Influence of Woody Vegetation Patterns on Overwinter Spatial Ecology and Demographics of Scaled Quail

by

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ABSTRACT

Scaled quail are a small gallinaceous upland game bird that has exhibited population declines throughout their geographic range over the past four decades. The Texas Rolling Plains scaled quail populations decline 79% between1978 to 1980 based on Texas Parks and Wildlife August roadside counts. Many factors have been attributed to Scaled quail declines such as habitat loss and fragmentation, increased predation, and disease however, consideration of environmental stressors and changes in landscape patterns and their influence on scaled quail population demographics have been minimally explored. Semi-arid landscapes such as the Texas rolling plains have experienced shifts in vegetation structure over the past century resulting in dense woody vegetation and fragmented landscapes. Limited research has addressed changes in landscape pattern effects on scaled quail populations integrated with comparisons of habitat resource selection and microclimate. The goal for this study was to quantify the relationship among woody vegetation and scaled quail winter parameters. My objectives were to 1) analyze landscape vegetation metrics and woody vegetation patterns using aerial drone images paired with ground vegetation surveys, 2) assess spatial ecology to estimate home range and core area sizes and assess habitat selection characteristics at multiple spatial scales and, 3) Assess and compare scaled quail winter survival within the context of landscape parameters quantified in objective 1. I monitored scaled quail (n=187) via GPS and VHF on 4 ranches throughout the Texas Rolling Plains. The ranches were divided into 2 stable and 2 intermittent population sites. I defined ranches that are composed of large grassland tracts roughly 45% of

total area with relatively low woody cover percentage (approximately 25−30%) and have relatively abundant SCQU populations as determined from annual surveys from Quail Tech as stable population ranches. The majority of the ranches I sampled limited or no scaled quail so I only completed the project objectives on 1 intermittent site (Dickens County) and one stable site (Potter County). I defined ranches with small, fragmented tracts of suitable cover, grassland tracts <45% and woody vegetation densities >25-30%, as intermittent population ranches. I utilized the Sensefly EBee fixed wing mapping drone to gather real-time high-resolution images to assess ranch level and higher spatial scale habitat selection and paired the images with ground vegetation surveys and microclimate data for land use land cover classification to assess multiple spatial scale habitat selection and over winter survival. I quantified scaled quail home ranges and core areas using Brownian Bridge movement model in program R at 50% and 90% isopleths respectively GPS tagged Scaled quail (n=27) and assessed habitat selection at the 2nd, 3rd and, 4th order spatial scales. I used the Nest Survival Model in Program Mark to assess overwinter survival between transmitter types, between and among ranches and, and between various vegetation and microclimate measurements obtained from my field methods (Exposure Period = 172 days: SE=0.52, UCL = 0.24, 95 % 95% LCL = 0.67). A combination of the results from each chapter of this study suggest reducing bare ground on the landscape to ~10% and maintaining woody vegetation to 25-30% (based on FRAGSTATS results) within 300 ha patches maximizes overwinter survival for SCQU on the Texas Rolling Plains.

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CHAPTER I

AN ASSESSMENT OF LANDSCAPE COMPOSITION BETWEEN RANCHES WITH INTERMITTENT AND STABLE POPULATIONS OF SCALED QUAIL

Abstract

A combination of disturbance regimes, topo-edaphic properties, and climate have contributed to the pattern and relative abundance of woody life forms and herbaceous species in arid and semi-arid lands. Shifts in vegetation structure in semi-arid landscapes, such as the Texas Rolling Plains (TRP) and Texas High Plains (THP), over the past century have resulted in landscapes that favor trees, shrubs, and post-climax seral stages that in general, are composed of more woody cover and more fragmentation. Despite Scaled Quail (*Callipepla squamata*; hereafter SCQU) demonstrating a positive response to moderate precipitation cycles, long-term population trends indicate the species is still in decline. Correlative studies suggest that brush encroachment (i.e., invasive, or exotic woody species) with corresponding decreases in grassland habitat availability and patch size has increased predation rates on SCQU and reduced population growth. However, there have been few studies that have compared the actual SCQU demographic response to brush encroachment and habitat patch size. Many studies have addressed changes in landscape patterns effects on species abundance, though limited research has focused on landscape characteristics and SCQU abundance. There is a need to examine landscape pattern changes in ecoregions such as the TRP and THP, which exhibit contrasts in population

trends and investigate specific landscape pattern changes and their effects on SCQU demographics.

The goal of this chapter is to characterize and compare landscape composition between ranches that have intermittent (defined as dynamic interannual booms and busts in SCQU abundance) and stable (defined as stable SCQU abundance between and among years) SCQU populations. To achieve my goal, I used a fixed wing unmanned aerial vehicle (Sensefly Ebee UAV Mapping Drone) to capture real-time high-resolution imagery of seasonal leaf loss, vegetation structure and composition, and percent woody, grassland, bare ground, and succulent cover for each study area, October 1 - March 15, 2018-2020. I uploaded contours obtained from global-positioned system (GPS)-tagged SCQU for each study area and flew the drone over the combined extent of all locations among all GPS-tagged SCQU once each field season. I ground-truthed the drone images with ground vegetation surveys obtained from global positioning system (GPS)-tagged SCQU locations to quantify percent woody, grassland, bare ground, and succulent cover for each study area, and then assessed landscape level metrics using Program FRAGSTATS after testing the classification metrics for precision and accuracy. The results indicated largest patch and percent of landscape of each classification type were statistically similar between stable and intermittent ranches. However, the composition of the stable population consisted of more hectares that was composed of grasslands, suggesting woody species encroachment and removal or overuse of other ecological drivers that increase bare ground may reduce total area available for scaled quail to use in winter. My findings suggest reducing woody vegetation at moderate scales (~50-100 ha) to grassland seral stages may maximize suitable landscape composition for SCQU during winter months.

Introduction

The following chapters consist of three independent journal articles. For this reason, there are certain redundancies between the three chapters in terms of methods and study area as they are independent documents. Each was formatted to the guidelines of The Journal of Wildlife Management

In Texas, two subspecies of Scaled Quail (*Callipepla squamata*; hereafter SCQU) inhabit the Texas Rolling Plains (hereafter TRP) and Texas High Plains (hereafter THP); the Arizona SCQU and Chestnut-bellied SCQU. Coveys of these gregarious quail range from 3-50 birds during the fall, winter, and dry periods however some reports of up to 100 SCQU have been documented (Brennan et al. 2017). Scaled quail have distinguishing features such as their chestnut bellies and their bluish gray scale-like "squamate" feathers which earn them such common names as "Blue quail" "Blues", "Scalies", or "Cotton tops", referring to the white crest on their heads (Wallmo 1956, Texas Parks and Wildlife Department 2016, Brennan et al. 2007; 2017). This study focused on the *C.s. pallida* subspecies otherwise known as the Arizona SCQU.

Scaled quail are distributed throughout most of the Southwestern United States ranging as far west as Southeastern Arizona to West Texas. Their range extends into the Great Plains of Southeastern Colorado and Southwestern Kansas and as far south as the arid Chihuahuan Desert scrublands (Zornes et al. 2010, Williford et al. 2014, Tanner et al 2017). In Texas, SCQU distribution has declined over the past century from the western half of Texas to the western one third of Texas, with scarce isolated remnant metapopulations intermittently appearing on the periphery of their geographic range (Texas Parks and Wildlife Department 2006, Silvy et al. 2007). Evidence suggests that during drought years their home ranges slightly expand eastward (Texas Parks and Wildlife Department 2006).

Scaled quail typically occur in arid and semiarid shortgrass prairies and shrub lands particularly associated with THP and TRP ecoregions. Scaled quail geographic range has significantly tapered; roughly 75-100 km west from the original 100th meridian as was historically documented based on collected specimens from counties such as, Coleman, Gillespie, Wichita, and Young, of which they are no longer found (Schemnitz 1959, Silvy et al. 2007, Brennan et al. 2017). Scaled quail distribution in Texas ranges throughout the western half of the state, though much of their geographic range has severely diminished based on specimens collected from eastern Texas counties where they no longer occur (Silvy et al. 2007). Scaled quail historic range occurs in the western one third of Texas, west of the 100th meridian, which roughly corresponds to the High Plains, Rolling Plains, Trans-Pecos mountains and basins, Edwards Plateau, and the Southern Plains of Texas ecoregions (Silvy et al. 2007, Audubon.org/field-guide/bird/scaled-quail Accessed April 2020, Figure1.1).

Elevation distributions of SCQU generally range from 30 m (close to sea level 100 ft) to nearly 1700 m above sea level (5,500 ft) however, their elevation distribution can reach up to 2,377 m in rare instances (Rea 1973, Silvy et al. 2007, Brennan et al. 2017). Scaled quail are most abundant in open grasslands larger than 250 hectares (100 acres) with 10-15 percent shrub cover (Brennan et al. 2017) however in the Chihuahuan desert, THP and TRP, their greatest densities occur in low lying sparse thorn scrub vegetation in well drained calcareous soils along creek beds, river edges drainages canyons and rough breaks (Silvy et al. 2007, Zornes et al. 2010, Williford et al. 2014, Brennan et al. 2017). Scaled quail diet varies according to nutritional needs and seasonal availability with four major categories of food. The categories include seeds, succulent fruit, green leafy material and insects. Approximately seventy percent of SCQU diet comes from seeds typically found in forbs and woody plants (Texas Parks and Wildlife Department 2006) with ten percent of their diet consisting of insects (Giuliano et al. 1996, Brennan et al. 2017). Prevailing woody plants on the rocky breaks include fragrant sumac (*Rhus aromatica*), honey mesquite (*Prosopis glandulosa*), junipers (*Juniperus spp.*), and true mountain mahogany (*Cercocarpus montanus*) which provide fruit/seed food for SCQU (Ault et al 1983). Scaled quail fall/winter diet is comprised of 30% forb seeds which include purple dalea (*Dalea lasiathera*), spreading sida (*Sida filicaulis*), and gray coldenia (*Coldenia canescens*); and 20% grass seeds with preference for the following: blue grama (*Bouteloua gracilis*), bristlegrasses (*Setaraia spp.*) hairy grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), and threeawns (*Aristida spp*.). Other seasonal diet options of plants include; common russian thistle (Salsola kali), snakeweed (*Xanthocephalum sarothrae*), sunflowers (*Helianthus spp*.), and western ragweed (*Ambrosia psilostachhya*) (Davis et al. 1975, Ault et al. 1983, Campbell et al. 1985, Medina 1988). Scaled quail can survive without pure water and can obtain their water demands from the food ingested and their natural digestive fluids (i.e., prefomed water) however, they will go to free standing water if it is available (Brennan et al. 2017). Fruits and seeds comprised 62-65% of SCQU summer diet with early summer diets primarily containing halls panicum (*Panicum hallii*) (Davis et al. 1975, Ault et al. 1983, Campbell et al. 1985).

While SCQU historically experienced boom and bust cycles throughout these ecoregions, their populations have not successfully recovered, especially in the TRP, and the fundamental processes driving their decline is currently unknown. Discrepancies in the decline of SCQU have been attributed to such factors as habitat loss, decrease in the amount of Conservation Reserve Program (CRP) lands, precipitation patterns, disease, increased predation, and poor rangeland management practices that has increased woody cover (Schemnitz 1961, Campbell 1968, Bridges et al 2001, Guthery et al 2001, Rollins and Carroll 2001, Joseph et al 2003, Cottam et al. 2009, Rho et al 2015). Conclusions from published field study observations match the landscape-level analysis indicating SCQU avoidance of dense stands of Mesquite (*Prosopis glandulosa*) and Juniper (*Juniperus* spp.) cover as these woody species inhibit ground foraging and their ability to escape predation (Stormer 1981, Guthery et al. 2001, and Pleasant et al. 2006). Dry land management issues concerning the rate of change and geographical extent of woody vegetation encroachment are, although globally recognized, yet to be systematically quantified (Asner et al. 2003).

Rates and dynamics of grass-woody vegetation are strongly influenced by spatial precipitation variability, local land management, and soil diversity, adding to the difficulty in assessing regional vegetation transitions over time (Asner et al. 2003). Asner et al. (2003) suggested that brush management results in temporary increases in biomass and reductions in woody plant cover accompanied by significant successive ecological rebounds in woody encroachment within ten years of the treatment application (Fuhlendorf et al. 2017, Fulbright et al. 2018). The woody encroachment phenomenon may be contributing to the decline of SCQU in TRP and THP as studies have suggested SCQU abundance is negatively correlated with woody cover more than >.5m in height (Rho et al. 2015). Advances in aerial photography, remote sensing platforms and analytical tools have made it possible to quantify, parameterize, and analyze woody vegetation expansion models fostering high resolution vegetation transition spatial analysis on a regional scale (Asner et al. 1998; 2003).

Trophic interactions and ecosystem functions are ultimately affected by habitat fragmentation, therefore understanding how fragmentation ecology is effected by landscape matrix controls is essential for landscape management practices (Cottam et al. 2009). Studies indicate that long-term declines in grassland bird populations can be attributed to several anthropogenic forces including agriculture, urban development and other broadly defined infrastructures (Roberts et al. 2017). Joseph et al. (2003) suggests that SCQU can benefit from grazing changes to seral stages in plant communities leaving desired stands of dense grass and diversity in vegetation structure providing interspersed landscape habitats patches used throughout the life cycle of

SCQU. However, moderate grazing, during periods of drought, can diminish cover and food and impact quail populations (Joseph et al. 2003). Decreased nesting habitat contributes to declines in annual breeding success leading to an overall reduction in abundance over time (Cottam et al. 2009). Few studies have examined avian responses to alterations of native short grass prairies after observing declines in population (Roberts et al. 2017). The conversion of grasslands to croplands decreased the spatial extent of shortgrass prairie significantly advancing the reduction of SCQU habitat (Long et al. 2014, Fulbright et al. 2019).

In Texas, SCQU abundance exhibited positive correlations to precipitation from 1980 to 1982 and negative correlations to drought from 1978 - 1980 (Bridges et al. 2001, txwildlifealliance.org/recovering-america-s-wildlife-act/texas-ecoregions.html. Accessed 6 January 2020). Population dynamics are strongly influenced by annual variation in weather, and their quantity and timing affect SCQU productivity, especially in semiarid environments (Lusk et al. 2007). Precipitation for the TRP and THP primarily occurs as rain between April and September, with peak precipitation events and amounts occurring in July and August (Campbell 1968). Scaled quail populations still respond positively to precipitation however, their long-term population response remains insignificant as population trends from 1978 - 2000 in the TRP ecoregion suggest an average annual decline rate of 9.2%, and 3.1% throughout their geographic range (Peterson 2001, Bridges et al. 2001, Silvy et al. 2007, and Rho et al. 2015). Reproduction is primarily centered around precipitation based on SCQU dependence on vegetation growth for the timing of pairing, nesting, and egg laying (Texas Parks and Wildlife Department 2006). Scaled quail are moderately sedentary (Campbell and Harris 1965). They follow consistent seasonal routines within their home range from morning and evening feedings and resting to roosting. This seasonal routine is of value to the birds, as knowing where important resources are is essential to quail survival especially during unfavorable periods (Brennan et al. 2017).

Despite SCQU positive response to moderate precipitation cycles long-term population trends indicate the species is still in decline. Correlative studies suggest that brush encroachment with corresponding decreases in grassland habitat availability and patch size has increased predation rates on SCQU and reduced population growth. However, there have been few studies that have compared the actual SCQU demographic response to brush encroachment and habitat patch size. Many studies have addressed changes in landscape patterns effects on species abundance, though limited research has focused on landscape characteristics and SCQU abundance. There is a need to examine landscape pattern changes in ecoregions such as the TRP which exhibit contrasts in population trends and investigate specific landscape pattern changes and their effects on SCQU demographics.

The objective of this study was to quantify woody, grassland, bare ground, and succulent landscape metrics with stable and intermittent SCQU populations using real time aerial drone raster images. I defined stable populations as those that occur in relative abundance inhabiting large grassland tracts where the percentage of woody cover is relatively low, whereas intermittent populations I defined as small groups or individual coveys expanding and contracting during periods of precipitation and drought and inhabiting small, isolated tracts with suitable cover however, unlikely to support the expansion and growth of the population. I predicted landscape composition would be dissimilar between ranches with intermittent and stable SCQU populations. Specifically, I hypothesize stable ranches will have more area and higher percent landscape of grassland, less woody cover, and less bare ground. With the advent of Geographic Information Science (GIS) and Unmanned Aerial Vehicle (UAV) technology, landscape analysis approaches can be used to determine changes in landscape patterns and how these changes influence SCQU population demographics, as well as analyze how these landscape patterns contribute to varying qualities relative to SCQU habitat use and selection. Woody plants and shrub clusters often are used by SCQU for escape cover and avoiding severe weather. However, decreased landscape heterogeneity and homogeneous tracts of woody vegetation result in SCQU avoidance (Rho et al. 2015, Fuhlendorf et al. 2017).

Study Area

I monitored SCQU on four study sites, two with stable populations and two with intermittent populations throughout the Texas Plains ecoregions. Sites with stable populations included a ranch in Potter County, a ranch in Dawson County, and the two study sites with intermittent populations include a ranch in Dickens County as well as a ranch in Mitchell County (Figure 1.2).

The ranch in Potter County is in the Texas Rolling Plains, north of Amarillo in the Canadian Breaks portion of the Rolling Plains ecoregion. This ranch was primarily used for cattle and horse grazing and oil production. Soils classes on this ranch included Acuff-PaloDuro-Olton, Mobeetie-Tascosa, Veal-Mobeetie, Weymouth-Vernon, and Likes-Tivoli, these are a mix of loamy, clayey, calcareous and non-calcareous soils (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The Vegetation community consisted of native grasses and woody shrubs. Although mostly shortgrass rangeland, this site consists of patches of shrubs, trees and succulents such as prickly pear (*Opuntia spp*.) and walking stick cholla (*Cylindropunta imbricata*). This site is known for year-round supplemental feeding of milo on maintained roads throughout the year which may be a factor in high abundance observations.

The site in Dawson county study site was located east of Lamesa texas which bisects the Caprock Escarpment, which forms the boundary between the Rolling Plains and Southern High Plains ecoregions. This study site was primarily used for cattle grazing. Soils on this site include: Alibates loam, Ady fine sandy loam, Amarillo fine sandy loam, Acuff sandy clay loam, Midessa fine sandy loam, Plemons loam, Portales loam, Veal loam, and Veron clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this ranch consisted of native grasses and woody shrubs and forbs along with patches of trees and succulents such as prickly pear and walking stick cholla.

The Site in Dickens County was located near the town of Spur Texas in the western Rolling Plains ecoregion. This ranch is also primarily used for cattle grazing.

The soils on this ranch included: Abiline clay, Colorado Loam, Latom gravelly fine sandy loam, Mansker loam, Miles fine sandy loam, Olton clay loam, Veal fine sandy loam, Vernon clay loam, and Weymouth clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this study site consisted of native grasses and woody shrubs (e.g. yucca (*Yucca filamentosa*), lote bush (*Ziziphus obtusifolia*), catclaw acacia (*Senegalia greggii*)) and forbs along with patches of trees and succulents such as prickly pear and walking stick cholla.

The Mitchell County ranch was just south of Colorado City, Texas located in the southwestern Rolling Plains. This ranch was used for farming and grazing. The soils on this study site include: Burkreek loam, Miles fine sandy loam, Colorado loam, Snyder loam, Sagerton clay loam, Pyron clay loam, Spade fine sandy loam, Spade-Latom fine sandy loam, Stamford clay, and Vernon clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this study site consisted of native grasses and woody shrubs (e.g. yucca, lote bush, catclaw acacia) and forbs along with patches of trees (e.g. honey mesquite, soapberries (*Sapindus saponara*), and Junipers) and succulents such as prickly pear and walking stick cholla.

The High Plains and Rolling Plains regions are the southern end of the Great Plains of the central United States. The Rolling Plains occurs just below the level plateau of the High Plains Caprock separated by steep slopes and canyons that comprise the escarpment transitions between the two ecoregions. Formation of the

Texas Plains ecoregions is a result of alluvial deposits from Rocky Mountain river origins (Modala et al. 2017). Elevations for the High Plains range from 3,000 to 4,500 feet above sea level whereas rolling plains elevations range from 800 to 3,000 feet above sea level. Average annual rainfall for the High Plains is between 36 and 61 cm, slightly lower than the 46 to 76 cm average annual rainfall seen in the Rolling plains (Modala et al. 2017).

Methods

Capture

To collect SCQU geospatial data for this analysis, I captured SCQU using modified Stoddard quail funnel traps (Smith et al. 1981, Figure 1.3). The traps were built with 14-gauge, 2.54 cm x 5.08 cm galvanized mesh wire. Using a 122 cm x 30.5 m roll, roughly twenty 61cm x 61cm x 20 cm funnel traps can be assembled. Funnel traps are hinged together with J hooks in order to collapse the traps for ease of transport and storage. Trap locations were selected based on SCQU sightings and suitable habitat containing the various cover types. Traps were then placed in areas with substantial loafing or escape cover such as shrubs, trees, and succulents.

Funnel traps were baited with milo and covered with available surrounding vegetation to reduce thermal stress and to reduce risk of predation. I set traps at or before sunrise, checked them at solar noon and again at sundown. Once checked, traps were flipped over to prevent inadvertent overnight captures of target and non-target species. All non-target species were immediately released upon arriving to the trap. Captured SCQU were removed from traps and placed into mesh bird bags and taken to the field vehicle to be processed. All birds were trapped under the authority of a Texas Parks and Wildlife Department Scientific Collecting Permit and processed within 30 minutes of being removed from the trap as per Texas Tech University Institutional Animal Care and Use (Protocol No. 19007-01)

Captured SCQU were fitted with aluminum butt-end leg bands (National Band and Tag Co., No. 8 bands, Newport, KY.) on the left leg of each bird and location (Universal Transverse Mercator Coordinate System; UTM) at the capture site along with age, sex, wing cord (mm), weight, time of capture, and date of capture were recorded. Gender was determined using the (Wallmo 1956) technique by identifying the absence or presence of longitudinal streaking down the throat accompanied with a dirty bluish grey color associated with females. Juveniles were differentiated from adults by examining the tips of the 1-7 primary wing coverts whereas sub adults older than twenty weeks display a buff-colored edge while adult primary tips were all gray (Cain and Beasom 1983, Smith et al. 1984, Figure 1.4).

GPS Tagging and Monitoring

The state-of-the-art GPS transmitters used in this study provided precision instrumentation to overcome temporal and spatial scale issues restricted by VHF technology and field observer limitations. I used Ecotones PICA 5.5-gram solar powered backpack style data loggers (hereafter GPS) for this assessment (Figure 1.5). The Ecotone Pica solar powered GPS store on board data logger (Ecotone, Gdynia, Poland) was attached using a backpack style attachment on at least one SCQU per captured covey (Hansen et al. 2014). The backpack data loggers were fixed with 2.0-

gram VHF (American Wildlife Enterprises, Monticello, Florida, USA) piggyback transmitters for retrieval. The GPS units had a reflective solar panel with an area of approximately 3.08 cm^2. The weight of the combined GPS and VHF ranged between 7.9 g – 8.9 g which was below the 5% body mass limit on tagged birds weighing ≥165g. I fit the GPS to the SCQU using black elastic string allowing a ~1.3 cm space between the bird's back and the transmitter to allow the wings to move freely and sill snug enough to remain attached to the bird during flight or moving through dense brush. The GPS loggers were remote user programmable to allow for selection of location intervals, number of positions recorded during each interval, maximum time for the GPS to attempt a location (work time limit), and the time frame in which the logger recorded each day. Data collection settings were loaded and transmitted to the data loggers using the Ecotone Tracker version 20181124 software. The data loggers were set to collect SCQU one location at one-hour intervals with an automatic shut off at the time of roosting in order to preserve battery voltage in low light hours.

I deployed ten GPS data loggers on SCQU throughout each field season at each study area. After a period of fourteen days, the data loggers were retrieved via telemetry, hand nets, and spotlights. Given the SCQU's affinity for running rather flushing, the retrievals were significantly more efficient at night. Once the initial roosting covey was broken up, individual tagged birds could be held in place with a spotlight upon locating the bird. After manually retrieving a tagged bird the data logger was removed and the bird was evaluated for signs of injury or distress. No manual recaptures resulted in mortalities and likewise showed no signs of injury.

