setophaga pensylvanica*	0	0	1	0	1	0	2
Passerine	Blackpoll Warbler	*Setophaga striata*	0	0	5	0	0	0	5
Passerine	Palm Warbler	*Setophaga palmarum*	14	0	5	1	2	0	22
Passerine	Pine Warbler	*Setophaga pinus*	27	0	1	0	2	0	30
Passerine	Yellow-rumped Warbler	*Setophaga coronata*	16	0	15	0	9	0	40
Passerine	Setophaga species		180	4	9	1	1	2	197
Passerine	Parulidae species		6	0	0	0	0	0	6
Passerine	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	22	1	0	0	0	0	23
Passerine	Passerine species		261	24	31	26	12	16	370
Unid. Avian	Unidentified bird species		122	39	24	82	20	27	314
Bat	Silver-haired bat	*Lasionycteris noctivagans*	111	128	211	141	4	3	598
Bat	Hoary bat	*Lasiurus cinereus*	9	79	13	64	3	1	169
Bat	Eastern red bat	*Lasiurus borealis*	49	51	60	145	1	3	309
Bat	Unknown low frequency species		5	7	0	0	0	0	12
Bat	Bat species		15	89	15	99	4	45	267
Bird/Bat	Bird/Bat		5	44	0	9	0	15	73

* State-listed as endangered with a probable identification

Table 11. Summary of Flight Heights and Velocities

Subtype	Common Name	Total Indiv.	Height (m above water surface)					Velocity (m/s)				
			# Null	# w/Data	Median	Min	Max	# Null	# w/Data	Median	Min	Max
Cuckoo	Yellow-billed Cuckoo	3.0	3.0	0.0				3.0	0.0			
Nightjar	Common Nighthawk	4.0	4.0	0.0				4.0	0.0			
Swift	Chimney Swift	2.0	1.0	1.0	6.0	6.0	6.0	1.0	1.0	0.7	0.7	0.7
Shorebird	Whimbrel	1.0	1.0	0.0				1.0	0.0			
Shorebird	White-rumped Sandpiper	1.0	1.0	0.0				1.0	0.0			
Shorebird	Shorebird species	15.0	4.0	11.0	110.0	11.1	208.9	14.0	1.0	5.0	5.0	5.0
Skua	Skua species	1.0	0.0	1.0	83.9	83.9	83.9	0.0	1.0	32.1	32.1	32.1
Gull	Bonaparte's Gull	1.0	1.0	0.0				1.0	0.0			
Gull	Laughing Gull	28.0	14.0	14.0	69.3	4.6	292.9	14.0	14.0	6.6	0.9	41.7
Gull	Franklin's Gull	1.0	1.0	0.0				1.0	0.0			
Gull	Herring Gull	84.0	70.0	14.0	84.4	6.1	351.6	70.0	14.0	10.1	2.3	61.2
Gull	Great Black-backed Gull	27.0	15.0	12.0	139.9	2.8	297.5	15.0	12.0	6.1	0.1	58.3
Gull	Lesser Black-backed Gull	2.0	1.0	1.0	79.5	79.5	79.5	1.0	1.0	6.9	6.9	6.9
Gull	Large Gull species	91.0	62.0	29.0	158.0	2.2	457.4	63.0	28.0	9.1	3.1	71.7
Gull	Small Gull species	11.0	11.0	0.0				11.0	0.0			
Gull	Gull species	43.0	26.0	17.0	134.1	1.9	310.2	26.0	17.0	11.3	0.1	44.5
Tern	Royal Tern	1.0	1.0	0.0				1.0	0.0			
Shearwater	Cory's Shearwater	2.0	1.0	1.0	50.7	50.7	50.7	1.0	1.0	7.3	7.3	7.3
Gannet	Northern Gannet	1.0	0.0	1.0	98.0	98.0	98.0	0.0	1.0	8.6	8.6	8.6
Anhinga	Anhinga	1.0	1.0	0.0				1.0	0.0			
Pelican	American White Pelican	15.0	15.0	0.0				15.0	0.0			
Raptor	Osprey	38.0	38.0	0.0				38.0	0.0			
Raptor	Mississippi Kite	2.0	1.0	1.0	23.1	23.1	23.1	1.0	1.0	3.9	3.9	3.9
Woodpecker	Northern Flicker	1.0	1.0	0.0				1.0	0.0			
Raptor	Merlin	1.0	1.0	0.0				1.0	0.0			

Subtype	Common Name	Total Indiv.	Height (m above water surface)					Velocity (m/s)				
			# Null	# w/Data	Median	Min	Max	# Null	# w/Data	Median	Min	Max
Raptor	Peregrine Falcon	83.0	67.0	16.0	50.4	9.0	90.2	67.0	16.0	17.6	4.0	35.8
Raptor	Raptor species	6.0	6.0	0.0				6.0	0.0			
Passerine	Eastern Phoebe	2.0	1.0	1.0	50.2	50.2	50.2	1.0	1.0	9.6	9.6	9.6
Passerine	Red-eyed Vireo	1.0	0.0	1.0	6.7	6.7	6.7	0.0	1.0	1.6	1.6	1.6
Corvid	Corvid species	2.0	1.0	1.0	35.9	35.9	35.9	1.0	1.0	12.2	12.2	12.2
Hirundine	Cliff Swallow	1.0	1.0	0.0				1.0	0.0			
Hirundine	Hirundine species	8.0	6.0	2.0	22.8	21.4	24.1	6.0	2.0	6.7	6.3	7.1
Passerine	Brown Creeper	13.0	7.0	6.0	9.3	4.0	54.8	7.0	6.0	7.8	2.5	35.1
Passerine	Winter Wren	19.0	16.0	3.0	3.2	3.1	4.6	16.0	3.0	3.5	3.0	5.6
Passerine	Wren species	7.0	3.0	4.0	18.4	7.0	27.6	3.0	4.0	5.3	4.7	9.1
Passerine	Gray-cheeked Thrush	1.0	0.0	1.0	53.9	53.9	53.9	0.0	1.0	11.6	11.6	11.6
Passerine	American Robin	4.0	3.0	1.0	93.5	93.5	93.5	3.0	1.0	11.2	11.2	11.2
Passerine	American Pipit	1.0	1.0	0.0				1.0	0.0			
Passerine	House Finch	1.0	1.0	0.0				1.0	0.0			
Passerine	Snow Bunting	4.0	2.0	2.0	30.7	26.6	34.8	2.0	2.0	9.2	5.3	13.0
Passerine	Dark-eyed Junco	1.0	1.0	0.0				1.0	0.0			
Passerine	White-throated Sparrow	2.0	1.0	1.0	16.1	16.1	16.1	1.0	1.0	6.1	6.1	6.1
Passerine	Bobolink	1.0	0.0	1.0	6.7	6.7	6.7	0.0	1.0	1.6	1.6	1.6
Passerine	Orchard Oriole	18.0	18.0	0.0				18.0	0.0			
Passerine	Brown-headed Cowbird	5.0	5.0	0.0				5.0	0.0			
Passerine	Common Grackle	1.0	1.0	0.0				1.0	0.0			
Passerine	Golden-winged Warbler	1.0	0.0	1.0	7.2	7.2	7.2	0.0	1.0	0.6	0.6	0.6
Passerine	Blue-winged Warbler	1.0	1.0	0.0				1.0	0.0			
Passerine	Black-and-white Warbler	16.0	11.0	5.0	11.2	2.9	20.5	11.0	5.0	4.1	2.3	6.7
Passerine	Prothonotary Warbler	4.0	3.0	1.0	9.1	9.1	9.1	3.0	1.0	5.6	5.6	5.6
Passerine	Hooded Warbler	1.0	1.0	0.0				1.0	0.0			

Subtype	Common Name	Total Indiv.	Height (m above water surface)					Velocity (m/s)				
			# Null	# w/Data	Median	Min	Max	# Null	# w/Data	Median	Min	Max
Passerine	American Redstart	7.0	4.0	3.0	16.4	15.5	25.2	4.0	3.0	11.5	4.3	30.0
Passerine	Kirtland's Warbler*	1.0	1.0	0.0				1.0	0.0			
Passerine	Cape May Warbler	124.0	109.0	15.0	6.9	2.7	11.7	109.0	15.0	5.0	0.4	8.2
Passerine	Northern Parula	1.0	1.0	0.0				1.0	0.0			
Passerine	Magnolia Warbler	5.0	5.0	0.0				5.0	0.0			
Passerine	Bay-breasted Warbler	7.0	2.0	5.0	7.1	4.2	13.7	2.0	5.0	4.8	3.3	11.4
Passerine	Blackburnian Warbler	5.0	3.0	2.0	5.1	2.7	7.5	3.0	2.0	7.0	6.4	7.6
Passerine	Yellow Warbler	9.0	8.0	1.0	24.6	24.6	24.6	8.0	1.0	6.0	6.0	6.0
Passerine	Chestnut-sided Warbler	1.0	1.0	0.0				1.0	0.0			
Passerine	Blackpoll Warbler	4.0	2.0	2.0	5.5	5.4	5.6	2.0	2.0	1.2	0.4	2.1
Passerine	Palm Warbler	20.0	14.0	6.0	5.0	3.4	8.4	14.0	6.0	2.9	0.6	6.9
Passerine	Pine Warbler	30.0	28.0	2.0	3.3	3.0	3.6	28.0	2.0	3.6	3.0	4.2
Passerine	Yellow-rumped Warbler	38.0	34.0	4.0	12.3	4.8	17.9	34.0	4.0	5.0	2.9	6.7
Passerine	Setophaga species	197.0	178.0	19.0	18.7	3.5	31.3	178.0	19.0	6.5	2.7	13.3
Passerine	Parulidae species	6.0	3.0	3.0	9.4	7.4	22.9	3.0	3.0	6.1	5.0	6.6
Passerine	Rose-breasted Grosbeak	11.0	6.0	5.0	8.4	2.8	24.3	6.0	5.0	5.4	3.4	8.3
Passerine	Passerine species	370.0	328.0	42.0	13.4	0.0	86.0	328.0	42.0	7.0	0.1	49.1
Unid. Avian	Unidentified bird species	314.0	235.0	79.0	31.1	1.5	461.9	235.0	79.0	7.7	1.0	53.2
Bat	Silver-haired bat	37.0	25.0	12.0	25.3	4.4	116.0	25.0	12.0	3.8	2.6	21.7
Bat	Hoary bat	16.0	12.0	4.0	23.8	10.3	32.2	12.0	4.0	5.4	3.4	6.0
Bat	Eastern Red bat	19.0	13.0	6.0	20.5	8.6	57.7	13.0	6.0	7.4	4.8	14.8
Bat	Bat species	266.0	188.0	78.0	39.7	5.2	166.0	188.0	78.0	6.3	0.6	50.0
Bird/Bat	Bird/Bat	73.0	67.0	6.0	15.5	5.4	177.3	67.0	6.0	5.3	1.6	16.4

* State-listed as endangered with a probable identification

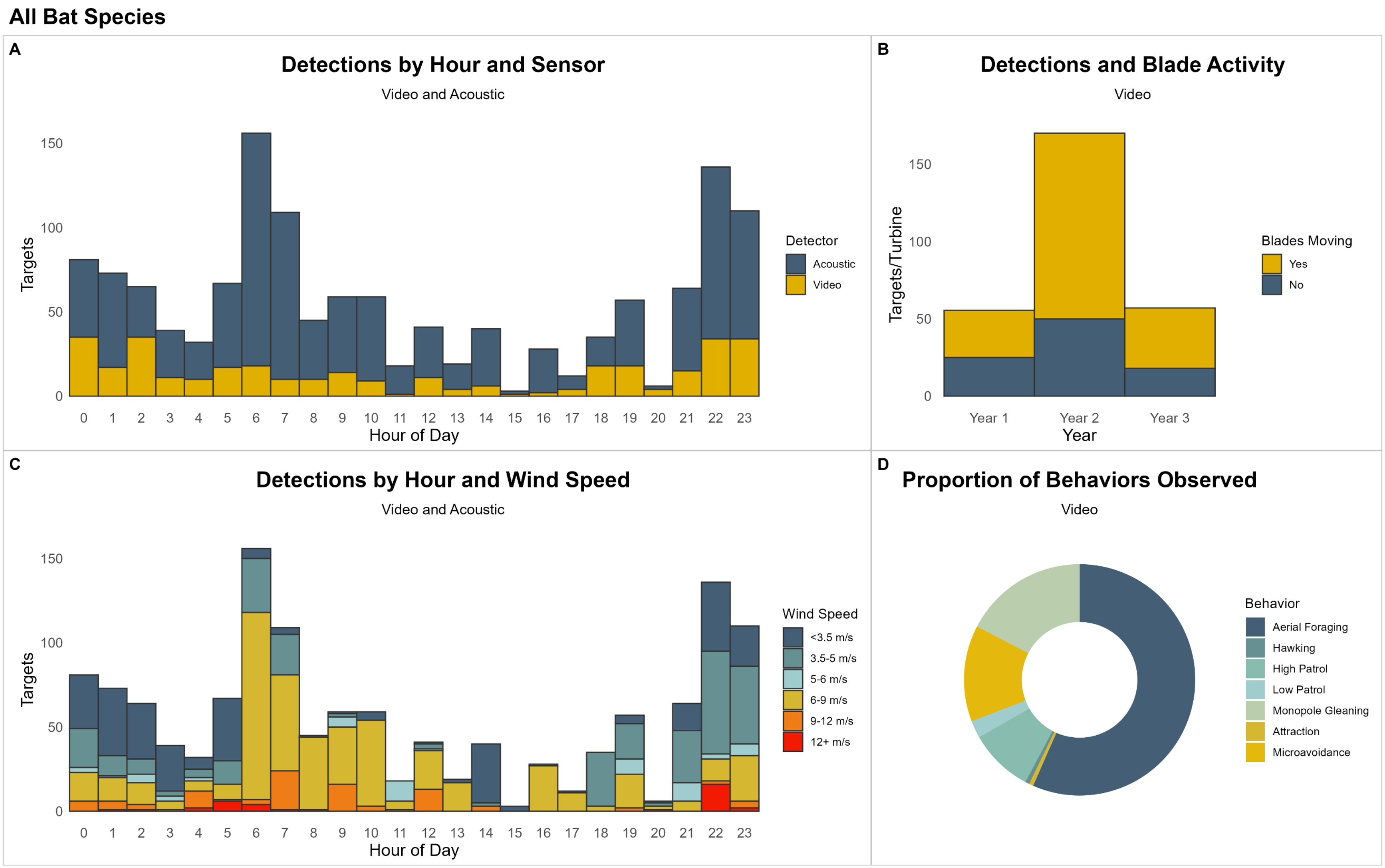


Figure 11. Bat activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years

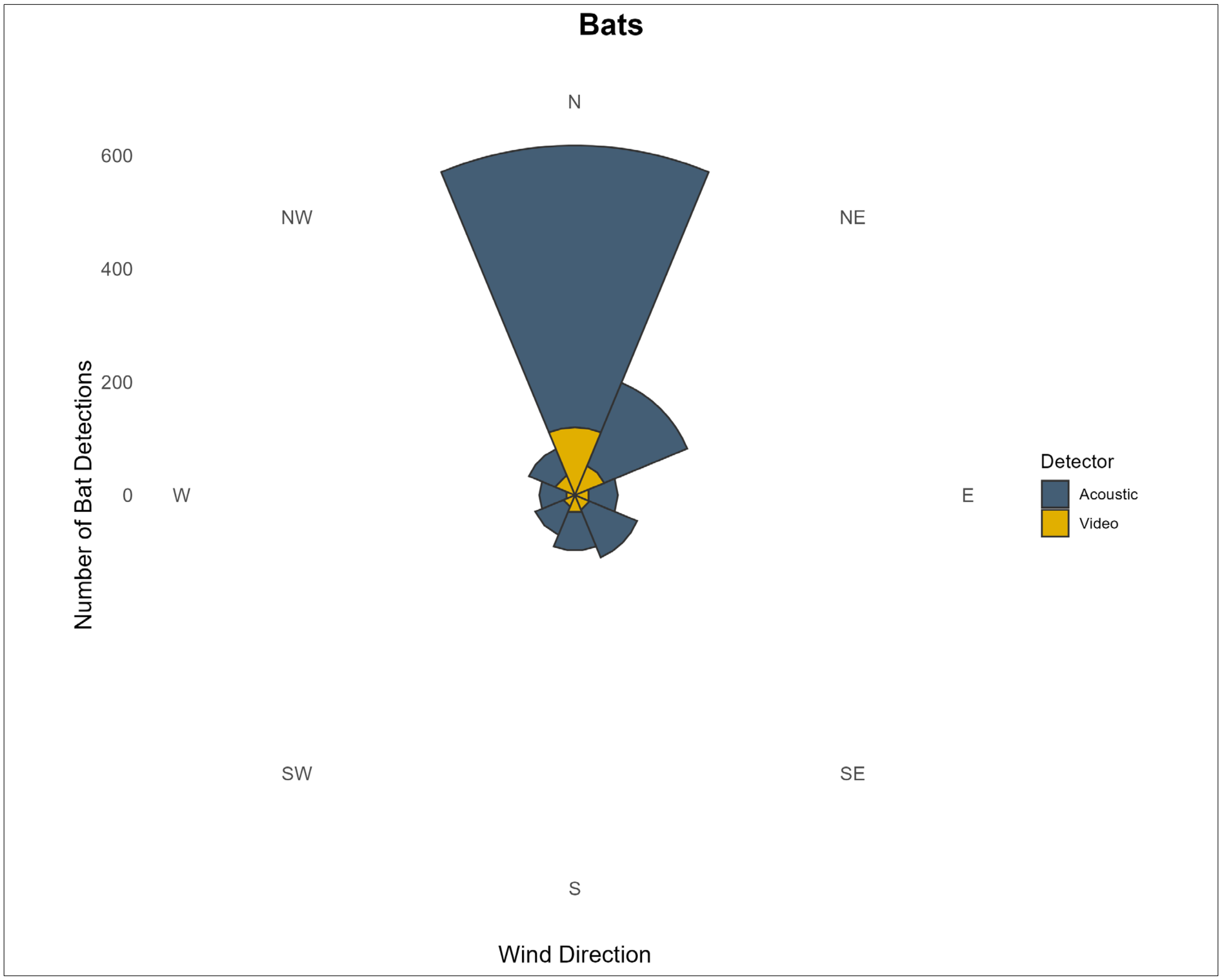


Figure 12. Wind direction relationship with bat detections.

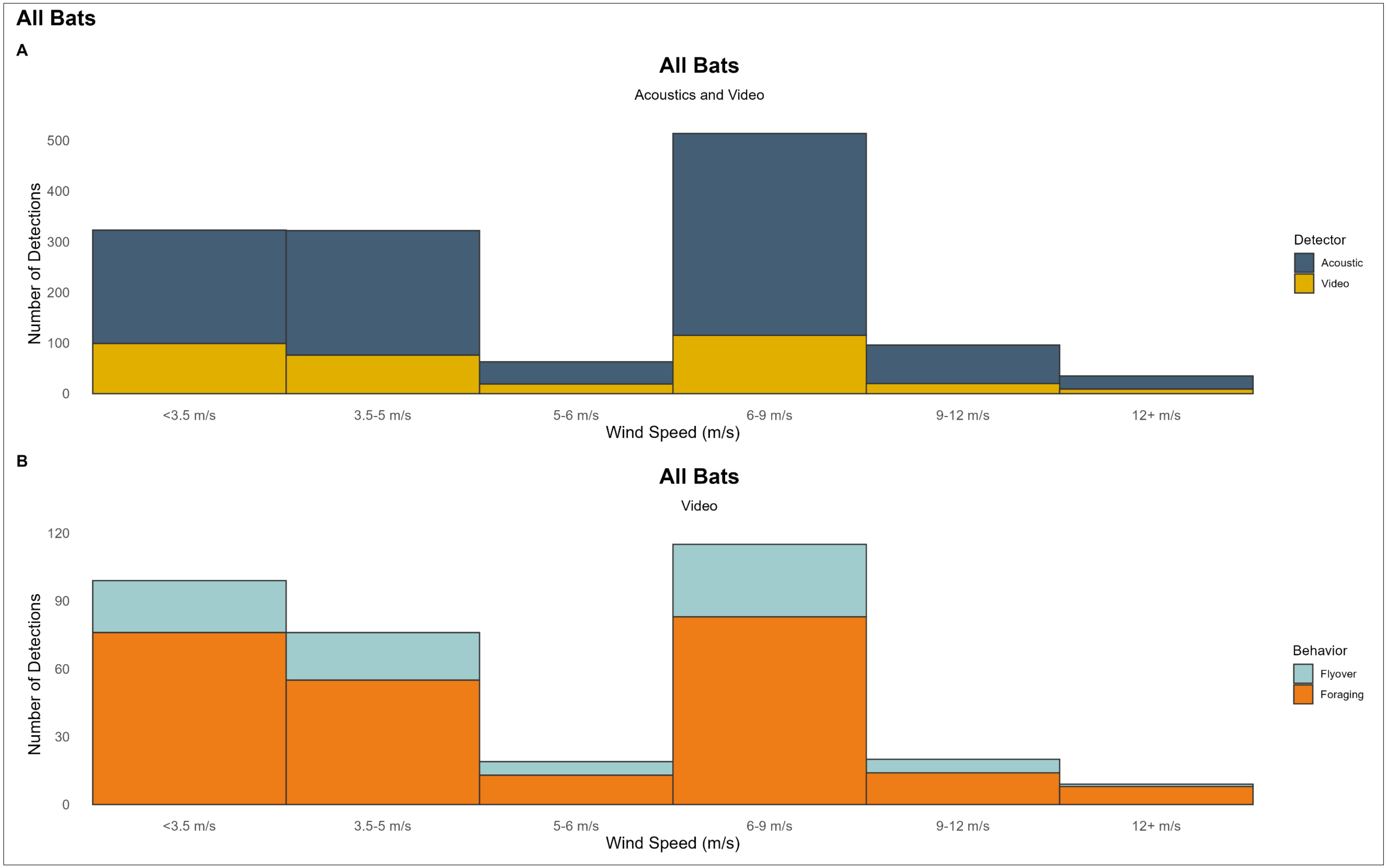
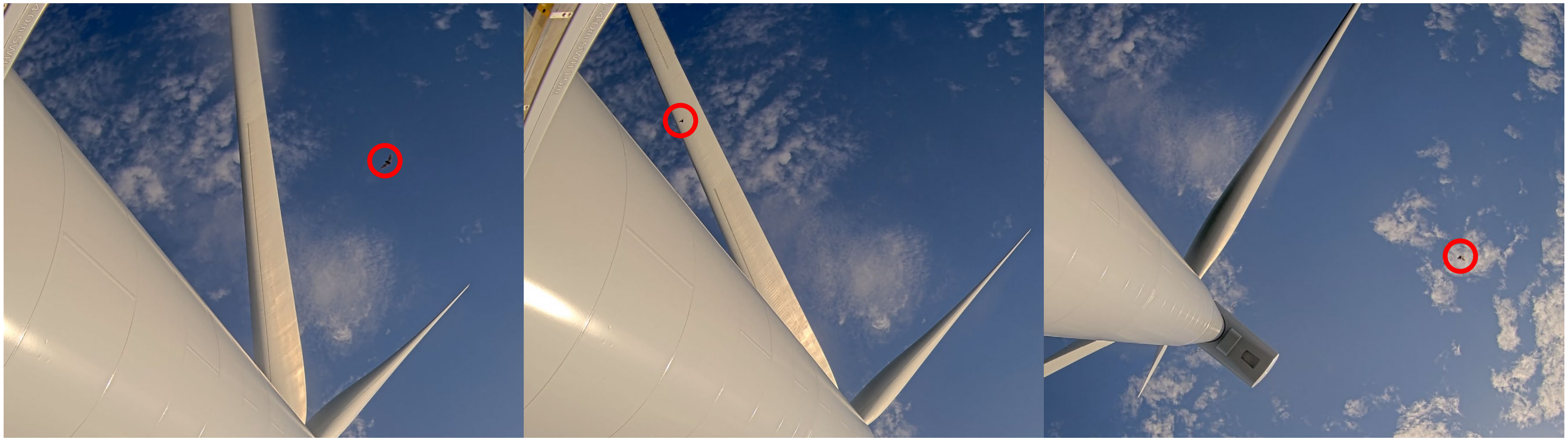


Figure 13. Number of bat detections at different wind speeds grouped by detector (A) and behavior (B).



Approaches blades Encounters air force Begins to fall

Figure 14. Bat approaching turbine blade, experiencing air-displacement, and falling; the bat recovered and continued activity.

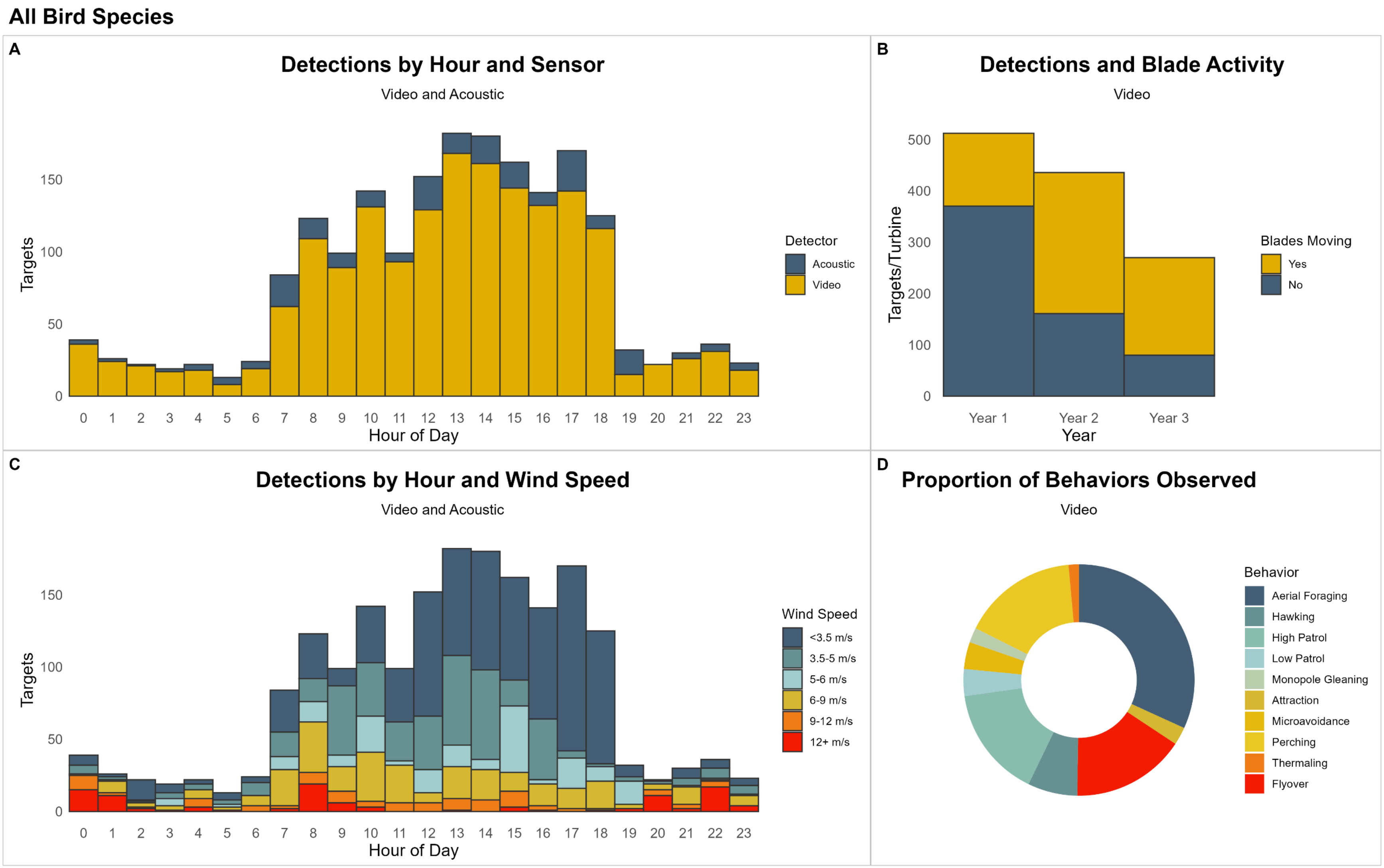


Figure 15. Bird activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.

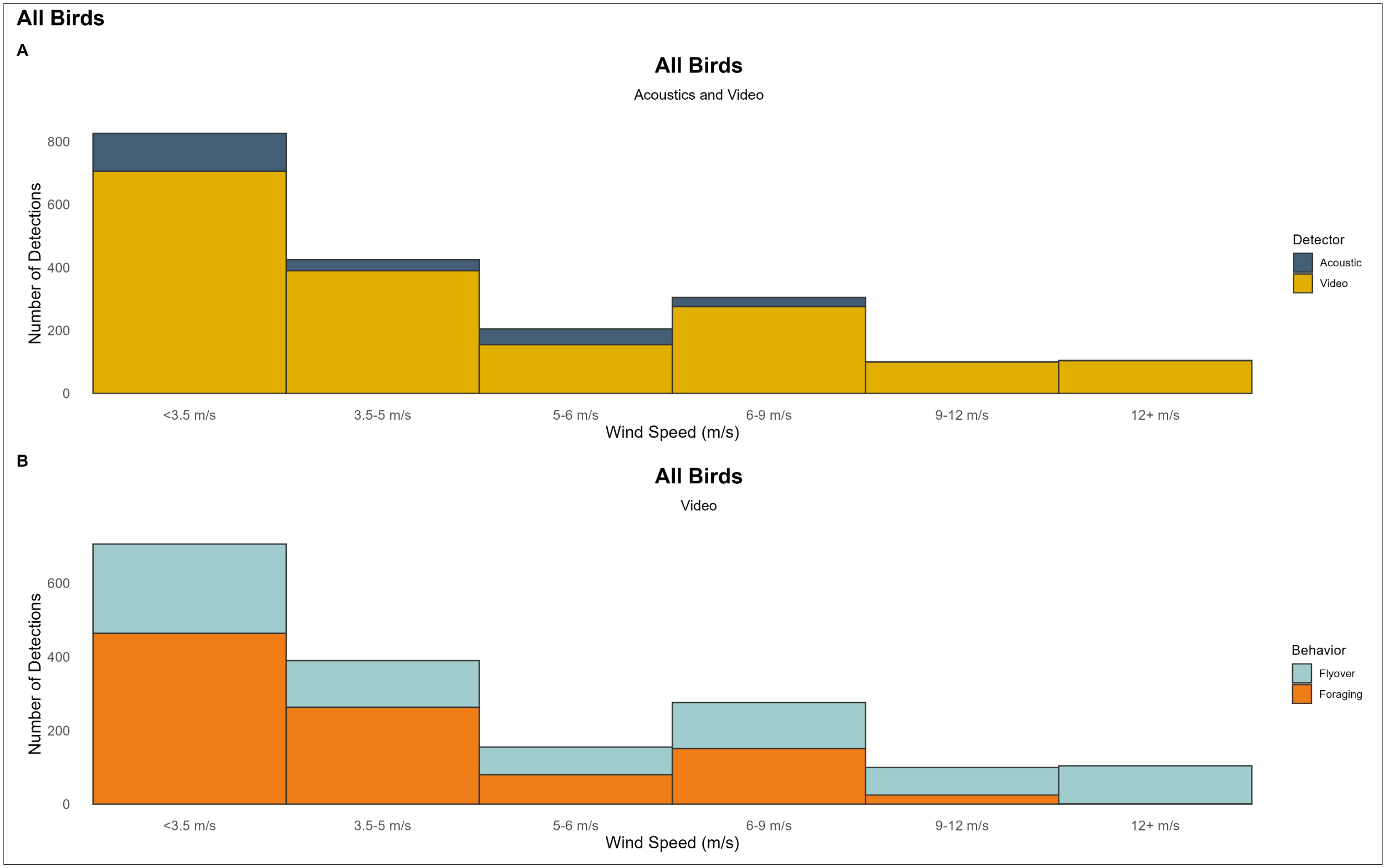


Figure 16. Number of bird detections at different wind speeds grouped by detector (A) and behavior (B).

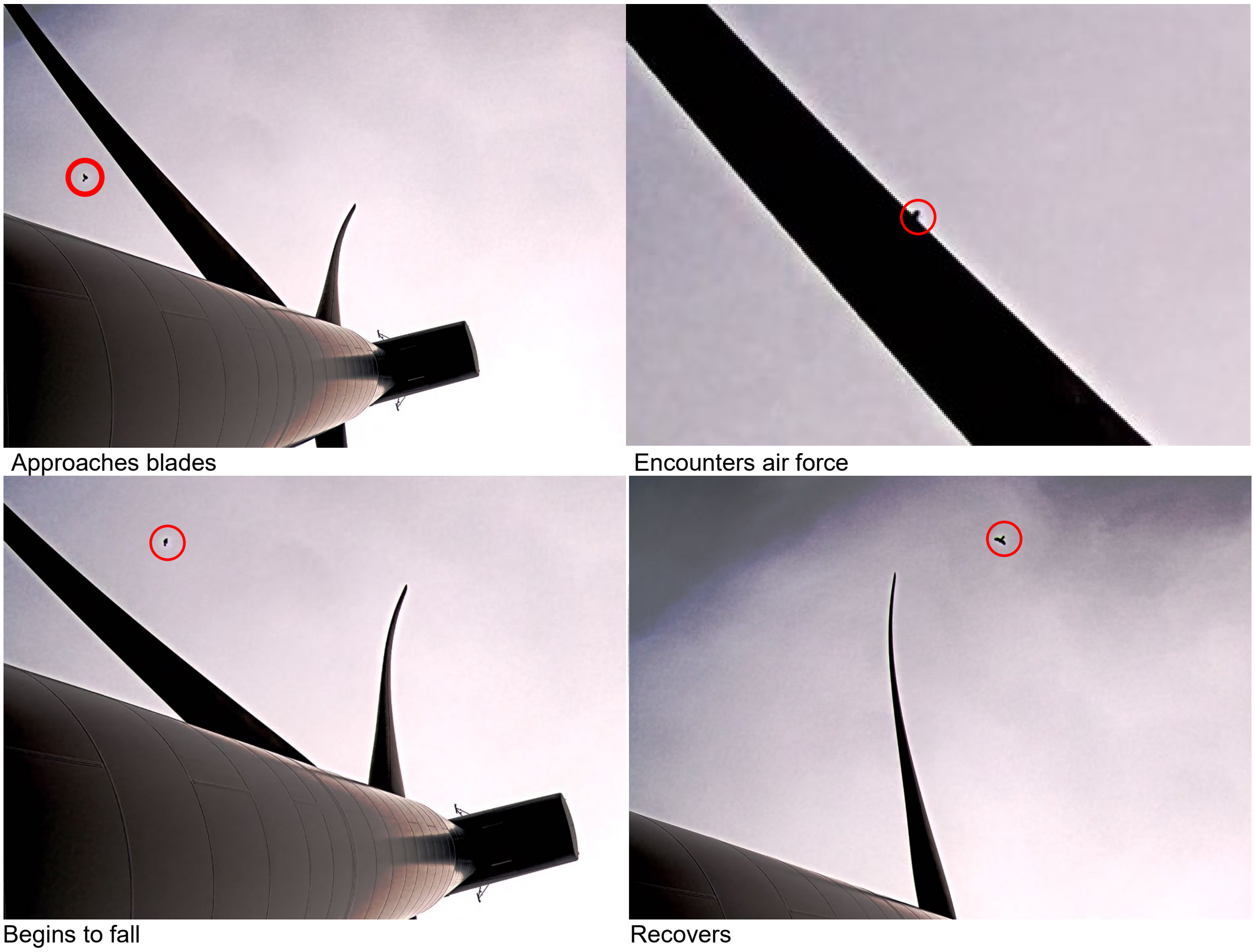


Figure 17. Bird approaching turbine blade, experiencing air-displacement, falling, and recovering.

