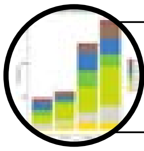
Grassland Breeding Bird Surveys and Drone Work on Missouri Department of Conservation and Partner Lands

FY 2025 Progress Report for Cooperative Agreement 6096

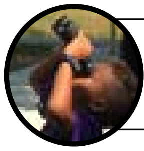
MRBO Mission

To contribute to the conservation of birds and all wildlife through scientific research, education and outreach, and conservation policy advocacy.



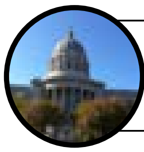
Science

To gather information about avian communities and habitat use that will assist state, federal, and private natural resource managers in their efforts to implement conservation programs.



Education

To provide opportunities for people of all ages to learn about species and their habitats.



Advocacy

To advocate for sound, science-based conservation policies that benefit birds, other wildlife and environmental quality.

Project Staff

Dana Ripper Duke
Director/Founder

Kendell Loyd
Field Technician

Ethan Duke
Director/Founder

Matt Longabaugh
Field Technician

Krista Cockrum
Field Technician

Josh Smith
Field Technician

Tracy Lewandowski
Field Technician

On the cover: Henslow's Sparrow by Linda Williams. MRBO Photography Contest Entry

Missouri River Bird Observatory
P.O. Box 16
406 Main St.
Arrow Rock, MO 65320
660.837.3888
https://mrbo.org
facebook.com/moriverbirdobs
instagram @moriverbirdobs

In This Report

Acknowledgements

This work was supported by the Missouri Department of Conservation (MDC), whose management practices on public lands and private land services sustain critical grassland habitats. We appreciate the contributions of the Missouri River Bird Observatory (MRBO) field technicians for collecting the data and the many partners and supporters whose past and ongoing collaboration make this work possible. Those stewarding public and private grasslands are the greatest hope for reversing the declines of grassland birds and conserving the habitats upon which we all depend.

Overview

This report is comprised of two sections. The first section focusses on MRBO grassland breeding bird monitoring that has been a collaborative endeavor since 2012. The second section reports on drone data workflows, outcomes, and vision that have developed since the spring of 2023. Drone data was collected by Ethan Duke, remote pilot in command, who is an FFA certified drone pilot with currency under CFR 14 Part 107. Flights were conducted in adherence to the MDC's Special Use Permit. Data from this pilot project have been packaged and delivered to MDC staff in the Hi Lonesome Priority Geography and can be delivered to other staff upon request.

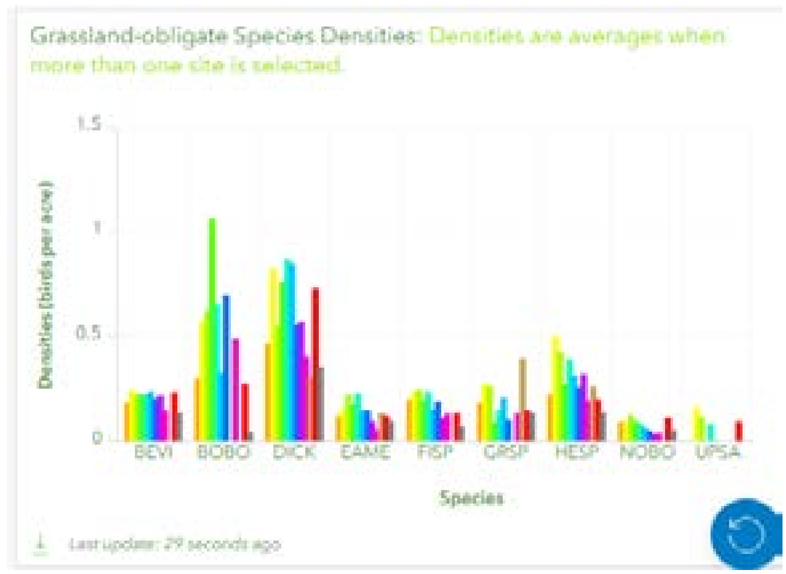
Introduction

North American grassland birds are experiencing steep population declines, with a documented loss of 700 million individuals since 1970 (Rosenberg et al., 2019). These declines are observable in Missouri. The MDC;s public properties and private lands partners provide critical habitats and serve as anchors for grassland-obligate birds, supporting both nesting and foraging activities. This report summarizes the results of 2024 bird surveys conducted by the Missouri River Bird Observatory (MRBO), presenting bird counts, densities, and bird-friendliness indices across MDC-managed grasslands. In addition to MDC sites, MRBO surveys included properties associated with the Native Forage Initiative (NFI), a Regional Conservation Partnership Program (RCPP), The Nature Conservancy's (TNC) Dunn Ranch, and properties owned by the Missouri Prairie Foundation (MPF).
The MDC's preservation of Missouri prairie landscapes through land acquisition, restoration, private land services, and active public lands management is a critical component of landscapes where conservationists are combating the steep decline of grassland birds. As the grassland bird guild has seen precipitous declines, the MDC properties provide high-quality refuges within fragmented, often hostile, landscapes. Monitoring grassland birds on MDC properties serves as a tool for extrapolating the overall health of the prairie with relative minimal resource investment. Grassland birds' presence/absence, density, abundance, and detected location provide insight into the effects of land management, restoration, and overall population trends.

Background
The Missouri River Bird Observatory (MRBO) has been monitoring grassland birds through breeding bird surveys since 2012. Surveys have encompassed a broad array of partnership projects and properties, including The National Audubon Society and its Audubon Conservation Ranching Program, the USFWS and the Partners for Fish and Wildlife Program, TNC lands, private landowner participants in USDA Natural Resources Conservation Services programs, Missouri State Parks, and MPF prairies.

Scope of work

Since 2012, surveys have been conducted on 164 sites across five states, covering over 2,000 transects totaling 462 miles. These surveys have amassed a sample size of 213,769 spatially-explicit bird detections. Approximately 80 sites are surveyed in the 2.5 month breeding season window each year, yielding 30,000 detection on average annually. In 2024, MRBO surveyed 93 sites, covering 846 transects totaling 304,867 meters (189 miles). Results of these surveys are included in this report, but we strongly recommend viewing and accessing the data on MRBO's dashboards, which provide continually-updated, mapped data of results with charts for bird-friendliness, densities, and counts across all years. (*Dashboards for public lands data results can be found at* https://mrbo.maps.arcgis.com)
Private lands data are not hosted on dashboards without permission, so data are delivered to partners via group membership in ArcGIS online.



A screenshot of MRBO's interactive dashboard showing the continued decline of grassland obligagte bird species' densities.

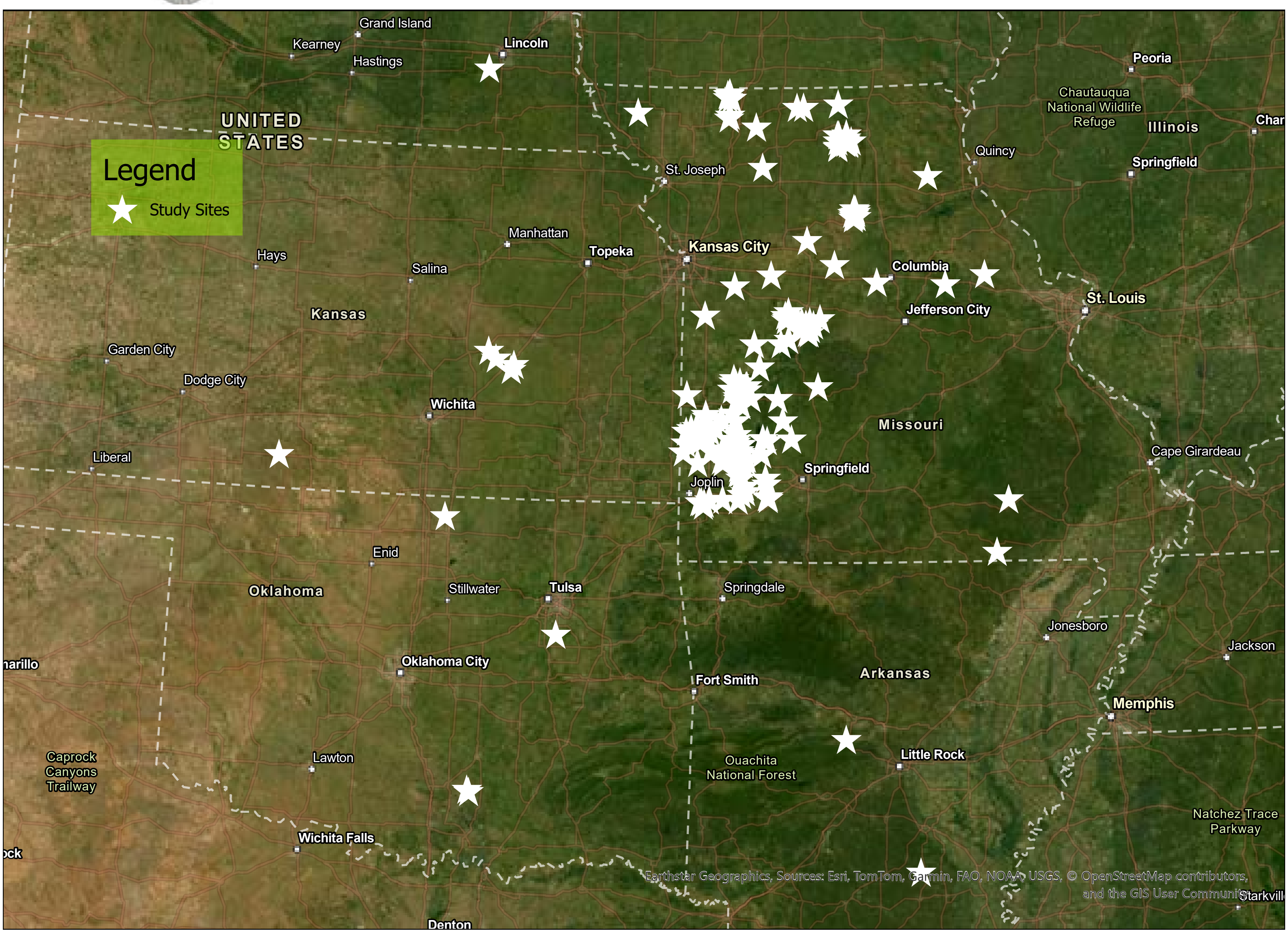
Study Areas
MRBO conducts grassland bird surveys in Missouri and several surrounding states. In Missouri, in keeping with the Missouri's Comprehensive Conservation Strategy (CCS), in-state site selection focusses on defined Priority Geographies. Those geographies include the Grand River, Hi Lonesome, Upper Osage, and Golden Grasslands. This year MRBO also conducted a first year of studies for two private lands projects, the Native Forage Initiation (NFI) and a RCPP focused on precision agriculture and prairie buffers. Both projects' data contribute to a larger monitoring component to assess these crucial programmatic impacts on working lands in Missouri.

