A Practical and Efficient Helicopter Survey Technique to Estimate Bobwhite Abundance on Texas Rangelands—An Update and Review

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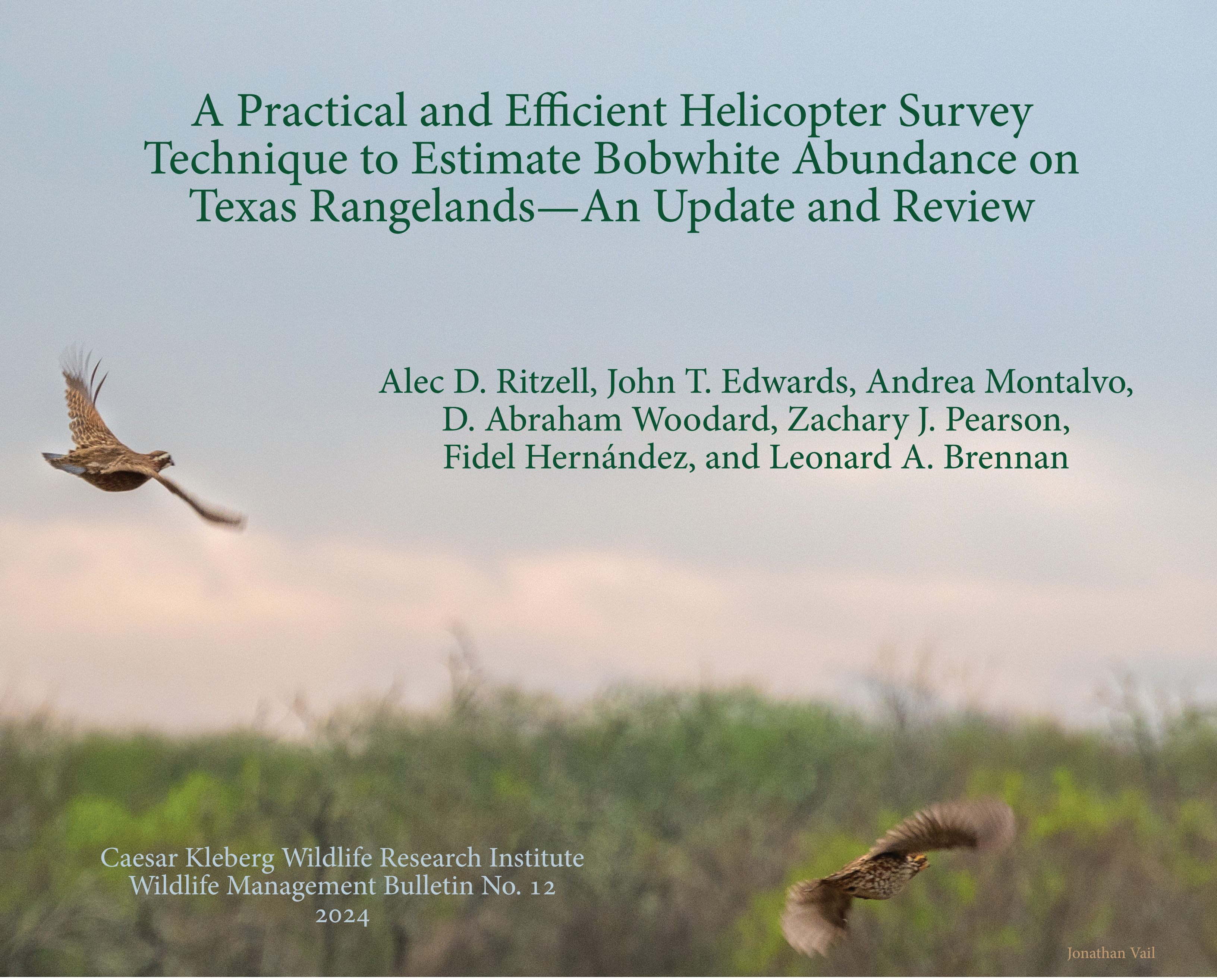

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Caesar Kleberg Wildlife Research Institute
Wildlife Management Bulletin No. 12
2024

Introduction

The importance of reliable population estimates for effective wildlife management has long been recognized. Reliable population estimates are needed for determining a species' conservation status, monitoring population responses to management, and determining appropriate harvest for game species. In Texas, there is a strong tradition of research and management of northern bobwhite (*Colinus virginianus*), owing in large part to the cultural heritage of this beloved gamebird as well as the stewardship of private landowners and their partnerships with wildlife research programs. Researchers at the Caesar Kleberg Wildlife Research Institute (CKWRI) have dedicated over 30 years of research to developing and improving techniques for estimating bobwhite populations.

In 2010, DeMaso et al. published a technical bulletin (CKWRI Technical Publication No. 2) that presented a method that permitted the conversion of raw counts (i.e., coveys per mile) obtained during helicopter-based surveys to bobwhite density (i.e., bobwhites per acre). This relationship—hereafter referred to as the conversion factor—allowed managers to empirically link an encounter rate to a density estimate and represented a big step forward in bobwhite management. Although this conversion factor was quite useful, it was—from an ecological perspective—based on a relatively small dataset (2007–2009). Since then, we have conducted considerably more research across a much larger space-time footprint, and we have learned new insights into the technique, the conversion factor, and its application.

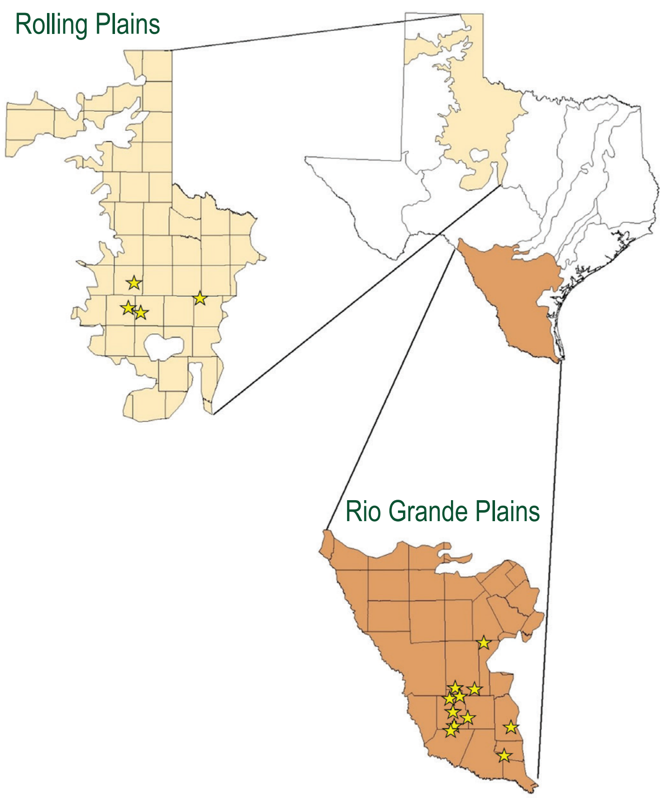

Figure 1. Stars indicate study sites in the Rio Grande Plains and Rolling Plains ecoregions where northern bobwhite were surveyed from 2014–2019.