Figure 18. A definite Peregrine Falcon from the 3-year bird and bat postconstruction monitoring at the Coastal Virginia Offshore Wind Pilot Project.

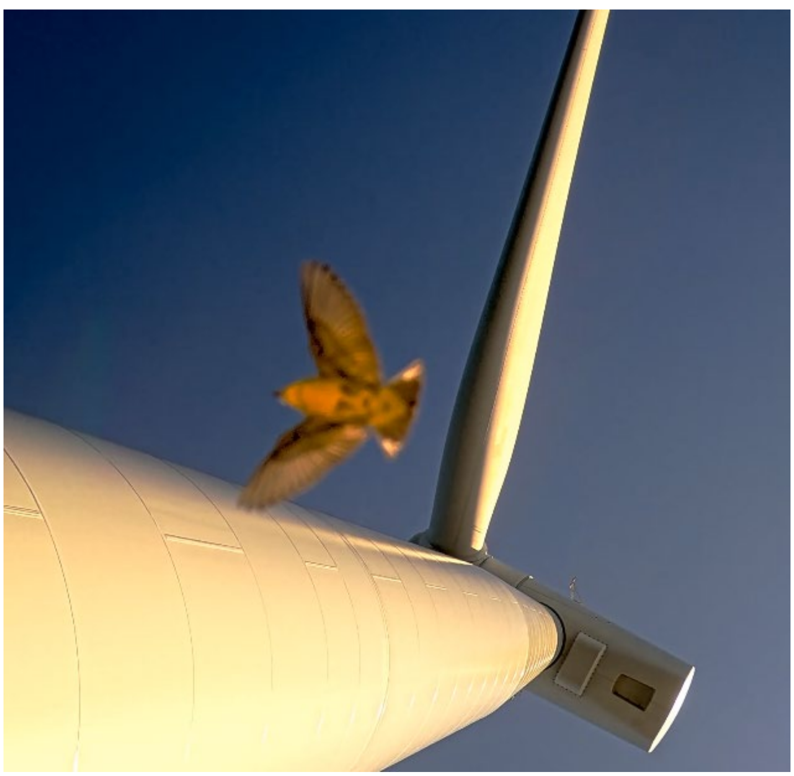


Figure 19. A probable Kirkland's Warbler from the fall 2021 ATOM field studies at the Coastal Virginia Offshore Wind Pilot Project.

Species Groups

Most passerine observations were observed with video sensors (93%) from 7:00 to 18:00 (Figure **20**a). Activity was minimal outside of these times. Passerines were most often observed when blades were not moving (68%) compared to when blades were moving (32%) (Figure **20**b). Passerines were most frequently observed during low wind speeds (<5 m/s): 78% of passerines were observed during wind speeds of <5 m/s, while only 3% were observed in wind speeds >9 m/s (Figure **20**c). Northerly and northwesterly wind directions were most frequently associated with passerine activity (Figure 21a). Passerine behavior was most associated with foraging as 82% of behavioral observations were either aerial foraging, hawking, perching, or monopole gleaning (Figure **20**d). Passerine foraging behaviors declined as wind speed increased especially at wind speeds above 9 m/s (Figure 22). The main foraging technique used was aerial (53% of behavior observations), capturing insects on the wing while actively flying in pursuit (Figure 23). Another observed foraging behavior used by passerines was hawking (using the turbine as a perching base, sallying forth to capture insects, and returning). Both hawking and aerial foraging sometimes resulted in birds gleaning insects from the monopole (Figure **20**d).

The majority of Setophaga warbler observations were observed with video sensors (91%) from 12:00 to 18:00 (Figure **24**a). Activity was much lower outside of these times. Setophaga warblers were most often observed when blades were not moving (79%) compared to when blades were moving (21%) (Figure **24**b). Setophaga warblers were most frequently observed during low wind speeds (<5 m/s): 85% of Setophaga warblers were observed during wind speeds of <5 m/s, while only 2% were observed in wind speeds >9 m/s (Figure **24**c). Northerly and northwesterly wind directions were most frequently associated with Setophaga warbler activity (Figure 21b). Setophaga warbler behavior was most associated with foraging as 89% of behavioral observations were either aerial foraging, hawking, perching, or monopole gleaning (Figure **24**d). The percentage of foraging behaviors declined as wind speed increased, especially above 3.5 m/s wind speed (Figure 25).

Gull activity was highest between 8:00 and 10:00 and from 13:00 to 18:00 with a lull in between. Most gull activity was recorded with video (74%), while 26% was recorded with acoustic sensors (Figure 26a). Gull activity was evenly distributed between blade activities with 54% of gulls observed while the blades were moving and 46% observed when the blades were stationary (Figure 26b). Gulls were more active at higher wind speeds than passerines with 19% of observations recorded in wind speeds >9 m/s (Figure 26c). Wind direction from the north and east were most associated with gull activity (Figure 21c). Most gull behaviors did not involve foraging with 82% of observations being either flyover, low/high patrol, thermaling, attraction, or microavoidance (Figure 26d). The percentage of non-foraging behaviors increased as wind speed increased, especially above 9 m/s wind speed (Figure 27).

Raptors were nearly all active during the day and all were detected using video (Figure 28a). Raptor activity was similar among years, though the majority of activity in years 1 and 2 was observed with the blades not spinning, and the majority of raptor activity in year 3 was when the blades were spinning (Figure 28b) and likely represented the same individuals remaining at the turbine for foraging purposes. Many observations in year 3 were of Osprey (*Pandion haliaetus*). Raptors were frequently active in higher wind speeds with 47% occurring in wind speeds >6 m/s and 12% occurring in wind speeds >9 m/s (Figure 28c); however foraging behavior occurred at speeds <12 m/s (Figure 29). There was no clear relationship between wind direction and raptor activity (Figure 21d). The most frequently recorded behavior for raptors was perching (47%) (Figure 30) followed by high patrol (23%) and aerial foraging (12%) (Figure 28d). Peregrine Falcons regularly foraged around the turbines and were seen with prey items (Figure 31).

Shorebird activity occurred throughout the day with a notable peak between 1:00 and 2:00, which was from a single flock of 10 birds (Figure 32a). Shorebirds were most abundant during year 3, and 88% of detections occurred when the blades were moving (Figure 32b). Shorebirds were most active during low (<5 m/s) and high (12+ m/s) wind speeds (Figure 32c, Figure 33). Shorebird activity was most commonly associated with winds from the northwest (Figure 21e). The most observed shorebird behaviors were flyovers (71%) and attraction (18%) (Figure 32d).

Tern activity occurred primarily during the day, and 93% of detections were acoustic (Figure 34a). The only tern detection in video occurred in year 3 and the blades were not moving (Figure 34b). All tern detections occurred when the wind was <6 m/s (Figure 34c, Figure 35). Tern activity was the highest when winds were out of the east (Figure 21f). The only tern observation in the video was during high patrol (Figure 34d).

Pelicans were active during the day, primarily detected by the video sensors (Figure **36**a), and only observed during year 3 (Figure **36**b). Pelicans were active during lower wind speeds of 5–6 m/s (Figure **36**c, Figure 37). Nearly all pelican observations were observed during northerly winds, though this was primarily influenced by a flock of 13 American White Pelicans (*Pelecanus erythrorhynchos*) (Figure 21g). All observed pelican behaviors were high flyovers (Figure **36**d).

Swallows were entirely observed during the day and exclusively on the video sensors (Figure **38**a). Detections were similar between blades moving and not moving (Figure **38**b). Most observations occurred during low wind speeds (<5 m/s) (Figure **38**c, Figure **39**), and there was no obvious trend in activity and wind direction (Figure 21h). Swallows were observed primarily performing aerial foraging (Figure **38**d).

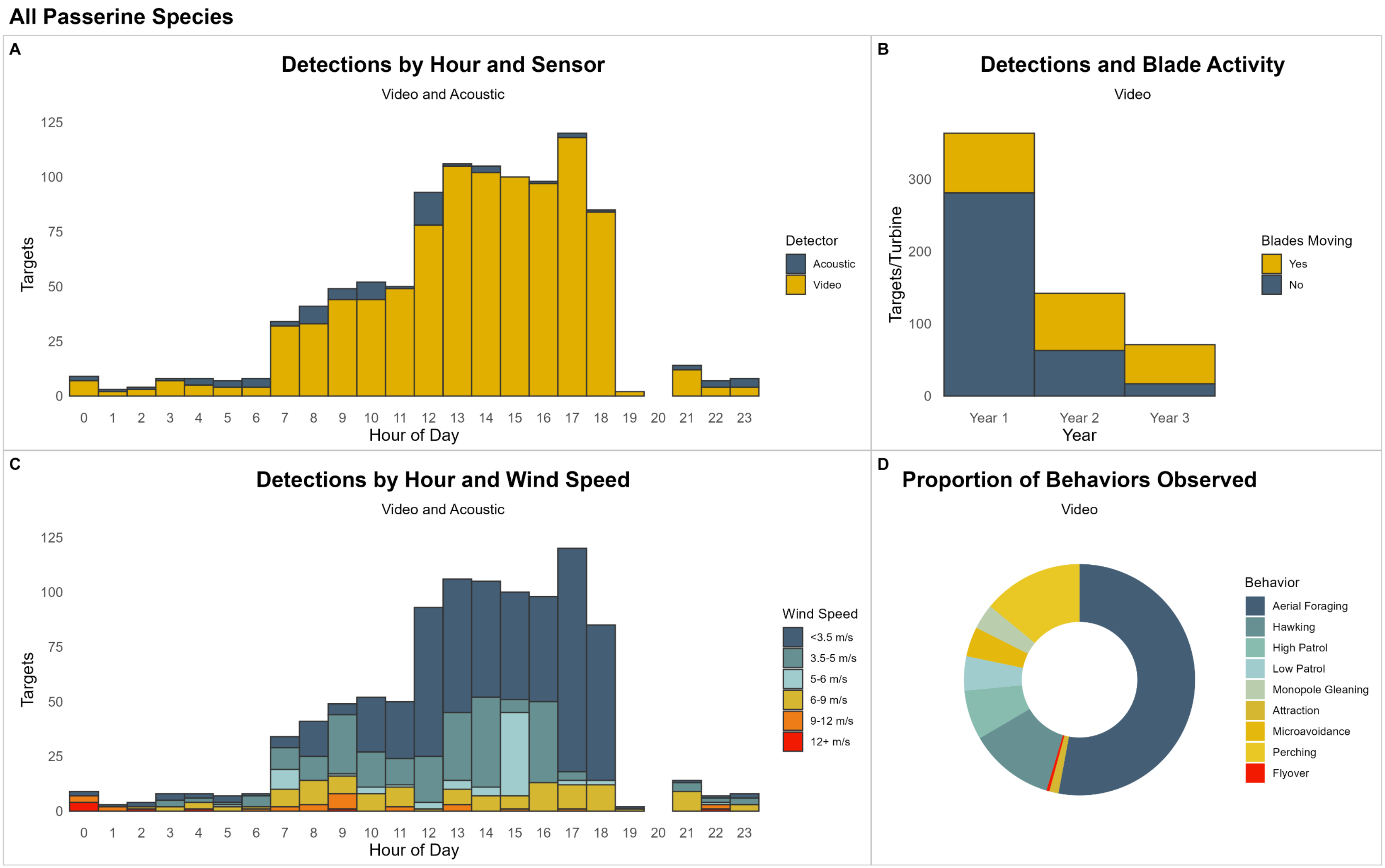


Figure 20. Passerine activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.

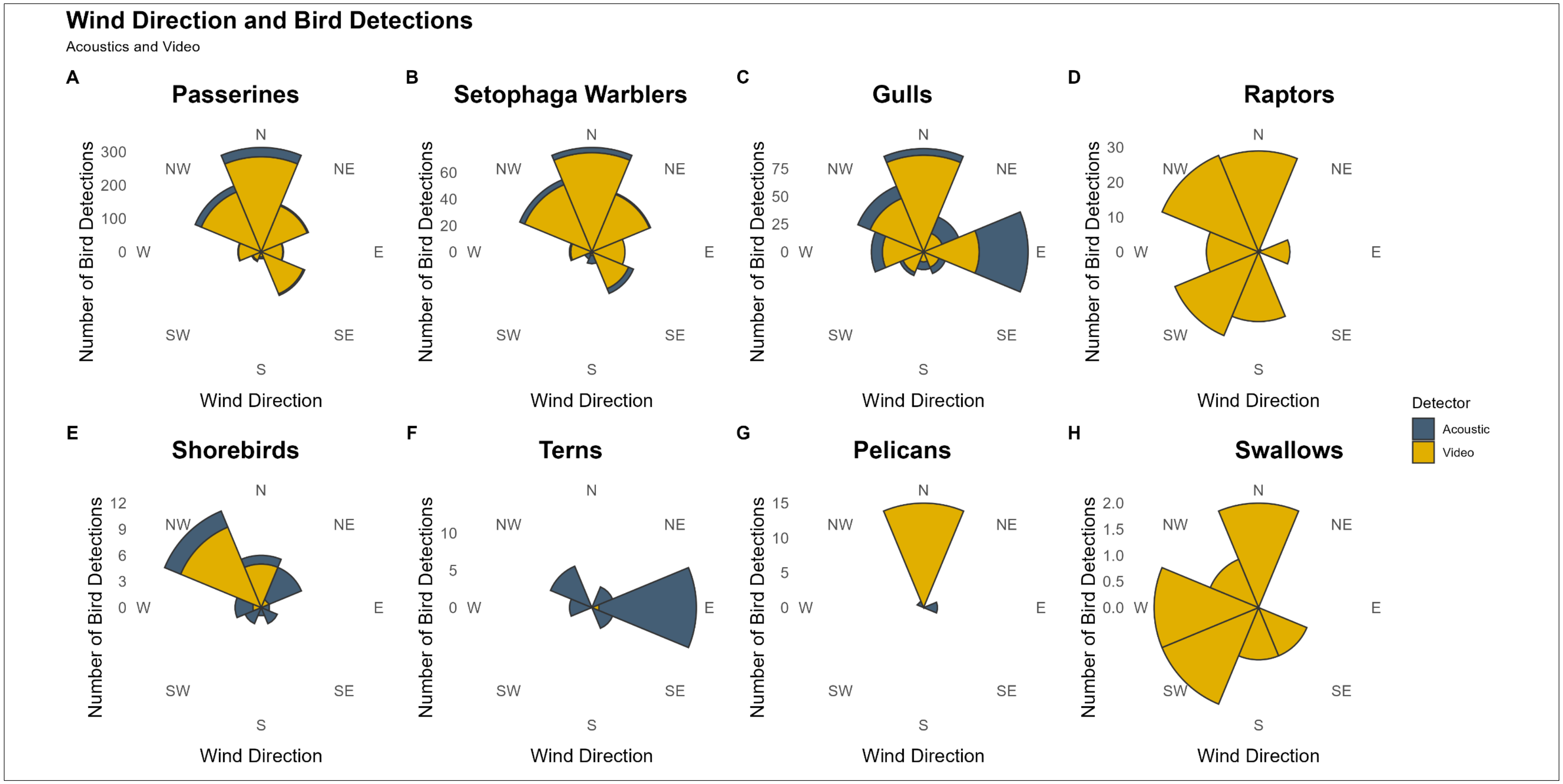


Figure 21. Wind direction relationship with bird detections among species groups.

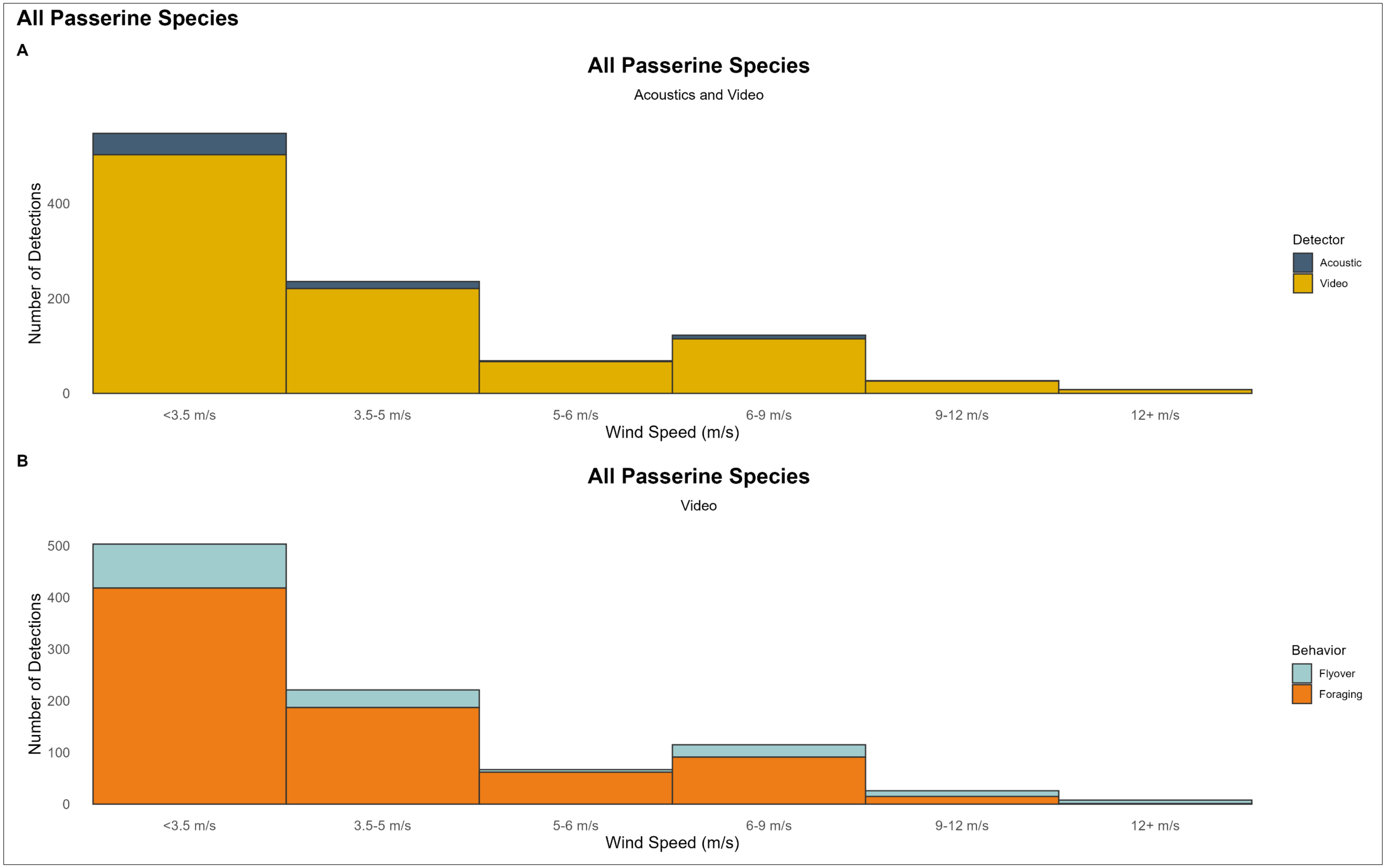


Figure 22. Number of passerine detections at different wind speeds grouped by detector (A) and behavior (B).

Figure 23. Cape May Warbler chasing a moth; the blades of the turbine were not moving.

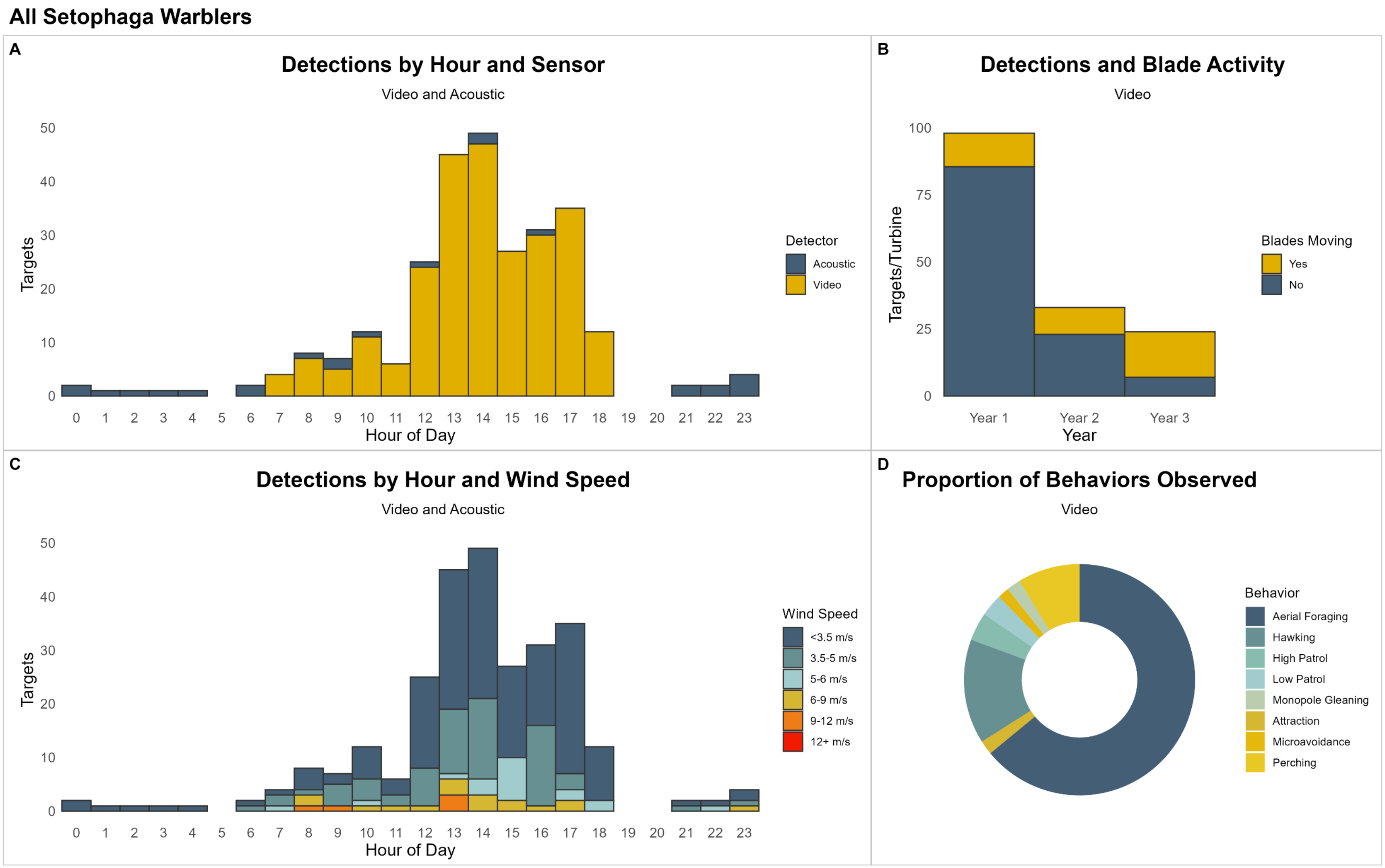


Figure 24. Setophaga warbler activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.

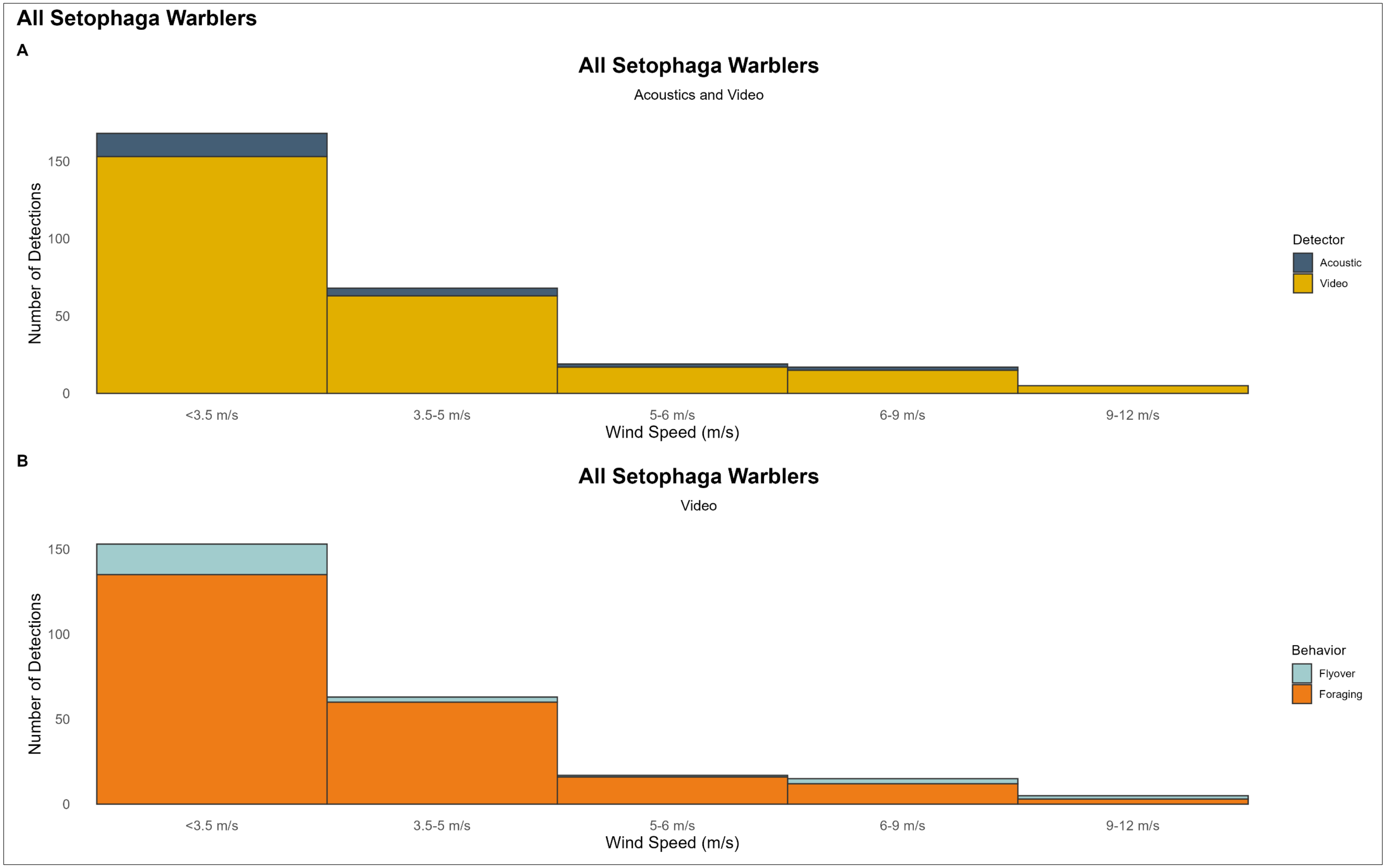


Figure 25. Number of Setophaga warbler detections at different wind speeds grouped by detector (A) and behavior (B).

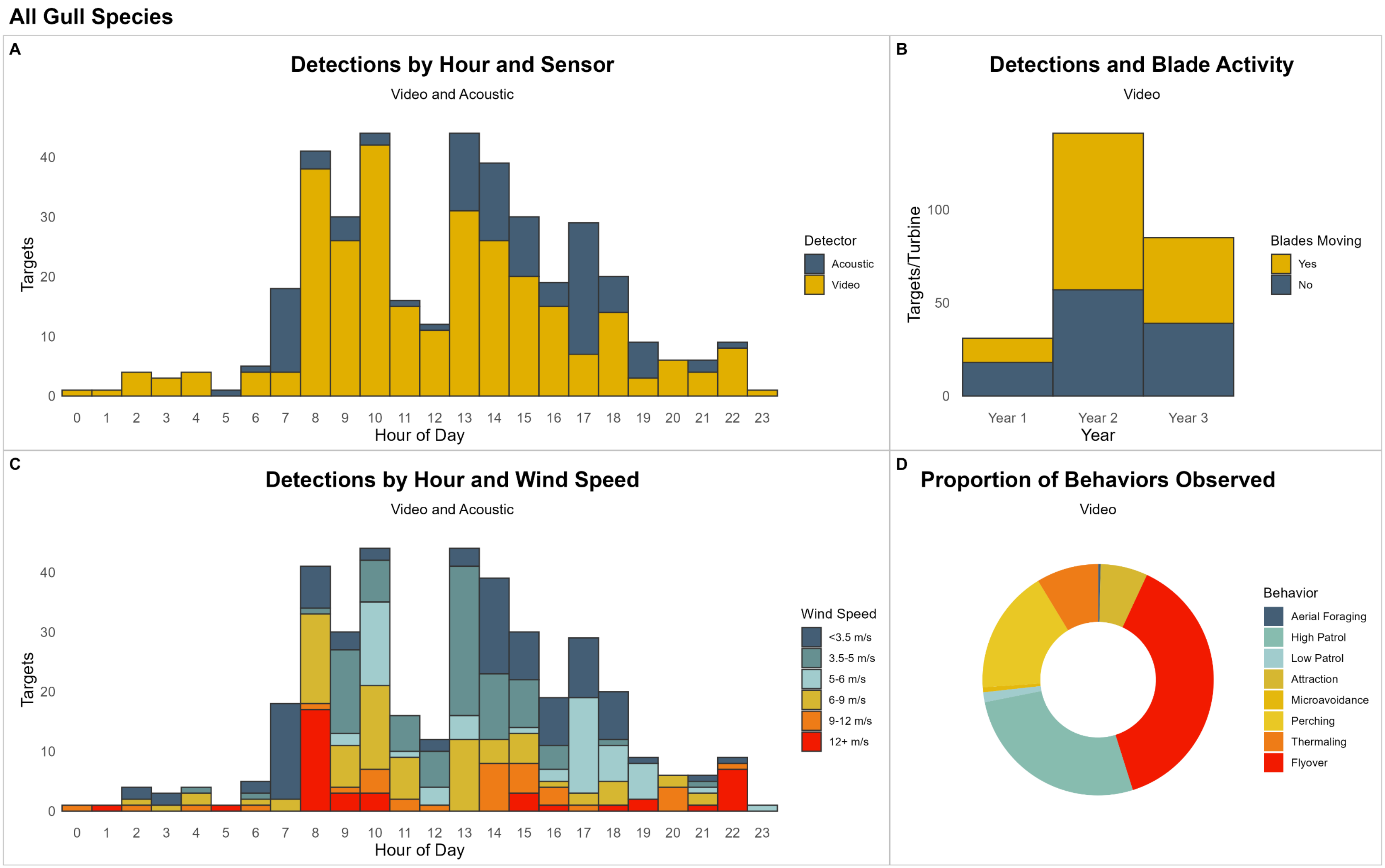


Figure 26. **Gull activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.**

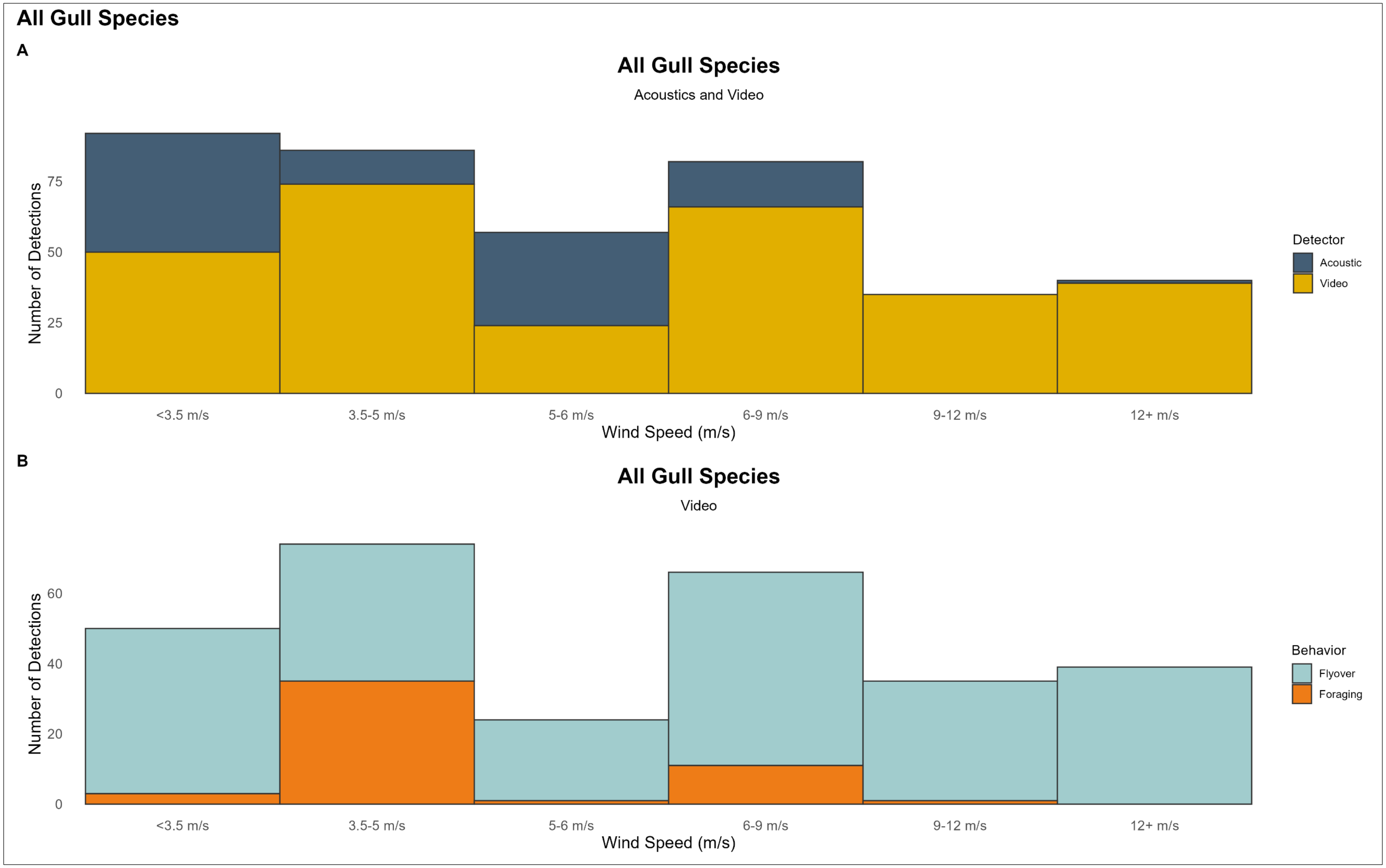


Figure 27. Number of gull detections at different wind speeds grouped by detector (A) and behavior (B).