Methods

Survey and Analysis Approach
Bird surveys are conducted using line-transect Distance sampling to estimate densities of grassland bird species. Observers employ mobile devices to collect spatially explicit detections, which are used to calculate distances from the transect lines. These data are analyzed using the Distance package in R to account for detectability and generate density estimates for each species. Spatially explicit detections were also used to create mappable datasets for visualization.

Field Methods
Based on protocol developed by MRBO, MDC, and the National Audubon Society, line-transect surveys are conducted by walking at a pace of approximately 1 mile/hour while recording all species detected by sight and sound. Detections are spatially recorded on ESRI's Field Maps application on mobile devices. Each survey begins 15 minutes before sunrise and lasts no longer than four hours after sunrise, ensuring that surveys are timed during birds' peak daily activity. Surveys are conducted during the peak grassland bird breeding season which generally begins in early May and lasts through early July. Surveys are only conducted under optimal weather conditions, which excludes conditions with precipitation and wind speeds exceeding 12 miles/hour.

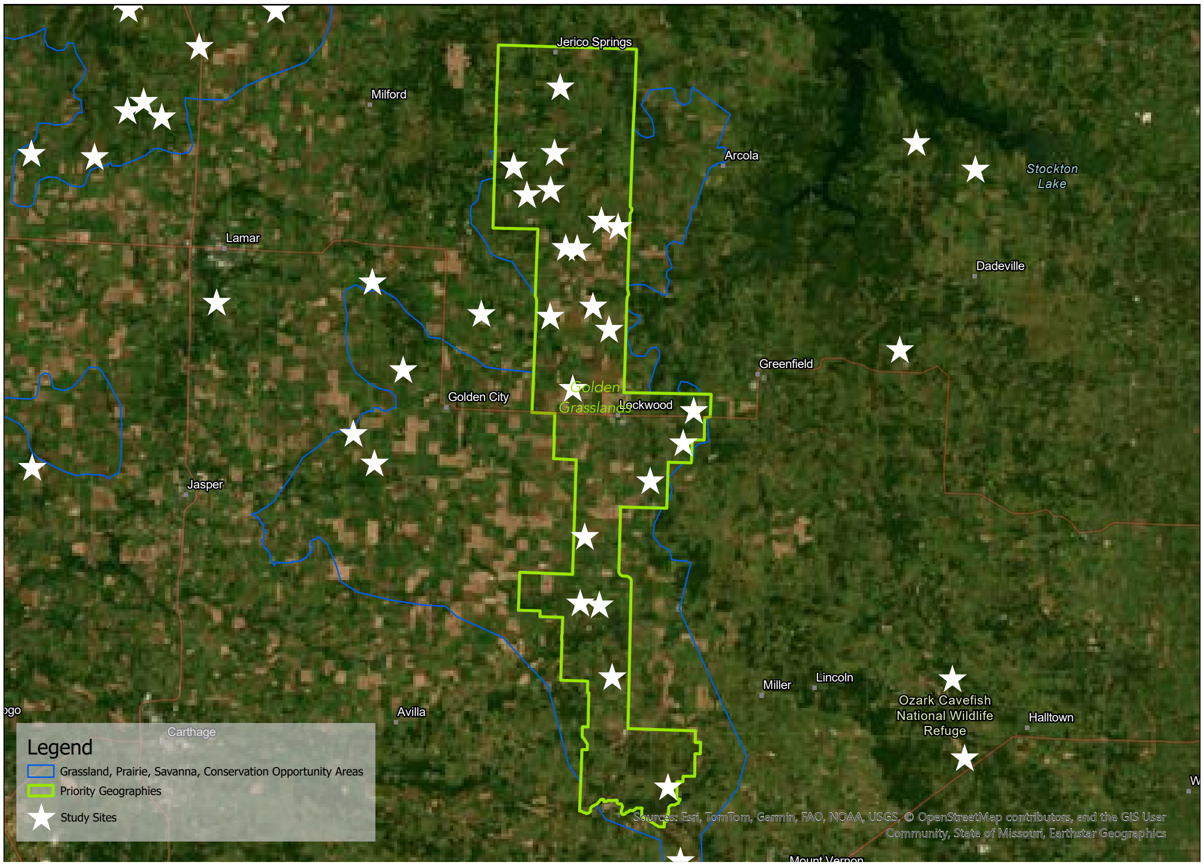
Missouri River Bird Observatory Grassland Bird Survey Sites 2012-2024



Study Areas

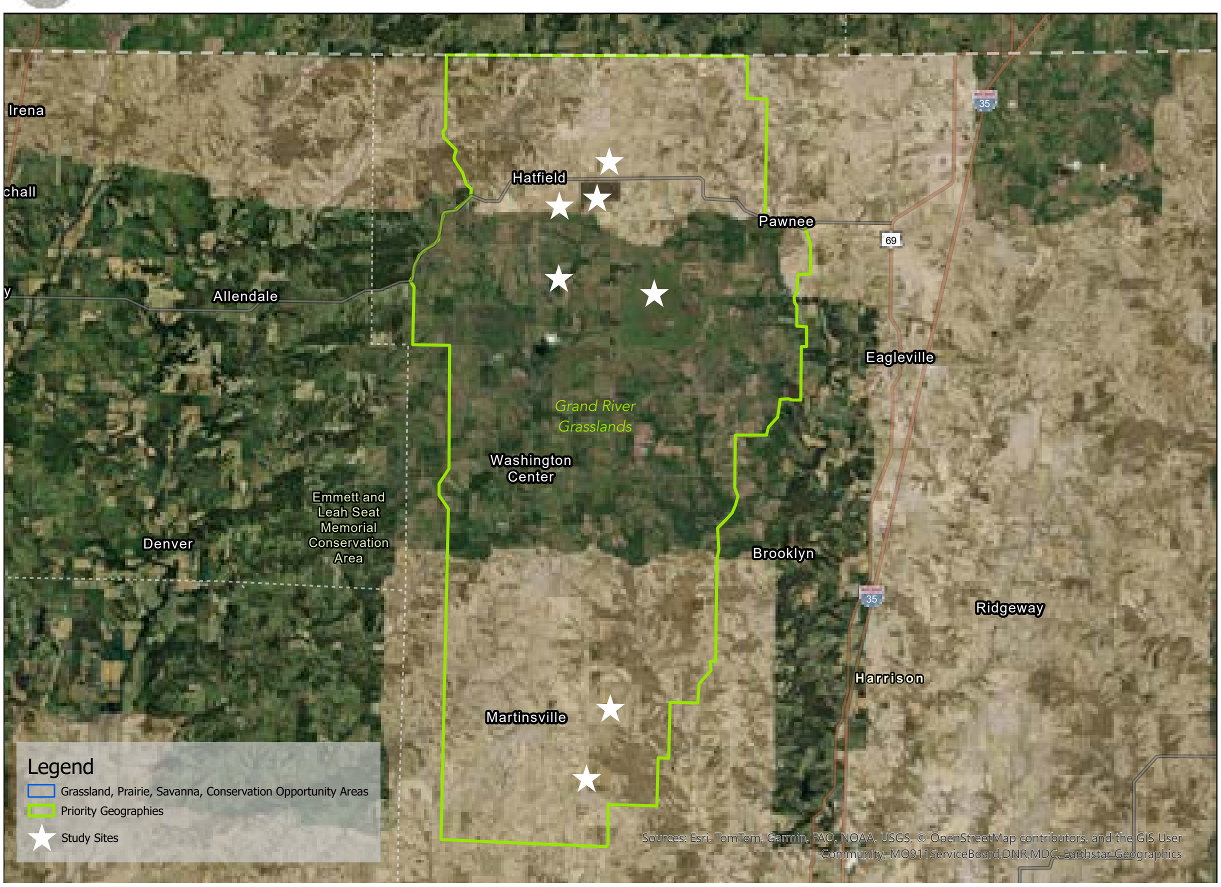
Missouri River Bird Observatory Priority Geography Survey Coverage 2012-2024

