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THE EFFICACY OF VIDEO CAMERAS TO ACCOUNT FOR NORTHERN BOBWHITES FLUSHED, BUT UNDETECTED, DURING AERIAL SURVEYS

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ABSTRACT

Over the past 20 years, conventional distance sampling from a helicopter platform has been used to estimate northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) density over large areas of rangeland vegetation. However, it has been speculated that aerial surveys can complicate the ability to meet the distance sampling assumption of detecting 100% of the target objects on the transect line due to the restricted observer view from the helicopter. We attempted to use video cameras to determine whether missed detections occurred and whether digital methods could improve the precision of bobwhite density estimates. Our objectives were to 1) determine whether video cameras are a viable option to detect if coveys are flushing behind the helicopter and missed by observers, 2) determine whether coveys are flushing underneath the helicopter and missed by observers, and 3) explore the use of video cameras in a mark-recapture distance sampling (MRDS) framework. We recorded video while traversing line-transects with a helicopter during 4 distance-sampling surveys across 2 ranches in South Texas, USA. For objective 1, we reviewed footage from cameras with a backward-facing view and detected only 1 pair of bobwhites (0.001% of 889 coveys detected) that flushed on video footage recorded during the surveys but were unnoticed by observers. These results indicated that when coveys flushed, they rarely flushed behind the helicopter, and the helicopter flew at what seemed to be the proper speed and altitude to detect late flushes. For objective 2, we reviewed footage from a helicopter-mounted camera that was recorded within a swath underneath the helicopter's center. We recorded 22 flushes within the swath, none of which was missed by the observers in the helicopter; as a result, we could not complete an MRDS analysis in Program Distance. This study improved confidence in fulfilling the assumptions of distance sampling and resulting density estimates but was limited to flushing birds only.

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Key words: aerial survey, *Colinus virginianus*, detection, distance sampling, northern bobwhite, video

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Monitoring and manipulative studies of animal populations depend on reliable density estimates to detect changes over time. Distance sampling techniques are often used in research because they account for objects undetected by the observer and provide density estimates with measures of variability. Line-transect distance sampling uses the observed perpendicular distances from the detections (x) to the transect (0) to estimate detection probability (Laake et al. 2008). Three fundamental assumptions determine the reliability of density estimates and associated variance measurements obtained through conventional distance sampling (CDS; Buckland et al. 2001): 1) objects directly on the line or point are detected with 100% certainty, or a probability of 1, where $g(0) = 1$; 2) objects are detected at their initial location and do not move in response to the observer; and 3) distances are measured accurately. Failure to satisfy the first assumption leads to difficulties when estimating detection probabilities and biases density estimates low if $g(0) < 1$ (Buckland et al. 2001, Bächler and Liechti 2007). The estimated $g(0)$ must be evaluated by addressing perception bias (when observers fail to detect animals at 0 distance even though animals are present) and availability bias (when animals are unavailable for detection; Marsh and Sinclair 1989).

Several studies have evaluated the use of line-transect distance sampling with northern bobwhites (*Colinus virginianus*; hereafter, bobwhite). These studies tested the feasibility of satisfying the 3 key assumptions (Guthery 1988, Rusk et al. 2007, Schnupp 2009) and obtaining the minimum number of detections from various platforms (e.g., helicopter, vehicle, walking). In tests of the first assumption, Rusk (2006) found that he was able to detect 70% of radio-marked coveys at 0 distance during fly-over trials and Schnupp (2009) found that he was able to detect whether radio-marked coveys were present in 94% of the 92 trials he flew. This discrepancy (70% vs. 94%) led us to further investigate the ability of observers to detect 100% of the objects at 0 distance. Additionally, adverse weather, dense brush, or an inexperienced observer may alter the results expected under ideal conditions. Using video cameras instead of radio-marked coveys may provide a less labor-intensive way to determine detection probability.

A proposed solution to the potential visibility biases in aerial surveys is the inclusion of high-resolution cameras mounted on aerial platforms (Buckland et al. 2015). Digital surveys using cameras to collect detection data with photographs or video (or both) have helped improve detection and reduce disturbance (i.e., response to observers) of water birds over large tracts of open water (Burt et al. 2009, Hexter 2009). Current methods include using a series of video cameras to survey large strips and estimating density via plot sampling (i.e., where observers can make a complete count in the swath). In applying this technique to bobwhites, an altitude higher than 10 m would be necessary to count birds within a reasonable swath width (50 m); however, previous research has suggested the low altitude (10 m) of a helicopter is necessary to elicit a covey flush in the case of quail (Shupe et al. 1987). Prior research has not tested the feasibility of counting bobwhites using cameras without observers in a strip transect.