All Raptor Species

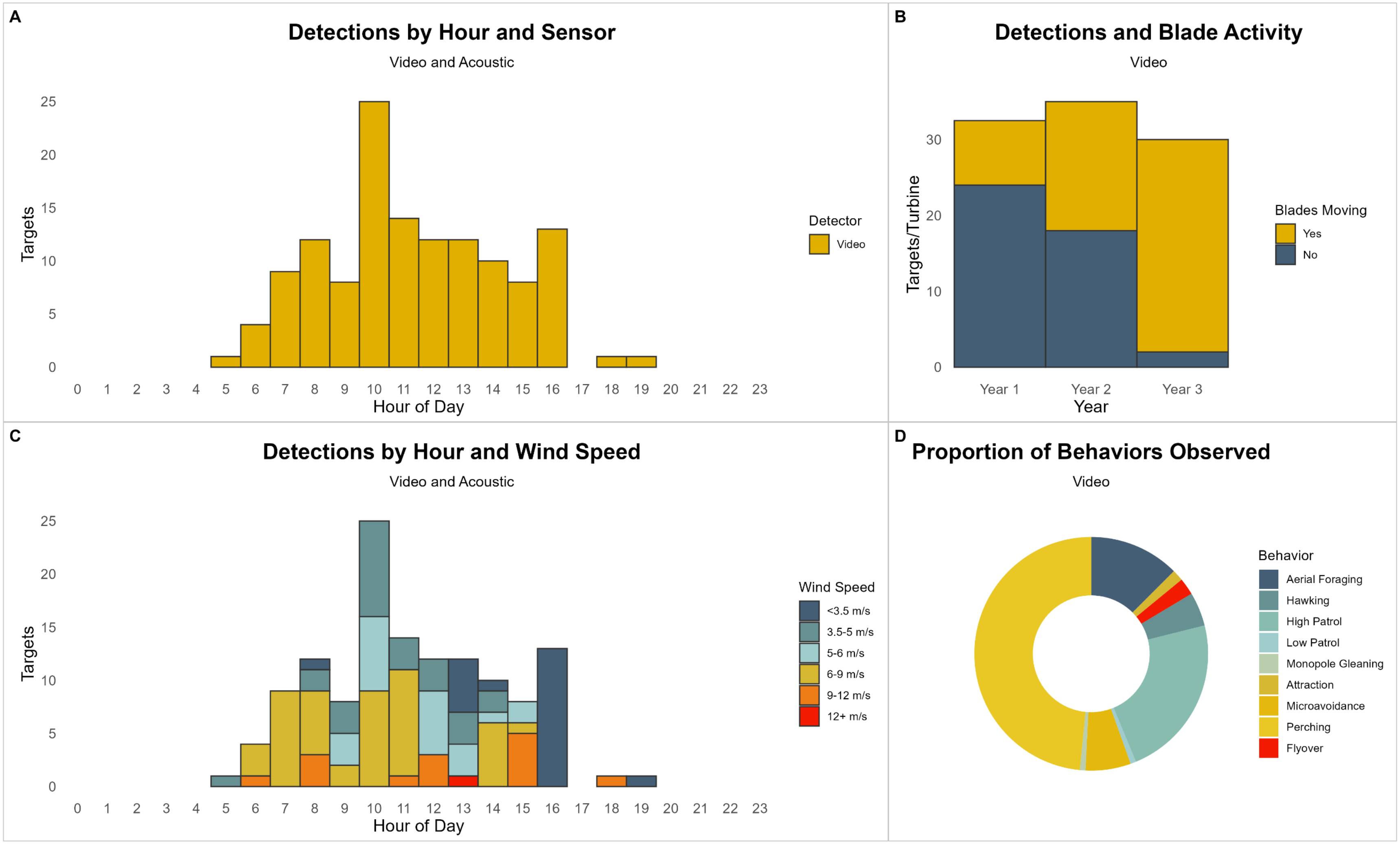


Figure 28. **Raptor activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.**

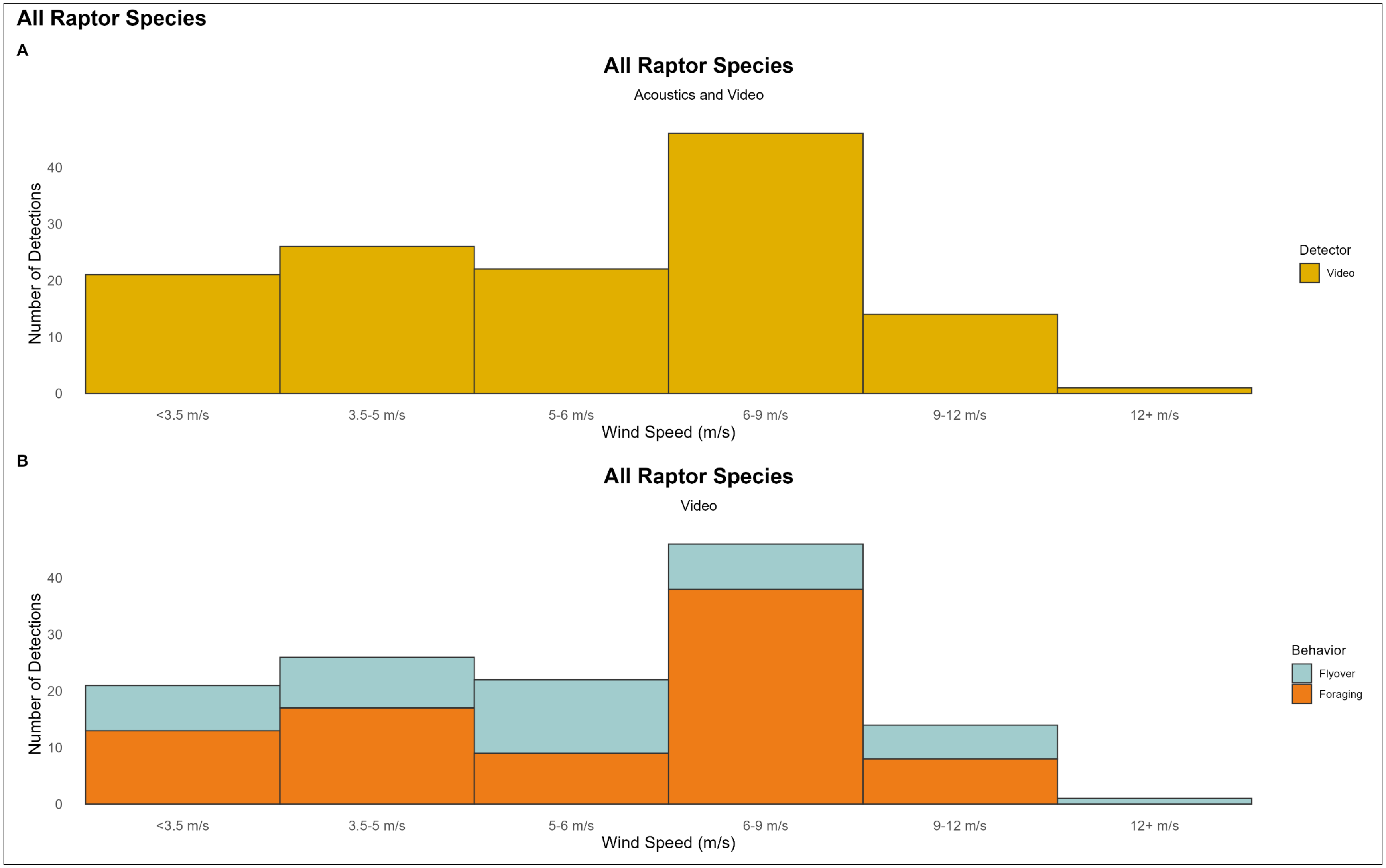


Figure 29. Number of raptor detections at different wind speeds grouped by detector (A) and behavior (B).

Figure 30. An Osprey coming to perch on the turbine platform.

Figure 31. Peregrine Falcon with prey landing on the turbine platform.

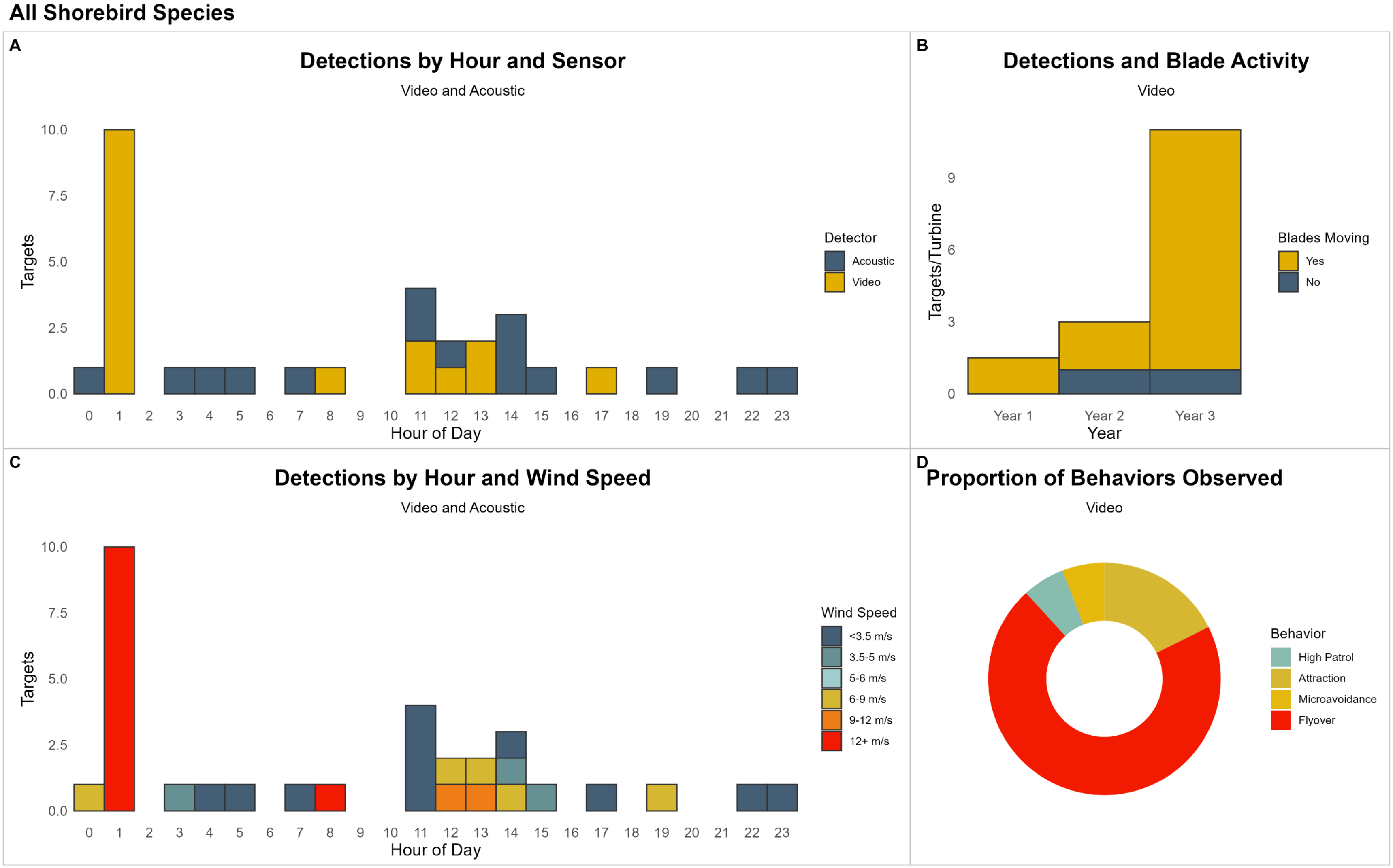


Figure 32. **Shorebird activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.**

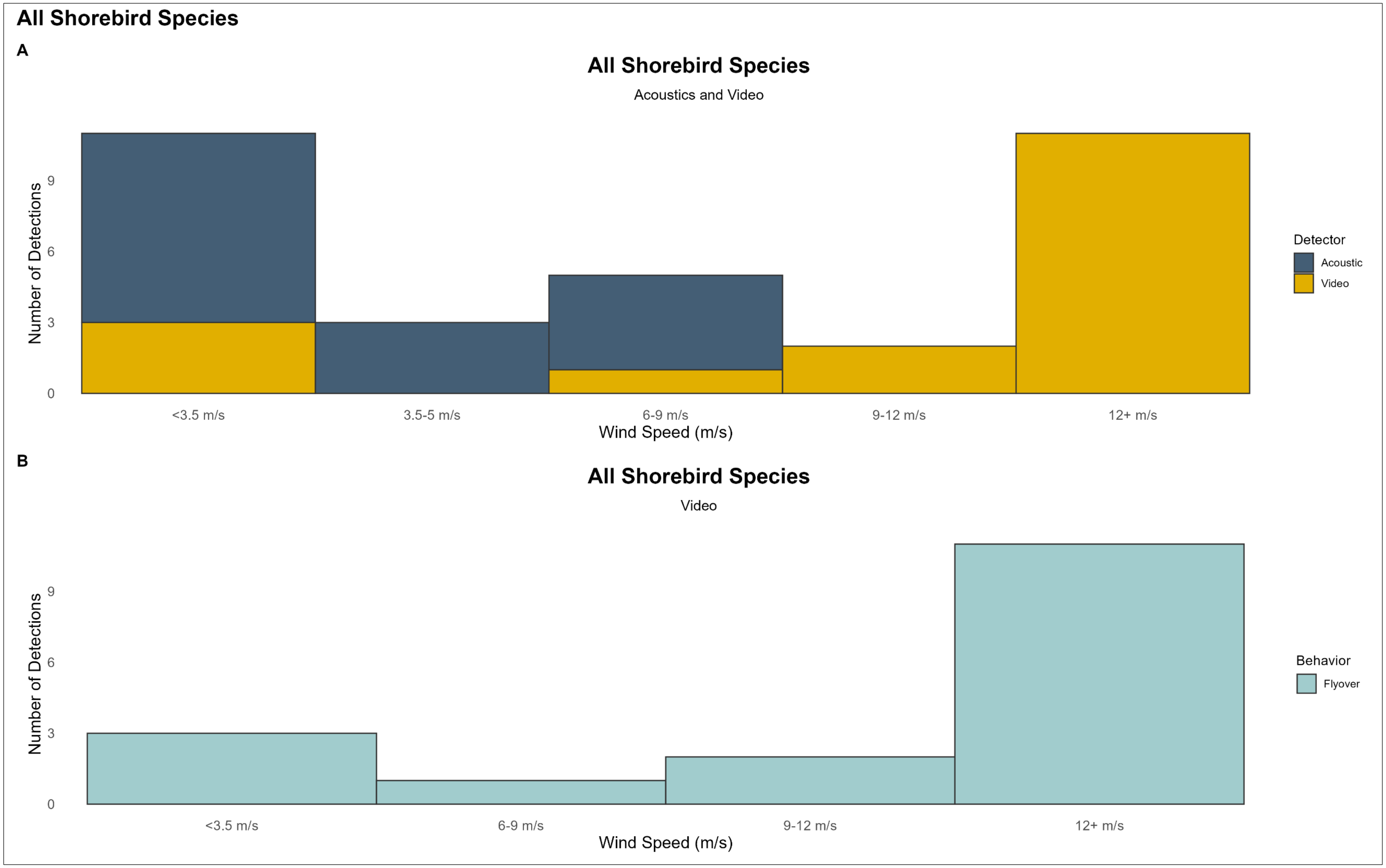


Figure 33. Number of shorebird detections at different wind speeds grouped by detector (A) and behavior (B).

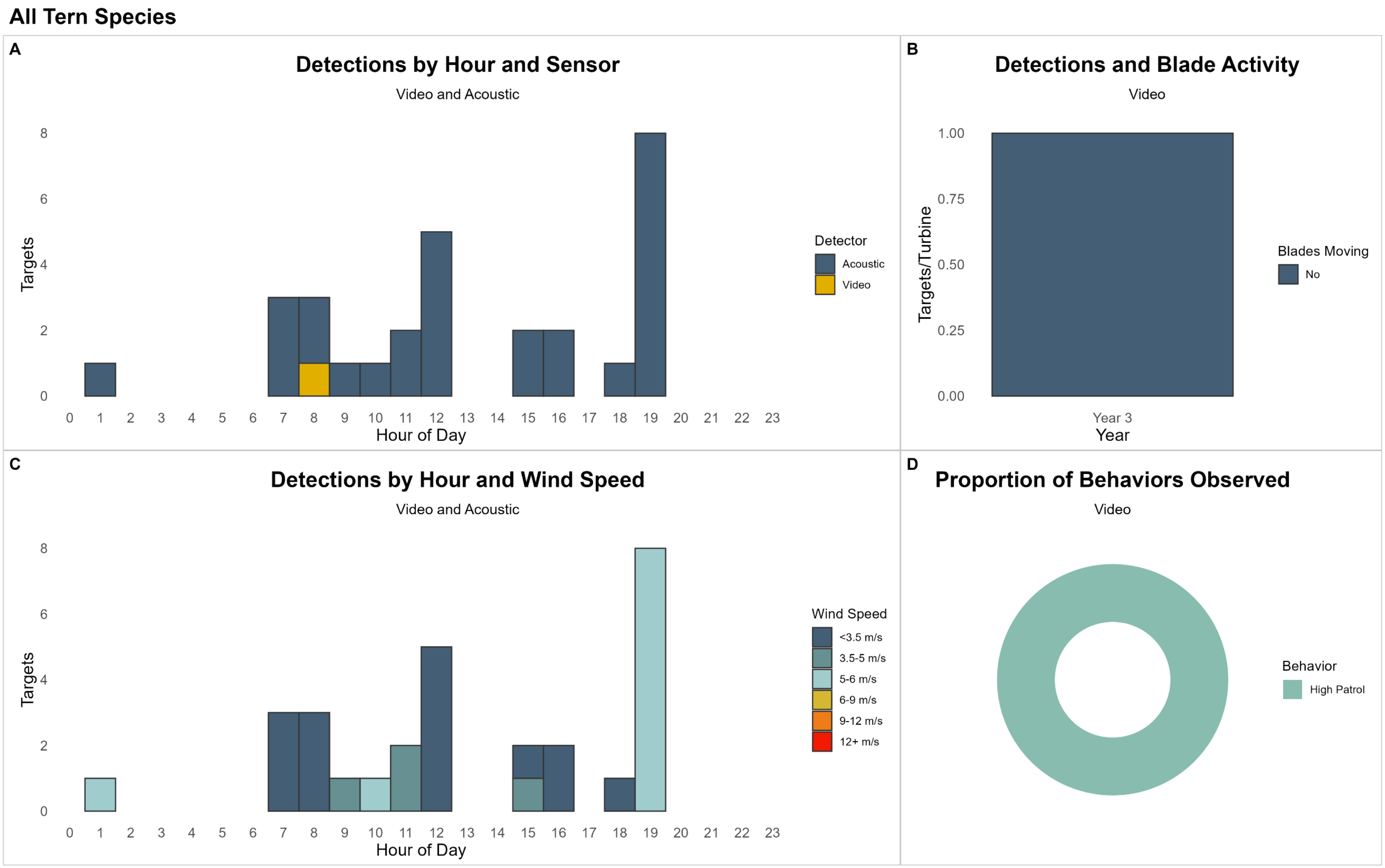


Figure 34. **Tern activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.**

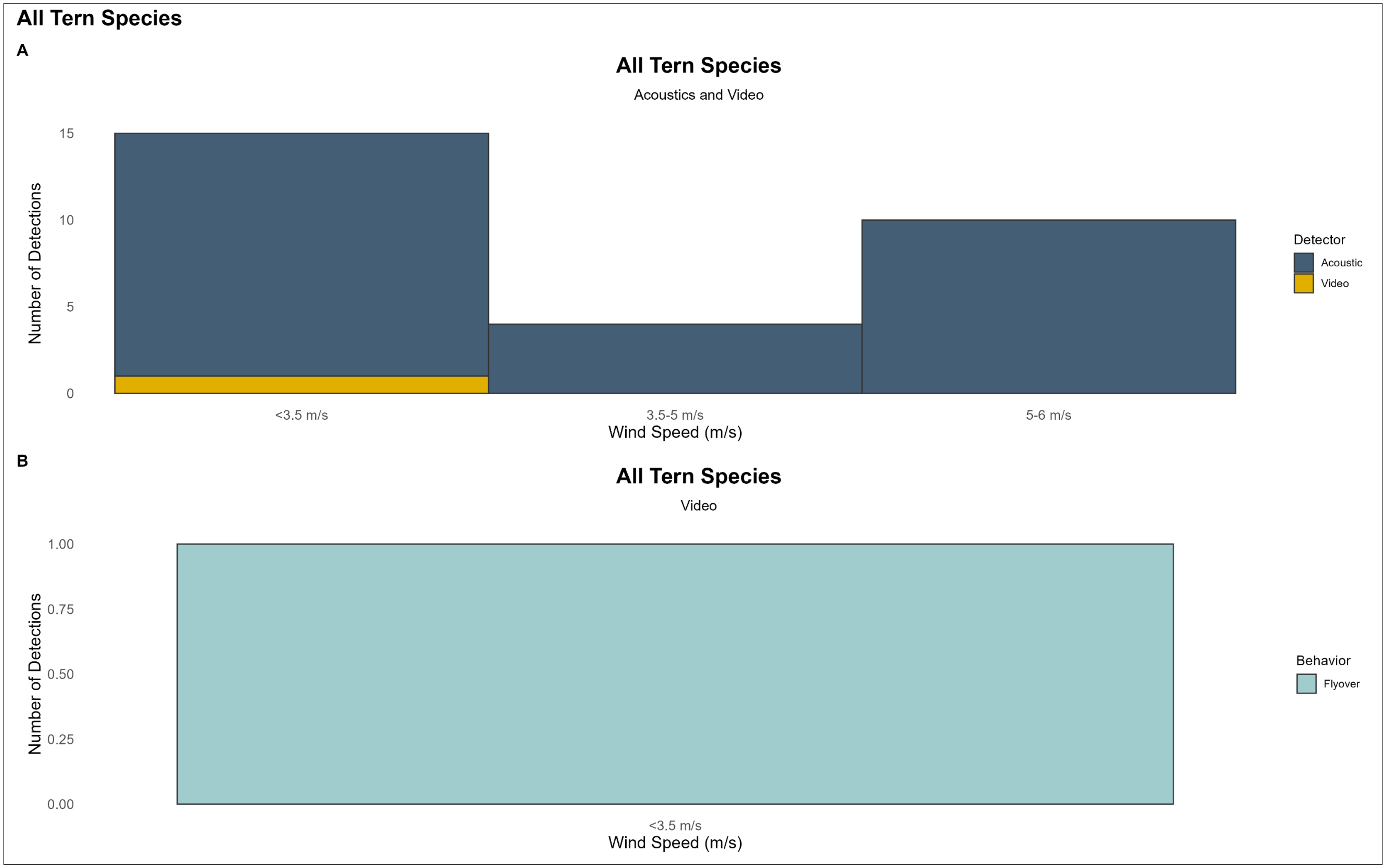


Figure 35. Number of tern detections at different wind speeds grouped by detector (A) and behavior (B).

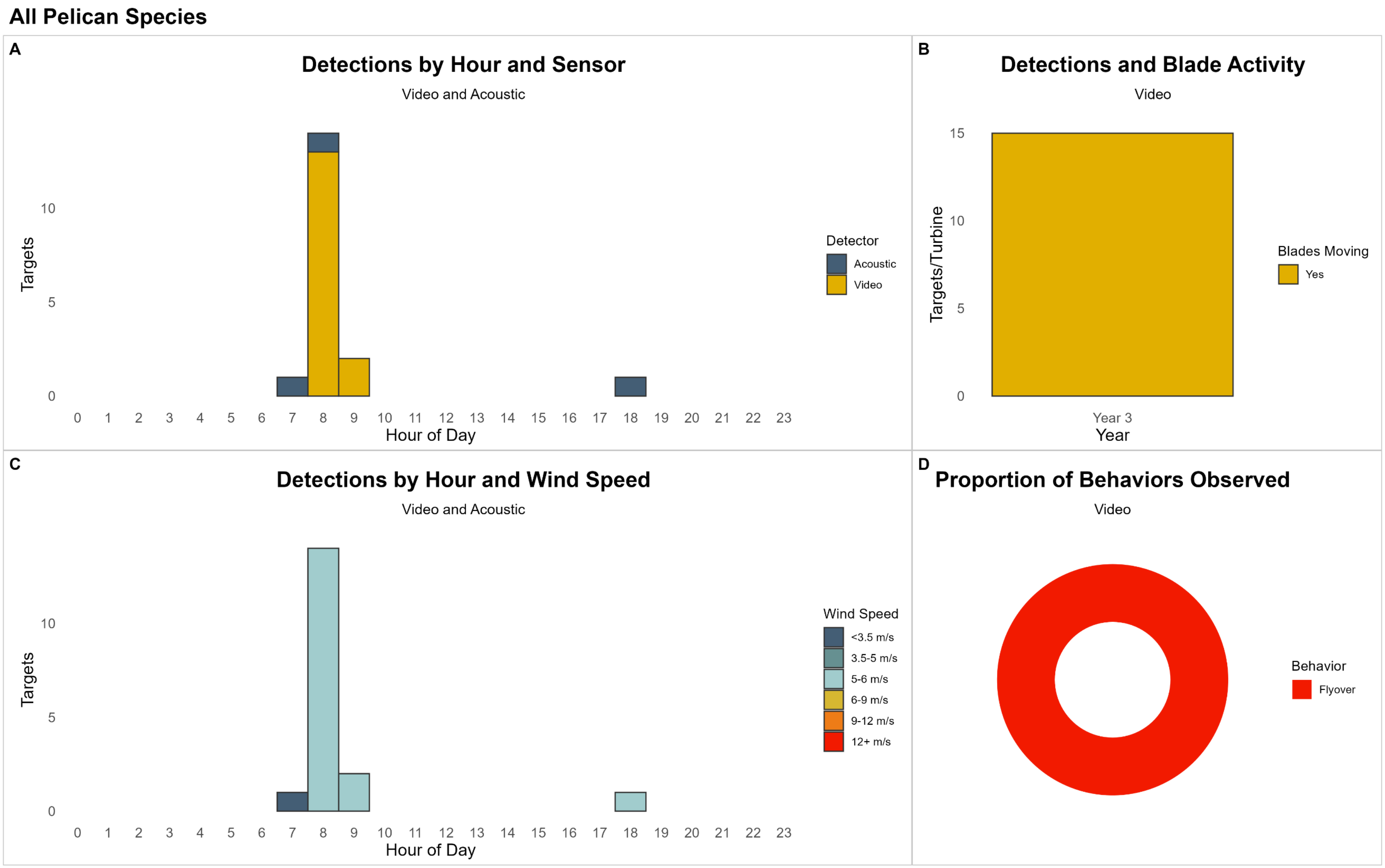


Figure 36. Pelican activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.

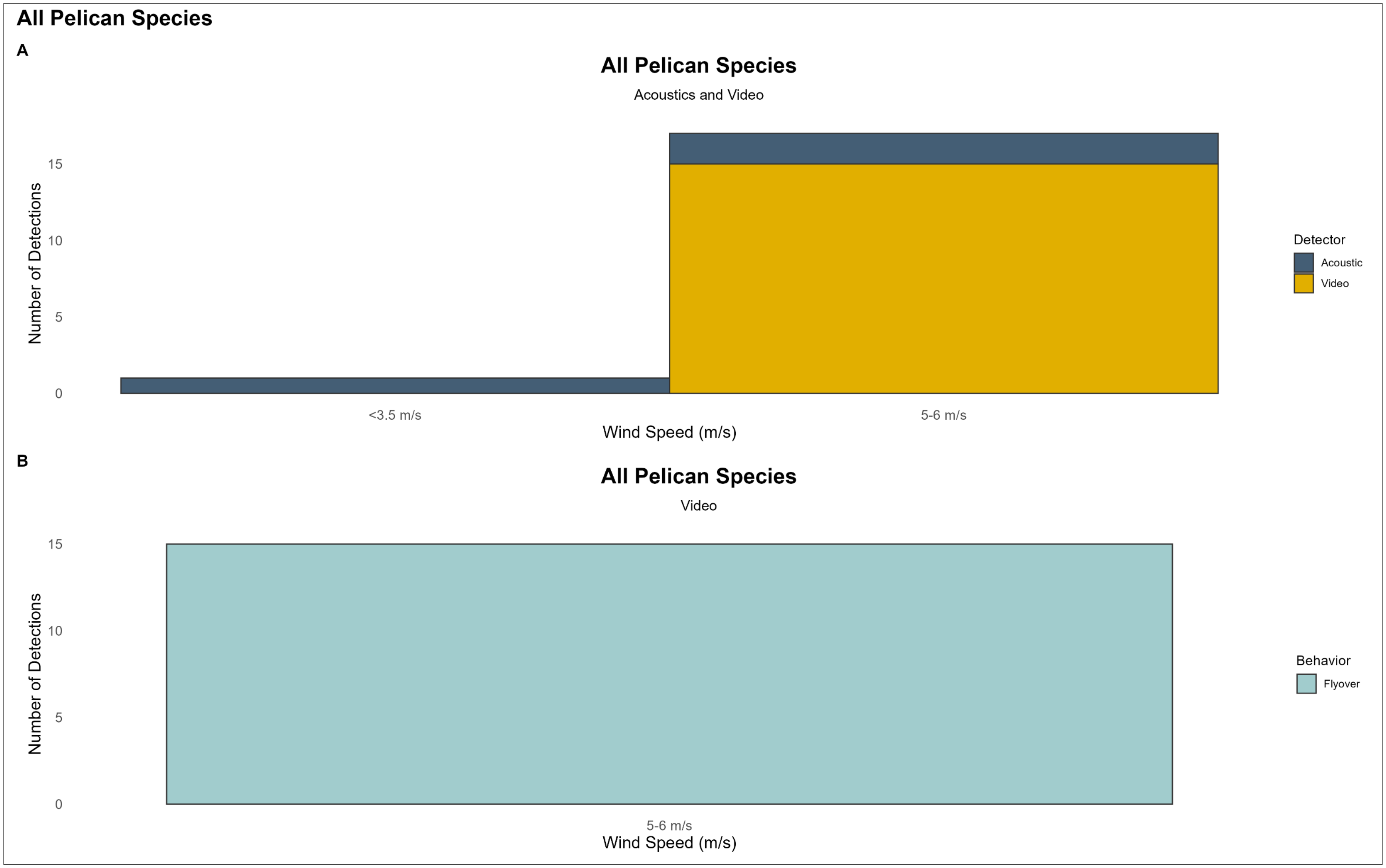


Figure 37. Number of pelican detections at different wind speeds grouped by detector (A) and behavior (B).

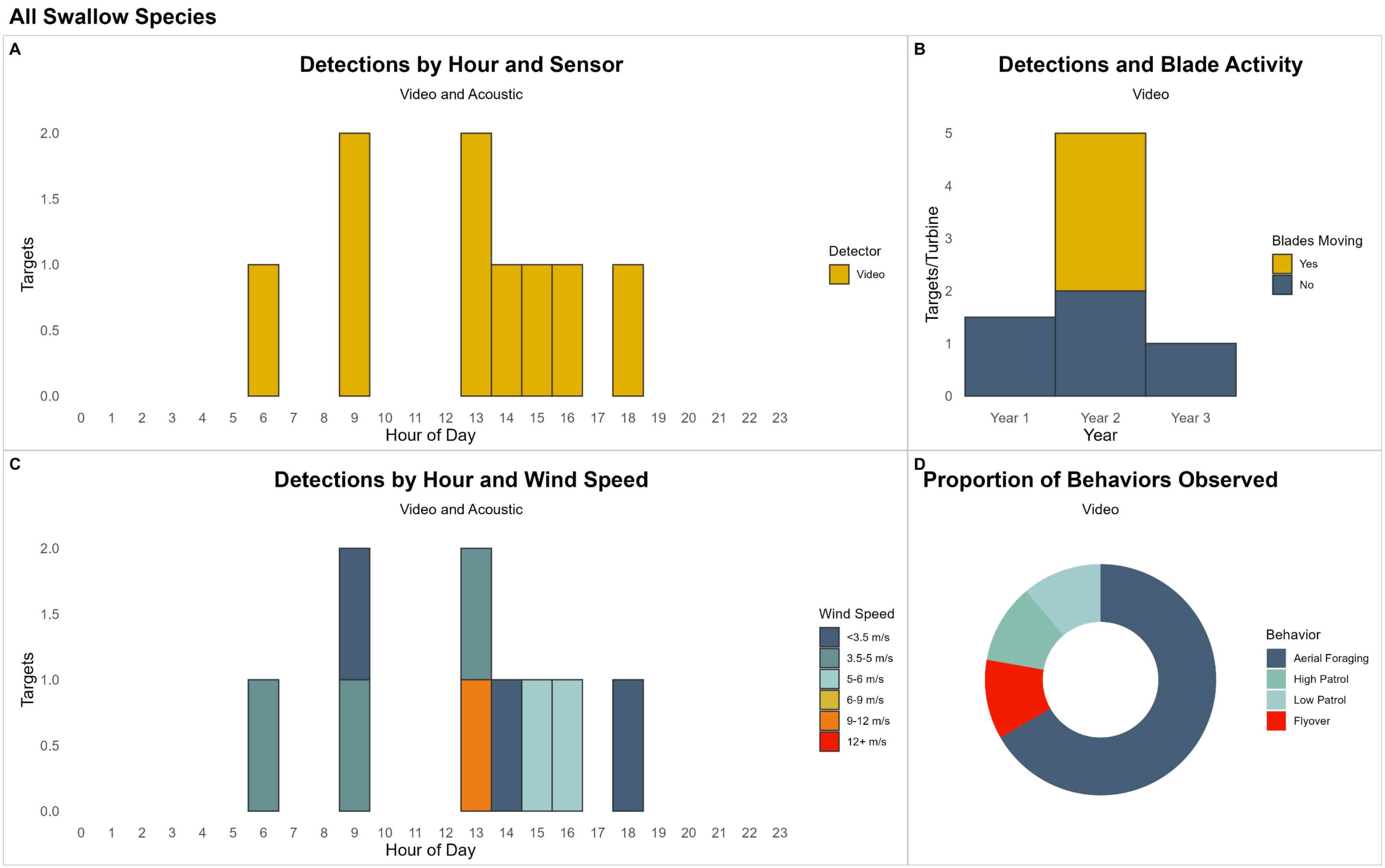


Figure 38. Swallow activity characterization by hour and year: A) Number of detections by hour for video and acoustic sensors, B) Number of detections by year when blades were moving and stationary, C) Number of detections by hour by wind speed, and D) Proportion of behavior observed across all three years.

Figure 39. Number of swallow detections at different wind speeds grouped by detector (A) and behavior (B).