Here we provide a review of the 2010 DeMaso et al. publication and discuss modifications to the original publication. We provide an updated conversion factor based on a larger dataset from recent research (2014–2019) and discuss how survey conditions (weather, time of day, and brush cover) may influence the conversion factor. We conclude with a brief discussion of practical considerations for bobwhite surveys (effort and number) and provide a summary of recommendations. For a brief history of past CKWRI research to provide context on how we arrived at the juncture, see Appendix A.

An Updated Conversion Factor Based on Recent Research

A Primer of DeMaso et al. (2010)

The DeMaso et al. (2010) technical bulletin provided bobwhite managers with a simple and easy-to-use tool to estimate bobwhite density. Application of the tool, however, came with caveats and warnings that users did not always heed. DeMaso et al. emphasized that use of the conversion factor "is reliable only if (1) bobwhites are in coveys at the time of the survey, (2) average covey size is about 8–9 bobwhites/covey, and (3) survey protocol is followed." For a discussion of these caveats, see Appendix B.

The Dataset

Since DeMaso et al. (2010), CKWRI has conducted numerous graduate research projects using helicopter-based distance sampling for bobwhites. These projects have been conducted over multiple years (2014–2019), properties (18 ranches), ecoregions (South Texas Plains and Rolling Plains), and conditions (wet and dry years) (Figure 1). The 65 surveys comprising this dataset included nearly 9,000 miles of survey effort across over 250,000 acres. In addition, these projects encompassed a broad spectrum of management styles and intensities as well as a diversity of landscapes.

All the projects followed the protocol outlined in DeMaso et al. (2010) in terms of timing (mid-December to early January), helicopter type (R-44), observer number (3, not including the pilot), observer configuration (1 in front passenger seat, 2 in rear seat on either side), speed (23 mph), and altitude (23–33 ft). The only deviation to the protocol was that surveys were conducted throughout the day and across a broad array of weather conditions rather than being limited in time (morning or late afternoon) or set weather conditions (clear, <80° F, and <15 mph). This, however, permitted us to evaluate the influence of these factors on bobwhite detections in addition to revising the conversion factor.

The resulting dataset included both "boom" and "bust" years. Encounter rates ranged from very low (0.5 coveys/mile) to very high (4.8 coveys/mile). Similarly, estimated bobwhite density also ranged from low (0.14 birds/acre) to high (1.6 birds/acre) (Figure 2A & B). Average covey size for the dataset was 8.6 birds.

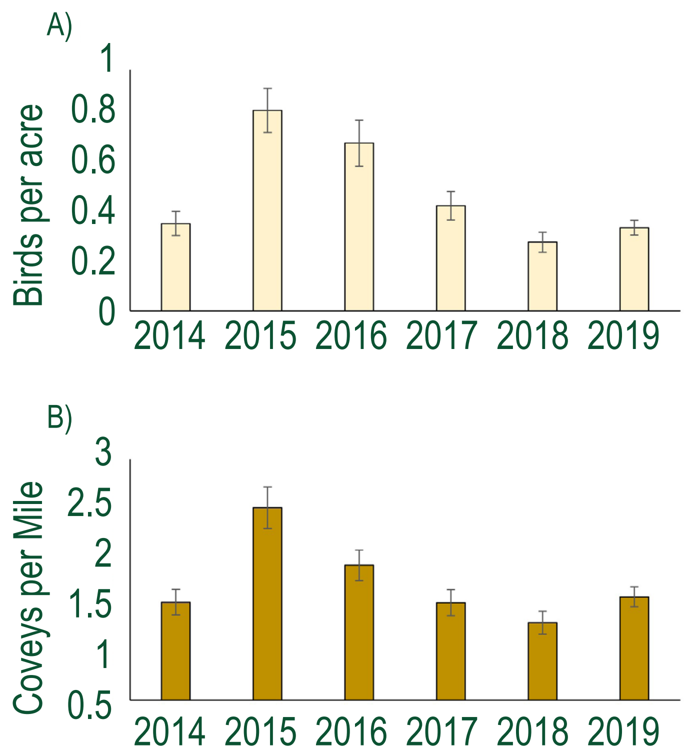

Figure 2. Average A) birds/acre and B) coveys/mile estimates of northern bobwhite by year in the Rio Grande and Rolling Plains ecoregions of Texas, 2014–2019.

A Revised Conversion Factor

We followed the same analysis used by DeMaso et al. (2010) to develop the conversion factor using the new dataset (Figure 3). The updated conversion factor differed from that of DeMaso et al. (2010). The general relationship was the same, but the slope differed, resulting in different bobwhite densities being estimated for a given encounter rate.

Original Conversion Factor (DeMaso et al. 2010):

Bobwhite density = 0.468 × (coveys seen/mile) – 0.002

Updated Conversion Factor:

Bobwhite Density = 0.335 × (coveys seen / mile) + 0.018

Upper Estimate: Bobwhite Density = 0.360 × (coveys seen/mile) + 0.064

Lower Estimate: Bobwhite Density = 0.311 × (coveys seen/mile) – 0.029

One addition that we made to the conversion factor is that we provided equations to calculate a lower and an upper estimate of bobwhite density. This is because the relationship between encounter rate and bobwhite density is not an exact one (as depicted by the bold line in Figure 3) but rather possesses some uncertainty (as evidenced by the scatter of points around the line). This uncertainty is illustrated as a shaded area around the line and represents the range of possible densities for a given encounter rate, where the upper estimate represents the best-case scenario (i.e., highest estimate of bobwhite density) and the lower estimate represents the worst-case scenario (i.e.., lowest estimate of bobwhite density). We recommend that managers calculate not only a point estimate of density but also upper and lower estimates to account for uncertainty, and to make the best decisions.