Golden Grasslands



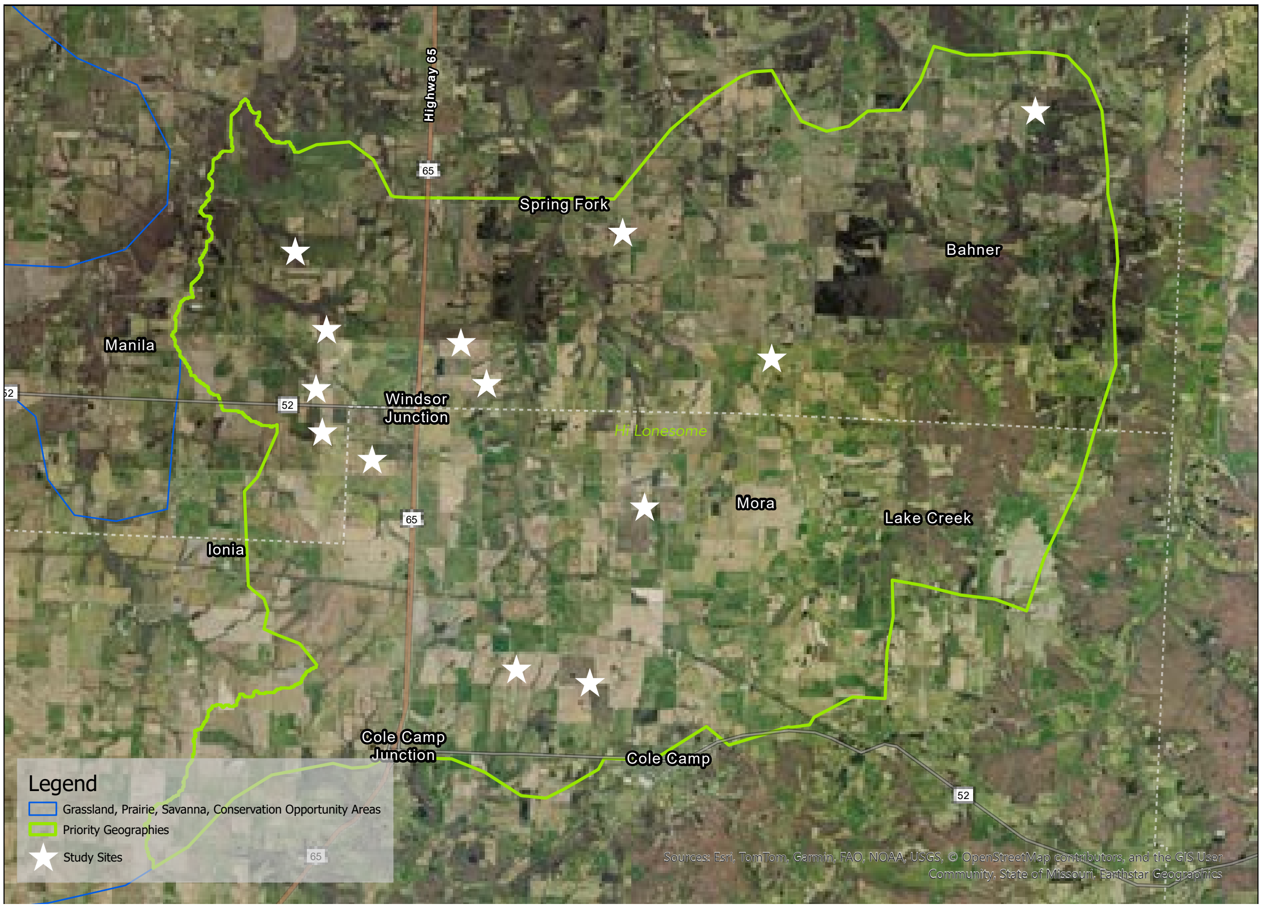
Missouri River Bird Observatory Priority Geography Survey Coverage 2012-2024

Grand River Grasslands



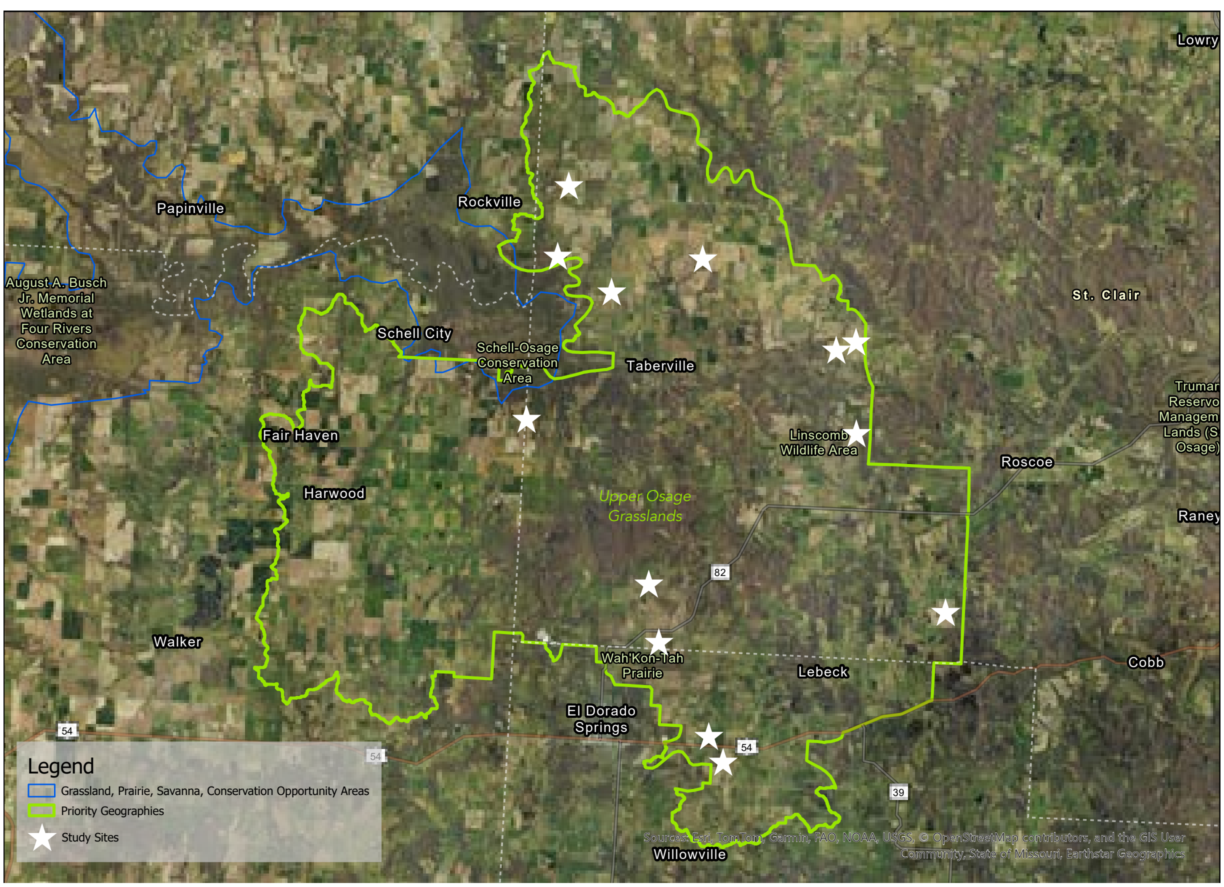
Missouri River Bird Observatory Priority Geography Survey Coverage 2012-2024

Hi Lonesome



Missouri River Bird Observatory Priority Geography Survey Coverage 2012-2024

Upper Osage Grasslands



Results

Analysis Results

Bird-Friendliness Metric

This combined metric provides a bird-centric index of ecosystem quality, emphasizing the presence of high-conservation-value species and overall community diversity. The formula integrates:

- Species Densities: Estimates for individual species from Distance analysis.
- Conservation Concern Scores: Weightings derived from the Partners in Flight Assessment Database.
- Brillouin Diversity Index: A measure of overall diversity among grassland obligate species on each property.

Bird-friendliness Formula

Bird-friendliness = The sum of Bird Species Densities x Conservation Concern Scores + Grassland-Obligate Species Diversity

Contextualizing Results

Missouri results align with broader declines in grassland bird populations as described by Rosenberg et al. (2019). Variation in density and bird-friendliness indices across properties may be attributed to differences in landscape-scale and site-specific factors, though further study is needed to establish causation. Further, multi-scale analysis is underway at MU under post-doctoral researcher, Tom Stevens. Private lands data can be made available upon request for MDC use via ArcGIS Online Group privileges.