Table 12. Bird Behavior by Species Observed When Blades are Spinning

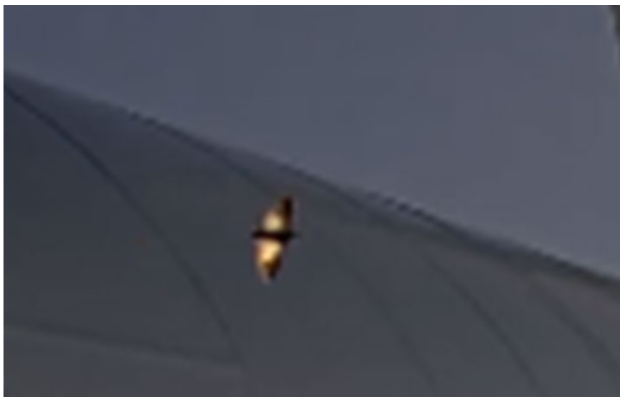
Subtype	Common Name	Scientific Name	Perching	Flyover	Microavoidance	Hawking	Low Patrol	Aerial Foraging	High Patrol	Attraction	Thermaling	Monopole Gleaning	Percent microavoidance
Cuckoo	Yellow-billed Cuckoo	*Coccyzus americanus*	2	0	0	0	0	1	0	0	0	0	0.0
Swift	Chimney Swift	*Chaetura pelagica*	0	0	0	0	0	2	0	0	0	0	0.0
Shorebird	Shorebird species		0	12	1	0	0	0	0	2	0	0	6.7
Gull	Laughing Gull	*Leucophaeus atricilla*	1	4	0	0	0	0	0	0	0	0	0.0
Gull	Herring Gull	*Larus argentatus*	39	9	0	0	3	0	1	0	0	0	0.0
Gull	Great Black-backed Gull	*Larus marinus*	0	12	1	0	0	0	0	0	2	0	6.67
Gull	Large Gull species		0	26	1	0	0	0	6	4	21	0	1.7
Gull	Small Gull species		0	1	0	0	0	0	1	0	0	0	0.0
Gull	Gull species		0	15	0	0	0	0	7	1	1	0	0.0
Pelican	American White Pelican	*Pelecanus erythrorhynchos*	0	15	0	0	0	0	0	0	0	0	0.0
Raptor	Osprey	*Pandion haliaetus*	30	1	0	0	0	0	0	0	0	0	0.0
Woodpecker	Northern Flicker	*Colaptes auratus*	1	0	0	0	0	0	0	0	0	0	0.0
Raptor	Peregrine Falcon	*Falco peregrinus*	15	0	6	6	1	1	0	0	0	0	20.7
Raptor	Raptor species		1	0	1	0	0	0	0	0	0	0	50.0
Passerine	Eastern Phoebe	*Sayornis phoebe*	0	0	0	0	0	1	0	0	0	0	0.0
Corvid	Corvid species		0	1	1	0	0	0	0	0	0	0	50.0
Hirundine	Hirundine species		0	1	0	0	0	1	1	0	0	0	0.0
Passerine	Brown Creeper	*Certhia americana*	0	0	3	0	0	4	0	0	0	1	37.5
Passerine	Winter Wren	*Troglodytes hiemalis*	0	0	2	0	0	8	3	0	0	0	15.4
Passerine	Wren species		0	0	2	0	0	2	0	0	0	0	50.0
Passerine	American Robin	*Turdus migratorius*	0	0	0	0	0	1	1	0	0	0	0.0
Passerine	American Pipit	*Anthus rubescens*	0	0	1	0	0	0	0	0	0	0	100.0
Passerine	Dark-eyed Junco	*Junco hyemalis*	1	0	0	0	0	0	0	0	0	0	0.0
Passerine	White-throated Sparrow	*Zonotrichia albicollis*	0	0	2	0	0	0	0	0	0	0	100.0
Passerine	Orchard Oriole	*Icterus spurius*	2	0	1	0	1	14	0	0	0	0	5.6

Subtype	Common Name	Scientific Name	Perching	Flyover	Microavoidance	Hawking	Low Patrol	Aerial Foraging	High Patrol	Attraction	Thermaling	Monopole Gleaning	Percent microavoidance
Passerine	Brown-headed Cowbird	*Molothrus ater*	0	0	0	0	1	3	1	0	0	0	0.0
Passerine	Common Grackle	*Quiscalus quiscula*	0	0	1	0	0	0	0	0	0	0	100.0
Passerine	Golden-winged Warbler	*Vermivora chrysoptera*	0	0	0	0	0	1	0	0	0	0	0.0
Passerine	Black-and-white Warbler	*Mniotilta varia*	0	0	0	1	0	2	1	0	0	0	0.0
Passerine	Hooded Warbler	*Setophaga citrina*	0	0	0	0	0	1	0	0	0	0	0.0
Passerine	American Redstart	*Setophaga ruticilla*	0	0	1	0	0	2	1	0	0	0	25.0
Passerine	Kirtland's Warbler*	*Setophaga kirtlandii*	0	0	0	0	1	0	0	0	0	0	0.0
Passerine	Cape May Warbler	*Setophaga tigrina*	0	0	1	1	0	7	0	0	0	0	11.1
Passerine	Magnolia Warbler	*Setophaga magnolia*	0	0	0	0	0	2	0	0	0	0	0.0
Passerine	Bay-breasted Warbler	*Setophaga castanea*	0	0	1	0	0	1	0	0	0	0	50.0
Passerine	Yellow Warbler	*Setophaga petechia*	4	0	0	0	0	0	0	0	0	0	0.0
Passerine	Palm Warbler	*Setophaga palmarum*	0	0	1	1	1	5	0	2	0	0	10.0
Passerine	Pine Warbler	*Setophaga pinus*	6	0	0	0	0	1	1	0	0	0	0.0
Passerine	Yellow-rumped Warbler	*Setophaga coronata*	1	0	0	2	0	8	0	0	0	0	0.0
Passerine	Setophaga species		13	0	3	11	0	18	1	0	0	2	6.3
Passerine	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	0	0	0	0	0	0	1	0	0	0	0.0
Passerine	Passerine species		23	2	19	8	13	48	15	3	0	4	14.1
Unid. Avian	Unidentified bird species		11	99	14	1	6	7	48	3	0	2	7.3

* State-listed as endangered with a probable identification

Relationships with Insect Activity

Over 7,000 insect detections occurred annually during the 3-year study. Insects included many butterflies, moths, and dragonflies (Figure 40), though only select detections were identified to species. Across the 3-year period of study, insect activity peaked during September and October and was lower during other periods (Figure 41). Within-day activity showed that insect activity peaked during the early morning hours (6:00–8:00) and then again in the late afternoon (16:00–18:00) (Figure 42). There was a moderate correlation between bat and insect activity ($\rho = 0.48$) (Figure 43) as well as passerine and insect activity ($\rho = 0.36$) (Figure 44).



Spodoptera frugiperda

Vanessa virginiensis

Polygonia interrogationis

Junonia coenia

Figure 40. Select butterfly and moth species detected during the spring, fall, and winter monitoring periods.

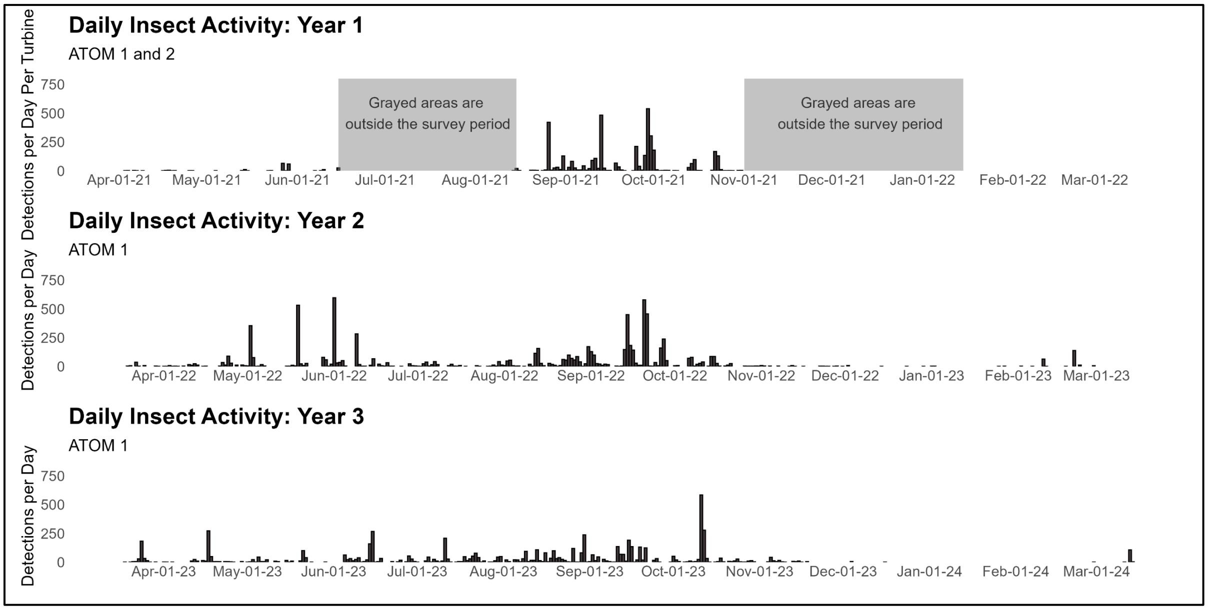


Figure 41. Temporal distribution of insect activity during the 3-year study.

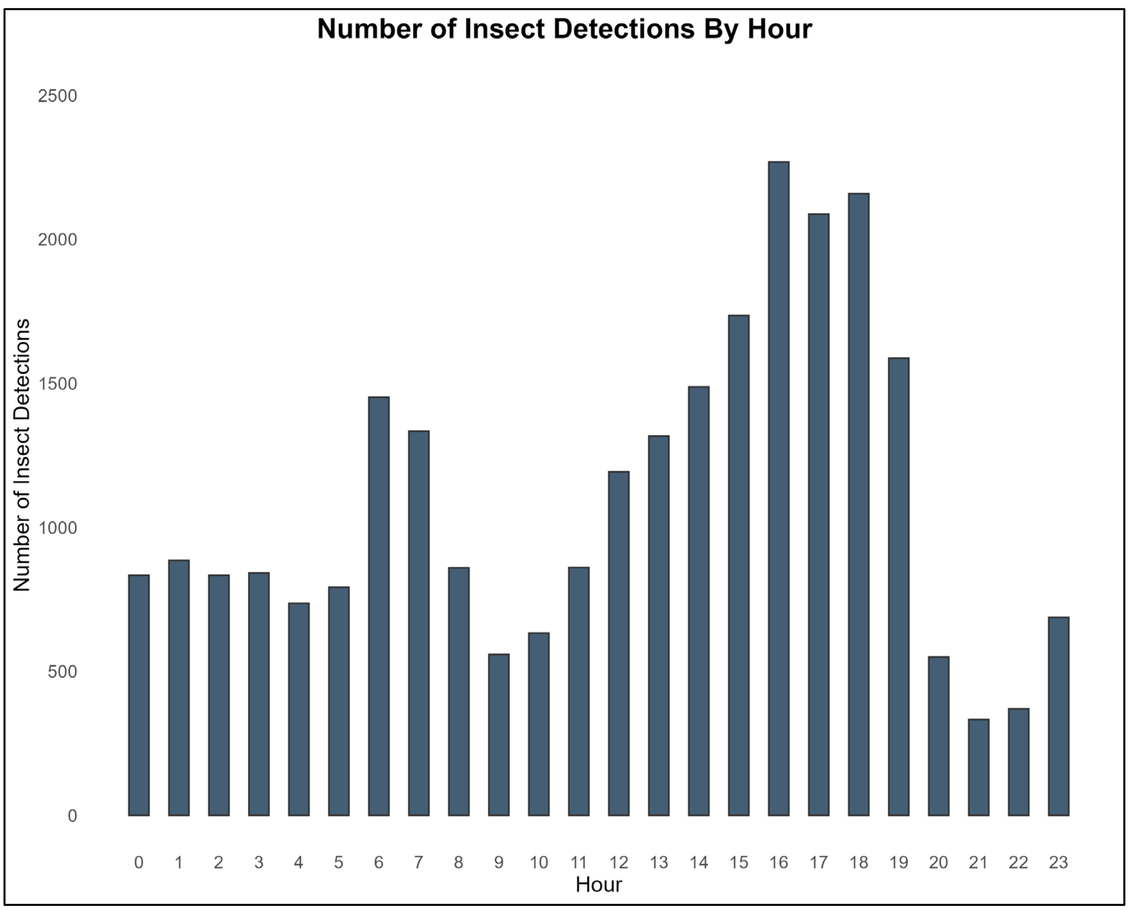


Figure 42. Within-day temporal distribution of insect activity during the 3-year study at the CVOW Pilot Project.

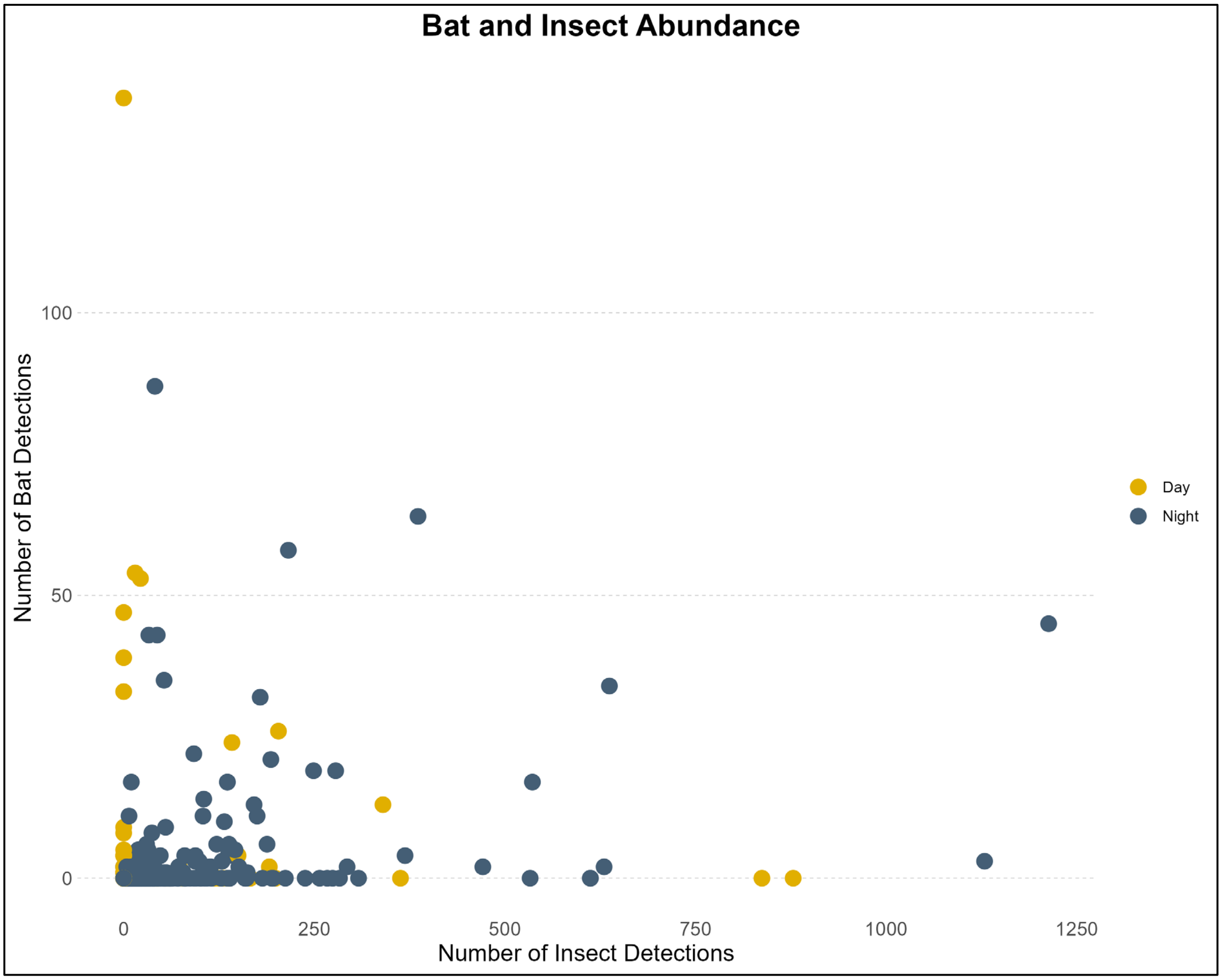


Figure 43. Relationship of bat and insect activity during the 3-year study.
Many overlapping points are not distinguishable.

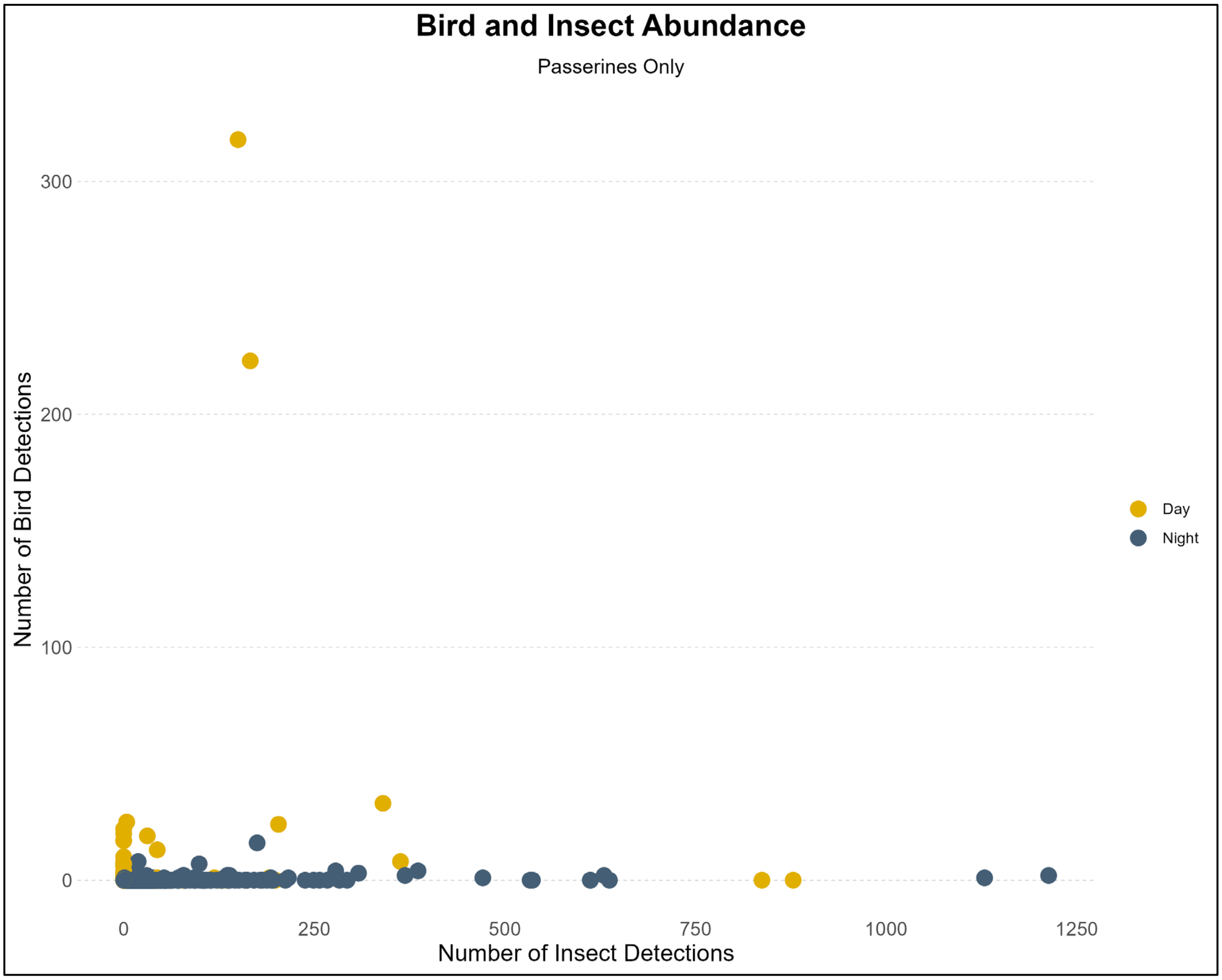


Figure 44. Relationship of passerine and insect activity during the 3-year study.
Many overlapping points are not distinguishable.

Discussion

Wildlife Data

During the three-year study no collisions were detected. Bird and bat activity in the offshore survey area is relatively low outside September and October, which contained 78% of bird and bat detections. This fall activity mostly represents southbound migration from breeding grounds to wintering grounds. We had higher bat activity during northerly winds during the fall, which was expected as these winds are favorable to southbound fall migration (Mabee et al. 2005). There was a decline in bat activity above wind speeds of 5 m/s and a further decline above 9 m/s (Figure 13), which was expected given that bats are typically more active when wind speeds are low (e.g., Hayes et al. 2019). This is significant because the cut-in speed for the turbines at the CVOW Pilot Project is between 3 and 5 m/s, which suggests that most bat activity could occur when the blades are not spinning. Furthermore, bat activity was lowest between 8:00 and 20:00, which means exposure would be less during this time (Figure 11a). Less bat activity when blades are spinning could reduce the likelihood of collisions and should be a consideration in collision risk model design. The association of passerines with northerly winds was expected given these winds are favorable to the southbound migration in the fall (Krietsch et al. 2020; Loring et al. 2020). With only 22% of passerine detections occurring when the wind speed was >5 m/s is notable due to the cut-in speed being 3–5 m/s for the turbines at the CVOW Pilot Project. Less bird activity when blades are spinning could reduce the likelihood of collisions and should be a consideration in collision risk model design.

Most (57%) bird activity occurred when turbine blades were not spinning; however, it is unknown whether this was a result of the lack of blade motion or because blades are less likely to be spinning at lower wind speeds when birds are more likely to be active. Foraging activity decreased as wind speed increased with flyovers being most frequent at higher wind speeds (Figure 16b). Most (65%) bat detections were recorded while the blades were spinning; however, it is not known if this was attraction to the moving objects or a willingness to forage at the higher wind speeds when the blades would normally be spinning.

Aerial foraging was the most observed behavior for passerines (Figure **20**d) and bats (Figure 11d) with perching being the second most common for passerines (Figure **20**d). Foraging behaviors have implications for collision risk when bats and birds are likely distracted while chasing prey (aerial foraging) or looking for prey (perching and hawking) and may be less aware of the presence of the blades (Smallwood and Bell 2020). However, most bird foraging behavior occurs when the blades are not moving (74% of aerial foraging, 74% of hawking, and 75% of monopole gleaning); therefore, it is likely that there is a lower risk of collision risk as birds are mostly foraging when turbine blades are not spinning.

Microavoidance behaviors were observed 45 times for bats and 65 times for birds (Table 12). Microavoidance reflects last-second action taken to avoid the turbine blades while in proximity to the blade surface (Cook et al. 2018). Microavoidance prevents a collision with the blade and is an essential behavior for reducing collision mortality.

The location of the CVOW Pilot Project appears to overlap with the migratory routes of species with quite different migratory strategies (Figure 45). This diversity in migratory strategies underscores the potential value of the location for foraging and resting for these species. Example species encountered at the turbines that have different migratory strategies include the following:

- Caribbean-wintering migrant ***Palm and Cape May Warblers***
- South American-wintering migrant ***Blackpoll Warbler and Bobolink***
- Cuban-wintering ***Northern Flicker***
- North Carolina and Florida-wintering ***Winter Wren and Brown Creeper***

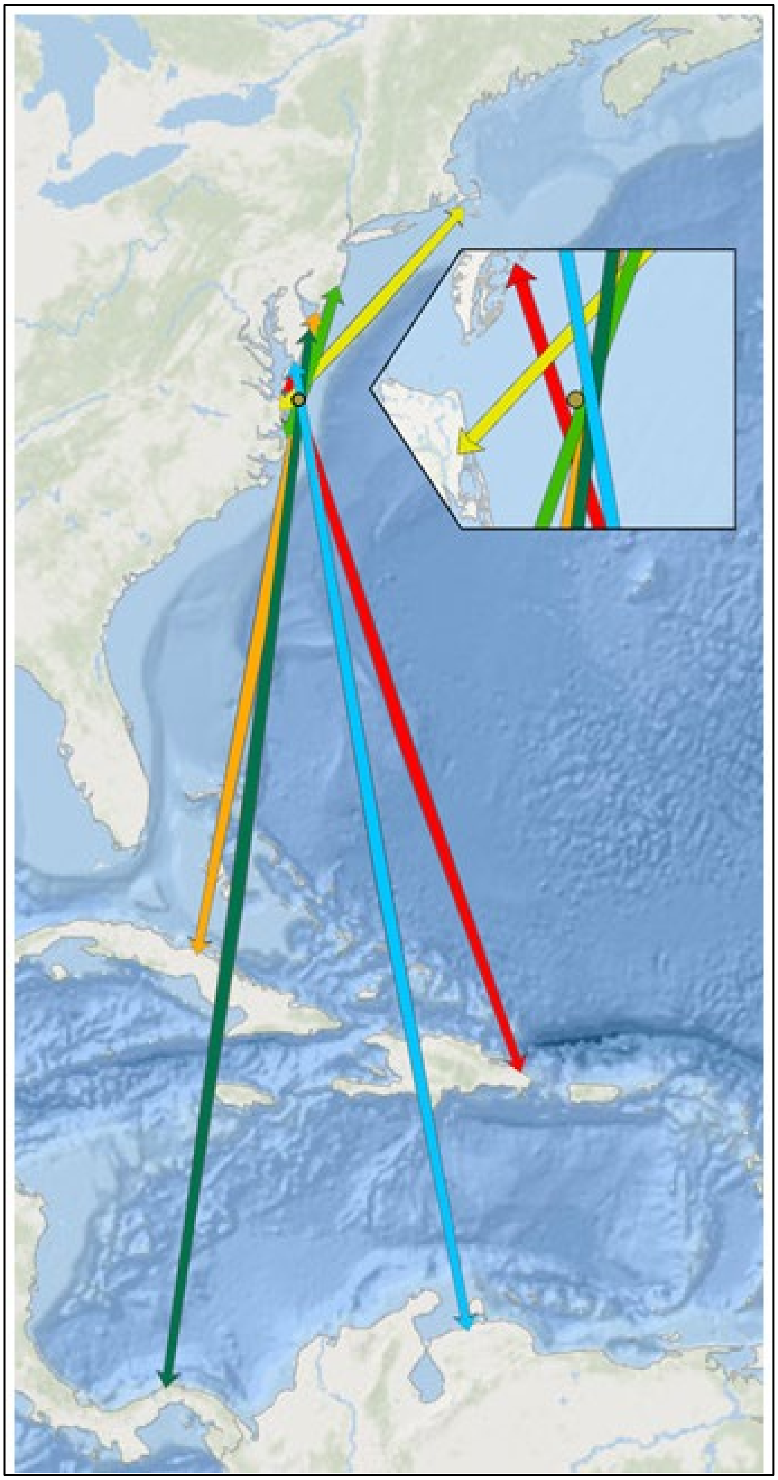


Figure 45. Migratory strategies of different birds that have been detected at the CVOW Pilot Project postconstruction monitoring study.

Sensor comparisons underscore the importance of a multi-sensor system for maximizing detections and species identifications (Robinson Willmott and Forcey 2014; Robinson Willmott et al. 2015, 2023). Nearly all bat species identifications were possible because of acoustic sensors, with only 5% of bat detections identified to species from the video alone. Acoustic sensors detected 75% of all bat detections but only 12% of bird detections. Video sensors found 87% of bird detections but only 25% of bat detections. Video was also critical for species identifications of birds that were not vocalizing. Acoustic sensors alone would have only detected 9 bird groups while video sensors would have captured 16 groups. Combined sensors captured 20 bird groups. Motus sensors did not have unique species groups, but 9 of the 11 species recorded by Motus were unique.

Lighting is likely a factor for insect (Wakefield et al. 2018) and bird (Kerlinger et al. 2010) attractions especially at night. At each turbine, there are three walkway lights, three navigation lights, one spotlight over the door, and one solid light illuminating the turbine number. The walkway lights and spotlight must be manually turned on and off and remain off unless personnel are on the platform. The navigation lights are amber LEDs with a photosensor. They automatically turn off and on depending on how much light the sensor receives. They are not set to any time schedule, and while they are typically on overnight, they could also come on during storm conditions or heavy fog due to low light conditions (Adam Cross, SGRE, personal communication). Many insects including *Spodoptera* moths are migratory (Nagoshi et al. 2012) and this likely explains their occurrence offshore along with other butterflies and dragonflies (Wikelski et al. 2006).

Challenges

Some challenges occurred during the 3-year monitoring study. During the spring in year 1, there was a system short that caused 3 weeks of lost data on ATOM 2. During the winter, a satellite modem was damaged by water intrusion that prevented remote repair of a disk storage issue on ATOM 1, causing 15 days of lost data on this system. Minor issues such as software bugs could be fixed remotely via the satellite modem. Other downtime in year 1 was due to power outages at the turbine. Overall reliability for year 1 was 93.25%. In years 2 and 3, periods of downtime were small and could mostly be attributed to power outages at the turbine. Reliability in years 2 and 3 was 95.5 % and 97.5%, respectively (Figure 3; Appendix A). While hardware issues cannot be repaired remotely, the software issues that arose during operation underscore the importance of having a system that can be updated, maintained, and repaired from a remote location.

While there was remote accessibility via the satellite modem, the speed of the connection and data transfer limits precluded us from using the connection to remotely transfer data. Use of the internet connection at the turbine was also not an option due to security concerns, though this may change in the future assuming proper cybersecurity standards are followed. Given internet access restrictions, data retrieval was done manually by traveling to each turbine system via boat approximately every 2–3 months. While this increased the labor required to operate the systems successfully, this schedule did ensure minimal data loss.

One issue limiting detections from the video data is the restricted viewshed of the blades when obscured by the monopole and the view of only one side of the turbine. The number of targets missed because of this issue is not known. Placement of additional systems around the monopole is restricted by access and safety concerns, which limits available space. Placement of systems on the nacelle could also improve video and acoustic detections in the upper portion of the RSZ; however, this was not part of this study. In addition, while the visible-light camera is useful during the day to augment detections from the thermal camera, it is of limited use at night. While artificial lighting does occur on the turbines, it does not provide sufficient lighting to assist with species identification. The artificial lights are amber LEDs with a photosensor. They automatically turn on in low light conditions (i.e., at night, during storm conditions, or in heavy fog).

During the 3-year study, acoustic detectors found 236 bird detections across 33 species and 1,016 bat detections across 3 species. Despite these detections, the offshore environment is challenging for acoustic detections, with many conditions that can mask detections of birds including operational turbine noise. High wind, turbine operations, or water-saturated microphones can cause excessive noise that can preclude detection of birds or bats (Figure 46).

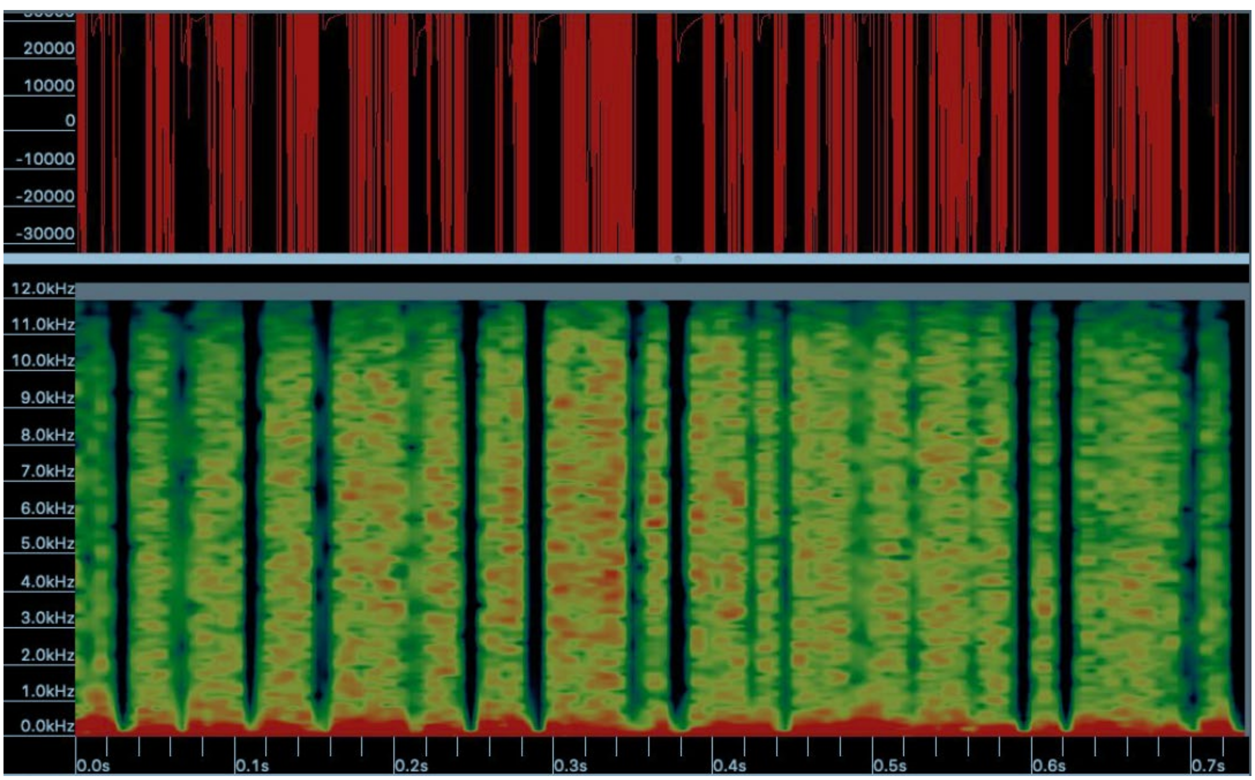


Figure 46. Example time signal (red, top) and spectrogram (bottom) of signal with high DC offset and high noise.

During the first year, the Motus setup at each turbine consisted of a Lotek SRX 800 receiver and two omnidirectional whip antennas. This antenna setup was originally chosen due to safety concerns with larger antennas. While a full formal calibration survey was not done with this setup, test-tag detections during turbine visits only occurred out to 1.25 mi (2 km) from the receiver. This system was also not capable of detecting the newer 434-Mhz tags.

In July 2022, the Motus receivers were upgraded to dual-band SensorStations manufactured by Cellular Tracking Technologies capable of detecting tags using the 166-MHz and the 434-MHz bands. In addition, antenna arrays at both turbines were upgraded to include 4 Yagi antennas and 2 Omni antennas. Turbine A01 uses 434-MHz Yagi antennas and 166-MHz Omni antennas; Turbine A02 uses 434-MHz Omni antennas and 166-MHz Yagi antennas. Antenna arrays used a split mast design where 2 Yagi antennas and 1 Omni antenna were on opposite sides of the monopole to minimize signal interference as much as possible. This upgrade improved the tag detection range from the Yagi antennas and allowed the 434-MHz tags to be detected. Despite the upgrades, there are known issues with this Motus setup generating false positive detections in the offshore environment; although, this issue can be addressed during the postprocessing of detections on the motus.org website. Formal calibration of this setup confirmed detection out to 3 mi (5 km) from the turbines (Figure 9, Figure 10).

Motus detection data often changed following initial identifications. Obviously spurious observations (e.g., sharp-tailed grouse) were discussed with USFWS and requests were made to Birds Canada to reprocess data. This is a known issue with noise in the offshore environment, especially with 166-MHz tags. Changing data on Motus.org made it challenging to report out as new observations could appear following the reporting period. Additionally, the maps that suggest flight routes have apparent errors and some tag detections appear to be found in random locations at random times even in species that are likely to occur and seem to have been detected at the turbines (see Appendix C).