When observers are unsure or unable to satisfy the first assumption of distance sampling, Buckland et al. (2001) recommend mark-recapture distance sampling (MRDS; Laake and Borchers 2004; Borchers et al. 2006), which allows relaxation of this assumption. In addition to the assumptions of CDS, the MRDS method requires some level of independence between observers, and the resulting analysis must be able to identify duplicate detections that qualify as "marks" by one observer and "recaptures" by another (Burt et al. 2014). The introduction of laser rangefinders in bobwhite surveys has allowed researchers to better meet the second and third assumptions of distance sampling, which involve detection location and measurement of distance (Schnupp et al. 2013). However, a helicopter must hover to measure perpendicular distances with rangefinders accurately. Hovering removes any independence between the groups of observers necessary in the independent-observer configuration for MRDS. Full independence requires constant movement by the helicopter and, as a result, for observers to visually estimate distances, which can introduce measurement error (Schnupp 2009). An alternative setup for MRDS surveys is a trial-observer configuration with point independence (Laake 1999, Laake and Borchers 2004). Here, the detection of one observer sets up trials on the line or point only for the other observer (Laake 1999). By implementing this approach with a camera mounted underneath the helicopter, the camera could act as the observer setting up trials on the lines for the observers in the helicopter (Laake and Borchers 2004). There is potential to combine digital surveys with trial-observer MRDS by using the camera to set up trials for detection at $g(0)$ (E. Rexstad and L. Thomas, Centre for Research into Ecological and Environmental Modelling, University of St. Andrews, personal communications). This method would relax the assumption of 100% detection at $g(0)$ and still allow observers to measure exact distances and estimate covey size. Using a video camera may also help address availability and perception bias at $g(0)$ given that the camera's resolution is sufficient to detect unflushed birds.

We used data collected during the initial phase of a long-term study on cattle grazing and bobwhite populations to assess whether video cameras can be used to: 1) evaluate missed detections behind the helicopter, 2) evaluate missed detections on the line, and 3) serve as a trial observer in an MRDS framework. For the first objective, we hypothesized that the altitude and speed of the survey we used were sufficient to elicit a covey flush upon approach, indicating bobwhite coveys would not flush behind the helicopter. For the second objective, we hypothesized that the camera would pick up all flushing bobwhites on the line (0 m) during surveys. If observers missed any of these coveys, we would be able to incorporate those detections into an MRDS analysis that would alleviate the constraints of satisfying the first assumption of CDS.

STUDY AREA

We conducted our study on 2 East Foundation ranches: the San Antonio Viejo Ranch and the Ranchito Ranch in Jim Hogg County, Texas, USA (Figure 1). We conducted video surveys during annual surveys on a 7,689-ha pasture on the San Antonio Viejo Ranch and 2,111 ha of the Ranchito Ranch. These ranches lie within the South Texas Plains ecoregion (Gould et al. 1960). The 30-year average annual precipitation in the area was 53.6 cm (PRISM Climate Group 2018). Based on the 30-year records, average temperatures were 12–13° C in January and 27–30° C in July (PRISM Climate Group 2018). Elevation in Jim Hogg County ranged from 60 m to 240 m. These areas were dominated by sandy soils. Woody plant communities in the study areas were dominated by honey mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), brasil (*Condalia hookeri*), granjeno (*Celtis pallida*), and prickly pear (*Opuntia* spp.). Seacoast bluestem (*Schizachyrium scoparium* var. *littorale*), purple threeawn (*Aristida purpurea*), Lehman lovegrass (*Eragrostis lehmanniana*), spotted beebalm (*Monarda fruticulosa*), and woolly croton (*Croton capitatus*) dominated the herbaceous plant community.

