Final Performance Report

Office of Conservation Investment

U.S. Fish and Wildlife Service

OK T-121-R-1 A Survey Protocol to Evaluate Distributions and Habitat Associations of Whip-poor-will and other Oklahoma Nightjars

Final Performance Report Generated 05/04/2026

Performance Report Approval Status:

Final Approved

Recipient:

OKLAHOMA DEPARTMENT OF WILDLIFE

Recipient Grant ID:

Federal Award Number:

F21AF02650

Funding Program(s) Name:

SWG Implementation

SWG Implementation Grants

Federal Award Start and End Date:

Jan 01, 2022 to Jun 30, 2025

Performance Reporting Period:

Jan 01, 2025 to Jun 30, 2025

Federal Award Recipient Contact(s):

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Federal Award Specialist(s):

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TRACS Group

Oklahoma Department of Wildlife Conservation

Type of Performance Report:

Final Performance Report

Public Description:

Birds that are aerial insectivores, including nightjars (family Caprimulgidae), are experiencing steep population declines across North America. The Whip-poor-will, which has declined by 69% since 1970, is an Oklahoma Species of Greatest Conservation Need that occurs in several Very High and High Priority Conservation Landscapes in the Ozarks and Ouachita Mountains Regions. Yet, the Whip-poor-will's population status and habitat associations are unknown in Oklahoma, largely due to the challenge of monitoring this and other nocturnal nightjar species. This project will increase information about Whip-poor-will and other Oklahoma nightjars through the development, validation, and implementation of a survey protocol that can be used in the future by ODWC to evaluate nightjar distributions and trends. During protocol development, we will analyze factors influencing nightjar detectability (e.g., lunar phase, time of night/year), which will provide invaluable information to refine and optimize the protocol. We will also use the validated survey protocol to generate baseline occurrence and distribution information and evaluate habitat associations for Whip-poor-will and other nightjars. This project will substantially increase knowledge about Whip-poor-will and other nightjars in Oklahoma, providing a baseline for monitoring future changes in population status, and benefiting range wide conservation efforts to recover the Whip-poor-will's North American population.

Federal Award Accomplishments

Strategy	Proposed Objective	Activity	Unit of Measure - Proposed	Unit of Measure - Reported
Research, Survey, Data Collection and Analysis	Conduct investigations (legacy)	Fish and wildlife species data acquisition and analysis (legacy)	1 Investigations	2 Investigations

Table of Contents - Project Statements

Project Statement: OK T-121-R-1 A Survey Protocol to Evaluate Distributions and Habitat Associations of Whip-poor-will and other Oklahoma Nightjars
Project Statement Approval Status: Final Approved

Objective Name: Objective 1 Conduct Investigations - Species Data

Strategy: Research, Survey, Data Collection and Analysis
Proposed Objective: Conduct investigations (legacy)
Pertains to R3: No

Activity Performed: Fish and wildlife species data acquisition and analysis (legacy)
# of Investigations: 1
Principal Investigator: Scott Loss
Geographic Location:

- General Location: Oklahoma
- Includes Marine Federal Waters: No
- Detailed Location:
    - Adair County
    - Cherokee County
    - Delaware County
    - Latimer County
    - Le Flore County
    - McCurtain County
    - Pushmataha County
    - Sequoyah County
- Location Description:

  Project activities will be implemented in eight counties within the Whip-poor-will's range in the Ozark Region and Ouachita Mountains, Arkansas Valley, and West Gulf Coastal Plain Region (Delaware, Cherokee, Adair, Sequoyah, Le Flore, Latimer, Pushmataha, and McCurtain counties). Specific transect and survey point locations are yet to be determined, but all surveys will be conducted from public roadways.

Activity Report Comments

This research investigation into the distribution and habitat associations of Eastern Whip-poor-wills and co-occurring nightjars was completed and the Final Report is provided.

* Totals to date represents a cumulative total of all periods of performance and may exceed the objective.

Objective Report	
Period of Performance	**# of Investigations**
Jan 1, 2022 to Dec 31, 2022	1
Jan 1, 2023 to Dec 31, 2023	
Jan 1, 2024 to Dec 31, 2024	
Jan 1, 2025 to Jun 30, 2025	1
Totals to Date*	2

Species Tags

Species Tags
Chuck-will's-widow *Antrostomus carolinensis*
Eastern Whip-poor-will *Antrostomus vociferus*
Common Nighthawk *Chordeiles minor*

Activity Performed Attachments

Note: Some attachments listed here may not appear in the Appendix due to file incompatibility. All attachments can be accessed using the links below.

Descriptive Name	Field Tags	Attachment Type
T-121-R-1 Nightjars FY2025 Final OSU	• Activity Report Comment	Performance Report / Performance Hard Copy Report

Performance Reporting Questionnaire

1. What progress has been made towards completing the objective(s) of the project?

This research investigation into the distribution and habitat associations of the Eastern Whip-poor-will and co-occurring nightjars in the eastern quarter of Oklahoma was completed. Below is a brief summary and the Final Performance Report is attached.

In this study, we developed and implemented a survey protocol to assess the distribution, factors affecting detection, and habitat associations of Eastern Whip-poor-will (*Antrostomus vociferus*), a Species of Greatest Conservation Need, as well as Chuck-will's-widow (*Antrostomus carolinensis*), in eastern Oklahoma. Using a stratified random sampling design, we established 51 road-based survey routes across eight counties and conducted two years of breeding-season monitoring in 2022 and 2023. We modeled detection and occupancy probability using a conditional co-occurrence occupancy framework, accounting for environmental variables and interactions between the two species. We found that detection of Whip-poor-wills was negatively associated with wind speed and that detection of Chuck-will's-widow was negatively associated with noise level. Detection of both species was positively associated with moon visibility and with a quadratic trend in temperature, with detection increasing with temperature until approximately 15–18 C (approximately 59-64 F) before declining with higher temperatures. We also found evidence that presence and calling behavior of Chuck-will's-widow may affect detection of Whip-poor-will. Specifically, Whip-poor-will detection probability was lower when Chuck-will's-widow was present and not calling and higher when Chuck-will's-widow was present and calling. Occupancy modeling revealed species-specific habitat preferences. Whip-poor-will was most likely to occupy sites at higher elevations and sites with intermediate proportions of young forest cover within 1500 m. Chuck-will's-widow occupancy was associated with a quadratic trend in elevation, peaking at ~200–300 m and declining as elevation increased further. Occupancy of both species strongly declined with increasing proportion of grassland cover surrounding a site within 1500 m—although Chuck-will's-widow appears to tolerate greater levels of grassland cover than Whip-poor-will. These findings underscore the importance of accounting for detection heterogeneity and interspecific interactions in surveys for the two nightjar species. Our protocol offers a robust framework for long-term monitoring of nightjars in Oklahoma and highlights opportunities for targeting land procurement, protection, and management activities that benefit the declining Whip-poor-will.

2. Please describe and justify any changes in the implementation of your objective(s) or approach(es).

There were no changes made to the scope of the project or its geographic area. No substantial modifications were needed to the project's approaches or objectives in order to complete it as planned.

3. If applicable, please share if the project resulted in any unexpected benefits, promising

practices, new understandings, cost efficiencies, management recommendations, or lessons learned.

This project increased our understanding of the distribution of Eastern Whip-poor-wills in eastern Oklahoma and provided unexpected insights into the relationship between Whip-poor-will occurrence and elevation and between occurrence and non-forest cover within the surrounding landscape. The Principal Investigators also examined the relationship between Eastern Whip-poor-wills and Chuck-wills-widows in the places where they both occurred and found that the presence of vocalizing Chuck-wills-widows can increase the detection rate for Eastern Whip-poor-wills. A survey protocol for nightjars, and specifically Eastern Whip-poor-wills, was developed that is a modification of nightjar survey techniques that have been evaluated in other states. This survey protocol takes into account lunar visibility, wind speed, noise, and temperature as the factors that have the greatest influence on calling behavior and detection probabilities for Whip-poor-wills and Chuck-wills-widows.

4. For Survey projects only: If applicable, does this project continue work from a previous grant? If so, how do the current results compare to prior results? (Recipients may elect to add attachments such as tables, figures, or graphs to provide further detail when answering this question.)

Although this was a survey project that looked specifically at nightjars, it was the first comprehensive survey of this kind in Oklahoma and was the first in the state to evaluate occupancy and detection rates for Eastern Whip-poor-wills and Chuck-will's-widows. The survey component of this project serves as the baseline for what we hope will be future monitoring efforts and assessments of nightjar geographic ranges in Oklahoma.

5. If applicable, identify and attach selected publications, photographs, screenshots of websites, or other documentation (including articles in popular literature, scientific literature, or other public information products) that have resulted from this project that highlight the accomplishments of the project.

Relevant highlights from this research project are included in the attached report and its four appendices.

6. Is this a project you wish to highlight for communication purposes?
Yes

Using a stratified random sampling design, the principal investigators established 51 road-based survey routes across eight counties in eastern Oklahoma and conducted two years of breeding-season monitoring in 2022 and 2023. They modeled detection and occupancy probabilities using a conditional co-occurrence occupancy framework that accounted for environmental variables and interactions between two nightjar species that often co-occurred together. They found that detection of Whip-poor-wills was negatively associated with wind speed and that detection of Chuck-will's-widow was negatively associated with noise level. Detection of both species was positively associated with moon visibility and with a quadratic trend in temperature, with detection increasing with temperature until approximately 15–18 C (approximately 59-64 F) before declining with higher temperatures. We also found evidence that presence and calling behavior of Chuck-will's-widow may affect detection of Whip-poor-will. Specifically, Whip-poor-will detection probability was lower when Chuck-will's-widow was present and not calling and higher when Chuck-will's-widow was present and calling. Occupancy modeling revealed species-specific habitat preferences. Whip-poor-will was most likely to occupy sites at higher elevations and sites with intermediate proportions of young forest cover within 1500 m. Chuck-will's-widow occupancy was associated with a quadratic trend in elevation, peaking at ~200–300 m and declining as elevation increased further. Occupancy of both species strongly declined with increasing proportion of grassland cover surrounding a site within 1500 m—although Chuck-will's-widow appears to tolerate greater levels of grassland cover than Whip-poor-will. These findings underscore the importance of accounting for detection heterogeneity and interspecific interactions in surveys for the two nightjar species. Our protocol offers a robust framework for long-term monitoring of nightjars in Oklahoma and highlights opportunities for targeting land procurement, protection, and management activities that benefit the declining Whip-poor-will. Recommendations were generated for developing a long-term monitoring procedure for the two nightjar species under multiple objectives.

Questionnaire Attachments

Note: Some attachments listed here may not appear in the Appendix due to file incompatibility. All attachments can be accessed using the links below.

Descriptive Name	Field Tags	Attachment Type
2025 Final Report T-121-R-1 Nightjars F2...	• Objective Completion Progress	Performance Report / Performance Hard Copy Report
T-121-R-1 Appendix 1 - Route-Stop GPS Lo...	• Objective Completion Progress	Performance Report / Research Data (to include a copy of MS or PhD product)
T-121-R-1 Appendix 2 - Nightjar Survey P...	• Objective Completion Progress	Performance Report / Performance Hard Copy Report

T-121-R-1 Appendix 3 - Field Data Sheet	• Objective Completion Progress	Performance Report / Research Data (to include a copy of MS or PhD product)

Appendix

FINAL PERFORMANCE REPORT

Federal Aid Grant No. F21AF02650 (T-121-R-1)

A Survey Protocol to Evaluate Distributions and Habitat Associations of Whip-poor-will and other Oklahoma Nightjars

Oklahoma Department of Wildlife Conservation

January 1, 2022 through June 30, 2025

FINAL PERFORMANCE REPORT

State: Oklahoma **Grant Number:** F21AF02650 (T-121-R-1)

Grant Program: State Wildlife Grants

Grant Title: A Survey Protocol to Evaluate Distributions and Habitat Associations of Whip-poor-will and other Oklahoma Nightjars

Grant Period: January 1, 2022 to June 30, 2025

Principal Investigators:
Scott R. Loss , Dept of Natural Resource Ecology and Management, Oklahoma State University
Matthew Broadway (Project Manager and PhD Student, Dept of Natural Resource Ecology and Management, Oklahoma State University
Timothy J. O’Connell, Dept. of Natural Resource Ecology and Management, Oklahoma State University
Robert C. Lonsinger, Oklahoma Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey and Oklahoma State University

ABSTRACT:

In this study, we developed and implemented a survey protocol to assess the distribution, factors affecting detection, and habitat associations of Eastern Whip-poor-will (*Antrostomus vociferus*), a Species of Greatest Conservation Need, as well as Chuck-will’s-widow (*Antrostomus carolinensis*), in eastern Oklahoma. Using a stratified random sampling design, we established 51 road-based survey routes across eight counties and conducted two years of breeding-season monitoring in 2022 and 2023. We modeled detection and occupancy probability using a conditional co-occurrence occupancy framework, accounting for environmental variables and interactions between the two species. We found that detection of Whip-poor-wills was negatively associated with wind speed and that detection of Chuck-will’s-widow was negatively associated with noise level. Detection of both species was positively associated with moon visibility and with a quadratic trend in temperature, with detection increasing with temperature until approximately 15–18 C (approximately 59-64 F) before declining with higher temperatures. We also found evidence that presence and calling behavior of Chuck-will’s-widow may affect detection of Whip-poor-will. Specifically, Whip-poor-will detection probability was lower when Chuck-will’s-widow was present and not calling and higher when Chuck-will’s-widow was present and calling. Occupancy modeling revealed species-specific habitat preferences. Whip-poor-will was most likely to occupy sites at higher elevations and sites with intermediate proportions of young forest cover within 1500 m. Chuck-will’s-widow occupancy was associated with a quadratic trend in elevation, peaking at ~200–300 m and declining as elevation increased further. Occupancy of both species strongly declined with increasing proportion of grassland cover surrounding a site within 1500 m—although Chuck-will’s-widow appears to tolerate greater levels of grassland cover than Whip-poor-will. These findings underscore the importance of accounting for detection heterogeneity and interspecific interactions in surveys for the two

nightjar species. Our protocol offers a robust framework for long-term monitoring of nightjars in Oklahoma and highlights opportunities for targeting land procurement, protection, and management activities that benefit the declining Whip-poor-will.

OBJECTIVES:

Objective 1: Develop and refine a survey protocol to effectively detect nightjars.

Objective 2: Generate baseline nightjar distribution data and evaluate factors influencing probability of detection to inform and optimize a spatiotemporal sampling design for future monitoring.

Objective 3: Quantify occurrence and species-specific habitat associations of nightjars in eastern Oklahoma.

INTRODUCTION and BACKGROUND:

North America has lost three billion breeding birds since 1970, and aerial insectivores including nightjars (family Caprimulgidae) are among the avian groups in steepest decline (Rosenberg et al. 2019; Spiller & Dettmers 2019). The Eastern Whip-poor-will (*Antrostomus vociferous*; hereafter, Whip-poor-will), which inhabits forests and woodlands in eastern Oklahoma during its breeding season, is of particular concern, having lost 69% of its North American population since 1970 (Rosenberg et al. 2019). This species has been placed on several lists of conservation concern and priority, including the international Partners in Flight Watch List (Rosenberg et al. 2016) and the IUCN Red List (BirdLife International 2018), as well as many state and provincial lists. The 2015 Oklahoma Comprehensive Wildlife Conservation Strategy (ODWC 2015) identifies Whip-poor-will as a Tier II Species of Greatest Conservation Need (SGCN) that occurs in several of the state's Conservation Landscapes of Very High, High, and Moderate Priority in the Ozarks Region and the Ouachita Mountains, Arkansas Valley, and West Gulf Coastal Plain Region.