Geospatial locations were downloaded using an Ecotone P5-2xSD Base station and Ecotone logger analyzer 271216 software. I converted locations from the GPS to .csv and .kml files, then uploaded the .kml file into eMotion 3.5.0 (senseFly SA, Route de Genève 38, 1033 Cheseaux-sur-Lausanne, Switzerland) drone flight software to create flight paths over used GPS location areas. I then deployed the drone over each study area to photograph the use areas at 3.0 mega pixel resolution.

Brownian Bridge Contours

Locations from GPS–tagged SCQU were used to establish utilization distribution (UD) and create home ranges [(defined as the 2nd order spatial scale habitat use per Johnson (1980)] using Brownian Bridge Movement Model (BBMM) in program R (Horne et al. 2007). I defined core areas and home ranges as 50% contours and 90% contour isopleths from the BBMM, respectively. I uploaded all 50 and 90% contour isopleth polygons to the drone for each ranch to create the landscape-level images described below.

Drone Mapping

I used a Sensefly Ebee mapping drone (Flightevolved.com/sensefly-ebee-drone/ Accessed October 2019) to create georeferenced maps of each SCQU use area on each study area (Figure 1.6). The Fixed wing Sensefly Ebee UAV (Unmanned Aerial Vehicle) is a single, rear facing propeller fixed wing aircraft with 96 cm wingspan. The UAV has a mass of 0.69 kg including the camera and battery (3-cell lithium-polymer), and the aircraft is constructed of expanded polypropylene foam. The maximum endurance of the EBee UAV was advertised 50 minutes however, field conditions did not allow for maximum battery life for each flight. The EBee is capable of a 1.5 cm Ground Sampling Distance (GSD) however images at these fine scales required calm winds and level ground conditions. Therefore, I standardized all flights at 3.0 cm GSD as a compromise to achieve high resolution images needed for this study while maintaining a flight ceiling below ~122 m dictated by federal law. The UAV is equipped with a SenseFly S. O. D. A. (Sensor Optimized for Drone Applications; SenseFly LTD Cheseaux-sur-Lausanne, Switzerland) 20 MP RGB camera with a 13.20 mm CMOS RGB sensor. Shutter speed, aperture, ISO ("film" sensitivity), and focal length were automatically selected by the camera based on conditions at the time of each photograph with each photo automatically georeferenced to WGS 1984 datum upon capture.

I uploaded all of the polygons I created from each GPS-tagged SCQU to the drone and flew the drone once per season per study area. I conducted drone flights on days where external conditions were clear skies and winds below 20 mph. I attempted flights at or around solar noon for optimum spectral reflectance and to minimize shadow appearance in the drone images. The drone images were downloaded from the cameras' SD card and stored in an external hard drive with flights filed by date, ranch, and season.

I processed the high-resolution real time aerial drone photos into digital surface model and orthomosaic for data analysis using Pix4Dmapper 4.6.4 (Pix4D S.A., Prilly, Switzerland) drone imagery processing software. The high-resolution real time aerial drone data were combined among GPS-tagged SCQU within season to create a land cover map for each study area. I used the land cover maps for each site to delineate land cover for each used area. The land cover orthomosaic maps provided real-time, seasonal, and landscape level land cover metrics that facilitates my understanding of SCQU habitat selection, landscape ecology and winter survival.

Land Use Land Cover Classification

I used the drone images paired with GPS contours to create georeferenced raster images for use in ArcGIS version 10.7.1 in order to create and quantify land use and land cover types relative to SCQU GPS locations. I created a geodatabase for each ranch for each season in ArcGIS for each raster and imported the raster files to the corresponding geodatabases. In ArcGIS I used the image classification tool to classify each raster into 4 land cover classes which include succulents, bare ground, grassland, and woody vegetation. I defined woody vegetation as fragrant sumac (*Rhus aromatica*), honey mesquite (*Prosopis glandulosa*), junipers (*Juniperus spp.*), soapberries (*Sapindus saponara*), lote bush (*Ziziphus obtusifolia*), catclaw acacia. I defined grassland vegetation as forb and grass species such as dalea (*Dalea lasiathera*), spreading sida (*Sida filicaulis*), gray coldenia (*Coldenia canescens*), blue grama (*Bouteloua gracilis*), bristlegrasses (*Setaraia spp.*), hairy grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), threeawns (*Aristida spp*.), common russian thistle (*Salsola kali*), snakeweed (*Xanthocephalum sarothrae*), sunflowers (*Helianthus spp*.), western ragweed (*Ambrosia psilostachhya*), halls panicum (*Panicum hallii*), bristle grass (*Setaria spp.*), big bluestem (*Andropogon gerardi*), little bluestem (*Schizachryium scoparium*). I defined bare ground as areas absent of any living or dormant vegetation, including rocky breaks, rock outcrops, and areas without any litter or debris where topsoil was exposed. I defined succulent vegetation as prickly pear (*Oppuntia spp*), yucca (*Yucca spp*), and tree cholla (*Cylindropuntia imbricata*).

Vegetation Sampling

Vegetation structure was quantified using a variety of sampling techniques to estimate woody tree species, stems per hectare, exotic plant species, Robel pole to estimate visual obstruction, and Daubenmire frame to assess percent canopy cover at two selected and randomly paired locations for each GPS-tagged SCQU. For this assessment, I used the in-field data to ground-truth the aerial imagery collected by the drone to calculate percent accuracy of each raster image.

I conducted vegetation habitat sampling at used and random paired locations and all measurements were collected at 5 m, 10 m, and 15 m intervals to account for GPS error for each location downloaded from the GPS unit. I used a modified 30.5 cm (length) x 30.5 cm (width) Daubenmire frame to estimate the percent ground cover of grass, shrubs, forbs, litter, and bare ground (Daubenmire 1959) at the center GPS point, and intervals above, and in each cardinal direction. I measured the tallest plant within each Daubenmire frame to assess the vegetation structure (cm). For consistency, each litter measurement was recorded in the northwest corner of each Daubenmire frame to reduce bias. Within each 15 m (length) x 15 m (width) quadrant of the Daubenmire frame, I also inventoried the overall woody vegetation species as well as recorded any exotic and succulent species. I measured visual obstruction readings at each survey location using a Robel pole at a distance of 4 m from the center and a height of 1 meter (Robel et al. 1970).

Fragstats Analysis

I used Drone imagery paired with ground vegetation surveys to establish Land Use Land Cover Data (LULCD) and quantify cover types for all study areas. I created four cover types for my assessment: woody vegetation, grassland vegetation, bare ground, and succulent vegetation. For each study area, I calculated Class Area (CA), Largest Patch Index (LPI), and Percent Land (PLAND) for each cover type for each study area using FRAGSTATS version 4.2. I used an Analysis Of Variance (ANOVA) to assess if differences in mean CA, LPI, and PLAND for each cover type existed among GPS-tagged SCQU and within and among ranches. I used a student's t-test to assess if differences existed in CA, LPI, and PLAND for each cover type between stable and intermittent populations.

Accuracy and Precision Estimation

I created training samples for each class using ground vegetation surveys from used and random SCQU GPS locations. Once the training samples were completed and merged, I created a signature file. To classify images, I used the Maximum Likelihood Estimator and input the signature files into ArcGIS 10.7. Once the raster classification was completed, I performed an accuracy assessment on each classified image by creating reference points shapefiles. I created 40 reference points for each class for each classified image and used the conversion tool to convert the points to pixels and created a point to raster shapefile. I then used the spatial analyst tool and combine tool to combine the point to raster file with the classified image. I used the output table from the combined shapefile and created a pivot table and exported the point to raster database table into Microsoft Excel for accuracy assessments. I calculated the overall accuracy, omission, commission user accuracy producer accuracy. I used the Kappa Coefficient to assess accuracy and precisions of classified raster images. I considered a Kappa Coefficient of ≥ 0.61 as having both an accurate and precise representation of the land cover matrix.

Results

Capture

Due to the small populations of SCQU on the majority of the ranches, I only completed the project tasks on two sites, one intermittent (Dickens County) and one stable population site (Potter County). I captured 187 SCQU from four ranches over two winter field seasons 110 SCQU in 2018-2019 and 77 in 2019-2020. I deployed 42 GPS units during the two winter field seasons, 20 units in 2018-2019 and 22 units in 2019-2020.

Land Use Land Cover Analysis

I collected 4,560 images during the combined 2018-2019 (2,816 images) and 2019-2020 (1,744 images) winter field seasons and stitched the images together in pix4d to create 11 raster images. I created 6 raster images in 2018-2019 and 5 raster images in 2019-2020 for each study site. The average overall accuracy for the 2018-2019 winter field season classified raster images was 90.46% with an average Kappa

Coefficient of 0.87. The overall accuracy and for the 2019-2020 winter field season raster images was 85.65% with a Kappa Coefficient of 0.81.

Landscape Composition

The factorial interaction of vegetation and stable and intermittent population sites was not statistically significant for class area (Tables 1.1, 1.2, and 1.3). Class area composition was the same within and among SCQU contours. However, the main effect of site was marginally dissimilar, indicating composition between stable and intermittent sites was different. The ranch with the stable SCQU population had a mean vegetation class area of 105.17 ha whereas the ranch with intermittent SCQU populations had a mean vegetation class area of 42.74 ha (Figure 1.7). Grasslands had the largest average area at 148.88 ha, woody vegetation averaged 77.93 ha, then bare ground at 42.12 ha, and succulents with the lowest average area at 26.92 ha (Figure 1.8). Inferences from the class area results determined that the site with stable SCQU populations tended to have, although only marginally statistically significant, more grasslands.

There was no difference in LPI between classes or between stable and intermittent population sites (Tables 1.4, 1.5, 1.6). Results from the LPI interactive model show that while classes did not differ in largest patch size, the ranch level statistics resulted in the intermittent population site had a single larger grassland patch (27.63 ha) compared to the stable population site grassland patch (15.99 ha).

The results for PLAND indicate percent landscape composition is different between the stable and intermittent populations for both field seasons combined and for class type based on Z values from the Generalized Estimating Equations (GEE) analysis (Table 8). The intermittent population site percent landscape composition for each class, which was made up of bare ground 18.61%, grassland 46.22%, succulents 8.61% and woody vegetation 26.56%, was different than that of the stable population landscape composition which was made up of 9.89% bare ground, 54.38% grassland, 12.34% succulents, and 23.38% woody vegetation.

Discussion and Management Implications

My major findings were 1) landscape composition was marginally different between stable and intermittent population sites, 2) percent landscape was different between sites, and 3) largest patches were different, however landscape area did not differ between sites. The intermittent population site has a single larger grassland compared to that of the stable population, but habitat selection data indicates SCQU select for same features at all spatial scales (Chapter 2), therefore, LPI is not a good management metric. Instead of creating one single area with abundant grasslands (or other vegetation classes), creating more areas that resemble the CA results are better for SCQU in winter. Brennan et al. (2017) found SCQU were most abundant in open grasslands > 250 hectares (100 acres) with ~10-15 percent shrub cover, and my results corroborate this finding, given the stable population site had higher SCQU abundances before, during, and after the study (B. Dabbert, Quail Tech Alliance, unpublished data).

Percent landscape (PLAND) is an important metric for SCQU overwinter ecology. General habitat preferences for SCQU are likely consistent throughout their range however, quality and availability of landscape composition metrics can greatly affect SCQU site specific habitat use (Bristow et al 2006). My findings support previous assessments that suggest the woody encroachment phenomenon is likely contributing to the decline of SCQU in TRP and THP as studies have suggested SCQU abundance is negatively correlated with woody cover more than >1.5 m in height (Rho et al. 2015). In fact, two of four study sites were excluded from this study due to lack of SCQU coveys, despite substantial trapping-efforts, and I speculate these ranches no longer meet the percent landscape qualifications to support SCQU populations. I recommend future assessments from Quail Tech Alliance fly drones once during the breeding season and again during the non-breeding season to quantify vegetation composition at Anchor Ranches to assess if each ranch meets the PLAND criteria below.

In general, any one ranch should meet the following metrics at the ranch level; ranch size (ha or ac) = 10% bare ground, >45% grassland, 10-15% succulents, and the remaining woody vegetation to maximize areas that are considered suitable overwinter habitat for SCQU as indicated by the PLAND from the stable ranches in this assessment and results from Chapters 2. The landscape would be considered more suitable if the number of patch areas that are composed of < 77 ha of woody vegetation, ~150 ha of grassland, ~15-25 ha of succulents, and < 40 ha of bare ground are maximized on each ranch. Managing for SCQU coveys at 300 ha blocks within these landscape composition ranges may result in higher yields of SCQU coveys, but these values can be mathematically transformed for smaller or larger ranches.

Observations from this study and others indicate that given the habitat use patterns of SCQU, land management practices which reduce grassland richness and increase woody vegetation composition likely significantly reduce overwinter habitat availability for SCQU populations (Bristow et al 2006, Rho et al 2015). Drone imageries are advantageous to satellite imagery because drone imagery is captured on the fly whereas satellite imagery can be collected months, if not years, before the study occurred. I was able to create 11 LULC thematic maps for SCQU landscape ecology that classified vegetation structure based on used GPS locations at a similar scale to that of traditional canopy cover methods such as Daubenmire frame quadrats to analyze landscape composition for SCQU at broad scales. Despite only having RGB spectral reflectance with the S.O.D.A. remote sensing camera I was able to create the 11 classified raster images with >0.64 Kappa Coefficients. While these results were substantial, I suspect that aggregating individual vegetation structures into broader categories such as succulents, bare ground grasslands, and woody vegetation contributed to this level of accuracy. However, with far infrared, near infrared, and ultraviolet sensors these classes can be further broken down for fine scale landscape composition analysis. Moreover, classifying dormant foliage during winter seasons added to the limitations of image classification. My maps were classified with greater than a 0.64 kappa coefficient, despite the lack of far and near infrared sensors used in a study by Jackson et al. (2020) in which their kappa coefficients performed lower than the results reported here.

Literature Cited

Arthur, S.M., B.F.J. Manly, L.L. McDonald, and G.W. Gardner. 1996. Assessing Habitat Selection when Availability Changes. Ecology. 77:215-227.

Asner, G.P., C.A. Wessman, D.S. Schimmel. 1998. Heterogeneity of Savannah Canopy Structure and Function from Imaging Spectrometry and Inverse Modeling. Ecological Environments. 8:926-941.

Asner, G.P., S. Archer, R.F. Hughes, R.J. Ansley, and C.A. Wessman. 2003. Net Changes in regional woody vegetation cover and carbon storage in Texas Drylands. Global Change Biology. 9:316-365Ault, S.C., and F.A. Stormer. 1983. Seasonal Food Selection by Scaled Quail in Northwest Texas. The Journal of Wildlife Management. 47:222-228.

Audubon.org/field-guide/bird/scaled-quail Accessed April 2020

Ault, S.C., and F.A. Stormer. 1983. Seasonal Food Selection by Scaled Quail in Northwest Texas. The Journal of Wildlife Management. 47:222-228.

Bestelmeyer, B.T., D.P.C. Peters, S.R. Archer, D.M. Browning, G.S. Okin, R.L. Schooley, and N.P. Webb. 2018. The grassland-shrubland regime shift in the southwestern United States: misconceptions and their implications for management. BioScience 68:678-690.

Brennan, L.A., D.L. Williford, B.M. Ballard, W.P. Kuvlesky Jr., E.D Graham, and S.J. Demaso. 2017. The Upland and Webless Migratory Game Birds of Texas. Ecology and Management, Texas A&M University Press, College Station, TX, USA.

Bridges, A.S., M.J. Peterson, N.J. Silvy, F.E. Smeins, and X.B. Wu. 2001. Differential Influence of Weather on Regional Quail Abundance in Texas. The Journal of Wildlife Management. 65:10-18.

Bristow, K.D., and R.A. Ockenfels. 2006. Fall and Winter Habitat Use by Scaled Quail in Southeastern Arizona. Rangeland Ecology and Management. 59:308-313.

Brown, D.E., C.L. Cochran, and T.E. Waddell. 1978. Using Call-Counts to Predict Hunting Success for Scaled Quail. The Journal of Wildlife Management. 42:281-287.

Cain, J. R., S.L. Beasom. 1983. A Guide for Aging Scaled Quail. Texas Agricultural Experimentation Bulletin. http://hdl.handle.net /1969.1/150034. Accessed 12 July 2019

Campbell, H., and B.K. Harris 1965.Mass Population Dispersal and Long-Distance Movements in Scaled Quail. The Journal of Wildlife Management. 29:801-805

Campbell, H., 1968. Seasonal Precipitation and Scaled Quail in Eastern New Mexico. The Journal of Wildlife Management. 32:641-644

Campbell, H.C., D.K. Martin, P.E. Ferkovich, and B.K. Harris. 1973. Effects of Hunting and Some Other Environmental Factors on Scaled Quail in New Mexico. Wildlife Monographs. 34:3-49

Cottam, M.R., S.K. Robinson, E.J. Heske, J.D. Brawn, and K.C Rowe. 2009. Use of landscape metrics to predict avian nest survival in a fragmented Midwestern forest landscape. Biological Conservation. 142:2464-2475

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science.33:43-64.

Davis, C.A., R.C. Barkley, and W.C. Haussamen. 1975. Scaled Quail foods in Southeastern New Mexico. The Journal of Wildlife Management. 39:496-502.

Flight evolved.com/sensefly-ebee-drone, Accessed october 2019)

Foster, L. J., K.M. Dugger, C.A. Hagen, and D.A. Budeau. 2018. Potential effects of GPS transmitters on greater sage-grouse survival in a post-fire landscape. BioOne Complete: URL: https://doi.org/10.2981/wlb.00479. Accessed 8/30/2020

Fuhlendorf, S.D., T. J. Hovick, R.D. Elmore, A.M. Tanner, D.M. Engle, and C.A. Davis. 2017. A Hierarchical Perspective to Woody Plant Encroachment for Conservation of Prairie-Chickens. Rangeland Economy and Management. 70: 9-14.

Fulbright, T.E., K. W. Davies, and S.R. Archer. 2018. Wildlife Responses to Brush Management: A Contemporary Evaluation. Rangeland Economy and Management. 71: 35-44.

Giuliano, W.M., R.S. Lutz, and R. Patino. 1996. Reproductive Responses of Adult Female Northern Bobwhite and Scaled Quail to Nutritional Stress. The Journal of Wildlife Management. 60:302-309.

Grisham, B.A., A.J. Godar, C.W. Boal, D.A. Haukos. 2016. Interactive effects between nest microclimate and nest vegetation structure confirm microclimate thresholds for Lesser Prairie-Chicken nest survival. The Condor. 118:728-746.

Guthery, F.S., N.M. King, W.P. Kuvlesky, Jr, S. DeStefano, S.A. Gall, and N.J. Silvy. 2001. Comparative Habitat Use by Three Quails in Desert Grassland. The Journal of Wildlife Management. 65:850-860.

Hansen, C. P., M. A. Gamo, R. S. Scott, and J. J. Millspaugh. 2014. Auxiliary VHF transmitter to aid recovery of solar Argos/GPS PTTs. Research Note RMRS–RN–72. U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, USA.

Hatch, D.E. 1975. Behavior and Ecology of Bobwhite (Colinus virginianus) and the Scaled Quail (Callipepla squamata) in their Area of Sympatry. Dissertation, University of Nebraska, Lincoln.

Henderson, C.W. 1971. Comparative Temperature and Moisture Responses in Gambel and Scaled Quail. The Condor. 73:430-436.

Heske, E.J., S.K. Robinson, and J.D. Brown. 1999. Predator activity and predation on songbird nests on forest edges in east central Illinois. Landscape Ecology. 14:345-354

Horne, J.S., E.O. Garton, S.M. Krone, and J.S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology. 88:2354-2363.http://txwildlife alliance.org/recovering-america-s-wildlife-act/texas-ecoregions.html. Accessed 6 January 2020

Jackson, M., C. Portillo-Quintero, R. Cox, G. Ritchie, M. Johnson, K. Humagain, and M. R. Subedi. 2020. Season, classifier, and spatial resolution impact honey mesquite and yellow bluestem detection using an unmanned aerial system. Rangeland Ecology AND Management 73:658–672.

Joseph, J., J.L Holechek, R. Valdez, M. Collins and M. Thomas. 2003. Research Observation: Effects of Rangeland Ecological Condition on Scaled Quail Sightings. Journal of Range Management. 56:314-318

Kie, J. G. J. Matthiopoulos, J. Fieberg, R.A. Powell, F. Cagnacci, M.S. Mitchell, J.M. Gaillard, and P.R Moorcroft. 2010. The home-range concept: are traditional estimators still relevant with modern telemetry technology? Philisophical Transactions of the Royal Society B. 365:2221-2231.

Long, A.M., W.E. Jensen, and R.S. Matlack. 2014. Influence of Prescribed Burning on Bird Abundance and Species Assemblage in a Semiarid Great Plains Grassland. Western North American Naturalist. 74:396-404.

Lusk, J.J., F.S. Guthery, M.J. Peterson, and S.J. DeMaso. 2007. Evidence for Regionally Synchronized Cycles in Texas Quail Population Dynamics. The Journal of Wildlife Management. 71:837-843.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, London, United Kingdom.

Medina, A.L. 1988. Diets of Scaled Quail in Southern Arizona. The Journal of Wildlife Management. 52:753-757.

Modala, N.R, S. Ale, D.W. Goldberg, M. Olivares, C.L. Munster, N. Rajan and R.A. Feagin. 2017. Climate Change Projections for the Texas High Plains and Rolling Plains. Theoretical and Applied Climatology. 129:263-280.

Nelson, T., J. L. Holechek, R. Valdez, and M. Cardenas. 1997. Wildlife numbers on late and mid seral Chihuahuan Desert Rangelands. Journal of Range Management. 50:593-599.

Orange, J.P., C.A. Davis, R.D. Elmore, E.P. Tanner, S.D. Fuhlendorf, and E.T. Thacker. 2016. Evaluating the Efficacy of Brood Flush Counts: A Case Study in Two Quail Species. Western North American Naturalist. 76:485-492.

Orange, J.P., C.A. Davis, R.D. Elmore, and S.D. Fuhlendorf. 2016. Temporary Communal Brooding in Northern Bobwhite and Scaled Quail Broods. Western North American Naturalist. 76:122-127.

Peterson, M.J. 2001. Northern Bobwhite and Scaled Quail Abundance and Hunting Regulation: A Texas Example. The Journal of Wildlife Management. 65:828-837.

Pleasant, G.D., C.B. Dabbert, and R.B. Mitchell. 2003. Evaluation of the Moisture Facilitated Nest Depredation Hypothesis in a Semiarid Environment. Management Journal of Wildlife. 115:343-346.

Pleasant, G.D., C.B. Dabbert, and R.B. Mitchell. 2006. Nesting Ecology and Survival of Scaled Quail in the Southern High Plains of Texas. Management Journal of Wildlife. 70:632-640.

Powell, R.A., and M.S. Mitchell. 2012. What is home range?. Journal of Mammology. 93:948-958

Rea, A.M. 1973. The Scaled Quail (Callipepla squamata) of the Southwest Systematic and Historical Consideration. The Condor. 3:322-329.

Rho, P., X.B. Wu, F.E. Smeins, N.J. Silvy and M.J. Peterson. 2015. Regional land cover patterns, changes and potential relationships with scaled quail (Callipepla squamata) Abundance. Journal of Ecology and Environment. 38:185-193.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between Visual Obstruction Measurements and Weight of Grassland Vegetation. Journal of Range Management. 23:295-297.

Roberts, A.J., C.W. Boal, and H.A. Whitlaw. 2017. Nesting Ecology of Grassland Birds Following a Wildfire in the Southern Great Plains. The Southwestern Naturalist. 62:39-45.

Rollins, D., and J.P. Carroll. 2001. Impacts of Predation on Northern Bobwhite and Scaled Quail. Wildlife Society Bulletin. 29:39-51.

Saiwana, L., J.L. Holechek, A. Tembo, R. Valdez and M. Cardenas.1998. Scaled Quail Use ofSeral Stages in the Chihuahuan Desert. Journal of Wildlife Management. 62:550- 556.

Schemnitz, 1959. Past and Present Distribution of Scaled Quail (Callipepla squamata) in Oklahoma. The Southwestern Naturalist. 4:148-152.