Data Access

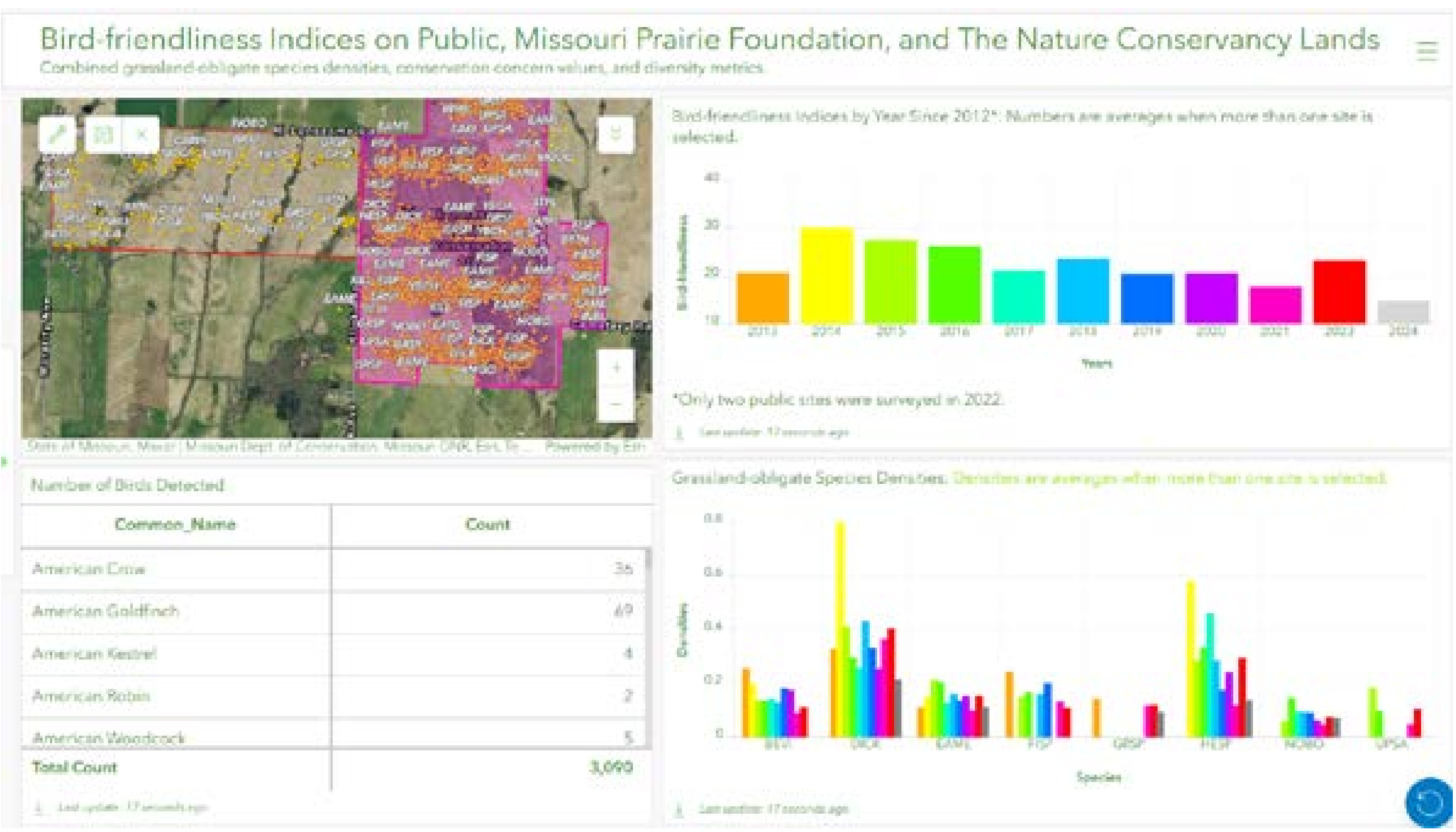
Interactive Dashboard Data Access

When examining results there are many iterations of species and sites over years, so we recommend exploring specific sites and species of interest on public and partner lands using our online dashboards at: https://mrbo.maps.arcgis.com/

Instructions are included in the dashboard slide out panel to the left of the dashboards and read as:

> *About*
>
> *This dashboard is designed to explore site level data and examine bird survey results over time. A brief video tutorial can on using this tool can be found here: https://youtu.be/3ZnZzXcywVU*
>
> *How are the bird-friendliness indices derived?*
>
> *The bird-friendliness indices for each site are determined by the grassland obligate bird species' densities and the diversity metric (i.e. (Sum of Grassland-obligate Species A, B, C, D, E Density x Concern Score (ACAD/MDC) + Diversity).*
>
> *Data should be viewed at the site level, as data viewed at the full extent, indicates the distribution of effort, rather than density.*
>
> *Accessing the Data*

1. *Select a site (required)*
2. *Pan, zoom, and/or search site. Alternatively, you can use the selection tool pop-up on the upper left area of the map to*



A screenshot of MRBO's interactive dashboard showing available data at the site level.

select multiple areas.
-Bird-friendliness indices will be populated in the chart to the upper right showing data for years when surveys were conducted. Density estimates will be displayed in the lower right for species with adequate sample sizes. Bird counts will filtered and displayed in the lower left.

3. *Select year(s) to compare*
   -Once a year is selected, both the mapped data and the species' densities chart will filter for the selection.
4. *Select species to compare*
   -Once species are selected, the mapped bird detections on the main map will be filtered based on selections).
   -You can select multiple years and or species to compare. All data can be downloaded from the small download buttons at the bottom of the charts. Source data will be filtered based on your selection.

Species Profiles

Not all grassland birds have similar habitat requirements; the following species profiles provide general habitat and dietary needs of grassland-obligate species found on study sites. Grassland-obligate birds depend on specific habitat conditions, including vegetation structure, patch size, and surrounding landscape context. These factors influence their ability to breed, forage, and persist in fragmented habitats. Below are profiles for focal grassland-obligate species observed.

Henslow's Sparrow (*Centronyx henslowii*)

- » Habitat Requirements: Prefers dense grasslands with minimal woody encroachment, thick litter layers, and tall vegetation for nesting (Herkert, 1994; Winter et al., 2003).
- » Diet: Primarily insectivorous during the breeding season, consuming grasshoppers, beetles, and caterpillars. Seeds are a significant component during migration and winter (Wiens, 1973).
- » Sensitivity:
  - o Edge Effects: Highly sensitive to edge habitats, avoiding areas near roads, forests, or urban interfaces (Herkert, 1994).
  - o Patch Size: Requires large, contiguous grasslands, with optimal patches exceeding 100 hectares (Helzer & Jelinski, 1999).
  - o Surrounding Landscape: Most successful in landscapes dominated by native grasslands rather than agricultural or urban land cover.

Grasshopper Sparrow (*Ammodramus savannarum*)

- » Habitat Requirements: Requires short to medium-height grasses with scattered bare ground for foraging and sparse vegetation for nesting. Avoids areas with dense litter or woody vegetation (Vickery, 1996).
- » Diet: Feeds heavily on orthopterans (grasshoppers and crickets) during the breeding season. Seeds of native grasses and forbs are consumed year-round (Wiens, 1973).
- » Sensitivity:
  - o Edge Effects: Moderately sensitive; exhibits reduced nest success near edges (Johnson & Temple, 1986).
  - o Patch Size: Requires medium to large patches of grassland, with a preference for areas over 50 hectares (Helzer & Jelinski, 1999).
  - o Surrounding Landscape: Prefers open landscapes with minimal woody encroachment and low-intensity land use.

Eastern Meadowlark (*Sturnella magna*)

- » Habitat Requirements: Occupies large, open grasslands, often preferring lightly grazed pastures or hayfields with low shrub density (Lanyon, 1995).
- » Diet: Primarily insectivorous during the breeding season, feeding on grasshoppers, beetles, and other arthropods. Seeds and grains become more important during non-breeding seasons (Kaspari & Joern, 1993).
- » Sensitivity:
  - o Edge Effects: Avoids areas near forested edges and urban structures, where predation risk increases (Herkert et al., 2003).
  - o Patch Size: Requires patches of at least 20–30 hectares but thrives in much larger, contiguous grasslands (Helzer & Jelinski, 1999).
  - o Surrounding Landscape: Most abundant in areas with high grassland connectivity and minimal agricultural fragmentation.

Bobolink (*Dolichonyx oryzivorus*)

- » Habitat Requirements: Prefers tallgrass prairies and lightly grazed pastures with dense vegetation for nesting. Avoids areas with woody vegetation or heavy grazing pressure (Renfrew et al., 2005).
- » Diet: Granivorous during migration and winter, feeding on seeds from grasses and forbs. During breeding, insects such as beetles and caterpillars are important (Martin & Gavin, 1995).
- » Sensitivity:
  - o Edge Effects: Avoids nesting near habitat edges, which are associated with higher rates of predation and brood parasitism (Renfrew et al., 2005).
  - o Patch Size: Requires large grassland patches, with nesting success highest in areas exceeding 50 hectares (Bollinger & Gavin, 2004).
  - o Surrounding Landscape: Prefers landscapes dominated by perennial grasslands with low-intensity agriculture.

Loggerhead Shrike (*Lanius ludovicianus*)

- » Habitat Requirements: Utilizes open grasslands with scattered shrubs or fence lines for perching and hunting. Prefers areas with thorny vegetation for caching prey (Yosef, 1996).
- » Diet: Carnivorous, feeding on insects, small mammals, and reptiles. Known for impaling prey on thorns or barbed wire as a storage strategy (Atkinson & Cade,

1993).

- » Sensitivity:
  - o Edge Effects: Less sensitive than other species but requires structural heterogeneity near grassland edges (Yosef, 1996).
  - o Patch Size: Utilizes smaller grasslands but benefits from larger landscapes for foraging (Chavez-Ramirez et al., 1994).
  - o Surrounding Landscape: Thrives in grassland mosaics with scattered shrub patches and minimal urban encroachment.