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Appendices

Appendix A. ATOM System Uptime During the First Year of Operation

Date	A1IR	A1HD	A2IR	A2HD	Comment
04/01/2021	100	100	100	59	
04/02/2021	23	26	100	59	
04/03/2021	0	18	100	59	
04/04/2021	96	96	100	59	
04/05/2021	100	100	100	59	
04/06/2021	100	100	100	59	
04/07/2021	100	100	100	36	
04/08/2021	100	100	100	0	
04/09/2021	100	100	100	0	
04/10/2021	100	100	100	0	
04/11/2021	100	100	99	89	
04/12/2021	94	94	93	94	
04/13/2021	100	100	100	100	
04/14/2021	100	100	41	41	A2 maint
04/15/2021	88	88	0	0	A1 maint
04/16/2021	100	100	26	26	
04/17/2021	100	100	100	100	
04/18/2021	100	100	100	100	
04/19/2021	100	100	100	100	
04/20/2021	100	100	33	33	
04/21/2021	100	100	0	0	A2 no power
04/22/2021	100	100	0	0	A2 no power
04/23/2021	100	100	0	0	A2 no power
04/24/2021	100	100	0	0	A2 no power
04/25/2021	100	100	0	0	A2 no power
04/26/2021	100	100	0	0	A2 no power
04/27/2021	100	100	0	0	A2 no power
04/28/2021	100	100	0	0	A2 no power
04/29/2021	100	100	0	0	A2 no power
04/30/2021	100	100	0	0	A2 no power
05/01/2021	100	100	0	0	A2 no power
05/02/2021	100	100	0	0	A2 no power
05/03/2021	100	100	0	0	A2 no power

Date	A1IR	A1HD	A2IR	A2HD	Comment
05/04/2021	100	100	0	0	A2 no power
05/05/2021	100	100	0	0	A2 no power
05/06/2021	100	100	0	0	A2 no power
05/07/2021	100	100	0	0	A2 no power
05/08/2021	100	100	0	0	A2 no power
05/09/2021	100	100	0	0	A2 no power
05/10/2021	100	100	0	0	A2 no power
05/11/2021	56	56	0	0	A1 maint, A2 no power
05/12/2021	100	100	54	53	A2 maint
05/13/2021	100	100	96	96	A2 maint
05/14/2021	100	100	100	100	
05/15/2021	100	100	100	100	
05/16/2021	100	100	100	100	
05/17/2021	100	100	100	100	
05/18/2021	100	100	100	100	
05/19/2021	100	100	100	99	
05/20/2021	100	100	100	100	
05/21/2021	100	100	100	100	
05/22/2021	100	100	100	99	
05/23/2021	100	100	100	100	
05/24/2021	100	100	100	100	
05/25/2021	100	100	100	100	
05/26/2021	100	100	100	100	
05/27/2021	100	100	100	100	
05/28/2021	100	100	100	100	
05/29/2021	12	100	100	100	A1:video off, no sat modem
05/30/2021	0	100	100	100	A1:video off, no sat modem
05/31/2021	0	100	100	100	A1:video off, no sat modem
06/01/2021	42	100	100	100	A1:video off, no sat modem
06/02/2021	100	100	100	100	
06/03/2021	100	100	100	100	
06/04/2021	100	100	100	99	
06/05/2021	100	100	100	100	
06/06/2021	100	100	100	100	
06/07/2021	100	100	100	100	
06/08/2021	100	100	100	100	
06/09/2021	100	100	100	100	
06/10/2021	100	100	100	100	
06/11/2021	100	100	100	100	
06/12/2021	100	100	100	100	

Date	A1IR	A1HD	A2IR	A2HD	Comment
06/13/2021	100	100	100	100	
06/14/2021	100	100	100	100	
06/15/2021	100	100	100	100	
08/15/2021	100	100	100	100	
08/16/2021	100	100	100	100	
08/17/2021	100	100	100	100	
08/18/2021	49	47	100	100	
08/19/2021	100	100	100	100	
08/20/2021	99	100	100	100	A2 Martin visit,some corrupt files
08/21/2021	100	100	100	100	
08/22/2021	100	100	100	100	
08/23/2021	100	100	100	100	
08/24/2021	100	100	100	100	
08/25/2021	100	99	100	100	some corrupt files
08/26/2021	100	100	100	100	
08/27/2021	99	100	100	100	some corrupt files
08/28/2021	99	99	100	100	some corrupt files
08/29/2021	99	100	100	100	some corrupt files
08/30/2021	57	57	89	89	A1 & A2 turbine pwr out 1.5 hours
08/31/2021	100	100	100	100	
09/01/2021	100	100	100	100	
09/02/2021	100	100	100	100	
09/03/2021	100	100	100	100	
09/04/2021	100	100	100	100	
09/05/2021	100	100	100	100	
09/06/2021	48	48	48	48	A1&A2 turbine pwr out 12hrs
09/07/2021	100	100	100	100	
09/08/2021	100	100	100	100	
09/09/2021	100	100	100	100	
09/10/2021	100	100	100	100	
09/11/2021	100	100	100	100	
09/12/2021	100	100	100	100	atom down 13:26-15:26
09/13/2021	100	100	100	100	
09/14/2021	100	100	61	58	A2 data retrieval, HD camera replace
09/15/2021	100	100	100	100	A1 data retrieval, A2 Lotek repair
09/16/2021	100	100	100	100	
09/17/2021	99	100	100	100	
09/18/2021	100	100	100	100	
09/19/2021	100	100	100	100	
09/20/2021	99	100	100	100	

Date	A1IR	A1HD	A2IR	A2HD	Comment
09/21/2021	100	100	100	100	
09/22/2021	100	99	100	100	
09/23/2021	100	100	100	100	
09/24/2021	100	100	100	100	
09/25/2021	100	100	100	100	
09/26/2021	100	100	100	100	
09/27/2021	100	100	100	100	
09/28/2021	100	100	100	100	
09/29/2021	100	100	100	100	
09/30/2021	100	100	100	100	
10/01/2021	99	100	100	100	
10/02/2021	100	99	100	100	
10/03/2021	100	100	100	100	
10/04/2021	100	100	100	100	
10/05/2021	87	87	100	100	A1 turbine power out 3 hours
10/06/2021	100	100	90	90	A2 turbine power out 2.2 hours
10/07/2021	100	100	100	100	
10/08/2021	100	100	100	100	
10/09/2021	100	100	100	100	
10/10/2021	100	100	100	100	
10/11/2021	100	100	100	100	
10/12/2021	100	100	100	100	
10/13/2021	100	100	100	100	
10/14/2021	100	100	100	100	
10/15/2021	100	100	100	100	
10/16/2021	100	99	100	100	
10/17/2021	100	100	100	100	
10/18/2021	30	31	31	31	A1&A2 turbine pwr out starting 9:23:27 EDT
10/19/2021	0	0	0	0	A1&A2 turbine pwr out
10/20/2021	0	0	0	0	A1&A2 turbine pwr out
10/21/2021	37	37	37	37	A1&A2 turbine pwr out until 15:02 EDT
10/22/2021	100	100	100	100	
10/23/2021	100	100	100	100	
10/24/2021	100	100	100	100	
10/25/2021	100	100	100	100	
10/26/2021	100	100	100	100	
10/27/2021	100	100	100	100	
10/28/2021	100	100	100	100	
10/29/2021	100	100	100	100	
10/30/2021	100	100	100	100	

Date	A1IR	A1HD	A2IR	A2HD	Comment
10/31/2021	100	100	100	100	
01/15/2022	72	97	100	100	
01/16/2022	99	99	100	100	
01/17/2022	98	99	100	100	
01/18/2022	91	98	100	100	
01/19/2022	99	99	100	100	
01/20/2022	95	95	100	100	Chris trip to A1
01/21/2022	100	100	100	100	
01/22/2022	100	100	100	100	
01/23/2022	100	100	100	100	
01/24/2022	100	100	100	100	
01/25/2022	100	100	99	99	
01/26/2022	33	33	100	100	A1 data not saved
01/27/2022	0	0	100	100	A1 data not saved
01/28/2022	0	0	100	100	A1 data not saved
01/29/2022	0	0	100	100	A1 data not saved
01/30/2022	0	0	100	100	A1 data not saved
01/31/2022	0	0	100	100	A1 data not saved
02/01/2022	0	0	100	100	A1 data not saved
02/02/2022	0	0	100	100	A1 data not saved
02/03/2022	0	0	100	100	A1 data not saved
02/04/2022	0	0	100	100	A1 data not saved
02/05/2022	0	0	100	100	A1 data not saved
02/06/2022	0	0	100	100	A1 data not saved
02/07/2022	0	0	100	100	A1 data not saved
02/08/2022	0	0	100	100	A1 data not saved
02/09/2022	33	33	82	82	data retrieval A1 and A2
02/10/2022	100	100	1	2	
02/11/2022	100	100	27	23	
02/12/2022	100	100	100	100	
02/13/2022	100	100	100	100	
02/14/2022	100	100	100	100	
02/15/2022	100	100	100	100	
02/16/2022	100	100	100	99	
02/17/2022	100	100	100	100	
02/18/2022	100	100	99	98	
02/19/2022	100	100	100	98	
02/20/2022	100	100	100	100	
02/21/2022	100	100	100	100	
02/22/2022	100	100	97	96	

Date	A1IR	A1HD	A2IR	A2HD	Comment
02/23/2022	100	100	99	99	
02/24/2022	100	100	100	100	
02/25/2022	100	100	100	100	
02/26/2022	100	100	100	100	
02/27/2022	100	100	100	100	
02/28/2022	100	100	99	100	
03/01/2022	100	100	87	97	
03/02/2022	100	100	100	100	
03/03/2022	100	100	100	99	
03/04/2022	100	100	100	99	
03/05/2022	100	100	100	100	
03/06/2022	100	100	100	100	
03/07/2022	100	100	98	99	
03/08/2022	100	100	100	97	
03/09/2022	100	100	100	100	
03/10/2022	100	100	100	100	
03/11/2022	98	99	99	100	
03/12/2022	94	95	100	99	
03/13/2022	100	100	100	99	
03/14/2022	100	100	98	99	
03/15/2022	100	100	100	99	
03/16/2022	100	100			
03/17/2022	100	100			
03/18/2022	100	100			
03/19/2022	100	100			
03/20/2022	100	100			
03/21/2022	100	100			
03/22/2022	100	100			
03/23/2022	100	100			
03/24/2022	100	100			
03/25/2022	100	98			
03/26/2022	100	100			
03/27/2022	100	100			
03/28/2022	100	98			
03/29/2022	100	100			
03/30/2022	98	97			
03/31/2022	100	100			
04/01/2022	100	100			
04/01/2022	100	100			
04/02/2022	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
04/03/2022	100	100			
04/04/2022	100	100			
04/05/2022	100	100			
04/06/2022	100	98			
04/07/2022	100	100			
04/08/2022	100	100			
04/09/2022	100	100			
04/10/2022	100	100			
04/11/2022	100	100			
04/12/2022	100	100			
04/13/2022	100	100			
04/14/2022	98	100			
04/15/2022	100	100			
04/16/2022	100	100			
04/17/2022	100	100			
04/18/2022	100	100			
04/19/2022	100	100			
04/20/2022	100	100			
04/21/2022	100	100			
04/22/2022	95	98			
04/23/2022	100	100			
04/24/2022	100	100			
04/25/2022	100	100			
04/26/2022	100	100			
04/27/2022	100	100			
04/28/2022	100	100			
04/29/2022	100	100			
04/30/2022	100	100			
05/01/2022	100	100			
05/01/2022	100	100			
05/02/2022	100	100			
05/03/2022	100	100			
05/04/2022	100	100			
05/05/2022	100	100			
05/06/2022	100	100			
05/07/2022	100	100			
05/08/2022	100	100			
05/09/2022	100	100			
05/10/2022	100	100			
05/11/2022	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
05/12/2022	100	100			
05/13/2022	100	98			
05/14/2022	98	98			
05/15/2022	100	100			
05/16/2022	100	100			
05/17/2022	100	98			
05/18/2022	100	100			
05/19/2022	100	100			
05/20/2022	100	100			
05/21/2022	100	100			
05/22/2022	100	100			
05/23/2022	100	100			
05/24/2022	100	100			
05/25/2022	100	100			
05/26/2022	100	100			
05/27/2022	100	100			
05/28/2022	100	100			
05/29/2022	100	100			
05/30/2022	100	100			
05/31/2022	20	21			data retrieval trip
06/01/2022	88	89			
06/01/2022	88	89			
06/02/2022	100	100			
06/03/2022	100	100			
06/04/2022	100	100			
06/05/2022	100	100			
06/06/2022	100	100			
06/07/2022	100	100			
06/08/2022	100	100			
06/09/2022	100	100			
06/10/2022	100	100			
06/11/2022	100	100			
06/12/2022	100	100			
06/13/2022	100	100			
06/14/2022	100	100			
06/15/2022	100	100			
06/16/2022	100	100			
06/17/2022	98	100			
06/18/2022	100	100			
06/19/2022	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
06/20/2022	49	55			data retrieval trip
06/21/2022	95	98			
06/22/2022	100	100			
06/23/2022	98	98			
06/24/2022	97	95			
06/25/2022	100	100			
06/26/2022	97	95			
06/27/2022	98	98			
06/28/2022	100	100			
06/29/2022	98	98			
06/30/2022	95	100			
07/01/2022	90	93			
07/01/2022	90	93			
07/02/2022	98	96			
07/03/2022	95	84			
07/04/2022	93	98			
07/05/2022	97	93			
07/06/2022	100	100			
07/07/2022	100	100			
07/08/2022	100	100			
07/09/2022	100	100			
07/10/2022	100	100			
07/11/2022	100	100			
07/12/2022	100	100			
07/13/2022	100	100			
07/14/2022	100	100			
07/15/2022	100	100			
07/16/2022	99	100			
07/17/2022	100	100			
07/18/2022	58	60			2 hr no video, storage disk issues
07/19/2022	0	0			turbine power off
07/20/2022	0	0			turbine power off
07/21/2022	0	0			turbine power off
07/22/2022	0	0			turbine power off
07/23/2022	100	100			
07/24/2022	99	100			
07/25/2022	100	100			
07/26/2022	100	100			
07/27/2022	100	100			
07/28/2022	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
07/29/2022	35	40			data retrieval trip, motus install
07/30/2022	100	100			
07/31/2022	100	100			
08/01/2022	96	100			
08/01/2022	96	100			
08/02/2022	100	100			
08/03/2022	100	100			
08/04/2022	100	100			
08/05/2022	58	21			HD night deleted for space
08/06/2022	100	18			HD night deleted for space
08/07/2022	100	100			
08/08/2022	100	100			
08/09/2022	100	100			
08/10/2022	99	100			
08/11/2022	100	100			
08/12/2022	100	61			HD night deleted for space
08/13/2022	100	17			HD night deleted for space
08/14/2022	100	100			
08/15/2022	100	100			
08/16/2022	100	100			
08/17/2022	100	100			
08/18/2022	100	100			
08/19/2022	0	0			no video, disk/connection issues
08/20/2022	0	0			no video, disk/connection issues
08/21/2022	0	0			no video, disk/connection issues
08/22/2022	100	90			
08/23/2022	88	72			
08/24/2022	77	62			
08/25/2022	100	95			
08/26/2022	100	31			HD night deleted for space
08/27/2022	100	0			HD night deleted for space
08/28/2022	100	0			HD night deleted for space
08/29/2022	0	0			HD night deleted for space
08/30/2022	100	0			HD night deleted for space
08/31/2022	100	0			HD night deleted for space
09/01/2022	79	0			HD night deleted for space
09/01/2022	79	0			HD night deleted for space
09/02/2022	0	0			HD night deleted for space
09/03/2022	100	0			HD night deleted for space
09/04/2022	100	0			HD night deleted for space

Date	A1IR	A1HD	A2IR	A2HD	Comment
09/05/2022	100	0			HD night deleted for space
09/06/2022	100	0			HD night deleted for space
09/07/2022	99	0			HD night deleted for space
09/08/2022	99	0			HD night deleted for space
09/09/2022	100	0			HD night deleted for space
09/10/2022	100	0			HD night deleted for space
09/11/2022	100	0			HD night deleted for space
09/12/2022	37	0			HD night deleted for space
09/13/2022	100	0			HD night deleted for space
09/14/2022	100	0			HD night deleted for space
09/15/2022	100	0			HD night deleted for space
09/16/2022	100	0			HD night deleted for space
09/17/2022	100	0			HD night deleted for space
09/18/2022	100	0			HD night deleted for space
09/19/2022	100	0			HD night deleted for space
09/20/2022	100	0			HD night deleted for space
09/21/2022	100	0			HD night deleted for space
09/22/2022	100	0			HD night deleted for space
09/23/2022	100	0			HD night deleted for space
09/24/2022	100	0			HD night deleted for space
09/25/2022	98	0			HD night deleted for space
09/26/2022	99	0			HD night deleted for space
09/27/2022	98	0			HD night deleted for space
09/28/2022	98	0			HD night deleted for space
09/29/2022	100	100			
09/30/2022	100	100			
10/01/2022	100	100			
10/01/2022	100	100			
10/02/2022	100	100			
10/03/2022	100	100			
10/04/2022	100	100			
10/05/2022	97	100			
10/06/2022	100	100			
10/07/2022	100	100			
10/08/2022	90	99			
10/09/2022	95	100			
10/10/2022	75	77			
10/11/2022	100	100			
10/12/2022	100	100			
10/13/2022	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
10/14/2022	100	100			
10/15/2022	100	100			
10/16/2022	100	100			
10/17/2022	100	100			
10/18/2022	100	100			
10/19/2022	54	53			
10/20/2022	100	100			
10/21/2022	100	100			
10/22/2022	100	100			
10/23/2022	100	100			
10/24/2022	100	100			
10/25/2022	100	100			
10/26/2022	100	100			
10/27/2022	100	100			
10/28/2022	100	100			
10/29/2022	100	100			
10/30/2022	100	100			
10/31/2022	100	100			
11/01/2022	100	100			
11/01/2022	100	100			
11/02/2022	100	100			
11/03/2022	100	100			
11/04/2022	100	100			
11/05/2022	100	100			
11/06/2022	100	100			
11/07/2022	100	100			
11/08/2022	100	100			
11/09/2022	100	100			
11/10/2022	100	100			
11/11/2022	100	100			
11/12/2022	100	100			
11/13/2022	100	100			
11/14/2022	100	100			
11/15/2022	65	65			
11/16/2022	100	100			
11/17/2022	98	98			
11/18/2022	100	100			
11/19/2022	100	100			
11/20/2022	100	100			
11/21/2022	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
11/22/2022	100	100			
11/23/2022	100	100			
11/24/2022	100	100			
11/25/2022	100	100			
11/26/2022	100	100			
11/27/2022	100	100			
11/28/2022	100	100			
11/29/2022	100	100			
11/30/2022	100	100			
12/01/2022	100	100			
12/01/2022	100	100			
12/02/2022	100	100			
12/03/2022	100	100			
12/04/2022	100	100			
12/05/2022	92	88			
12/06/2022	100	100			
12/07/2022	100	100			
12/08/2022	100	100			
12/09/2022	100	100			
12/10/2022	100	100			
12/11/2022	100	100			
12/12/2022	47	46			
12/13/2022	100	100			
12/14/2022	100	100			
12/15/2022	100	100			
12/16/2022	51	50			
12/17/2022	0	0			
12/18/2022	0	0			
12/19/2022	0	0			
12/20/2022	0	0			
12/21/2022	0	0			
12/22/2022	100	100			
12/23/2022	100	100			
12/24/2022	100	100			
12/25/2022	100	100			
12/26/2022	100	100			
12/27/2022	100	100			
12/28/2022	100	100			
12/29/2022	100	100			
12/30/2022	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
12/31/2022	99	100			
01/01/2023	100	100			
01/01/2023	100	100			
01/02/2023	100	100			
01/03/2023	100	100			
01/04/2023	100	100			
01/05/2023	100	100			
01/06/2023	100	100			
01/07/2023	100	100			
01/08/2023	100	100			
01/09/2023	100	100			
01/10/2023	100	100			
01/11/2023	100	100			
01/12/2023	100	100			
01/13/2023	100	99			
01/14/2023	100	100			
01/15/2023	100	100			
01/16/2023	100	100			
01/17/2023	100	100			
01/18/2023	100	100			
01/19/2023	100	100			
01/20/2023	100	100			
01/21/2023	100	100			
01/22/2023	100	100			
01/23/2023	100	100			
01/24/2023	100	100			
01/25/2023	100	100			
01/26/2023	100	100			
01/27/2023	100	100			
01/28/2023	100	100			
01/29/2023	100	100			
01/30/2023	100	100			
01/31/2023	100	100			
02/01/2023	100	100			
02/01/2023	100	100			
02/02/2023	100	100			
02/03/2023	100	100			
02/04/2023	100	100			
02/05/2023	100	100			
02/06/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
02/07/2023	99	99			
02/08/2023	99	100			
02/09/2023	100	100			
02/10/2023	100	100			
02/11/2023	100	100			
02/12/2023	100	100			
02/13/2023	100	100			
02/14/2023	100	100			
02/15/2023	100	100			
02/16/2023	100	100			
02/17/2023	100	100			
02/18/2023	100	100			
02/19/2023	100	100			
02/20/2023	100	100			
02/21/2023	100	100			
02/22/2023	100	100			
02/23/2023	100	100			
02/24/2023	100	100			
02/25/2023	100	100			
02/26/2023	100	100			
02/27/2023	100	100			
02/28/2023	100	100			
03/01/2023	100	100			
03/02/2023	100	100			
03/03/2023	100	100			
03/04/2023	100	100			
03/05/2023	100	100			
03/06/2023	100	100			
03/07/2023	100	100			
03/08/2023	100	100			
03/09/2023	100	100			
03/10/2023	100	100			
03/11/2023	100	100			
03/12/2023	100	100			
03/13/2023	100	100			
03/14/2023	100	100			
03/15/2023	100	100			
03/16/2023	100	100			
03/17/2023	100	100			
03/18/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
03/19/2023	100	100			
03/20/2023	100	100			
03/21/2023	100	100			
03/22/2023	100	100			
03/23/2023	100	100			
03/24/2023	100	100			
03/25/2023	100	100			
03/26/2023	100	100			
03/27/2023	100	100			
03/28/2023	100	100			
03/29/2023	100	100			
03/30/2023	100	100			
03/31/2023	100	100			
04/01/2023	100	100			
04/01/2023	100	100			
04/02/2023	100	100			
04/03/2023	100	100			
04/04/2023	70	72			turbine visit, disk swap
04/05/2023	100	100			
04/06/2023	100	100			
04/07/2023	100	100			
04/08/2023	100	100			
04/09/2023	100	100			
04/10/2023	100	100			
04/11/2023	100	100			
04/12/2023	100	100			
04/13/2023	100	100			
04/14/2023	100	100			
04/15/2023	100	100			
04/16/2023	100	100			
04/17/2023	100	100			
04/18/2023	100	100			
04/19/2023	100	100			
04/20/2023	100	100			
04/21/2023	100	100			
04/22/2023	100	100			
04/23/2023	100	100			
04/24/2023	100	100			
04/25/2023	100	100			
04/26/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
04/27/2023	100	100			
04/28/2023	100	100			
04/29/2023	100	100			
04/30/2023	100	100			
05/01/2023	100	100			
05/01/2023	100	100			
05/02/2023	100	100			
05/03/2023	100	100			
05/04/2023	100	100			
05/05/2023	100	100			
05/06/2023	100	100			
05/07/2023	100	100			
05/08/2023	0	0			turbine lost power for 34 hours, SGRE confirmed
05/09/2023	0	0			turbine lost power for 34 hours, SGRE confirmed
05/10/2023	0	0			turbine lost power for 34 hours, SGRE confirmed
05/11/2023	100	100			
05/12/2023	100	100			
05/13/2023	100	100			
05/14/2023	100	100			
05/15/2023	100	100			
05/16/2023	100	100			
05/17/2023	100	100			
05/18/2023	100	100			
05/19/2023	100	100			
05/20/2023	100	100			
05/21/2023	100	100			
05/22/2023	100	100			
05/23/2023	100	100			
05/24/2023	100	100			
05/25/2023	100	100			
05/26/2023	100	100			
05/27/2023	100	100			
05/28/2023	100	100			
05/29/2023	100	100			
05/30/2023	100	100			
05/31/2023	100	100			
06/01/2023	100	100			
06/01/2023	100	100			
06/02/2023	100	100			
06/03/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
06/04/2023	100	100			
06/05/2023	100	100			
06/06/2023	100	100			
06/07/2023	100	100			
06/08/2023	100	100			
06/09/2023	100	100			
06/10/2023	100	100			
06/11/2023	100	100			
06/12/2023	100	100			
06/13/2023	100	100			
06/14/2023	100	100			
06/15/2023	100	100			
06/16/2023	100	100			
06/17/2023	100	100			
06/18/2023	100	100			
06/19/2023	45	0			disk swp, turbine power off for 2 hours, hd video stopped overnight
06/20/2023	100	0			hd video stopped over previous night
06/21/2023	89	90			
06/22/2023	46	45			
06/23/2023	100	100			
06/24/2023	100	100			
06/25/2023	100	100			
06/26/2023	100	100			
06/27/2023	100	97			
06/28/2023	100	100			
06/29/2023	100	100			
06/30/2023	100	100			
07/01/2023	100	100			
07/01/2023	100	100			
07/02/2023	100	100			
07/03/2023	100	100			
07/04/2023	100	100			
07/05/2023	100	100			
07/06/2023	100	100			
07/07/2023	100	100			
07/08/2023	100	100			
07/09/2023	100	100			
07/10/2023	100	100			
07/11/2023	100	100			
07/12/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
07/13/2023	100	100			
07/14/2023	100	100			
07/15/2023	100	100			
07/16/2023	100	100			
07/17/2023	100	100			
07/18/2023	100	100			
07/19/2023	100	100			
07/20/2023	92	92			
07/21/2023	100	100			
07/22/2023	100	100			
07/23/2023	100	100			
07/24/2023	100	100			
07/25/2023	100	100			
07/26/2023	100	100			
07/27/2023	100	100			
07/28/2023	100	100			
07/29/2023	100	100			
07/30/2023	100	100			
07/31/2023	0	0			turbine power out as of 14:28 UTC
08/01/2023	0	0			turbine power out all day
08/01/2023	0	0			turbine power out all day
08/02/2023	0	0			turbine power out until 16:28 UTC
08/03/2023	100	100			
08/04/2023	100	100			
08/05/2023	100	100			
08/06/2023	100	100			
08/07/2023	98	100			
08/08/2023	100	100			
08/09/2023	100	100			
08/10/2023	100	100			
08/11/2023	100	100			
08/12/2023	100	100			
08/13/2023	100	100			
08/14/2023	100	100			
08/15/2023	100	100			
08/16/2023	100	100			
08/17/2023	100	100			
08/18/2023	100	100			
08/19/2023	100	100			
08/20/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
08/21/2023	100	100			
08/22/2023	100	100			
08/23/2023	100	100			
08/24/2023	100	100			
08/25/2023	100	100			
08/26/2023	100	100			
08/27/2023	100	100			
08/28/2023	100	100			
08/29/2023	100	100			
08/30/2023	100	100			
08/31/2023	100	100			
09/01/2023	100	100			
09/01/2023	100	100			
09/02/2023	100	100			
09/03/2023	100	100			
09/04/2023	100	100			
09/05/2023	100	100			
09/06/2023	0	0			data retrieval
09/07/2023	100	100			
09/08/2023	100	100			
09/09/2023	100	100			
09/10/2023	100	100			
09/11/2023	97	98			
09/12/2023	56	57			
09/13/2023	100	100			
09/14/2023	100	100			
09/15/2023	100	100			
09/16/2023	100	100			
09/17/2023	100	100			
09/18/2023	100	100			
09/19/2023	100	100			
09/20/2023	100	100			
09/21/2023	100	100			
09/22/2023	100	100			
09/23/2023	100	100			
09/24/2023	100	100			
09/25/2023	100	100			
09/26/2023	100	100			
09/27/2023	100	100			
09/28/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
09/29/2023	100	100			
09/30/2023	100	100			
10/01/2023	100	100			
10/01/2023	100	100			
10/02/2023	100	100			
10/03/2023	92	98			
10/04/2023	100	100			
10/05/2023	100	100			
10/06/2023	100	100			
10/07/2023	100	100			
10/08/2023	100	100			
10/09/2023	100	100			
10/10/2023	100	100			
10/11/2023	100	100			
10/12/2023	100	100			
10/13/2023	100	100			
10/14/2023	100	100			
10/15/2023	100	100			
10/16/2023	100	100			
10/17/2023	100	100			
10/18/2023	100	100			
10/19/2023	100	100			
10/20/2023	100	100			
10/21/2023	100	100			
10/22/2023	100	100			
10/23/2023	100	100			
10/24/2023	100	100			
10/25/2023	100	100			
10/26/2023	100	100			
10/27/2023	100	100			
10/28/2023	100	100			
10/29/2023	100	100			
10/30/2023	100	100			
10/31/2023	100	100			
11/01/2023	100	100			
11/01/2023	100	100			
11/02/2023	100	100			
11/03/2023	100	100			
11/04/2023	100	100			
11/05/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
11/06/2023	100	100			
11/07/2023	98	98			data retrieval
11/08/2023	100	100			
11/09/2023	100	100			
11/10/2023	100	100			
11/11/2023	100	100			
11/12/2023	100	100			
11/13/2023	100	100			
11/14/2023	100	100			
11/15/2023	100	100			
11/16/2023	100	100			
11/17/2023	100	100			
11/18/2023	100	100			
11/19/2023	100	100			
11/20/2023	100	100			
11/21/2023	100	100			
11/22/2023	100	98			
11/23/2023	100	100			
11/24/2023	100	100			
11/25/2023	100	100			
11/26/2023	100	100			
11/27/2023	100	100			
11/28/2023	100	100			
11/29/2023	100	100			
11/30/2023	100	100			
12/01/2023	100	100			
12/01/2023	100	100			
12/02/2023	100	100			
12/03/2023	100	100			
12/04/2023	98	98			
12/05/2023	98	98			data retrieval
12/06/2023	100	100			
12/07/2023	100	100			
12/08/2023	100	100			
12/09/2023	100	100			
12/10/2023	100	100			
12/11/2023	100	100			
12/12/2023	100	100			
12/13/2023	100	100			
12/14/2023	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
12/15/2023	0	0			4.5 hours power outage
12/16/2023	100	100			
12/17/2023	100	100			
12/18/2023	100	100			
12/19/2023	100	100			
12/20/2023	85	85			
12/21/2023	0	0			power outage
12/22/2023	0	0			
12/23/2023	100	100			
12/24/2023	100	100			1 hour power outage
12/25/2023	100	100			
12/26/2023	100	100			
12/27/2023	100	100			
12/28/2023	100	100			
12/29/2023	100	100			
12/30/2023	100	100			
12/31/2023	100	100			
01/01/2024	100	100			
01/01/2024	100	100			
01/02/2024	100	100			
01/03/2024	100	100			
01/04/2024	100	100			
01/05/2024	100	100			
01/06/2024	100	100			
01/07/2024	100	100			
01/08/2024	100	100			
01/09/2024	100	100			
01/10/2024	97	99			
01/11/2024	100	100			
01/12/2024	100	100			
01/13/2024	100	100			
01/14/2024	100	100			
01/15/2024	100	100			
01/16/2024	100	100			
01/17/2024	100	100			
01/18/2024	100	100			
01/19/2024	100	100			
01/20/2024	100	100			
01/21/2024	100	100			
01/22/2024	94	95			

Date	A1IR	A1HD	A2IR	A2HD	Comment
01/23/2024	0	0			
01/24/2024	0	0			
01/25/2024	0	0			
01/26/2024	0	0			
01/27/2024	100	100			
01/28/2024	100	100			
01/29/2024	100	100			
01/30/2024	100	100			
01/31/2024	100	100			
02/01/2024	100	100			
02/01/2024	100	100			
02/02/2024	99	99			data retrieval
02/03/2024	100	100			
02/04/2024	100	100			
02/05/2024	100	100			
02/06/2024	100	100			
02/07/2024	100	100			
02/08/2024	100	100			
02/09/2024	100	100			
02/10/2024	100	100			
02/11/2024	100	100			
02/12/2024	100	100			
02/13/2024	100	100			
02/14/2024	100	100			
02/15/2024	100	100			
02/16/2024	100	100			
02/17/2024	100	100			
02/18/2024	100	100			
02/19/2024	100	100			
02/20/2024	100	100			
02/21/2024	100	100			
02/22/2024	100	100			
02/23/2024	100	100			
02/24/2024	100	100			
02/25/2024	100	100			
02/26/2024	100	100			
02/27/2024	100	100			
02/28/2024	100	100			
02/29/2024	100	100			
03/01/2024	100	100			

Date	A1IR	A1HD	A2IR	A2HD	Comment
03/01/2024	100	100			
03/02/2024	100	100			
03/03/2024	100	100			
03/04/2024	100	100			
03/05/2024	0	0			
03/06/2024	100	100			
03/07/2024	100	100			
03/08/2024	100	100			
03/09/2024	100	100			
03/10/2024	100	100			
03/11/2024	100	100			
03/12/2024	100	100			
03/13/2024	100	100			
03/14/2024	100	100			
03/15/2024	100	100			
03/16/2024	100	100			
03/17/2024	100	100			
03/18/2024	100	100			
03/19/2024	100	100			
03/20/2024	100	100			
03/21/2024	100	100			
03/22/2024	100	100			
03/23/2024	100	100			
03/24/2024	100	100			
03/25/2024	100	100			
03/26/2024	100	100			
03/27/2024	100	100			
03/28/2024	100	100			
03/29/2024	100	100			
03/30/2024	100	100			
03/31/2024	100	100			
04/01/2024	100	100			

Appendix B. Calibration

Video Calibration

Prior to testing, we reviewed the body size and wingspan for 75 bird species likely to or known to occur in the offshore environment. Bird species were reviewed from the following families: goose, swan, duck, loon, grebe, fulmar, petrel, shearwater, storm-petrel, booby, gannet, cormorant, pelican, Ardeidae, raptor, shorebird, phalarope, skua, auk, gull, tern, sterna tern, and passerines. We binned the body size and wingspans using the natural breaks classification to generate 5 average bird size categories to represent 5 average categories of birds (Table B-1).

Table B-1. Dimensions of Targets

Target	Body Length (cm)	Wingspan (cm)
1	12.3	17.1
2	20.8	46.6
3	39.5	80.5
4	58.7	109.0
5	99.6	163.0

For each target size, we fabricated two foam targets to be carried underneath an operating drone. For each of the 5 bird target sizes, two physical models were made: wings entirely extended, and wings partially folded in to simulate diving or other movements where wings are not fully extended (Figure B-1). Each target was painted black to increase infrared (IR) visibility for the ATOM system and to simulate body heat from a bird or bat.

ATOM testing was conducted along the apron of a local grass airstrip. Due to the 400-ft altitude restriction of unmanned aircraft system (UAS) flights enforced by the Federal Aviation Administration (FAA), an overhead pass of the drone was performed 400 ft above the ATOM system. This was done to ensure comparability with subsequent drone flights when the ATOM system would be tilted so that longer distances could be tested between ATOM and the drone. Following this 400-ft test flight, the ATOM system was tilted to an angle of 22 degrees (Figure B-2). This allowed testing to use the hypotenuse distance to approximate the vertical distance from the ATOM system while still accommodating the 400-ft FAA restriction. Twenty-two degrees was chosen to allow 1,000 ft of hypotenuse distance. This is farther than the maximum distance from the turbine platform to the top of the rotor swept area (187 m; 613 ft).

During testing, the ATOM system was powered up and operated normally while the physical bird models were attached to the drone and flown at varying distances from the ATOM system. The test drone recorded its GPS position at 0.2-s intervals. The drone and ATOM clocks were synchronized, and each GPS position reading was paired with the temporally nearest IR video frame. For each set of GPS coordinates, a distance (d) was computed relative to the ATOM system (Figure B-3). This distance is equivalent to the altitude above the ATOM system for a conventional vertically oriented ATOM system. Distance d is calculated by converting the GPS latitude (λ) and altitude (α) to Cartesian coordinates y and z relative to the ATOM system. A constant of 111,132 m per degree of latitude is used for this conversion. The GPS longitude can be ignored because the system is aligned along a north–south axis.