Schemnitz, 1961. Ecology of the Scaled Quail in the Oklahoma Panhandle. Wildlife Monographs. 2:429-433.

Schemnitz, 1964. Comparative Ecology of Bobwhite and Scaled Quail in the Oklahoma Panhandle. The American Midland Naturalist. 2:429-433.

Silvy, N.J., D. Rollins, and W. Whisenant. 2007. Scaled Quail Ecology and Life History.In Texas Quails: Ecology and Management. College Station: A&M Press. 65-68.

Smith, D.S., F.E. Stormer, and R.D. Godfrey Jr. 1981. A Collapsible Quail Trap. Rocky Mountain Forest and Range Experiment Station: USDA Forrest Service. 1-3.

Smith, D.S. and J.R. Cain. 1984. Criteria for age Classification of Juvenile Scaled Quail. Journal of Wildlife Management. 48:187-191.

Stohlgren, T.J., K.A. Bull, and Y. Otsuki. 1998. Comparison of Rangeland Vegetation Sampling Techniques in the Central Grasslands. Journal of Range Management. 51:164-172.

Stormer, F.E. 1984. Night-Roosting Habitat of Scaled Quail. The Journal of Wildlife Management. 1:191-197.

Tanner, E.P., M. Papes., R.D. Elmore, S.D. Fuhlendorf, and C.A. Davis. 2017. Incorporating Abundance Information and Guiding Variable Selection for Climate-Based Ensemble Forecasting of Species Distributional Shifts. PLoS ONE 12(9):e0184316.

Tanner, E.P., R.D. Elmore, C.A. Davis, and S.D. Fuhlendorf. 2017. Evidence in Scaled Quail (Callipepla squamata) Following an Anthropogenic Disturbance. The Wilson Journal of Ornithology. 129:354-359.

Texas Parks and Wildlife [internet].2020. Austin (TX): Quail Forecast 2019-2020; [cited Sep16, 2020].Available from: http://www.tpwd.state.tx.us/huntwild/hunt/planning/quail_forecast/forecast/.

Texas Parks and Wildlife Department. 2006. Scaled Quail in Texas: Their Biology and manangement.Austin T.X. USA. 1-34.

Tharp, J.E. 1971. A Study of Scaled and Bobwhite Quail with Special Empasis on Habitat Requirements and Brush Control. Thesis, Texas Tech University, Lubbock, TX, USA.

Tomacek, J.M., B.L. Pierce and M..J. Peterson. 2015. Quail Abundance, Hunter Effort, and Harvest of Two Texas Quail Species: Implications for Hunting Management. Wildlife Biology. 21:303-311.

Wallmo, O.C. 1956. Determination of Sex and Age of Scaled Quail. The Journal of Wildlife Management. 20:154-158.

WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020.

Williford, D., R.W. Deyoung, R.L. Honeycutt, L.E. Brennan and F. Hernandez. 2014. Phylogeography of the Scaled Quail in the American Southwest. Western North American Naturalist. 74: 18-32.

Zornes, M., and R.A. Bishop, 2010. Western Quail Conservation Plan: Association of Fish and Wildlife Agencies Resident Game Bird Workshop Group. Wildlife Management Institute. Cabot, VT, USA

Figures

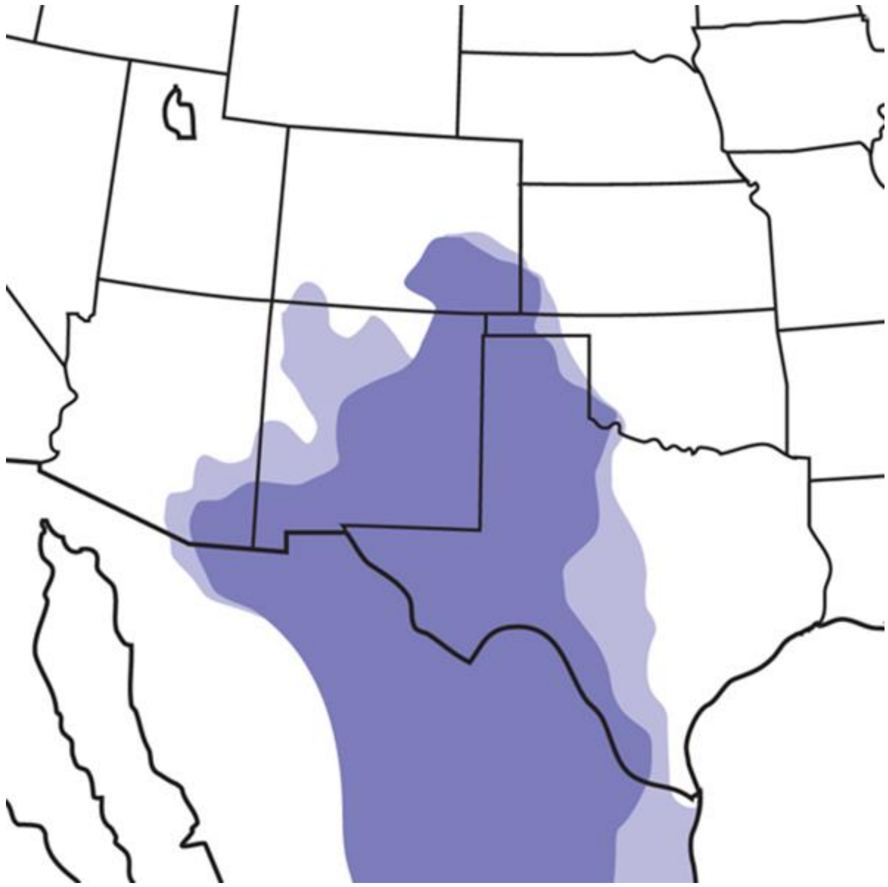

Figure 1.1. Estimated current and historical Scaled quail (*Callipepla squamata*) geographic ranges. Figure is from Audubon.org/fieldguide/bird/scaled-quail.

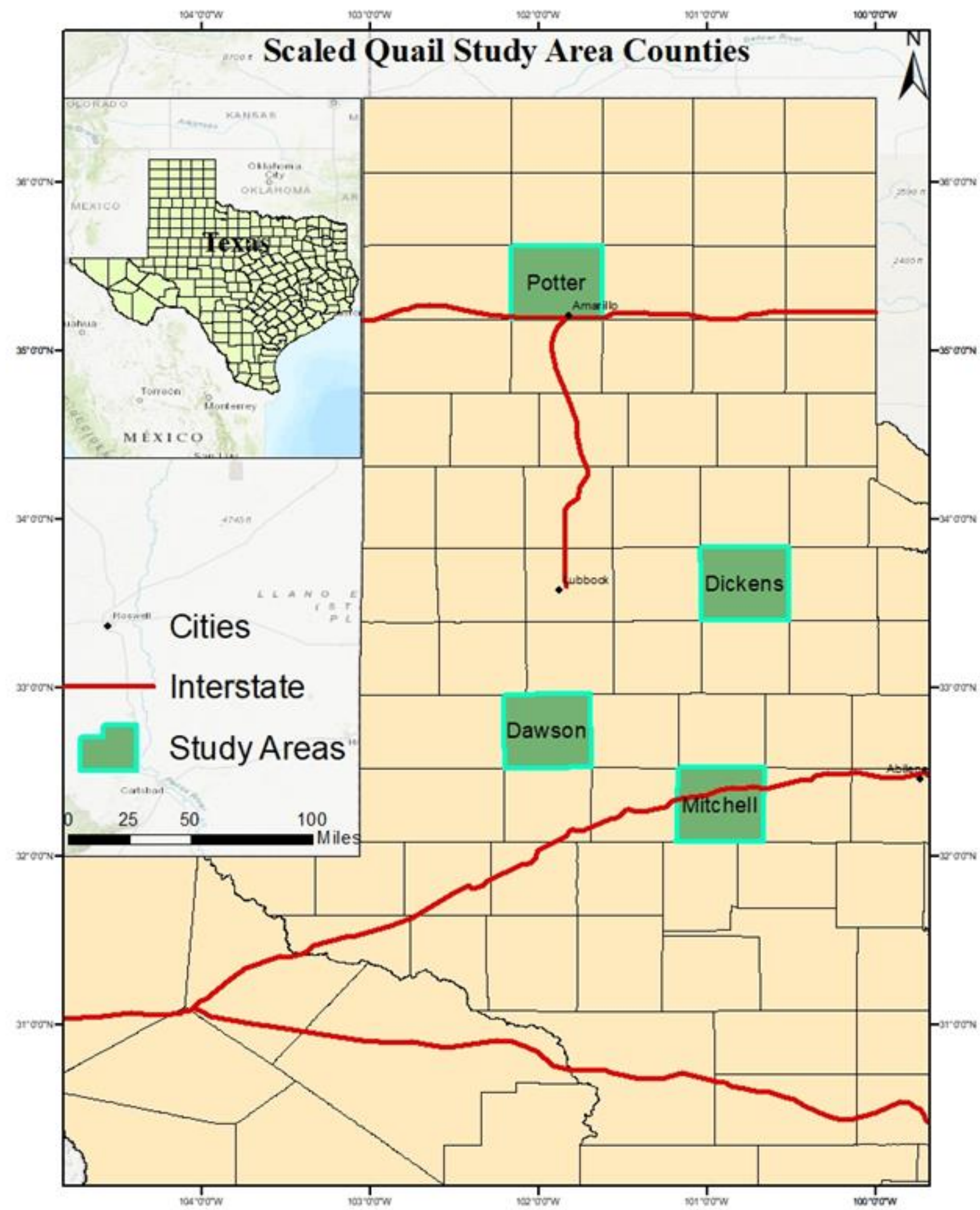

Figure 1.2. Scaled quail (*Callipepla squamata*) overwinter ecology study area map by county in the Texas Rolling Plains and Texas High Plains, Texas Rolling and High Plains, 2018-2020.

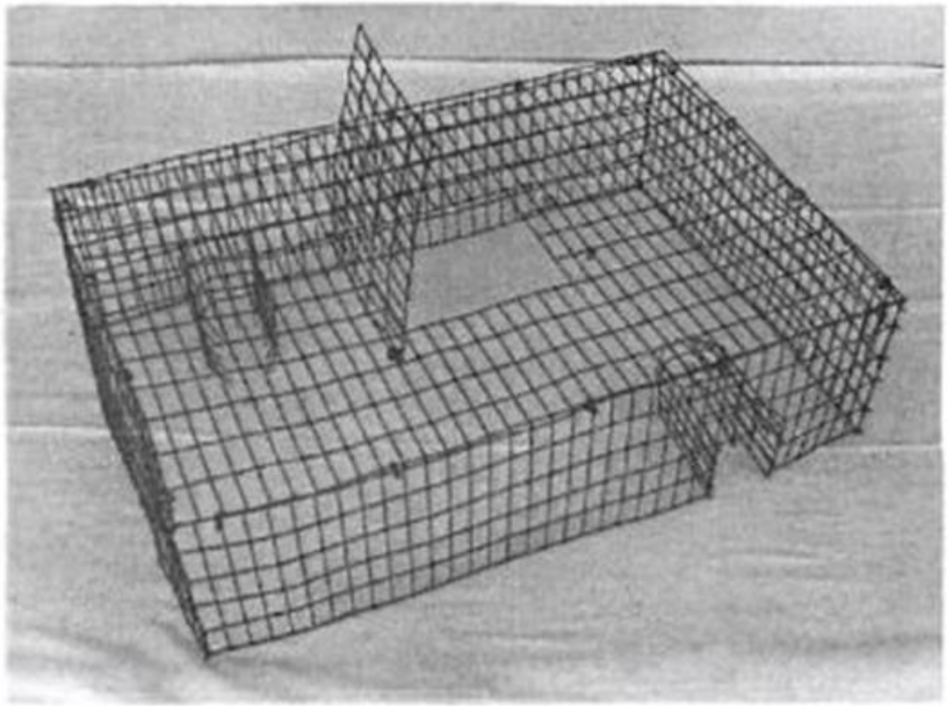

Figure 1.3. I used a modified Stoddard Funnel Trap to capture Scaled quail (*Callipepla squamata*) from September 1 to March 15, Texas Rolling and High Plains, 2018-2020. Figure is from Smith et al. (1981).

Figure 1.4. I differentiated Scaled quail (*Callipepla squamata*) by age using the 1-7 primary wing technique to assess daily survival based on age, from 1 Sept – 15 March, Texas Rolling and High Plains, 2018–2020 Figure is from Cain and Beasom (1983).

Figure 1.5. I attached backpack style solar powered GPS-transmitters on Scaled quail (*Callipepla squamata*) to obtain Brownian Bridge Contours to upload to the drone to estimate land use and land cover metric on stable and intermittent ranches, 2018–2020.

Figure 1.6. I used a SeneseFly Ebee drone to assess Scaled quail (*Callipepla squamata*) land cover and land use at multiple spatial scales from 1 October – 15 March, Texas Rolling and High Plains, 2018–2020 (Flight evolved.com/sensefly-ebee-drone. Accessed October 2019).

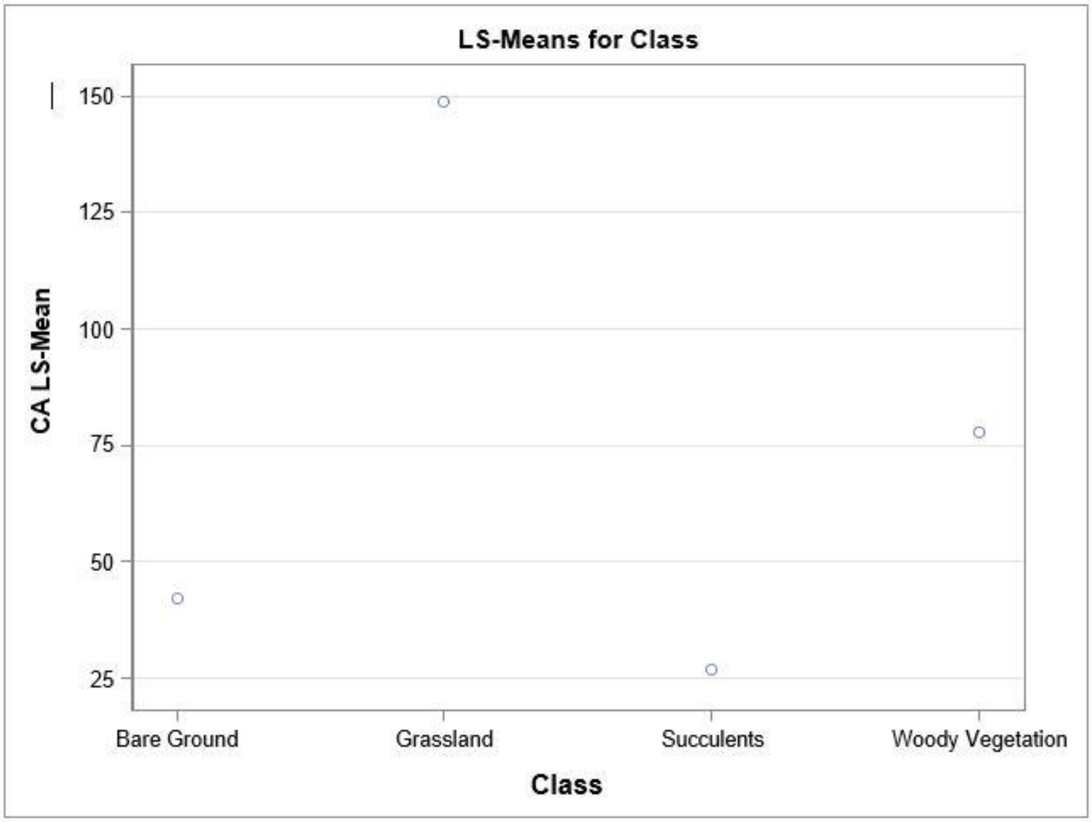

Figure 1.7. Class area (ha) for each vegetation type among all ranches used in this assessment.

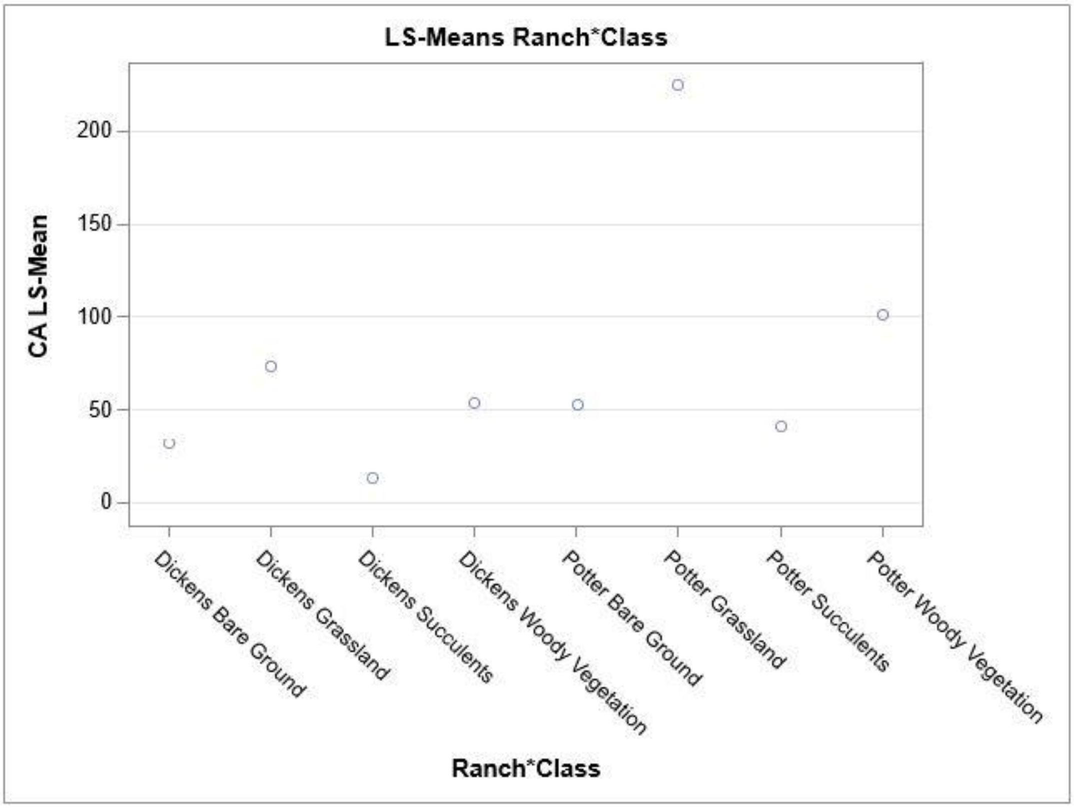

Figure 1.8. Class area (ha) for each vegetation type between ranches used in this assessment.

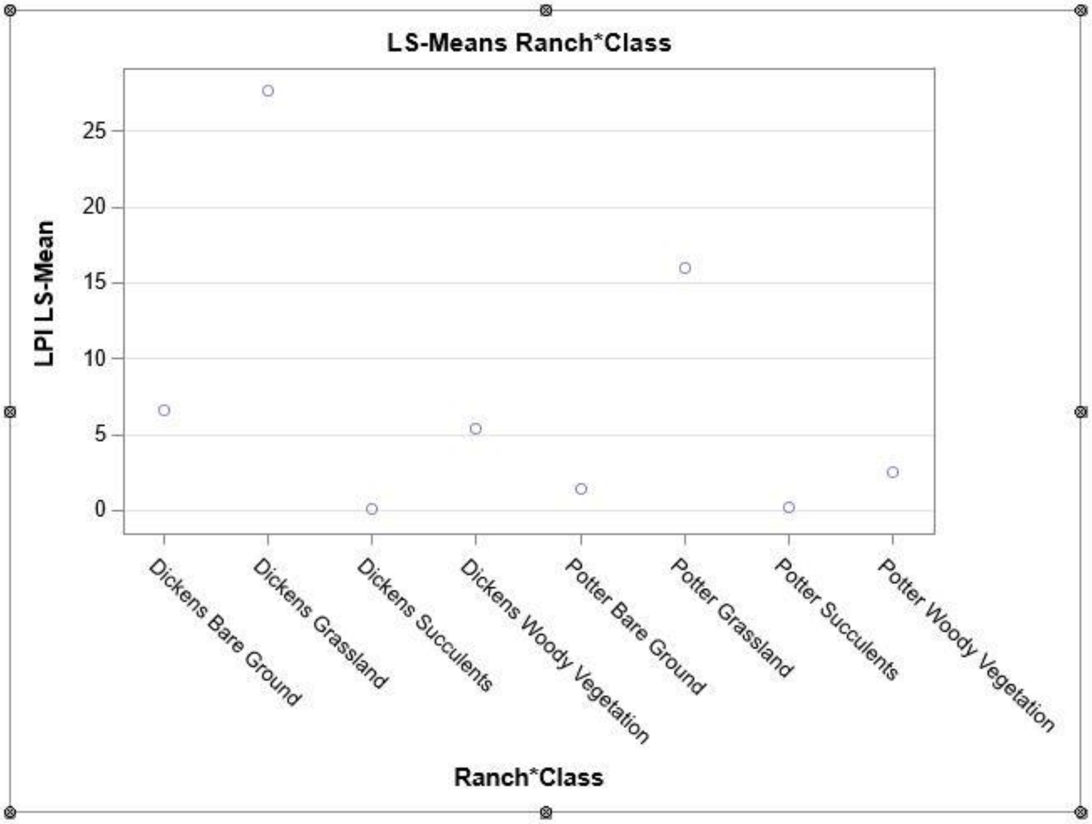

Figure 1.9. Largest patch index for each vegetation type between ranches used in this assessment.

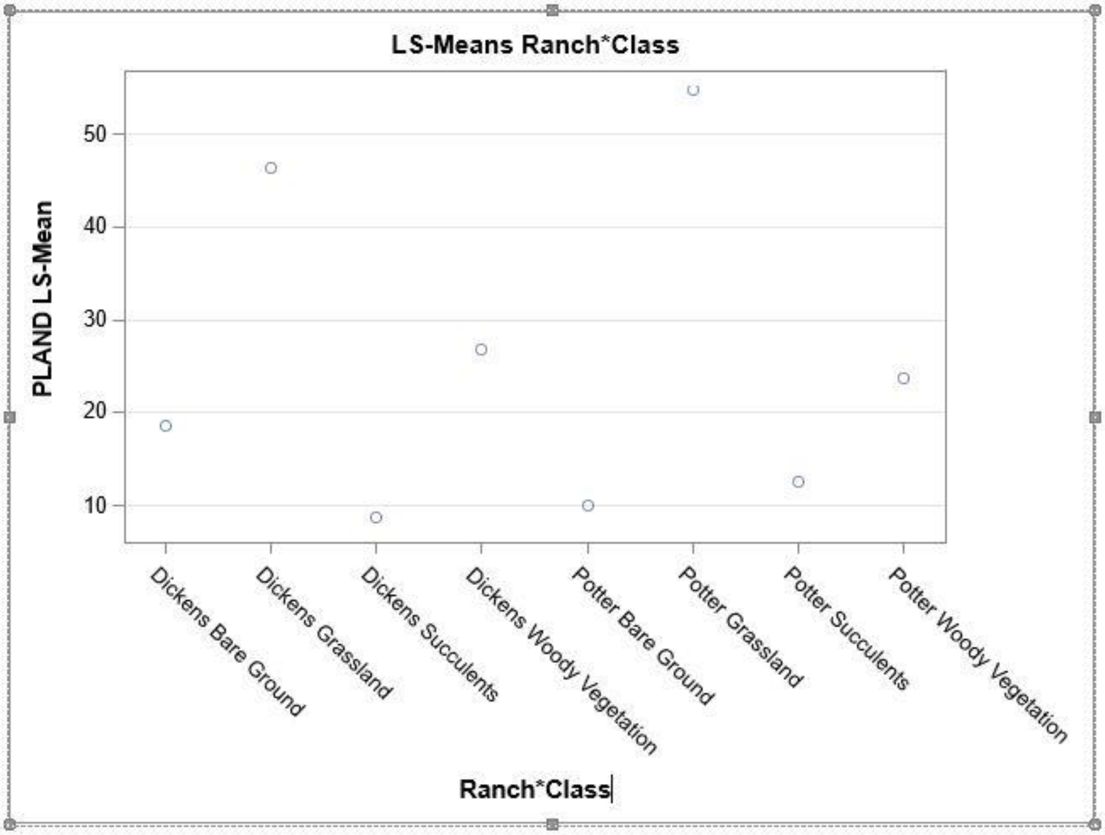

Figure 1.10. Percent landscape for each vegetation type between ranches used in this assessment.