For Whip-poor-will, the Oklahoma nightjar species of greatest conservation concern, fine-scale distributions, population trends, and even basic habitat associations, are largely unknown throughout the range, including in Oklahoma (Cink et al. 2017). Only a few studies have advanced beyond anecdotal information to systematically document Whip-poor-will habitat affinities. These studies suggest that the species prefers open woodlands and regenerating woodlands next to mature forests, as opposed to extensive, mature, closed-canopy forests (Wilson & Watts 2008; Slover & Katzner 2016). Whip-poor-will abundance and occurrence also appear to be influenced by broad-scale factors, as studies indicate a positive effect from the amount of forested land cover in the surrounding landscape and negative effects from the amount of urban and agricultural land (Brenner & Jorgensen 2019; Vala et al. 2020). The Whip-poor-will's distribution also may be influenced by elevation; this species may outnumber its more common relative, the Chuck-will's-widow (*Antrostomus carolinensis*), at relatively high elevations in the Ouachita and Ozark mountains of Arkansas (James and Neal 1986), but it decreases with increasing elevation in the Appalachian Mountains (Slover & Katzner 2016). Despite these studies, no research has evaluated distributions and habitat associations of Whip-poor-will and other nightjar species in Oklahoma. This lack of information limits the understanding of nightjar population statuses and trends in the state, and the potential habitat management interventions that could help stabilize and recover populations of Whip-poor-wills and Chuck-wills-widows.

A major factor contributing to the lack of information about Whip-poor-will and other nightjars is the significant challenge of monitoring these species. Nightjars call and forage under cover of darkness and are largely inactive during typical, early-morning bird survey periods. As a result, they go largely undetected in major bird survey efforts like the North American Breeding Bird Survey and state Breeding Bird Atlases. Moreover, the probability of detecting nightjars that are present in a location is influenced by the rate of calling by territorial males, and calling rate is in turn influenced by lunar illumination and phase (Wilson & Watts 2006). Failure to identify and account for variation in nightjar detectability in relation to lunar cycles, as well as other factors that may influence detection (e.g., time of night, ambient and human-generated noise, and presence and calling behavior of other nightjar species; Slover & Katzner 2016; Vala et al. 2020), can limit the ability to evaluate changes in population distributions and abundance (Wilson & Watts 2006). *A targeted survey effort that focuses on sampling nightjars, and that accounts for variation in detectability, is needed to generate improved information about distributions, population trends, and habitat associations of Whip-poor-will and other nightjar species in Oklahoma*.

The purpose of this project was to develop and validate a survey protocol that can be used to evaluate population distributions and trends for the Whip-poor-will (a Tier II SGCN) and other nightjar species in Oklahoma. Additionally, we implemented the survey protocol to generate baseline occurrence and distribution information for Whip-poor-wills, and to evaluate habitat associations for Whip-poor-wills and Chuck-will's-widows in eastern Oklahoma.

APPROACH:

Project personnel: Project personnel included the Principal Investigators (Scott Loss, Timothy O'Connell, and Robert Lonsinger), the PhD student managing the project (Matthew Broadway) and field technicians and undergraduate students that assisted with field work and data management (Emma Ainsworth, Gunner Labyer, and Chris Lloyd).

Study area: The spatial scope to address the objectives of this study (hereafter "study area") is based on the Whip-poor-will's suspected range in Oklahoma at the time of project initiation in 2022. This area spans 8 counties in the Ozark Region and the Ouachita Mountains, Arkansas Valley, and West Gulf Coastal Plain Region (Delaware, Cherokee, Adair, Sequoyah, LeFlore, Latimer, Pushmataha, and McCurtain Counties). We also sought to monitor the similar Chuck-will's-widow during surveys because its calling behavior is similar to that of the Whip-poor-will, and because there may be direct or indirect competition between these two species that influences occurrence and calling behavior of Whip-poor-wills.

Our study area represents the approximate southwestern and western breeding range extents of Whip-poor-will and Chuck-will's-widow, respectively. The eight-county study area covers 22,072 km^2 across five ecoregions in eastern Oklahoma. These ecoregions are generally humid with 30-year normal precipitation amounts during survey seasons of 12.6 cm (range: 8.6-17 cm); 30-year normal maximum and minimum temperatures for May-July were approximately 30 °C and 18 °C, respectively (https://mesonet.org/). The Ozark Highlands (2,205 km^2), Boston

Mountains (4,274 km^2), Arkansas Valley (1,894 km^2), Ouachita Mountains (10,638 km^2), and Gulf Coastal Plain (3,061 km^2) ecoregions contrast in vegetation, land-use practices, and topography. A rich mosaic of vegetation communities including mixed and monoculture oak (*Quercus* spp.), hickory (*Carya* spp.), and pine (*Pinus* spp.) forests, oak savannah, and bottomland hardwood juxtaposed to remnant tallgrass prairies comprised the prevailing natural vegetation communities across ecoregions. Cultivation of loblolly pine (*Pinus taeda*) outside of its native range is a dominant land-use practice in the Ouachita Mountains. Contrastingly, crop, livestock, and hardwood timber production are predominate land uses in the Arkansas Valley, Gulf Coastal Plains, Boston Mountains, and Ozark Highlands, depending on soil fertility and dominant land-cover type. Open water constitutes ~598 km^2 of the entire study area, mostly attributable to man-made lakes. Karst features, including perennial streams and ephemerally wet valleys, occur throughout more rugged ecoregions. Elevation varies from valleys to plateaus (Ozark Highlands) and east-west mountain formations (Ouachita Mountains) from 99-811 m above sea-level.

<u>Objective 1: Develop and refine a survey protocol to effectively detect nightjars</u>: Monitoring is most valuable when accounting for imperfect detection of the focal species, and understanding factors that influence detection is paramount when synchronously monitoring multiple species. The first year of monitoring in 2022 was designed primarily to generate data to evaluate factors influencing detection probabilities for Whip-poor-wills and Chuck-will's-widows; information that helped further optimize our sampling design for monitoring in 2023. In this section, we first describe development of the 2022 sampling protocol and then discuss how evaluations of detectability, further reported under objective 2, were used to refine our survey protocol in 2023.

Selection of Survey Routes in Year 1 (2022): We used a stratified random sampling design to generate survey routes along accessible roads in the study area. Because of the high diversity of land cover types in the study area, as well as the low predicted occupancy of Whip-poor-wills, we determined that obtaining high spatial replication of survey routes and points would be crucial for drawing reliable inferences about the environmental factors influencing nightjar detection and occupancy. To ensure adequate sampling of all land cover types, we divided the study area into 16 km x 16 km grid cells using the Spatial Analyst Fishnet tool in ArcGIS 10.8 (ESRI Systems, Redlands, California). In each grid cell (n=64), we generated three to six random points using the Spatial Analyst Generate Random Points tool in ArcGIS, and we snapped points to the nearest accessible road using the 2021 TIGER/Line shapefile (U.S. Census Bureau 2021). This approach ensured that the entire area within a cell was available for sampling, reducing sampling biases that arise from generating random points on roads. Next, we connected the first randomly generated point to nearby points using the Route Builder Tool in ArcGIS Pro (ESRI Systems, Redlands, California). If resulting routes were ≥16 km long, we trimmed routes from the end point until they were approximately 16 km in length and thus could include ≥10 survey points/stops per route, each spaced ≥1 km apart.

For practical reasons, we stratified routes by road type and accessibility, avoiding major highways, private roads, roads under construction, and roads determined to pose a safety risk to project personnel. In cases where one or more route endpoints were inaccessible, we trimmed routes from the opposite or both directions until desired route length was achieved. If during field work a route was determined to be impractical due to the above conditions, we re-constructed the problematic route portion and retained the viable portion (however, if ≥ 70% of a route was inaccessible, we eliminated it and randomly generated a replacement route). All routes included ≥10 survey stops. In cases of route non-linearity, which in some cases would have led to surveyed areas overlapping among stops, we extended routes beyond 16 km to achieve 10 independent stops. Because all selected stops were considered independent, each stop constitutes a sampling unit (or "survey site") within an occupancy modeling framework (MacKenzie et al. 2002). A map of selected and backup survey routes and an example route are shown in Figure 1.

Development of Survey Protocol: We conducted nocturnal point-count surveys for Whip-poor-wills and Chuck-will's-widows at all routes and stops throughout the breeding season regardless of male calling activity (Wilson & Watts 2006). Surveys followed a protocol used by the Nightjar Survey Network (www.nightjars.org/) with minor adjustments to the sampling duration and lunar phases during which sampling occurred. In 2022, we surveyed routes between 14 April and 24 June and across all primary and secondary lunar phases. We conducted ≥ two replicate surveys at all stops across three synodic months (i.e. lunar cycles; or 29.53 days), emphasizing replication within and among lunar phases. Surveys were conducted between 30 minutes after sunset and 15 minutes before sunrise. At each stop, we conducted timed five-minute surveys, recording all individual calling males of both nightjar species and one-minute bins in which each individual was heard. This approach allows either a single-or multi-scale approach to modeling detection (Nichols et al. 2008). Distinguishing detections at finer temporal scales within a sampling period, as in a multi-scale approach, allows investigators to better inform the detection process when true occupancy of a target species is low (MacKenzie and Royle 2005, Nichols et al. 2008); disregarding finer scale detection patterns may preclude reasonable detection estimates (Nichols et al. 2008, Hines et al. 2010, Amundson et al. 2014).

Between 14 April and 24 June of 2022, we sampled 47 distinct random routes, achieving an average of 3.4 replications (range: 1-6) across all routes for a total of 158 independent route runs. In total, 482 independent sampling stops were sampled ≥ two times each, while logistics or accessibility precluded sampling 29 points (~3 routes) more than once. Sampling effort was well-distributed across different moon phases, which we expected to influence nightjar calling rates and thus detection probability. Overall, we ended the first survey season with 80 total route surveys occurring when the moon was not visible by the observer and 94 route surveys completed while the moon was visible (during 16 of 158 route surveys, the moon transitioned from not visible to visible between route start and end).

Evaluation of 2022 sample representativeness to inform 2023 survey protocol adjustments: After completion of the 2022 field season, we conducted analyses to determine if our routes provided a representative sample of land cover types in our study area. We did this because the occupancy modeling approach we used (further described under Approach for Objectives 2 and 3) is a variant of logistic regression modeling where, like all linear modeling techniques, reliability of the results and interpretation depend on realization of model assumptions, including that samples are representative. For example, occupancy models assume sampling units (i.e. survey stops in our case) are determined in a probabilistic fashion where all locations have an equal probability of being sampled. In occupancy modeling, we generally seek to determine relationships between a given landscape and a species' population. However, the sample population is not the same as the entire population for which we wish to make inference, as it represents only a proportion of that larger population. Hence, sampling units must be representative of the larger population and landscape to make reliable inferences.

We compared the proportional occurrence of land cover characteristics within the area sampled in 2022 to the respective proportional occurrence of land covers across our entire study area. To do this, we calculated the proportional representation of each land cover type across the study area, providing a known-population, no-uncertainty value for each cover type. We also calculated the proportional representation of the same cover types within all 500-meter buffers surrounding the survey stops. Based on this analysis, we found that Low (<30%) and Medium (30-70%) forest canopy-cover classes were sampled in proportion to their availability in the landscape, while High (>70%) canopy-cover was under-sampled and non-forested cover was over-sampled (Figure 2). Moreover, most specific land cover categories were sampled in proportion to their availability, with exceptions mirroring the differences found for canopy-cover class. Specifically, grasslands (also considered non-forested) were over-sampled relative to their availability on the landscape, and forests were under-sampled (Figure 3). Overall, the mean difference between expected and observed land cover proportions was 8.3%. Because these land cover categories were likely to be spatially auto-correlated, reducing the sampling of portions of the study area containing mostly non-forested land was expected to result in an equivalent increase in sampling of forested area. <u>Based on this analysis, we realized that we could increase logistic efficiency by reducing the number of total survey stops sampled in 2023 by ~150</u> (31% reduction from the 511 stops sampled in 2022) by balancing representation of land cover types, and specifically, by removing approximately two times more grassland stops than forest stops.

Our protocol for conducting nightjar surveys did not change substantially in 2023 except that we did not sample certain routes that contained a higher proportion of grassland habitat. This was done based on the above analysis, which indicated we could reduce the number of survey stops sampled by ~31%. In 2023, we sampled 51 routes between 30 April and 2 July (an average of 3 replications per route; range: 1-6; total independent route runs: 153; total independent sampling stops: 467) and reduced overall sampling by 9.5%.

<u>Objective 2: Generate baseline nightjar distribution data and evaluate factors influencing probability of detection to inform and optimize a spatiotemporal sampling design for future monitoring:</u>

Data collection for detection predictor variables: To evaluate factors affecting nightjar detectability, information that also helped us generate less-biased estimates of nightjar occupancy, we collected field data and made calculations of potential correlates of detection probability. During our nightjar surveys, we recorded observation-level covariates that are unique to, and variable among, each observation, and that may explain variability in the detection process (Kéry et. al. 2010, Mackenzie et al. 2017). Thompson et al. (2022) observed variation among observers in their ability to detect Chuck-will's-widow and Whip-poor-will calls during surveys similar to ours, and other studies found negative effects of ambient noise (Slover & Katzner 2016) and wind (Palumbo et al. 2021) on Whip-poor-will detectability.

The observation-level detection covariates we recorded were temperature, wind speed, noise level, cloud cover, date, survey time, and lunar characteristics. Using a handheld barometer, we recorded minimum temperature (°C) during the survey and wind speed expressed as the average during a 30-second interval at the mid-point of each survey. We recorded ambient noise as a four-level ordinal value (i.e., none, low, medium, high), and percent cloud cover (to the nearest 10-percent) during each survey. The detection process also may be explained by biological processes that vary across surveys. We expected temporal variation in species-specific detection in response to seasonally variable environmental conditions (e.g., declining food availability; Thompson et al. 2022) or variation within a sampling evening (i.e., survey time; Souza-Cole et al. 2022). Thus, we recorded season date expressed as an ordinal (i.e., day of season) value and survey time relative to local sunset, as additional observation-level covariates to explain detection. Because detection of male nightjar calling may depend on dynamic lunar variables (Wilson & Watts 2006; Knight et al. 2022), we used the lunar (Lazaridis 2014) and suncalc (Benoit & Elmarhraoui 2019) packages in Program R version 4.1.3 (R Core Team 2023) to acquire spatiotemporally explicit lunar data, including moon face illumination and altitude. We compared linear, as well as quadratic structures, of these lunar variables with a simple binomial classification of moon visibility during a survey (i.e., no = 0, yes = 1) and used only the most supported independent lunar covariate to explain detection. Additionally, we recorded year, individual observer, and observer experience as nuisance covariates that may affect detection.

Analysis of factors affecting nightjar detection using occupancy modeling: We used the conditional co-occurrence occupancy modeling framework because it permits simultaneous modeling of detection (p) and occupancy (ψ) parameters for two species, as well as interspecific effects (Richmond et al. 2010; Table 1). Differing parameter constraints among candidate models can provide evidence for interspecific interactions related to presence and behavior. Additionally, the model permits consideration of independent covariate effects on occupancy and detection; however, parameter counts increase dramatically due to conditional co-occurrence structures which may hinder parameter estimation. To limit issues of model convergence, the influence of covariates on species-specific detection and occupancy are often evaluated first, and then the information from those model structures is used when constructing the 12 conditional co-occurrence model structures of Richmond et al. (2010). Therefore, we considered an *a priori* suite of observation- and site-level covariates to identify the most-supported detection and occupancy structures for each nightjar species in single-season, single-species occupancy models using an all-possible-combinations build-up approach (MacKenzie et al. 2002; Doherty et al. 2012; Morin et al. 2020). Here we describe aspects of the analysis related to the detection portion of the model, and the aspects related to the occupancy portion are described further below - although we note that some repetition exists between these sections because the analysis framework seamlessly meshes both detection and occupancy analyses.

We first used a Pearson correlation coefficient to test for pairwise correlations among detection-related explanatory variables prior to additive model construction. Unbounded continuous covariates were not included together in models when $|r| > 0.5$ (Dormann et al. 2013) or when correlation plots revealed non-linear structure between covariates. We detected a positive correlation between season date and ambient temperature during surveys ($r = 0.54$); we discarded the season date covariate because of its relatively weak effect on detection and model fit compared to that of ambient temperature. For single-season, single-species occupancy analyses, we first modeled detection as a function of covariates while holding occupancy constant (i.e., the intercept-only model). Separately, we identified the most-supported occupancy models using the inverse approach whereby occupancy was modeled as a function of covariates and detection was held constant. As also described under objective 3, the most-supported model structures from each stage were then combined to jointly model detection and occupancy each as functions of independent covariates. In each stage, we corrected for overdispersion to avoid over-fitting models using the estimated c-hat from the global model for each species and compare models using quasi-likelihood (Lebreton et al. 1992). We combined only those model structures from each stage with ≤5 $\Delta QAIC_c$ units from the most-supported model, or in descending order of $QAIC_c$ rank until ≥90% of the total weight was recovered (Morin et al. 2020). In the last stage, the combined detection and occupancy parameterization structures were compared, and the most-supported model was used to parameterize a two-species, conditional co-occurrence model (hereafter, co-occurrence model; Richmond et al. 2010).