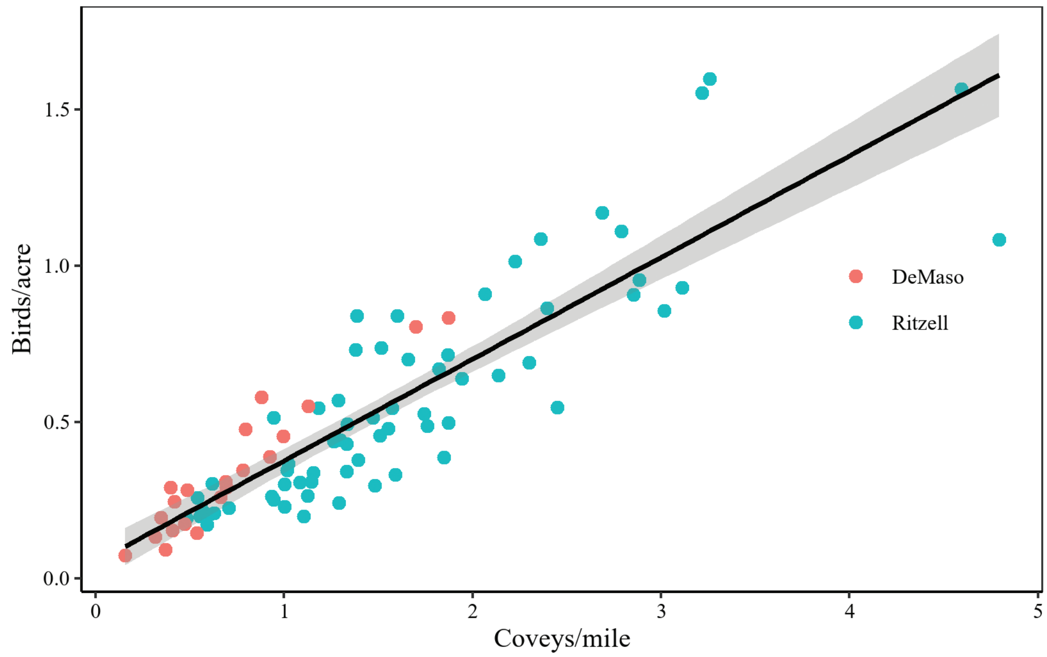

Figure 3. Relationship between the encounter rate (coveys/mile) and density (birds/acre) for northern bobwhites for the updated conversion factor from Ritzell et al. (2024) (green dots) with data from DeMaso et al. (2010) (orange dots) included for reference..

Although we documented differences between the original and the updated conversion factors, this appears to simply be the result of the smaller dataset used by DeMaso et al. (2010), which itself appears to be a subset of the updated dataset. However, note the updated conversion factor presented here relies solely on the new dataset due to differences in survey timing and analysis criteria from those in DeMaso et al. (2010).

An Example

Suppose you lease for hunting a 3,000-acre pasture on a ranch that has good bobwhite habitat. You wish to implement a 20% harvest of the autumn population based on research recommendations (Guthery et al. 2000, Sands 2010). You conduct a bobwhite survey using the methodology described above and observe 1.8 coveys/mile. Based the updated conversion factor, the estimated bobwhite density would be 0.62 bobwhites/acre, with an upper estimate of 0.71 bobwhites/acre and a lower estimate of 0.53 bobwhites/acre.

Estimated Density:

Bobwhite Density = 0.335 × (1.8 coveys seen/mile) + 0.018 = 0.62 bobwhites/acre

Upper Estimate:

Bobwhite Density = 0.360 × (1.8 coveys seen/mile) + 0.064 = 0.71 bobwhites/acre

Lower Estimate:

Bobwhite Density = 0.311 × (1.8 coveys seen/mile) – 0.029 = 0.53 bobwhites/acre

Given a 3,000-acre area, a 20% harvest of the autumn population would be 372 bobwhites (0.62 bobwhites/acre × 3,000 acres × 0.20 harvest). However, if you wished to implement a more conservative harvest, you could use the lower estimate to calculate the 20% harvest (Woodard et al. 2022). This would result in a harvest of only 318 bobwhites (0.53 bobwhites/acre × 3,000 acres × 0.20 harvest).

INFLUENCE OF SURVEY CONDITIONS ON BOBWHITE DETECTIONS

A question that often has arisen since the publication of DeMaso et al. (2010) is how survey conditions may influence bobwhite detections and thus the conversion factor. DeMaso et al. (2010) noted that "clear, cool days with minimal wind are ideal for counting" and recommended that surveys ideally be conducted under such conditions (i.e., clear, <80° F, and <15 mph). Additionally, he recommended constraining surveys to 1 hour after sunrise for 3 hours and 3 hours until one-half hour before sunset. However, managers are often limited as to when surveys may be conducted and may not always be able meet these criteria. This begs the question, "How do survey conditions influence bobwhite detections?"

We evaluated effects of weather (e.g., temperature, cloud cover, wind speed) and time of day on the probability of detection of bobwhite coveys. Brush cover was not explicitly considered by DeMaso et al. (2010) but also one that may influence the probability of covey detection. Thus, we also evaluated the effect of brush cover. To do so, we calculated the percent of brush cover surrounding the location of each covey detection (within a 65-ft radius) and categorized brush cover into 3 classes: low (0–10%), moderate (11–50%), and high (51–95%).

Wind Speed

Wind speed had the greatest impact on detection probability of coveys compared to other conditions. We observed a trend for increasing probability of detection with increasing wind speed (Appendix C, Figure 1A). When wind speeds were in the high category (>15 mph), there was a higher probability of detection (0.63) compared to the moderate and low categories (~0.55). However, there was no difference in the probability of detection between the moderate and low categories. Most detections (90%) occurred in the low and moderate categories, which fall within the prescribed range of DeMaso et al. (2010).

We do not know why higher wind speeds resulted in a higher detection probability. One reason may be that higher wind speeds carry the sound of the helicopter better than low wind speeds potentially resulting in higher flushing rates of coveys. Alternatively, it may be that higher winds muffle the sound of the helicopter and coveys are surprised by the helicopter when it passes over them. Although detection probability increases with wind speed, surveys generally are not conducted in winds over >20 mph for safety reasons.