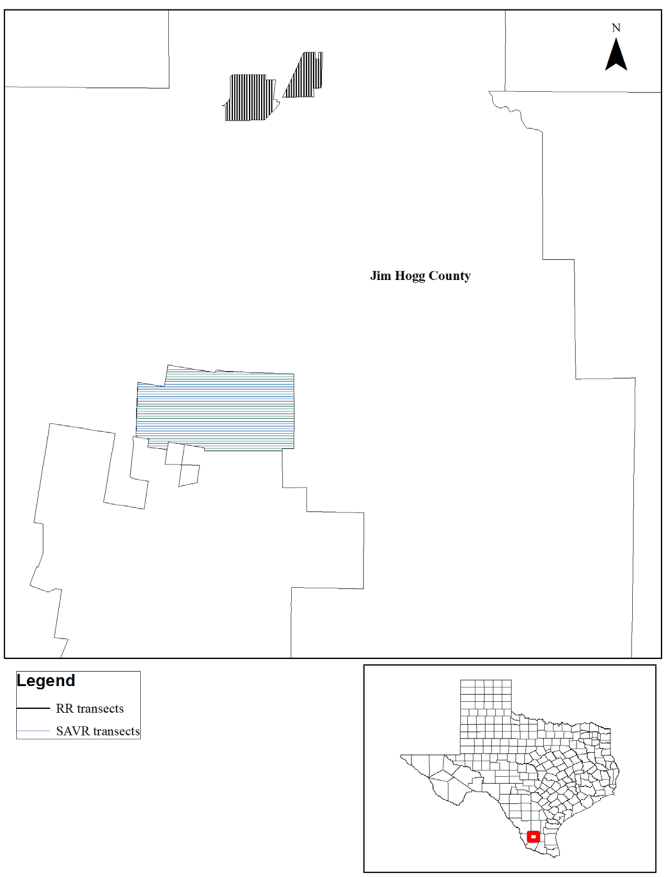

Fig. 1. Map of the flight transects and survey boundaries on the Ranchito Ranch (RR) and San Antonio Viejo Ranch (SAVR) in Jim Hogg County, Texas, USA used in 2015, 2016, and 2021.

METHODS

Aerial Surveys

We video-recorded 2 surveys in December 2015, 1 survey in December 2016, and 1 survey in March 2021. Surveys in December were conducted on the San Antonio Viejo Ranch, and the survey in March was conducted on Ranchito Ranch. Transects were spaced 200 m apart on both study sites (Figure 1). The surveys in 2015 were replicate surveys that occurred within 10 days of each other (hereafter, survey 1 and survey 2). For all surveys, 3 observers and the pilot traversed transects in a Robinson R-44 helicopter (Rio Grande Helicopters, Laredo, TX) at a height of approximately10 m and a velocity of 37 km/hour (as recommended by Rusk et al. 2007, Schnupp 2009, Schnupp et al. 2013) in sequential order with a random start point. Altitude may have varied between 7 m and 15 m based on brush cover and terrain; however, the pilot aimed to fly at 10 m when able. We followed the search and survey protocol developed by Schnupp et al. (2013), where the front-seat observer scanned the area directly in front of the helicopter to the doorframe of the back seat, and the 2 back-seat observers scanned the area from the doorframe to the tail rotor. The pilot also made detections when able but was not considered an observer.

When a covey was detected, the pilot moved the helicopter into a hover position that was perpendicular to the transect line; the back-seat observers took a reading of range, azimuth, and inclination with a laser rangefinder (Trimble Laser Ace 1000, Trimble Navigation Ltd., Sunnyvale, CA, USA) at the initial point of detection. The laser rangefinder was linked to a Juno hand-held unit (Trimble Juno 5 series handheld, Trimble Navigation Ltd.) via Bluetooth, which records and stores the following information: observer positions and names, date, time of detection, survey region, transect number, transect length, covey location (x, y), covey size, and the range, azimuth, and inclination of each detection via the CKWRI Wildlife Survey Database application (Schnupp Consulting, LLC, Kingsville, TX). At data import, each covey location was stored at the helicopter's position at the time of detection. CyberTracker uses the information collected by the laser rangefinder (range, azimuth, and inclination) to calculate the location of the covey. Perpendicular distance is then calculated from the flight path to the moved covey location.

Camera Methods

Rear-mounted cameras.—In 2015, we installed 2 Model Hero3+® (GoPro, San Mateo, CA) cameras angled at the tail rotor on either side of the helicopter doorframes to observe whether coveys were flushing after the helicopter passed (Figure 2A). We attached the cameras using 2 pilot-approved GoPro roll bar mounts. We recorded footage at a resolution of 720 pixels and 60 frames/second to review footage at 0.5 speed. We faced cameras backward to investigate visibility bias in our survey methods. If coveys waited to flush after

National Quail Symposium Proceedings, Vol. 9 [2022]

a helicopter passed, we wanted to know whether observers could still detect these late flushes. We also wanted to test whether the GoPros could detect bobwhites that did not flush and were not detected by observers. Following the survey, we matched count data from observers inside the helicopter against video footage by converting the video start and end time into real-time (GoPros are not enabled with a time stamp on-screen). We indicated positive detections in the video when the helicopter increased altitude and turned 90° into a hover. Any coveys in the footage that were passed by the helicopter, not detected (no hover or pause in the video), and not matched with a detected time stamp were considered a missed detection.