Objective 3: Quantify occurrence and species-specific habitat associations of nightjars in eastern Oklahoma:

Data collection for occuapancy predictor variables: Landscape characteristics, including composition of coarse landcover types, play critical roles in structuring ecological communities (Bonthoux et al. 2017; Duflot et al. 2017). However, forest cover is a prerequisite vegetative community for the Whip-poor-will across its range and no studies have identified Chuck-will's-widow responses to analogous land-cover types (English et al. 2017; Spiller & Dettmers 2019; Spiller & King 2021). Therefore, we investigated relative effects of land-cover composition on the occupancy of each species. We extracted land-cover classification data from the Landfire Existing Vegetation Type (LANDFIRE 2020) geospatial dataset using ArcGIS; this dataset provides a 30 m pixel resolution generated using ground-truthing and lidar techniques that improve discretization of vegetative communities. As we were specifically interested in nightjar responses to broad-scale land-cover composition, we collapsed similar vegetation classes in our study area from the original 70 down to 9 categories based on vegetation structure similarities but were interested in the effects of only five categories (see below). The importance of early successional forest structure to Whip-poor-wills has been observed or implied in other studies (Tozer et al. 2014; Akresh & King 2016; Thompson et al. 2022). Therefore, we further separated mature forests from those representing young forest regrowth, regardless of dominant stand composition. Thereafter, we calculated the proportion of the following five land-cover classes of interest surrounding all sites: grassland, forest, young forest, urban, and wetland. The importance of land-cover composition and land use to Whip-poor-wills may vary across latitudes or depend on landscape context (Farrell et al., 2019; Souza-Cole et al. 2022; Vala et al. 2020); therefore, we used land-cover class variables comparable to previous studies. Because landscape characteristics affect populations through direct and indirect mechanisms at multiple spatial scales (Fahrig 1997; Hingee et al. 2022), we conducted a multi-scale analysis to determine the most appropriate scale-of-effect at which species-specific occupancy was most influenced by each respective land-cover class (Brennan et al. 2002). For each land-cover class variable, we identified the most-supported scale-of-effect to carry forward into occupancy and detection analyses by comparing model fit based on Akaike's Information Criterion adjusted for small sample size (AIC_c; Akaike 1973) for each variable computed in 500-, 1000-, 1500-, and 5000-meter radii buffers surrounding the stops.

Analysis of factors affecting nightjar occupancy and co-occurrence using occupancy modeling: As described for detection predictor variables under Objective 2, we used a Pearson correlation coefficient to test for pairwise correlations among explanatory variables prior to additive model construction. Proportional land-cover covariates were not included in the same model when they exhibited even moderate pairwise correlation (i.e., $|r| > 0.25$; Valle et al. 2024). We observed moderate (i.e., $|r| > 0.25$) correlations between the proportion of grassland and forest cover at all spatial scales. We subsequently excluded the proportion of forest cover from further consideration allowing the inclusion of another important forest classification (i.e., young forest) and grassland cover without limiting inference only to two forest cover variables.

As described under Objective 2, we used the conditional co-occurrence occupancy modeling framework because it permits the simultaneous modeling of detection (p) and occupancy (ψ) parameters for two species, as well as interspecific effects (Richmond et al. 2010; Table 1). For single-season, single-species occupancy analyses, we first modeled detection as a function of covariates while holding occupancy constant (i.e., the intercept-only model). Separately, we identified the most-supported occupancy models using the inverse approach whereby occupancy was modeled as a function of covariates and detection was held constant. The most-supported model structures from each stage were then combined to jointly model detection and occupancy each as functions of independent covariates. In each stage, we corrected for overdispersion to avoid the over-fitting of the models using the estimated c-hat from the global model for each species and compared models using quasi-likelihood (Lebreton et al. 1992). We combined only those model structures from each stage with ≤5 $\Delta QAIC_c$ units from the most-supported model, or in descending order of $QAIC_c$ rank until ≥90% of the total weight was recovered (Morin et al. 2020). In the last stage, the combined detection and occupancy parameterization structures were compared, and the most-supported model was used to parameterize a two-species, conditional co-occurrence model (hereafter, co-occurrence model; Richmond et al. 2010).

We investigated co-occurrence between these two nightjar species with overlapping morphology, diet, and activity patterns for which a dominance hierarchy was unclear. Boyce and Martin (2019) acknowledged that if competitive interactions are more important at the trailing edge of a species' range (Whip-poor-will in this study), a competitive dominant (Chuck-will's-widow) may display elevated interspecific aggression towards a subordinate (MacArthur 1984; Jankowski et al. 2010), a condition that may structure patterns of co-occurrence. Additionally, competitive dominance is often attributed to body mass (Leighton et al. 2023). In concert, those paradigms suggest Chuck-will's-widows may exclude the more specialized Whip-poor-wills. However, the presupposition of size-based dominance often ignores the interconnected constraints of metabolic demands, resource availability (i.e., site quality), competition, and degree of specialization (Devictor et al. 2008). Often conflated with "dominance" (Peiman & Robinson 2010), competitive ability depends on reproductive fitness relative to environmental conditions, and theory further predicts a smaller consumer like the Whip-poor-will may be competitively superior even with multiple shared resources (Levins 1962; Bagchi & Ritchie 2012). Hence, a broadly adapted larger-bodied generalist like Chuck-will's-widow may be poorly suited to exploit resources (e.g., food items) under conditions in which a specialist like the Whip-poor-will is better suited, and vice versa. Indeed, foraging theory predicts the exclusion of a generalist competitor by a specialist when the latter more efficiently uses resources thus supporting a competing hypothesis that Whip-poor-wills may exclude Chuck-will's-widows (MacArthur & Levins 1964; Tilman 1981; Robinson & Wilson 1998). We use reciprocal dominance-subordinate species orientations in co-occurrence models to test competing hypotheses related to the direction of interspecific interactions between the two species.

We performed all occupancy analyses in Program MARK version 10.3 (White & Burnham 1999) and, because there is no method of adjustment for over-dispersion in conditional co-occurrence models, evaluated these based on relative support using AIC_c (Akaike 1973; Burnham et al. 1998). However, we excluded from further consideration any models with covariates that had 85% CIs overlapping zero, regardless of AIC_c weight (Arnold 2010), and we also discarded models that failed to converge. We report relevant model weights (w_i) and ΔAIC_c values, as well as unstandardized covariate effect sizes (β ± SE) from the most-supported single-species model for each species used to parameterize the co-occurrence model (Richmond et al. 2010). We selected this approach because the unconditional co-occurrence model of Rota et al. (2016): 1) does not identify the direction of interspecific effects between a species pair, which is an important consideration under an ambiguous dominance hierarchy, and 2) does not accommodate interspecific effects on detection, a crucial component to our objectives.

RESULTS AND DISCUSSION:

Objective 1: Develop and refine a survey protocol to effectively detect nightjars:

The deliverable for this objective was the survey protocol described in detail in the Approach section. We have no other specific results to present in association with this objective; however, we provide the GPS points for all routes and route stops in Appendix 1, a protocol outline in Appendix 2, and a field data sheet for surveys in Appendix 3.

Objective 2: Generate baseline nightjar distribution data and evaluate factors influencing probability of detection to inform and optimize a spatiotemporal sampling design for future monitoring:

Descriptive Results of Surveys and Nightjar Occurrence: In both 2022 and 2023, we conducted two or more replicate surveys at all stops across three synodic months (i.e., lunar cycles or 29.53 days), emphasizing replication within and among lunar phases. In 2022, we sampled 47 random routes (3.4 replications per route; range: 2–6; total independent route runs: 158; total independent sampling stops: 482). In 2023, we sampled 51 routes (an average of 3 replications per route; range: 1-6; total independent route runs: 153; total independent sampling stops: 467).

Between 31 April and 10 July, we conducted 1,634 and 1,169 nocturnal point count surveys in 2022 and 2023, respectively (total: 2,803). We sampled 565 sites for an average of 4.96 surveys per site (range: 1–6). We recorded 1,232 Chuck-will's-widows (551 in 2022 and 681 in 2023) at 277 sites (naïve occupancy = 0.49) and 191 Whip-poor-wills (93 in 2022 and 98 in 2023) at 81 sites (naïve occupancy = 0.14). Across both 2022 and 2023, the total number of routes on which we detected Chuck-will's-widows and Whip-poor-wills was 47 (92%) and 22 (43%), respectively. For locations of routes with Whip-poor-will detections, see Figure 4.

Factors affecting detection of each species: Site-level occupancy and observation-level detection covariates had variable effects between species (Table 2 and Table 3). However, a consistent theme in detection emerged: the quadratic form of ambient temperature and the binomial variable capturing moon visibility were consistently present in all competing models for both species. The most-supported single-species Whip-poor-will model indicated that detection was negatively associated with wind speed ($\beta_{wind} = -0.23 \pm 0.13$), positively associated with moon visibility ($\beta_{moon} = 0.70 \pm 0.27$), and associated with a quadratic trend in temperature ($\beta_{temperature} = 0.49 \pm 0.24$; $\beta_{temperature^2} < -0.01 \pm < 0.01$; see Table S3 in Appendix 4). Similarly, the most-supported single-species Chuck-will's-widow model indicated detection was negatively associated with noise level ($\beta_{noise} = -0.47 \pm 0.16$), positively associated with moon visibility ($\beta_{moon} = 0.92 \pm 0.23$), and associated with a quadratic trend in temperature ($\beta_{temperature} = 0.57 \pm$

0.21; $\beta_{temperature^2} < -0.01 \pm < 0.01$); Chuck-will's-widow detection also differed between years ($\beta_{year} = -0.37 \pm 0.23$; see Table S4 in Appendix 4). Overall, detection of each species was higher when the moon was visible and increased with temperature until approximately 15–18 C (or approximately 59-64 F) before declining with higher temperatures.

Potential effects of each species on detection of the other species: Co-occurrence model results are presented in greater detail under objective 3, but relevant to objective 2, we found evidence that the presence of each nightjar species likely effects the detection of the other species — although detection structures differed depending on which species was considered dominant. When Whip-poor-will was considered dominant (Species A), the model indicating that Whip-poor-will detection was not conditional on the presence of Chuck-will's-widow (Species B) (i.e., $p^A = r^A$) had greater support than the model indicating that Whip-poor-will detection may be influenced by Chuck-will's-widow presence (i.e., $p^A \neq r^A$, Table 4). When Chuck-will's-widow was considered dominant (Species A), there was no model uncertainty and the only supported model considered Whip-poor-will detection (Species B) to be conditional on Chuck-will's-widow presence, presence and detection, or presence and lack of detection ($p^B \neq r^{BA} \neq r^{Ba}$; Table 4). Specifically, Whip-poor-will detection probability was ~30% lower when Chuck-will's-widow was absent or undetected (r^{Ba}) and 1.57× higher when Chuck-will's-widow was present and detected (r^{BA}; Figure 5).

Discussion: To summarize, detection of Whip-poor-will was negatively associated with wind speed and positively associated with moon visibility. Detection of Chuck-will's-widow was negatively associated with noise level and positively associated with moon visibility. Detection of both species was associated with a quadratic trend in temperature, with detection of each species increasing with temperature until approximately 15–18 C (or approximately 59-64 F) before declining with higher temperatures. We further discuss the implications of these results for future nightjar monitoring efforts in the Management Recommendations section.

The observation process for each nightjar species, on which ecological inferences about land cover affinities depend, was modulated by co-occurrence and behavior of the other species when considering Chuck-will's-widow to be the dominant species, and there was considerable support for reciprocal effects when Whip-poor-will was considered dominant. We suspect that much of the observed variation in detection within each co-occurrence hierarchy is a direct result of behavioral responses to the other co-occurring species. Male singing behavior serves a critical evolutionary role in the competition for mates and resources between conspecifics (Gil & Gahr 2002; Catchpole & Slater 2003). However, individuals also may increase calling behavior in the presence of congenerics competing for resources. For instance, Black-capped (*Poecile atricapillus*) and Mountain (*Poecile gambeli*) Chickadees differ in their respective response to congeners depending on social dominance; the socially dominant Black-capped Chickadee responds weakly to congeneric calls compared to conspecifics (Grava et al. 2012). Hence, our observation of Chuck-will's-widow detection depending on Whip-poor-will presence may indicate that the former species exhibits a behavioral response to the presence of the latter. However, increased Chuck-will's-widow detection in the presence of Whip-poor-will also could be an artifact of heterogeneous site conditions resulting in high abundance of Chuck-will's-widow, therefore increasing detection probability, while also supporting Whip-poor-will occupancy. Conversely, we usually detected a single Whip-poor-will and rarely detected ≥ two individuals of this species during surveys; therefore, differences in Whip-poor-will detections are likely due to the response to Chuck-will's-widow rather than variation in local abundance coinciding with the presence of a congener. Specifically, the mean detection of Whip-poor-wills increased 1.57-fold when Chuck-will's-widows were present and detected but declined by ~30% when Chuck-will's-widows were present and undetected. Higher detection rates of Whip-poor-wills could result from individuals increasing call frequency in the presence of Chuck-will's-widows via counter singing (Gil & Gahr 2002; Logue 2021). If both nightjar foraging and mating behavior occur synchronously, each may strategically countersing to overcome the impediments of the other species' calls on mate attraction or to maintain foraging territories (Gil & Gahr 2002). In controlled experiments, Naguib (1999) observed that nightingales altered their singing timing in response to playbacks and chickadees have been observed avoiding song overlap to avoid signal masking (Wilson et al. 2016). Modifying song timing to avoid overlapping with a heterospecific would likely increase an individual's detectability. Moreover, nightjars may modify vocal activity in response to congeners to maintain territory boundaries, a ubiquitous pattern observed between closely related species pairs (Cowen et al. 2020).

Regardless of the mechanisms underlying the potential effects of each nightjar species on the calling behavior of the other species, our results indicate that analyses of survey data in regions where both Whip-poor-will and Chuck-will's-widow occur — including in eastern Oklahoma — may need to consider and account for such inter-specific effects. Variability in the detection process determines inferences drawn from the analysis of ecological data (Kéry & Royle 2016). Ecological data are frequently analyzed within occupancy modeling frameworks that assume: (1) no unmodeled detection heterogeneity, and (2) constant detection among sites, unless adequately accounted for with observation-level covariates. If co-occurrence and behavior of one of the nightjar species modulates observability of another, the accompanying risk of violating model assumptions implies greater potential for unreliable inferences about factors affecting detection and affinities of species with land cover characteristics. Failing to account for heterogeneous detection driven by interspecific effects could lead to, depending on the direction of effect, over- or under-estimation of a species' occurrence probability. Elucidating broad-scale conservation and management implications while considering interspecific effects on patterns of space use and detection appears to be a relevant research avenue (Kéry & Royle 2016; Zhao et al. 2022; Twining et al. 2025), including for nightjars like the Whip-poor-will and Chuck-will's-widow.

Objective 3: Quantify occurrence and species-specific habitat associations of nightjars in eastern Oklahoma:

Factors affecting occupancy of each species: For proportion grassland and young forest cover, the 1500 m scale was the most supported for both species. However, a quadratic trend in the effect of young forest was most supported only for Whip-poor-will. Conversely, single-species models demonstrated inverse relationships between each species and elevation. Initial model fitting of occupancy covariates for Whip-poor-wills demonstrated nearly equivalent support for both linear and quadratic forms of two covariates: elevation and proportion young forest within 1500 m (see Table S5 in Appendix 4). Hence, we conducted a post-hoc evaluation of the decision to include the additional quadratic term for either covariate by comparing AIC_c values of the most-supported model with and without this term. Model structures lacking the quadratic term in elevation and including the quadratic term for proportion young forest within 1500 m were more supported and thus retained (see Table S7 in Appendix 4). Whip-poor-will occupancy probability was positively associated with a linear increase in elevation, while Chuck-will's-widow occupancy was negatively related to a quadratic trend in elevation (see Table S6 in Appendix 4). Inspection of beta coefficients in competitive models revealed all other land-cover variables had 85% confidence intervals that overlapped with zero (Arnold, 2010; see Table S7 and Table S8 in Appendix 4); therefore, there was no support for any of these other land cover variables in explaining occupancy probability.