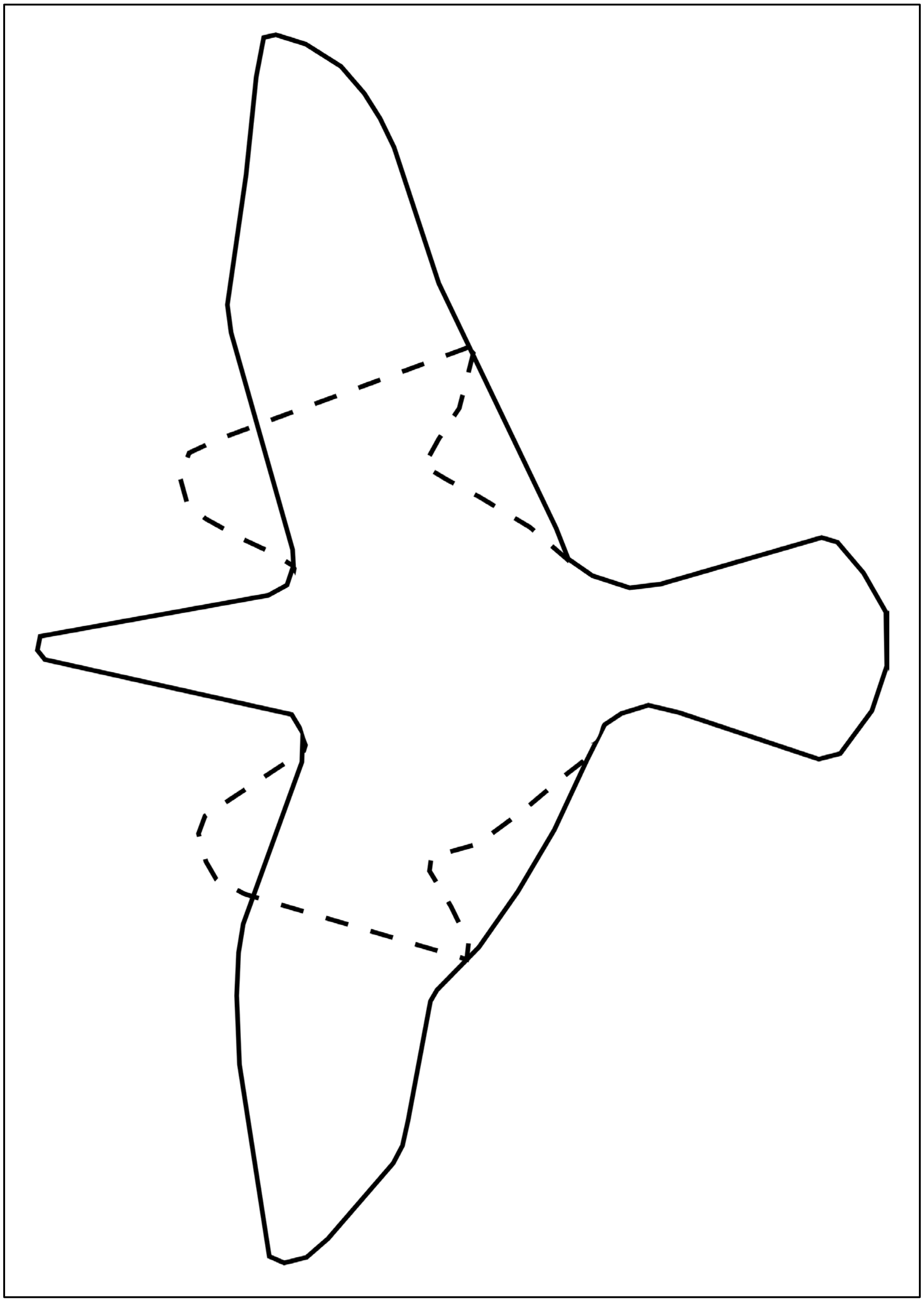


Figure B-1. Profile outlines of largest target.
Dotted lines show wings retracted; solid lines show wings extended.

Figure B-2. ATOM system tilted to 22 degrees to accommodate longer distance testing otherwise restricted by the FAA 400-ft drone flight height restriction.

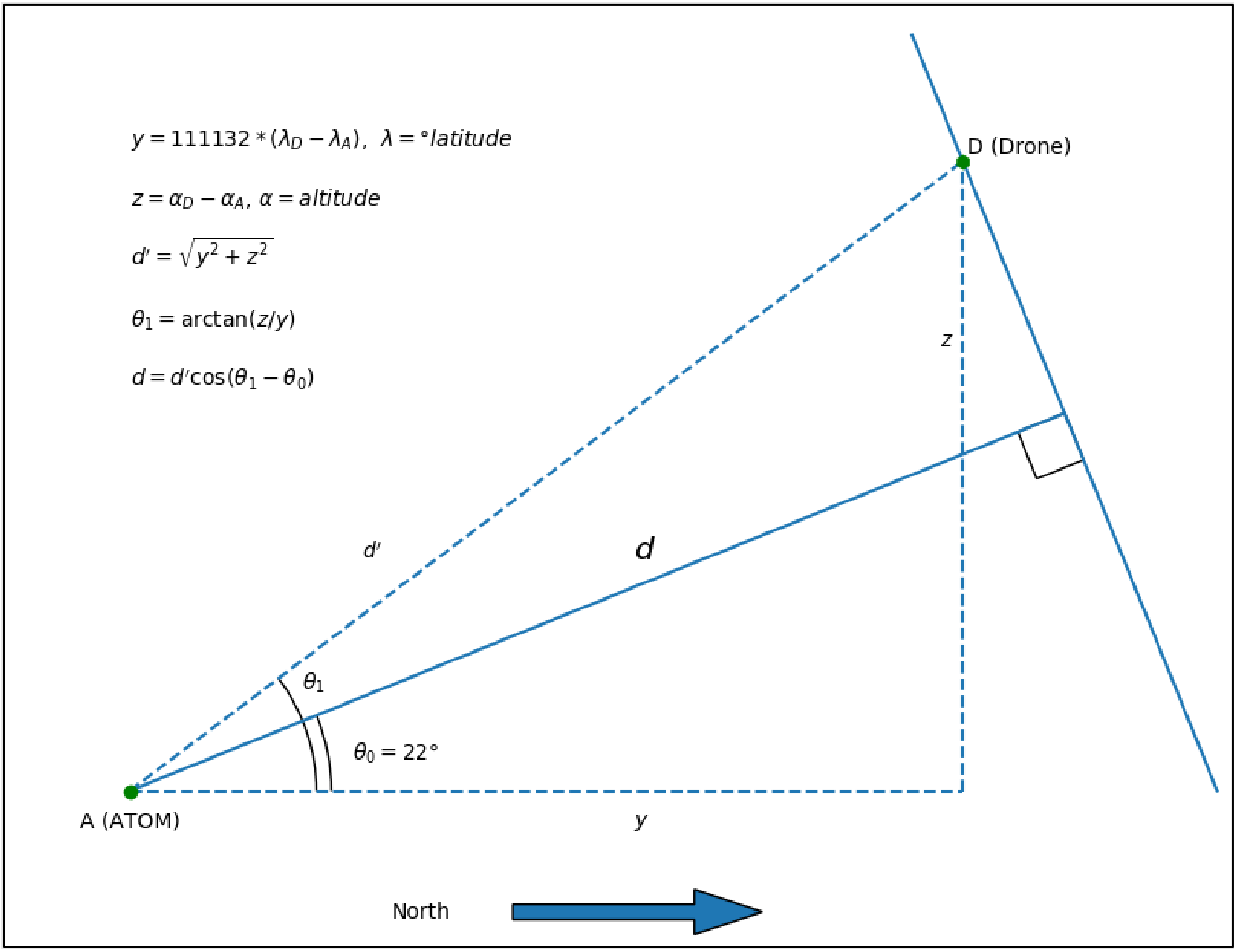


Figure B-3. Calculation of drone "altitude" (straight-line distance) relative to tilted ATOM system.

The first and last 1 second of each flight were used to establish the GPS position of the ATOM system and quantify the error of the GPS data. During the first and last second, the drone was known to be approximately 10 m due North of the ATOM system. The standard deviation of these 50 coordinate sets was 5.0 m, and their median was used to establish the position of the ATOM for all subsequent calculations.

The ATOM system tracks objects in each of its two IR cameras independently. An object tracked in only one IR camera is categorized as tracked, and these tracks were used to establish the detectability limits of the ATOM system. An object tracked in both IR cameras simultaneously is categorized as both tracked and stereo tracked. Stereo tracking permits flight height calculations of an object. These stereo tracks were used to establish the accuracy of the ATOM flight height calculations. Five test flights were conducted with various flight patterns. For each flight, the ATOM track data was compared to the drone GPS data to determine the maximum range at which the ATOM could track the drone and the accuracy of the ATOM flight height calculations.

For time periods when the drone was stereo tracked, *d* determined by the GPS position was compared to the flight height as determined by the ATOM system *(h)* based on the relative position of the drone in each IR camera.

After the completion of the tests, the test data were processed to extract tracks. The extracted tracks were then reviewed to separate drone tracks from bird, insect, and artifact tracks detected during the tests. Over the duration of the test approximately 300 bird and insect tracks were recorded in addition to the drone tracks.

To test the ability of the ATOM system to detect smaller targets that would mimic the size of a bat or small bird, we used a tennis ball as a surrogate object. For these tests we set up the ATOM system in the same way as the drone tests and tossed a tennis ball into the air at set distances from the system. Tosses were recorded at 1.5-m (5-ft) intervals from 7.6 m to 30.5 m (25 ft to 100 ft). For each trial, we recorded the time when the ball was thrown and the known horizontal distance from the system. The horizontal distance from the system and the angle of the ATOM system above ground allowed us to calculate the straight-line distance from the system.

Acoustic Calibration

Detection range of acoustic microphones is highly variable depending on the environmental conditions, ambient noise, sound volume, and sound frequency. For example, a 20-kHz sound at 20°C with 50% relative humidity can be detected from 5 m to 63 m depending on volume (Wildlife Acoustics 2014), but this does not include the highly noisy offshore environment, turbine noise, and varying weather conditions. Because it is not possible to consider all possible conditions that would affect the acoustic detection range at the turbine, we present the example above as an approximate detection range.

Motus Calibration

During each visit to the Motus system we used a test tag to validate the Motus system was working properly. The test tag was detected out to a range of 1.25 miles. A full calibration survey using methods outline by the US Fish and Wildlife Service (USFWS) will be done on an upgraded Motus system in 2022–2023.

Detection Range

Efforts to establish the detection range of the system were complicated by a lower than anticipated rate of object tracking. Due to the slow speed of the drone relative to a typical bird/bat in flight and motion of the drone directly toward or away from the cameras, the automated tracking system only detected the presence of the drone 22.4% of the time across all 5 flights. However, the maximum tracked ranges of 262.9–292.8 m achieved during flights 2, 3, and 4 are consistent with the point at which the drone becomes imperceptible in the recorded video. Further testing would be needed to establish a maximum plausible detection range, but the 280 m achieved for the drone alone during flight 4 (with no target attached) can be considered the reasonable limit at which an object of the size of the drone will be detected (Table B-2).

The area of the drone as detected by the ATOM system is approximately 3,800 cm² as determined from track data at the beginning of flight 5 prior to the attachment of the target bird cutout. For other size objects, the maximum detection range D_{MAX} will be proportional to the cross-sectional area of the object A. That is:

$$D_{MAX} \propto \sqrt{A} \quad \text{Equation 1}$$

Using the drone detection distance of 280 m for a hypothetical object 1,000 cm² in area, this would suggest a detection range of 144 m.

Table B-2. ATOM Detection Ranges for Five Flights

Variability in detection ranges can be due to the flight tracks, angle of the flights, object velocity, and environmental factors

Flight	Attached Bird Model	Max *d* tracked (m)	Max *d* (m)	Flight duration (s)	% Tracked
1	None	65.3	110.1	177	10.0
2	Target 1, extended	262.9	314.2	636	21.2
3	Target 4, retracted	292.8	316.9	702	32.3
4	None	280.6	537.7	514	7.7
5	Target 2, retracted	134.6	134.9	289	34.4
Total		292.8	537.7	4635	22.4

Flight: the flight number
Attached Bird Model: the bird model, if any, suspended from the drone during the specified flight
Max *d* tracked: the maximum GPS distance (*d*) at which the drone was tracked by the ATOM system
Max *d*: the maximum GPS distance (*d*) recorded during the flight
Flight duration: the length of the flight
% Tracked: the percentage of the flight that was tracked by the ATOM system

Further tests of the ATOM system were performed by tossing a tennis ball into the air at set distances from the system, which was set up as it was for the drone tests. During these tests the tennis ball was tracked by the system up to a maximum distance of 24.4 m. Beyond that distance the tennis ball was not tracked and was not clearly visible in the recorded IR video. Given the 35-cm² cross section area of a standard tennis ball and the previously discussed relationship between maximum detection range and cross-sectional area (Equation 1), this result implies a detection range of 130 m for a hypothetical object 1,000 cm² in area, which is similar to the 144 m estimate calculated from the drone detection distance.

The ATOM system calculates flight heights (*h*) for all stereo-tracked objects to assist in assessing the risk from wind turbine blades. For these tests, *h* values computed by the ATOM system do not represent altitude due to the non-standard orientation of the ATOM system. To establish the accuracy of the ATOM flight height values we have compared them to an equivalent GPS distance *d* (Figure B-4; Table B-3). The accuracy of *h* values decreases with distance from the ATOM system due to the nature of stereo range finding. This can be seen in Figure B-5, which charts the standard deviation of $d - h$ binned by *d*, as well as in Figure B-6 to Figure B-9, which plot *d* and *h* versus time for each of the 5 test flights.

For distances of less than 100 m, the standard deviation of $d - h$ is less than the standard deviation of d alone (8.0 m, n=50) at the beginning of each flight. This suggests that h (height estimated by ATOM*)* is at least as accurate as the GPS data for flight heights under 100 m. Beyond 100 m the flight height data becomes less accurate (Figure B-6 to Figure B-9).

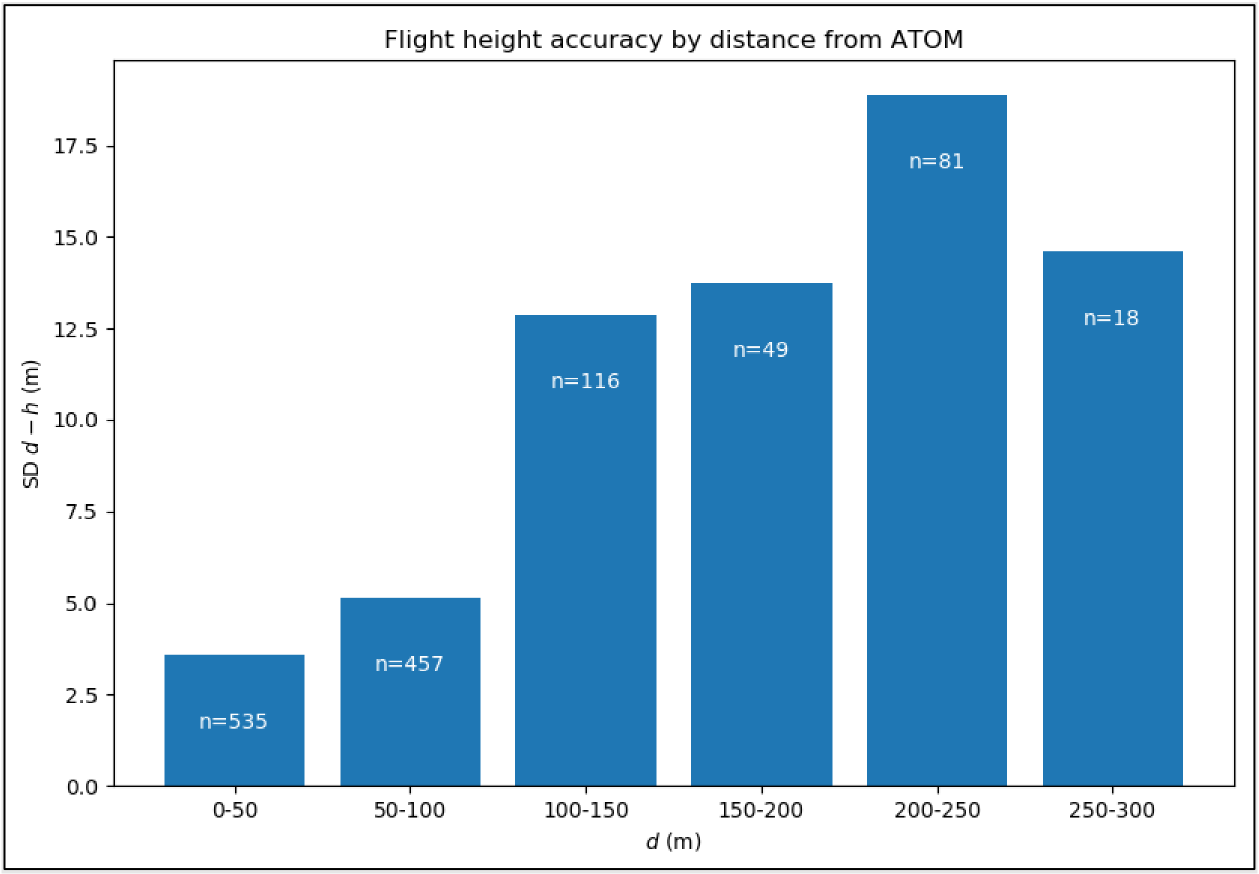


Figure B-4. Comparison of ATOM-calculated flight height to equivalent GPS flight height values binned by distance from ATOM system.

d represents the flight height calculated by the GPS (x-axis); SD *d-h* represents the difference in standard deviation of the flight height calculated by ATOM from the height recorded by the GPS unit (y-axis). n is the number of stereo-tracked video frames in each distance bin.

Table B-3. Selected Test Result Statistics Aggregated by Flight Number

Flight	Attached Bird Model	% Stereo tracked	Location Samples	Mean distance delta (m)	Distance delta SD (m)
1	None	7.0	62	-3.0	1.7
2	Target 1, extended	13.1	416	-4.3	2.9
3	Target 4, retracted	8.9	313	16.7	28.2
4	None	3.5	90	2.3	0.7
5	Target 2, retracted	26.0	375	-5.7	10.1
Total		10.8	1256	1.1	10.2

Flight: the flight number
Attached Bird Model: the bird model, if any, suspended from the drone during the specified flight
% Stereo Tracked: the percentage of the flight tracked by both ATOM IR cameras and for which distance calculations are available
Location samples: the number of GPS coordinates for which ATOM flight height data was available
Mean distance delta: The mean of (*d* - *h*) for data points that were stereo tracked
Distance delta SD: The standard deviation of the distance delta (see Mean distance delta)

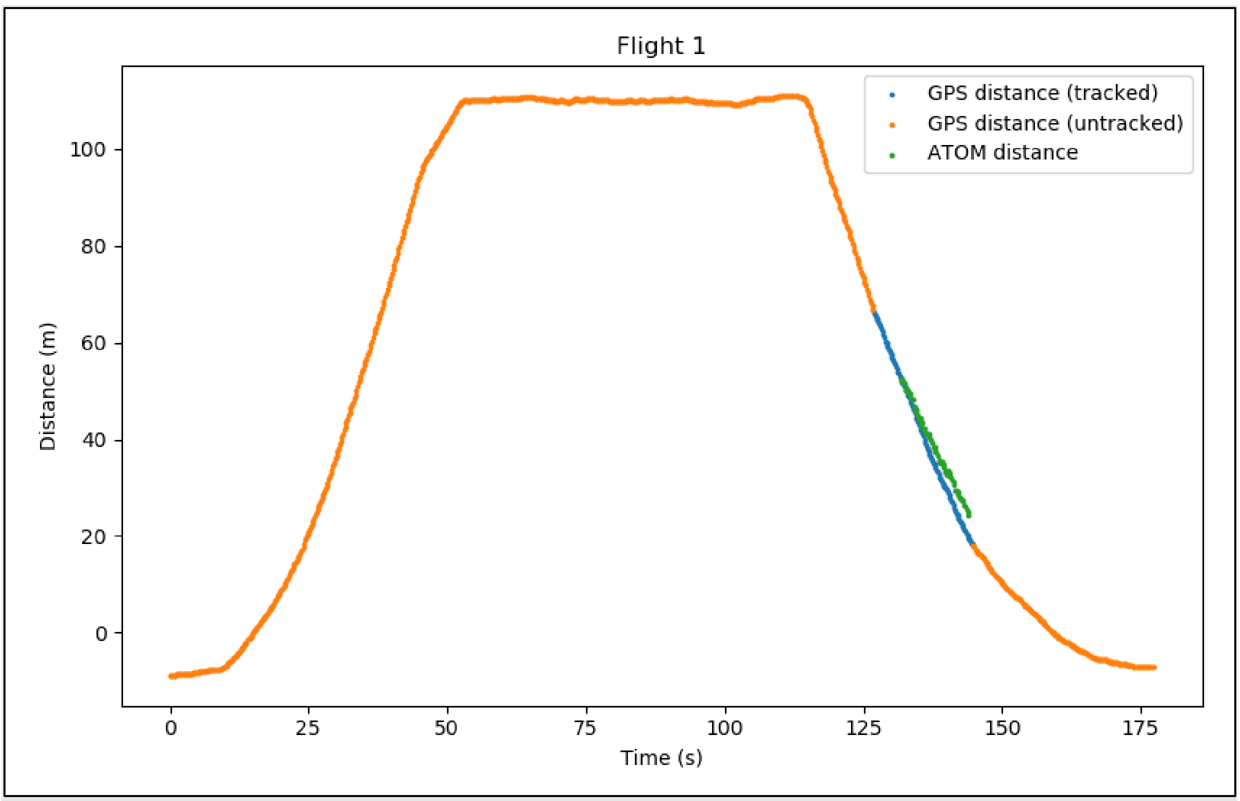


Figure B-5. Difference between *d* and *h* values from the GPS and ATOM system respectively during the duration of flight 1 as defined on the x-axis.

The presence of blue and green dots indicates stereo tracking and the closer the blue and green dots are together, the more accurate the ATOM system distance estimate. No ATOM estimates were available when the targets were untracked (orange points) or when tracked with one camera only (blue dots without green dots).

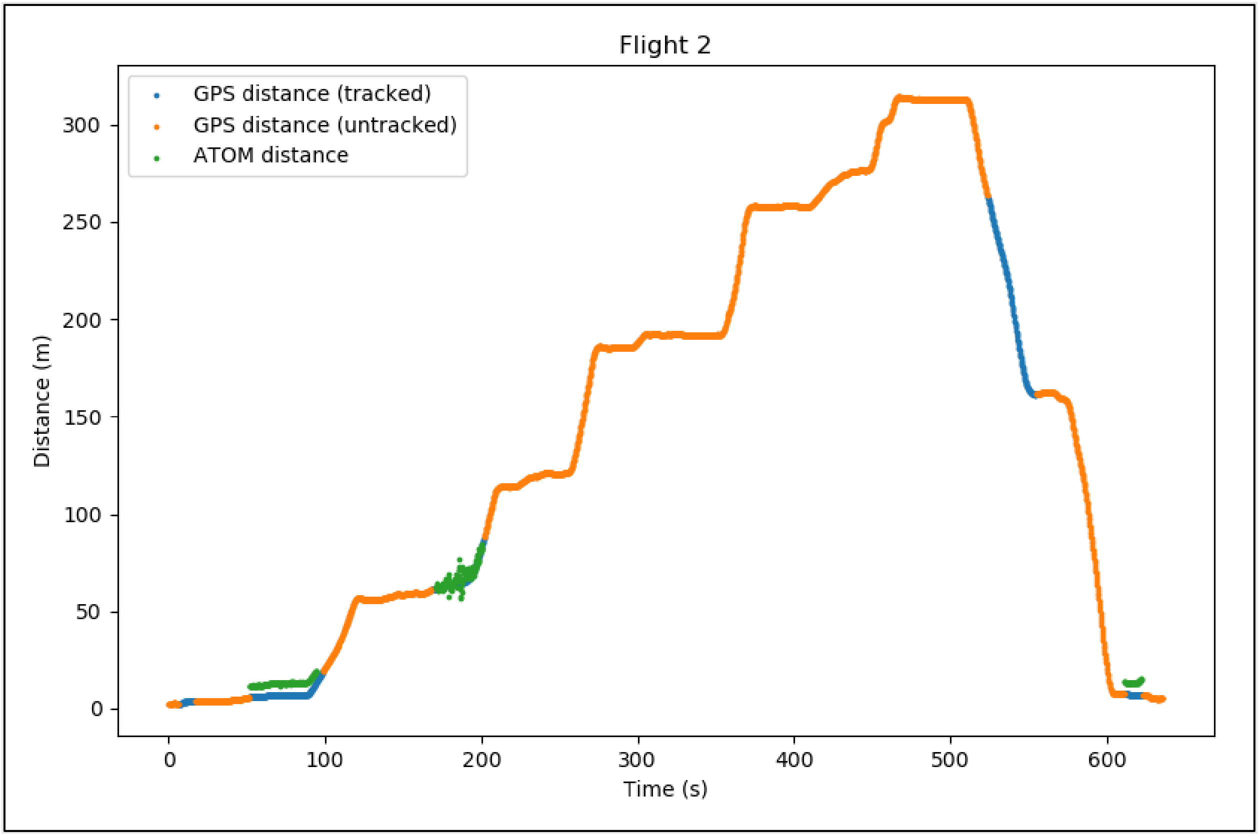


Figure B-6. Difference between *d* and *h* values from the GPS and ATOM system respectively during the duration of flight 2 as defined on the x-axis.

The presence of blue and green dots indicates stereo tracking and the closer the blue and green dots are together, the more accurate the ATOM system distance estimate. No ATOM estimates were available when the targets were untracked (orange points) or when tracked with one camera only (blue dots without green dots).

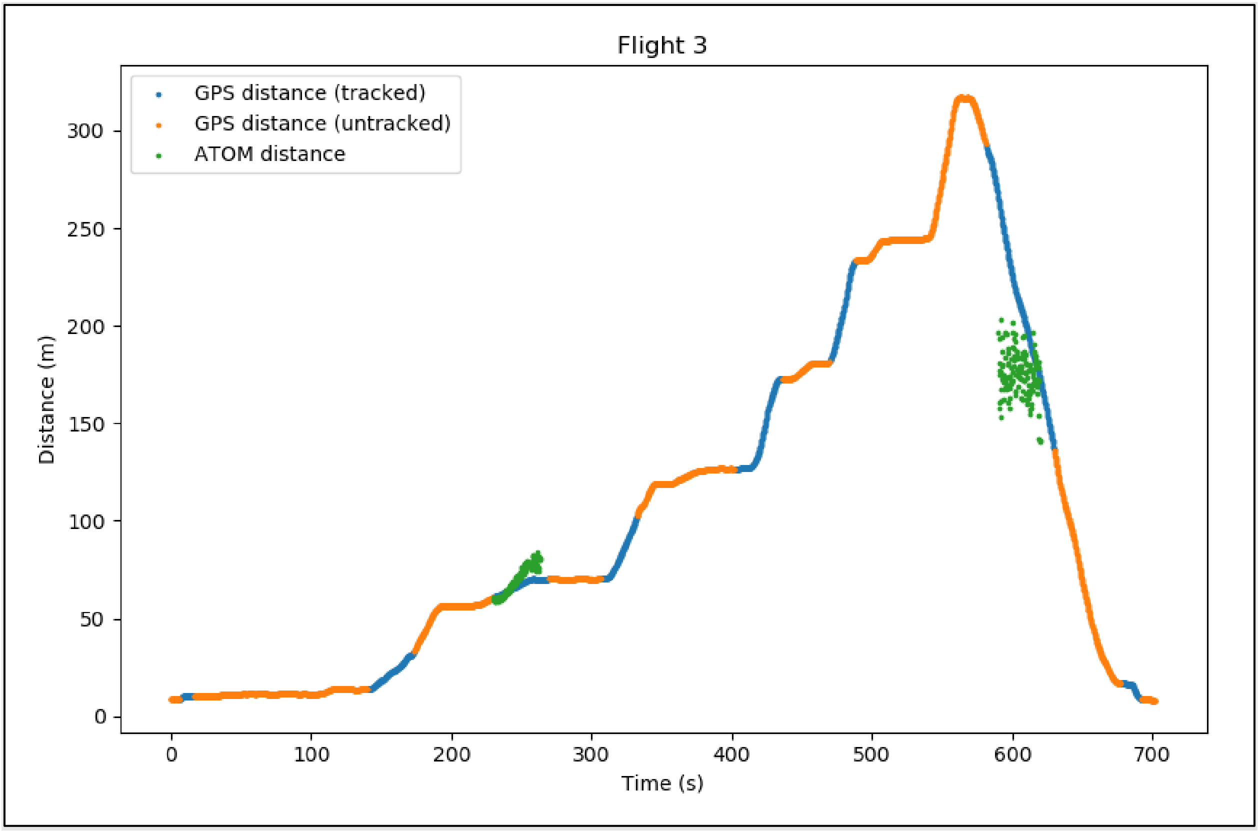


Figure B-7. Difference between *d* and *h* values from the GPS and ATOM system respectively during the duration of flight 3 as defined on the x-axis.

The presence of blue and green dots indicates stereo tracking and the closer the blue and green dots are together, the more accurate the ATOM system distance estimate. No ATOM estimates were available when the targets were untracked (orange points) or when tracked with one camera only (blue dots without green dots).

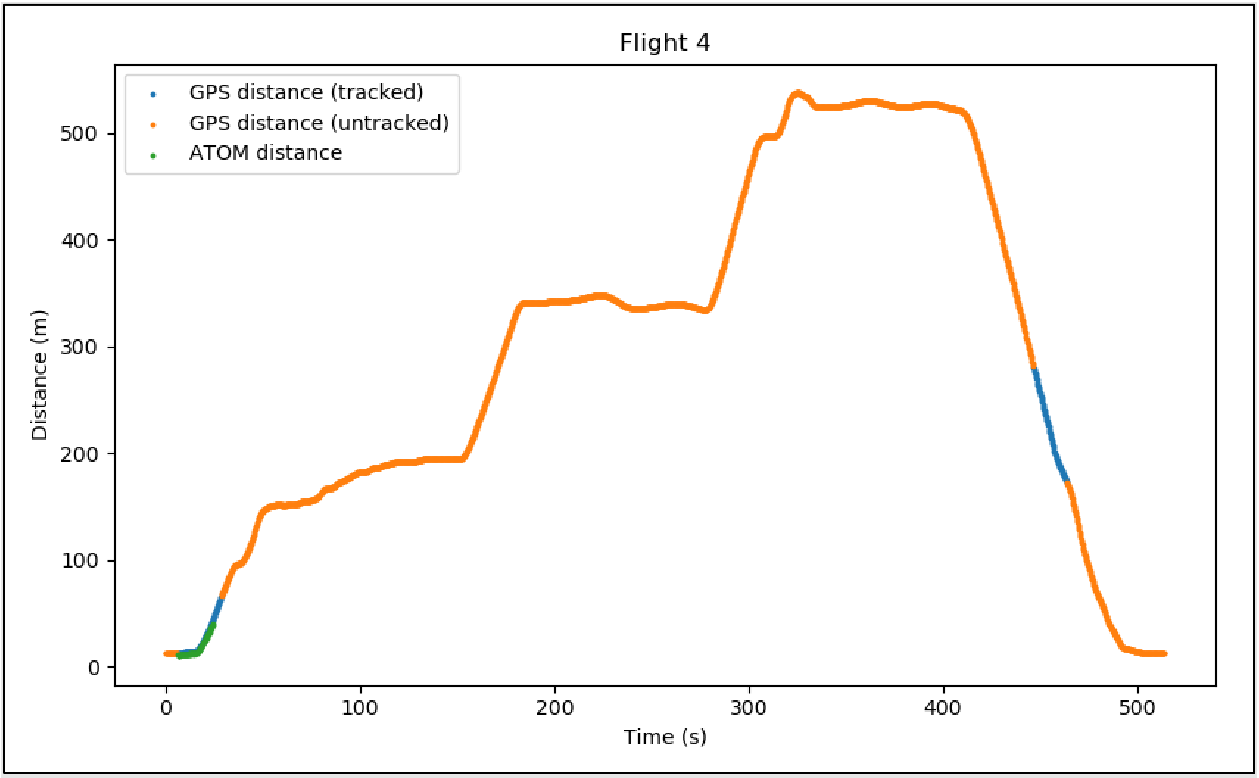


Figure B-8. Difference between *d* and *h* values from the GPS and ATOM system respectively during the duration of flight 4 as defined on the x-axis.

The presence of blue and green dots indicates stereo tracking and the closer the blue and green dots are together, the more accurate the ATOM system distance estimate. No ATOM estimates were available when the targets were untracked (orange points) or when tracked with one camera only (blue dots without green dots).

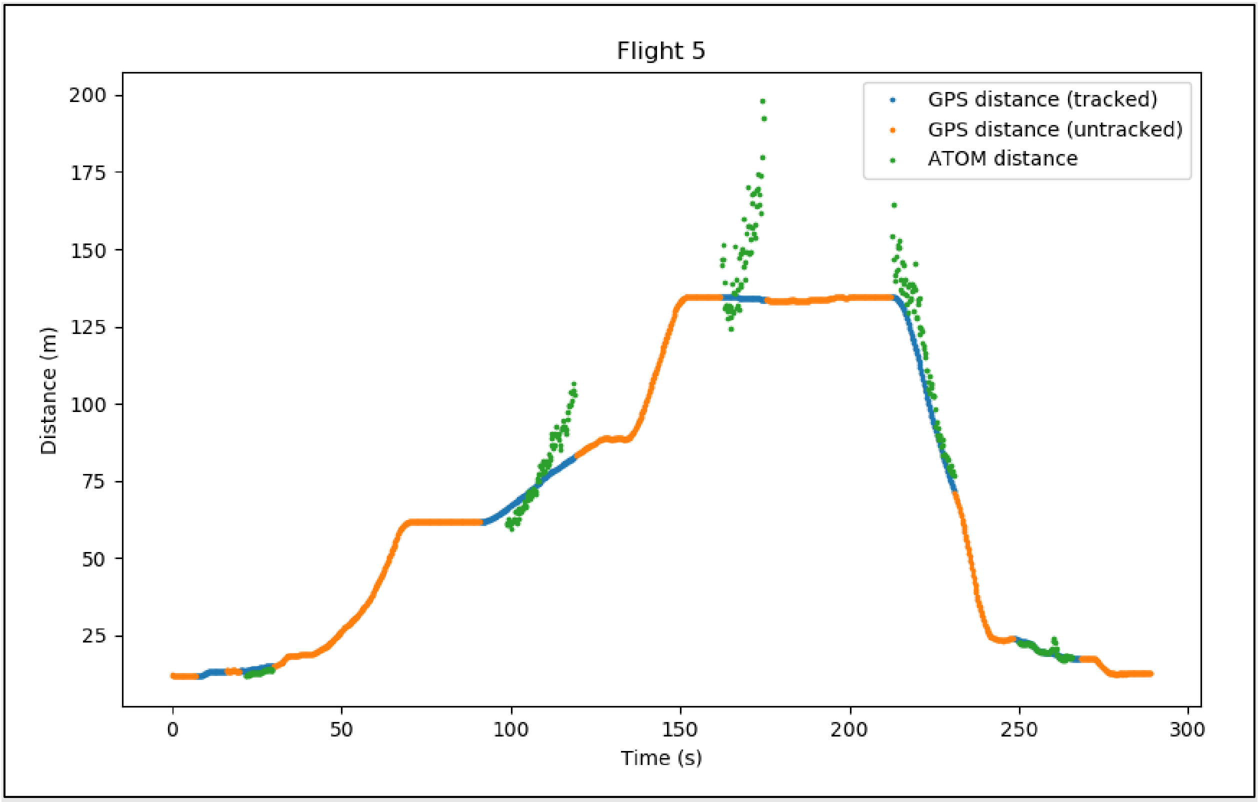


Figure B-9. Difference between *d* and *h* values from the GPS and ATOM system respectively during the duration of flight 5 as defined on the x-axis.

The presence of blue and green dots indicates stereo tracking and the closer the blue and green dots are together, the more accurate the ATOM system distance estimate. No ATOM estimates were available when the targets were untracked (orange points) or when tracked with one camera only (blue dots without green dots).