Tables

Table 1.1. Summary data of generalized linear model ANOVA of class area (ha).

Analysis #1 - By Class Area					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Value**	**P-Value**
Model	7	61935.58	8847.94	2.49	0.11
Error	8	28461.27	3557.65		
Corrected Total	15	90396.85			

Table 1.2. Summary data of the class area (CA) diagnostic R-Square test.

Class Area R-Square Test			
R-Square	Coeff Var	Root MSE	CA Mean
0.68	80.64	59.64	73.95

Table 1.3. Analysis of class area (ha) composition among classes, between ranches, and among ranches.

Type III Sums of squares for class area (ha)					
Source	**DF**	**Type III SS**	**Mean Square**	**F-Value**	***P-Value***
Class	3	35420.13	11806.71	3.32	0.07
Ranch	1	15589.77	15589.77	4.38	0.06
Ranch*Class	3	10925.66	3641.88	1.02	0.43

Table 1.4. Summary data of Generalized Linear model ANOVA of Largest Patch Index (ha).

Analysis #2 - By Largest Patch Index (LPI)					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Value**	***P-Value***
Model	7	1298.97	185.56	1.18	0.40
Error	8	1261.33	157.66		
Corrected Total	15	2560.31			

Table 1.5. Summary data of Largest Patch Index (LPI) diagnostic R-Square test.

Largest Patch Index R-Square Test			
R-Square	Coeff Var	Root MSE	LPI Mean
0.50	167.15	12.55	7.51

Table 1.6. Analysis of largest Patch Index (LPI) composition among classes, between ranches, and among ranches.

Type III Sums of squares Largest Patch Inex (LPI) Analysis					
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	***P-Value***
Class	3	1127.95	375.90	2.38	0.14
Ranch	1	96.63	96.63	0.61	0.45
Ranch*Class	3	74.39	24.79	0.16	0.92

Table 1.7. Analysis of Largest Patch Index (LPI) Interactive Model between ranches by class

Largest Patch Index Interactive Model Analysis		
LID	Class	LPI LSMEAN
Dickens	Bare Ground	6.66
Dickens	Grassland	27.62
Dickens	Succulents	0.18
Dickens	Woody Vegetation	5.41
Potter	Bare Ground	1.40
Potter	Grassland	15.98
Potter	Succulents	0.24
Potter	Woody Vegetation	2.58

Table 1.8. Analysis of generalized equation estimator results for percent landscape among vegetation classes, between ranches, and by class and ranch interaction.

Analysis Of GEE Parameter Estimates Empirical Standard Error Estimates								
Parameter			**Estimate**	**Standard Error**	**95% CI**		**Z**	***P-Value***
Intercept			23.38	1.44	20.54	26.21	16.18	<.0001
Class	Bare Ground		-13.48	3.01	-19.39	-7.58	-4.48	<.0001
Class	Grassland		31	3.11	24.9	37.1	9.96	<.0001
Class	Succulents		-11.03	5.67	-22.17	0.09	-1.94	0.05
Class	Woody Vegetation		0	0	0	0	.	.
Ranch	Dickens		3.13	9.8	-16.03	22.4	0.32	0.74
Ranch	Potter		0	0	0	0	.	.
Ranch*Class	Dickens	Bare Ground	5.53	5.85	-5.94	17	0.94	0.34
Ranch*Class	Dickens	Grassland	-11.34	17.27	-45.21	22.52	-0.66	0.51

CHAPTER II

OVERWINTER CORE AREA AND HOME RANGE SIZE AND MULTIPLE SPATIAL SCALE HABITAT SELECTION OF SCALED QUAIL BETWEEN STABLE AND INTERMITTENT POPULATIONS

Abstract

Minimal consideration has been dedicated to scaled quail (*Callipepla squamata*) regarding environmental stressors and changes in landscape patterns and their influence on the species population demographics. Habitat characteristic preferences among quail species are generally consistent throughout their geographic range; however, quality of habitat differs depending on availability of site-specific resources and microclimate characteristics affecting habitat selection. Scaled quail (SCQU) habitats are associated landscape metrics with a variety of land cover types used by SCQU throughout their life cycle, requiring a heterogeneous landscape of interspersed habitats for nesting, brooding, escaping, food, and loafing. Simultaneous comparisons of habitat resource selection and microclimate are lacking for this species. The goal of this chapter was to quantify the overwinter spatial ecology of GPS-tagged scaled quail to better understand the fine-scale interactions between vegetation (including woody species) and microclimate that have not been incorporated into previous assessments of SCQU ecology. I had four objectives: 1) estimate core area and home range sizes using Brownian Bridge Movement Models 2) examine winter site selection using microclimate dataloggers at paired used (as determined by locations from GPS-tagged scaled quail) and random points to compare temperature and aridity 3) collect

vegetation structure and composition data at same used and random points as objective 2, and 4) conduct a multiple-spatial scale habitat select assessment for SCQU using data from chapter 1 and objectives 1, 2, and 3 here-in. My study occurred over 2 discrete winter field seasons from 1 October to 15 March, 2018-2019 and 2019-2020. I GPS-tagged 27 scaled quail on 2 study sites with stable populations (consistent annual occupancy) and 2 study sites with intermittent populations (inconsistent annual occupancy). I estimated core areas and home ranges from GPS locations using the 'BBMM' package in Program R. I estimated resource selection using land use land cover data collected from real time drone imagery, which I classified in the GIS programs FRAGSTATS and ArcMap and Resource Selection Function in Program R. I collected microclimate (relative humidity and temperature) every 10 minutes over a 14-day period using ibuttons. I selected point from SCQU GPS locations for microclimate sampling and paired each with a random point. I used microclimate data from 24 SCQU from two winter field seasons and converted relative humidity readings to vapor pressure deficit as a better indicator of aridity. Results from the microclimate analysis indicate that SCQU selected for warmer and dryer locations during winter.

I conducted ground vegetation surveys measuring woody tree species density, stems per hectare density, exotic plant species composition, visual obstruction reading (VOR) estimate using a Robel pole, and percent canopy cover using a Daubenmire frame from 100 selected GPS points and paired random points with >11,500 individual vegetation readings. I combined the ground vegetation surveys with drone imagery and GPS data to create land cover classified home ranges and core areas from Brownian Bridge Movement Models and quantified the land cover metrics in FRAGSTATS. I used a multi-design (Type II and III, respectively) to assess habitat selection at the 2^{nd} 3^{rd} and 4^{th} order. Core areas and home ranges did not differ by number of locations, number of days deployed, by ranches or between field seasons. The combined results indicated scaled quail selected overwinter habitat concomitantly at multiple spatial scales, the pattern of selection was consistent between stable and intermittent ranches, and temperature was a better predictor of habitat selection in winter compared to vegetation. There was no consistent pattern of vegetation selection at multiple spatial scales, which suggest scaled quail demonstrated flexibility among vegetation metrics when selecting habitat in winter. The post-hoc assessment indicated vegetation and microclimate interact to influence scaled quail habitat, and areas that were composed of more bare ground ($\beta = 27.48$) and woody vegetation ($\beta = 17.62$) were warmer, but inferences are limited due to limited sample size associated with microclimate data ($n = 27$ GPS-tagged scaled quail).

Introduction

Rolling Plains scaled quail (*Callipepla squamata*; hereafter SCQU) populations have declined 70% over the past forty years, with several factors including habitat loss/fragmentation, increased predation, and disease likely to explain the decline (Zornes and Bishop 2010). Throughout their range, SCQU historically experienced boom and bust cycles positively correlated with moderate annual precipitation (Peterson 2001, Bridges et al. 2001, Silvy et al. 2007, and Rho et al.

2015, TPWD 2020). Landscape pattern analysis from the 1970s through 1990s suggests that primary changes in habitat in the Texas Rolling Plains (hereafter TRP) were increased percent cover and a proliferated density of forest patches throughout the landscape along with a decrease of grassland cover (Rho et al. 2015, Fulbright et al. 2018). Landscape-level habitat loss impacts SCQU demographics and is believed to be the primary driver of population declines across most of their geographic range. Rho (2003) observed a decrease in grasslands and herbaceous rangelands from 53.9% to 44.6% in the TRP (Rho et al. 2015).

Scaled quail likely are negatively affected by habitat fragmentation resulting from woody cover encroachment, excessive grazing, and the disturbances following the subdivision and sale of land into small tracts for non-agricultural use, especially near cities as these changes reduce the availability of suitable habitat and lack sufficient connectivity of usable grasslands and savannas that can support SCQU (Asner et al. 2003, Rho et al. 2015, Frank et al. 2018). Scaled quail abundance is negatively correlated with increasing patch density and decreased patch size (Rho et al. 2015). For prey populations such as SCQU, fragmentation may have severe consequences because predators become more efficient as they achieve greater densities in these fragmented landscapes (Cottam et al. 2009). Depredation rates on birds are much greater in fragmented landscapes; as much as 52% of losses were attributed to mesocarnivores (Rollins and Carrol 2001) compared to larger habitat tracts, meaning nest survival/success rates were positively correlated to grassland habitat patch size (Heske et al. 1999). In the TRP, patch densities and sizes have decreased since the 1970s, likely creating small habitat patches unsuitable to support stable SCQU populations (Rho et al. 2015).

Scaled quail favor habitat that consists of grass patches and dense shrub divided by bare ground areas (TPWD 2006, Zornes and Bishop 2010, Brennan et al. 2017) . Large areas of bare ground are crucial in scaled quail movements (Hammerquist-Wilson and Crawford 1987). Smith et al. (1996) reported SCQU sightings are rare in areas dominated by dense stands of grasses such as black gramma (*Bouteloua eriopoda*) which obstruct SCQU mobility. However, quail were present in adjacent areas with heterogeneous vegetation components comprised of 33% bunchgrass (i.e., dropseed *Sporobolus* spp., bluestem *Andropogon* spp.), scattered shrubs (i.e., Lote bush (*Ziziphus obtusifolia*), catclaw acacia (*Senegalia greggii*), *Ephedra* spp.) and significant bare ground (Smith et al. 1996). Saiwana et al. (1998) examined SCQU use of different seral stage communities defined as high seral: dense stands of stoloniferous (horizontal creeping) grasses, mid seral: woody vegetation (i.e., honey mesquite) with bunchgrass species and shrub species, and low seral: mostly shrubs and honey mesquite. A study conducted on the Chihauhuan Desert Rangeland Research center reported more sightings of SCQU in low seral stage shrub land than in high seral grassland communities except in winter (Saiwana et al. 1998). Shrub grass mosaic habitat was an important factor to SCQU populations as fewer were observed in grassland communities near the climax suggesting those areas are less suitable habitat than mid seral communities dominated by shrubs and forbs (Saiwana et al. 1998). Habitat preferences among quail species outside of south Texas are generally consistent throughout their geographic range; however, quality of habitat differs depending on availability of site-specific resources affecting habitat use (Arthur et al. 1996, Bristow and Ockenfels 2006). Scaled quail selected habitats of sparse vegetation regardless of what region they are studied. Scaled quail exhibit plasticity in a variety of range conditions, however, Bristow and Ockenfels (2006) found that SCQU preferred grass canopy cover exceeding 26% and avoided areas with tree canopy cover over 10% (Brennan et al. 2017). Studies from the mid 1990's suggest SCQU selected for ranges in mid seral states based on sightings that were twice as high as sightings on late seral states (sightings were n = 16.2 vs 8.1 respectively; $p = 0.14$) after a 10-year above average precipitation period (Nelson et al. 1997, and Joseph et al. 2003).

Landscape metrics related to SCQU habitats are associated with a variety of land cover types used by SCQU throughout their life cycle. Scaled quail require a heterogeneous landscape of interspersed habitats for nesting brooding, escaping, food, and loafing cover types. Land cover patch types in the TRP and THP include shrubland, grassland-herbaceous rangeland, pasture-cropland, and forest patterns (Rho et al. 2015). Grassland-herbaceous rangeland is essential for the five cover types associated with SCQU in the TRP and THP (Rho et al. 2015).

The estimated home range of an animal is linked to its cognitive map, therefore understanding biological processes that affect location distributions is important in understanding the mechanistic, biological foundations of home-range behavior, (Powell and Mitchell, 2012). With the introduction of GIS and GPS trackers, the complexity of point and location data have become more refined. Minimum Convex

Polygon's (MCP) are traditional tools in assessing use; however, when joined with empirical and mechanistic models it can complement GPS and GIS data in analyzing the spatio-temporal factors that are used to determine home range (Kie et al.2010).

Habitat Use and Selection

Brood Cover

Brood habitat includes shallow soil with low grass cover and rough broken habitat (Tharp 1971, Silvy et al. 2007) with an abundance of high protein food sources. Chicks feed almost completely on insects within the first few weeks after hatch, then begin to consume large amounts of seeds and green vegetation. Scaled quail spend a significant amount of time in their brood habitat raising their chicks in close proximity of nesting cover. Good brood cover provides chicks protection from predators with adequate screening canopy cover (Pleasant et al. 2006).

Escape Cover

Scaled quail escape cover is an area that allows quail immediate protection from predators. Scaled quail are lower on the trophic level and a food preference of many species. When threatened, SCQU become motionless and assemble in a tight group then flush when danger is near. Using this flush defense method, 70% escape predators while the remaining 30% flee by foot by running for safety toward mesquite or non-shrub cover, this escape method was observed by researchers (TPWD 2006, Brennan et al. 2017). Quail survival is dependent on their ability to maintain food resources and relocate in order reduce exposure to predation.

Escape screening cover creates a visual obstruction that conceals quail from predators and is essential during extreme weather and harsh weather conditions. Foliage with a closed canopy and open base is a prime escape cover. Forbs such as broom weed (*Amphiachyris dracunculoides*), partridge pea (*Chamaecrista fasiculata*), and western ragweed (*Ambrosia psilostachya*) create excellent screening cover and also serve as an additional resource that quail depend on as these plants provide seed and attract insects (Ault et al 1983). Plants that require deeper soils occur on the lower elevations include, sand sagebrush (*Artenmisia filifolia*), walkingstick cholla (*Opuntia imbricate*), and yucca (*Yucca angustifolia*) provide additional escape and screening cover and are prolific in the TRP and THP (Schemnitz 1961, Arthur et al. 1996, Rho et al 2015, Brennan et al. 2017). Human structures have also been observed to provide extended form of escape cover (Schemnitz 1961, Brennan et al. 2017). Hatch (1975) observed that SCQU flushed along rivers primarily used boulders, dense brushes of skunk bush and patches of Soap weed *(Yucca glauca)* escape cover.

Roosting Cover

Comparisons from this study substantiate that roost sites in the TRP and THP typically occur in open grasslands with no overhead canopy away from high obstructive vegetation as a defense against nocturnal predation. Roosting vegetation structure is usually about 1 foot tall with no overhead canopy (Brennan et al. 2017). Moreover, in other studies of 70 different roost locations 69% were located in valley slopes and statistically 27% in rolling breaks (Stormer et al. 1984). Escarpments or steep breaks are not supportive of roosting habitat. Frequently identified lateral cover of roosts included forbs (predominantly yucca), and subshrubs like snakeweed (*Xanthocephalum sarothrael*) (Stormer et al. 1984). Stormer et al. (1984) found that although yucca was present in all extensive vegetation types with roost locations, it is the dominant species in the Texas-New Mexico border of the TRP study site vegetation areas, whereas mountain mahogany was present in 36% and Walking Stick Cholla was present in 76% of the site-specific vegetation types. Frequently, vegetation at roost sites, lateral cover was comprised of more than one type of vegetation with naïve grasses as the dominant lateral cover.

Loafing Cover

Scaled quail morning routines consist of feeding then moving to locations that can allow rest for digestion while providing safety from ground and aerial predators. Loafing cover is large in size and composed of dense brush of different vegetation combinations of lotebush (*Ziziphus obtusifolia*), honey mesquite (*Prosopis glandulosa*), plums (*Prunus spp*.) and sumac (*Rhus spp*.). Vegetation structures roughly the size of a small car (e.g., Volkswagen Beetle) are preferred loafing habitat of SCQU (Brennan et al. 2017).

Nesting Cover

Nesting habitat for SCQU is selected based on their thermal environments and their implications for successful reproduction. Neonate fitness is influenced by thermal environments that embryos are ultimately exposed to dictating nest site selection behaviors. Physical environment and landscape components can promote or constrain stages in reproduction. Scaled quail will use a variety of available vegetation structures and species given the appropriate visual obstruction. Pleasant et al. (2006) found that SCQU nest success was positively correlated with nest sites having sufficient cover and a visual obstruction of 0.5-0.75 m in height.

Nests are scratched out of prickly pear typically within their core area which is essential to surviving during the incubation period. Scaled quail build their nests in native grasses. Other nest preferences include lechuguilla (*Agave spp.),* sotol (*Dasylirion spp.)* and yucca (yucca spp.) (Silvy et al. 2007). Both male and female SCQU have been observed in gathering dead grass to line the nest. Males have also been observed to assist in incubation to an unknown extent (Brennan et al. 2017). Nests range from 5-22 eggs, incubation ranges an average of 22 days (Brennan et al. 2017). Approximately 3 days after hatching SCQU will move their broods near water. Most nest failures were credited to human interference linked to agricultural activities however, more recent studies suggest that predation is the principal source of nest failure (Schemnitz 1961, Rollins and Carroll 2001, Brennan et al. 2017).

Surface texture of soils in the TRP and THP range from clays, loams, to pockets of fine sands and varying acidic and calcareous properties (Rho et al. 2015). The soil in the rolling plains vary from tight clay, shales to very coarse sands. Texas High Plains and the TRP are dominated by farmland or a combination of ranching and livestock. Shortgrass prairie is the dominant native vegetation in the TRP and THP. The most common invasive species is honey mesquite, contributing to the rolling plains description of mesquite-shortgrass savanna (http://txwildlifealliance.org/recovering-america-s-wildlife-act/texas-ecoregions.html.Accessed 6 January 2020).

The differences in annual and regional precipitation significantly impacts breeding and overall SCQU demographics and abundance (Wallmo et al. 1958, Schemintz et al. 1961, Brown 1969, Campbell et al. 1973, Giuliano 1993, Bridges et al. 2007, Silvy et al. 2007). During drought years there is less recruitment which decreases the overall population over time. Precipitation averages for the THP and TRP range from 36 – 76 cm annually with the most rainfall between April and September (http://txwildlifealliance.org/recovering-america-s-wildlife-act/texas-ecoregions.html.Accessed 6 January 2020). Predator efficiency is amplified in semiarid environments where microbial growth is increased resulting in quail scent production (Pleasant et al. 2003).Pleasant et al. (2003) studied SCQU in the Southern High Plains and concluded moisture-facilitated depredation hypothesis was not supported by their data however brood loss was related to cool wet weather. Precipitation further affects vegetation growth leading to changes in microclimate.

The thermal ecology of the species is fundamentally unknown despite substantial efforts to conserve SCQU and their habitats, and information for predictive modeling of the role habitat structure may have on the thermal ecology of the species is scarce. Scaled quail are efficient at evaporative cooling and dissipating metabolic heat at temperatures up to 40° C without the use of gular fluttering as seen in similar ground nesting birds of semiarid and arid ecoregions (Henderson 1971). Scaled quail have been observed to respond to thermal stress by dusting their bodies under shaded trees (Schemnitz 1961, Brennan et al. 2017).

Although many factors have been suggested to contribute to the decline of SCQU, they are still not well understood. The goal for this research was to quantify the fundamental mechanisms that shape habitat use and selection influenced by microclimate and vegetation structure conditions as well as compare home range and core area sizes at multiple spatial scales and assess habitat use and selection between intermittent and stable populations. Therefore, understanding the role of environmental stressors on SCQU influencing habitat selection may identify fine-scale interactions between vegetation and microclimate that have not been incorporated into previous assessments of SCQU ecology.

My first objective is to estimate core area and home range sizes using Brownian Bridge Movement Models. I define stable populations as those that occur in relative abundance inhabiting large grassland tracts where the percentage of woody cover is relatively low, whereas intermittent populations we define as small groups or individual coveys expanding and contracting during periods of precipitation and drought and inhabiting small, isolated tracts with suitable cover however, unlikely to support the expansion and growth of the population. I predict SCQU in intermittent populations will have larger home ranges compared to those in stable populations, because of the need to travel farther to meet their daily and seasonal requirements to survive and reproduce. Throughout their range, the largest abundance of SCQU were observed in open grasslands larger than 250 hectares with low percentage of shrub coverage ranging between 10-15% (Brennan et al. 2017). In the THP and TRP, and Chihuahaun Desert SCQU high abundances were observed along creek beds, river edges, and canyons with low thorn scrub vegetation (Silvy et al. 2007, Zornes et al. 2010, Williford et al. 2014, and Brennan et al. 2017). Schemnitz (1961) observed SCQU movements of up to approximately 20 hectares and varying from 9.7 to 34 hectares (24 to 84 acres) during the winter months. Other similar studies have shown average daily movements of winter coveys (small flock of SCQU) ranging between 60.7 to 303.5 hectares fluctuating based on winter severity (Wallmo 1956).

My second objective is to deploy microclimate dataloggers at paired used (as determined by locations from GPS-tagged scaled quail) and random points to compare temperature and aridity in winter. I predict SCQU will select for habitat based on structural and thermal features. Plant species vary throughout the geographic distribution of SCQU, therefore evaluating habitat and microclimatic features provide information on interactions that influence habitat use (Guthery et al. 2001). Studies indicate that during the winter months scaled quail movements occur within approximately 20 ha with variations from 10 to 34 ha (Schemnitz 1961). Similar studies in western Texas indicated average daily movement occur within a 65 ha area, with winter covey movements up to 303 ha (Wallmo 1956). Summer months revealed dispersal from winter home ranges and individual SCQU movements did not exceed 3200 m (Wallmo 1956).

My third objective is to collect vegetation structure and composition data at same used and random points as objective 2. I predict that composition at used points will be different compositionally than at random points. Habitat selection varies depending on quality and availability of specific resources within their geographic range, however, SCQU are generally consistent when selecting for structural features that provide cover from predators and the elements (Arthur et al. 1996, Bristow and Ockenfels 2006).

My fourth objective is to conduct a multiple-spatial scale habitat selection assessment for scaled quail using data from chapter 1 and objectives 1, 2, and 3 here-in. I predict that SCQU will select resources differently between and among stable and intermittent population sites.

Study Area

I monitored SCQU on four study sites, two with stable populations and two with intermittent populations throughout the Texas Plains ecoregions. Sites with stable populations include a ranch in Potter County, a ranch in Dawson County, and the two study sites with intermittent populations include a ranch in Dickens County as well as a ranch in Mitchell County.

The ranch in Potter County is in the Texas Rolling Plains, north of Amarillo in the Canadian Breaks portion of the Rolling Plains ecoregion. This ranch is primarily used for cattle and horse grazing and oil production. Soils classes on this ranch include Acuff-PaloDuro-Olton, Mobeetie-Tascosa, Veal-Mobeetie, Weymouth-Vernon, and Likes-Tivoli, these are a mix of loamy, clayey, calcareous and non-calcareous soils (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The Vegetation community consists of native grasses and woody shrubs. Although mostly shortgrass rangeland, this site consists of patches of shrubs, trees and succulents such as prickly pear (*Opuntia spp*.) and walking stick cholla (*Cylindropunta imbricata*). This site is known for year-round supplemental feeding of milo on maintained roads throughout the year which may be a factor in high abundance observations.

The site in Dawson County study site is located east of Lamesa Texas which bisects the Caprock Escarpment, which forms the boundary between the Rolling Plains and Southern High Plains ecoregions. This study site is primarily used for cattle grazing. Soils on this site include: Alibates loam, Ady fine sandy loam, Amarillo fine sandy loam, Acuff sandy clay loam, Midessa fine sandy loam, Plemons loam, Portales loam, Veal loam, and Vernon clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this ranch consists of native grasses and woody shrubs and forbs along with patches of trees and succulents such as prickly pear and walking stick cholla.