Tow ball-mounted cameras.—In 2016 and 2021, we used a FlightCam 360 (Flight Flix LLC, Maple Grove, MN, USA) camera with an 8-hour streaming capability on a single battery instead of the GoPro. We mounted the camera, facing down (0°), to the tow ball of the helicopter (Figure 2B) with a pilot-approved clamp with vibration control (VibeX Ball Mount; Flight Flix LLC). We recorded footage at a resolution of 960 pixels to increase battery life and 60 frames/second for review at ≤0.5 speed. Because the FlightCam was enabled with an onscreen time stamp, we could match exact covey detection times from inside the helicopter to the video footage. We

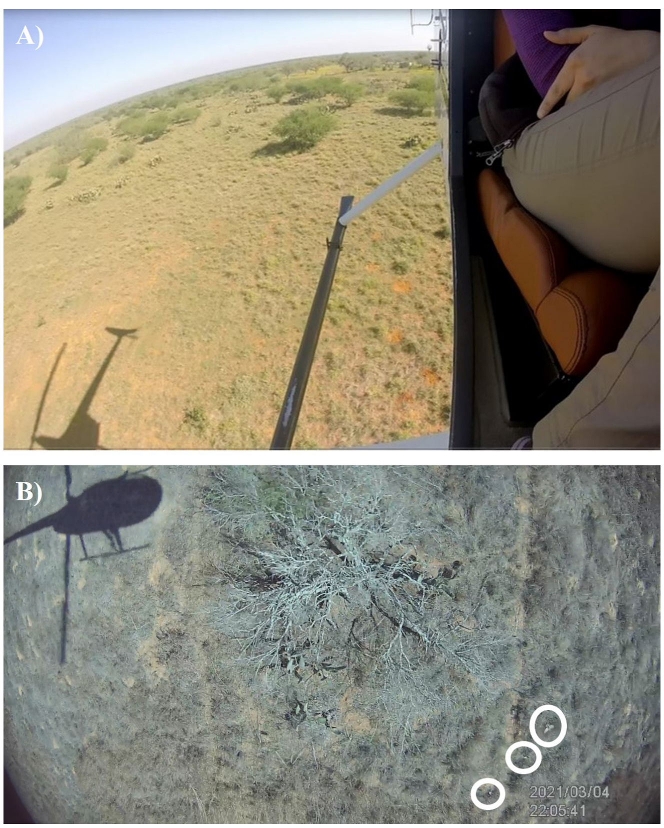

Fig. 2. Camera view from A) rear-facing mount in 2015 and B) tow-ball (downward facing) mount in 2016 and 2021. A covey flush is shown in the bottom right (white circles). Cameras were mounted to an R-44 helicopter during distance sampling surveys for northern bobwhites (*Colinus virginianus*) conducted on the Ranchito Ranch and San Antonio Viejo Ranch in Jim Hogg County, Texas, USA.

used the previously described methods to determine whether observers detected or missed a covey during post-survey reviews.

These surveys served as a trial run for using a digital observer in trial-observer MRDS with point independence using Program Distance, version 7.3 (Thomas et al. 2010). For observers to be able to use this mark-recapture method, the camera must be able to determine the covey size and perpendicular distance or distance bin (coveys within the camera's swath width) for any detections marked by the camera at 0 distance but not recaptured by the observers in the footage. To measure distances within the swath, the camera is set at a known angle (0°), and an object with a known length and height is recorded at the survey altitude to set a scale for the video. We calculated swath width using the following formula,

$$Width = \frac{\text{Altitude}}{\cos(\propto)} \times 2\tan\frac{AOV}{2},$$

where AOV corresponds to the camera angle of view. In Program Distance, we analyzed the data by 1) using the swath as a distance bin from 0 to x distance on either side of the centerline, and 2) determining the centerline of the video (0 distance) and measuring the distance to covey by equating the number of pixels in the video to a meter using an object of known distance present in the video. While we conducted MRDS sampling, there were no differences between camera detections and observer detections, and therefore we could not run an MRDS analysis for the trial-observer point independence in Program Distance.