Temperature

We also documented that detection probability of coveys increased with increasing temperatures (Appendix C, Figure 1B). However, most of our surveys (81%) were conducted below the 80° F threshold that was recommended by DeMaso et al. (2010). The analysis indicated that temperature was correlated with time of day, which intuitively makes sense considering that bobwhites become more active as the day progresses and in higher temperatures in winter. We observed that detection was significantly lower in temperatures <46° F. However, we had few observations (3%) below this threshold because we rarely had cold temperatures that lasted the span of an entire survey. We recommend avoiding surveys in temperatures below this threshold if logistically feasible. Adhering to this condition should not cause large delays because temperatures typically rose above 46° F after 10:00 AM in our studies.

Time of Day

When we reviewed survey times as suggested by DeMaso et al. (2010), there was no significant difference between recommended times (morning and evening only) and non-recommended times (afternoon). This suggests that surveys may be flown throughout the day, without the previously recommended restriction on afternoon surveying. However, as noted above, we observed a trend of increasing probability of detection with time of day (Appendix C, Figure 1C), when viewing each time period (morning, afternoon, evening) independently. Detection probability was similar between the morning and afternoon categories but highest in the evening category (after 3:00 PM). While detection was higher in the evening category, surveys may be flown over a full day (i.e., > 6 hours) without limitation since bobwhites can still be detected well throughout the day. For smaller properties that will only require a survey of 2-4 hours, or in years of low abundance, managers may want to survey in the evening to capitalize on slightly higher detection.

Cloudiness

We documented no difference in detection probability of coveys between clear and cloudy conditions. These two broad categories encompassed a range of conditions within each group; however, we observed no difference in detection probability in preliminary analyses evaluating each category independently. On occasions, the cloudy category also involved mornings with light fog, which could affect the visibility of flushing bobwhites. Pilots will not fly in heavy fog. Thus, conducting surveys in light fog should be okay from a perspective of detection probability contingent on safe flying conditions.

Brush Cover

We documented that the probability of detection of coveys decreased with increasing brush cover (Appendix C, Figure 1D). Probability of covey detection was highest in the low brush cover (<10%). However, there was no difference in detection probability between moderate (10–50%) and high (>50%) brush cover. Average brush cover at covey detections was about 20%, and ranged from 0% to 95%. Additionally, there were no correlations between brush cover and weather variables in this study suggesting that the influence of brush cover on covey detection was independent of weather factors such as temperature or wind. We would caution against utilizing this aerial survey methodology, or at least temper expectations, on properties that have contiguous heavy brush cover for the entire area, as covey detectability will be generally low. On other properties, it is important that individual survey transects span across areas with varying levels of the brush so as to not bias results.

Synthesis

In general, there appears to be some influence of external factors on the probability of covey detection during helicopter-based surveys. However, the influence is mild and thus does not appear to warrant correction as long as managers are aware of these factors and avoid extreme cases. Our results broaden the range of acceptable survey conditions originally outlined in DeMaso et al. (2010).

Table 1. Current recommendations for helicopter survey conditions for northern bobwhites.

Condition	Current recommendations	Range of conditions
Cloud Condition	Clear or Cloudy	0 – 100%
Temperature (°C)	46°F to 90°F	0 – 90°F
Wind (kph)	< 20 miles/hr	0 – 27 miles/hr
Time of day (24-hr)	Detection was similar in morning and afternoon, but highest after 3:00 p.m.	7:06 a.m. – 6:21 p.m.
Brush Cover (%)	< 50%*	0 – 95%

Use caution in areas with >50% brush cover.

PRACTICAL CONSIDERATIONS OF SURVEY EFFORT

How Many Miles Should be Flown?

In distance sampling, the calculation of reliable density estimates depends upon there being sufficient covey observations to adequately estimate probability of detection. The number of covey detections therefore is a driving consideration when determining survey effort. Generally, 60–80 observations are recommended for reliable density estimates (Buckland et al. 2001); however, reliable density estimates sometimes can be with less detections (30–40 detections; Guthery 1988).

In our dataset, the minimum number of detected coveys within a survey was 40, and our minimum encounter rate using this criterion was 0.5 coveys/mile. Based on this minimum encounter rate, you would need to fly at least 80 miles of survey to obtain 40 covey detections. In a square 5,000-acre pasture (i.e., 2.8 miles × 2.8 miles), a survey design of 29 equally spaced transects (~150 yd apart) would achieve the target of an 80-mile survey effort (29 transects × 2.8 miles/transect = 81.2 miles) and 40 covey detections (assuming an encounter rate of 0.5 coveys/mile).

Survey-effort recommendations sometimes are expressed in terms of percent coverage of the survey area. Traditionally, surveyors have assumed detection of coveys up to 100 yd on either side of the helicopter. Under this assumption, a 200-yard spacing of transects would result in 100% coverage.

In the example above, 100% coverage (200-yd space transects) of the 5,000-acre pasture would result only in 24 transects (compared to 29 transects with 150-yd spacing) in the pasture thereby potentially failing to acquire the minimum number of detections. The recommended survey effort of 5–10 miles per 1,000 acres in DeMaso et al. (2010) also would fall short of this requirement (10 miles/1,000 acres × 5,000 acres = 50 miles; 50 miles × 0.5 coveys/mile = 25 coveys). Our recommendation of survey effort (minimum of 40 coveys) is based on a low encounter rate (0.5 coveys/mile) and should be considered only as a minimum baseline. The recommendation of DeMaso et al. (2010) likely is still relevant in average years (i.e., when encounter rates are greater than 0.5 coveys/mile).

The past assumption that coveys were detected within 100 yards on either side of the helicopter may be met occasionally but likely is too optimistic. In the revised dataset, >90% of all detections occurred within 50 yds of either side of the helicopter, a pattern also noted by DeMaso et al. (2010). Based on distance-sampling analyses, the average effective strip width—that is, the distance at which you detect as many coveys as you miss beyond—was about 35 yards. Thus, the past assumption of coverage (coveys are observed within 100 yd on either side of the helicopter) appears unrealistic and double the actual coverage (35–50 yd on either side of the helicopter).