In the final models combining the best occupancy and detection structures for each species, we observed species-specific patterns of occupancy probability in response to differences in the proportion of specific land-cover types and site elevation (see Table S7 in Appendix 4). The proportion of grassland cover and young forest were important predictors of nightjar occupancy (Figure 6b, c). Single-species occupancy modeling indicated that Whip-poor-wills were most likely to occupy sites containing intermediate proportions of young forest within 1500 m of the site ($\beta_{yf} = 12.75, \pm 5.38$; $\beta_{yf}{}^2 = -23.19, \pm 13.26$; Figure 6c). Additionally, occupancy of both species strongly declined with increasing proportion of grassland cover surrounding the site within 1500 m (Whip-poor-will: $\beta_{grassland} = -9.25 \pm 2.61$; Chuck-will's-widow: $\beta_{grassland} = -8.26 \pm 2.34$; Figure 6b). However, Chuck-will's-widows were less sensitive to changes in grassland cover as the probability of this species occupying a site was still 0.26 when the proportion of grassland cover reached 0.44, a point at which Whip-poor-will occupancy probability declined to < 0.01 (i.e., functionally zero). Further, we observed species-specific relationships between occupancy probability and elevation, with Whip-poor-will occupancy increasing with increasing elevation ($\beta_{elevation} = 0.11 \pm 0.03$), whereas Chuck-will's-widow occupancy was best explained by a quadratic pattern in elevation ($\beta_{elevation} = -0.16, \pm 0.14$; $\beta_{elevation}{}^2 < -0.01, \pm < 0.01$), peaking at ~200–300 m and declining as elevation increased further but with increasing uncertainty (Figure 6a).

Nightjar co-occurrence patterns: Although we found evidence that the presence of each nightjar species likely effects the detection of the other species (Objective 2 Results), contrastingly, we observed no evidence that occupancy of either species depended on the presence of the other species ($\psi^{Ba} = \psi^{BA}$; Table 4), regardless of dominant-subordinate orientation. Co-occurrence model structures estimating unconditional occupancy of each species in response to the other were consistently more supported. Consequently, the presence of the more-specialized Whip-poor-will, or the more generalist Chuck-will's-widow, did not appear to influence the space-use patterns of the other species.

Discussion: To summarize, our models indicated that Whip-poor-wills were most likely to occupy sites at higher elevations and sites containing intermediate proportions of young forest within 1500 m. Chuck-will's-widow occupancy was explained best by a quadratic pattern in elevation, peaking at ~200–300 m and declining as elevation increased further. Additionally, occupancy of both species strongly declined with increasing proportion of grassland cover surrounding the site within 1500 m — although Chuck-will's-widows appear to tolerate greater levels of nearby grassland cover than Whip-poor-wills.

Anthropogenic disturbances are common across our study region and may partially replicate historical ecological disturbances that establish and maintain early successional, young-forest communities on which Whip-poor-wills appear to depend both in eastern Oklahoma and elsewhere (Farrell et al. 2017; Hanberry & Thompson 2019; Bragg et al. 2020; Thompson et al. 2022). In our study area near the southwestern edge of their breeding range, Whip-poor-will occupancy probability was highest at sites with intermediate proportions of young forest cover. Similarly, in other areas of their breeding range, Whip-poor-will relative density increased adjacent to recently disturbed (i.e., clearcut) loblolly pine (*P. taeda*) forests (Wilson & Watts 2008), while occupancy increased >3-fold after recent disturbance events (i.e., clearcuts <16 years old) in managed pine-dominated landscapes of Ontario, Canada (Tozer et al. 2014; but see Farrell et al. 2019). Whip-poor-wills may experience indirect and direct effects of forest disturbance; specifically, Whip-poor-wills may indirectly benefit from ecological disturbance resulting in regenerating young forests with increased floral diversity, smaller average tree size, and dense canopy supporting higher prey species diversity and abundance (Root et al. 2017; Cook et al. 2024). Importantly, intense anthropogenic disturbance to forests can negatively affect the abundance of moths, a critical food source for both nightjar species (Summerville et al. 2004), but this relationship may potentially be countered by improved prey detectability. Whip-poor-wills ostensibly vary their foraging activity in response to ambient moonlight affecting the detectability of insect prey (Mills 1986), some of which may occupy different vertical strata during flight activity (Ashton et al. 2016). Hence, regenerating young forests may provide perching structures that improve prey detection in vertical strata that would otherwise be less accessible in mature forests without mid-canopy structure. Additionally, young forest structure may confer direct benefits to Whip-poor-wills, such as higher quality daytime roosting or nesting areas (Akresh & King 2016; Grahame et al. 2021).

The strong negative effects of increasing grassland cover that we documented reinforce previous observations of Whip-poor-will responses to landscape composition (Farrell et al. 2019; Souza-Cole et al. 2022). The direction and magnitude of the effect of grassland cover was similar between species and was best explained at identical spatial scales (i.e., 1500 m), although the minimum threshold of grassland cover for Whip-poor-wills was more than two times lower than that for Chuck-will's-widows. Whip-poor-wills and Chuck-will's-widows nest and roost in a variety of upland habitats (Akresh & King 2016; Straight & Cooper 2020); therefore, declining availability of upland habitat types associated with increasing open non-forest cover at the scales observed is unlikely to be limiting for either species. However, nightjar occurrence may be explained by the influence of broad-scale landscape characteristics on important insect prey communities (English et al. 2017). Farrell et al. (2019) identified that Whip-poor-wills were more likely to occupy sites with higher proportions of wetland area within 5-km, a relationship attributed to higher abundances of insect prey in wetlands. Inversely, anthropogenic land-use practices have been correlated with population declines of primary food items for insectivorous birds (Forister et al. 2012; Tallamy & Shriver 2021; Wagner 2020; Rumohr et al. 2023).

The probability of site occupancy for both nightjar species depended on elevation. The probability of Whip-poor-wills occupying a site increased by more than an order of magnitude across the range of elevations sampled, a pattern inconsistent with previously published negative effects of elevation on Whip-poor-wills (Slover & Katzner 2016). Conversely, the Chuck-will's-widow's occupancy probability declined with increasing elevation at similar rates, a pattern previously undocumented. Consequently, nightjar distributions may depend on bottom-up processes generated by abiotic and floral communities that vary geographically (i.e., biogeographical gradient theory; Nebel et al. 2010). Whip-poor-will and Chuck-will's-widow diets are largely comprised of nocturnally active, medium-sized moth species (e.g., *Noctuidae*, *Geometridae*; Straight & Cooper 2020; Souza-Cole et al. 2022) for which globally consistent patterns of species richness peak at mid-elevations (Beck et al. 2017), elevations consistent with mid-to-high elevations in our study. Similarly, *Coleopterans* (beetles) are important food sources and they also vary in biomass and richness with increasing elevation (Hodkinson 2005; Rappa et al. 2022). Collectively, both insect guilds respond to forest composition and structure characteristics that may vary across elevational gradients (Ober & Hayes 2010; Highland et al. 2013; Descombes et al. 2017; Rappa et al. 2022). Considering patterns of primary prey composition across elevational gradients and forest community structure, conditions may allow Whip-poor-wills to meet metabolic demands at higher elevations, while Chuck-will's-widow may be constrained at higher elevations if alternate prey availability limits necessary prey switching strategies (Charnov 1976; Scheiner & Willig 2011). Thus, observed patterns of nightjar space use in our study may parallel trends in prey communities responding to bottom-up constraints imposed by the interaction of abiotic, topographic, and vegetative features.

RECOMMENDATIONS:

Nightjar Monitoring Survey Protocol: Assuming continued interest and availability of funding to support future nightjar monitoring in Oklahoma, we recommend use of the final version of our protocol that we implemented in 2023. We provide GPS points for all routes and route stops in Appendix 1, a protocol outline in Appendix 2, and a field data sheet for surveys in Appendix 3. Regarding locations of future surveys, if feasible, we recommend using the 51 survey routes that we sampled in 2023 as a basis for long-term monitoring of nightjar status in the state. If resources are limited, a subset of these routes could be used, but we note that our approach to select this final group of 51 routes was based on the goal of meeting assumptions of our occupancy modeling analysis framework. As described in greater detail under objectives 2 and 3, occupancy modeling is a variant of logistic regression modeling where, like all linear modeling techniques, the reliability of the results and their interpretation depend on realization of model assumptions, including that samples are representative. Our analysis showed that these 51 routes provided a representative sample of land cover types in the 8-county study area. Using a subset of these survey routes for future monitoring could result in a non-representative sample of land cover types. This could limit reliability of conclusions generated from linear modeling analyses that use data collected on future surveys to ask questions about factors affecting nightjar detection or occupancy. A non-representative sample may be of less concern if the goal is to use survey data solely to identify locations where nightjars occur or to generate estimates of naïve occupancy (i.e., the proportion of sites occupied by a species) — notwithstanding the issue that descriptive results carry caveats as they can lead to biased estimates of a species' occurrence and distribution.

Regarding seasonal timing of nightjar surveys, we recommend conducting surveys between 4 May and 17 July, consistent with recommendations of the Nightjar Survey Network protocol. Surveys earlier than 4 May are likely to capture passing migrants that do not breed in the study area. Starting in late June, but especially after mid-July, nightjar calling rates decline substantially, and therefore, detection of birds also greatly declines on later surveys. Nevertheless, our detection modeling results indicated no effect of sampling date within the above date range on detection of either nightjar species; therefore, it is unlikely that targeting particular calendar dates within the time window will increase detections.

Importantly, the detection of Whip-poor-wills was negatively associated with wind speed and positively associated with moon visibility. Detection of Chuck-will's-widows was negatively associated with noise level and positively associated with moon visibility. Detection of both species was associated with a quadratic trend in temperature, with detection of each species increasing with temperature until approximately 15–18 C (or approximately 59-64 degrees F) before declining with higher temperatures. These results suggest that survey efforts to document nightjars may be hindered by high winds (Whip-poor-will), high levels of ambient noise (Chuck-will's-widow) and high nighttime temperatures (both species), and that surveys should therefore not be conducted when such conditions occur. Although cloud cover did not receive as much support in explaining detection, its effects are well-established in the literature and our results could be an artifact of low sample sizes across a gradient of cloud densities. Nonetheless, based on previous literature, we also recommend that surveys be conducted when cloud cover is broken, generally <50% if possible, and that this variable be recorded during future surveys. Further, if there is a need to focus on periods when nightjars are likely to be detected, our results indicate that surveys should be prioritized during periods when the moon is visible. In particular, surveys could be prioritized for nights when the sky is predicted to be clear during the two-week period centered on the full moon of each lunar cycle — a period during which the moon is ≥50% illuminated and visible above the horizon for most of the night.

Regarding the desired frequency of conducting nightjar surveys, the development of flexible occupancy modeling approaches permits the use of several study design and effort combinations for future nightjar monitoring efforts. Sufficient replication to make inferences about nightjar occurrence or habitat associations can be achieved using replication through time, across space, or both. Surveying for uncommon species usually demands an increase in spatial replication of surveys, where the number of sites is more important than the number of surveys conducted. A reasonable minimum annual survey effort would include at least two visits to each point on 20 transects (i.e., 200 total points/sites) distributed across the study region, including in areas where neither species occurs. Using a hierarchical design, temporal replication also can be achieved by 'binning' the detection data into minutes within a survey where a 5-minute survey is split into two surveys of two minutes each, separated by a pause in data collection during the third minute of sampling. In this manner, temporal replication can be achieved without visiting each site/transect a second time, reducing the cost-per-unit effort. This design would allow flexibility for use in several occupancy modeling frameworks, including single-season, hierarchical, and dynamic occupancy models. Given sufficient annual replication, the Dail-Madsen model also could be fit using only single annual visits of 5-minutes each; however, this model is "data hungry" and data missingness would certainly be a limiting factor. Alternatively, the agency could elect to sample every other year with equal or greater effort, with the understanding that interpretation of occupancy dynamics parameters (e.g., site extinction, colonization) would need to be reframed on the appropriate time scale (i.e., bi-annual). Importantly, any of the aforementioned models currently can be fit into the 'unmarked' package in Program R and, assuming file names and variables do not change, they can then be updated in nearly real-time.

Although recommending how to administer and manage nightjar surveys is beyond the scope of our project, we do note that it should be possible for these surveys to be conducted by either ODWC staff or trained citizen volunteers. With respect to volunteer participants, it would be ideal to enlist participation from members of the public with experience conducting road-based surveys, such as birders who have participated in the North American Breeding Bird Survey, Breeding Bird Atlases, or similar monitoring programs. However, less-experienced participants with a willingness to conduct nocturnal surveys in remote locations should be able to successfully contribute given that minimal training would be required to detect and identify

Whip-poor-wills and Chuck-will's-widows, both of which are fairly easy to identify by call alone.

Implications of Land Cover Associations for Management: To summarize, our models indicated that the Whip-poor-will was most likely to occupy sites at higher elevations and sites containing intermediate proportions of young forest within 1500 m. Chuck-will's-widow occupancy was explained by a quadratic pattern in elevation, peaking at ~200–300 m and declining as elevation increased further. Additionally, occupancy of both species strongly declined with increasing proportion of grassland cover surrounding a site within 1500 m — although the Chuck-will's-widow appears to tolerate greater levels of nearby grassland cover than the Whip-poor-will.

Findings from this study can help inform land procurement, protection, and management approaches designed to benefit the rapidly declining Whip-poor-will in Oklahoma. Obviously, our results also have implications for managing populations of Chuck-will's-widow, which also are experiencing a decline across their range. However, because this species remains relatively abundant and widespread across the eastern two-thirds of Oklahoma, we focus on providing recommendations for Whip-poor-wills. Our results regarding the association of Whip-poor-wills with young forests support previous research suggesting that regenerating forests adjacent to mature forest stands provide critical habitat features, including foraging perches and nesting cover (Wilson & Watts 2008; Tozer et al. 2014; Akresh & King 2016). Additionally, Whip-poor-will occupancy declined sharply with increasing grassland cover, with the species being functionally absent in locations where grassland cover in the surrounding landscape exceeded ~44%. Not surprisingly for this species that is known to be associated with wooded landscapes, this result suggests that large expanses of open, non-forested land are unsuitable for Whip-poor-wills, likely due to reduced prey availability and lack of suitable nesting or roosting cover. This finding aligns with past studies showing that Whip-poor-wills decline in association with open agricultural and grassland-dominated landscapes (Farrell et al. 2019; Souza-Cole et al. 2022).

Based on our results and those of previous studies, management strategies should prioritize maintaining a heterogeneous forested landscape by providing a mix of early successional forest patches within a matrix of mature forest. Practices such as prescribed fire and selective thinning, as well as natural disturbance regimes (e.g., windthrow, ice storms, and wildfires) can help sustain the young forest structure preferred by Whip-poor-wills (Bragg et al. 2020; Cook et al. 2024). However, care should be taken to avoid creating large, homogeneous tracts of young forest, which may not provide the structural diversity needed for Whip-poor-will nesting and foraging. In summary, effective management of Whip-poor-will populations should focus on enhancing young forest cover at intermediate levels and targeting conservation efforts at higher elevations where occupancy is highest. These strategies can be integrated into broader land-use planning that prioritizes where to implement management activities, to support the long-term viability of this declining species.

Table 1. Descriptions of parameters estimated by the conditional two-species occupancy model (adapted from Richmond et al. 2010).

Parameter	Description
ψ^{A}	Species A occupancy probability
ψ^{BA}	Species B occupancy probability, given species A is present
ψ^{Ba}	Species B occupancy probability, given species A is absent
p^{A}	Detection probability of species A, given species B is absent
p^{B}	Detection probability of species B, given species A is absent
r^{A}	Detection probability of species A when both species are present
r^{BA}	Detection of species B, given species A is present and detected
r^{Ba}	Detection of species B, given species A is present and not detected

Table 2. Detection (p) beta coefficients (β) with standard error and 95% lower (LCI) and upper (UCI) confidence intervals from the most supported single-season single-species models combining both detection and occupancy covariates used to parameterize the conditional co-occurrence model of Richmond et al. (2010). Statistics for covariates not included in the most supported model were taken from the global model for each species.