Upland Sandpiper (*Bartramia longicauda*)

- » Habitat Requirements: Occupies large, open grasslands with short vegetation and minimal shrub cover. Often nests in lightly grazed or hayed pastures (Houston et al., 2011).
- » Diet: Primarily insectivorous, consuming beetles, grasshoppers, and caterpillars. Seeds and grains are occasionally eaten (Dechant et al., 2003).
- » Sensitivity:
  - o Edge Effects: Avoids edges near roads and other human disturbances (Houston et al., 2011).
  - o Patch Size: Requires expansive grasslands, often over 100 hectares for breeding success (Brennan & Kuvlesky, 2005).
  - o Surrounding Landscape: Benefits from landscapes with low fragmentation and dominance of perennial vegetation.

References

1. Herkert, J. R. (1994). The effects of habitat fragmentation on midwestern grassland bird communities. *Ecological Applications, 4*(3), 461-471Helzer, C. J., & Jelinski, D. E. (1999). The relative importance of patch area and perimeter-area ratio to grassland breeding birds. *Ecological Applications, 9*(4), 1448-1458.
2. Winter, M., Johnson, D. H., & Shaffer, J. A. (2003). Variability in vegetation effects on density and nesting success of grassland birds. *The Journal of Wildlife Management, 67*(2), 265-275.
3. Vickery, P. D. (1996). Grasshopper Sparrow (*Ammodramus savannarum*). *Birds of North America Online.* Cornell Lab of Ornithology.
4. Renfrew, R. B., Ribic, C. A., & Nack, J. L. (2005). Edge avoidance by nesting grassland birds: A futile strategy in a fragmented landscape. *The Auk, 122*(2), 618-636.
5. Kaspari, M., & Joern, A. (1993). Prey choice by three insectivorous grassland birds: Reevaluating opportunism. *Oikos, 68*(3), 414-430.
6. Bollinger, E. K., & Gavin, T. A. (2004). Bobolink responses to habitat and management changes. *Journal of Wildlife Management, 68*(4), 915-923.
7. Atkinson, E. C., & Cade, T. J. (1993). Loggerhead Shrike (*Lanius ludovicianus*). *Birds of North America Online.* Cornell Lab of Ornithology.
8. Houston, C. S., Bowen, D. E., & Houston, M. I. (2011). Upland Sandpiper (*Bartramia longicauda*). *Birds of North America Online.* Cornell Lab of Ornithology.
9. Rosenberg, K. V., Dokter, A. M., Blancher, P. J., et al. (2019). Decline of the North American avifauna. *Science, 366*(6461), 120-124.
10. Winter, M., Johnson, D. H., & Shaffer, J. A. (2003). Variability in vegetation effects on density and nesting success of grassland birds. *The Journal of Wildlife Management, 67*(2), 265-275.
11. Vickery, P. D. (1996). Grasshopper Sparrow (*Ammodramus savannarum*). *Birds of North America Online.* Cornell Lab of Ornithology.
12. Martin, S. G., & Gavin, T. A. (1995). Bobolink (*Dolichonyx oryzivorus*). *Birds of North America Online.* Cornell Lab of Ornithology.

"Booming on the Lek" by Eric Wilhoit. Greater prairie-chickens, once detected in small numbers on MRBO surveys, are no longer detected in Missouri.

Drone-Based Habitat Data Collection: Overview, Capabilities, and Future Plans

Introduction
The use of Drone Data Deliverables for Grassland Conservation
Incorporating drone technology into grassland habitat data collection offers numerous advantages over traditional methods, providing **cost-effective, efficient, and precise** deliverables that can enhance conservation efforts as outlined in Missouri's Comprehensive Conservation Strategy (CCS). These drone-based deliverables — such as high-resolution orthomosaics, digital elevation models (DEMs), and multispectral imagery — serve as critical tools for addressing complex conservation challenges, including woody encroachment, habitat degradation, and adaptive management planning.

Accomplishments
Drone data were acquired on 14 sites, include drone data acquired on multiple visits. All data are packaged and deliverable for sites where data were acquired. Including all mapping, over 2,700 acres were captured. Most of the data are usable in the current iteration, but we recommend reacquiring data using workflows developed during the pilot project to obtain the most precise and high quality data.

Drone imagery from Paint Brush Prairie CA showing post-burn habitat conditions.

Drone Data Workflow Devolopement

MRBO has developed drone-based data collection workflows, evolving through the use of various Real-Time Kinematic (RTK) solutions to achieve the highest levels of accuracy for habitat monitoring and management. This evolution has enabled us to develop a robust workflow that integrates advanced drone technology, GIS processing tools, and high-precision georeferencing methods.

Initially, we had planned to rely on the Missouri Department of Transportation's (MoDOT) GNSS network for RTK corrections via

A screenshot of some of the othomosaic and point cloud data provided in a packaged product to MDC Staff.

mobile connections. While this provided some improvement over standard GPS accuracy, challenges with connectivity in remote field locations limited the reliability of this approach. Recognizing the need for more consistent and precise data collection, we acquired a DJI RTK-2 base station. This equipment significantly enhanced relative accuracy, allowing us to achieve centimeter-level precision within individual missions. However, among other limitations the lack of absolute accuracy remained a limitation, especially for long-term monitoring and multi-mission data integration.

In the summer of 2024, we further advanced our capabilities by acquiring two Emlid Reach 3 GNSS receivers. These receivers provided the means to establish Ground Control Points (GCPs) with centimeter-level absolute accuracy using NOAA's Online Positioning User Service (OPUS). By incorporating known points into our workflows and using these GNSS receivers as base stations for RTK corrections, we have achieved both relative and absolute accuracy across all missions.

This comprehensive workflow—combining the DJI Mavic 3M drone, Emlid Reach 3 GNSS receivers, and ESRI's Site Scan for ArcGIS—now forms the foundation of our habitat data collection efforts. Moving forward, we will apply this workflow systematically to all sites within the Hi-Lonesome priority geography. This will enable us to deliver a detailed, highly accurate suite of data to support vegetation structure analysis, phenology tracking, and conservation management decisions.

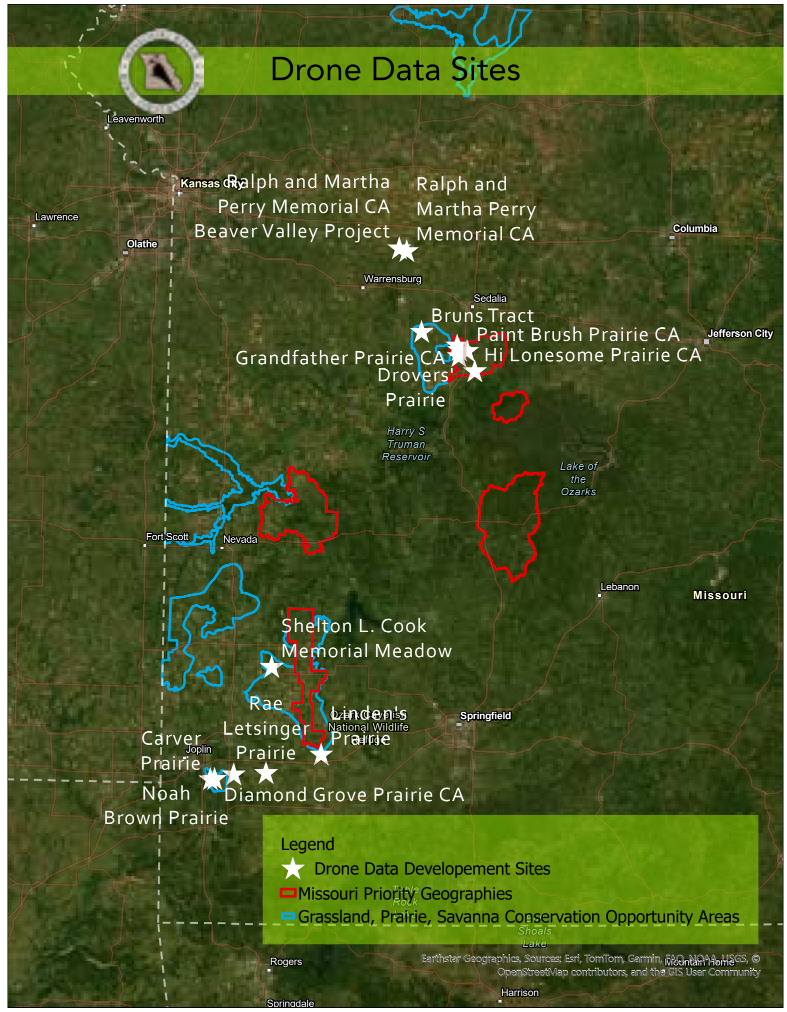
Our iterative approach to improving RTK solutions has equipped us with the tools necessary to provide reliable, repeatable, and precise habitat data. This ensures that MDC can lead the way in innovative and efficient tools to capture the critical information needed to effectively steward Missouri's natural resources.

Cost and Time Efficiency

1. Rapid Data Acquisition:
   Drone flights can cover areas in a fraction of the time it would take for ground-based surveys or manned aerial

Drone Efficacy

   flights. For example:
   - A 400-foot altitude flight can capture high-resolution imagery of 800 acres in as little as 10-20 hours.
   - Comparable data collected through traditional methods (e.g., field surveys or satellite imagery procurement) could take weeks or months and come with significant logistical challenges.
2. Reduced Expense:
   Traditional methods of data collection, such as manned aerial surveys or LiDAR scans, are costly, often requiring more specialized aircraft and personnel. Drones like the DJI Mavic 3M can achieve comparable results at a fraction of the cost, offering:
   - Multispectral imagery for identifying vegetation characteristics such as phenology.
   - 3D modeling and elevation data without the need for expensive LiDAR equipment.