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We recommend determining survey effort based on encounter rate rather than coverage. However, survey coverage is a common measure used by managers, and misunderstandings of coverage can result in false conclusions, especially if multiplying estimated densities by area surveyed to determine total bobwhite abundance. Thus, we would recommend the following definitions of coverage based on the effective strip widths observed in the updated dataset:

100% coverage = 100-yd transect spacing (50-yd each side)

50% coverage = 200-yd transect spacing (100-yd each side)

How Many Surveys do I Need to Conduct?

DeMaso et al. (2010) recommended that surveys be repeated 3 times and spaced several days apart. Repeat surveys distributed over multiple days allow for the removal of potential bias associated with any one survey due to external factors (i.e., weather, observer fatigue, covey behavior, etc.) by averaging out these influences. In this context, we also recommend flying repeat surveys over multiple days when possible. However, we recognize that repeat surveys may not be practical for managers. If only one day of survey is possible, then we recommend 100% coverage (100-yd spacing of transects) with alternation of transects (i.e., skip every other on the first pass, then survey the previously-skipped transects on the second pass). Complete coverage would minimize the potential bias in counts arising from non-surveyed areas and would eliminate the need for any assumptions about them. Alternating transects would help to minimize potential bias arising from covey disturbance associated with sequentially flown transects. Alternating transects also could help average out potential bias from external factors such as those discussed above.

SUMMARY

Our purpose for revisiting DeMaso et al. (2010) was to provide managers with current knowledge and resources regarding helicopter-based surveys for bobwhites. We hope the updated conversion factor and the information contained in this technical bulletin will aid landowners and managers in making the best management decisions for quail. Below, we provide a summary of our key findings and recommendations:

Survey protocol:

o Surveys should be conducted in December–January when bobwhites are in coveys.

o Use of the conversion factor is appropriate when average size is 8–9 birds/covey. See Appendix D for small covey considerations.

o Bobwhite surveys should be conducted independently from other wildlife surveys.

o Surveys should be conducted on randomly placed transects with detections only recorded when “on-transect.”

o Observer search patterns should follow the protocol outlined for distance sampling surveys and focus closer to the helicopter flight path (i.e., transect line).

Conversion factor:

o The updated conversion factor provides a more reliable estimate of bobwhite density across a wider range of densities, encounter rates, and environmental conditions compared to those of DeMaso et al. (2010).

o Density estimates obtained using the conversion factor have an associated uncertainty. Always calculate the upper and lower estimates of density for the surveyed area. Conservative estimates of density can be obtained by using the lower bound.

Survey conditions:

o Temperature and wind appear to influence the probability of detection of coveys. Surveys should not be conducted in low temperatures (<46° F) or high winds (>20 mph). No temperature or wind speed restrictions are warranted beyond adherence to these thresholds.

o Full-day surveys (>6 hours) can be flown anytime during daylight hours. Smaller properties where surveys only last 2–3 hours may wish to conduct surveys after 3 pm when probability of detection is highest.

o Although probability of detection tended to decrease with increasing brush cover, the influence was minimal. Managers generally should be aware of this influence, particularly in areas containing high brush cover (>50%), but no correction in the density estimate is necessary as long as transects span areas of heavy and light brush cover.

Effort:

o If quail detections are low during surveys and repeating surveys is not feasible, increase survey coverage to 100% and alternate every other transect, traversing skipped transects on the second pass.

Helicopter surveys remain an important tool for bobwhite managers across Texas. We hope the updated technical bulletin provides insight into the development and application of this user-friendly tool for estimating bobwhite density and abundance. Research on helicopter-based distance sampling for bobwhites continues through collaborative efforts between CKWRI and its many partners. This research will advance our knowledge on the subject thereby permitting further refinements in the future.

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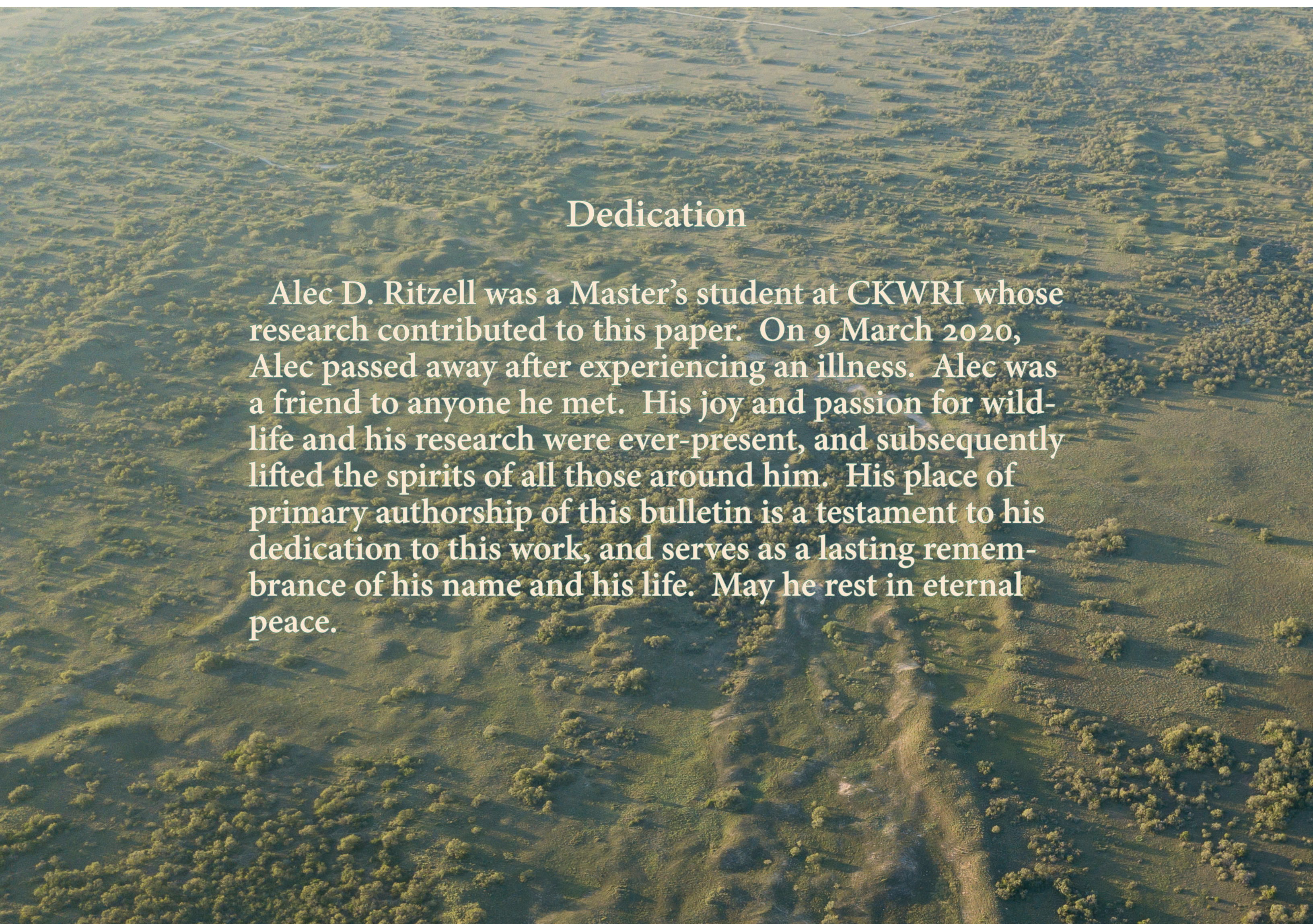