Detection Covariate	β	SE	95% LCI	95% UCI
Eastern Whip-poor-will				
Year	-0.3457	0.2858	-0.9059	0.2146
Survey Time	-0.0009	0.0011	-0.0030	0.0012
Noise	-0.1882	0.1988	-0.5778	0.2013
Wind Speed	-0.2353	0.1298	-0.4897	0.0190
Observer Experience	0.1325	0.2625	-0.3820	0.6470
Temperature	0.4883	0.2421	0.0139	0.9628
Temperature^2	-0.0035	0.0018	-0.0070	-0.0001
Moon Visibility	0.6951	0.2709	0.1640	1.2261
Chuck-will's-widow				
Year	-0.3593	0.2335	-0.8169	0.0983
Survey Time	0.0009	0.0010	-0.0011	0.0030
Noise	-0.4676	0.1586	-0.7785	-0.1566
Wind Speed	-0.0411	0.1092	-0.2552	0.1730
Observer Experience	0.2868	0.2381	-0.1800	0.7534
Temperature	0.5717	0.2084	0.1632	0.9801
Temperature^2	-0.0041	0.0015	-0.0071	-0.0012
Moon Visibility	0.9272	0.2256	0.4849	1.3693

Table 3. Occupancy (ψ) beta coefficients (β) with standard errors and 95% lower (LCI) and upper (UCI) confidence intervals from the most supported single-season single-species models combining both detection and occupancy covariates used to parameterize the conditional co-occurrence model of Richmond et al. (2010). Statistics for covariates not included in the most supported model were taken from the global model for each species.

Occupancy Covariate	β	SE	95% LCI	95% UCI
Eastern Whip-poor-will				
Elevation	0.0115	0.0035	0.0047	0.0182
Grassland @ 1500 m	-9.0806	2.6198	-14.2154	-3.9458
Young Forest @ 1500 m	17.9718	6.5967	5.0422	30.9014
Young Forest^2 @ 1500 m	-42.6847	22.5853	-86.9519	1.5825
Wetland @ 1500 m	-16.5530	94.8635	-202.4854	169.3794
Urban @ 1500 m	-6.0801	18.5141	-42.3677	30.2075
Chuck-will's-widow				
Elevation	0.0165	0.0144	-0.0117	0.0446
Elevation^2	-0.00004	0.00003	-0.0001	0.00002
Grassland @ 1500 m	-8.2606	2.3405	-12.8479	-3.6733
Young Forest @ 1500 m	12.6343	14.0614	-14.9260	40.1946
Wetland @ 1500 m	-14.2101	47.1722	-106.6677	78.2474
Urban @ 1500 m	2.1022	26.5593	-49.9540	54.1583

Table 4. Model selection results for conditional two-species occupancy models treating either Whip-poor-will (*Antrostomus vociferus*) or Chuck-will's-widow (*Antrostomus carolinensis*) as the dominant species (Species A) in eastern Oklahoma, USA, during May–July (2022–2023).

Occupancy Structure[a]	Detection Structure[b]	ΔAIC_c	w_i	Like.	K	Dev.
Whip-poor-will as dominant (Species A)						
ψ^{A}, $\psi^{BA} = \psi^{Ba}$,	$p^{A} = r^{A}$, $p^{B} = r^{BA} = r^{Ba}$	0.00	0.62	1.00	20	3554.01
ψ^{A}, $\psi^{BA} = \psi^{Ba}$,	p^{A}, r^{A}, $p^{B} = r^{BA} = r^{Ba}$	1.85	0.25	0.40	25	3544.99
ψ^{A}, ψ^{BA}, ψ^{Ba},	$p^{A} = r^{A}$, $p^{B} = r^{BA} = r^{Ba}$	3.98	0.09	0.14	24	3549.32
ψ^{A}, ψ^{BA}, ψ^{Ba},	$p^{A} = r^{A}$, p^{B}, $r^{BA} = r^{Ba}$	5.33	0.04	0.07	29	3539.63
Chuck-will's-widow as dominant (Species A)						
ψ^{A}, $\psi^{BA} = \psi^{Ba}$,	p^{A}, r^{A}, p^{B}, r^{BA}, r^{Ba}	0.00	1.00	1.00	36	3474.63
ψ^{A}, $\psi^{BA} = \psi^{Ba}$,	$p^{A} = r^{A}$, p^{B}, r^{BA}, r^{Ba}	10.97	0.00	0.00	30	3499.16
ψ^{A}, $\psi^{BA} = \psi^{Ba}$,	p^{A}, r^{A}, $p^{B} = r^{BA} = r^{Ba}$	19.94	0.00	0.00	26	3517.01
ψ^{A}, $\psi^{BA} = \psi^{Ba}$,	$p^{A} = r^{A}$, p^{B}, $r^{BA} = r^{Ba}$	21.27	0.00	0.00	31	3507.22

Models appear in descending order by relative difference in Akaike Information Criterion (corrected for small sample size; ΔAIC_c) from the most-supported model and reported with the Akaike weight (w_i), likelihood (Like.), parameter count (K), and deviance (Dev.); all models contain the most-supported combination of occupancy and detection parameters for each species-specific parameter.

[a] Model abbreviations: ψ^{A} = occupancy of dominant species; ψ^{B} = occupancy of subordinate species in the presence (ψ^{BA}) and absence (ψ^{Ba}) of the dominant species

[b] Model abbreviations: p^{A} = detection of dominant species in the absence of subordinate species; r^{A} = detection of dominant species in the presence of subordinate species; p^{B} = detection of subordinate species in the absence of dominant species; r^{B} = detection of subordinate species when dominant species was present and either detected (r^{BA}) or not detected (r^{Ba})

Figure 1: Unmodified routes (yellow and black-dashed lines) and modified routes (blue lines) created for 2022 and 2023 monitoring seasons (left), and an example route (black and white-dashed line) connecting 11 survey stops (right), McCurtain County, Oklahoma.

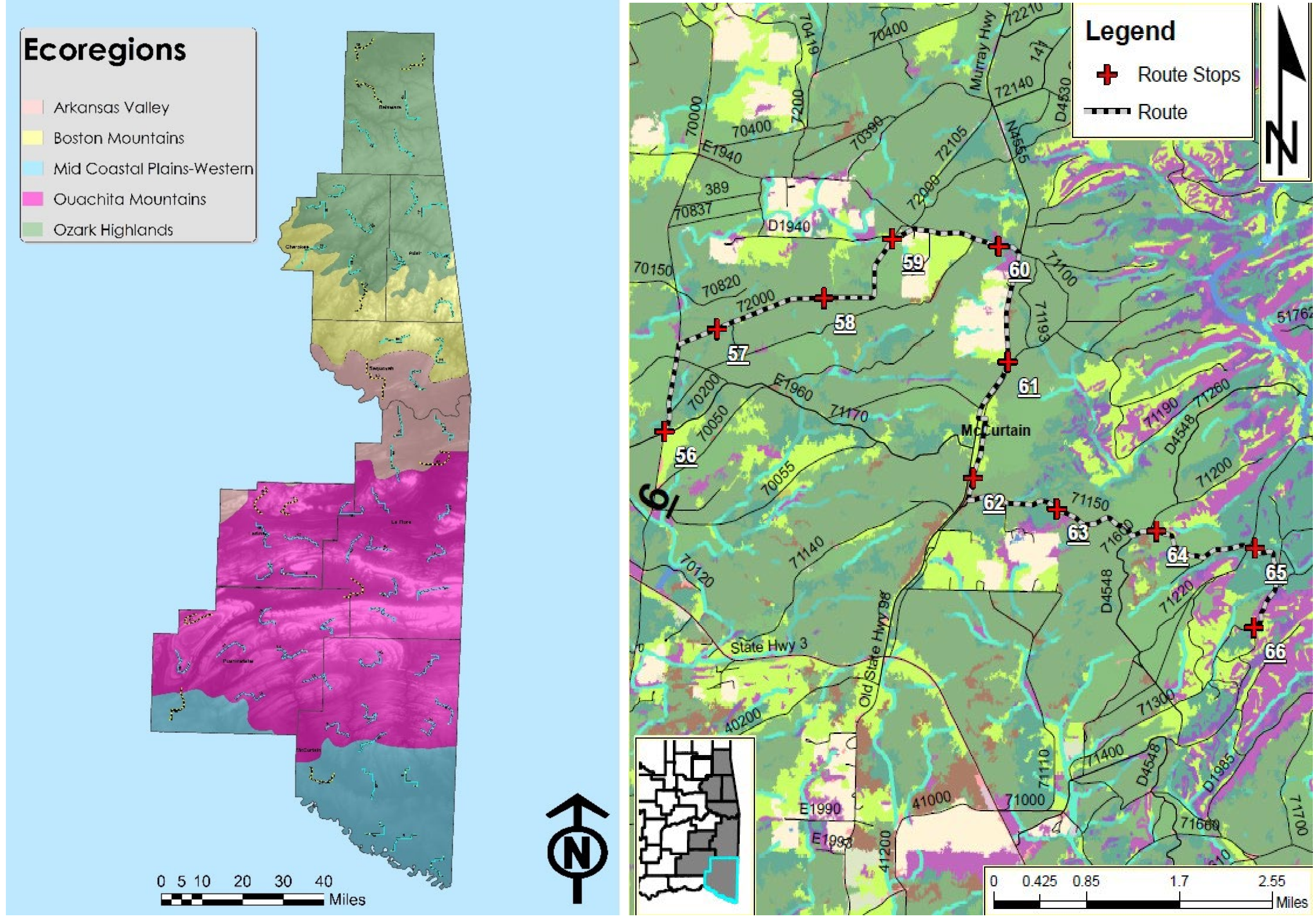


Figure 2. Relative availability of four forest canopy-cover categories expressed as a percentage of the entire 8-county study area (red bars) and of the 500 m radius areas surrounding all stops sampled in 2022 (blue bars). Raw percentage values are included at the base of each column.

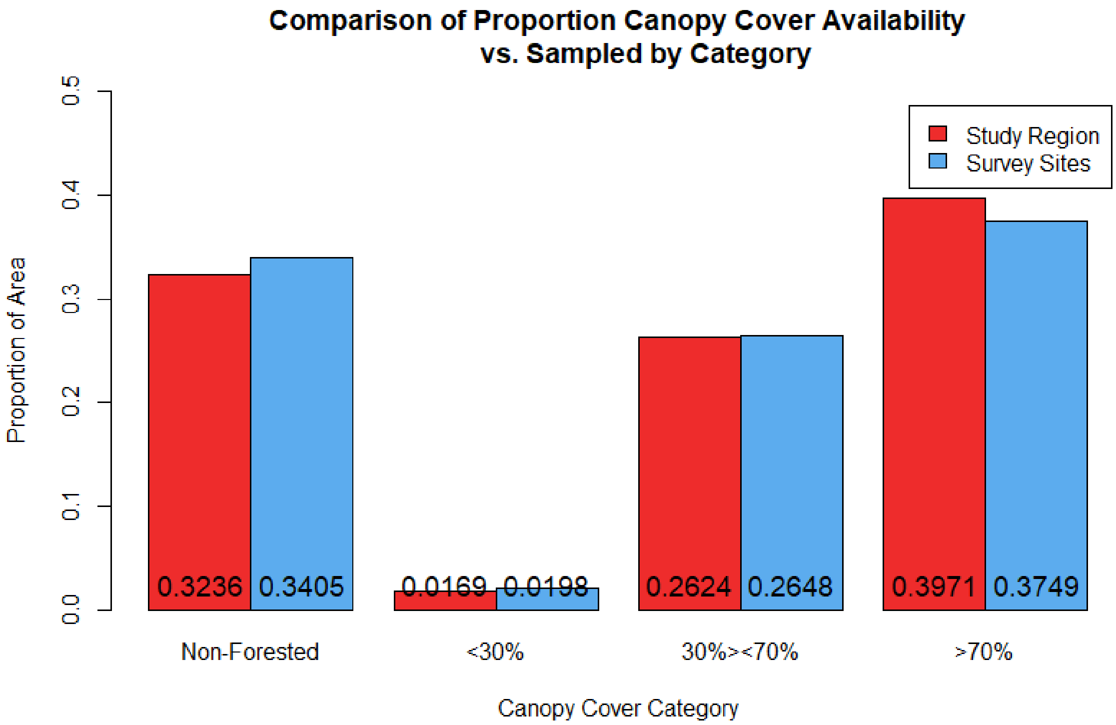


Figure 3. Relative availability of nine specific land-cover classes expressed as a percentage of the entire 8-county study area (red bars) and within the revised sampling area in Year 2 (2023) of the study that reduces number of stops surveyed by 31% (blue bars). Raw percentage values are included at the base of each column and rounded to the nearest 0.01 percent.

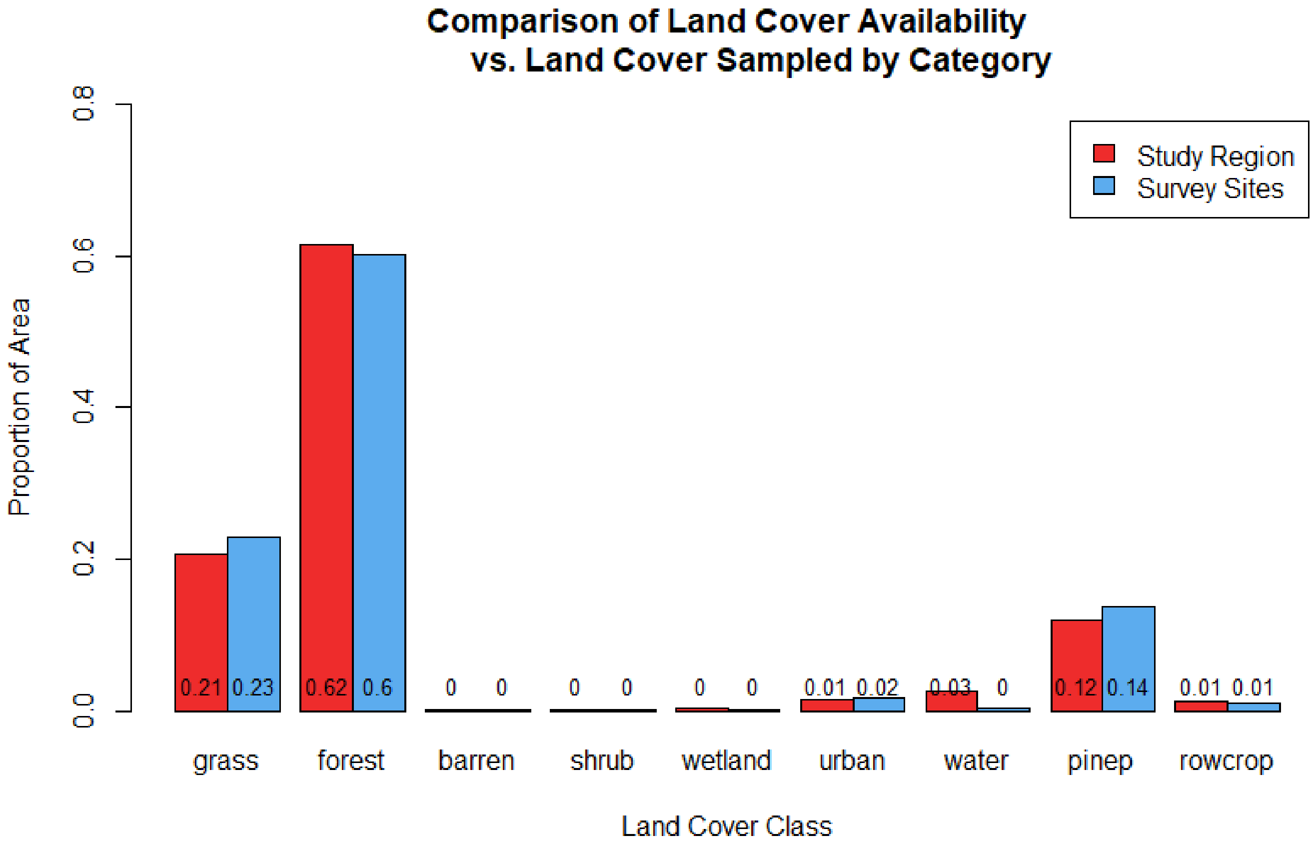


Figure 4. Locations of all routes (route IDs indicated by smaller black numbers) with observations of Eastern Whip-poor-will during 2022 and 2023 nightjar monitoring field seasons, and total number of Whip-poor-will detections (larger yellow numbers) on each route combined across all surveys. As some individual birds were likely detected more than once on a route, numbers should not be interpreted as total individuals.