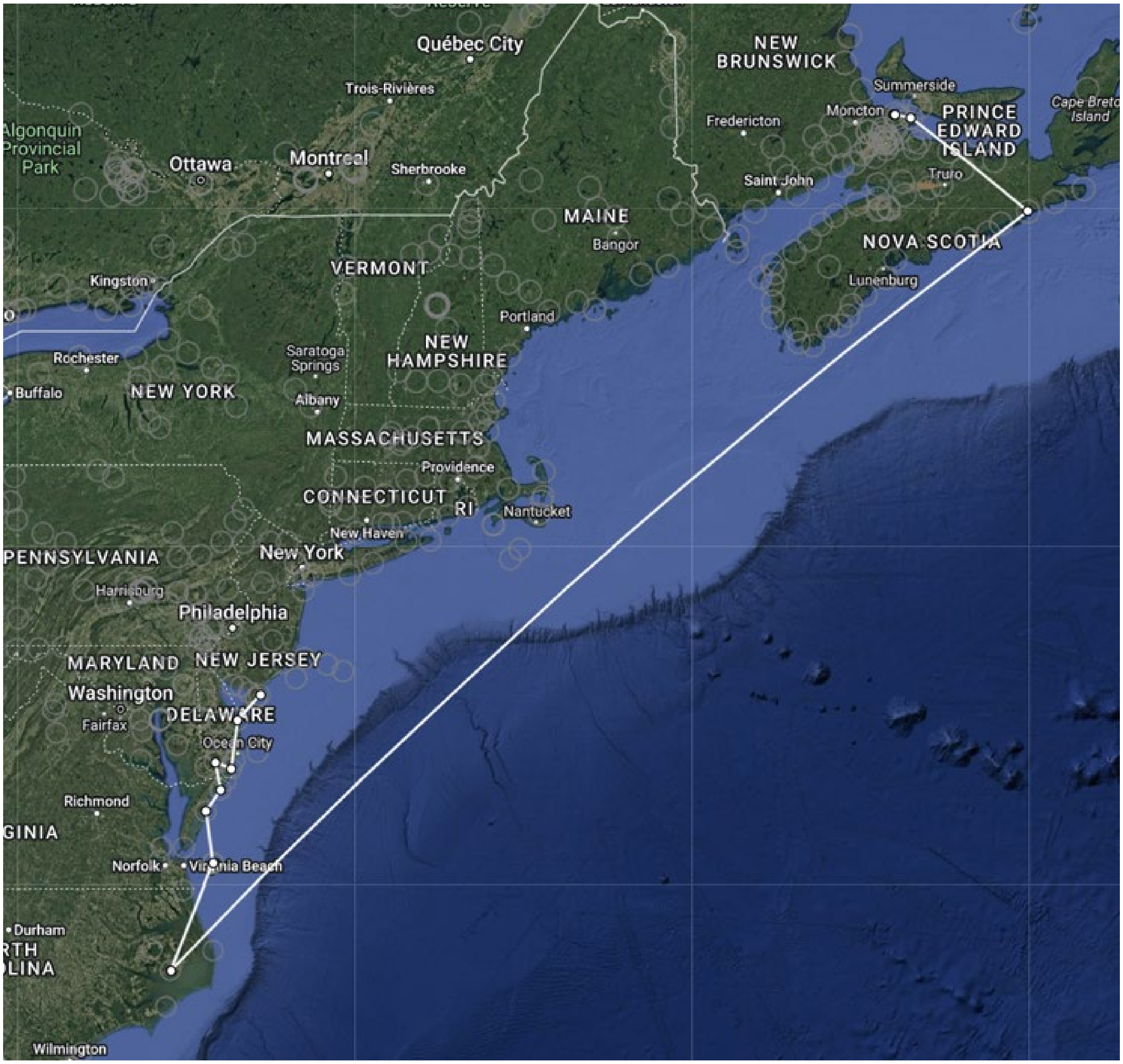
Flight 2, target A attached

Flight 3, target B attached

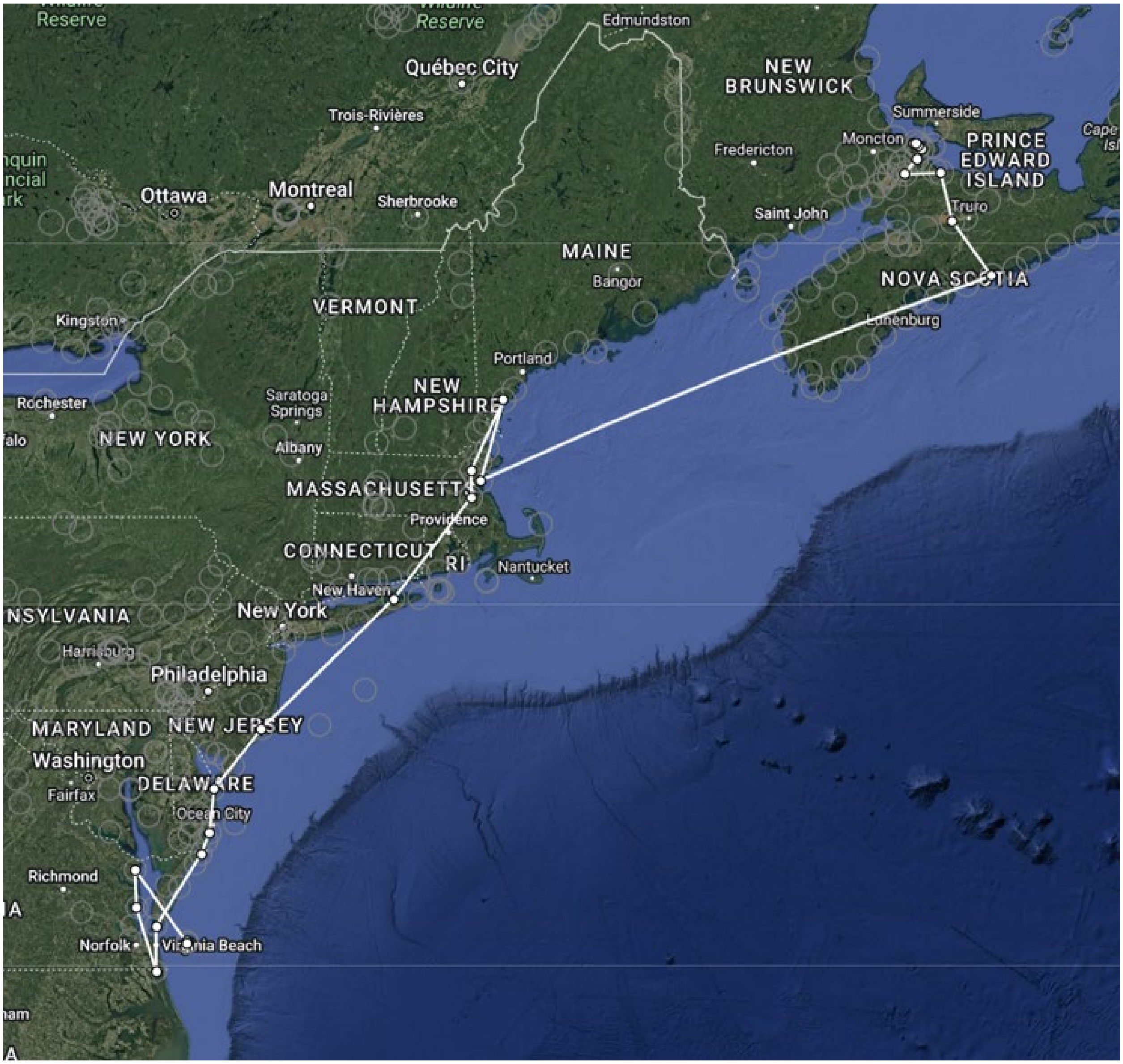
Flight 5, target C attached

Appendix C. Locations Where Birds Detected at the CVOW Pilot Project Were Also Detected

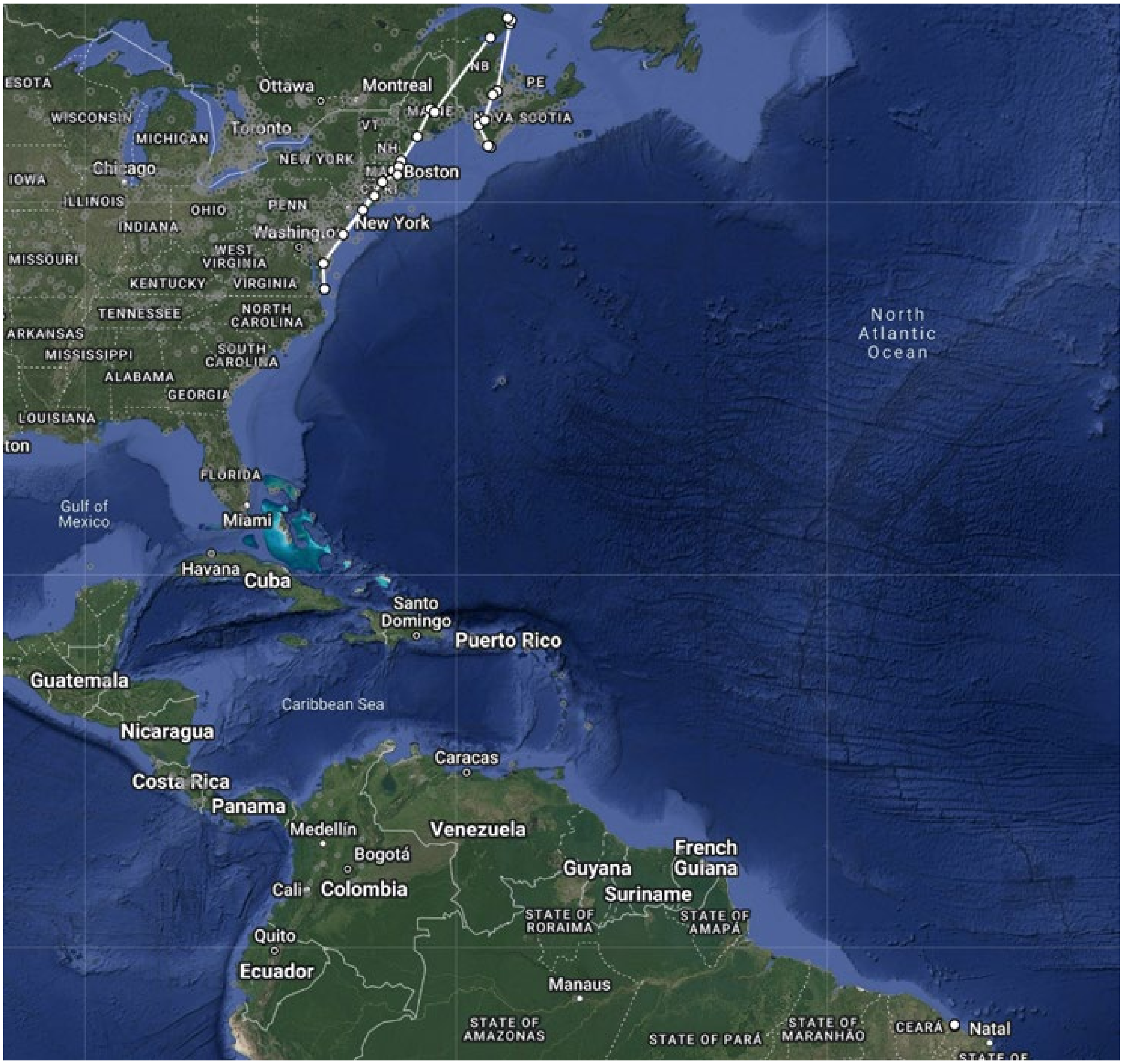
Detection Date and Local Time: 09/18/2022 05:30
Turbine: A01
Species: Sanderling
Tag ID: 61422 (https://motus.org/data/track?tagDeploymentId=42342)



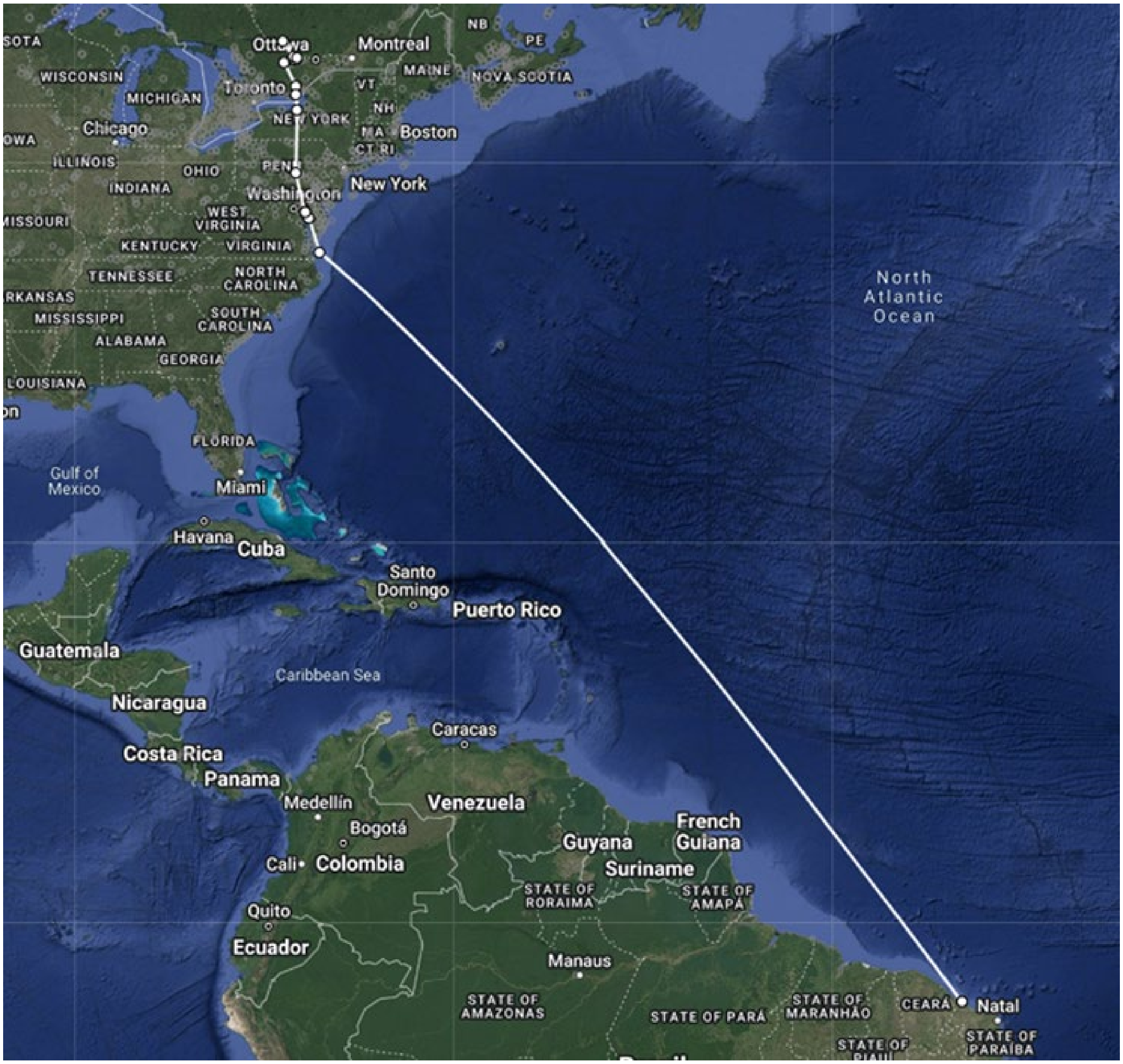
Detection Date and Local Time: 09/24/2021 22:00
Turbine: A01
Detection Date and Local Time: 09/24/2021 23:00
Turbine: A02
Species: Semipalmated Sandpiper
Tag ID: 55948 (https://motus.org/data/track?tagDeploymentId=35217)



Detection Date and Local Time: 05/09/2024 15:45
Turbine: A01
Detection Date and Local Time: 05/09/2024 15:30
Turbine: A02
Species: Short-billed Dowitcher
Tag ID: 83380 (https://motus.org/data/track?tagDeploymentId=52634)

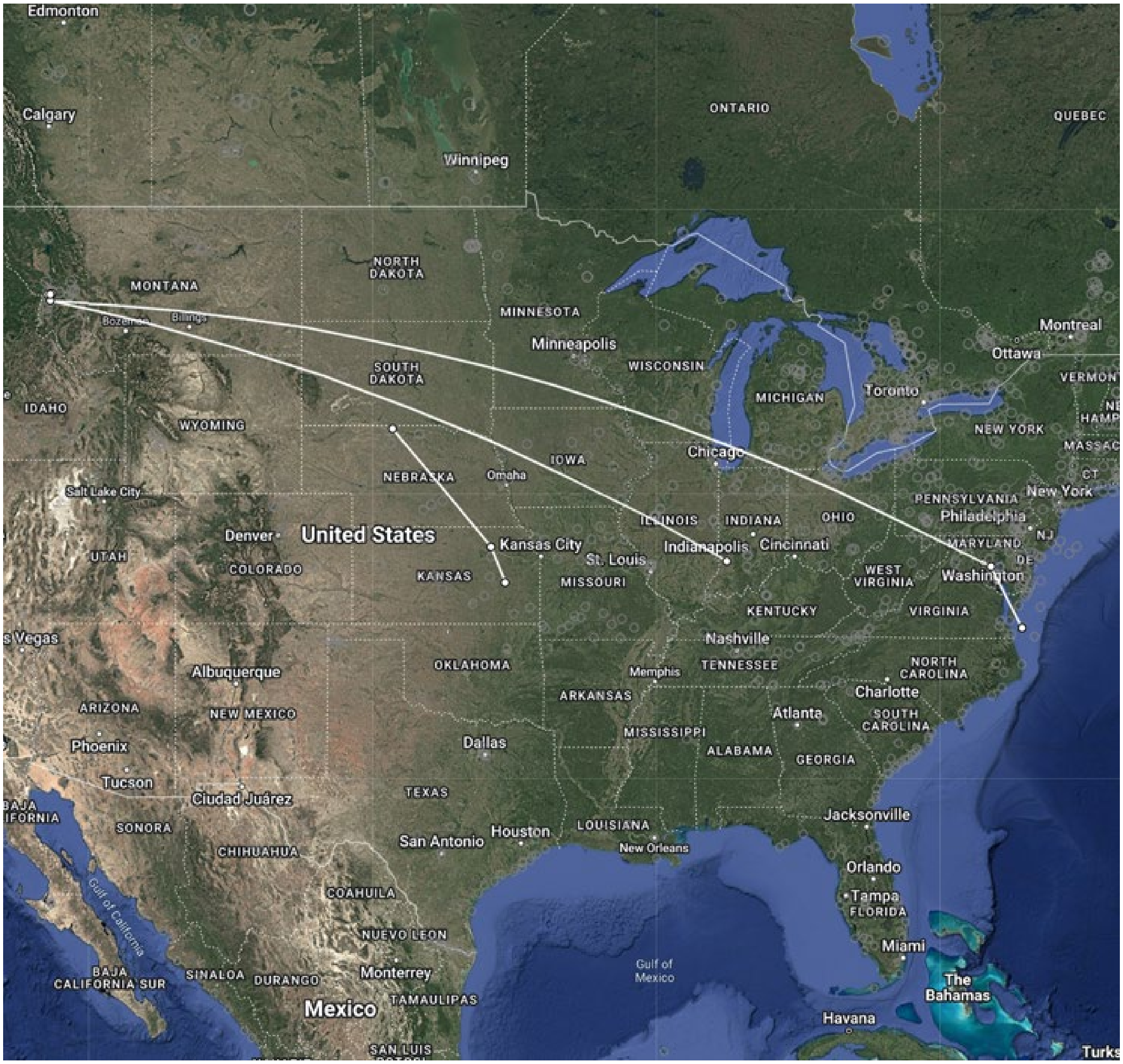


Detection Date and Local Time: 05/16/2022 4:45
Turbine: A01
Species: Black-bellied Plover
Tag ID: 82326 (https://motus.org/data/track?tagDeploymentId=51042)

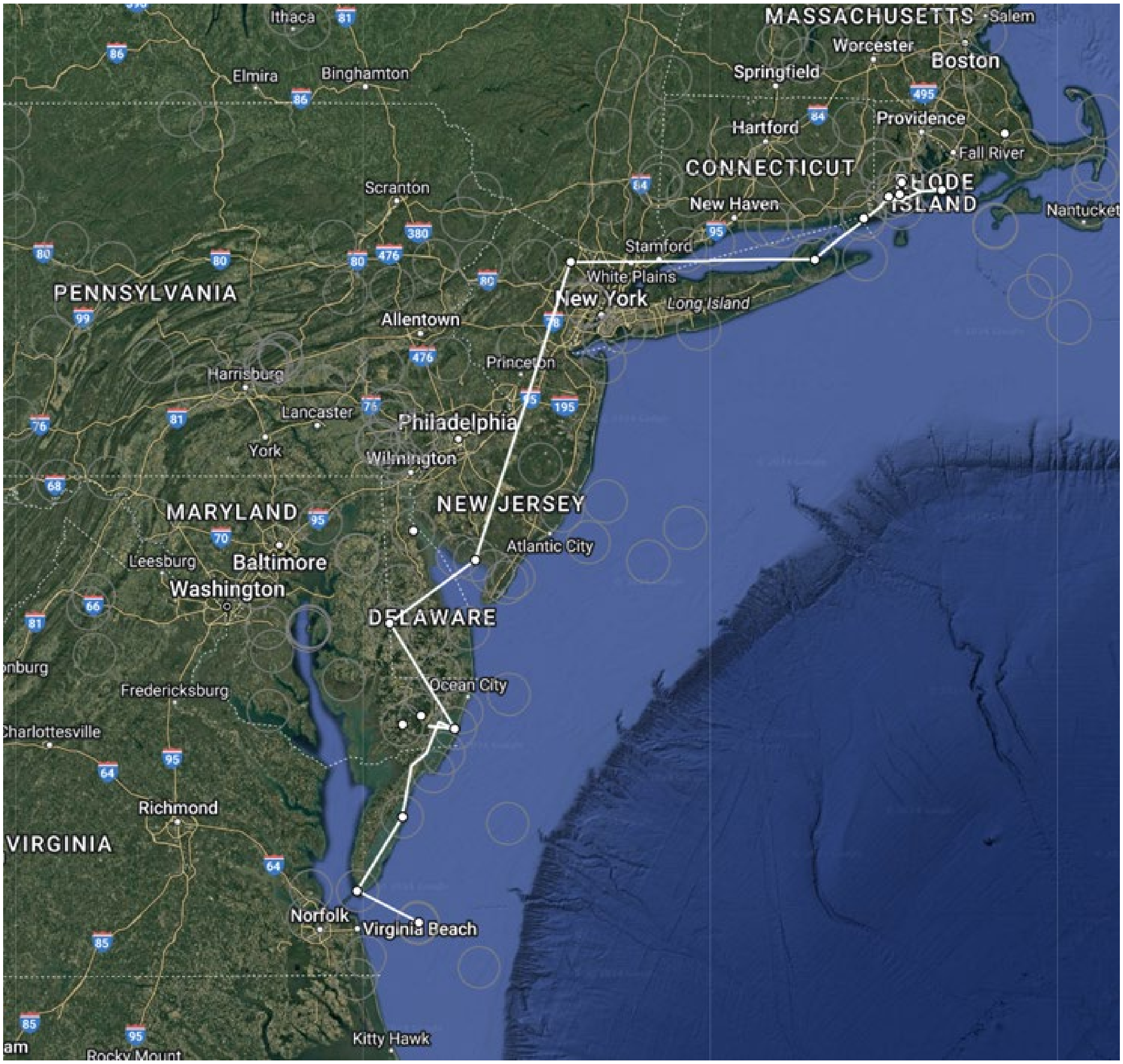


Detection Date and Local Time: 08/09/2021 2:45
Turbine: A02
Species: Semipalmated Plover
Tag ID: 45368 (https://motus.org/data/track?tagDeploymentId=33965)

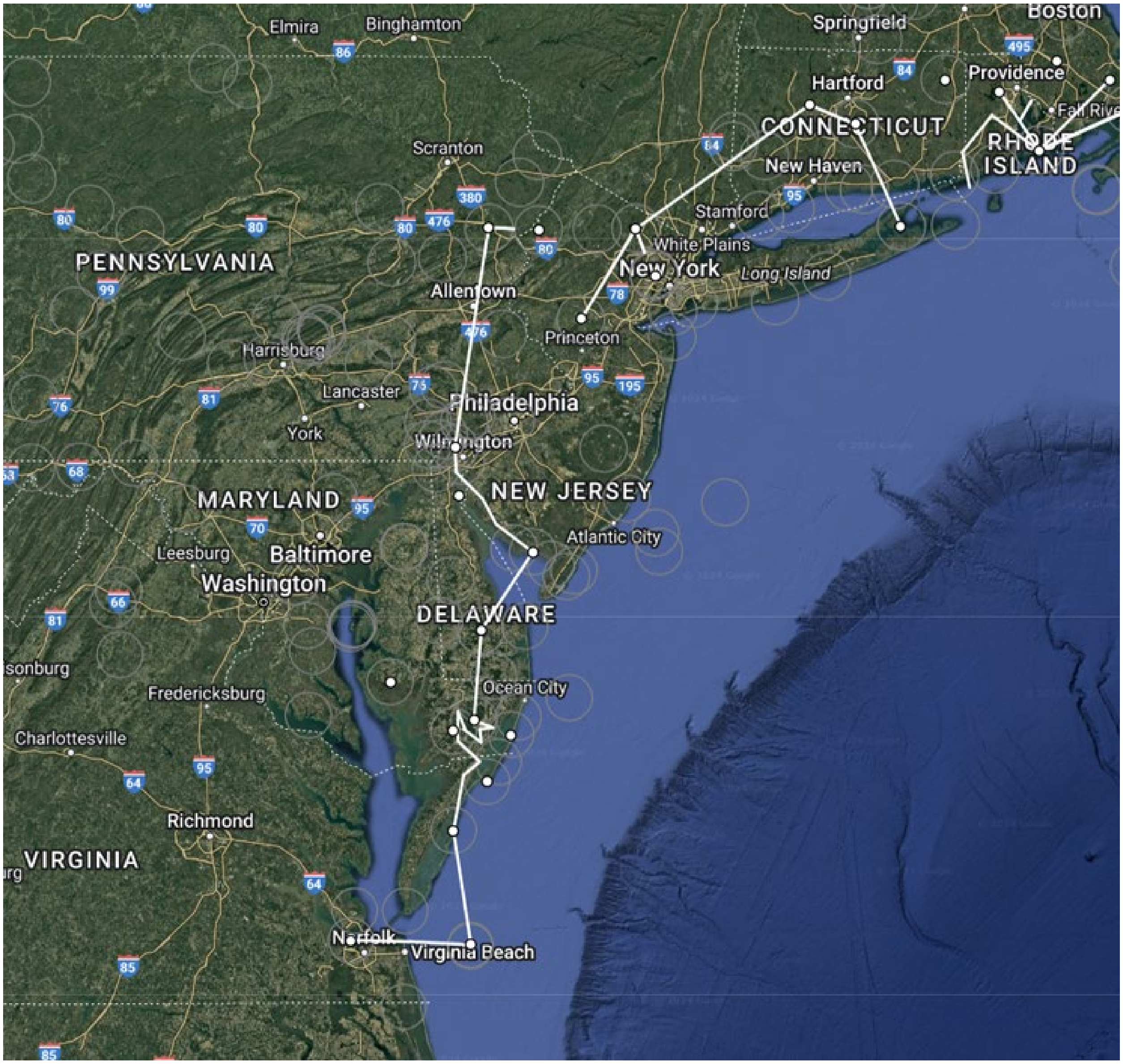
Detection Date and Local Time: 09/12/2023 04:10
Turbine: A01
Detection Date and Local Time: 09/12/2023 04:10
Turbine: A02
Species: Common Nighthawk
Tag ID: 71189 (https://motus.org/data/track?tagDeploymentId=47506)



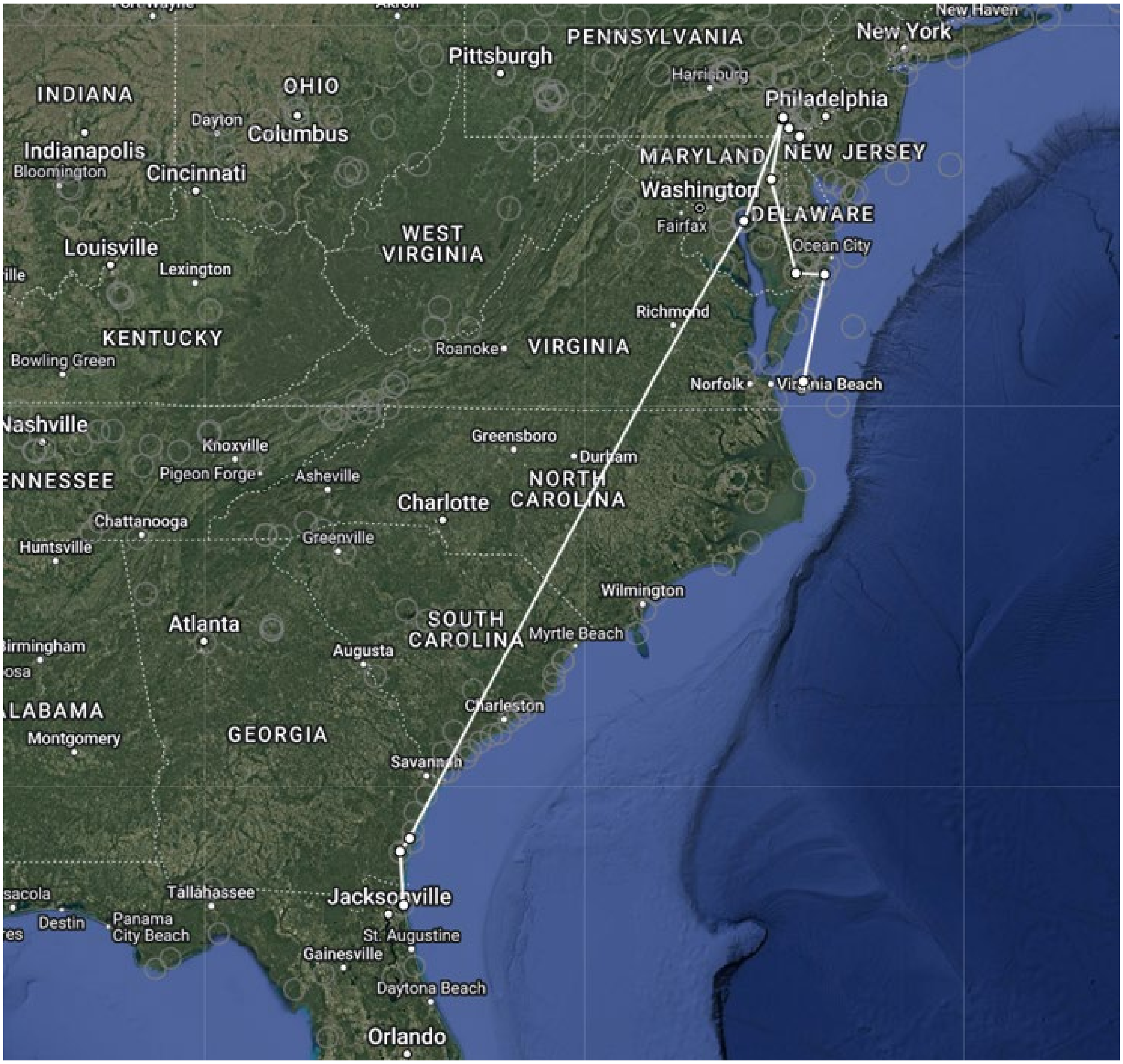
Detection Date and Local Time: 10/03/2023 17:00
Turbine: A01
Species: American Kestrel (Northern)
Tag ID: 76334 (https://motus.org/data/track?tagDeploymentId=47546)



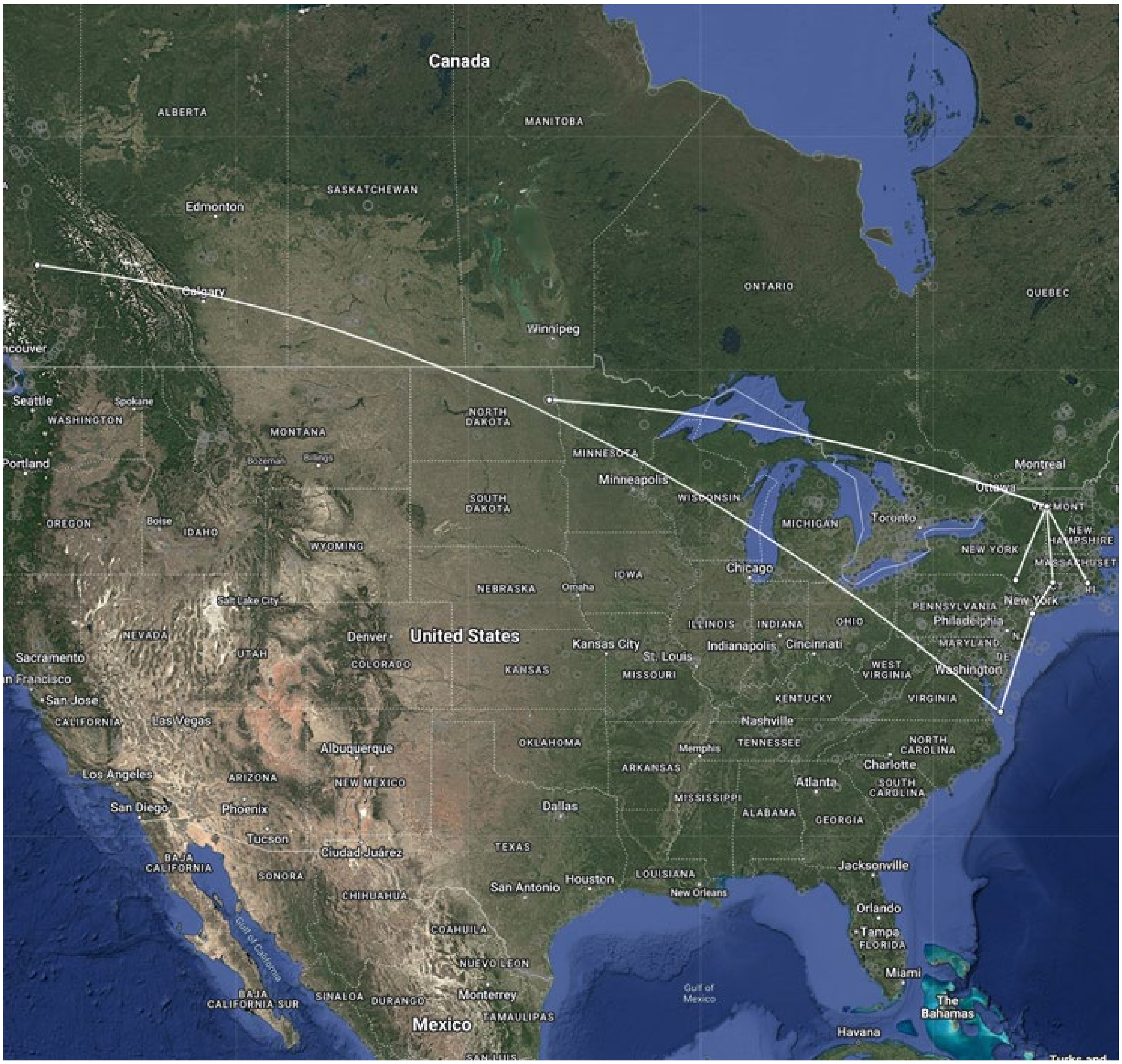
Detection Date and Local Time: 09/15/2022 18:15
Turbine: A01
Species: American Kestrel (Northern)
Tag ID: 67435 (https://motus.org/data/track?tagDeploymentId=40720)



Detection Date and Local Time: 09/14/2023 4:15
Turbine: A02
Species: Bobolink
Tag ID: 75566 (https://motus.org/data/track?tagDeploymentId=46480)