The Site in Dickens County is located near the town of Spur Texas in the western Rolling Plains ecoregion. This ranch is also primarily used for cattle grazing. The soils on this ranch include: Abilene clay, Colorado loam, Latom gravelly fine sandy loam, Mansker loam, Miles fine sandy loam, Olton clay loam, Veal fine sandy loam, Vernon clay loam, and Weymouth clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this study site consists of native grasses and woody shrubs (e.g. yucca (*Yucca filamentosa*), lote bush (*Ziziphus obtusifolia*), catclaw acacia

(*Senegalia greggii*) and forbs along with patches of trees and succulents such as prickly pear and walking stick cholla.

The Mitchell County ranch is just south of Colorado City, Texas located in the southwestern Rolling Plains. This ranch is used for farming and grazing. The soils on this study site include: Burkreek loam, Miles fine sandy loam, Colorado loam, Snyder loam, Sagerton clay loam, Pyron clay loam, Spade fine sandy loam, Spade-Latom fine sandy loam, Stamford clay, and Vernon clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this study site consists of native grasses and woody shrubs (e.g. yucca, lote bush, catclaw acacia) and forbs along with patches of trees (e.g. honey mesquite, soapberries (*Sapindus saponara*), and Junipers) and succulents such as prickly pear and walking stick cholla.

The High Plains and Rolling Plains regions are the southern end of the Great Plains of the central United States. The Rolling Plains occurs just below the level plateau of the High Plains Caprock separated by steep slopes and canyons that comprise the escarpment transitions between the two ecoregions. Formation of the Texas Plains ecoregions is a result of alluvial deposits from Rocky Mountain River origins (Modala et al. 2017). Elevations for the High Plains range from 914 m to 1.37 km above sea level whereas rolling plains elevations range from 243 m to 914 m above sea level. Average annual rainfall for the High Plains is between 36 to 61cm inches, slightly lower than the 46 to 76 cm average annual rainfall seen in the Rolling plains (Modala et al. 2017).

Methods

Capture

To collect SCQU geospatial data for this analysis, I captured SCQU using modified Stoddard quail funnel traps (Smith et al. 1981, Figure 3). The traps are built with 14-gauge, 2.54 cm x 5.08 cm galvanized mesh wire. Using a 122 cm x 30.5 m roll, roughly twenty 61 cm x 61 cm x 20 cm funnel traps can be assembled. Funnel traps were hinged together with J hooks in order to collapse the traps for ease of transport and storage. Trap locations were selected based on SCQU sightings and suitable habitat containing the various cover types. Traps were then placed in areas with substantial loafing or escape cover such as shrubs, trees, and succulents.

Funnel traps were baited with milo and covered with available surrounding vegetation to reduce thermal stress and to reduce risk of predation. Traps were set at or before sunrise, checked at solar noon and again at sundown. Once checked, traps were flipped over to prevent inadvertent overnight captures of target and non-target species. All non-target species were immediately released upon arriving to the trap. Captured SCQU were removed from traps and placed into mesh bird bags and taken to the field vehicle to be processed. All birds were trapped under the authority of a Texas Parks and Wildlife Department Scientific Collecting Permit and processed within 30 minutes of being removed from the trap as per Texas Tech University Institutional Animal Care and Use (Protocol No. 19007-01)

Captured SCQU were fitted with aluminum butt-end leg bands (National Band and Tag Co., No. 8 bands, Newport, KY.) on the left leg of each bird and location (Universal Transverse Mercator Coordinate System; UTM) at the capture site along with age, sex, wing cord (mm), weight, time of capture, and date of capture were recorded. Gender was determined using the (Wallmo 1956) technique by identifying the absence or presence of longitudinal streaking down the throat accompanied with a dirty bluish grey color associated with females. Juveniles were differentiated from adults by examining the tips of the 1-7 primary wing coverts whereas sub adults older than twenty weeks display a buff-colored edge while adult primary tips were all gray (Cain and Beasom 1983, Smith et al. 1984, Figure 4).

GPS Monitoring

The advanced GPS transmitters used in this study provide precision instrumentation to overcome temporal and spatial scale issues restricted by VHF technology and field observer limitations. I collected fine-scale habitat selection data from sampled SCQU at each site using Ecotones PICA 5.5 gram solar powered backpack style data loggers (hereafter GPS). The Ecotone Pica solar powered GPS store on board data logger (Ecotone, Gdynia, Poland) was attached using a backpack style attachment on at least one SCQU per captured covey (Hansen et al. 2014). The backpack data loggers were fixed with 2.0 gram VHF (American Wildlife Enterprises, Monticello, Florida, USA) piggyback transmitters for retrieval. The GPS units had a reflective solar panel with an area of approximately 3.08 cm^2. The weight of the combined GPS and VHF ranged between 7.9 g – 8.9 g which was below the 5% body mass limit on tagged birds weighing ≥165 g. I fit the GPS to the SCQU using black elastic string allowing a ~1.3 cm space between the bird’s back and the transmitter to allow the wings to move freely and sill snug enough to remain attached to the bird during flight or moving through dense brush. The GPS loggers were remote user programmable to allow for selection of location intervals, number of positions recorded during each interval, maximum time for the GPS to attempt a location (work time limit), and the time frame in which the logger recorded each day. Data collection settings were loaded and transmitted to the data loggers using the Ecotone Tracker version 20181124 software. The data loggers were set to collect SCQU one location at one-hour intervals and programmed to shut off at night during roosting in order to preserve battery voltage in low light hours.

I deployed 10 GPS data loggers on SCQU throughout each field season at each study area. After a period of fourteen days, the data loggers were retrieved via telemetry, hand nets, and spotlights. Given the SCQU's affinity for running rather flushing, the retrievals were significantly more efficient at night. Once the initial roosting covey was broken up, individual tagged birds could be held in place with a spotlight upon locating the bird. After manually retrieving a tagged bird the data logger was removed and the bird was evaluated for signs of injury or distress. No manual recaptures resulted in mortalities and likewise showed no signs of injury. Geospatial locations were downloaded using an Ecotone P5-2xSD Base station and Ecotone logger analyzer 271216 software. I converted locations from the GPS to .csv and .kml files, then uploaded the .kml file into eMotion 3.5.0 (senseFly SA, Route de Genève 38, 1033 Cheseaux-sur-Lausanne, Switzerland) drone flight software to create flight paths over used GPS location areas. I then deployed the drone over each study area to photograph the use areas at 3.0 mega pixel resolution.

Drone Mapping

See Chapter 1 for field methods.

Vegetation Sampling

I quantified vegetation structure using a variety of metrics and sampling techniques: woody tree species density, stems per hectare density, exotic plant species composition, visual obstruction reading (VOR) estimate using a Robel pole, and percent canopy cover using a Daubenmire frame to at 2 selected locations and 2 random locations for each GPS-tagged SCQU for the first winter field season. I sampled 100 individual selected and random points for the stable and intermittent population sites over 2 winter field seasons and collected >11,500 individual vegetation readings. I changed the vegetation sampling from 2 selected and 2 random points to 3 selected and 3 random points for the second field season for more robust data collection as well as to mitigate for ibutton failures. I randomly selected used locations from SCQU GPS points and paired them with random points using a free-floating dial spinner. Field technicians were instructed to spin the dial for a directional heading, walk 15 m in that direction then spin the dial once more and proceed another 15 m with the new heading and begin the randomly selected vegetation analysis in that location.

I conducted vegetation habitat sampling at used and random paired locations and all Daubenmire measurements were collected at 5 m, 10 m, and 15 m intervals to account for GPS error for each location downloaded from the GPS unit. I used a modified 30.5 cm square Daubenmire frame to estimate the percent ground cover of grass, shrubs, forbs, litter, and bare ground (Daubenmire 1959) at the center GPS point, and intervals above, and in each cardinal direction. I measured the tallest plant within each Daubenmire frame to assess the vegetation structure (cm).

For consistency, each litter measurement was recorded in the northwest corner of each Daubenmire frame. Within each 15-cm square quadrant of the Daubenmire frame, I also inventoried the overall woody vegetation species as well as recorded any exotic and succulent species. I estimated VOR at each survey location using a Robel pole at a distance of 4 m from the center with eye-height at ~1 meter (Robel et al. 1970). I recorded visual obstruction at 100% and 0% intervals, where 0% was the location on the Robel Pole that was completely blocked by vegetation (recorded to the nearest dm), and 100% was the location on the Robel Pole where the tallest piece of vegetation was located (recorded to the nearest dm).

Microclimate

Microclimate data were collected at each vegetation survey location using Maximum Integrated Semiconductor data loggers (otherwise known as and here after ibutton; Maximum Integrated Products, Sunnyville, CA). I used the microclimate data to assess the interactive effects of temperature, aridity, and woody vegetation influence on SCQU habitat selection. I programed ibuttons to record relative humidity and ambient temperature every 10 minutes for 14 days. I deployed ibuttons at selected and random paired locations where the fine scale habitat data were collected. Time and date were recorded during the deployment and retrieval of each ibutton.

I attached ibuttons on 15.24 cm steel spike fasteners with clear quick drying all weather adhesive so each sit exactly the same way at the soil surface. Each spike was carefully driven into the ground, so as not to dislodge the data logger, at exactly 12.7 cm relative to the body mass surface area of the adult SCQU. I placed the spike and ibutton at point center of each selected and random location. Ibuttons from each replicate vegetation survey sight were retrieved approximately 14 days from initial date of deployment. After retrieval I downloaded relative humidity and temperature data and exported each to a .csv file for statistical analysis. Techniques for ibutton microclimate data analysis were derived from Grisham et al. (2016). I calculated the vapor pressure deficit (VPD), the difference between the amount of moisture in the air and how much moisture the air can hold when saturated (mmHG), by using the paired temperature and relative humidity measurements from each data logger (Anderson 1936). Vapor pressure deficit is a better measure of aridity than relative humidity, which is not a reliable measure of atmospheric moisture unless the temperature and relative humidity measurements are identical (Anderson 1936).

Data Analysis

Microclimate

I compared empirical distribution functions (EDF) of temperature and VPD for used and random locations. An empirical distribution function is the distribution of the cumulative data points in the sample that converge to a probability of 1 (Zar 2010). I used a Kolmogorov-Smirnov test to assess differences in empirical distribution functions for temperature and VPD for each comparison. For each assessment, I reported the asymptotic Kolmogorov-Smirnov statistic (KS_a), the maximum deviation (MD), and the percentage of observations that fell to the left of the MD. The MD was the value that maximized differences in the empirical distribution function among parameters. A greater proportion of observations to the left of the MD for temperature meant that the distribution function is cooler. Conversely, more observations to the left of the MD for VPD meant that the distribution function is more arid. I ranked temperature EDFs between used and random for the daylight hours only (defined as 0600–1800). I ranked VPD EDFs between used and random for the daylight hours only (defined as 0600–1800).

Home Range

Locations from GPS-tagged SCQU were used to establish utilization distributions (UD) and model home ranges at the 2nd order of habitat selection (Johnson 1980) using Brownian Bridge Movement Model (BBMM) in program R (Horne et al. 2007, Nielson et al. 2015). I defined core areas and home ranges as 50% and 90% contour isopleths from the BBMM, respectively. I used a generalized linear model using PROC GLM in SAS 9.4 to assess if core area and home range sizes (response variables) were a function of the number of GPS-locations collected per scaled quail, the number of days each scaled quail was equipped with the GPS-tag (predictor variables). I used a student's t-test to assess if core area sizes differed between field seasons (2018–2019; 2019–2020) and stable and intermittent ranches after assessing for equality of variances.

Drone Imagery

Results from this analysis are included in Chapter 1.

Land Use Land Cover Classification

I used the methods from chapter 1 to classify drone images of used habitat at intermittent and stable population sites. I used the 50% and 90% isopleths to quantify land cover metrics in ArcGIS. I overlaid the 50% and 90% polygons for each SCQU over the classified raster images and clipped the data from the classified raster images and input them into FRAGSTATS.

Habitat Selection

For this assessment, I used a multi-design (Type II and III, respectively) study per Manly et al. (2002) to assess habitat selection at the 2nd, 3rd, and 4th orders (Johnson 1980). For the second order habitat selection the used data were from percent total area observed in each class (1-Succulents, 2-Bare Ground, 3-Shrubland, 4-Grassland, and 5-Woody Vegetation) within the home range for each GPS-tagged SCQU and available data were percent total expected in each class among the combined landscape images from all GPS-tagged SCQU for each ranch (Type II Design). The used (home range) and available (landscape level) data are included in detail in Chapter 1. I used a generalized estimation equation in PROC Genmod in SAS 9.4 to assess if each classification was used more or less than expected within each home range among the combined classified images for each ranch (landscape level). I included ranch, GPS-tagged SCQU and vegetation classification as categorical predictor variables and the response variable was the percent observed used classification types within each home range for each GPS-tagged SCQU. Alpha was set at 0.90 and I considered predictor variables significant if the 90% confidence intervals did not overlap zero for each parameter.

For the third order habitat selection the used data were from percent total area observed in each class within the core area for each GPS-tagged SCQU and available data were percent total expected in each home range among the individual home ranges from GPS-tagged SCQU for each ranch (Type III Design). The used (core area) and available (home range) percent area data are included in detail in Chapter 1. I used a generalized estimation equation in PROC Genmod in SAS 9.4 to assess if each classification was used more or less than expected within the core area compared to each respective home range. I included ranch, GPS-tagged SCQU, and vegetation classification as categorical predictor variables and the response variable was the percent observed used classification types within each home range for each GPS-tagged SCQU. Alpha was 0.90 and I considered predictor variables significant if the 90% confidence intervals did not overlap zero for each parameter.

For the fourth order habitat assessment I used the vegetation survey data obtained from GPS-tagged SCQU as the used data, and the random point data for the available data. I used a type III selection design and assessed habitat selection at the fourth order using a logistic analysis of covariance in PROC Glimmix in SAS 9.4. I incorporated ranch and bird ID as categorical variables and visual obstruction at 0%, percent ground cover of grass, shrubs, forbs, litter, and bare ground, density of woody vegetation, and maximum percent deviation from mean empirical distribution for temperature and VPD, maximum temperature, minimum temperature, average temperature, maximum VPD, minimum VPD, and average VPD derived microclimate parameters as predictor variables. To obtain the derived microclimate parameters I used PROC Means in SAS 9.4 to obtain summary statistics for temperature and VPD for each GPS-tagged SCQU, sample (1^{st} or 2^{nd} vegetation survey), and used or random point. I used PROC npar1way to obtain maximum percent deviation from mean empirical distribution for temperature and VPD.

I used each GPS-tagged SCQU, sampled, and used or random point as class variables. The response variable for this analysis was used (1) or random (0) and I treated each bird as the random effect to control for variation among individuals and how each selected habitat. I developed resource selection functions using a stepwise approach in a hierarchical modeling framework in program SAS, where each variable was removed and then allowed to stay in the analysis if $p > 0.35$ upon entry. I conducted three separate stepwise logistic regression models, the first only incorporated vegetation data, the second only incorporated microclimate parameters, and the third combined the top preforming variables from models 1 and 2 to assess habitat selection among the top preforming microclimate and vegetation metrics, respectively. I incorporated the log-transformed visual obstruction at 0%, averaged arcsine-transformed percent ground cover of grass, shrubs, forbs, litter, and bare ground (averaged among all four cardinal directions at 0, 5, 10, 15 m), and density of woody vegetation as predictor variables for model 1. I averaged the canopy cover data to avoid over-parameterizing the model and to account for percent canopy cover at point center as well as the entirety of the sampled location. I incorporated the maximum percent deviation from mean empirical distribution for temperature and VPD, maximum temperature, minimum temperature, average temperature, maximum VPD, minimum VPD, and average VPD derived microclimate parameters as predictor variables for model 2. Predictor variables for model 3 are reported in the results. Alpha was 0.90 for all modelling efforts and I considered the predictor variables significant if the 90% confidence intervals did not overlap zero for each parameter.

Results

Capture

Due to the small populations of SCQU on the majority of the ranches, I only completed the project tasks on two sites, one intermittent (Dickens County) and one stable population site (Potter County). I captured 187 SCQU from four ranches over two winter field seasons 110 SCQU in 2018-2019 and 77 in 2019-2020. I deployed 41 GPS units and over the two winter field seasons, 20 GPS units in 2018-2019 and 22 units in 2019-2020.

Home Range and Core Area Estimation

I created 27 individual core areas (50% BBBM Isopleths) and home ranges (90% BBMM Isopleths) from 27 GPS-tagged SCQU. My results for core areas and home ranges did not differ based on number of locations (Tables 2.1 and 2.2), number of days deployed (Tables 2.1 and 2.2; Figures 2.1 and 2.2), did not differ by ranches (Tables 2.3 and 2.4; Figures 2.3, 2.4, 2.5, 2.6), or between fields seasons (Tables 2.5 and 2.6; Figures 2.7, 2.8).

Microclimate

I compared the distribution of temperature and VPD data from random and selected points (n = 12 GPS-tagged SCQU, $\overline{\mathrm{X}}$ $\text{microclimate points} = 1514, \text{range} = 1340 - 1559$). The maximum temperature value was 12.1 degrees with 16% of random locations occurring to left of maximum EDF and 9% of selected locations occurring left of maximum EDF (Figure 2.9). The maximum VPD value was -11.1 with 56% and 66% of random locations and selected locations, respectively, occurring left of maximum EDF (Figure 2.10). These results indicate that SCQU selected for warmer (KS_a = 5.71, p < 0.001; t_{35267} = -13.15, p < 0.001; Figure 2.11) drier locations in the winter (KS_a = 9.65, p < 0.001; t_{34315} = 23.62, p < 0.001; Figure 2.12).

Second Order Resource Selection

Vegetation classification types within the home range were used disproportionately to their availability on the landscape ($X^x_{df=4} = 225.88; p < 0.001$), but SCQU did not select or avoid any one classification type (Table 2.7) within their home range as indicated by 90% CIs. However, SCQU did not select or avoid any one classification in winter and this result was consistent between stable and intermittent ranches ($X^x_{df=8} = 245881; p < 0.001;$ Table 2.8).

Third Order Resource Selection

Scaled quail (*n* = 27) used vegetation classification types within the core area disproportionately to their availability in the home range ($X^{x}_{df=4} = 75{,}570; p < 0.001$), but SCQU did not select or avoid any one classification type (Table 2.9) within each core area based on 90% CIs. Scaled quail (*n* = 27) also did not select or avoid vegetation classification types in winter within the core areas in respect to home ranges between stable and intermittent ranches ($X^{x}_{df=8} = 245881; p < 0.001;$ Table 2.10).

Fourth Order Resource Selection

Model One -- Model one was statistically significant ($X^{x}_{df=4} = 10.40; p = 0.3$), and all variables were included in the final model as product of the stepwise approach. Scaled quail selected for vegetation composition and structure, specifically, SCQU habitat selection was positively correlated with percent woody vegetation and visual obstruction at 0% (Table 2.11).

Model Two -- Model two was not statistically significant ($X^{x}_{df=7} = 12.84; p = 0.8$), and all variables were removed in the final model as product of the stepwise approach. Scaled quail did not select for any derived microclimate parameter because the intercept only model was the most supported in the stepwise approach. (Table 2.12).

Model Three -- Among all microclimate parameters, maximum percent deviation from mean empirical distribution for temperature was the most supported in model two, but it did not have a significant impact on SCQU habitat selection (Table 2.12). However, I incorporated it into the final model to assess if vegetation and temperature influenced selection concurrently. Model three was statistically significant ($X^x_{df=5} = 101.42; p < 0.001$), and all variables were included in the final model as product of the stepwise approach. Scaled quail selected for maximum percent deviation from mean empirical distribution for temperature (Table 2.13) instead of vegetation metrics, which suggests 1) microclimate is a better predictor of fine scale habitat selection in winter for scaled quail, 2) SCQU selected for warmer locations at fine scale, and 3) distributions are a better metric of microclimate descriptors compared to point estimates.

Post-Hoc Interactive Assessment -- I conducted a post-hoc interactive assessment to assess if vegetation metrics and maximum percent deviation from temperature EDF interactively influenced SCQU habitat selection, and this model was statistically significant (($X^x_{df=4} = 16.16; p = 0.003$). Percent litter and visual obstruction did not interact with temperature to influence selection, but percent bare ground and woody vegetation interactions with temperature were significant predictors of selection (Table 2.14).

Habitat Selection Results Among Assessments--The combined results indicated SCQU selected overwinter habitat concomitantly at multiple spatial scales, the pattern of selection was consistent between stable and intermittent ranches, and temperature was a better predictor of habitat selection in winter compared to vegetation. There was no consistent pattern of vegetation selection at multiple spatial scales, which suggest scaled quail demonstrated flexibility among vegetation metrics when selecting habitat in winter. The post-hoc assessment indicated vegetation and microclimate interact to influence SCQU habitat, and areas that were composed of more bare ground ($\beta = 27.48$) and woody vegetation ($\beta = 17.62$) were warmer, but inferences were limited due to limited sample size associated with microclimate data ($n = 12$).

Discussion

In this study, core areas and home ranges did not differ between stable and intermittent SCQU populations, nor between field seasons. The spatial models I compared were valid because model size was not influenced by number of days or locations. My results did not support my initial hypothesis that SCQU in intermittent populations have larger home ranges than those in stable populations because of the need to travel farther to meet their daily and seasonal requirements to survive and reproduce. Brownian Bridge movement model development proved successful in creating core areas and home ranges and it allowed me to create any percentile isopleth I coded in the function. I determined that SCQU core areas and home ranges were best described by the 50th and 90th percentiles, respectively, for both stable and intermittent population sites. Börger et al. (2006) defined home range and core area contours using 50% and 90 % isopleths based on smoothing methods from mixed effect models using covariates for roe deer (Kie et al. 2010). A study focused on long distance movements and dispersal of SCQU suggested that winter covey home ranges averaged ~182 ha and the largest movement of SCQU was recorded at 303 ha and reported daily movements or core areas were generally within 64 ha (Wallmo 1956, Campbell and Harris 1965).

I found supporting evidence for my hypothesis that SCQU select for habitat based on structural and thermal features. Temperature was the significant factor in winter habitat selection because SCQU selected for warmer and drier locations. Environmental stressors on ground nesting birds such as SCQU are an important component for overwinter habitat selection (Grisham et al. 2016). Understanding these roles of environmental stressors on habitat selection may identify fine scale interactions between winter vegetation and microclimate not previously incorporated into SCQU habitat selection assessments (Grisham et al. 2016).

Fourth order SCQU habitat selection was positively correlated with woody vegetation and visual obstruction at 0%. These results did not support my hypotheses that vegetative composition differs between SCQU locations and the overall habitat, between stable and intermittent population SCQU locations, and that SCQU selection would exhibit a negative correlation to woody vegetation. My fourth order habitat selection was limited to the 4 classes of succulents, bare ground, grassland, and woody vegetation due to limitations in UAV imagery spectral reflectance. Therefore, the positive correlation to woody vegetation in my fourth order selection analysis was likely due to the inclusion of shrub species within the woody vegetation class. Shrubs are important for wintering SCQU for roosting, loafing, and escape cover.

These fine scale vegetation metrics were useful to better understand landscape composition and selection at the fourth order scale and highlighted the importance of

VOR and woody vegetation to SCQU habitat selection throughout the TRP. Habitat for grassland obligate species is rapidly approaching a threshold of woody encroachment throughout much of the TRP and THP that will inhibit effective fire management reintroduction, thereby reducing the functional capacity of these areas for these species (Fuhlendorf et al. 2017).

The results for my final objective, a multiple-spatial scale habitat selection assessment, indicated that SCQU did not select or avoid any one landscape classification type within their home range or core area based on 90% CI's at the second order and third order spatial scales in winter. Scaled quail of stable and intermittent population sites did not select resources differently during my study. The results of my multiple-spatial scale habitat selection assessment, while not significant among groups compared, provided greater detail of overwinter habitat selection in the TRP. Population conservation and management occurring on public and private lands faces many challenges, including the challenge of understanding species that select habitat at multiple spatial scales and how to correspond ecological scales to management scales (Fuhlendorf et al. 2017).

Literature Cited

Anderson, D. B. 1936. Relative humidity or vapor pressure deficit. Ecology 17:277–282.

Arthur, S.M., B.F.J. Manly, L.L. McDonald, and G.W. Gardner. 1996. Assessing Habitat Selection when Availability Changes. Ecology 77:215-227.

