Assessment of Thermographic Imaging Systems on Small Unmanned Aerial Systems (sUAS) to Identify Artificial Grassland Bird Nests

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Key words: [thermography; sUAS; grassland bird; nests]

Abstract
Grassland bird populations can be good indicator species of ecosystem health. However, their populations are declining at greater rates than any other group of birds. A well-established method of monitoring rapidly disappearing bird populations is by locating and identifying active nests. Studies quantifying grassland birds tend to have low statistical power due to low sample sizes, high labor costs, and high levels of disturbance - associated with difficulty finding nests. However, advances in small unmanned aerial systems (sUAS) and thermographic imaging technologies have the potential to improve efficiency and accuracy of locating nests, while causing minimal disruption. Early research has evaluated nest detectability using a thermal imaging system equipped to a sUAS. The sUAS was flown at three different altitudes to detect simulated nests at incremental depths in monoculture grass stand canopies. This study evaluated nest detection accuracy using visual assessment of two different types of thermal imagery. The first type of imagery used third-party software to create a stitched thermal map of the research area, while the second method utilized real-time video feed from the thermal sensor to identify simulated nest locations. Both methodologies were tested in a blind evaluation, using five evaluators and two replications. Results from this study have suggested that mapping software does not optimize nest detectability and identification, and the analysis of videos proves to be a much more precise way to detect and identify nests.

Introduction
Historically, grasslands were very common throughout the United States, and these prairies provided habitat for several wildlife species (Keyser et al., 2019). However, native grass prairies have been replaced by exotic grasses such as bermudagrass (*Cynodon dactylon* (L.) Pers), bahiagrass (*Paspalum notatum* Flueggé), cogongrass (*Imperata cylindrica* (L.) P. Beauv.), and tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort., nom. cons.). Wildlife, more specifically, grassland bird species, do not typically fare well in areas that are dominated by exotic species. These exotic grasses provide poor habitat for grassland birds because of the thick, dense mats of sod that offer little bare ground to allow swift movement away from predators (Barnes et al., 2013). However, some exotics are beginning to be replaced due to their negative effects, and the re-establishment of native warm season grasses has become more common across the country (Brazil, 2019). Consequently, as native grassland acreage has steadily increased, researchers have also developed methods determine if these re-established native grasslands act as beneficial habitat for wildlife (Bakker and Higgins, 2009). One popular way to measure habitat quality in reclaimed grasslands is by quantifying the use by one of America's most imperilled avian groups, grassland birds (Martin and Geupel, 1993). One established way of quantifying grassland bird use throughout reclaimed native grasslands is by assessing nest prevalence and density. The ability to monitor grassland bird populations could aid efforts to reclaim and restore native grassland habitats needed for these populations to thrive. Grassland bird nest detection has also proven to be a useful method in monitoring grassland bird population numbers. This research project evaluated using sUAS equipped with thermal imaging technology for grassland bird nest detection. Thermal imagery was collected and evaluated in two forms: live video or matrixed map. Further, this research sought to 1) identify strengths and weaknesses of currently available thermal imagery capturing and processing technology, 2) define accuracy and precision of human interpretation of those outputs, and 3) assess the validity and overall feasibility of this methodology. This novel technological approach to detecting grassland bird nests may prove to be quicker and easier than traditional detection methods (Scholten, 2019).

Methods and Study Site
Research was conducted at Mississippi State University RR Foil Plant Science Research Center (33.467952, -88.754920) and HH Leveck Animal Research Center (33.423582, -88.792412) near Starkville, MS from September 2019 to December 2020. Simulated nest searches were conducted in five stands of grass species consisting of giant miscanthus (*Miscanthus x giganteus* J.M. Greef & Deuter ex Hodkinson & Renvoize

[*sacchariflorus x sinensis*]), big bluestem (*Andropogon gerardii* (L.) Vitman), eastern gamagrass (*Tripsacum dactyloides* (L.) L., and two different ecotypes (upland and lowland) of switchgrass (*Panicum virgatum* L.). Technology evaluated consisted of the DJI Matrice 200 V2 sUAS (S2 DJI Co-LTD, Shenzhen, China) equipped with DJI Zenmuse XT2 R 640 13 mm (30Hz) thermal camera. The sUAS was flown at three different altitudes (9, 12, and 15 m above ground level (AGL) to detect simulated nests at incremental depths in grass canopies. Simulated nests were placed at ground level and ascending half-meter increments until reaching maximum canopy height. Maximum canopy height between grass species ranged from 0.5 to 2.5 m. Ten simulated nests were randomly distributed within each monoculture stand. Three flights – one at each altitude – were conducted before nests were moved to the next canopy height. At canopy heights above ground level, nests were attached to plant stems using rubber bands.