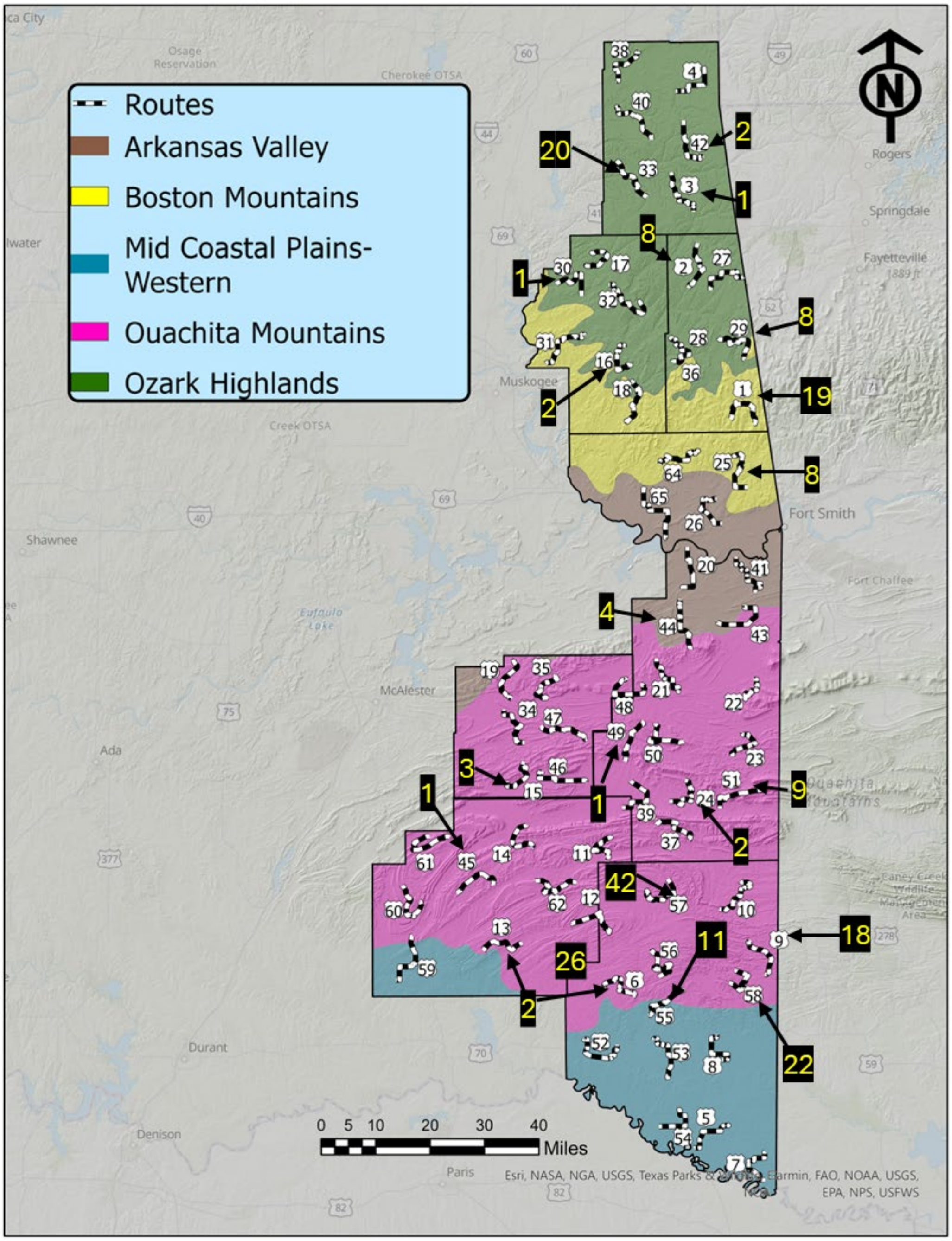


Figure 5. Detection probability (*p*) estimates with 95% confidence intervals from the most-supported model with standardized individual covariates when Chuck-will's-widows (*Antrostomus carolinensis*) were considered dominant (Species A) and Whip-poor-wills (*Antrostomus vociferus*) were subordinate (Species B). Detection of Species A was lower in the absence of Species B (*p*A = 0.40) than in the presence of Species B (*r*A = 0.62), and detection of Species B in the absence of Species A (*p*B = 0.23) was moderate relative to the detection of Species B in the presence of Species A when Species A was detected (*r*BA = 0.36) or not (*r*Ba = 0.16).

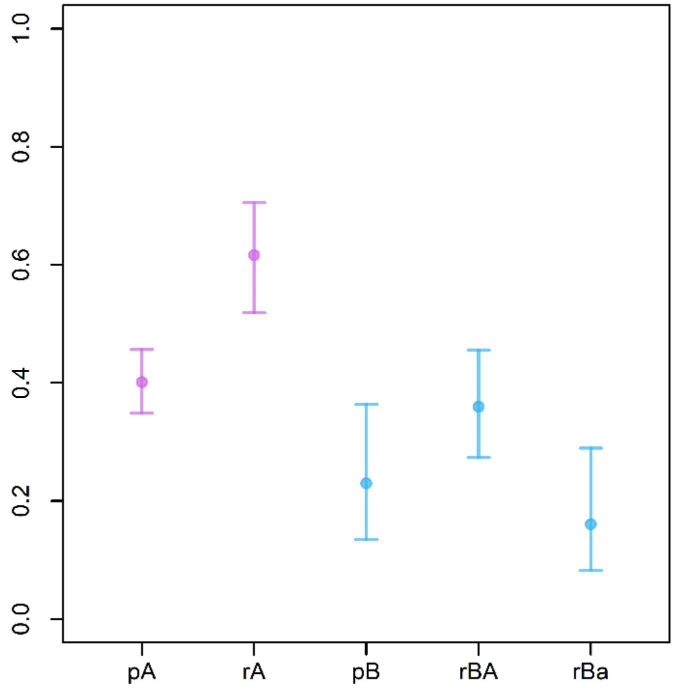
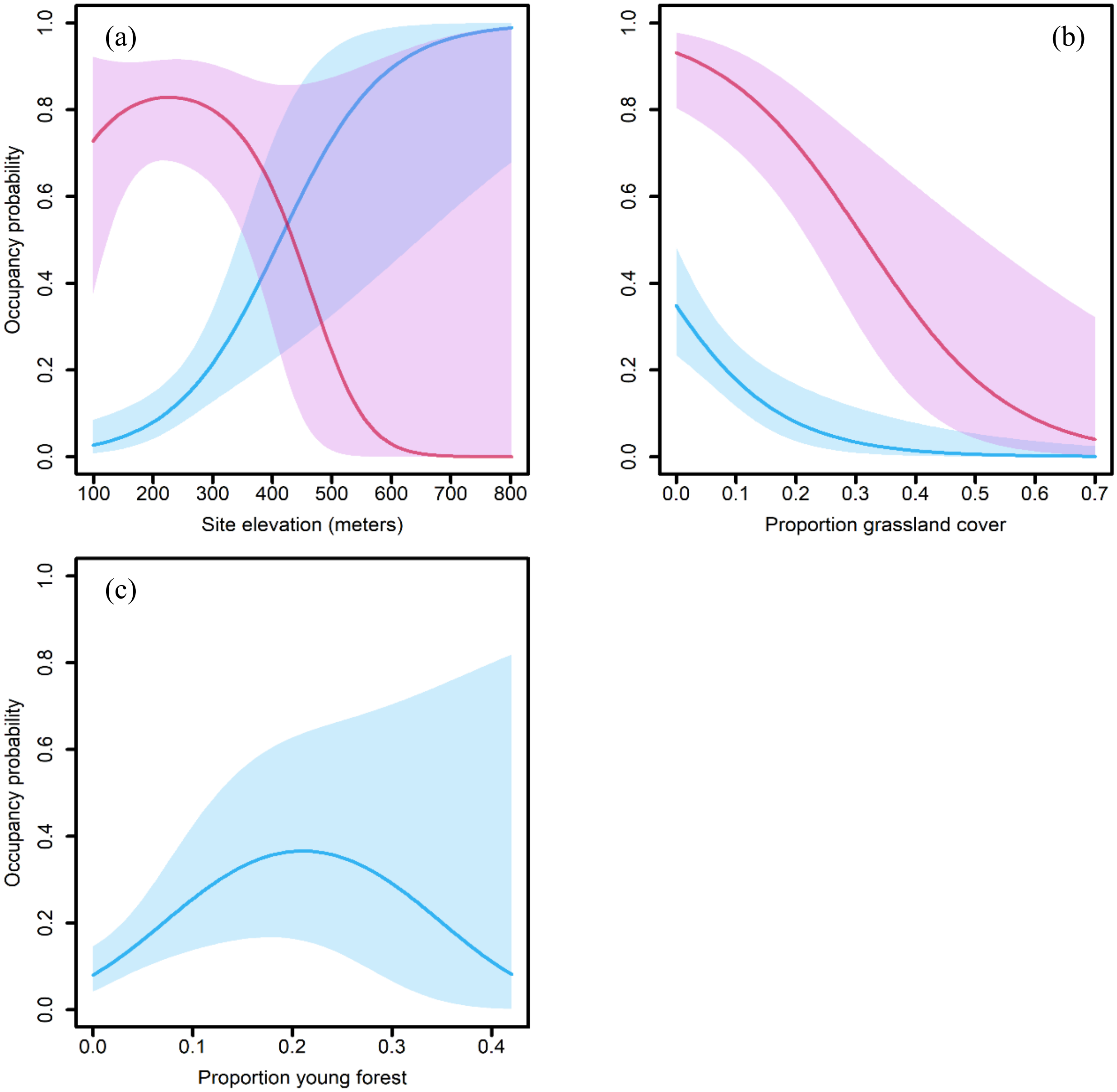


Figure 6. Estimated occupancy probabilities for Whip-poor-will (*Antrostomus vociferus*) and Chuck-will's-widow (*Antrostomus carolinensis*) as a function of elevation (a), proportion of grassland (b) within 1500 m of a site, and the proportion of young forest within 1500 m of a site (c) in Eastern OK, USA. Shaded areas represent 95% confidence intervals. All estimates are from the most-supported single-species single-season occupancy models.



Appendices:

Appendix 1: GPS points for all nightjar survey route stops used in final 2023 survey protocol, as well as number of Whip-poor-wills and Chuck-will's-widow observations on each route.

Appendix 2: Outline of nightjar survey protocol used at all survey route stops.

SIGNIFICANT DEVIATIONS:

Not applicable.

EQUIPMENT:

No equipment was purchased using grant funds.

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Appendix 1: GPS points for all nightjar survey route stops used in final 2023 survey protocol, as well as number of Whip-poor-wills and Chuck-will's-widow observations on each route.

site	route	point	xcoord	ycoord	EWPW	CWWI
R1P0	1	0	-94.5193	35.658	5	0
R1P1	1	1	-94.514	35.6723	1	0
R1P10	1	10	-94.5947	35.6734	0	0
R1P2	1	2	-94.5205	35.687	4	0
R1P4	1	4	-94.5322	35.7113	1	1
R1P5	1	5	-94.549	35.7135	6	0
R1P6	1	6	-94.5664	35.7125	2	4
R1P3	1	3	-94.5211	35.7027	0	2
R1P7	1	7	-94.5773	35.7176	0	1
R1P8	1	8	-94.5844	35.7059	0	0
R1P9	1	9	-94.5876	35.6933	0	2
R2P20	2	20	-94.7182	36.0295	1	2
R2P21	2	21	-94.729	36.0204	7	3
R2P11	2	11	-94.6958	36.1377	0	0
R2P12	2	12	-94.7036	36.1224	0	0
R2P13	2	13	-94.7063	36.1058	0	0
R2P14	2	14	-94.6969	36.0928	0	0
R2P15	2	15	-94.6903	36.0818	0	0
R2P16	2	16	-94.6795	36.071	0	0
R2P17	2	17	-94.685	36.0629	0	1
R2P18	2	18	-94.6975	36.0509	0	1
R2P19	2	19	-94.7088	36.0379	0	1
R3P26	3	26	-94.7691	36.2793	1	3
R3P23	3	23	-94.7809	36.3255	0	2
R3P24	3	24	-94.7761	36.3087	0	6
R3P25	3	25	-94.7798	36.293	0	3
R3P27	3	27	-94.7636	36.264	0	0
R3P28	3	28	-94.7555	36.2545	0	0
R3P29	3	29	-94.743	36.2495	0	0
R3P30	3	30	-94.7277	36.2468	0	1
R3P31	3	31	-94.7156	36.2413	0	1
R3P32	3	32	-94.7081	36.2313	0	1
R3P33	3	33	-94.7081	36.2213	0	3
R5P45	5	45	-94.7458	33.7502	0	0
R5P46	5	46	-94.7291	33.7514	0	1
R5P47	5	47	-94.7293	33.7689	0	2
R5P48	5	48	-94.7217	33.7839	0	1
R5P49	5	49	-94.7137	33.794	0	9
R5P50	5	50	-94.6961	33.794	0	1
R5P51	5	51	-94.6785	33.794	0	7

R5P52	5	52	-94.6609	33.794	0	4
R5P53	5	53	-94.6534	33.8078	0	4
R5P54	5	54	-94.6361	33.8085	0	11
R5P55	5	55	NA	NA	0	3
R6P60	6	60	-94.9787	34.1999	1	0
R6P61	6	61	-94.9769	34.1855	1	1
R6P56	6	56	-95.0316	34.176	0	6
R6P57	6	57	-95.0235	34.1888	0	0
R6P58	6	58	-95.0066	34.193	0	0
R6P59	6	59	-94.9958	34.2006	0	1
R6P62	6	62	-94.9821	34.1709	0	0
R6P63	6	63	-94.9686	34.1673	0	1
R6P64	6	64	-94.9527	34.1648	0	1
R7P67	7	67	-94.5209	33.736	0	2
R7P68	7	68	-94.5239	33.7214	0	3
R7P69	7	69	-94.5415	33.7214	0	2
R7P70	7	70	-94.5555	33.7177	0	2
R7P71	7	71	-94.5695	33.7141	0	1
R7P72	7	72	-94.5728	33.6999	0	0
R7P73	7	73	-94.5657	33.6887	0	0
R7P74	7	74	-94.5501	33.6825	0	0
R7P75	7	75	-94.538	33.6732	0	0
R7P76	7	76	-94.5287	33.6633	0	0
R7P77	7	77	-94.5211	33.6633	0	0
R8P0	8	0	NA	NA	0	0
R8P79	8	79	-94.6699	34.05	0	1
R8P80	8	80	-94.6786	34.0411	0	0
R8P81	8	81	-94.6873	34.0322	0	0
R8P82	8	82	-94.6874	34.0146	0	2
R8P83	8	83	-94.6872	33.9972	0	2
R8P84	8	84	-94.6696	33.9973	0	1
R8P85	8	85	-94.652	33.9973	0	2
R8P86	8	86	-94.6345	33.9973	0	5
R8P87	8	87	-94.6351	33.9829	0	4
R8P88	8	88	NA	NA	0	3
R9P89	9	89	-94.5115	34.2063	1	3
R9P90	9	90	-94.4974	34.2111	3	3
R9P91	9	91	-94.4968	34.2275	4	5
R9P92	9	92	-94.49	34.2431	3	7
R9P93	9	93	-94.4963	34.2538	2	4
R9P95	9	95	-94.5233	34.2706	4	3
R9P97	9	97	-94.5549	34.2777	1	2
R9P94	9	94	-94.5067	34.2669	0	7