Asner, G.P., C.A. Wessman, D.S. Schimmel. 1998. Heterogeneity of Savannah Canopy Structure and Function from Imaging Spectrometry and Inverse Modeling. Ecological Environments 8:926-941.

Asner, G.P., S. Archer, R.F. Hughes, R.J. Ansley, and C.A. Wessman. 2003. Net Changes in regional woody vegetation cover and carbon storage in Texas Drylands. Global Change Biology. 9:316-365.

Ault, S.C., and F.A. Stormer. 1983. Seasonal Food Selection by Scaled Quail in Northwest Texas. Journal of Wildlife Management 47:222-228.

The Audubon Society. 2020. Guide to North American Birds. Scaled Quail. <audubon.org/field-guide/bird/scaled-quail> Accessed 4 April 2020.

Ault, S.C., and F.A. Stormer. 1983. Seasonal Food Selection by Scaled Quail in Northwest Texas. Journal of Wildlife Management 47:222-228.

Bestelmeyer, B.T., D.P.C. Peters, S.R. Archer, D.M. Browning, G.S. Okin, R.L. Schooley, and N.P. Webb. 2018. The grassland-shrubland regime shift in the southwestern United States: misconceptions and their implications for management. BioScience 68:678-690.

Börger, L., N. Franconi, N. Ferretti, F. Meschi, G. De Michele, A. Gantz and, T. Coulson. 2006. An integrated approach to identify spatio-temporal and individual-level determinants of animal home range size. American Naturalist 168, 471 –485. (doi:10.1086/507883)

Brennan, L.A., D.L. Williford, B.M. Ballard, W.P. Kuvlesky Jr., E.D Graham, and S.J. Demaso. 2017. The Upland and Webless Migratory Game Birds of Texas. Ecology and Management, Texas A&M University Press, College Station, TX, USA.

Bridges, A.S., M.J. Peterson, N.J. Silvy, F.E. Smeins, and X.B. Wu. 2001. Differential Influence of Weather on Regional Quail Abundance in Texas. Journal of Wildlife Management. 65:10-18.

Bristow, K.D., and R.A. Ockenfels. 2006. Fall and Winter Habitat Use by Scaled Quail in Southeastern Arizona. Rangeland Ecology and Management. 59:308-313.

Brown, D.E., C.L. Cochran, and T.E. Waddell. 1978. Using Call-Counts to Predict Hunting Success for Scaled Quail. Journal of Wildlife Management. 42:281-287.

Cain, J. R., S.L. Beasom. 1983. A Guide for Aging Scaled Quail. Texas Agricultural Experimentation Bulletin. http://hdl.handle.net /1969.1/150034. Accessed 12 July 2019.

Campbell, H., and B.K. Harris 1965.Mass Population Dispersal and Long-Distance Movements in Scaled Quail. Journal of Wildlife Management 29:801-805.

Campbell, H., 1968. Seasonal Precipitation and Scaled Quail in Eastern New Mexico. Journal of Wildlife Management 32:641-644.

Campbell, H.C., D.K. Martin, P.E. Ferkovich, and B.K. Harris. 1973. Effects of Hunting and Some Other Environmental Factors on Scaled Quail in New Mexico. Wildlife Monographs 34:3-49.

Cottam, M.R., S.K. Robinson, E.J. Heske, J.D. Brawn, and K.C Rowe. 2009. Use of landscape metrics to predict avian nest survival in a fragmented Midwestern forest landscape. Biological Conservation 142:2464-2475.

Dardanelli, S., M.L. Nores, and M. Nores. 2006. Minimum area requirements of breeding birds in fragmented woodland of Central Argentina. Diversity and Distributions 12:687-693.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

Davis, C.A., R.C. Barkley, and W.C. Haussamen. 1975. Scaled Quail foods in Southeastern New Mexico. Journal of Wildlife Management 39:496-502.

Foster, L. J., K.M. Dugger, C.A. Hagen, and D.A. Budeau. 2018. Potential effects of GPS transmitters on greater sage-grouse survival in a post-fire landscape. BioOne Complete. https://doi.org/10.2981/wlb.00479 Accessed 30 August 2020.

Fuhlendorf, S.D., T. J. Hovick, R.D. Elmore, A.M. Tanner, D.M. Engle, and C.A. Davis. 2017. A Hierarchical Perspective to Woody Plant Encroachment for Conservation of Prairie-Chickens. Rangeland Economy and Management 70: 9-14.

Fulbright, T.E., K. W. Davies, and S.R. Archer. 2018. Wildlife Responses to Brush Management: A Contemporary Evaluation. Rangeland Economy and Management 71: 35-44.

Giuliano, W.M., R.S. Lutz, and R. Patino. 1996. Reproductive Responses of Adult Female Northern Bobwhite and Scaled Quail to Nutritional Stress. Journal of Wildlife Management 60:302-309.

Grisham, B.A., A.J. Godar, C.W. Boal, D.A. Haukos. 2016. Interactive effects between nest microclimate and nest vegetation structure confirm microclimate thresholds for Lesser Prairie-Chicken nest survival. The Condor 118:728-746.

Guthery, F.S., N.M. King, W.P. Kuvlesky, Jr, S. DeStefano, S.A. Gall, and N.J. Silvy. 2001. Comparative Habitat Use by Three Quails in Desert Grassland. Journal of Wildlife Management. 65:850-860.

Hammerquist-Wilson, M.M., and J.A. Crawford. 1987. Habitat selection by Texas bob- whites and chestnut-bellied scaled quail in South Texas. Journal of Wildlife Management 51:575−582.

Hatch, D.E. 1975. Behavior and Ecology of Bobwhite (*Colinus virginianus*) and the Scaled Quail (*Callipepla squamata*) in their Area of Sympatry. Dissertation, University of Nebraska, Lincoln.

Henderson, C.W. 1971. Comparative Temperature and Moisture Responses in Gambel and Scaled Quail. The Condor 73:430-436.

Heske, E.J., S.K. Robinson, and J.D. Brown. 1999. Predator activity and predation on songbird nests on forest edges in east central Illinois. Landscape Ecology. 14:345-354.

Horne, J.S., E.O. Garton, S.M. Krone, and J.S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology. 88:2354-2363.

http://txwildlifealliance.org/recovering-america-s-wildlife-act/texas-ecoregions.html. Accessed 6 January 2020

Ilgenfritz, D. 2016. Sensefly Ebee Drone: 3 Reasons To Buy, and Why We Won’t. http://flight-evolved.com/sensefly-ebee-drone/# Accessed 1 October 2019.

Johnson, D. H. 1980. The Comparison of Usage and Availability Measurements for Evaluating Resource Preference. Ecology 61:65-71.

Joseph, J., J.L Holechek, R. Valdez, M. Collins and M. Thomas. 2003. Research Observation: Effects of Rangeland Ecological Condition on Scaled Quail Sightings. Journal of Range Management 56:314-318.

Kie, J. G., J. Matthiopoulos, J. Fieberg, R.A. Powell, F. Cagnacci, M.S. Mitchell, J.M. Gaillard, and P.R Moorcroft. 2010. The home-range concept: are traditional estimators still relevant with modern telemetry technology? Philisophical Transactions of the Royal Society B 365:2221-2231.

Long, A.M., W.E. Jensen, and R.S. Matlack. 2014. Influence of Prescribed Burning on Bird Abundance and Species Assemblage in a Semiarid Great Plains Grassland. Western North American Naturalist 74:396-404.

Lusk, J.J., F.S. Guthery, M.J. Peterson, and S.J. DeMaso. 2007. Evidence for Regionally Synchronized Cycles in Texas Quail Population Dynamics. Journal of Wildlife Management 71:837-843.

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, London, United Kingdom.

Medina, A.L. 1988. Diets of Scaled Quail in Southern Arizona. Journal of Wildlife Management 52:753-757.

Modala, N.R, S. Ale, D.W. Goldberg, M. Olivares, C.L. Munster, N. Rajan and R.A. Feagin. 2017. Climate Change Projections for the Texas High Plains and Rolling Plains. Theoretical and Applied Climatology 129:263-280.

Nelson, T., J. L. Holechek, R. Valdez, and M. Cardenas. 1997. Wildlife numbers on late and mid seral Chihuahuan Desert Rangelands. Journal of Range Management 50:593-599.

Nielson, R. M., H. Sawyer, T. L. McDonald. 2015. Package ‘BBMM’: Brownian bridge movement model for estimating the movement path of an animal using discrete location data. In: R Foundation for Statistical Computing. http://CRAN.Rproject.org/package=BBMM

Orange, J.P., C.A. Davis, R.D. Elmore, E.P. Tanner, S.D. Fuhlendorf, and E.T. Thacker. 2016. Evaluating the Efficacy of Brood Flush Counts: A Case Study in Two Quail Species. Western North American Naturalist 76:485-492.

Orange, J.P., C.A. Davis, R.D. Elmore, and S.D. Fuhlendorf. 2016. Temporary Communal Brooding in Northern Bobwhite and Scaled Quail Broods. Western North American Naturalist 76:122-127.

Peterson, M.J. 2001. Northern Bobwhite and Scaled Quail Abundance and Hunting Regulation: A Texas Example. Journal of Wildlife Management 65:828-837.

Pleasant, G.D., C.B. Dabbert, and R.B. Mitchell. 2003. Evaluation of the Moisture Facilitated Nest Depredation Hypothesis in a Semiarid Environment. Management Journal of Wildlife 115:343-346.

Pleasant, G.D., C.B. Dabbert, and R.B. Mitchell. 2006. Nesting Ecology and Survival of Scaled Quail in the Southern High Plains of Texas. Management Journal of Wildlife 70:632-640.

Powell, R.A., and M.S. Mitchell. 2012. What is a home range? Journal of Mammalogy 93:948-958.

Rea, A.M. 1973. The Scaled Quail (*Callipepla squamata*) of the Southwest Systematic and Historical Consideration. The Condor 3:322-329.

Rho, P., X.B. Wu, F.E. Smeins, N.J. Silvy and M.J. Peterson. 2015. Regional land cover patterns, changes and potential relationships with scaled quail abundance. Journal of Ecology and Environment 38:185-193.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between Visual Obstruction Measurements and Weight of Grassland Vegetation. Journal of Range Management 23:295-297.

Roberts, A.J., C.W. Boal, and H.A. Whitlaw. 2017. Nesting Ecology of Grassland Birds Following a Wildfire in the Southern Great Plains. The Southwestern Naturalist 62:39-45.

Rollins, D., and J.P. Carroll. 2001. Impacts of Predation on Northern Bobwhite and Scaled Quail. Wildlife Society Bulletin 29:39-51.

Saiwana, L., J.L. Holechek, A. Tembo, R. Valdez and M. Cardenas. 1998. Scaled Quail Use of Seral Stages in the Chihuahuan Desert. Journal of Wildlife Management 62:550-556.

Schemnitz, 1959. Past and Present Distribution of Scaled Quail (*Callipepla squamata*) in Oklahoma. The Southwestern Naturalist 4:148-152.

Schemnitz, 1961. Ecology of the Scaled Quail in the Oklahoma Panhandle. Wildlife Monographs 2:429-433.

Schemnitz, 1964. Comparative Ecology of Bobwhite and Scaled Quail in the Oklahoma Panhandle. The American Midland Naturalist 2:429-433.

Silvy, N.J., D. Rollins, and W. Whisenant. 2007. Scaled Quail Ecology and Life History. Pages 65-68 *in* L.A. Brennan editor. Texas Quails: Ecology and Management. College Station: A&M Press. 65-68.

Smith, D.S. F.E. Stormer, and R.D. Godfrey Jr. 1981. A Collapsible Quail Trap. Rocky Mountain Forest and Range Experiment Station: USDA Forrest Service 1-3.

Smith, D.S. and J.R. Cain. 1984. Criteria for age Classification of Juvenile Scaled Quail. Journal of Wildlife Management 48:187-191.

Stohlgren, T.J., K.A. Bull, and Y. Otsuki. 1998. Comparison of Rangeland Vegetation Sampling Techniques in the Central Grasslands. Journal of Range Management 51:164-172.

Stormer, F.E. 1984. Night-Roosting Habitat of Scaled Quail. Journal of Wildlife Management 1:191-197.

Tanner, E.P., M. Papes., R.D. Elmore, S.D. Fuhlendorf, and C.A. Davis. 2017. Incorporating Abundance Information and Guiding Variable Selection for Climate-Based Ensemble Forecasting of Species Distributional Shifts. PLoS ONE 12(9):e0184316.

Tanner, E.P., R.D. Elmore, C.A. Davis, and S.D. Fuhlendorf. 2017. Evidence in Scaled Quail (*Callipepla squamata*) Following an Anthropogenic Disturbance. Wilson Journal of Ornithology 129:354-359.

Frank, M., A. James, A. Gobleli, J. Hardin, R. Perez, and J. Cathey. 2018. Potential Caues of the Texas Quail Decline. Texas A&M Natural Resource Institute.

Texas Parks and Wildlife Department. 2020. Texas Bobwhite Quail Forecast 2019-2020. http://www.tpwd.state.tx.us/huntwild/hunt/planning/quail_forecast/forecast/ Accessed 16 September 2020.

Texas Parks and Wildlife Department. 2006. Scaled Quail in Texas: Their Biology and manangement. Austin, USA.

Tharp, J.E. 1971. A Study of Scaled and Bobwhite Quail with Special Empasis on Habitat Requirements and Brush Control. Thesis, Texas Tech University, Lubbock, USA.

Tomacek, J.M., B.L. Pierce and M.J. Peterson. 2015. Quail Abundance, Hunter Effort, and Harvest of Two Texas Quail Species: Implications for Hunting Management Wildlife Biology 21:303-311.

Wallmo, O.C. 1956. Determination of Sex and Age of Scaled Quail. Journal of Wildlife Management 20:154-158.

Web Soil Survey. 2020. Natural Resources Conservation Service of USDA. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx Accessed 3 August 2020.

Williford, D., R.W. Deyoung, R.L. Honeycutt, L.E. Brennan and F. Hernandez. 2014. Phylogeography of the Scaled Quail in the American Southwest. Western North American Naturalist 74: 18-32.

Zar, J. H. 2010. Biostatistical Analysis, fifth edition. Prentice-Hall, Upper Saddle River, NJ, USA.

Zornes, M., and R.A. Bishop, 2010. Western Quail Conservation Plan: Association of Fish and Wildlife Agencies Resident Game Bird Workshop Group. Wildlife Management Institute. Cabot, VT, USA.

Figures

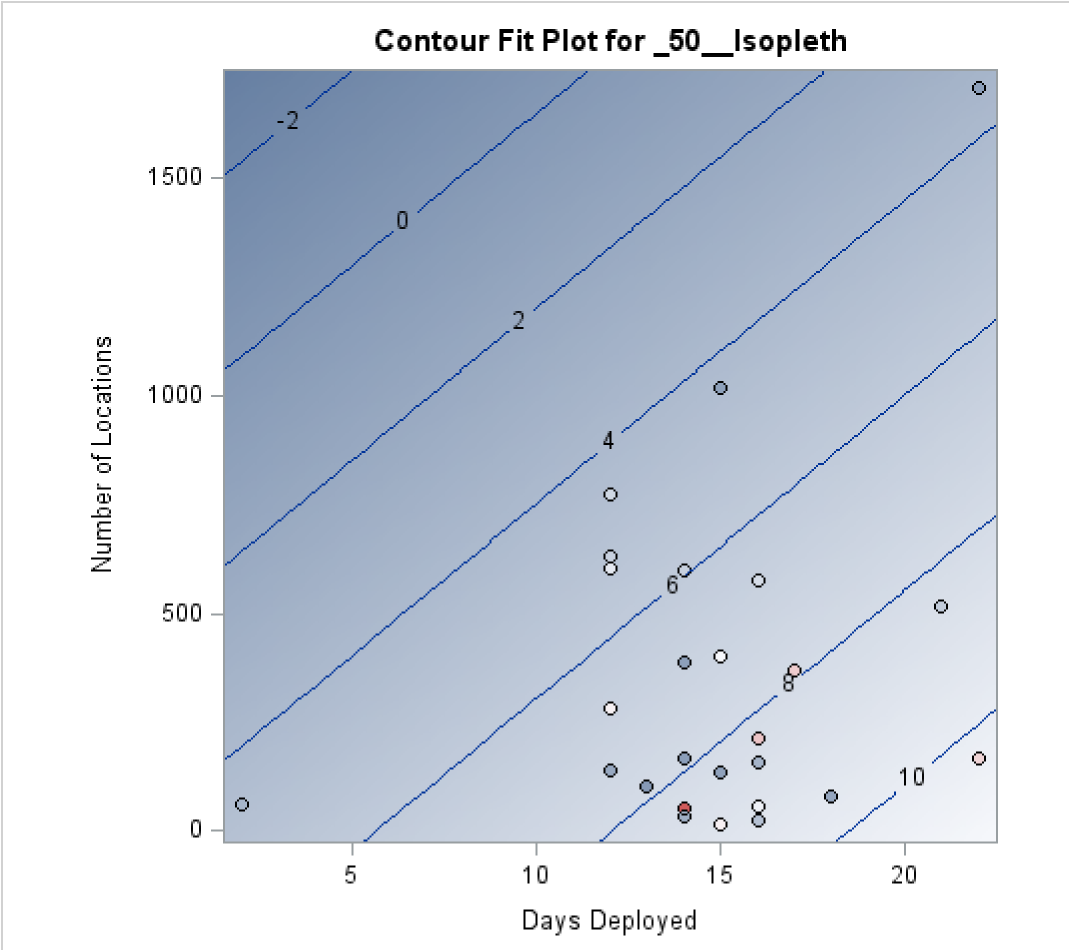

Figure 2.1. Contour fit plot to assess the relationship among days deployed, number of locations collected, and core area size for GPS-tagged scaled quail (*Callipepla squamata*)), 2018–2020

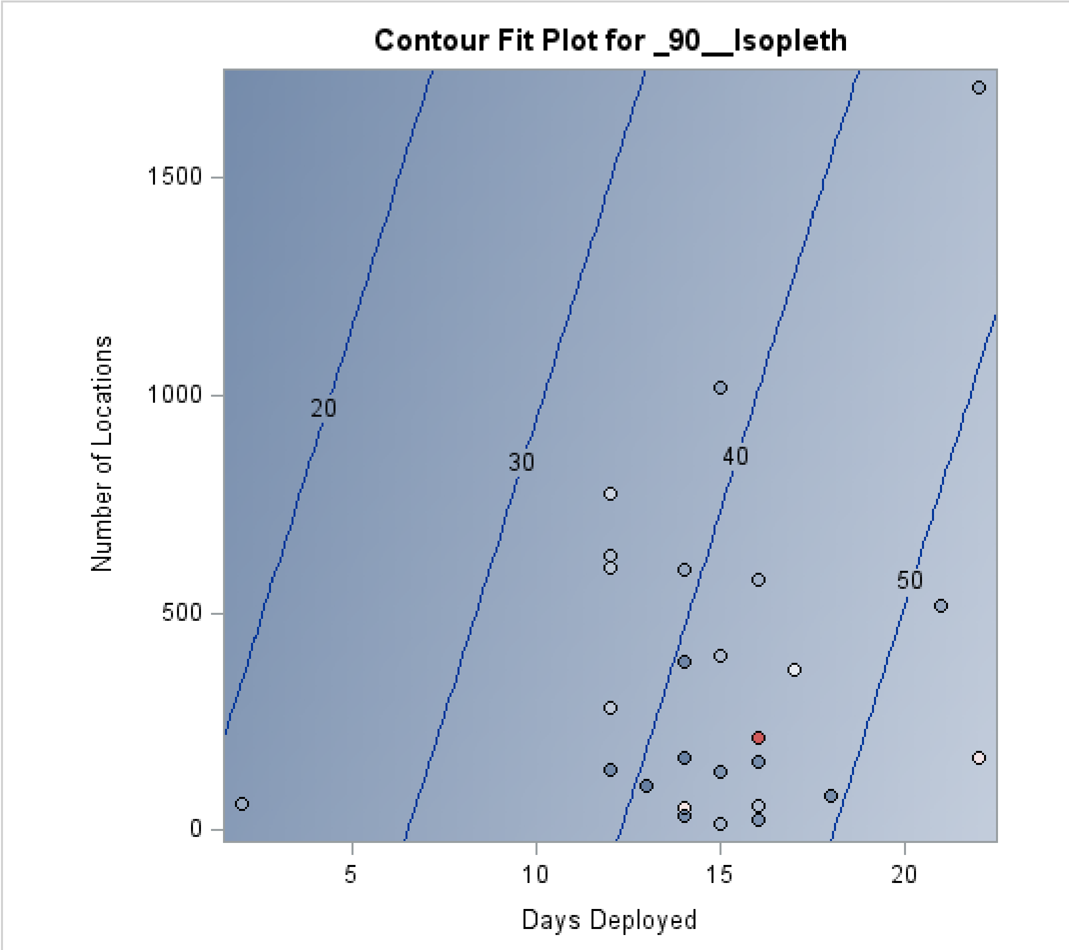

Figure 2.2. Contour fit plot to assess the relationship among days deployed, number of locations collected, and home range size for GPS-tagged scaled quail (*Callipepla squamata*), 2018–2020.

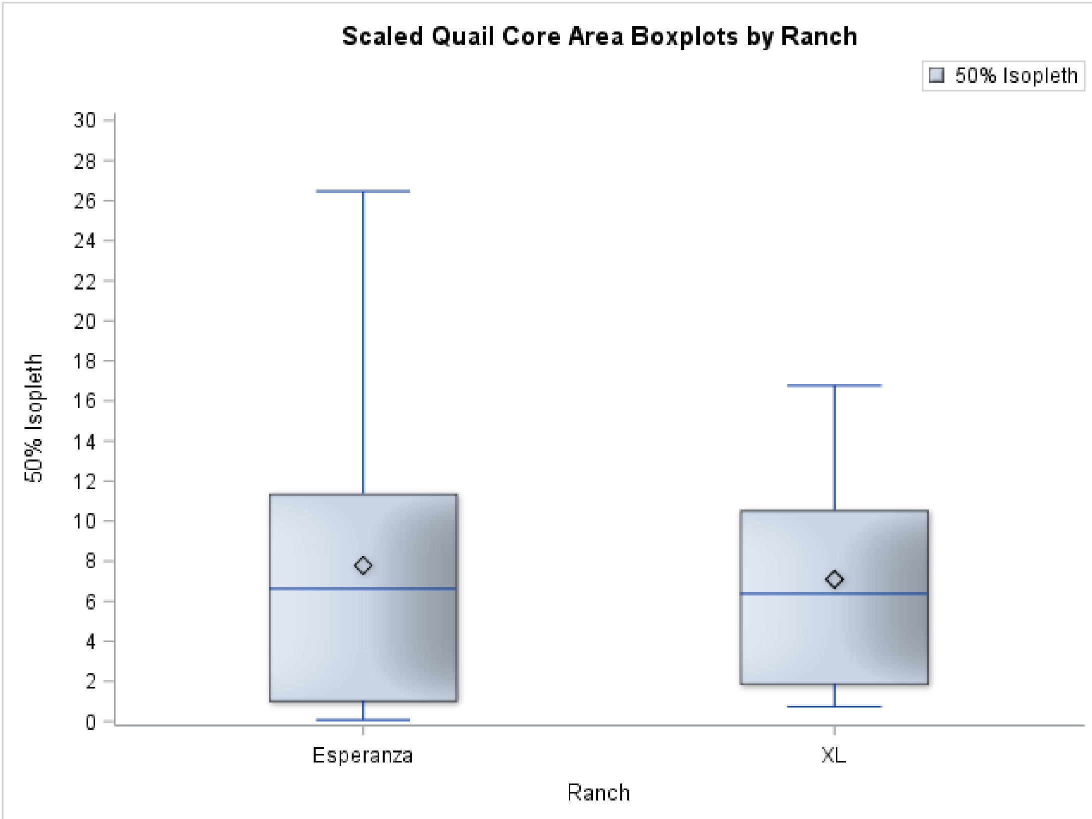

Figure 2.3. Histogram of descriptive statistics for core area sizes between intermittent (Esperanza) and stable (XL) ranches, 2018–2020.

