

2022

Examination of an Anecdotal “October Disappearance” of Northern Bobwhite in the Rolling Plains of Texas Through Demographic Data

Jessica A. Mehta
Texas Tech University

Rowdy A. White
Texas Tech University

Joshua B. Luft
Texas Tech University

C. Brad Dabbert
Texas Tech University

Follow this and additional works at: <https://trace.tennessee.edu/nqsp>



Part of the [Natural Resources and Conservation Commons](#), [Population Biology Commons](#), and the [Terrestrial and Aquatic Ecology Commons](#)

Recommended Citation

Mehta, Jessica A.; White, Rowdy A.; Luft, Joshua B.; and Dabbert, C. Brad (2022) "Examination of an Anecdotal “October Disappearance” of Northern Bobwhite in the Rolling Plains of Texas Through Demographic Data," *National Quail Symposium Proceedings*: Vol. 9 , Article 45.

<https://doi.org/10.7290/nqsp09MN6T>

Available at: <https://trace.tennessee.edu/nqsp/vol9/iss1/45>

This article is brought to you freely and openly by Volunteer, Open-access, Library-hosted Journals (VOL Journals), published in partnership with The University of Tennessee (UT) University Libraries. This article has been accepted for inclusion in National Quail Symposium Proceedings by an authorized editor. For more information, please visit <https://trace.tennessee.edu/nqsp>.

EXAMINATION OF AN ANECDOTAL “OCTOBER DISAPPEARANCE” OF NORTHERN BOBWHITE IN THE ROLLING PLAINS OF TEXAS THROUGH DEMOGRAPHIC DATA

Jessica A. Mehta

Department of Natural Resources Management, Box 42125, Texas Tech University, Lubbock, TX 79409, USA

Rowdy A. White¹

Department of Natural Resources Management, Box 42125, Texas Tech University, Lubbock, TX 79409, USA

Joshua B. Luft

Department of Natural Resources Management, Box 42125, Texas Tech University, Lubbock, TX 79409, USA

C. Brad Dabbert

Department of Natural Resources Management, Box 42125, Texas Tech University, Lubbock, TX 79409, USA

ABSTRACT

Landowners and wildlife managers in the Rolling Plains ecological region of Texas, USA often report encountering northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) in summer but observe what they perceive as a decrease in quail by early to mid-fall. As most bobwhite research in the Rolling Plains is focused on either breeding season or overwinter survival and movement, researchers rarely record demographic data during this late summer and early fall period. We examined weekly survival probabilities of bobwhite ($n = 244$) across 7 sites in the western Rolling Plains Ecoregion from August to late November in 2016, 2017, 2019, and 2020. Bobwhites were captured and equipped with very high frequency (VHF) transmitters and tracked 1–5 times/week. We used Akaike’s Information Criterion adjusted for small sample sizes (AIC_c) to evaluate a suite of candidate models comparing survival among and between years and survival between individual weeks to determine whether an unreported population decrease occurred during the study years. Our comparison of weekly survival probabilities considered survival to be different if 95% confidence intervals did not overlap. Our best supported model held survival constant among years and allowed survival to vary week by week. All other models received little support ($\Delta AIC_c > 14.0$). Examination of weekly survival probabilities failed to support a demographically driven hypothesis for decreased bobwhite observations from August to November. Though there was an observed decrease of weekly survival in the fourth week of September, it was not different than 16 of the 17 other weeks. We conclude that, for the years we measured, there was no support for a mass die-off hypothesis. Factors outside survival (e.g., a change in bobwhite behavior) may be driving the difference in detectability between late summer and late fall in the Rolling Plains of Texas.

Citation: Mehta, J. A., R. A. White, J. B. Luft, and C. B. Dabbert. 2022. Examination of an anecdotal “October disappearance” of northern bobwhite in the Rolling Plains of Texas through demographic data. National Quail Symposium Proceedings 9:177–183. <https://doi.org/10.7290/nqsp09MN6T>

Key words: *Colinus virginianus*, northern bobwhite, Rolling Plains, survival, Texas

¹ E-mail: rowdy.white@TTU.edu

© Mehta, White, Luft, and Dabbert and licensed under CC BY-NC 4.0.

The northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) has suffered range-wide population declines and region-specific extirpations during the last century (Pardieck et al. 2020). As one of the most popular hunted and economically significant game species, the bobwhite has rightly been the focus of great conservation and research effort to counter this decline (Burger et al. 1999, Rollins 2007, Johnson et al. 2012, Brennan et al. 2014). For a nonmigratory, ground-dwelling species, the bobwhite has an expansive range, extending across the midwestern and southeastern regions of the United States and the Caribbean, and into Mexico (Brennan et al. 2014). Despite the substantial body of bobwhite research, this large geographic range with differing climate, vegetation, stakeholder experiences, and management philosophies presents managers and researchers with challenges in managing at the population and metapopulation level while addressing region-specific issues. These region-specific philosophies and issues include differing opinions on “cultural management” (e.g., supplemental feeding, predator management), climate-driven population changes including drought, and perceived “die-offs” and their possible causes (e.g., drought, disease, parasites, predators).

As in other regions, habitat is paramount for bobwhites in the Rolling Plains ecological region of Texas, USA, with populations often fluctuating due to habitat quality, habitat accessibility, and availability of sufficient food and nesting resources (Rollins 2007). In the Rolling Plains, quail habitat is primarily influenced by 2 factors: rainfall and rangeland management (Jackson 1962, Rollins 2007). In addition to the long-term decline, Rollins (2007) analyzed Texas Parks and Wildlife Department data and noted bobwhite harvest was high (668,167 birds) in 1982, compared to a much lower harvest (87,570 birds) in 1996. This difference is in keeping with the trend observed by Jackson (1962), who stated bobwhites exhibit a “boom and bust” growth cycle that is correlated directly to annual precipitation averages (Koerth and Guthery 1991, Rollins 1999a, Hernández et al. 2005, Tri et al. 2013). In contrast, some observers have reported rapid bobwhite disappearance even during wet years, which they hypothesize is controlled by some factor unrelated to rainfall (Henry et al. 2020).

Landowners and hunters have reported observing bobwhites in summer, but very few during the start of hunting season (Brym et al. 2018). While numerous studies have indicated bobwhite population fluctuations are influenced by factors such as habitat loss, predation, land management, and drought (Koerth and Guthery 1991, Rollins 1999b, Brennan et al. 2005, Hernández et al. 2005, Hernández and Peterson 2007, Tri et al. 2013), stakeholders have suggested alternative explanations, including viral pathogens, parasites, decreases in fur buying resulting in an increase in mesomammals, and an increase in raptors (Rollins 1999a, Silvy et al. 2000, Urban et al. 2013, Brym et al. 2018). These alternative explanations remain unevaluated, and survival during the late summer to early fall periods has largely not been quantified for this continuous time period. Most published bobwhite survival data focus on the breeding season and winter survival, and

this emphasis has left late summer and early fall understudied as a distinct portion of the bobwhite life cycle. The current uncertainty concerning the cause of a possible late summer and early fall disappearance of bobwhites could lead to missteps in how we allocate limited research and management resources (Johnson et al. 2014).

While this perceived incidence of declining bobwhite populations in the Rolling Plains may seem isolated and relatively small compared to the overall bobwhite population decline, landowners situated in a boom-bust cycle are sensitive to any perceived decline. Many stakeholders including landowners, managers, hunters, and natural resources management agencies could benefit from data and supplemental evidence to quantify this anecdotally observed time-specific decrease in bobwhite sightings. Scientists have long sought to explain the overall bobwhite population decline, and if this “October disappearance” were demographically driven, identifying it could inform bobwhite restoration decisions. Landowners also have a vested interest in understanding how a localized population fluctuation could be appropriately managed to inform harvest decisions (Jackson 1962, Brennan et al. 2005, Rollins 2007).

Our goal was to provide stakeholders with data that could explain this localized disappearance and further region-wide research to investigate bobwhite population declines. Using survival data across 4 of 5 consecutive years, we examined weekly survival of bobwhite from 1 August through 30 November. We hypothesized that if this disappearance were demographically driven, weekly survival rates would vary between when stakeholders observed an abundance of bobwhites and when their absence was first noted.