3. On-Demand Flexibility:
   Drones provide the flexibility to perform surveys on-demand, allowing for seasonal or event-driven monitoring (e.g., after a prescribed burn or grazing event). This adaptability supports the CCS's goal of responsive, data-driven management.

Further Supporting the CCS Framework

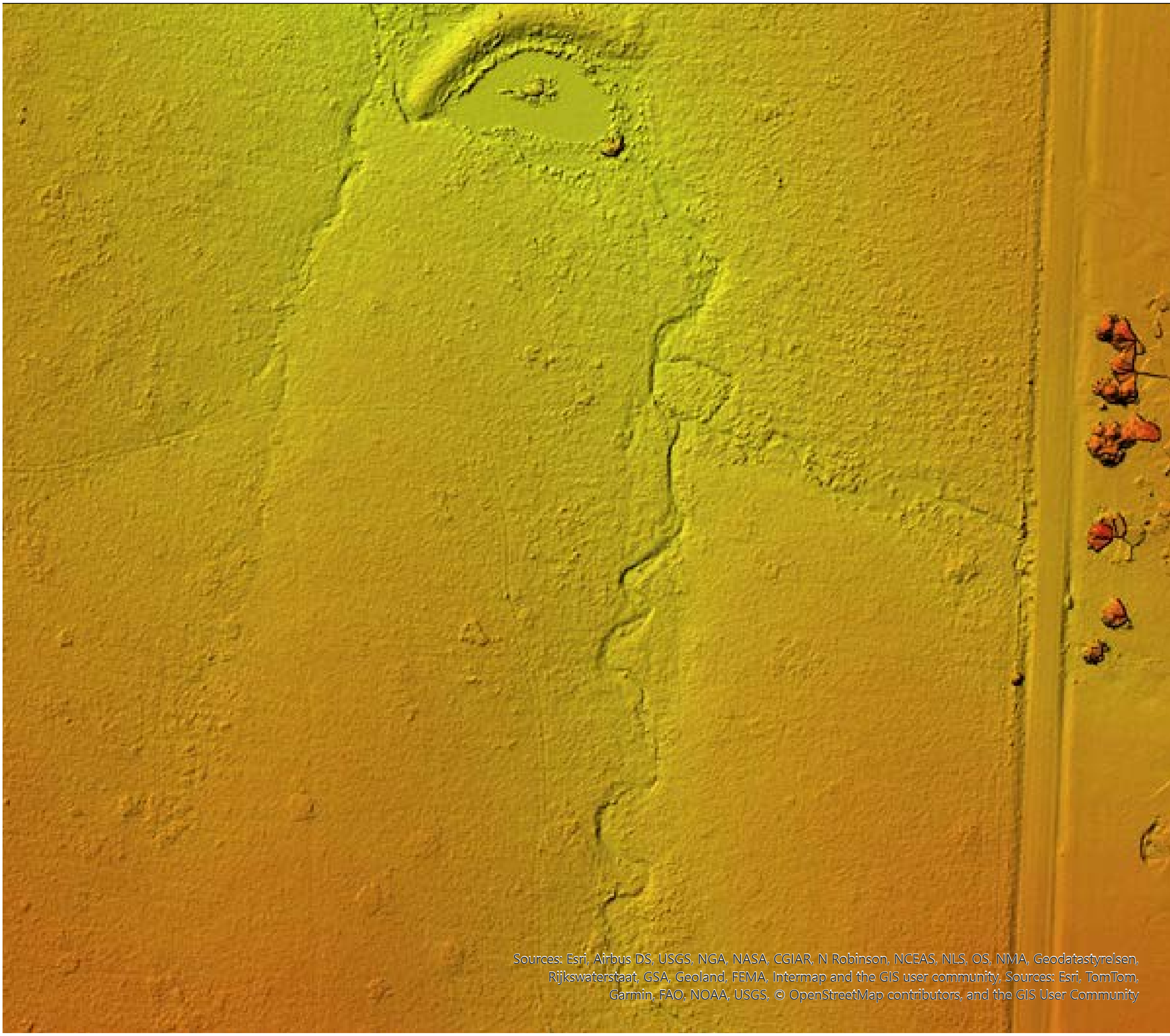
The ability to rapidly and affordably collect high-accuracy drone data aligns with the CCS's emphasis on:

- Focusing resources on Priority Geographies to achieve maximum conservation impact.
- Facilitating adaptive management through timely, data-driven decisions.
- Enhancing collaboration with partners by sharing high-quality data and insights.

By integrating drone-based workflows with RTK solutions and Ground Control Points (GCPs), MRBO provides a powerful toolset for achieving the CCS's grassland conservation objectives. This approach ensures that critical habitats are monitored, managed, and restored efficiently, supporting the long-term viability of Missouri's grasslands and the diverse species that depend on them. In addition to addressing woody encroachment, drone data deliverables can support several other grassland conservation goals outlined in the CCS:

Addressing Woody Encroachment

Woody encroachment — the gradual invasion of shrubs and trees into



Example of Digital Elevation Models (DEMs) that are created as a standard product from drone data processing.

grasslands — is a major threat to prairie ecosystems, reducing habitat quality for grassland bird species and altering native plant communities. Drone data deliverables help address this issue by providing:

1. Quantifying Woody Occupancy:
   High-resolution RGB imagery and 3D point clouds enable precise quantification of woody plant cover. By mapping the extent and density of woody vegetation, conservationists can:
   - Identify hotspots of encroachment.
   - Plan targeted management actions, such as mechanical removal or prescribed fire.
2. Tracking Change Over Time:
   By conducting repeat drone surveys, changes in woody encroachment can be tracked over time. This longitudinal data helps:
   - Measure the effectiveness of management interventions (e.g., fire, grazing, or herbicide treatments).
   - Inform adaptive management to ensure long-term grassland health.
3. Cost-Effective Monitoring:
   Traditional field surveys for woody encroachment are labor-intensive. Drone imagery allows for rapid assessment across large areas, reducing the need for extensive fieldwork and enabling managers to allocate resources more effectively.

Habitat Management Information

1. Multispectral Imagery can be used to generate vegetation indices (e.g., NDVI, Red-Edge NDVI) that assess plant health, vigor, and help identify coarse species composition.
    - This information helps determine the quality of habitat for species of greatest conservation need (SGCN), such as Henslow's sparrow and grasshopper sparrow that have seek unique grassland structure and composition.
2. Monitoring Management Responses:
    - Drone data can evaluate the outcomes of prescribed burns, grazing regimes, or invasive species removal.
    - By comparing pre- and post-management imagery, land managers can quantify vegetation recovery and fine-tune future strategies.
    - Imagery products can be used for more detailed management measures in office GIS and loaded for in-field mobile applications such as Field Maps for ArcGIS.
3. Phenology Tracking:
    - Frequent drone flights allow for detailed tracking of seasonal changes in vegetation (e.g., flowering, senescence).
    - This supports the CCS objective of aligning management activities with the life cycles of key species and plant communities.
4. Elevation and Hydrology Mapping:
    - Digital Elevation Models (DEMs) and contour maps generated from drone imagery help identify drainage patterns, erosion issues, and wetland areas within grasslands.
    - This data is critical for managing habitats that support amphibians, waterfowl, and other wetland-associated species.
5. Invasive Species:
    - High-resolution imagery aids in detecting, mapping, and quantifying invasive species such as sericea lespedeza or Johnson grass.
    - Early detection through drone surveys allows for timely intervention, preventing the spread of invasives that degrade grassland habitats.

Drone Capabilities

Capabilities of the Mavic 3M Drone

The DJI Mavic 3M is a highly capable multispectral drone designed for capturing high-precision habitat data. Its features include:

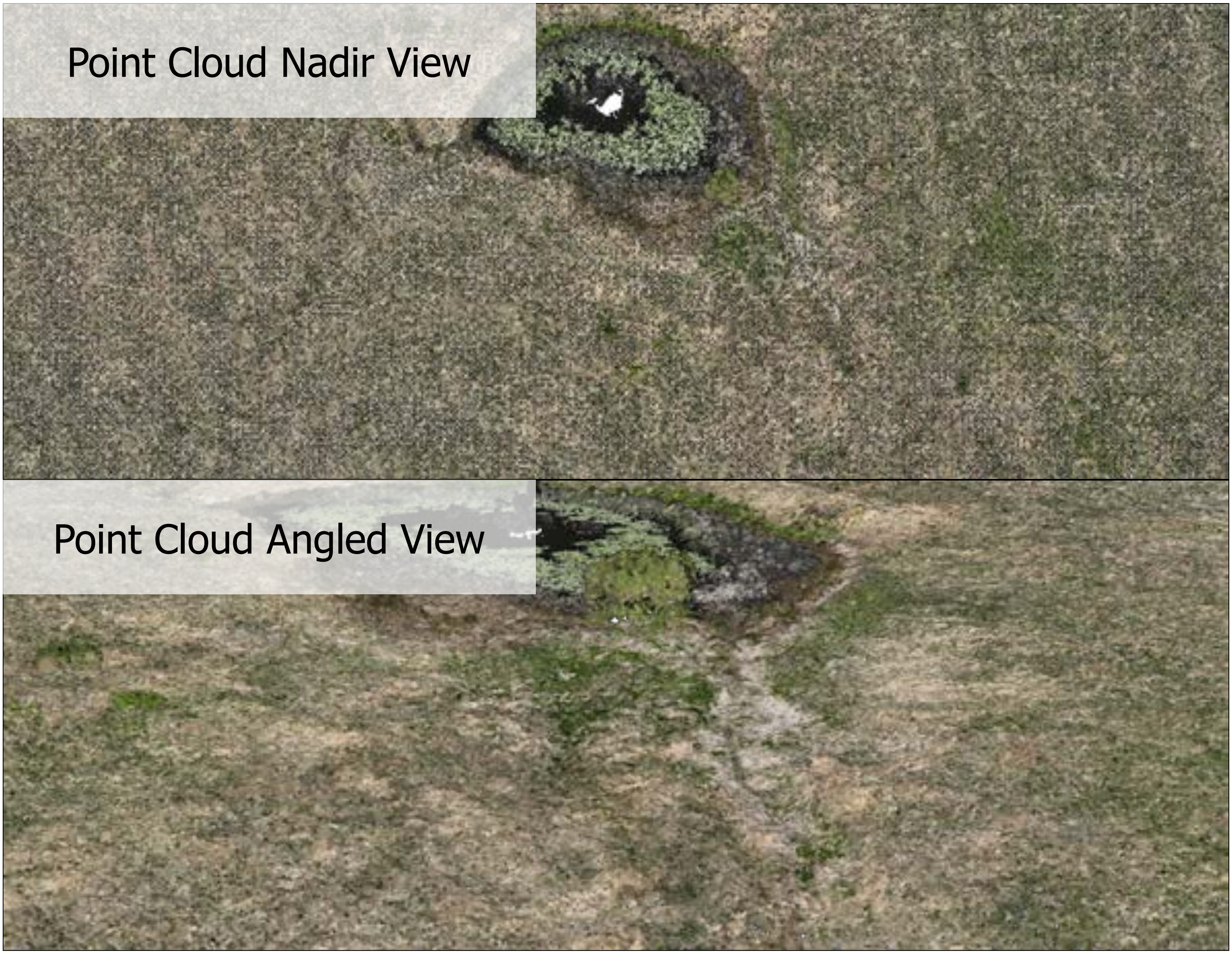
1. High-Resolution Imaging:
    - RGB Imagery: Captures high-resolution data at 2 cm per pixel.
    - Multispectral Imagery: Captures data at 5 cm per pixel, enabling the calculation of vegetation indices like NDVI and Red-Edge NDVI.
2. RTK Integration:
    - Initially, flights relied on connecting to the Missouri Department of Transportation's (MoDOT) GNSS network via mobile connection. The acquisition of a DJI RTK-2 base station improved relative accuracy to within centimeters during flight. Subsequent acquisition of the Emlid GNSS receivers provided absolute accuracy.
3. Flight Efficiency:
    - Over 21 missions covering over 15 sites, the Mavic 3M accumulated over 12 hours of flight time. These missions provided detailed habitat imagery for properties managed by MDC and the Missouri Prairie Foundation.

Drone Workflows and Planning

Data Collection Workflow and Rationale

To achieve centimeter-level absolute accuracy, MRBO assessed the incorporation of Ground Control Points (GCPs) and Emlid Reach 3 GNSS receivers into our workflows. These tools enhanced the accuracy of drone data collection in the following ways:

1. Establishing Known Points:
    - Known points were established using the NOAA OPUS tool to process raw GNSS data. These points serve as Ground Control Points for georeferencing and as locations for base station setups during drone missions.
2. Base Station Setup:
    - Deploying the Emlid Reach 3 receiver on a known point allows for broadcasting RTK corrections to the Mavic 3M, ensuring centimeter-level accuracy during flight.
3. Enhanced Accuracy:
    - Using the base station on known points, incorporating GCPs and RTK corrections significantly improves the accuracy of orthomosaics, DEMs, and point clouds, ensuring reliable data for conservation planning and management.



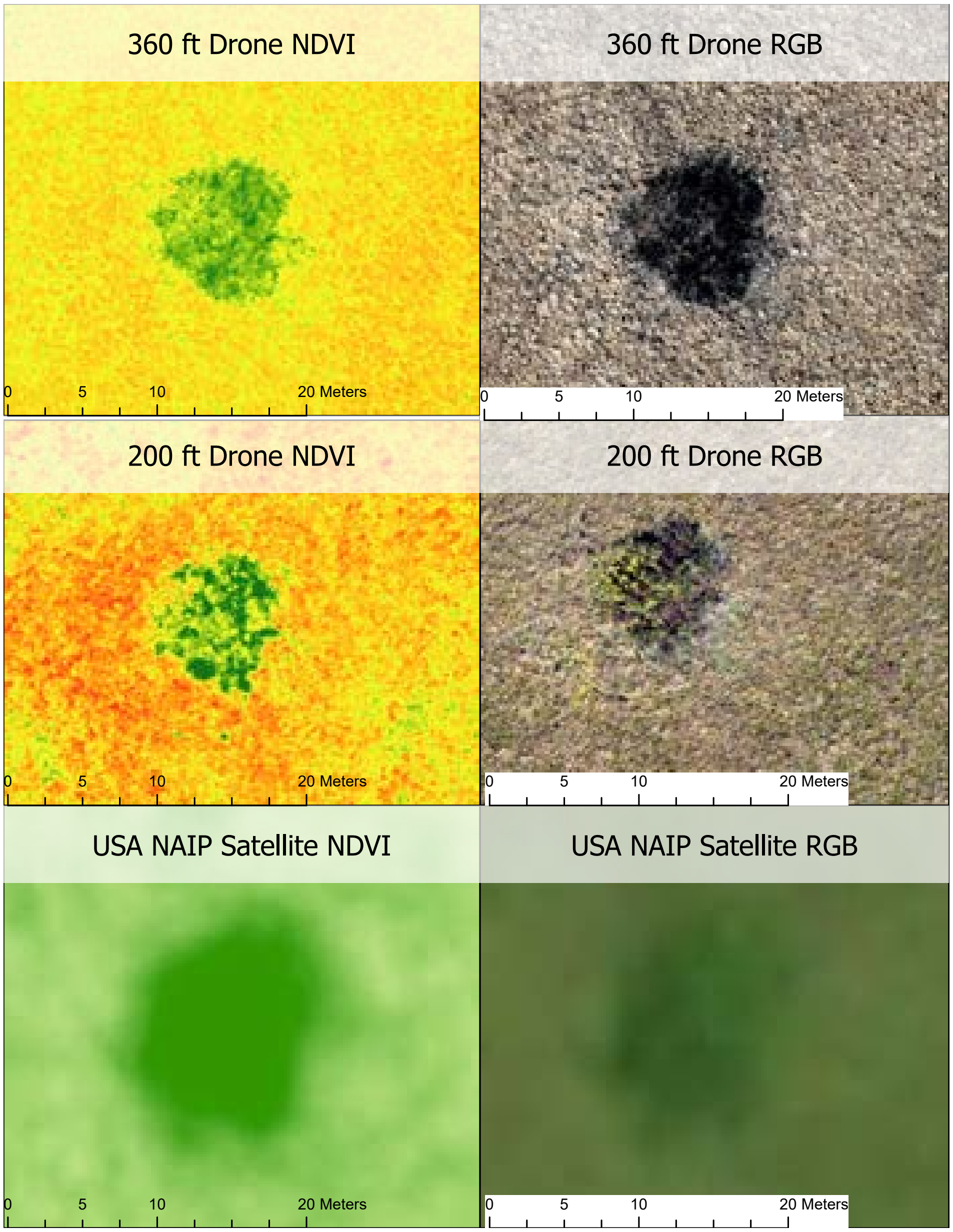
Views of colorized point cloud products showing detail of ground elevation and height of vegetation.

Practical Considerations for Planning

When planning future drone data capture, several practical attributes need to be considered, imagery resolution, area size, and time.

Resolution (GSD) and Tradeoffs of Drone Data Collection
The Ground Sampling Distance (GSD) of drone imagery varies with flight altitude, affecting detail, coverage, and efficiency. The following table outlines GSD and estimated flight times for different altitudes (50 to 400 feet AGL) and property sizes (80 to 800 acres):

Flight Altitude (AGL)	GSD for RGB Imagery	GSD for Multispectral Imagery	Flight Time for RGB (80 acres)	Flight Time for Multispectral (80 acres)	Flight Time for RGB (800 acres)	Flight Time for Multispectral (800 acres)
50 feet (15 m)	0.7 cm per pixel	1.8 cm per pixel	4-5 hours	5-6 hours	40-45 hours	50-55 hours
100 feet (30 m)	1.4 cm per pixel	3.5 cm per pixel	3-4 hours	4-5 hours	30-35 hours	40-45 hours
200 feet (61 m)	2.8 cm per pixel	7.0 cm per pixel	2-3 hours	3-4 hours	20-25 hours	30-35 hours
400 feet (122 m)	5.6 cm per pixel	14.0 cm per pixel	1-2 hours	2-3 hours	10-15 hours	15-20 hours



Views of Ground Sampling Distances (GSD). Images L-R, Top to Bottom. Drone NDVI at 360 ft, Drone RGB imagery at 360ft, Drone NDVI at 200 ft, and Drone RGB at 200 ft, as compared with USA NAIP Satellite data.

You can notice the difference of the 5 cm per pixel of the multispectral imagery and the 2 cm per pixel of the RGB imagery. Similarly, granular detail of the 200 ft RGB reveals greater resolution of grass blades and leaves than that of the 360 ft example.