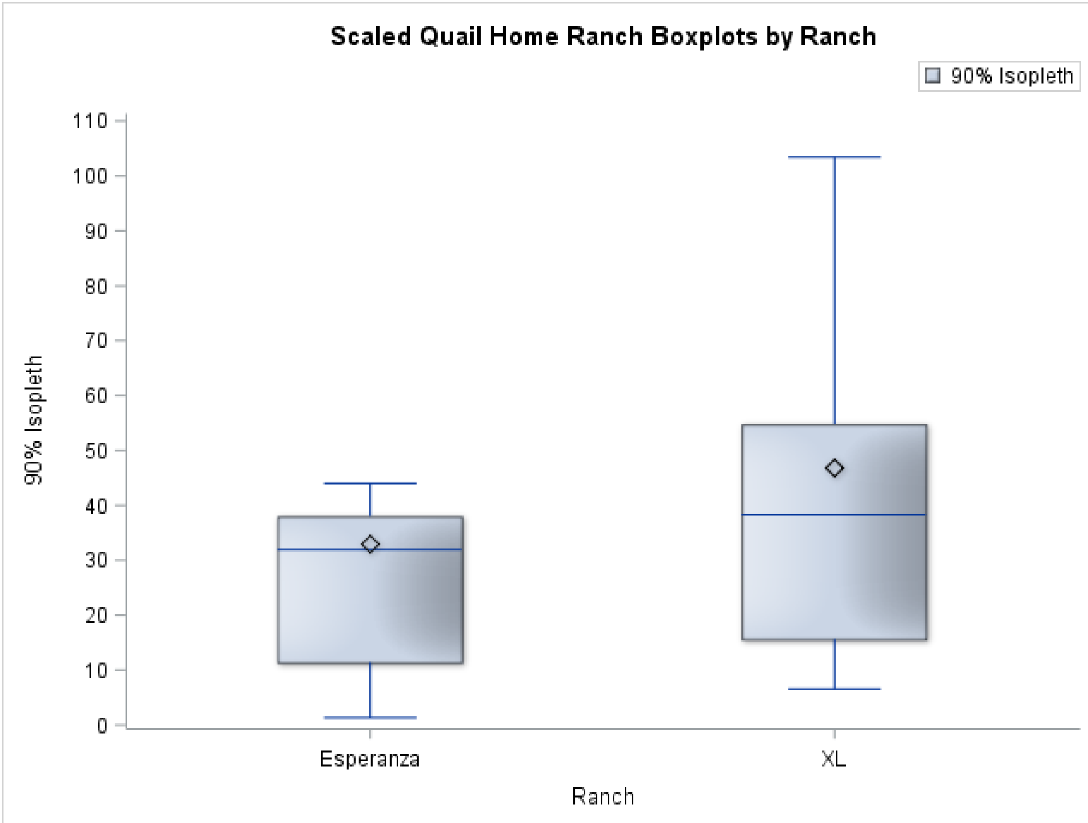

Figure 2.4. Histogram of descriptive statistics for home range sizes between intermittent (Esperanza) and stable (XL) ranches, 2018–2020.

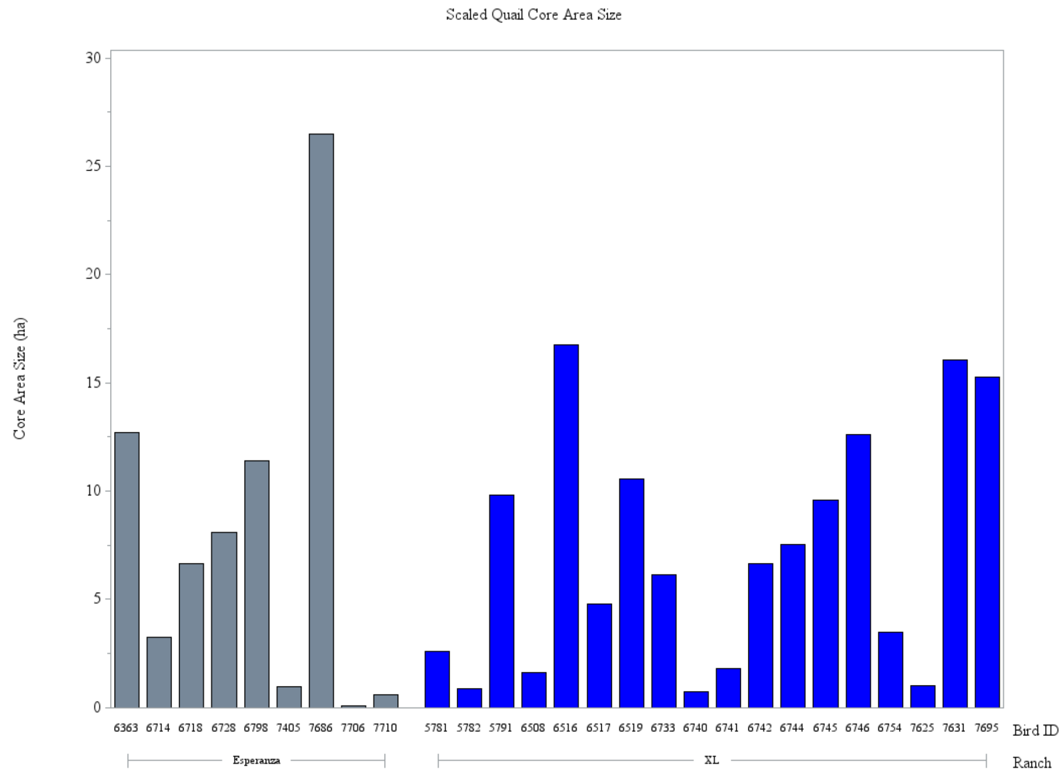

Figure 2.5. Core area sizes (ha) for each GPS-tagged scaled quail (*Callipepla squamata*) on each ranch used in this assessment, 2018–2020.

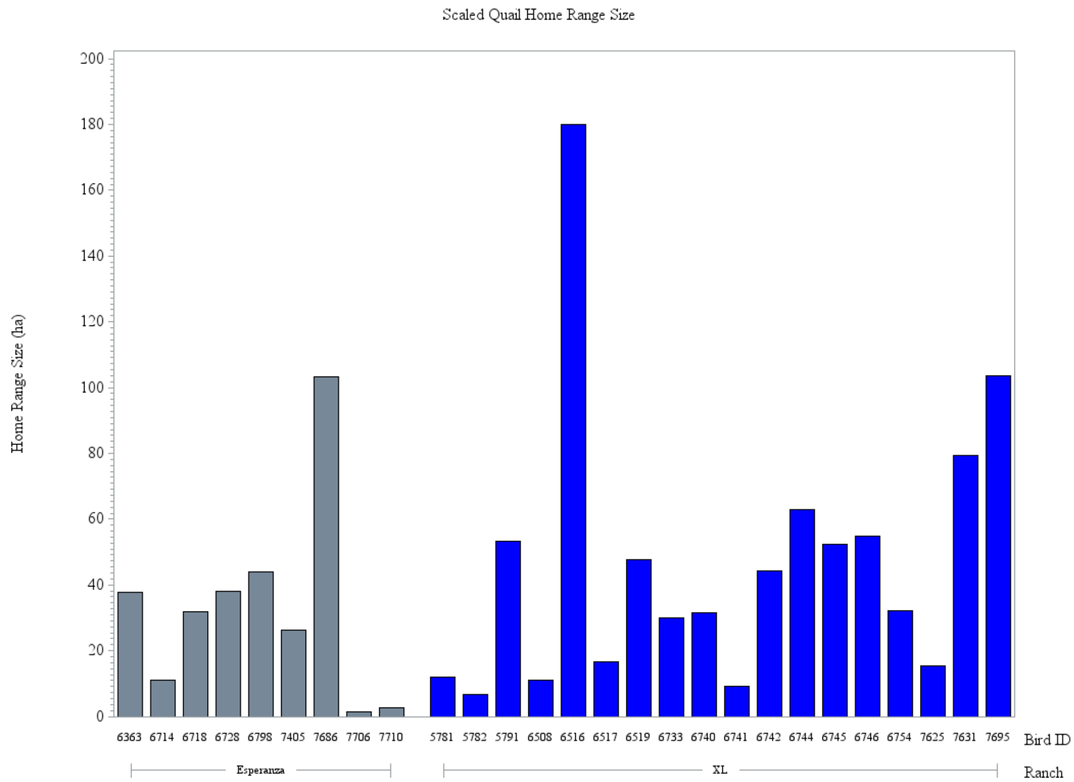

Figure 2.6. Home range sizes (ha) for each GPS-tagged scaled quail (*Callipepla squamata*) on each ranch used in this assessment, 2018–2020.

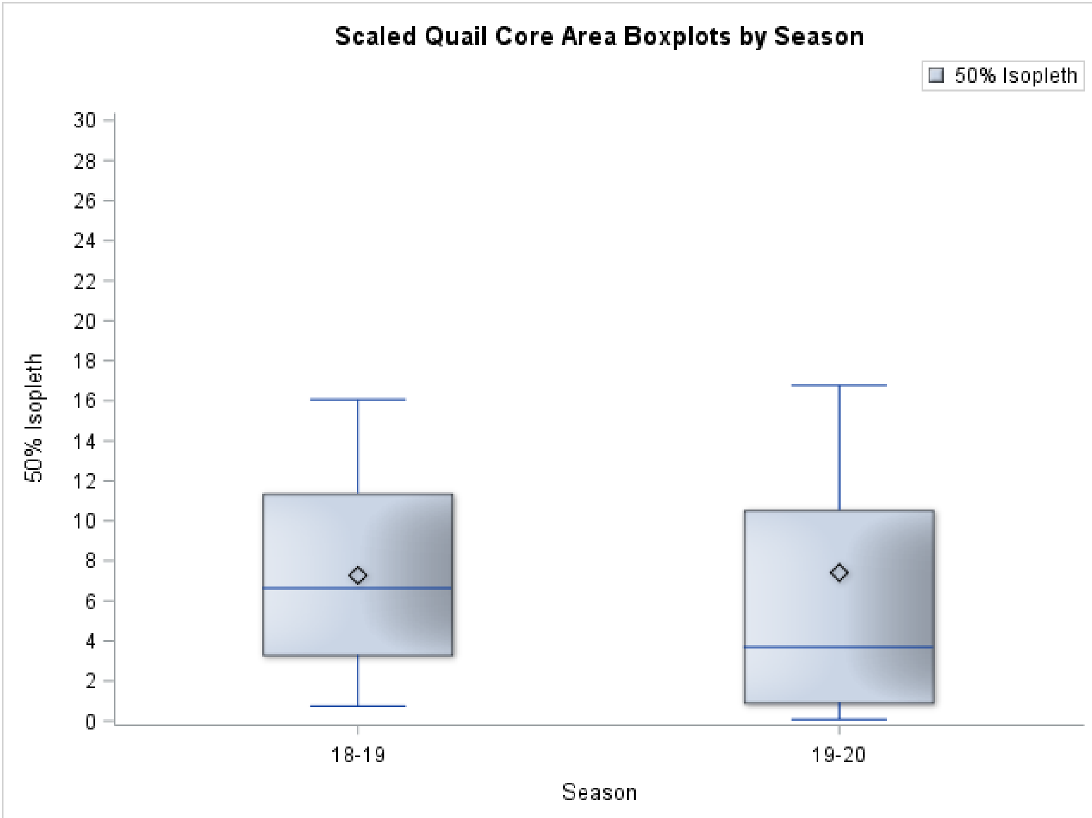

Figure 2.7. Histograms of summary statistics of core area sizes between field seasons from GPS-tagged scaled quail (*Callipepla squamata*), 2018–2020.

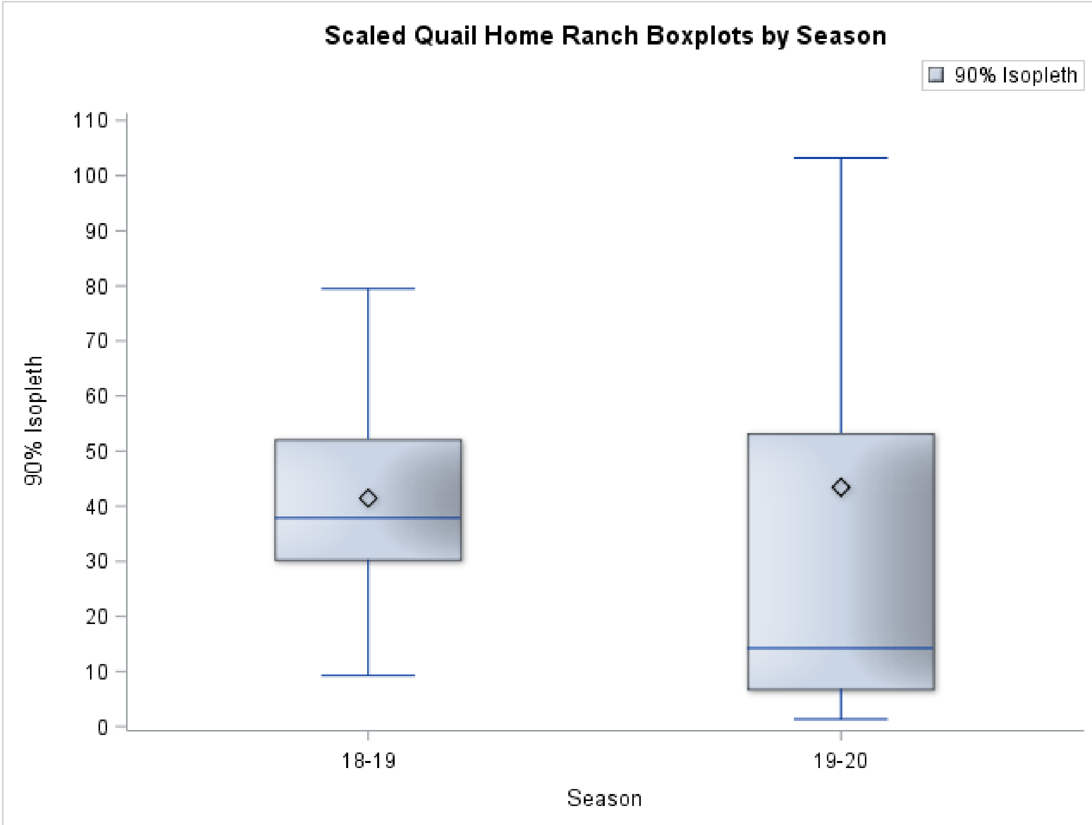

Figure 2.8. Histograms of summary statistics of home sizes between field seasons from GPS-tagged scaled quail (*Callipepla squamata*), 2018–2020.

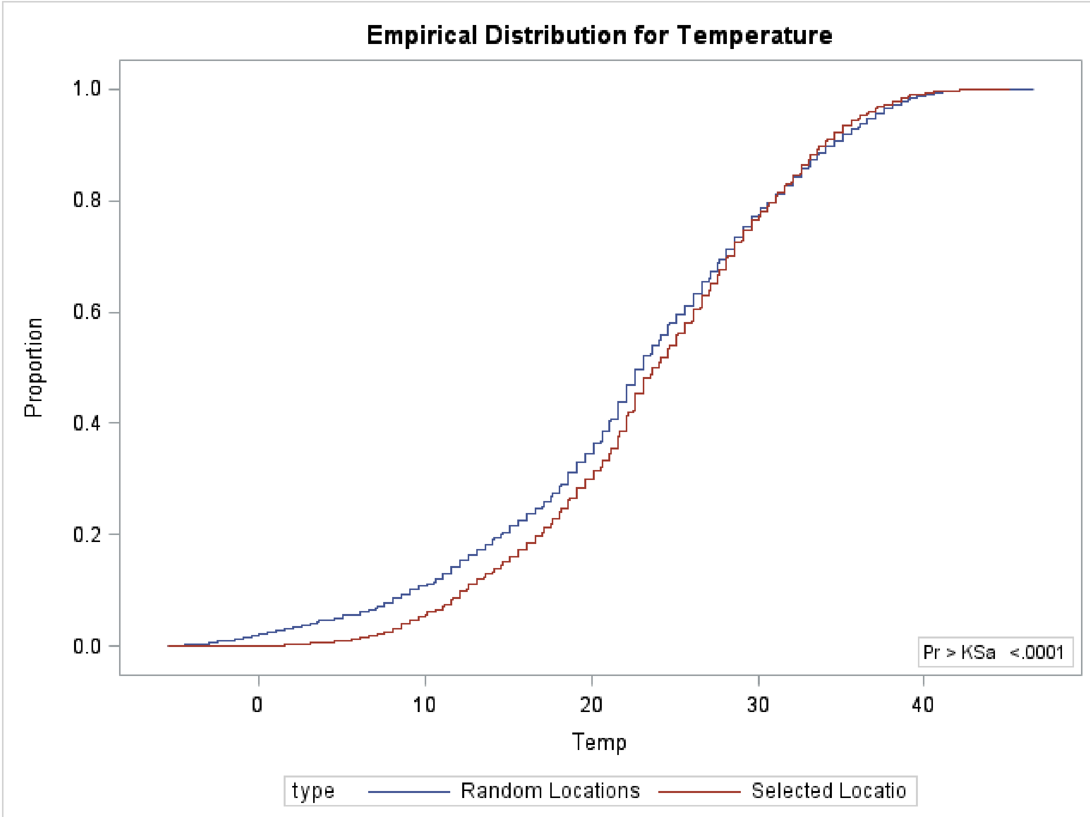

Figure 2.9. Evaluation of empirical distribution function for scaled quail (*Callipepla squamata*) temperatures between selected and random points, 2018–2020.

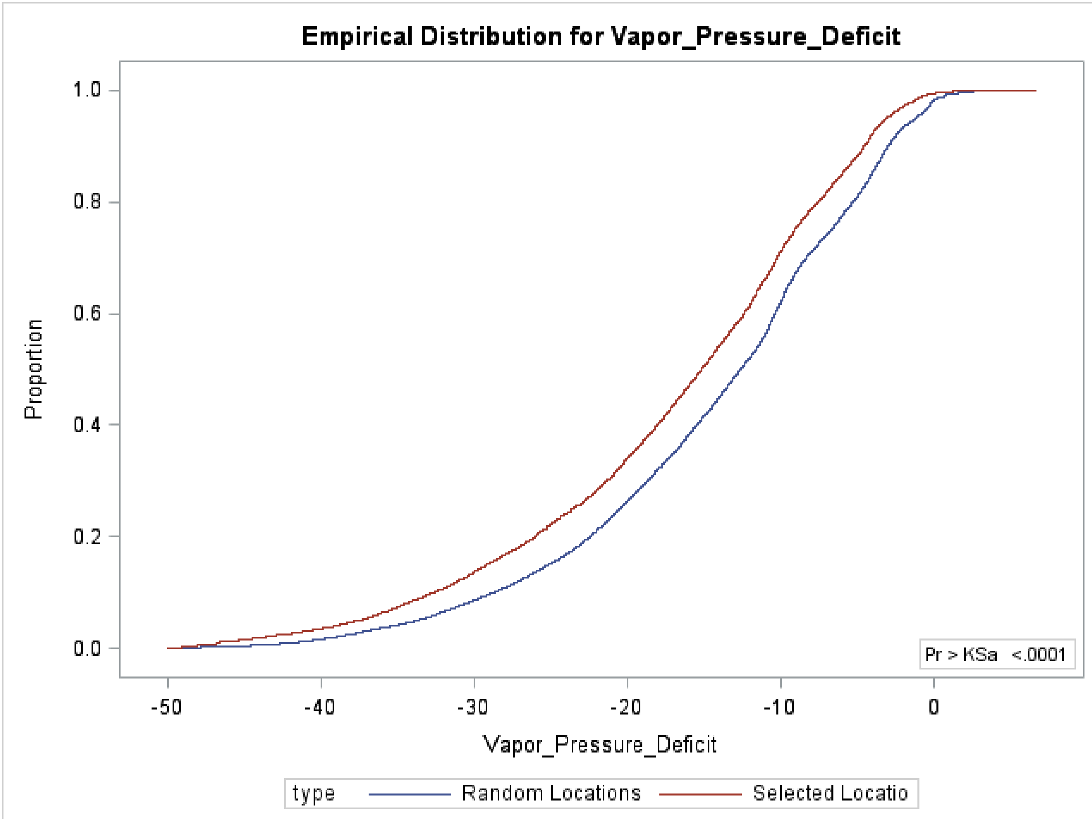

Figure 2.10. Evaluation of empirical distribution function for scaled quail (*Callipepla squamata*) VPD between selected and random points, 2018–2020.

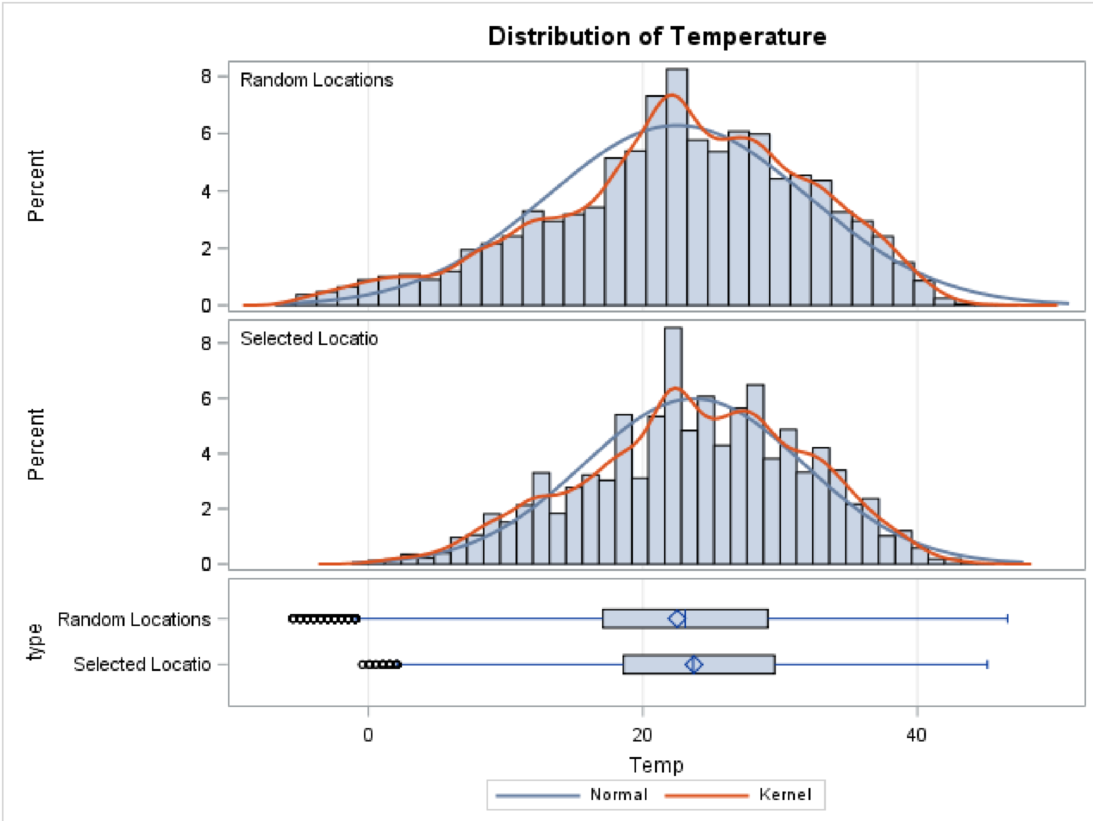

Figure 2.11. Evaluation of distribution functions for scaled quail (*Callipepla squamata*) temperature between selected and random points, 2018–2020.