STUDY AREA

Our study area consisted of 7 ranches enrolled in The Quail – Tech Alliance’s Anchor Ranch program across 7 counties in the western Rolling Plains of Texas (32°59’37”N, 101°8’41”W). These sites formed a latitudinal gradient across a large swath of the north-to-south extent of the western Rolling Plains. The counties were Collingsworth, Dawson, Dickens, Kent, King, Motley, and Nolan (Figure 1). Total precipitation ranged from 48.34 cm to 80.21 cm across study years in the northernmost study site (Collingsworth County), and the average temperature ranged from 16.5° C to 17.3° C (NOAA National Centers for Environmental Information 2021). In the southern study sites (Dawson, Dickens, Nolan counties) total precipitation ranged from 72.29 cm in the wettest year of the study (2016), to 39.80 cm in the driest year (2017). Average temperatures for these sites ranged from 16.2° C to 18.3° C across study years (NOAA National Centers for Environmental Information 2021).

The landscape varied from tight clays to large areas of sand and sandy loam. Vegetation included little bluestem (*Schizahyrium scoparium*), tobosagrass (*Hilaria mutica*), sand dropseed (*Sporobolus cryptandrus*), threeawns (*Aristida*

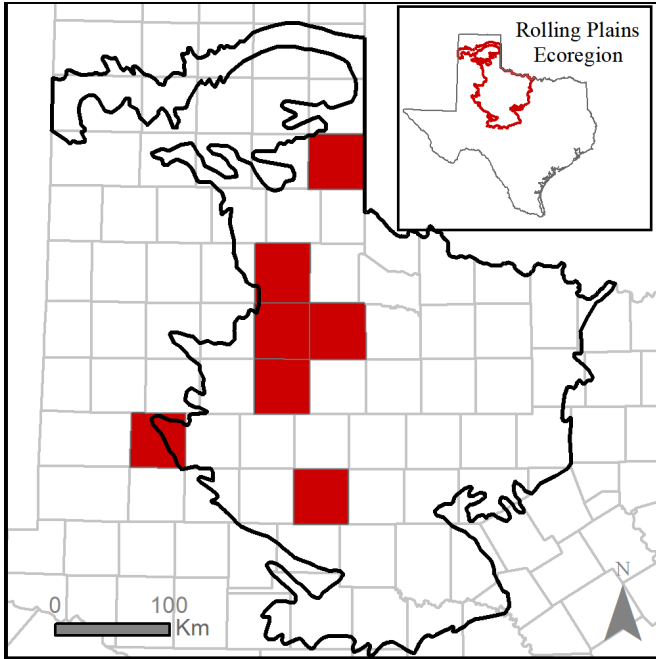


Fig. 1. Counties sampled for northern bobwhite (*Colinus virginianus*; n = 242) late-summer survival study in the Rolling Plains Ecoregion of Texas, USA, 2016, 2017, 2019, 2020.

spp.), annual broomweed (*Amphiachyris dracunculoides*), western ragweed (*Ambrosia psilostachya*), lotebush (*Ziziphus obtusifolia*), yucca (*Yucca glauca*), honey mesquite (*Prosopis glandulosa*), and sand shin oak (*Quercus havardii*).

METHODS

We captured bobwhites between 1 August–1 November in 2016, 2017, 2019, and 2020 with walk-in Stoddard style traps baited with sorghum (*Sorghum bicolor*; Stoddard 1931). Traps were covered with vegetation acquired nearby to provide thermal cover and concealment from predators. Each bobwhite was banded with a numbered Monel butt-end band (National Band and Tag, Newport, KY, USA) and weighed to the nearest gram with a digital scale (Ohaus Corp., Parsippany, NJ, USA). Bobwhites weighing ≥ 125 g were outfitted with a 6 g pendant-style transmitter with necklace harness (American Wildlife Enterprises, Monticello, FL, USA). Radio-marked bobwhites were tracked ≥ 1 time/week during 2016 and 2017 and ≥ 3 times/week in 2019 and 2020 using the homing telemetry method (White and Garrott 1990). During each telemetry session fate (i.e., alive, dead, unknown) was recorded for each bobwhite.

We organized our telemetry data into a weekly survival format covering 1 August–30 November and analyzed it in Program MARK using a model with staggered entry (White and Burnham 1999). To test our hypothesis of decreased weekly survival, we developed 3 sets of candidate models, each of which contained models that allowed survival to vary week to week and others that held weekly survival constant paired with functions that considered survival to be different on a year, ranch, or ranch and year basis using Program MARK. We developed these model suites to assess whether individual sites or years (as a surrogate for difference in rainfall and vegetation, disease outbreak, or increase in parasites or predators) were different than the other years or ranches (Table 1). We censored the first 7 days of each bobwhite’s data as a conditioning period to minimize any transmitter-

Table 1. Three suites of models, each ranking 4 *a priori* candidate models used to assess weekly survival rates for northern bobwhite (*Colinus virginianus*) in the Rolling Plains Ecoregion of Texas, USA, 2016, 2017, 2019, 2020. Each suite was used to evaluate the possibility of a localized (Ranch) or time specific (Year) difference in survival (e.g., decrease in survival due to disease, parasite, increased predator abundance, or other unknown factor) or their interaction (Ranchyear). No direct comparisons or inferences were made between models in separate suites.