R9P96	9	96	-94.5397	34.2743	0	6
R9P98	9	98	-94.5604	34.2897	0	4
R9P99	9	99	-94.5566	34.2971	0	8
R10P100	10	100	-94.6541	34.3804	0	8
R10P101	10	101	-94.637	34.3789	0	8
R10P102	10	102	-94.6236	34.3855	0	4
R10P103	10	103	-94.611	34.3883	0	7
R10P104	10	104	-94.6068	34.4031	0	8
R10P105	10	105	-94.5955	34.4108	0	2
R10P106	10	106	-94.5847	34.4195	0	3
R10P107	10	107	-94.5801	34.4328	0	0
R10P108	10	108	-94.5639	34.437	0	2
R10P109	10	109	-94.554	34.4456	0	0
R10P110	10	110	-94.5672	34.4499	0	2
R10P111	10	111	-94.5832	34.4513	0	8
R11P113	11	113	-95.003	34.576	0	2
R11P117	11	117	-95.056	34.545	0	2
R11P118	11	118	-95.0556	34.5401	0	3
R11P122	11	122	-95.0135	34.527	0	0
R11P123	11	123	-95.0213	34.5239	0	1
R12P131	12	131	-95.0425	34.3704	0	8
R12P132	12	132	-95.0406	34.3634	0	8
R12P133	12	133	-95.0352	34.3509	0	10
R12P136	12	136	-95.0172	34.321	0	10
R12P125	12	125	-95.1333	34.3466	1	7
R12P126	12	126	-95.1168	34.3506	5	10
R12P127	12	127	-95.0997	34.3546	4	2
R12P128	12	128	-95.083	34.36	5	6
R12P129	12	129	-95.066	34.3644	6	5
R12P130	12	130	-95.0504	34.3722	2	11
R12P134	12	134	-95.0267	34.3399	1	8
R12P135	12	135	-95.0159	34.3298	2	10
R13P140	13	140	-95.4102	34.2879	0	9
R13P141	13	141	-95.3969	34.298	0	7
R13P142	13	142	-95.3812	34.2998	0	9
R13P144	13	144	-95.3472	34.2993	0	13
R13P145	13	145	-95.3384	34.2844	0	9
R13P146	13	146	-95.3233	34.2802	0	8
R13P147	13	147	-95.3111	34.291	0	12
R13P148	13	148	-95.2945	34.2967	0	11
R13P139	13	139	-95.422	34.2774	1	8
R13P143	13	143	-95.3643	34.2966	1	10
R14P150	14	150	-95.278	34.6075	0	4

R14P151	14	151	-95.2946	34.6032	0	1
R14P152	14	152	-95.3083	34.5932	0	1
R14P153	14	153	-95.3186	34.579	0	3
R14P154	14	154	-95.3246	34.5627	0	0
R14P155	14	155	-95.3123	34.5512	0	1
R14P156	14	156	-95.2982	34.5537	0	0
R14P157	14	157	-95.2828	34.5589	0	0
R14P159	14	159	-95.2623	34.5474	0	1
R15P161	15	161	-95.3362	34.7101	0	2
R15P162	15	162	-95.3186	34.71	0	1
R15P163	15	163	-95.3057	34.7184	0	2
R15P164	15	164	-95.29	34.7263	0	1
R15P165	15	165	-95.2761	34.7365	0	0
R15P166	15	166	-95.2832	34.7503	0	6
R15P167	15	167	-95.2825	34.7598	0	6
R15P168	15	168	-95.2921	34.7595	0	4
R15P169	15	169	-95.2853	34.7754	0	4
R15P160	15	160	-95.34	34.7239	3	3
R16P171	16	171	-94.9432	35.8667	0	0
R16P172	16	172	-94.9565	35.8709	0	0
R16P173	16	173	-94.9597	35.8563	0	0
R16P174	16	174	-94.9675	35.8467	0	1
R16P175	16	175	-94.9683	35.8294	0	0
R16P176	16	176	-94.9674	35.8119	0	0
R16P177	16	177	-94.9568	35.8073	0	3
R16P178	16	178	-94.942	35.8128	0	5
R16P179	16	179	-94.9308	35.8196	1	4
R16P180	16	180	-94.9225	35.822	1	3
R17P181	17	181	-95.0686	36.0838	0	1
R17P182	17	182	-95.0534	36.0807	0	0
R17P183	17	183	-95.0377	36.0814	0	0
R17P184	17	184	-95.0206	36.0839	0	0
R17P185	17	185	-95.0136	36.0962	0	0
R17P186	17	186	-94.9996	36.1024	0	2
R17P187	17	187	-95.001	36.113	0	1
R17P188	17	188	-95.0157	36.1183	0	2
R17P189	17	189	-95.0327	36.1173	0	2
R17P190	17	190	-95.0471	36.1133	0	0
R20P215	20	215	-94.7434	35.3371	0	0
R20P216	20	216	-94.7435	35.3195	0	0
R20P217	20	217	-94.7416	35.3038	0	0
R20P218	20	218	-94.7347	35.2932	0	0
R20P219	20	219	-94.7308	35.2764	0	0

R20P220	20	220	-94.7258	35.2608	0	0
R20P221	20	221	-94.7259	35.2432	0	0
R20P222	20	222	-94.7314	35.2312	0	0
R20P223	20	223	-94.749	35.2313	0	0
R20P224	20	224	-94.7612	35.2259	0	1
R21P225	21	225	NA	NA	0	0
R21P226	21	226	-94.8489	35.044	0	7
R21P227	21	227	-94.8477	35.0266	0	9
R21P228	21	228	-94.8329	35.02	0	3
R21P229	21	229	-94.8325	35.004	0	2
R21P230	21	230	-94.8224	34.9943	0	1
R21P231	21	231	-94.8097	34.9894	0	0
R21P232	21	232	-94.7959	34.9856	0	1
R21P233	21	233	-94.7961	34.968	0	0
R21P234	21	234	-94.7808	34.9675	0	1
R21P235	21	235	-94.7757	34.9566	0	3
R22P237	22	237	-94.5333	34.9856	0	0
R22P238	22	238	-94.5227	34.9785	0	0
R22P239	22	239	-94.5202	34.9665	0	0
R23P249	23	249	-94.5707	34.8463	0	1
R23P250	23	250	-94.5591	34.8402	0	0
R23P251	23	251	-94.5463	34.8323	0	2
R23P252	23	252	-94.5352	34.8199	0	4
R23P253	23	253	-94.5384	34.8129	0	2
R23P254	23	254	-94.552	34.8084	0	2
R23P255	23	255	-94.5694	34.8063	0	1
R23P256	23	256	-94.5862	34.8018	0	1
R23P257	23	257	-94.6011	34.7949	0	2
R23P258	23	258	-94.6057	34.7833	0	0
R24P261	24	261	-94.7951	34.6665	0	5
R24P262	24	262	-94.7823	34.6605	0	8
R24P264	24	264	-94.7616	34.672	0	5
R24P265	24	265	-94.7449	34.6667	0	6
R24P266	24	266	-94.739	34.6792	0	1
R24P267	24	267	-94.7418	34.6913	0	11
R24P268	24	268	-94.7455	34.701	0	2
R24P269	24	269	-94.7495	34.7148	0	6
R24P270	24	270	-94.7609	34.7214	0	6
R24P260	24	260	-94.8127	34.6664	1	5
R24P263	24	263	-94.7694	34.6623	1	1
R25P271	25	271	-94.5423	35.4923	0	7
R25P272	25	272	-94.5599	35.4923	0	3
R25P273	25	273	-94.5775	35.4924	0	3

R25P274	25	274	-94.5844	35.5031	0	5
R25P275	25	275	-94.5845	35.5207	0	6
R25P276	25	276	-94.5749	35.5316	0	3
R25P277	25	277	-94.5667	35.5437	0	3
R25P278	25	278	-94.5657	35.5525	0	6
R25P279	25	279	-94.5604	35.5671	0	3
R25P280	25	280	-94.5638	35.5789	7	3
R25P281	25	281	-94.5791	35.5774	1	12
R26P283	26	283	-94.6279	35.3982	0	0
R26P284	26	284	-94.6455	35.3982	0	1
R26P285	26	285	-94.6565	35.4055	0	0
R26P286	26	286	-94.6688	35.4181	0	0
R26P287	26	287	-94.6821	35.429	0	1
R26P288	26	288	-94.6985	35.435	0	0
R26P289	26	289	-94.6909	35.4469	0	0
R26P290	26	290	-94.6898	35.4635	0	0
R26P291	26	291	-94.6742	35.4603	0	0
R26P292	26	292	-94.6579	35.4618	0	3
R26P293	26	293	-94.6449	35.4635	0	3
R27P0	27	0	-94.6551	36.0136	0	0
R27P1	27	1	-94.6551	36.0275	0	0
R27P10	27	10	-94.5648	36.0459	0	0
R27P11	27	11	-94.548	36.0461	0	0
R27P2	27	2	-94.6552	36.042	0	0
R27P3	27	3	-94.642	36.0458	0	0
R27P4	27	4	-94.6242	36.0458	0	0
R27P5	27	5	-94.6194	36.0565	0	0
R27P6	27	6	-94.6062	36.0603	0	0
R27P7	27	7	-94.5888	36.0589	0	0
R27P8	27	8	-94.5738	36.061	0	0
R27P9	27	9	-94.5658	36.0533	0	0
R29P24	29	24	NA	NA	0	0
R29P25	29	25	-94.5479	35.8305	0	0
R29P26	29	26	-94.5452	35.8443	0	1
R29P27	29	27	-94.5399	35.8557	0	2
R29P28	29	28	-94.5336	35.8673	0	1
R29P29	29	29	-94.5362	35.8798	0	1
R29P34	29	34	-94.5946	35.8739	0	1
R29P35	29	35	-94.6006	35.8859	0	1
R29P36	29	36	-94.6167	35.8828	0	0
R29P37	29	37	-94.6303	35.8867	0	0
R29P30	29	30	-94.5536	35.8811	1	2
R29P31	29	31	-94.564	35.8746	3	0

R29P32	29	32	-94.5746	35.8795	1	0
R29P33	29	33	-94.586	35.8752	3	0
R30P37	30	37	NA	NA	0	0
R32P37	30	37	NA	NA	0	1
R30P39	30	39	-95.1501	36.0411	0	0
R30P40	30	40	-95.134	36.0467	0	1
R30P41	30	41	-95.123	36.0381	0	2
R30P42	30	42	-95.1088	36.0409	0	0
R30P43	30	43	-95.1006	36.0505	0	0
R30P44	30	44	-95.0947	36.0602	0	0
R30P45	30	45	-95.0829	36.0555	0	0
R30P46	30	46	-95.0828	36.041	0	0
R30P47	30	47	-95.0828	36.0265	0	0
R30P48	30	48	-95.0837	36.0124	0	1
R30P49	30	49	-95.0828	36.0023	0	0
R30P38	30	38	-95.1654	36.0347	1	2
R31P42	31	42	NA	NA	0	0
R31P50	31	50	-95.2022	35.825	0	3
R31P51	31	51	-95.1862	35.8275	0	1
R31P52	31	52	-95.1771	35.8362	0	0
R31P53	31	53	-95.1735	35.8497	0	1
R31P54	31	54	-95.1628	35.8587	0	1
R31P55	31	55	-95.1628	35.8732	0	0
R31P56	31	56	-95.1601	35.8854	0	0
R31P57	31	57	-95.145	35.8879	0	0
R31P58	31	58	-95.1331	35.8927	0	0
R31P59	31	59	-95.1159	35.8945	0	0
R31P60	31	60	-95.1008	35.8949	0	0
R31P61	31	61	-95.0856	35.8926	0	0
R31P62	31	62	-95.074	35.9005	0	0
R32P62	32	62	NA	NA	0	1
R32P63	32	63	-94.8892	35.9854	0	0
R32P64	32	64	-94.8818	35.9737	0	0
R32P65	32	65	-94.8769	35.961	0	0
R32P66	32	66	-94.8881	35.9558	0	2
R32P67	32	67	-94.9047	35.9592	0	1
R32P68	32	68	-94.9168	35.9691	0	2
R32P69	32	69	-94.9244	35.9816	0	2
R32P70	32	70	-94.9407	35.9806	0	1
R32P71	32	71	-94.9503	35.989	0	1
R32P72	32	72	-94.9514	36.0024	0	0
R32P73	32	73	-94.9606	36.0092	0	0
R32P74	32	74	-94.9702	36.0168	0	1

R32P75	32	75	-94.9757	36.027	0	1
R32P76	32	76	-94.9915	36.0313	0	2
R33P78	33	78	-94.9695	36.3493	0	0
R33P81	33	81	-94.9435	36.3298	0	3
R33P82	33	82	-94.936	36.3196	0	1
R33P89	33	89	-94.8786	36.2691	0	2
R33P79	33	79	-94.9561	36.3546	2	6
R33P80	33	80	-94.9457	36.3435	1	0
R33P83	33	83	-94.9244	36.3174	1	0
R33P84	33	84	-94.908	36.3156	2	2
R33P85	33	85	-94.9016	36.3069	1	1
R33P86	33	86	-94.9032	36.296	2	3
R33P87	33	87	-94.8905	36.2912	5	0
R33P88	33	88	-94.8923	36.2782	3	0
R33P90	33	90	-94.8636	36.2623	3	0
R34P100	34	100	-95.3102	34.8305	0	2
R34P101	34	101	-95.2976	34.8255	0	4
R34P102	34	102	-95.2829	34.8255	0	1
R34P90	34	90	NA	NA	0	0
R34P91	34	91	-95.3491	34.9128	0	1
R34P92	34	92	-95.3489	34.8984	0	2
R34P93	34	93	-95.3313	34.8984	0	1
R34P94	34	94	-95.3204	34.8912	0	3
R34P95	34	95	-95.314	34.8797	0	2
R34P96	34	96	-95.3008	34.8727	0	5
R34P97	34	97	-95.2994	34.8661	0	6
R34P98	34	98	-95.307	34.8559	0	2
R34P99	34	99	-95.3124	34.8447	0	1
R36P113	36	113	-94.7901	35.8915	0	0
R36P114	36	114	-94.7798	35.8851	0	0
R36P115	36	115	-94.7722	35.8763	0	0
R36P116	36	116	-94.7619	35.8703	0	0
R36P117	36	117	-94.7544	35.8627	0	0
R36P118	36	118	-94.745	35.8559	0	0
R36P119	36	119	-94.7313	35.8522	0	2
R36P120	36	120	-94.7333	35.8427	0	4
R36P121	36	121	-94.7504	35.8421	0	2
R36P122	36	122	-94.755	35.8343	0	1
R36P123	36	123	-94.7621	35.8239	0	2
R36P124	36	124	-94.7775	35.827	0	0
R36P125	36	125	-94.7841	35.8256	0	2
R36P126	36	126	NA	NA	0	1
R37P126	37	126	-94.855	34.6065	0	0

R41P173	41	173	-94.5843	35.3091	0	2
R41P174	41	174	-94.5844	35.2946	0	2
R41P175	41	175	-94.5733	35.2891	0	1
R41P176	41	176	-94.5667	35.2799	0	1
R41P177	41	177	-94.5553	35.2746	0	0
R41P178	41	178	-94.5489	35.2653	0	0
R41P179	41	179	-94.5487	35.251	0	0
R41P180	41	180	-94.5376	35.2454	0	0
R41P181	41	181	-94.5222	35.2398	0	0
R41P182	41	182	-94.5049	35.2382	0	0
R41P183	41	183	-94.509	35.2274	0	0
R41P184	41	184	-94.5224	35.2237	0	1
R41P185	41	185	-94.5226	35.2146	0	1
R41P186	41	186	NA	NA	0	0
R42P186	42	186	-94.7376	36.4619	0	0
R42P187	42	187	-94.7375	36.4474	0	0
R42P188	42	188	-94.7374	36.4329	0	0
R42P190	42	190	-94.7282	36.4079	0	3
R42P191	42	191	-94.7321	36.3942	0	2
R42P192	42	192	-94.7293	36.3807	0	1
R42P194	42	194	-94.7093	36.3656	0	0
R42P195	42	195	-94.696	36.3618	0	1
R42P196	42	196	-94.6838	36.364	0	0
R42P197	42	197	-94.6721	36.3656	0	0
R42P198	42	198	NA	NA	0	0
R42P189	42	189	-94.7357	36.4188	1	1
R42P193	42	193	-94.726	36.3668	1	1
R44P211	44	211	-94.7692	35.1995	0	0
R44P212	44	212	-94.7725	35.1871	0	0
R44P213	44	213	-94.7702	35.1744	0	0
R44P214	44	214	-94.7702	35.1599	0	2
R44P215	44	215	-94.7715	35.1512	0	7
R44P216	44	216	-94.7693	35.1388	0	3
R44P217	44	217	-94.7702	35.1246	0	2
R44P218	44	218	-94.7626	35.1163	0	2
R44P219	44	219	-94.7481	35.1129	0	4
R44P220	44	220	-94.7433	35.1033	0	5
R44P221	44	221	-94.7438	35.0893	0	6
R44P222	44	222	-94.7396	35.0762	1	7
R44P223	44	223	-94.7373	35.0671	3	7
R45P225	45	225	-95.4938	34.4382	0	6
R45P226	45	226	-95.4832	34.4496	0	5
R45P227	45	227	-95.469	34.4581	0	5