Dedication

Alec D. Ritzell was a Master's student at CKWRI whose research contributed to this paper. On 9 March 2020, Alec passed away after experiencing an illness. Alec was a friend to anyone he met. His joy and passion for wildlife and his research were ever-present, and subsequently lifted the spirits of all those around him. His place of primary authorship of this bulletin is a testament to his dedication to this work, and serves as a lasting remembrance of his name and his life. May he rest in eternal peace.

Appendix A: Historical CKWRI Quail Research

Distance sampling is a survey method used extensively by researchers since its inception in the late 1980s to estimate the density of wildlife. The method involves traversing transects and recording detections, their size (no. of individuals), and distance from transects. Transects can be traversed by various modes of transport, including foot, horseback, all-terrain vehicles (ATV), and helicopters. The collected data are used to calculate an estimate of density that accounts for the fact that not all animals are detected during surveys. Guthery (1988) first used distance sampling in the 1980s to estimate bobwhite density in South Texas. He and graduate students walked transects and used a tape measure to document the distance to bobwhite detections, a simple but cumbersome approach. Distance sampling via walking line transects proved to be a reliable method for estimating bobwhite density; however, the technique was limited to small scales (e.g., 1,000 acres). Shupe et al. (1987) subsequently evaluated the use of helicopters as a mode of transport to survey bobwhites at larger scales. Helicopter-based distance sampling proved feasible but introduced new considerations. Shupe et al. (1987) documented that helicopter speed and altitude influenced covey flushes. In addition, obtaining accurate perpendicular distances to bobwhite detections posed a challenge, and Shupe et al. (1987) resorted to visual estimation of distances, which was not optimal given that accurate distances are needed for distance sampling.

Since these early studies, CKWRI has been conducting research to refine helicopter-based distance sampling for bobwhites. Rusk et al. (2007) integrated an electronic system for data collection that alleviated observer effort during surveys and integrated data into a geographical information system (GIS). Schnupp (2009) subsequently refined the survey method by decreasing both the speed and altitude of helicopters during surveys and introduced a flight modification (hovering when coveys were detected) to allow for more accurate measurement of perpendicular distances. Schnupp et al. (2013) also streamlined the electronic data collection process whereby researchers could obtain exact distance measurements (collected via laser rangefinder) along with spatial data and covey information.

From 2014 to the present, multiple research projects at CKWRI (Smith 2017, Couvillon 2017, Bruno 2018, Edwards 2019, Ritzell 2022, Z. Pearson Texas A&M University-Kingsville, unpublished data, Woodard 2022) have applied these methods and further refined helicopter survey techniques to address research questions on a variety of management topics (e.g., cattle grazing, brush management, invasive grass management, harvest, etc.). Surveys have been flown continuously on some sites for >5 years thereby permitting the long-term documentation of bobwhite population response to management practices.

Appendix B: Caveats for DeMaso et al. (2010) Recommendations

Bobwhite Coveys

Helicopter-based distance sampling for bobwhites primarily relies on eliciting covey flushes to permit detection. Bobwhites typically are found in coveys from October to March in South Texas, although this period can vary depending on rainfall and region. The ability to detect bobwhites in coveys also can be hindered by late-season hatches (October–December) because bobwhites may still be breeding, incubating, or brooding (Woodard et al. 2019). Thus, delaying surveys until bobwhites are in coveys with birds capable of flight (>2 weeks old) is optimal for the greatest number of detections and best density estimate.

DeMaso et al. (2010) recommended conducting bobwhite surveys in December, which generally is appropriate timing for bobwhites to be in coveys. However, managers often try to combine bobwhite surveys with surveys for other species, such as white-tailed deer (Odocoileus virginianus), nilgai (Boselaphus tragocamelus), or feral hogs (Sus scrofa). We do not recommend such an approach because surveys for other species generally occur earlier in the year (mid-September–early October) and outside the optimal time to find bobwhites in coveys. In addition, simultaneously counting multiple species disperses observer focus and can bias counts for all species.

Average Covey Size

The average covey size of the original dataset from which the 2010 conversion factor was developed was 8–9 birds. DeMaso et al. (2010) noted that the conversion factor became less accurate as the average covey size deviated below or above this average. Covey size is beyond the control of managers; however, it is important to recognize the risks associated with applying the conversion factor outside of the conditions in which it was developed. Outside an average covey size of 8–9 birds or when the population size is smaller or larger than those observed by DeMaso et al. 2010 (0.07–0.83 birds/acre) the conversion factor may have unknown levels of bias and reduced reliability.