Suite	Model ^a	AIC _c ^b	Δ AIC _c	w _i	£	K
Ranch	S(t)	945.228	0.00	0.99	1	21
	S(.)	959.612	14.38	<0.01	<0.01	1
	S(g)	959.880	14.65	<0.01	<0.01	7
	S(ranch * t)	1,009.65	64.43	0.000	0	115
Year	S(t)	945.228	0.00	0.99	1	21
	S(.)	959.612	14.38	<0.01	0.00	1
	S(g)	961.764	16.54	0.000	0.00	4
	S(year * t)	963.496	18.27	0.000	0.00	71
Ranchyear	S(t)	982.286	0.00	1.00	1	21
	S(.)	999.774	17.49	0.00	<0.01	1
	S(g)	1,002.250	19.96	0.00	<0.01	10
	S(ranchyear * t)	1,098.150	115.86	0.00	0	158

^a Ranch = samples grouped by study site, Year = samples grouped by year, Ranchyear= samples completely separated by year and ranch. S(t) = survival allowed to vary over time, S(.) = survival held constant, S(g) = survival different between groups, but constant across time, S(g * t) = survival allowed to vary across group (Ranch, Year, or Ranchyear) and across time.

^b Abbreviations in column headers: AIC_c = Akaike’s Information Criterion adjusted for small sample sizes, Δ AIC_c = differences in AIC_c, w_i = model weights, £ = likelihood, K = number of parameters.

induced survival effects (Burger et al. 1995, Buckley et al. 2015, McLaughlin et al. 2019). Quail hunting season in Texas opens the last weekend of October and closes the last day of February (Texas Parks and Wildlife Department 2022). To our knowledge, none of our tagged bobwhites was harvested during the weeks sampled.

We used Akaike's Information Criterion adjusted for small sample sizes (AIC_c), ΔAIC_c values, and Akaike weights (W_i) to evaluate our models. We classified any model with $\Delta AIC_c < 2$ as competitive (Burnham and Anderson 2004). Using the Weekly Survival Rate (WSR) and the associated standard error (SE) and 95% confidence intervals (CIs), we evaluated the change in bobwhite survival over the study period. We considered WSR different if 95% CIs did not overlap.

All in-field methods, animal capture, marking, and handling protocols were approved by Texas Tech Institutional Care and Use Protocol #19007-01.

RESULTS

During 2016, 2017, 2019, and 2020 we placed radio-transmitters on 244 bobwhites on 7 sites across the western Rolling Plains of Texas. Bobwhites ≥ 125 g represented 92% of total captured birds (Table 2). We estimated weekly survival probabilities of all 244 bobwhites. The model that held survival constant between years while allowing survival to differ between weeks received most of the weight (Table 1). The differences in survival between weeks were not significant except for 1 week in September and another week in November, which were statistically different than each other (but not with any other weeks). Excluding weeks that no bobwhites perished, weekly survival estimates ranged 0.89–0.99 (Figure 2).

DISCUSSION

The goal of our project was to evaluate the role of survival in a perceived "October disappearance" of bobwhite in the Rolling Plains of Texas. Our major findings were that, across 4 different years on 7 different sites in the Rolling Plains of Texas, weekly survival rates were not different; the exception was the fourth week in September, which was different than a week in November. All other 95% CIs overlapped with the CI of the week with the lowest survival estimate. We rejected our hypothesis that any reported disappearance was demographically driven. Our data did not indicate a mass die-off or any rate of mortalities different than normal attrition for bobwhites for the years and sites studied during late summer or early fall (Teinert et al. 2014, Palmer and Sisson 2017, McLaughlin et al. 2019, Wann et al. 2020). We observed no detectable difference between most weeks, nor did we experience any substantial number of unexplained missing bobwhites. These findings illustrate the importance of using demographic data to assess population changes.