RESULTS

Rear-mounted Cameras

From the 2015 footage, we reviewed 12 hours and 36 minutes of footage at 0.5 speed from both the left- and right-side cameras from survey 1 and 8 hours and 8 minutes of footage from survey 2. We observed 484 coveys over 380.3 km of transect for survey 1 and 405 coveys over 380.3 km of transect for survey 2. We identified one pair of bobwhites (<1% of total detections) on camera missed by observers; this pair flushed 30 seconds after a separate detection was made. This pair may have been a part of the detection. We suspected the resolution of the GoPros was not sufficient to detect coveys that did not flush but could not document this empirically because either no unflushed coveys were recorded, or all coveys flushed.

Tow Ball-mounted Cameras

During the 2016 survey, the bolt that connected the camera to the tow-ball mount broke and the camera was secured to the helicopter using available materials. As a result, we could not properly adjust the camera angle. Due to the camera angle from this video, we could not calculate the camera swath width. However, we analyzed the footage for any missed detections.

We reviewed 4 hours and 47 minutes of footage at 0.5 speed, approximately 50% of the total survey. The time stamp on this video made detection matching more reliable than the previous year. We observed 178 coveys over 192.8 km of the transect. There were no obvious flushes of large coveys missed by observers during the recorded survey. On 5 occasions (3% of 178 detections), we observed singles or pairs of birds flushing shortly after a covey was detected (<5 seconds); these birds were likely part of the detection made. On one occasion, we observed an undercount of the covey size recorded. We corrected the count using the video; however, it was rare to confirm counts as individuals disappeared when the video was paused, or part of the covey flushed out of frame. On 6 occasions, a single bird flushed outside of recorded covey detections (>60 seconds), but we could not make a positive identification on the bird species either because of the poor resolution or because it flew out of the frame too quickly.

In 2021, we reviewed 2 hours and 50 minutes of survey footage at 0.3–0.5 speed with the camera at 0° (pointed to the ground). We observed 85 coveys over 96.1 km of transect at a survey altitude of 10 m and an AOV of 120° at 10 m from the subject. Our swath width for this survey was 6.4 m. In matching the time stamp on the video to our survey footage, we did not observe any missed detections recorded by the camera. Like previous surveys, we recorded 4 occasions of a single bird flush outside of a covey detection where we could not identify the species. The resolution on this camera may not be able to detect any birds on the ground that did not flush; the camera did not record any known coveys on the ground to test this theory.

The camera and the observers detected 100% of detections within the swath width or 22 of the 85 total detections (26%). Of these 22 flushes, the perpendicular distance measured by observers using laser rangefinders was within the swath width of 6.4 m on 3 occasions (13% of duplicate occasions). This may indicate a different issue with the precision of our rangefinders. Throughout the survey, observers detected 15 coveys on the ground, 7 of which occurred within the camera swath: however, on-the-ground coveys could not be seen on the video. If we account for any variation in altitude during detections, larger swaths may have been recorded. If we recorded at 15-m altitude, our swath width would increase to 9.6 m, putting duplicate detections within the swath in 5 instances (22% of duplicate occasions). At a maximum, if the altitude were 20 m at the time of detection, our swath width would increase to 12.8 m, where duplicate detections within the swath occurred in 6 instances (27% of duplicate occasions).

DISCUSSION

Rear-mounted Cameras

The video footage data from these surveys supported the prediction that bobwhite coveys rarely flush behind the helicopter or that observers can detect these flushes. We observed birds flushing once the helicopter passed, but they flushed in the field of view of the back-seat observers and were detected. The results from the rear cameras reinforce the supposition that the helicopter survey speed and altitude are sufficient to flush coveys upon approach. The vantage points of the camera in 2015 allowed us to view the observer and, in some instances, a covey flush in the same frame. When both could be seen, we could confirm instances where observers were not recording distances from the initial point of covey flush. When observers incorrectly identified the initial flush point, we witnessed observers angling the rangefinder toward a different location than where the observed flush occurred. This can be corrected in future surveys by using trained observers, and evidence of an assumption violation enforces the need for observer training days where observers can practice detecting coveys with rangefinders with less pressure.