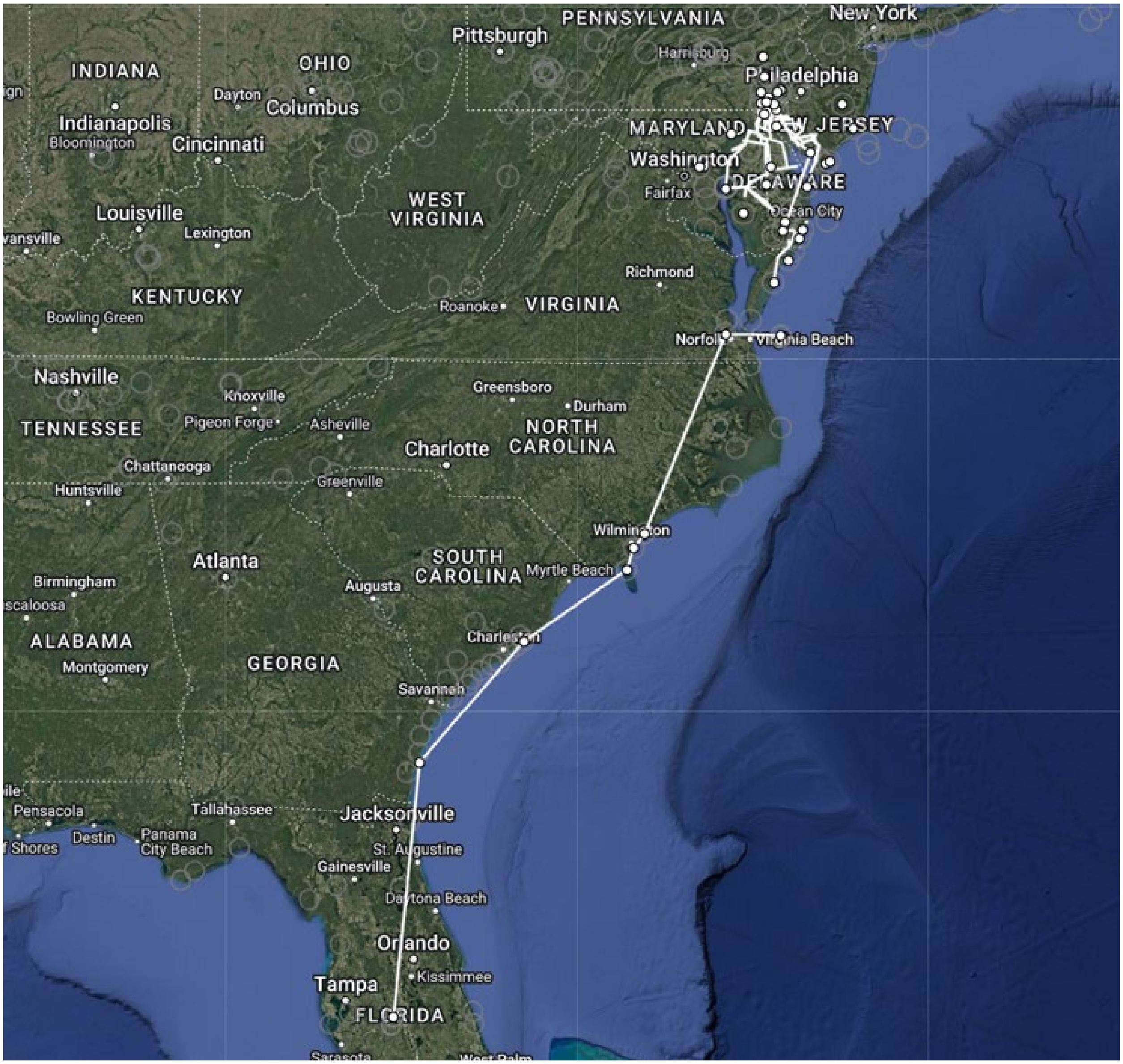


Detection Date and Local Time: 10/02/2023 7:10
Turbine: A02
Species: Bobolink
Tag ID: 75424 (https://motus.org/data/track?tagDeploymentId=47618)

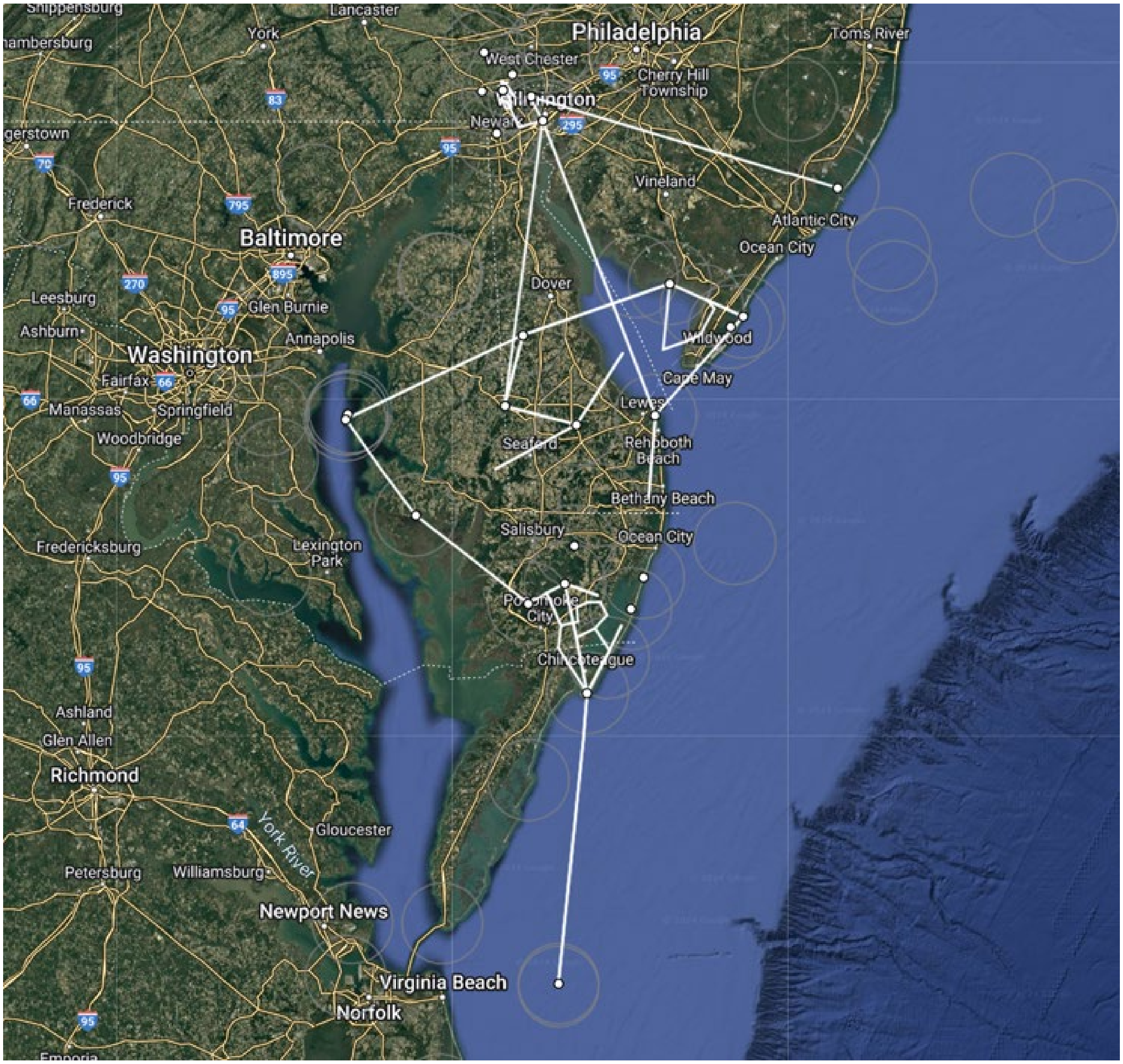


Detection Date and Local Time: N/A
Turbine: A01
Detection Date and Local Time: N/A
Turbine: A02
Species: Short-billed Dowitcher
Tag ID: 88298 (https://motus.org/data/track?tagDeploymentId=58856)

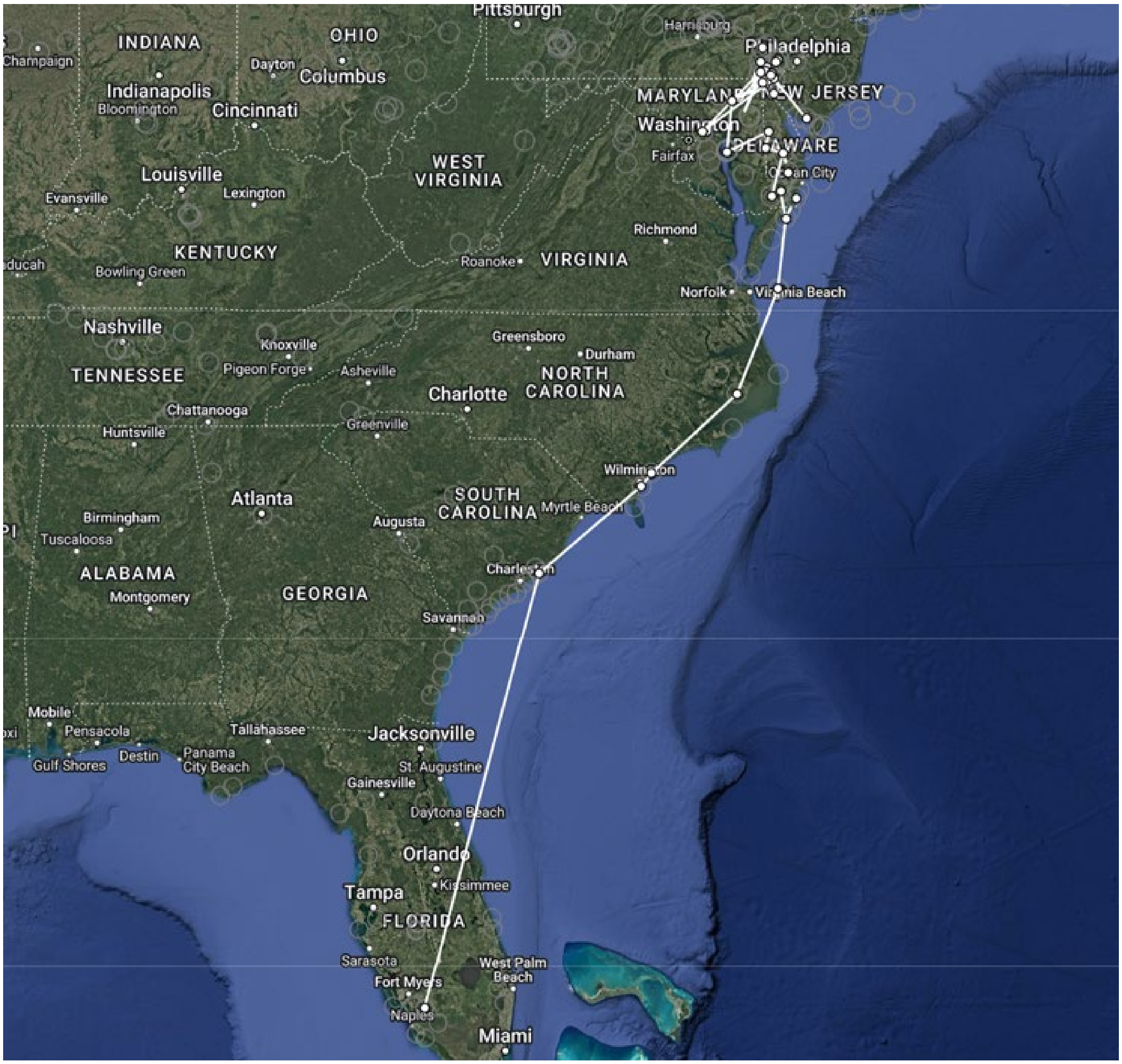
Detection Date and Local Time: 09/07/2022 17:15
Turbine: A01
Detection Date and Local Time: 09/09/2022 10:30
Turbine: A02
Species: Purple Martin
Tag ID: 61221 (https://motus.org/data/track?tagDeploymentId=40988)



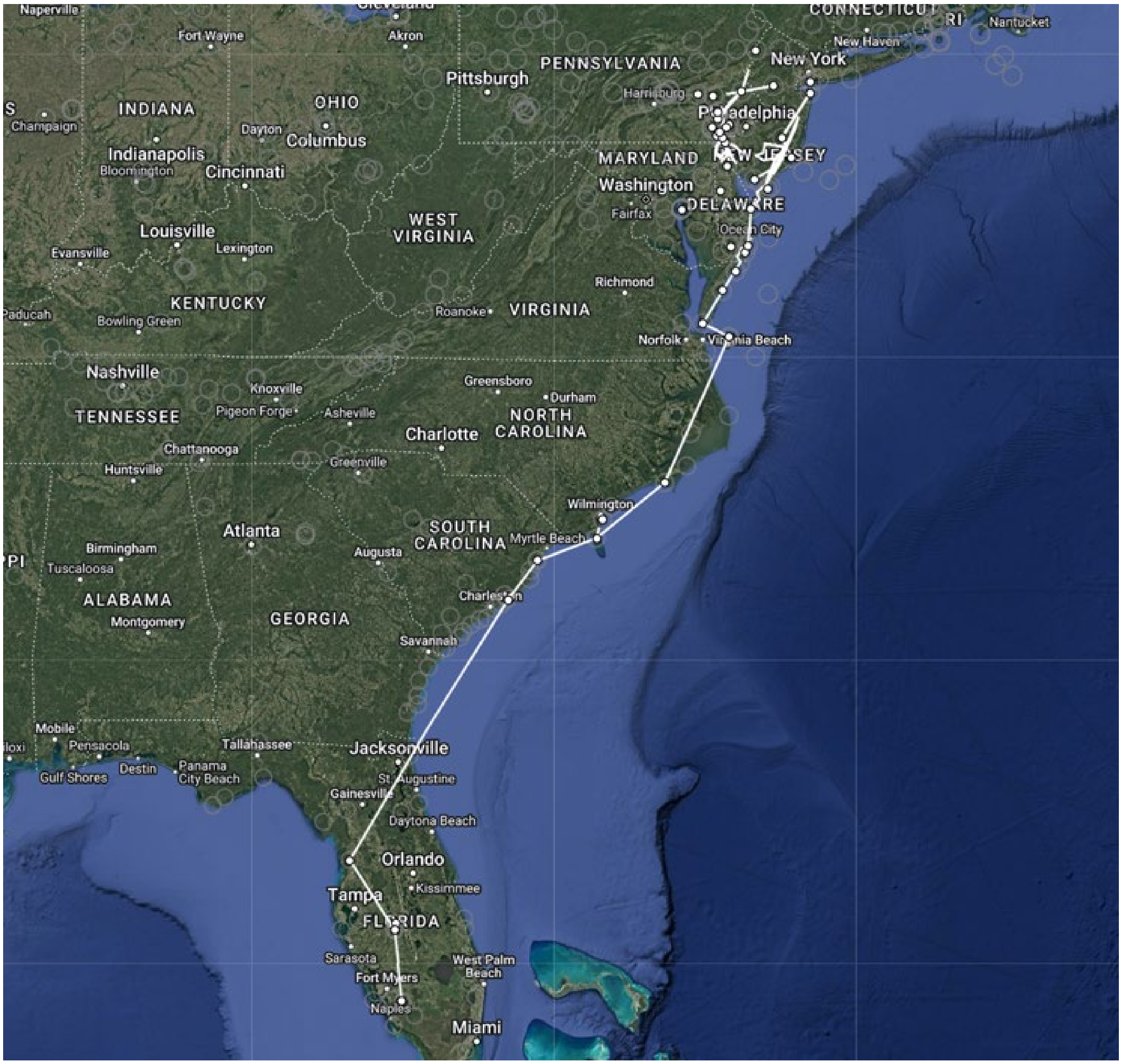
Detection Date and Local Time: 08/12/2022 18:00
Detection Date and Local Time: 08/14/2022 11:00
Detection Date and Local Time: 08/15/2022 11:00
Turbine: A01
Species: Purple Martin
Tag ID: 60790 (https://motus.org/data/track?tagDeploymentId=40986)



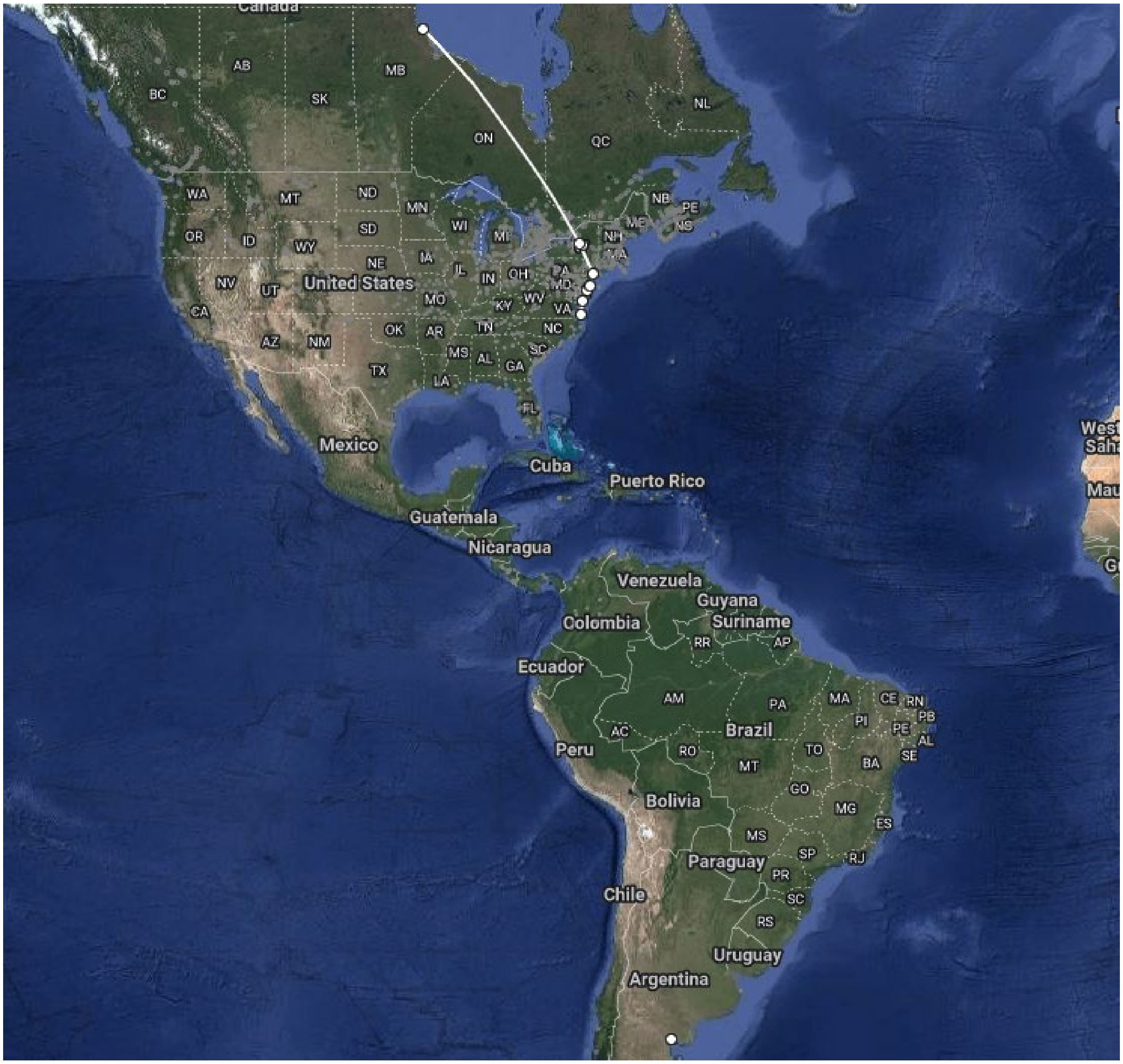
Detection Date and Local Time: 08/25/2022 16:50
Turbine: A01
Species: Purple Martin
Tag ID: 66283 (https://motus.org/data/track?tagDeploymentId=41038)



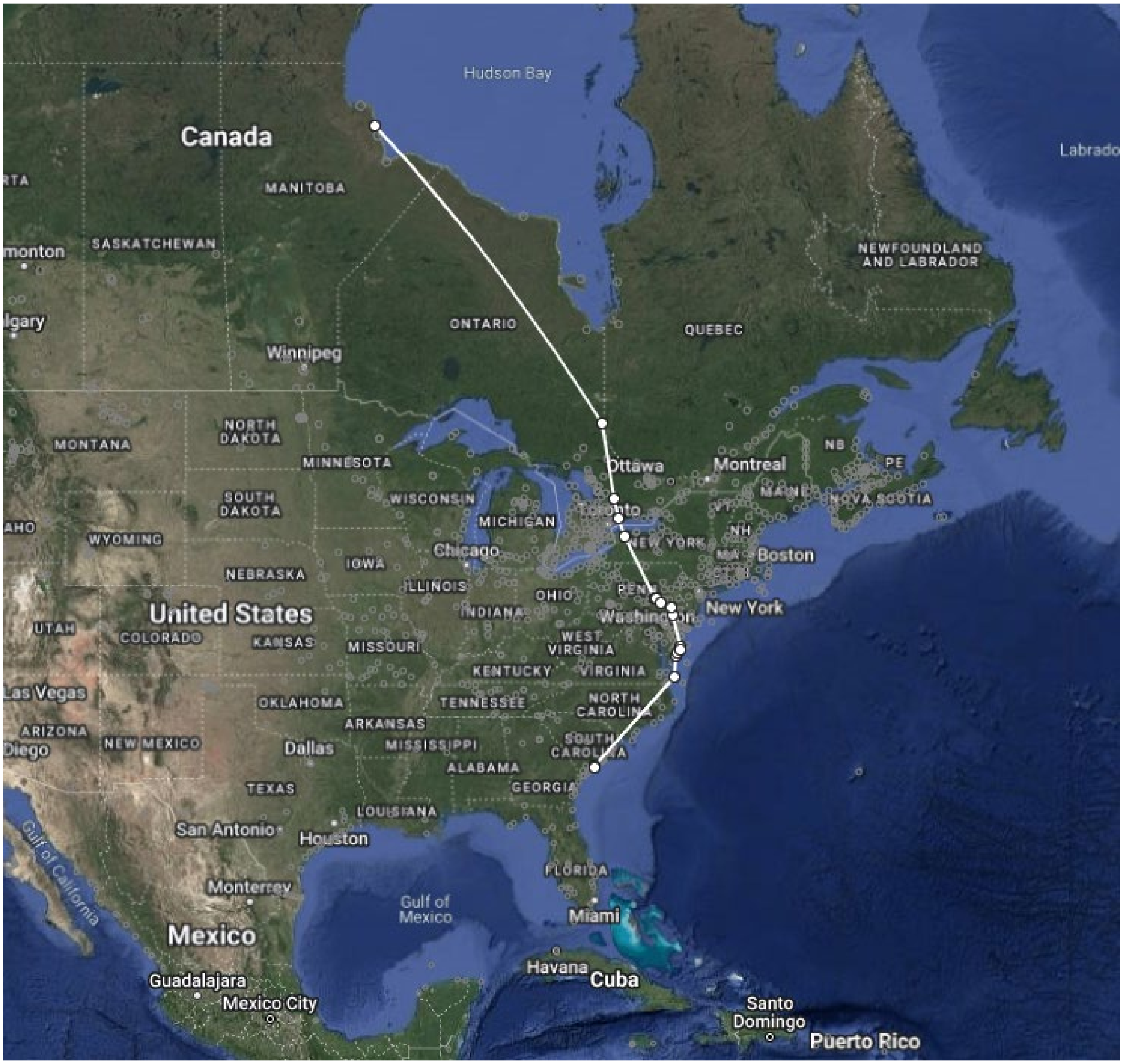
Detection Date and Local Time: 09/11/2023 18:50
Turbine: A01
Species: Purple Martin
Tag ID: 69626 (https://motus.org/data/track?tagDeploymentId=47941)



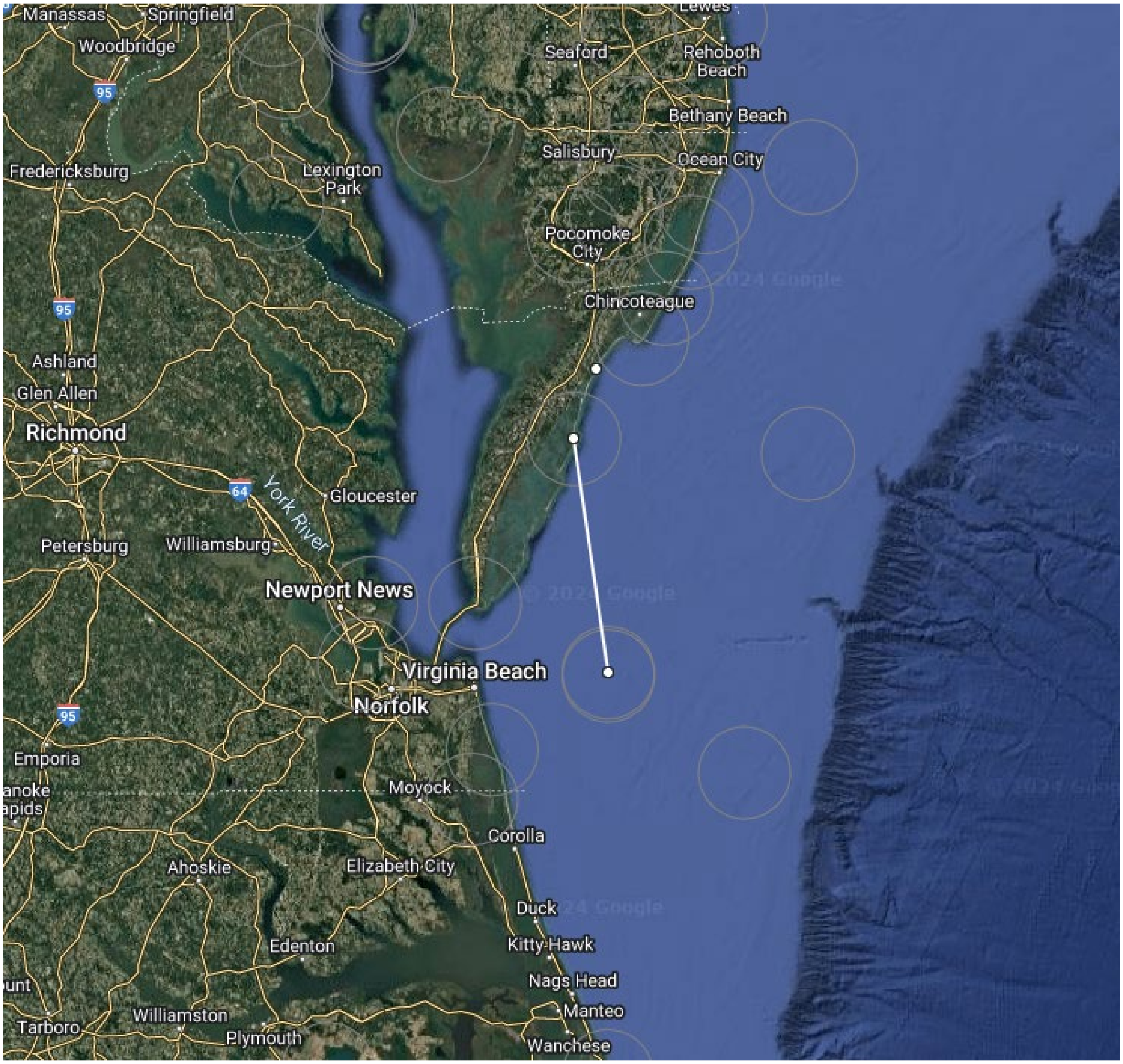
Detection Date and Local Time: 06/11/2023 4:15
Turbine: A02
Species: Red Knot
Tag ID: 64686 (https://motus.org/data/track?tagDeploymentId=49253)



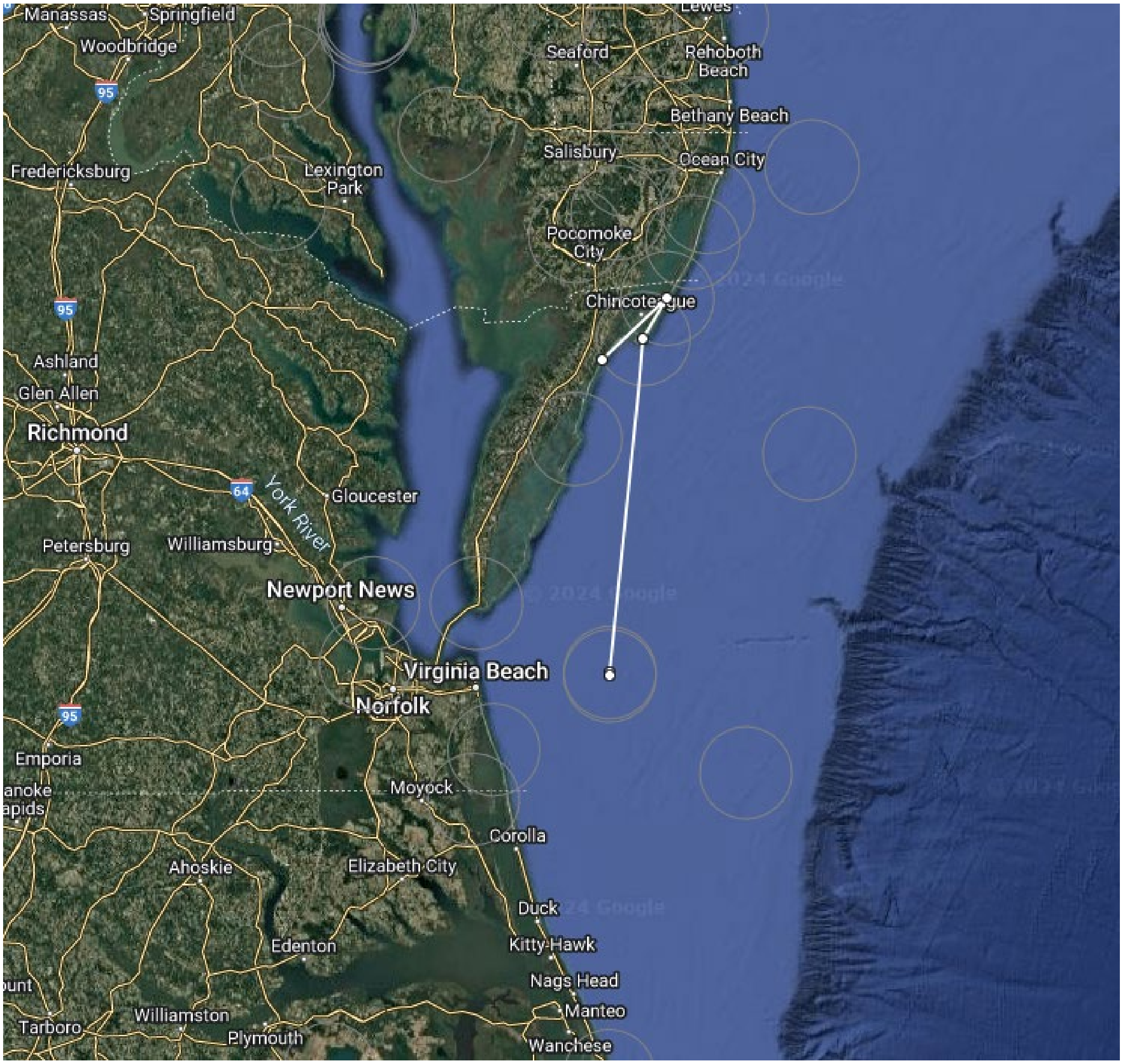
Detection Date and Local Time: 05/21/2023 11:00
Turbine: A02
Species: Red Knot
Tag ID: 63590 (https://motus.org/data/track?tagDeploymentId=48566)



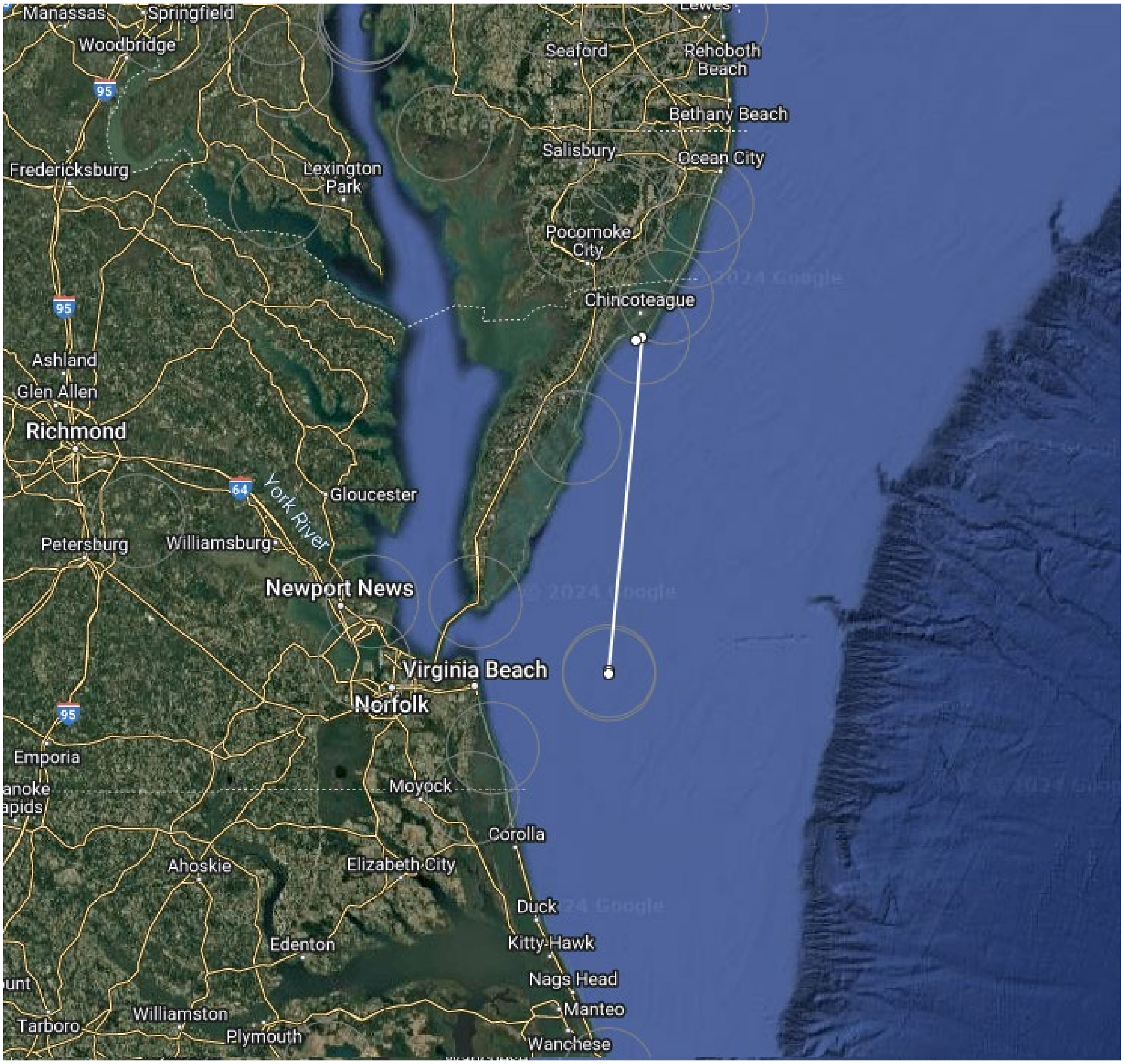
Detection Date and Local Time: 07/22/2023 1:30
Turbine: A01
Species: Piping Plover
Tag ID: 75074 (https://motus.org/data/track?tagDeploymentId=46763)



Detection Date and Local Time: 07/23/2023 3:00
Turbine: A01
Detection Date and Local Time: 07/23/2023 3:10
Turbine: A02
Species: Piping Plover
Tag ID: 75080 (https://motus.org/data/track?tagDeploymentId=47228)



Detection Date and Local Time: 07/26/2024 3:10
Turbine: A01
Detection Date and Local Time: 07/26/2024 3:15
Turbine: A02
Species: Piping Plover
Tag ID: 86469 (https://motus.org/data/track?tagDeploymentId=56282)



Detection Date and Local Time: 08/05/2023 23:45
Detection Date and Local Time: 08/06/2023 0:00
Turbine: A02
Species: Piping Plover
Tag ID: 75094 (https://motus.org/data/track?tagDeploymentId=48146)