It is possible observers perceive a reduction in bobwhite

abundance when a reduction has not occurred. Observers develop their perception of bobwhite abundance from a variety of sources, including hearing calling birds and sightings of adults and broods. However, observers can overestimate the abundance of wildlife, especially when using cues such as calls (Brewster et al. 2017). If anecdotal observations of fewer bobwhites during this time period were valid, and since there was no documented population decline, then the most likely explanation is some behavioral response that changes bobwhite detectability or distribution. On several occasions we observed movements from capture sites in August and September to other locations. For example, in 2016 ≥ 8 birds captured in August made permanent movements out of the study area that were ≥ 500 m (straight-line distance). Possible behavioral explanations include the "fall shuffle" as well as a change in behavior predicated on the fall raptor migration. Throughout the summer adult bobwhites shepherd their broods across the landscape in search of forage. It is possible there is an abundance of forbs and arthropods near the

Table 2. Northern bobwhite (*Colinus virginianus*; $n = 244$) radio-collared by county and year to measure late-summer survival in the Rolling Plains Ecoregion of Texas, USA, 2016, 2017, 2019, 2020.

County	2016	2017	2019	2020
Collingsworth			38 (97%) ^a	
Dawson	21 (97%)	20 (88%)		
Dickens	25 (82%)	12 (100%)		34 (100%)
Kent	11 (95%)			
King	14 (91%)			
Motley				56 (100%)
Nolan	13 (80%)			
Total	84	32	38	90

^a Percentages in parentheses denote percentage of total captured bobwhites >125 g and thus radio-collared.

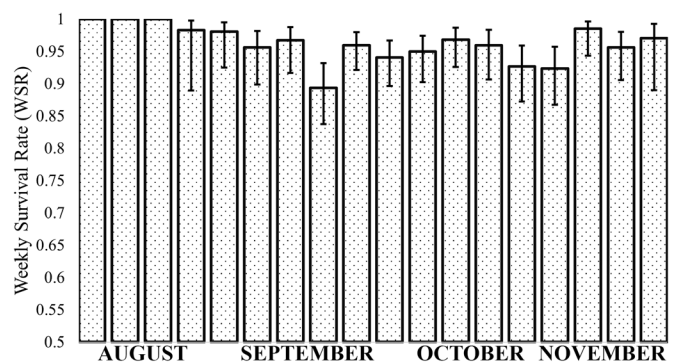


Fig. 2. Weekly survival rates for northern bobwhite (*Colinus virginianus*; $n = 242$), 1 August–30 November in the Rolling Plains Ecoregion of Texas, USA, 2016, 2017, 2019, 2020; y-axis truncated to detail differences in 95% confidence intervals.

roadside (Lee and Power 2013, Rotholz and Mandelik 2013), making broods more conspicuous than during other times of the year. During the early fall, brood groups separate to form coveys (Agee 1957), and it is possible this change in behavior reduces their detection probability between late summer and mid-fall. Additionally, raptor migration occurs in early fall for much of the Rolling Plains of Texas (Allan and Sime 1943). Predator avoidance may also change behavior and may cause bobwhites to select cover, making them less observable. While Turner et al. (2014) did not detect a difference in the amounts of woody cover in the home ranges of South Texas bobwhites before and during raptor migration, they acknowledged the resolution of their woody cover estimates may have been at too coarse a level to detect change.

Disease- and parasite-driven mortality events have been observed in other Galliformes. In 2003, West Nile virus was identified as a contributing cause of a 25% reduction in late summer survival in greater sage-grouse (*Centrocercus urophasianus*) across 4 sites (Naugle et al. 2004, Moynahan et al. 2006). Moynahan et al. (2006) documented a mortality rate 16 times greater than the background mortality rate during late July and mid-August, which the authors attributed to West Nile virus. West Nile virus has been observed in bobwhites in the Rolling Plains of Texas (Urban et al. 2013), but it has not yet been demographically linked to a bobwhite decline. We hypothesize that if a disease-driven “die-off” were occurring between nesting season and hunting season in bobwhites, the evidence would present similarly to Naugle et al. (2004). During 2 of the 4 years of our study we observed a small nonsignificant decrease in weekly survival estimates in either late September or early October that may have been consistent with raptor migration, but not precipitous enough to indicate an acute, mass die-off from either raptors or other causes (e.g., disease event).