Given that pairs of bobwhites are typically rare in December, the single missed flush may be the result of 1) part of the larger detected covey flushing for the second time or 2) part of a larger detected covey that did not flush initially. If a rangefinder malfunctioned or did not register a reading on the first hit, the hover became prolonged while observers resolved technical difficulties. During an extended hover, coveys may have settled and partially flushed (i.e., only a fraction of the covey flushes) again once the survey was resumed. Observers in the helicopter communicated to avoid double counting a flushed covey; however, we could not determine this from the video alone. The only remedy is to note which coveys partially flush or flush twice in the helicopter and mark them with the time stamp on the electronic system.

Tow Ball-mounted Cameras

We were able to confirm that the observers missed no flushing birds within the swath width (area recorded by the camera); however, we could not detect unflushed birds with the camera alone. We succeeded with using the tow-ball cameras in a trial-observer configuration on the line, but the observers would have had to miss detections for the MRDS analysis to run. In this case, the Flight Flix camera with a tow ball mount allowed us to obtain the view necessary to survey directly below the helicopter. This camera also had a time stamp, which made matching the observations on the video to the data more efficient. In both 2016 and 2021, we observed occasions where singles and pairs of bobwhites flushed in proximity (time and distance) to other detections. These were likely part of a detected covey that did not flush together. As described earlier, we often observed delayed flushing in the helicopter and typically made the call to include these as part of the detected covey; however, we could not confirm these detections through the footage.

With our current camera, we could not estimate $g(0)$ and incorporate that known detection probability into the distance analysis. In natural color, the footage could not address availability bias at $g(0)$ in that we could not see unflushed coveys in the video. Therefore, we cannot compare our

National Quail Symposium Proceedings, Vol. 9 [2022]

findings to the *g*(0) of 70% and 94% obtained by Rusk (2006) and Schnupp (2009) via radio-marked birds.

Additionally, had the cameras recorded a covey missed by the observer, we would have been unable to confidently 1) estimate covey size and 2) match the distances recorded by the camera to the observers. The angle of the camera and speed of the helicopter made it difficult to count covey size accurately; therefore, an average would need to be used. We could match only 3 of the distances measured by observers to the detections in the camera swath, which indicates some error in the rangefinder's ability to place points at the correct location. Since we did not miss any detections (flushed) that the camera recorded, the use of digital methods was extremely time-consuming to post-process compared to human observer-only methods.

Bröker et al. (2019) used an approach similar to the one that we detail to determine the density of narwhals (*Monodon monoceros)* in Greenland. The authors used human observers to make track-line (0 m) detections and oblique-facing cameras on either side of a fixed-wing aircraft to record images every 3 seconds from 0 m to 515 m on either side of the helicopter. They found that both the images and observers recorded a statistically similar number of sightings and produced similar density estimates; however, the measured distances and group sizes differed (Bröker et al. 2019). The results from both Bröker et al. (2019) and this study succeeded at providing researchers with confidence in their ability to make detections. Still, they fell short of supplementing or replacing observers entirely due to limitations in the cameras.

Future research could focus on the use of thermal or infrared cameras with unmanned aerial systems (UASs) to aid in covey size estimation and the detection of unflushed coveys under certain conditions, particularly at night when bobwhites are roosting (identifiable by a circular configuration). In natural color, the resolution at ground level was poor in the cameras used in this study, making it difficult for observers to positively identify missed detections as bobwhites unless the shape and covey formation were clear. Thermal cameras were found to increase detections of several kangaroo species by 30% compared to observers in western Australia (Lethbridge et al. 2019). Despite limitations in survey time and area, UASs with thermal cameras used at night may be able to operate at a higher altitude to survey a broader swath and obtain a complete count of roosting coveys in the camera swath. This would take care of both perception and availability bias, particularly in the open grasslands of South Texas, where brush cover was not high. Surveys incorporating UAS technology have been employed in surveys of nesting birds (Choi et al. 2020), marine mammals (Hodgson et al. 2019), and terrestrial mammals (Van Andel et al. 2015), but not for terrestrial birds such as bobwhites. Additionally, the most promising uses of UAS and digital methods are their ability to increase observer safety by reducing helicopter time and potentially increase the precision of distance estimates.

There should be a continued focus on using technology and MRDS to relax the assumptions of distance sampling with bobwhites. Our study shows that human observers can confidently detect objects that flush during distance sampling surveys both on the line and behind the helicopter but cannot give insight into the detection of unflushed coveys.

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