Survey Protocol

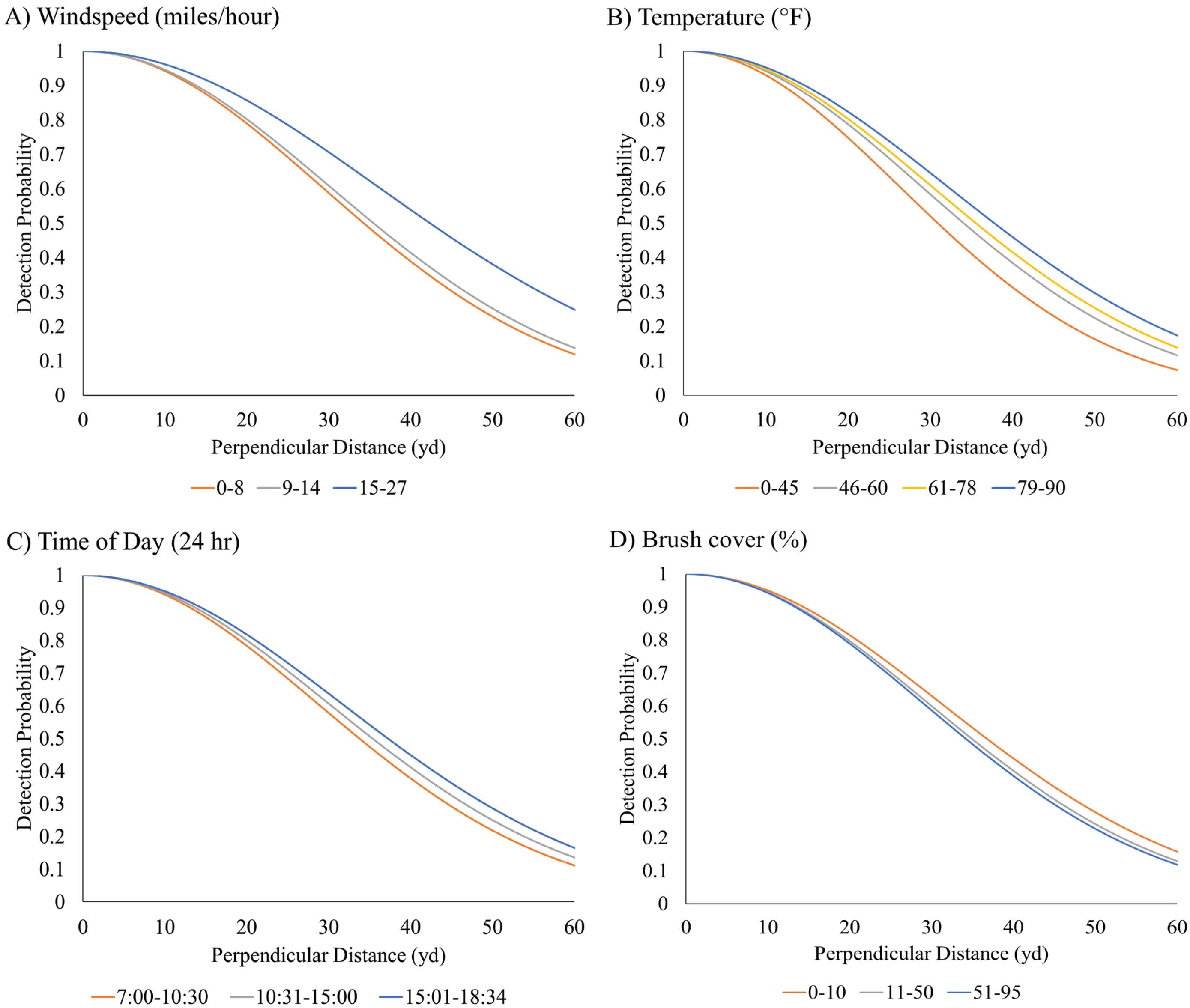
DeMaso et al. (2010) noted 2 important caveats regarding survey protocol: 1) avoidance of simultaneously surveying for both bobwhites and other wildlife, and 2) counting bobwhites only when "on transects." The first was discussed above. However, there are additional concerns. Surveys for other wildlife generally are flown at twice the speed and altitude of a bobwhite survey, and this change in protocol reduces the ability to count coveys reliably. The speed and altitude recommendations for bobwhite surveys were researched and set based on maximizing covey flushes from a helicopter. In addition, general wildlife surveys often go off-transect to obtain additional data on the species detected (e.g., age of deer, antler size, etc.), which can cause off-transect flushes, double counts of coveys, or unflushed coveys on the transect to go undetected, all of which complicate the reliability of the density estimate for bobwhites. Although conducting a bobwhite survey while also counting other wildlife may be appealing, it is not recommended.

The second caveat noted by DeMaso et al. (2010) was the restriction of counting coveys only when "on-transect." Distance sampling relies on a strict, systematic design for transects; adherence to this design is necessary for reliable density estimates. For example, the placement of survey transects needs to be random with respect to on-the-ground features (e.g., not flying directly along feed/disc lanes, pipelines, fences, etc.) to ensure unbiased counts. Any deviance from the protocol, such as counting coveys while "off transect," can lead to biases in the density estimates and nullify the use of the conversion factor.

One last caveat not explicitly mentioned by DeMaso et al. (2010) but nevertheless important is maintaining the observer search protocol recommended by Schnupp et al. (2013) for helicopter-based distance sampling. This protocol pertains to search pattern (surveying under, to the side, and behind the helicopter), distance searched (surveying closer to the helicopter and not scanning the horizon), and observer positioning (doors off, back-seat observers facing to their respective side). One of the key points is to have a specific survey area (0–65 ft) on either side of the helicopter and to make a thorough scan of it before searching at further distances. The goal is not to detect every quail in view (especially those far away) but rather those on the transect and near the helicopter. Distance-sampling theory assumes that observers will detect 100% of the individuals along the transect but miss detections as the distance away from the transect increases.

In summary, we emphasize the caution noted by DeMaso et al. (2010): "Applications of the technique outside of the conditions in which it was developed are not valid or recommended." These include using the conversion factor when covey size is below or above their average (8–9 birds), density is outside those observed in the study (0.07–0.83 birds/acre), survey timing is earlier than recommended (December), or bobwhite surveys are combined with other species.

Appendix C: Graphical Representations of Detection Probability



Appendix C Figure 1. Detection functions (detection probability out of 100% by distance from the observer) by the level of A) Windspeed, B) Temperature, C) Time of Day, and D) Brush cover. For example, 0.8 = 80% probability of detection by the observer.

Appendix D: Considerations for Small Coveys

The original conversion factor was derived from surveys where the average covey size was 8-9 birds; however, the average covey size can vary depending on the year and location. The average covey size in the surveys used for these analyses ranged from 5 to 11 birds per covey.