We acknowledge sample sizes were unequal between years and ranches; however, our best candidate model pooled these groups. Models including ranch or year had $>14 \Delta AIC_c$, and the beta values for approximately 17% of weeks crossed zero, so we did not consider these models informative and did not report them. We also acknowledge a difference in the length between location attempts in 2016, 2017 and 2019, 2020. Due to project logistics during the first 2 years, we located the birds ≥ 1 time/week while during subsequent years we located the birds ≥ 3 times/week. As this difference may have led to scavenged carcasses being incorrectly categorized as mammal depredations, we did not assess cause-specific mortality for this study. While we monitored 7 ranches across the western Rolling Plains for 4 years, there could have been a localized decline on a study site that we did not monitor. We concede parasites or disease may create the possibility of subacute debilitation that, while not detectable over short temporal scales, could be cumulative over time. However, other demographic factors such as reduced nest success and chick survival, which were documented in the areas, are the most likely factors contributing to population declines (Young 2019, Mote 2021).

Our results did not support a decline beyond normal attrition observed in other seasons (Teinert et al. 2014, Palmer and Sisson 2017, McLaughlin et al. 2019, Wann et al. 2020). While little published data exist for the specific time of our study—this temporal range is often divided into breeding and nonbreeding partitions—our mean weekly survival rate (0.96) and derived annual survival rate (0.13) is comparable to rates from studies during different time periods. Wann et al. (2020) worked with the fairly stable and high-density bobwhite populations found on properties managed for bobwhites in the southeastern United States and reported weekly survival probabilities for winter and summer (~ 0.95) and derived annual survival probabilities (0.11) similar to our study. During winter 2007–2008, Teinert et al. (2014) reported overwinter weekly survival similar to our data, with bobwhites in a single week experiencing a decrease from ~ 0.95 WSR to ~ 0.70 . The authors attributed this decrease to inclement weather. Bobwhite densities in the Rolling Plains of Texas were relatively high during that year and the following year (Texas Parks and Wildlife Department 2021). While our goal was to merely identify the existence of a decline through demographic data and not its ultimate cause, the absence of an observed decline allows us to infer that no acute mortality event from a factor such as increased depredation or disease occurred during our study. With no steep decline in weekly survival in most weeks of fall, it is possible fall raptor migration may have had a greater effect on bobwhite behavior than it did population demographics. Certainly, migrating raptors use bobwhites as prey; however, our data do not support a raptor-driven population decline during the season and years that we studied. The single week we observed survival rates $<90\%$ occurred when migrating raptors move through the Rolling Plains of Texas; however, the impact was neither severe nor long enough to cause a substantial decline, as our data indicate. Finally, the suspected occurrence of an acute mortality event has been used to form hypotheses concerning the influence of disease processes on bobwhite populations in the Rolling Plains of Texas (Urban et al. 2013, Brym et al. 2018). However, our data do not support the occurrence of an acute mortality event during late summer–fall (Figure 2).

MANAGEMENT IMPLICATIONS

Our data provide evidential weight against mass mortality being responsible for decreased bobwhite observations between August and fall, and highlight the importance of using objective, quantifiable analyses to test hypotheses. The juxtaposition of anecdotal observations and a portion of the bobwhite life cycle that is often lost in the division between breeding and nonbreeding seasons have created a situation where managers may incorrectly attribute a perceived reduction in bobwhite abundance to an unknown cause. We encourage researchers to continue monitoring radio-collared bobwhites beyond the typical winter and summer seasons to further our knowledge of bobwhite survival and behavior in seasons not typically measured.

ACKNOWLEDGMENTS

We are grateful for the technicians in the field who made this project possible, including D. Johns, L. Barina, and the student technicians at The Quail – Tech Alliance. Dr. B. Grisham provided valuable insight concerning data analysis.