Simulated nests were designed to meet a target nest temperature of 30°C, the mean temperature of typical grassland bird nests. Simulated nests were constructed by using standard HotHands® hand warmers placed inside Glad® 4oz. mini round food storage containers and secured with snap-on lids. When left in open air, hand warmers rapidly reached temperatures in excess of 38°C, however, when air was completely restricted, hand warmers failed to meet or maintain target temperature. To maintain consistent temperature, multiple designs that allowed circulation of fresh air within each nest were tested for consistency. The most reliable design from these trials resulted from perforating each nest lid with four holes, each approximately 0.635 cm diameter. Hand warmers were removed from packaging, shaken for approximately 15 seconds, placed inside containers, and lids were applied. Nests were allowed to rest for 15 minutes, during which temperatures were recorded in five-minute intervals. On average, simulated nests reached target temperature within nine minutes and maintained target temperature for over three hours. The maintenance of temperature was crucial in order to accurately portray grassland bird nest temperatures and accurately determine the usefulness of sUAS/thermal technology for nest detection.

Flight plans for mapping each grass monoculture were created using DroneDeploy® (San Francisco, California) software prior to arriving on scene. All flight plans were programmed with specific flight altitude (9, 12, or 15 m AGL), front and side overlap (90%), and flight speed (8 kmh^{-1}). Thermal videos were recorded simultaneously during flight with the application MyScreenRecorder® (MyMovie Inc.; Huamao City, Beijing). The two imagery capture applications were launched and operated simultaneously throughout flight.

Both thermal maps and videos were analyzed by a blind review process. All identifiable information (monoculture species, flight elevation, canopy height, and date) was blinded during evaluation of imagery. Including the pilot, a total of five evaluators were trained to identify heat signatures in thermal imagery. Individually, evaluators were given all maps - arranged in a random order sequence - and asked to analyze each map for heat signatures. This process was repeated for video analysis. Data were compiled and analyzed using PROC GLM in SAS® statistical analysis software, version 9.4. Evaluators, flight altitude, depth in canopy, and grass species were all treated as dependent variables. All main effects and interactions were considered significant at $\alpha = 0.05$ level.

Results

Results indicated that accuracy and precision of nest detection from camera imagery are significantly increased when analyzing live video feed as opposed to matrixed maps. Overwhelmingly, altitude had little impact on accuracy of detection when using matrixed maps. However, altitude of flight did create variability in quality of matrixed maps. At a flight altitude of 15 m, images matrixed well, and maps generally yielded high detectability. At an altitude of 9 m, however, image stitching quality was generally sub-optimal, and the number of positive nest detections declined.

While evaluators indicated that maps are ideal for timely analysis of imagery, current mapping software is not capable of accurately translating thermal imagery into maps at low flight altitudes. It was assumed that low flight altitudes would be required for researchers to positively identify nests. However, current hypotheses propose that low flight altitudes lead to inadequate geospatial data, causing mapping algorithms to fail to create maps with correct overlap of images. Currently maps from this research tend to have areas of duplication, blur, and distortion caused by the mapping algorithm used. These inconsistencies decrease accuracy and precision in nest estimation.

When analyzing video, evaluators indicated that, on average, over 90% of nests were detected during each flight no matter the depth in canopy in four of the five grass species. While detection rate in videos average over 90%, the average detection rate in maps was approximately 50%.

When looking at map detection success across grasses, eastern gamagrass had the highest success rate of nest detection at 100% followed by big bluestem (65%), upland switchgrass (55%), lowland switchgrass (50%), and giant miscanthus (30%). These data support the hypothesis that taller, thicker stature grasses lead to a decrease in nest detection success. Conversely, when analyzing video, eastern gamagrass and lowland switchgrass had the highest detection success rate at 100%, followed by big bluestem (97%), upland switchgrass (95%), and lastly miscanthus (82%).

Discussion [Conclusions/Implications]

Like other nest detection and small mesocarnivore detection studies, the results from this research also show that the sUAS and thermal camera method of detection is possible, and it could prove to be a very useful and economical alternative to traditional methods of nest detection. From the results, it is possible to fly a sUAS at 15 m AGL and detect simulated nests within the canopy up until about 1.5 m deep into the canopy of thicker, taller stature grasses. Which means that most grassland bird nests should be detectable when flying the sUAS at the 15 m altitude over grasslands unless the grasses were planted very thick.

Future research would benefit from focusing on the implementation of this technology *in situ*. The authors have initiated multiple studies utilizing the methods described herein to detect grassland bird nests in reclaimed grasslands, however, wild populations of grassland birds and active nests are often limited. In addition, current limitations in map matrixing at altitudes below 12 m AGL altitudes sometimes required to detect nests does not allow for construction of reliable maps with pinpointed nest locations. Future studies could also implement image recognition software to analyze and record nests in videos simultaneously.

Acknowledgements

The authors would like to acknowledge the North American Coal Corporation for their proactive commitment to environmental stewardship and funding this research project. The authors would also like to acknowledge the Mississippi Agricultural and Forestry Experiment Station for providing the facilities and resources for conduction this experiment.

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