Tradeoffs of Different Elevations

- » Low Altitude (50–100 feet):
  - » Highest Detail for fine-scale vegetation analysis but requires longer flight times and produces large datasets.
- » Medium Altitude (200 feet):
  - » Balances detail and efficiency, making it suitable for general habitat assessments and phenology tracking.
- » High Altitude (400 feet):
  - » Provides broad coverage and shorter flight times but with lower detail and reduced elevation accuracy.

Future Plans for the Hi-Lonesome Priority Geography

MRBO plans to expand drone-based data collection to cover all sites within the Hi-Lonesome priority geography. By combining:

- » High-resolution data from the Mavic 3M,
- » Processing workflows in Site Scan,
- » Accurate georeferencing with GCPs and Emlid Reach 3 GNSS receivers,

we will create a comprehensive and highly accurate suite of data to support habitat monitoring, phenology tracking, and land management. This approach ensures:

- » Detailed understanding of vegetation structure and phenological changes,

» Accurate evaluation of management responses,
» Reliable basemaps for future conservation planning and data collection.

This integrated workflow positions MRBO and its partners to make data-driven decisions and maintain the long-term health of Missouri's prairies and priority conservation areas.

The following time estimates are for the five Hi Lonesome MDC public properties based on current workflows. These estimates are for flights at 200 ft AGL considering RTK base station use and GCP placement for all properties totaling 1,871 acres.

Flight Time (at 200 ft AGL)
» RGB Only: ~80 acres per battery
» RGB + Multispectral (RBB): ~60 acres per battery

Flight Time Estimates for 1,871 Acres:
» RGB Only: ≈ 15.6 hours flight time
» RGB + Multispectral: ≈ 20.8 hours flight time

Total Effort in Time (Estimate Including RTK and GCPs)

Task	Time Estimate
RTK Base Setup (5 properties)	~12 hours
GCP Placement (90-120 points)	18-30 hours
Flight Time (200 ft, RGB + MS)	20.8 hours
Total Time	50-68 hours

Drone view of a prescribed fire in action.

Summary
» Largest Property (649 acres, 200 ft AGL): ~16-21 hours
» Total for All Properties (1871 acres, 200 ft AGL): ~45-58 hours

These estimates include time for RTK setup, GCP placement, flight time, and verification processes. The lower altitude (200 ft AGL) increases flight time but may yield higher-resolution results. Batteries are changed throughout the mission. Using MRBO's mobile power setup, four batteries can be recharged within an hour.

Recommendations

Conservationists can take advantage of rapidly emerging technologies in many capacities to help stop the decline of our grassland-obligate species. Missouri's public lands contain some of last and prairie remnants in the state and are an anchor for grassland birds in all seasons. Private land conservationists are essential to build sustainable landscape-scale habitat. We must also consider full lifecycle stewardship meeting the habitat requirements of grassland species. Of importance are partnerships with other state agencies need to be strengthened in gulf states where Missouri's short-distance grassland birds winter.

We at MRBO have developed innovative and highly-efficient workflows thanks to the support agencies and other partners. These technologies have become accessible and potentially scalable across larger regions.

Applied Technologies

The success of the current workflows demonstrates the potential for broader implementation of efficient GIS-based habitat management and strategic planning across the department. By leveraging accessible technology, spatial analysis, and readily available bird monitoring metrics, area managers and supervisors can enhance the precision and effectiveness of their conservation efforts. Expanding the adoption of these workflows will help ensure that habitat management decisions are data-driven and aligned with conservation goals.

Our approach to combining field-collected bird survey data with modern GIS tools has streamlined the process of evaluating habitat quality and management impacts. This integrated workflow not only improves data accuracy but also facilitates real-time visualization and analysis, empowering decision-makers to adapt management practices responsively. We envision a future where:

1. **All area managers and supervisors have access to the same GIS tools and metrics** that MRBO has utilized, enabling them to visualize bird densities, diversity indices, and bird-friendliness scores with ease. This will foster a more collaborative and informed approach to habitat management.
2. **Interactive dashboards are expanded and standardized** across public and private lands, providing intuitive platforms to explore survey results, compare sites over time, and download filtered datasets for strategic planning.
3. **Data-driven decision-making becomes a cornerstone** of habitat management practices. Managers can quickly assess the impact of their actions on grassland bird populations and refine strategies based on evidence gathered through these workflows.
4. **Training and support are provided** to ensure that area managers, supervisors, and field technicians are proficient in using GIS tools and interpreting bird monitoring metrics. This will democratize access to data and insights, promoting consistent and high-quality habitat management across the department.

By embracing these workflows, the Missouri Department of Conservation can continue to lead in grassland habitat preservation and support the recovery of grassland bird populations. This future-focused approach will ensure that conservation actions are efficient, transparent, and impactful, safeguarding critical habitats for generations to come.

Future Vision: Scaling Drone-Based Habitat Data Collection for Greater Conservation Impact
The advancements made in drone-based habitat data collection during the pilot project provide a scalable, efficient, and cost-effective foundation for enhancing grassland conservation efforts across Missouri. By embracing this technology at a broader departmental level, the MDC can achieve unprecedented coverage, accuracy, and responsiveness in its habitat monitoring and management practices. Once authoritative drone data products are produced, they could be made more widely available at scale by being housed under MDC or current GIS data repositories such as MSDIS. This valuable data should be available to all public land managers, supervisors, administration, and researchers.

Efficiency and Precision at Scale
The workflows developed by MRBO, integrating the DJI Mavic 3M drone, Emlid Reach 3 GNSS receivers, and Site Scan for ArcGIS, offer a repeatable and high-accuracy method for collecting habitat data. These workflows can be systematically applied to larger areas and multiple priority geographies, enabling the department to:

» **Capture High-Resolution Data Across Vast Landscapes:**
Our experience capturing 2,700 acres across 14 sites demonstrates the potential for scaling operations. With current workflows, sites covering thousands of acres can be surveyed efficiently within weeks rather than months, drastically reducing project timelines.

» **Enhance Data Accuracy and Consistency:**
The use of Ground Control Points (GCPs) and RTK base stations ensures centimeter-level accuracy, supporting consistent data collection over time. This precision is critical for long-term monitoring, allowing the department to track subtle changes in vegetation structure, phenology, and management outcomes with confidence.

» **Respond Rapidly to Conservation Needs:**
Drone technology provides on-demand flexibility to conduct surveys following critical events such as prescribed burns, grazing rotations, or invasive species treatments. This rapid-response capability enables adaptive management aligned with the **Comprehensive Conservation Strategy (CCS)**, ensuring timely data for decision-making.

Cost-Effective and Resource-Efficient Conservation
Scaling drone-based workflows reduces reliance on more expensive and logistically complex methods like manned aerial flights or extensive ground surveys. The Mavic 3M, equipped with multispectral and high-resolution RGB sensors, delivers data comparable to traditional LiDAR and field surveys at a fraction of the cost. By investing in expanded drone operations, MDC can:

» **Maximize Conservation Budgets:**
Achieve comprehensive monitoring without the high operational costs of conventional methods. Drone-based surveys can be performed with minimal personnel and equipment costs, freeing resources for other critical conservation activities.

» **Optimize Staff Time and Effort:**
By replacing or supplementing labor-intensive ground surveys with rapid drone flights, MDC staff can focus on data interpretation, management planning, and field interventions rather than extensive data collection efforts.

Broader Applications for Conservation Goals
Expanding drone-based data collection offers versatile applications beyond woody encroachment monitoring. At scale, these technologies can support multiple CCS objectives, including:

» **Invasive Species Detection:**
Early identification and mapping of invasive plants like sericea lespedeza and Johnson grass can facilitate timely management, preventing habitat degradation across larger regions.

» **Phenology Tracking Across Landscapes:**
Frequent, systematic drone flights enable detailed monitoring of seasonal changes in vegetation, informing management practices that align with the life cycles of key species such as Henslow's and grasshopper sparrows.

» **Elevation and Hydrology Mapping:**
Generating Digital Elevation Models (DEMs) for extensive areas supports erosion control, wetland management, and habitat restoration projects critical for amphibians, waterfowl, and other species of concern.

A Vision for Statewide Implementation
By adopting MRBO's drone workflows for statewide implementation, MDC can lead the way in innovative conservation practices. This vision includes:

1. **Systematic Monitoring of Conservation Opportunity Areas (COAs):**
Applying drone surveys across COAs ensures that conservation efforts are focused where they are most needed and that progress is accurately tracked.
2. **Collaboration with Conservation Partners:**
Sharing high-quality drone data with partners like the Missouri Prairie Foundation (MPF) and other stakeholders enhances collective conservation impact and promotes data-driven decision-making.
3. **Data-Driven Policy and Planning:**
Reliable drone data can inform policy, guide habitat restoration projects, and support grant applications, reinforcing MDC's leadership in conservation.
4. **Continuous Improvement and Innovation:**
As drone technology advances, MDC can stay at the forefront by integrating new tools, refining workflows, and expanding capabilities to address emerging conservation challenges.

Conclusion
The efficiency, accuracy, and adaptability demonstrated in MRBO's drone-based habitat data collection make a compelling case for department-wide adoption. By scaling these operations, MDC can unlock new levels of effectiveness in managing and conserving Missouri's grasslands, ensuring these vital ecosystems and their species thrive for generations to come. MRBO will continue to pioneer new technologies and report on our developed workflows and lessons learned. We are thankful for the opportunities provide by MDC support to develop and expand this pioneering work.

"Dickcissel in the Morning" by Russell Kinerson