LITERATURE CITED

- Agee, C. P. 1957. The fall shuffle in Central Missouri bob-whites. *Journal of Wildlife Management* 21:329–335.
- Allan, P. F., and P. R. Sime. 1943. A hawk census on Texas Panhandle highways. *Wilson Bulletin* 55:29–39.
- Brennan, L. A., S. DeMaso, F. Guthery, J. Hardin, C. Kowaleski, S. Lerich, R. Perez, M. Porter, D. Rollins, M. Sams, T. Trail, and D. Wilhelm. 2005. Where have all the quail gone? The Texas Quail Conservation Initiative, Texas, USA.
- Brennan, L. A., F. Hernández, and D. Williford. 2014. Northern bobwhite (*Colinus virginianus*), version 2.0. in A. F. Poole, editor. *The birds of North America*. Cornell Lab of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bna.397>
- Brewster, R. K., S. E. Henke, A. Ortega-Santos, J. M. Tomecek, and B. L. Tuner. 2017. Do you hear what I hear? Human perception of coyote group size. *Human-Wildlife Interactions* 11:167–174.
- Brym, M. Z., C. Henry, and R. J. Kendall. 2018. Elevated parasite burdens as a potential mechanism affecting northern bobwhite (*Colinus virginianus*) population dynamics in the Rolling Plains of West Texas. *Parasitology Research* 117:1686–1688.
- Buckley, B. R., A. K. Andes, B. A. Grisham, and C. B. Dabbert. 2015. Effects of broadcasting supplemental feed into roadside vegetation on home range and survival of female northern bobwhite. *Wildlife Society Bulletin* 39:301–309.
- Burger, L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. *Journal of Wildlife Management* 59:417–426.
- Burger, L. W. Jr., D. A. Miller, and R. I. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. *Journal of Wildlife Management* 27:1010–1018.
- Burnham, K. P., and D. R. Anderson. 2004. Multimodel inference: understanding AIC and BIC in model selection. *Sociological Methods & Research* 33:261–304.
- Henry, C., M. Z. Brym, K. Skinner, K. R. Blanchard, B. J. Henry, A. L. Hay, J. L. Herzog, A. Kalyanasundaram, and R. J. Kendall. 2020. “Weight of evidence” as a tool for evaluating disease in wildlife: an example assessing parasitic infection on northern bobwhite (*Colinus virginianus*). *International Journal for Parasitology: Parasites and Wildlife* 13:27–37.
- Hernández, F., F. Hernández, J. A. Arredondo, F. C. Bryant, L. A. Brennan, and R. L. Bingham. 2005. Influence of precipitation on demographics of northern bobwhite in southern Texas. *Wildlife Society Bulletin* 33:1071–1079.
- Hernández, F., and M. J. Peterson. 2007. Northern bobwhite ecology and life history. Pages 117–141 in Brennan, L. A., editor. *Texas quails: ecology and management*, Chapter 4. Texas A&M University, College Station, USA.
- Jackson, A. S. 1962. A pattern to population oscillations of the bobwhite quail in the lower plains grazing regions of northwest Texas. *Proceedings of the Southeastern Association Game and Fish Commissioners* 16:120–126.
- Johnson, F. A., G. Hagan, W. E. Palmer, and M. Kemmerer. 2014. Uncertainty, robustness, and the value of information in managing a population of northern bobwhites. *Journal of Wildlife Management* 78:531–539.
- Johnson, J. L., D. Rollins, and K. S. Reyna. 2012. What’s a quail worth? A longitudinal assessment of quail hunter demographics, attitudes, and spending habits in Texas. *National Quail Symposium Proceedings* 7:294–299.
- Koerth, N. E., and F. S. Guthery. 1991. Water restriction on northern bobwhite reproduction. *Journal of Wildlife Management* 55:132–137.
- Lee, M. A., and S. A. Power. 2013. Direct and indirect effects of roads and road vehicles on the plant community composition of calcareous grasslands. *Environmental Pollution* 176: 106–113.
- McLaughlin, J. W., D. S. Wiley, C. B. Dabbert, and T. M. Terhune. 2019. Broadcast supplemental feeding and northern bobwhite demographics in Texas. *Journal of Wildlife Management* 83:52–63.
- Mote, K. W. 2021. Effects of predator reduction on northern bobwhite nest success and chick survival in the Rolling Plains of Texas. Thesis, Texas Tech University, Lubbock, USA.
- Moynahan, B. J., M. S. Lindberg, and J. W. Thomas. 2006. Factors contributing to process variance in annual survival of female greater sage-grouse in Montana. *Ecological Applications* 16:1529–1538.
- Naugle, D. E., C. L. Aldridge, B. L. Walker, T. E. Cornish, B. J. Moynahan, M. J. Holloran, K. Brown, G. D. Johnson, E. T. Schmidtman, R. T. Mayer, C. Y. Kato, M. R. Matchett, T. J. Christiansen, W. E. Cook, T. Creekmore, R. D. Falise, E. Thomas Rinkes, and M. S. Boyce. 2004. West Nile virus: pending crisis for greater sage-grouse. *Ecological Letters* 7:704–713.
- NOAA National Centers for Environmental Information. 2021. Climate data online search. Asheville, NC: National Oceanic and Atmospheric Administration. <<https://www.ncdc.noaa.gov/cdo-web/search>>. Accessed 5 Jul 2021.
- Palmer, W. E., and D. C. Sisson. 2017. Demographics. Pages 3–22 in W. E. Palmer and D. C. Sisson, editors. *Tall Timbers’ bobwhite quail management handbook*. Tall Timbers Press, Tallahassee, Florida, USA.
- Pardieck, K. L., D. J. Ziolkowski, Jr., M. Lutmerding, V. I. Aponte, and M.-A. R. Hudson. 2020. North American breeding bird survey dataset 1966–2019: U.S. Geological Survey data release. <https://doi.org/10.5066/P9J6QUF6>
- Rollins, D. 1999a. A pattern to quail irruptions in the Rolling Plains of Texas. Texas Agricultural Extension Service, San Angelo.
- Rollins, D. 1999b. Is there a place for predator control in quail management? A point. Pages 45–48 in *Proceedings of preserving Texas’ quail heritage into the 21st century symposium*, 13–15 October 1999, Abilene, Texas. K. A. Cearley, editor. Texas Cooperative Extension, San Angelo, USA.
- Rollins, D. 2007. Quails on the Rolling Plains. Pages 117–141 in Brennan, L. A., editor. *Texas quails: ecology and management*. Texas A&M University, College Station, USA.
- Rotholz, E., and Y. Mandelik. 2013. Roadside habitats: effects on diversity and composition of plant, arthropod, and small mammal communities. *Biodiversity and Conservation* 22:1017–1031.
- Silvy, N. J., M. J. Peterson, R. J. Purvis, and A. S. Bridges. 2000. Relationships of fur market conditions to Texas quail populations. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 54:266–273.
- Stoddard, H. L. 1931. *Northern bobwhite quail: its habitats, preservation and increase*. Scribner’s Sons, New York, New York, USA.
- Teinert, T. W., L. A. Brennan, F. Hernández, S. J. DeMaso, J. P. Sands, D. Rollins, M. J. Schnupp, and R. M. Perez. 2014. Overwinter survival of northern bobwhites on non-hunted areas in the Rolling Plains and South Texas Plains of Texas. *Texas Ornithological Society* 46:22–29.