Implicit to this argument, however, is the question of what a covey is and what effect non-covey detections have on the relationship that is the basis for the conversion factor. For example, it is generally standard practice for managers and researchers to count every quail they detect—whether a single, pair or 30-bird covey—and each of these detections enters the analysis (whether distance sampling or conversion factor) as a covey. Therefore, we sought to determine the effect of non-covey detections and determine what the cutoff point is for the number of birds per covey in relation to the conversion factor analysis.

We re-evaluated all the original density estimates and the resulting relationships for bobwhite and covey density, removing "non-covey" detections. We evaluated 3 independent subsets: 1) removing singles (individual bird detections) from the analysis, 2) removing pairs and singles, and 3) removing any detections ≤ 3 birds. For each analysis, we compared the density output for each ranch and the resulting relationships to the "base" conversion factor analysis, which again included all detections. Lastly, we compared average covey sizes across surveys within each covey-size subset listed above.

None of our evaluations of covey size showed any significant impact on our density estimations. The average covey size remained the same across our covey-size data subsets (Appendix D,Table 1). Likewise, pair-wise densities from each survey did not change with varying covey subsets, and conversion factor estimates between subsets were not significantly different. In general, this reveals that small covey-size detections (<3 birds/detection) do not significantly impact overall density estimates and can be included in any analysis. However, in extreme numbers of singles and pairs that indicate a late-season hatch, we suggest suspending the survey and waiting until bobwhites are formed in coveys (Woodard et al. 2019).

Covey density correction factor

We also evaluated the relationship between covey density (coveys/acre) and encounter rate (coveys/mile) to find a conversion factor equation not inherently dependent upon an average covey size. This analysis resulted in this equation:

Covey Density = 0.033(Coveys Seen / Mile) + 0.011.

To use this equation would further require an additional multiplier of average covey size within the survey, ideally based on specific survey data.

Bobwhite Density (birds/acre) = Covey Density (coveys/acre) * Average Covey Size (birds/covey)

It should be noted that this covey density correction factor is specifically intended for surveys or properties in which the noted average covey size is well outside the range of 8-9 birds/covey for which the primary correction factor was determined. Surveys in which the average covey size is either less than 6 or greater than 10 birds would benefit from utilizing this formula.

Appendix D Table 1. Average northern bobwhite covey size across data subsets. All = no detections removed; >1 = coveys with only 1 bird detected were removed; >2 = coveys with 1 or 2 birds were removed; >3 = coveys of 3 or fewer birds were removed.

Subset	Mean Covey Size after detections removed
All	8.0
>1	8.3
>2	8.6
>3	8.9

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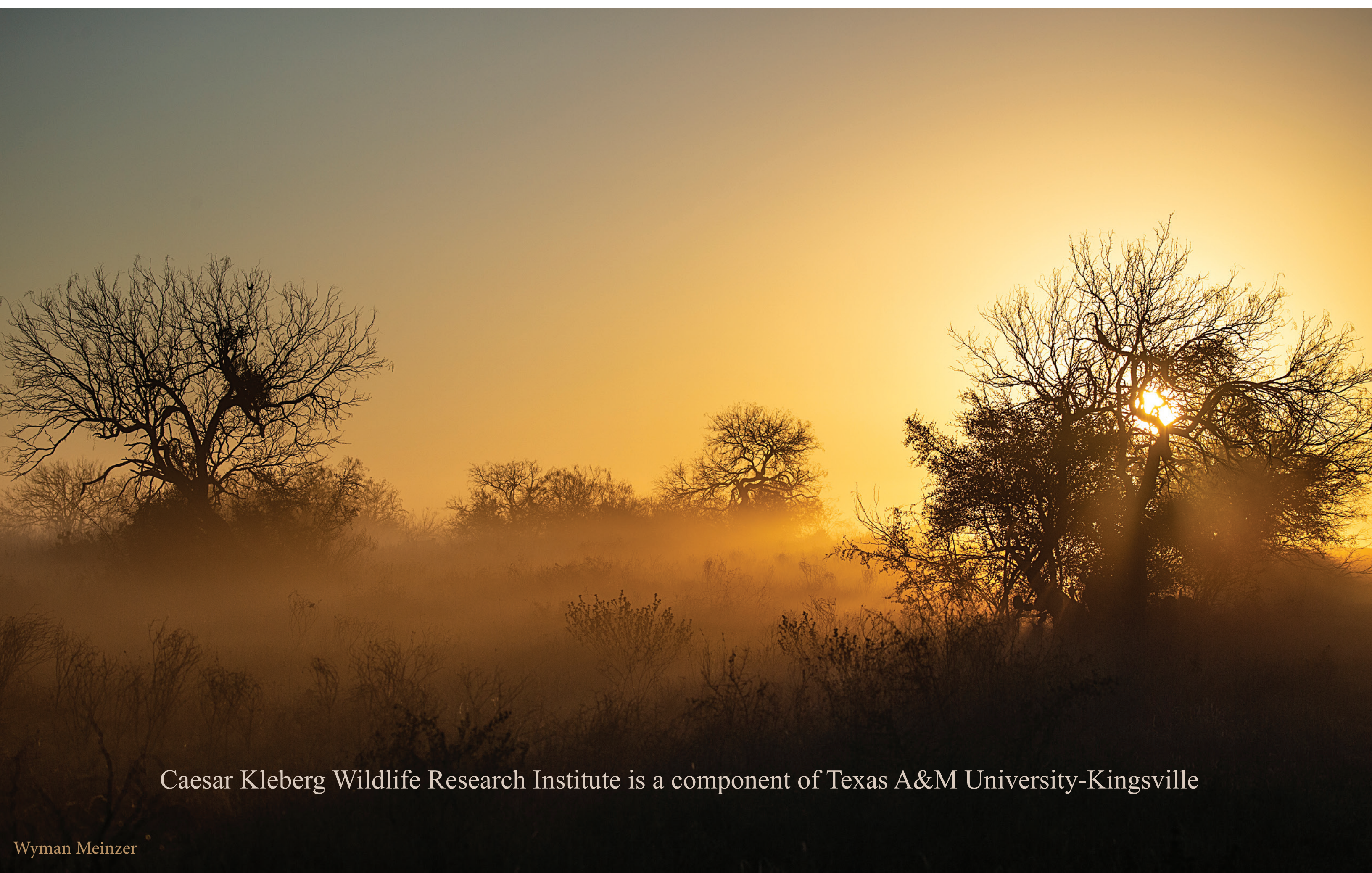

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