R45P228	45	228	-95.4555	34.467	0	2
R45P229	45	229	-95.4428	34.4744	0	4
R45P230	45	230	-95.4283	34.48	0	3
R45P231	45	231	-95.4131	34.4748	0	8
R45P232	45	232	-95.3991	34.4687	0	6
R45P233	45	233	-95.3861	34.4636	0	6
R45P234	45	234	-95.3878	34.4495	0	5
R45P224	45	224	-95.5054	34.4295	1	7
R46P235	46	235	-95.2265	34.7481	0	1
R46P236	46	236	-95.2352	34.7399	0	0
R46P237	46	237	-95.2311	34.7311	0	0
R46P238	46	238	-95.2135	34.7313	0	1
R46P239	46	239	-95.196	34.7313	0	1
R46P240	46	240	-95.1826	34.7277	0	0
R46P241	46	241	-95.1689	34.724	0	0
R46P242	46	242	-95.1513	34.7241	0	0
R46P243	46	243	-95.1338	34.7241	0	2
R46P244	46	244	-95.1162	34.7241	0	2
R46P245	46	245	-95.0986	34.7243	0	0
R46P246	46	246	-95.0843	34.7191	0	0
R47P247	47	247	-95.1021	34.8263	0	1
R47P248	47	248	-95.0949	34.8379	0	1
R47P249	47	249	-95.1034	34.846	0	2
R47P250	47	250	-95.1164	34.8522	0	1
R47P251	47	251	-95.1285	34.8595	0	4
R47P252	47	252	-95.1457	34.8603	0	6
R47P253	47	253	-95.1587	34.8586	0	5
R47P254	47	254	-95.1754	34.8618	0	3
R47P255	47	255	-95.191	34.8611	0	2
R47P256	47	256	-95.2019	34.8548	0	4
R47P257	47	257	-95.2178	34.8592	0	7
R47P258	47	258	-95.2239	34.8505	0	2
R48P260	48	260	-94.9622	34.9875	0	1
R48P261	48	261	-94.973	34.9763	0	0
R48P262	48	262	-94.9841	34.9659	0	1
R48P263	48	263	-94.9891	34.9535	0	0
R48P264	48	264	-94.9771	34.9493	0	0
R48P265	48	265	-94.9595	34.9496	0	1
R48P266	48	266	-94.9419	34.95	0	0
R48P267	48	267	-94.9243	34.9506	0	0
R48P268	48	268	-94.8923	34.9549	0	0
R48P269	48	269	-94.8926	34.9667	0	1
R48P270	48	270	-94.9017	34.9748	0	1

R49P271	49	271	-94.9562	34.774	0	0
R49P272	49	272	-94.951	34.7877	0	0
R49P273	49	273	-94.9563	34.7959	0	0
R49P274	49	274	-94.9512	34.8063	0	0
R49P275	49	275	-94.9453	34.8174	0	0
R49P276	49	276	-94.9368	34.8301	0	0
R49P277	49	277	-94.9324	34.8436	0	0
R49P278	49	278	-94.9257	34.8528	0	0
R49P279	49	279	-94.9116	34.8614	0	0
R49P281	49	281	-94.894	34.8798	0	0
R49P280	49	280	-94.899	34.8704	1	0
R50P282	50	282	-94.8551	34.8716	0	2
R50P283	50	283	-94.8508	34.8608	0	2
R50P284	50	284	-94.8537	34.8471	0	0
R50P285	50	285	-94.8569	34.834	0	2
R50P286	50	286	-94.873	34.8307	0	2
R50P287	50	287	-94.8655	34.8231	0	1
R50P288	50	288	-94.8484	34.8251	0	1
R50P289	50	289	-94.8322	34.8283	0	0
R50P290	50	290	-94.815	34.8278	0	1
R50P291	50	291	-94.7983	34.8255	0	0
R50P292	50	292	-94.7813	34.8226	0	0
R50P293	50	293	-94.7645	34.8236	0	0
R51P294	51	294	-94.6487	34.6458	0	6
R51P295	51	295	-94.6484	34.6602	0	4
R51P300	51	300	-94.6117	34.6793	0	0
R51P301	51	301	-94.5959	34.6832	0	0
R51P307	51	307	NA	NA	0	0
R51P296	51	296	-94.6497	34.6747	1	4
R51P297	51	297	-94.6411	34.6734	1	0
R51P298	51	298	-94.6326	34.6697	1	1
R51P299	51	299	-94.6284	34.6757	1	0
R51P302	51	302	-94.5789	34.6857	1	0
R51P303	51	303	-94.5615	34.687	1	0
R51P304	51	304	-94.5444	34.6904	1	0
R51P305	51	305	-94.5273	34.692	1	0
R51P306	51	306	-94.5099	34.6938	1	0
R53P317	53	317	-94.828	33.9332	0	3
R53P318	53	318	-94.8259	33.945	0	0
R53P319	53	319	-94.8245	33.9591	0	0
R53P320	53	320	-94.8179	33.9714	0	0
R53P321	53	321	-94.8179	33.9859	0	0
R53P322	53	322	-94.8219	33.9972	0	4

R53P323	53	323	-94.8267	34.0077	0	7
R53P324	53	324	-94.8268	34.0223	0	6
R53P325	53	325	-94.8436	34.0226	0	1
R53P326	53	326	-94.8567	34.0262	0	0
R53P327	53	327	-94.8611	34.0371	0	0
R53P328	53	328	-94.8725	34.0383	0	2
R54P329	54	329	-94.7916	33.8521	0	0
R54P330	54	330	-94.7916	33.8396	0	2
R54P331	54	331	-94.7758	33.8375	0	0
R54P332	54	332	-94.7742	33.8244	0	2
R54P333	54	333	-94.7742	33.8099	0	2
R54P334	54	334	-94.7901	33.8085	0	2
R54P335	54	335	-94.8075	33.8085	0	2
R54P336	54	336	-94.8249	33.8085	0	0
R54P337	54	337	-94.8423	33.8085	0	0
R54P338	54	338	-94.8597	33.8085	0	0
R54P339	54	339	NA	NA	0	0
R54P340	54	340	NA	NA	0	0
R54P341	54	341	NA	NA	0	0
R55P339	55	339	-94.8886	34.1029	0	5
R55P341	55	341	-94.8786	34.1213	0	14
R55P343	55	343	-94.8551	34.1315	0	15
R55P344	55	344	-94.8407	34.1323	0	17
R55P345	55	345	-94.8304	34.1352	0	17
R55P346	55	346	-94.8196	34.1464	0	7
R55P350	55	350	-94.7718	34.1706	0	2
R55P340	55	340	-94.8765	34.1097	1	8
R55P342	55	342	-94.8704	34.1288	1	16
R55P347	55	347	-94.808	34.1566	2	3
R55P348	55	348	-94.7956	34.1664	5	10
R55P349	55	349	-94.786	34.1658	2	12
R56P351	56	351	-94.8536	34.2033	0	1
R56P352	56	352	-94.8389	34.2109	0	1
R56P353	56	353	-94.8239	34.2164	0	0
R56P354	56	354	-94.8227	34.2262	0	0
R56P355	56	355	-94.8171	34.2368	0	0
R56P356	56	356	-94.8298	34.232	0	0
R56P357	56	357	-94.8389	34.2241	0	0
R56P358	56	358	-94.8539	34.2236	0	0
R56P359	56	359	-94.8669	34.225	0	0
R56P360	56	360	-94.8584	34.233	0	0
R56P361	56	361	-94.8565	34.2465	0	0
R57P363	57	363	NA	NA	0	1

R57P369	57	369	-94.8661	34.4081	0	13
R57P365	57	365	-94.8919	34.4239	2	15
R57P366	57	366	-94.8866	34.427	1	15
R57P367	57	367	-94.8879	34.4179	2	13
R57P368	57	368	-94.8805	34.4101	10	11
R57P370	57	370	-94.8495	34.4078	4	12
R57P371	57	371	-94.8346	34.4079	5	16
R57P372	57	372	-94.8271	34.42	1	14
R57P373	57	373	-94.8106	34.4216	4	11
R57P374	57	374	-94.8019	34.4231	2	6
R57P375	57	375	-94.8038	34.4374	2	12
R57P376	57	376	-94.8116	34.4497	4	9
R57P377	57	377	-94.8216	34.4614	5	4
R58P379	58	379	-94.6255	34.2094	0	2
R58P386	58	386	-94.587	34.1797	0	7
R58P387	58	387	-94.5846	34.1677	0	2
R58P388	58	388	-94.598	34.1687	0	4
R58P380	58	380	-94.6241	34.2192	5	2
R58P381	58	381	-94.6088	34.2182	5	4
R58P382	58	382	-94.593	34.2134	5	3
R58P383	58	383	-94.5771	34.2086	4	14
R58P384	58	384	-94.5691	34.2	1	11
R58P385	58	385	-94.5745	34.1879	1	8
R58P389	58	389	-94.6106	34.1783	1	2
R60P398	60	398	NA	NA	0	0
R60P399	60	399	NA	NA	0	0
R60P400	60	400	NA	NA	0	0
R60P401	60	401	-95.6824	34.4491	0	0
R60P402	60	402	-95.6728	34.4377	0	0
R60P403	60	403	-95.6686	34.4257	0	0
R60P404	60	404	-95.6594	34.4162	0	0
R60P405	60	405	-95.6574	34.4093	0	0
R60P406	60	406	-95.6669	34.3985	0	0
R60P408	60	408	-95.6668	34.3712	0	0
R60P409	60	409	-95.6523	34.3706	0	0
R60P410	60	410	-95.6421	34.3743	0	1
R60P412	60	412	-95.6234	34.3941	0	0
R60P413	60	413	-95.6252	34.4071	0	0
R62P425	62	425	NA	NA	0	1
R62P426	62	426	NA	NA	0	1
R64P439	64	439	NA	NA	0	2
R64P440	64	440	NA	NA	0	5
R64P441	64	441	NA	NA	0	5

R64P442	64	442	-94.8305	35.5556	0	5
R64P443	64	443	-94.8233	35.566	0	6
R64P444	64	444	-94.8077	35.5677	0	7
R64P445	64	445	-94.8039	35.5771	0	5
R64P446	64	446	-94.7886	35.5708	0	7
R64P447	64	447	-94.772	35.5695	0	4
R64P448	64	448	-94.7568	35.566	0	5
R64P449	64	449	-94.7391	35.5659	0	1
R64P450	64	450	-94.7368	35.5785	0	5

Appendix 2: Outline of nightjar survey protocol used at all survey route stops.

SURVEY INFORMATION AND PROTOCOLS

Seasonal Survey Timing

Survey Window: 1 May – 17 July

Conducting Surveys

Surveys must be conducted only when the moon is above the horizon and not obscured by clouds. Nightjars call less frequently when the moon is still below the horizon or obstructed by cloud cover. Local moonrise times can be found at the US Naval Observatory Website (http://aa.usno.navy.mil), or on the Nightjar Survey Network website (www.nightjars.org). Please note the moon rises later each successive day and may not rise on later dates of each cycle until after 11:00pm. Because of this, it is recommended that surveys are conducted earlier in the survey window.

Data Collection

1) Route surveys **start no earlier than 30 minutes after local sunset and continue until no later than 15 minutes before local sunrise**.
2) The first survey is the start of the route and survey points are spaced ~ 1 mile apart (driving distance) along routes. Routes will have 10 stops.
3) **Stops** may be moved ~ 0.1 miles in either direction to avoid unsafe road conditions. If this is not possible, skip the point and note that is needs to be removed.
4) Points along routes are **surveyed for exactly 5-minute periods** at each stop.
5) Routes do not need to be completed within a prescribed window. Do not drive dangerously; but don't waste time either.
6) **Record every unique individual** of all the target species heard at a stop. If you hear 3 individuals of 3 different species at a stop, there will be 9 rows for that stop.
7) Record the minute interval in which you hear an individual (See example data sheet).
    a. For example, if you hear 1 EWPW in minutes 1, 2, and 4. Put a '1' under the columns for those minutes in which it was detected, and a leave blank or put a '0' (zero) in the columns for each minute it was *not* heard. Do this for every individual of every species heard at a survey point. See example below.

NONE = no birds detected

Stop#	Species	1	2	3	4	5
1	EWPW	1	1	1		
1	CHUCK			1	1	1
2	GHOW		1			
3	EWPW	1	1	1	1	
3	EWPW		1	1	1	1
4	NONE					

- At Stop #1, One Eastern Whip-poor-will was heard in the first 3 minutes of the survey and not heard thereafter.
- Also a Chuck-will's-widow was heard at Stop #1 only during the 3rd through 5th minute of the count
- There were no Nightjars heard at Stop #2 so a value of NONE was entered
- At Stop #3, one Eastern Whip-poor-will was heard in the first 4 minutes of survey and not heard thereafter
- Also, another Eastern Whip-poor-will was heard at Stop #3 but only during the 2nd through 5th minute of survey.
- At Stop #4, no nightjars were detected so a value of NONE was entered for this Stop.

The following ambient conditions are recorded for ALL individual points. Further instruction and explanation is provided in the survey packet provided from the Nightjar Survey Network. NOTE: THERE ARE SOME DIFFERENCES.

8) **Wind:** This is based on a Beaufort scale (0-4). Do not conduct surveys during strong winds ≥ 18 mph. High winds diminish your ability to hear Nightjars

Code	Wind Speed	Description
0	Calm (0-1 mph)	Smoke rises vertically
1	Light (1-3 mph)	Direction of wind shown by smoke drift, but not by wind vanes.
2	Light Breeze (4-7 mph)	Leaves rustle; ordinary vanes moved by wind.
3	Gentle Breeze (8-12 mph)	Leaves and small twigs in constant motion; wind extends light flag.
4	Moderate Breeze (13-18 mph)	Raises dust and loose paper; small branches are moved.

9) **Background Noise**: Indicate the level that background noise impairs your ability to hear Nightjars.

Code		Description
0	None	Relatively quiet, little interference
1	Moderate	Some interference with listening.
2	High	Substantial interference with listening.
3	Excessive	Extreme interference with listening.

10) **Sky Condition**: Do not begin a survey if the sky is completely overcast, or in persistent rain. These conditions will diminish calling rates of Nightjars and hamper your survey.

Code	Sky	Description
0	0%	Clear, can see stars and moon clearly
1	10%	
2	20%	
3	30%	
4	40%	
5	50%	
6	60%	
7	70%	
8	80%	
9	90%	
10	100%	Overcast. Do not conduct survey.
11	100%*	*Dense Fog. Do not conduct survey.

11) **Moon Visible**? Enter Y for YES or N for NO to indicate if the moon can be seen above the horizon
12) You may estimate distances (this is optional). Record to the nearest estimated 25 meters.
13) Do not mimic calls to elicit responses.
14) Do not use flashlights to spot birds

TARGET SPECIES LIST AND ABBREVIATIONS

Common Nighthawk - **CONI**
Eastern Whip-poor-will – **EWPW**
Chuck-will's widow – **CWWI**
Great-Horned Owl – **GHOW**
Barred Owl – **BARO**
Barn Owl – **BANO**
Eastern Screech Owl – **EASO**

Date (mm/dd/yy)	Route #	Point #	Obs.	Start Time	Wind Speed	Temp.	Cloud Cover	Noise (0,1,2,3)	Moon Visible (Y/N)	Playback (Y/N)	Species	1	2	3	4	5