- Texas Parks and Wildlife Department. 2021. TPWD quail roadside survey historical data 1978–2019. <https://tpwd.texas.gov/huntwild/hunt/planning/quail_forecast/forecast/historical.phtml>. Accessed 30 Jun 2021.
- Texas Parks and Wildlife Department. 2022. Outdoor annual: quail 2021–2022 seasons and regulations. <<https://tpwd.texas.gov/regulations/outdoor-annual/regs/animals/quail>>. Accessed 5 Jan 2022.
- Tri, A. N., J. P. Sands, M. C. Buelow, D. Williford, E. M. Wehland, J. A. Larson, K. A. Brazil, J. B. Hardin, F. Hernández, and L. A. Brennan. 2013. Impacts of weather on northern bobwhite sex ratios, body mass, and annual production in south Texas. *Journal of Wildlife Management* 77:579–586.
- Turner, J. W., F. Hernández, C. W. Boal, B. M. Ballard, F. C. Bryant, and D. B. Wester. 2014. Raptor abundance and northern bobwhite survival and habitat use. *Wildlife Society Bulletin* 38:689–696.
- Urban, K. N., A. G. Gibson, C. B. Dabbert, and S. M. Presley. 2013. Preliminary disease surveillance in west Texas quail (Galliformes: Ondotophoridae) populations. *Journal of Wildlife Diseases* 49:427–431.
- Wann, G. T., P. E. Howell, J. M. Yeiser, I. B. Parnell, and J. A. Martin. 2020. Estimating harvest rate and the effects of hunting pressure on northern bobwhite survival. *Wildlife Biology* 2020(2). doi: 10.2981/wlb.00667
- White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46:120–139.
- White, G. C., and R. A. Garrott. 1990. *Analysis of wildlife-tracking data*. Academic Press, San Diego, California, USA.
- Young, I. E. 2019. Influence of predator management on northern bobwhite nest success. Thesis, Texas Tech University, Lubbock, USA.