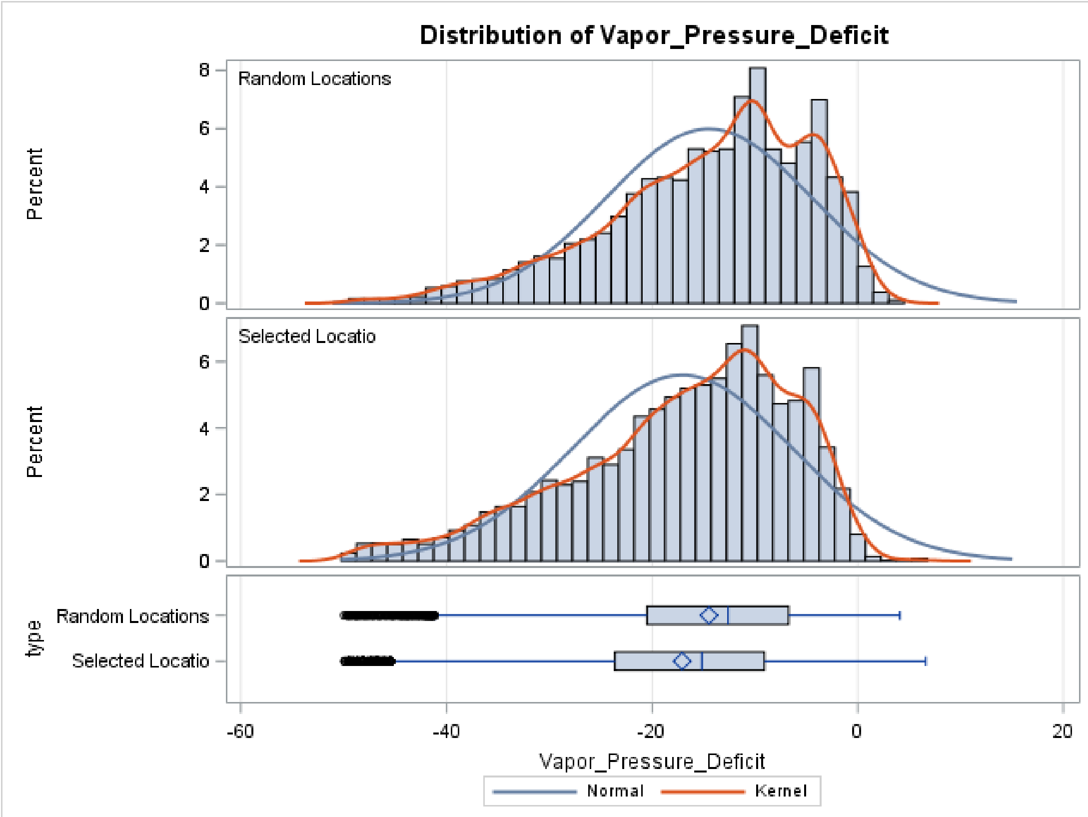

Figure 2.12. Evaluation of distribution functions for scaled quail (*Callipepla squamata*) VPD between selected and random points, 2018–2020.

Tables

Table 2.1. Results from a generalized linear model to assess if core area size were correlated to the number of days deployed on scaled quail *(Callipepla squamata)* and the number of locations collected per GPS unit, 2018–2020.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	*P*
Model	2	83.42	41.71	1.01	0.38
Error	24	995.70	41.49		
Corrected Total	26	1079.21			

R-Square	Coefficient of Variation	RMS Error	Core Area Mean
0.07	87.90	6.44	7.32

Source	Degrees of Freedom	Type III Sum of Squares	Mean Square	F-Value	*P*
Days Deployed	1	33.58	33.58	0.81	0.37
Number of GPS Locations	1	69.75	69.75	1.68	0.20

Table 2.2. Results from a generalized linear model to assess if home range size were correlated to the number of days deployed on scaled quail *(Callipepla squamata)* and the number of locations collected per GPS unit, 2018–2020.

Source	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F-Value**	***P***
Model	2	1046.99	523.49	0.33	0.72
Error	24	38238.7	1593.28		
Corrected Total	26	39285.6			

R-Square	**Coefficient of Variation**	**Root Mean Square Error**	**Home Range Mean**
0.02	94.63	39.91	42.17

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F-Value**	***P***
Days Deployed	1	1035.18	1035.18	0.65	0.42
Number of GPS Locations	1	141.9	141.9	0.09	0.76

Table 2.3. Results from a generalized linear model to assess if core area size were the same among stable or intermittent ranches, 2018–2020.

Source	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F-Value**	***P***
Model	1	2.89376	2.893	0.07	0.79
Error	25	1076.32	43.05		
Corrected Total	26	1079.21			

R-Square	**Coefficient of Variation**	**Root Mean Square Error**	**Core Area Mean**
0.002	89.54	6.561	7.32

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F-Value**	***P***
Ranch	1	2.89	2.89	0.07	0.79

Table 2.4. Results from a generalized linear model to assess if home range sizes were the same among stable or intermittent ranches, 2018–2020.

Source	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F-Value**	***P***
Model	1	1152.93	1152.93	0.76	0.39
Error	25	38132.7	1525.31		
Corrected Total	26	39285.6			
R-Square	**Coefficient of Variation**	**Root Mean Square Error**	**Home Range Mean**		
0.02	92.59	39.05	42.1779		
Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F-Value**	***P***
Ranch	1	1152.93	1152.93	0.76	0.39

Table 2.5. Student's t-test results used to assess if core area sizes were different between field seasons, 2018–2020.

	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
18-19	6	7.16	4.54	1.85	0.96	12.68
19-20	3	9.04	15.08	8.71	0.08	26.46
Diff (1-2)		-1.88	8.93	6.31		

Season	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
18-19		7.16	2.392	11.93	4.54	2.83	11.14
19-20		9.04	-28.42	46.52	15.08	7.85	94.81
Diff (1-2)	Pooled	-1.88	-16.82	13.04	8.93	5.90	18.17
Diff (1-2)	Satterthwaite	-1.88	-37.27	33.50			

Method	Variances	Degrees of Freedom	t-Value	*P*
Pooled	Equal	7	-0.3	0.77
Satterthwaite	Unequal	2.18	-0.21	0.85

Equality of Variances

Method	Numerator Degrees of Freedom	Denominator Degrees of Freedom	F-Value	*P*
Folded F	2	5	11.02	0.02

Table 2.6. Student's t-test results used to assess if home range sizes were different between field seasons, 2018–2020.

Mean	**N**	**Mean**	**Standard Deviation**	**SE**	**Minimum**	**Maximum**	
18-19	6	31.53	11.67	4.76	11.15	43.98	
19-20	3	35.73	58.43	33.73	1.3076	103.2	
Diff (1-2)		-4.20	32.75	23.16			
Season	**Method**	**Mean**	**95% CL Mean**		**Std Dev**	**95% CL Std Dev**	
18-19		31.55	19.28	43.788	11.67	7.28	28.63
19-20		35.73	-109.4	180.00	58.43	30.42	367.2
Diff (1-2)	Pooled	-4.20	-58.971	50.56	32.75	21.65	66.66
Diff (1-2)	Satterthwaite	-4.20	-145.5	137.1			
Method	**Variances**	**Degrees of Freedom**	**t-Value**		***P***		
Pooled	Equal	7	-0.18		0.86		
Satterthwaite	Unequal	2.08	-0.12		0.91		
		Equality of Variances					
Method	**Numerator Degrees of Freedom**	**Denominator Degrees of Freedom**	**F-Value**		***P***		
Folded F	2	5	25.04		0.005		

Table 2.7. Parameter estimates, standard errors, 90% confidence intervals, and p-values for percent bare ground, woody vegetation, grassland, and succulent from the generalized estimation model to assess if classification types were used disproportionately to their availability on the landscape within the home range, 2018–2020.

Analysis Of GEE Parameter Estimates

Empirical Standard Error Estimates

Parameter	**Vegetation**	**Estimate**	**Standard Error**	**Wald Chi-Square**		***P***	**Parameter**
Intercept		-1.65	1.22	-3.66	0.35	-1.36	0.174
EXPECTED*CLASS	Bare Ground	0.93	0.11	0.74	1.13	8.09	<.0001
EXPECTED*CLASS	Woody Vegetation	0.91	0.10	0.74	1.09	8.72	<.0001
EXPECTED*CLASS	Grassland	0.86	0.07	0.74	0.98	11.68	<.0001
EXPECTED*CLASS	Succulents	1.05	0.15	0.80	1.31	6.89	<.0001

Table 2.8. Parameter estimates, standard errors, 90% confidence intervals, and p-values for percent bare ground, woody vegetation, grassland, and succulent from the generalized estimation model to assess if classification types were used disproportionately to their availability on the landscape within the home range among between stable and intermittent ranches, 2018–2020.

Analysis Of GEE Parameter Estimates								
Empirical Standard Error Estimates								
Parameter	**Ranch Type/Vegetation**		**Estimate**	**Standard Error**	**Wald Chi-Square**		***P***	**Parameter**
Intercept			0.14	1.59	-2.47	2.75	0.09	0.92
EXPECTED*RANCH*CLASS	I	Bare Ground	0.42	0.20	0.09	0.76	2.11	0.03
EXPECTED*RANCH*CLASS	I	Woody Vegetation	0.74	0.14	0.50	0.97	5.22	<.0001
EXPECTED*RANCH*CLASS	I	Grassland	0.29	0.13	0.07	0.51	2.21	0.02
EXPECTED*RANCH*CLASS	I	Succulents	0.20	0.10	0.02	0.37	1.92	0.05
EXPECTED*RANCH*CLASS	S	Bare Ground	1.04	0.13	0.83	1.26	7.99	<.0001
EXPECTED*RANCH*CLASS	S	Woody Vegetation	0.93	0.15	0.67	1.19	5.96	<.0001
EXPECTED*RANCH*CLASS	S	Grassland	0.99	0.04	0.92	1.06	23.62	<.0001
EXPECTED*RANCH*CLASS	S	Succulents	1.07	0.17	0.79	1.36	6.29	<.0001

Table 2.9. Parameter estimates, standard errors, 90% confidence intervals, and p-values for percent bare ground, woody vegetation, grassland, and succulent from the generalized estimation model to assess if classification types were used disproportionately to their availability within home rages for each core area, 2018–2020.

Analysis Of GEE Parameter Estimates							
Empirical Standard Error Estimates							
Parameter	**Vegetation**	**Estimate**	**Standard Error**	**Wald Chi-Square**		***P***	**Parameter**
Intercept		-0.11	0.09	-0.26	0.02	-1.32	0.18
EXPECTED*CLASS	Bare Ground	1.00	0.01	0.97	1.02	68.82	<.0001
EXPECTED*CLASS	Woody Vegetation	1.02	0.01	0.99	1.05	64.71	<.0001
EXPECTED*CLASS	Grassland	0.99	0.01	0.96	1.01	68.03	<.0001
EXPECTED*CLASS	Succulents	1.02	0.02	0.98	1.05	48.66	<.0001

Table 2.10. Parameter estimates, standard errors, 90% confidence intervals, and p-values for percent bare ground, woody vegetation, grassland, and succulent from the generalized estimation model to assess if classification types were used disproportionately to their availability within home ranges for core areas among between stable and intermittent ranches, 2018–2020.

Analysis Of GEE Parameter Estimates								
Empirical Standard Error Estimates								
Parameter	**Ranch Type/Vegetation**		**Estimate**	**Standard Error**	**Wald Chi-Square**		***P***	**Parameter**
Intercept			-0.13	0.10	-0.30	0.03	-1.29	0.19
EXPECTED*RANCH*CLASS	I	Bare Ground	1.00	0.02	0.96	1.04	41.59	<.0001
EXPECTED*RANCH*CLASS	I	Woody Vegetation	1.07	0.05	0.99	1.16	21.01	<.0001
EXPECTED*RANCH*CLASS	I	Grassland	0.93	0.05	0.84	1.03	16.29	<.0001
EXPECTED*RANCH*CLASS	I	Succulents	1.03	0.05	0.95	1.12	20.55	<.0001
EXPECTED*RANCH*CLASS	S	Bare Ground	1.00	0.02	0.95	1.04	34.27	<.0001
EXPECTED*RANCH*CLASS	S	Woody Vegetation	1.03	0.02	0.98	1.08	35.56	<.0001
EXPECTED*RANCH*CLASS	S	Grassland	0.99	0.02	0.95	1.02	45.49	<.0001
EXPECTED*RANCH*CLASS	S	Succulents	1.02	0.02	0.98	1.07	37.77	<.0001

Table 2.11. Parameter estimates, standard errors, and p-values for vegetation metrics collected at fine scale to assess if scaled quail (*Callipepla squamata*) selected for structure or composition of vegetation at fine scales, 2018–2020.

Analysis of Maximum Likelihood Estimates					
Parameter	**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	***P***
Intercept	1	-1.08	1.23	0.77	0.37
FBG	1	2.02	1.29	2.45	0.11
FLit	1	-2.86	2.00	2.03	0.15
FWood	1	4.41	1.64	7.21	0.007
LVOR0	1	1.00	0.97	1.07	0.30

Table 2.12. Parameter estimates, standard errors, and p-values for microclimate data collected at fine scale to assess if scaled quail (*Callipepla squamata*) selected for temperature or vapor pressure deficit at fine scales, 2018–2020.

Analysis of Maximum Likelihood Estimates					
Parameter	**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	***P***
Intercept	1	0.1542	0.5563	0.0768	0.7817

Table 2.13. Parameter estimates, standard errors, and p-values for microclimate data collected at fine scale to assess if scaled quail (*Callipepla squamata*) selected for temperature or vapor pressure deficit or structure or composition of vegetation at fine scales 2018–2020.

Analysis of Maximum Likelihood Estimates					
Parameter	**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	***P***
Intercept	1	-14.95	7.55	3.91	0.04
EDFatMaxT	1	20.22	5.43	13.84	0.002
FBG	1	4.43	6.51	0.46	0.49
Flit	1	-4.95	8.28	0.35	0.55
Fwood	1	5.03	6.38	0.62	0.43
LVOR0	1	0.94	4.61	0.04	0.83

Table 2.14. Parameter estimates, standard errors, and p-values for microclimate data collected at fine scale to assess if scaled quail (*Callipepla squamata*) selected for interactive effects of temperature and vegetation composition of vegetation at fine scales, 2018–2020.

Analysis of Maximum Likelihood Estimates					
Parameter	**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	***P***
Intercept	1	-13.14	3.31	15.76	<.0001
EDFatMaxT*FBG	1	27.48	9.07	9.17	0.002
EDFatMaxT*FLit	1	11.61	7.36	2.48	0.11
EDFatMaxT*FWood	1	17.62	8.53	4.26	0.03
EDFatMaxT*LVOR0	1	5.54	4.28	1.67	0.19

CHAPTER III

OVERWINTER SURVIVAL OF SCALED QUAIL BETWEEN STABLE AND INTERMITTENT POPULATIONS

Abstract

Scaled quail (*Callipepla squamata*; hereafter SCQU) populations have declined precipitously over the past four decades, with several factors including habitat loss and fragmentation, increased predation, and disease believed to explain the decline. However, the underlying mechanisms driving this decline are still poorly understood. Scaled quail demographics are influenced by extreme variations in annual weather observed in semi-arid ecoregions such as the Rolling Plains of Texas. Scaled quail follow predictable seasonal routines within their home range from morning feedings, loafing, evening feedings, to roosting. Consequently, negotiating similar routes and knowing where important resources are located is essential to SCQU survival, especially during unfavorable weather. Likewise, fragmentation has severe implications on SCQU populations due to increases in edge habitats, which allow predators more efficiency to locate prey at higher densities in fragmented landscapes. To understand the influence of density independent (e.g., temperature, humidity , vegetation structure) and dependent factors (e.g., age , sex , body mass) on SCQU demographics I evaluated the winter survival rates of scaled quail within the Rolling Plains and High Plains of Texas. I radio-marked and GPS tagged 135 Scaled quail on 2 study sites with stable populations (consistent annual occupancy) and 2 study sites with intermittent populations (inconsistent annual occupancy). I estimated weekly survival during two winter field seasons (1 Oct - 15 Mar), 2018−2019, and

2019−2020, using the Nest Survival Model in Program MARK for four separate assessments of overwinter survival: 1) comparison in daily survival probabilities (DSP) between VHF vs. GPS-tagged SCQU, 2) comparison in DSP between stable and intermittent populations, age (adult, sub adult) and sex (male, female), 3) comparison in DSP between various land use/ land cover data obtained from GPS-tagged SCQU and aerial imagery, 4) comparison in DSP between various vegetation and microclimate measurements obtained in field from GPS-tagged SCQU. My major finding for this assessment was 1) survival did not differ by transmitter type, 2) age was the best predictor of survival across all sites, 3) ranches with stable populations have mixture of age classes whereas ranches with intermittent populations tend to be composed of adult SCQU, and 4) woody vegetation within the home range and percent of landscape within home range that was bare ground both negatively influenced overwinter survival of SCQU. My results are consistent with previous assessments of overwinter survival, and model averaged results suggest overwinter survival for SCQU in context of landscape-level vegetation composition was 0.52 (Exposure Period = 172 days: SE=0.52, UCL = 0.24, 95 % 95% LCL = 0.67). My results suggest reducing bare ground on the landscape to ~10% and maintaining woody vegetation to 25-30% (based on FRAGSTATS results) within 300 ha patches maximizes overwinter survival for SCQU on the Texas Southern High Plains.

Introduction

Scaled quail (*Callipepla squamata*; hereafter SCQU), is a new world gallinaceous upland game bird species (*Odontophoridae*) whose distribution ranges from the Southwestern United States into the Northwestern Mexican desert scrub lands. Two subspecies of SCQU occur in Texas: the Arizona SCQU (*C. s. pallida*) ranges across west Texas, the Rolling Plains, the western Edwards Plateau and the Texas Panhandle, and the Chestnut-bellied SCQU (*C. s. castanogastris*) which occurs in South Texas and the Tamaulipan biotic province of northern Mexico (Brennan et al. 2007; 2017). Scaled quail are ground-dwelling, non-migratory gamebirds that select short grasslands and shrub lands due to their propensity to walk or run rather than flush or fly (Saiwana et al. 1998, Joseph et al. 2003). The species is well adapted to arid and semi-arid habitats, where annual precipitation averages between 10-61 centimeters (Silvy et al. 2007).

The Texas Rolling Plains (hereafter TRP) and Texas High Plains (hereafter THP) have experienced population declines in SCQU abundance over the past 40 years according to Texas Parks and Wildlife Department (TPWD) August roadside counts (TPWD 2020). Population trends in the TRP and THP ecoregions experienced a 9.2% to 3.1% decline from 1978−2000 (Peterson 2001, Bridges et al. 2001, Silvy et al. 2007, Rho et al. 2015). Boom bust cycles in the TPWD August roadside counts revealed that during the drought between 1978 and 1980, SCQU abundance in the TRP declined 79% (13.09 to 2.73 birds per route) and 64% in the THP (2.06 to 1.33 birds per route; TPWD 2020). Populations increased with increased precipitation between 1980 and 1982 however, the TRP and THP experienced a 70% decline in SCQU abundance during 1983 (TPWD 2020). Scaled quail in the THP experienced a population boom cycle in 2015 yet the TRP has not experienced a population boom since 1983 (TPWD 2020). Much like the TRP and THP, SCQU populations have declined considerably since the early 1960s throughout their geographic range (Fig. 1.1). Scaled quail populations declined 3.8% per year from 1966−1991 to 8.2% from 1982−1996 (Rollins and Carroll, 2001). Texas A&M Natural Resource Institute (2017) annual SCQU call counts from 2014 reported an average of 0.19/km (0.3/mi) roosters per mile marker to 0.6 roosters in 2015, their numbers increased to 1.12/km (1.8/mi) roosters per mile marker in 2016 with the highest densities at 1.74/km (2.8/mi) per mile marker in the Edwards Plateau these numbers still remain historically low based on TPWD annual roadside counts from 1980−2020 (TPWD 2020). Schemnitz (1964) and Rollins (2001) suggest the decline is related to increased populations of predators, high rate of disease and anthropogenic interference such as farming, crop production and habitat fragmentation. Since the implementation of radio telemetry in SCQU research, studies have documented estimated annual survival rate of 17% with sub-adult survival estimated at 14% based on hunter surveys of banded birds in New Mexico (Texas Parks and Wildlife Department 2006, Brennan et al. 2017).

Large-scale habitat loss has contributed to grassland avifauna declines in North America (Cottam et al. 2009). Declines are associated with changes in ecological drivers that manipulate vegetation composition and structure and include changes to grazing management, fire suppression, non-native species invasion, and increases in energy development, woody encroachment, increased afforestation, and intensification of agricultural practices (Tanner et al. 2017). Wild SCQU are relatively short lived with high annual turnover rates similar to other quail species; few die of old age. Campbell et al (1973) estimated that by the beginning of year 5 of their study, only 0.1% of SCQU were still alive (Silvy et al 2007). Scaled quail mortalities are caused by extreme variations in weather conditions and predation however, other sources of mortality include parasites, disease, toxic substances (i.e., herbicides, pesticides, etc.), malnutrition, and hunter harvest, and numerous factors are interrelated (Brennan et al 2007; 2017, Tomececk et al 2015). Although several factors have been suggested as major contributors for low SCQU abundance estimates, there is limited data supporting any of those hypotheses for the nearly four-decade decline. There are very few studies published regarding SCQU management and the lack of data warrants research to quantify the density dependent and independent factors driving overwinter survival.

The decline of SCQU in Texas has been attributed to factors such as habitat loss, decrease in Conservation Reserve Program (CRP) area, precipitation patterns, disease, increased predation, and poor rangeland management practices that has increased woody cover (Schemnitz 1961, Campbell 1968, Bridges et al 2001, Guthery et al 2001, Rollins and Carroll 2001, Joseph et al 2003, Cottam et al. 2009, Rho et al 2015). Conclusions from published field study observations match the landscape-level analysis indicating SCQU avoidance of dense stands of mesquite (*Prosopis glandulosa*) and juniper (*Juniperus* spp.) cover as these woody species inhibit ground foraging and their ability to escape predation (Chapter 2; Stormer 1981, Guthery et al. 2001, and Pleasant et al. 2006). Dry land management issues concerning the rate of change and geographical extent of woody vegetation encroachment are, although globally recognized, yet to be systematically quantified (Asner et al. 2003).

Rates and dynamics of grass-woody vegetation are strongly influenced by spatial precipitation variability, local land management, and soil diversity, adding to the difficulty in assessing regional vegetation transitions over time (Asner et al. 2003). Asner et al. (2003) suggested that brush management results in temporary increases in biomass and reductions in woody plant cover accompanied by significant successive ecological rebounds in woody encroachment within ten years of the treatment application (Fuhlendorf et al. 2017, Fulbright et al. 2018). The woody encroachment phenomenon may be contributing to the decline of SCQU in TRP and THP as studies have suggested SCQU abundance is negatively correlated with woody cover more than 5 feet (<1.5m) in height (Rho et al. 2015). Advances in aerial photography, remote sensing platforms and analytical tools have made it possible to quantify, parameterize, and analyze woody vegetation expansion models fostering high resolution vegetation transition spatial analysis on a regional scale (Asner et al. 1998, 2003) as well as facilitate our ability to incorporate these landscape-level parameters into survival analyses.

Recent studies have increasingly recognized microclimate (relative humidity and temperature) as a critical component of habitat as near-ground temperatures are important factors in overwinter habitat selection (Elmore et al. 2017). Studies from several species of ground-nesting birds including SCQU report observations of physiological stress, altered behavior and movement patterns or reduced survival when exposed to temperatures outside of their thermo-neutral zones (25°C−35°C, Henderson 1971, Guthery et al. 2005, Carroll et al. 2015, Grisham et al. 2017, Rakowski et al. 2018). Temperatures throughout the landscape are influenced by many factors including vegetation, topography and their interactions (Hovick et al. 2014, Carroll et al. 2015, Hall et al. 2016, Rakowski et al. 2018, Kauffman 2020). Temperature is both spatially and temporally heterogeneous much like the influential landscape features vegetation, soil, moisture, and topography (Riera et al. 1998, Suggitt et al. 2011, Kauffman 2020). Moreover, these features can potentially alter near-ground temperatures and changes at even relatively small scales can create distinct microclimates at fine scales that are observably different than the overall landscape climate conditions (Riera et al. 1998, Hovick et al. 2014, Kauffman 2020). Microclimates are relevant to ground-dwelling species' habitat selections such as shrub canopy and south facing slopes provide thermal refuge on the landscape (Hovick et al. 2014, Rho et al. 2015, Rakowski et al. 2018, Kauffman 2020). Studies suggest that vegetation communities and the thermal environments in which they create are critical components to understanding SCQU overwinter survival and subsequently, population dynamics are ultimately influenced by variations in their characteristics (Kauffman 2020).

The goals of my study were to quantify microclimate conditions and assess the influence of transmitter type, landscape composition, microclimate, and fine-scale vegetation on overwinter survival of SCQU and compare between stable and intermittent populations in the TRP. My first objective was to compare survival between birds equipped with GPS and birds equipped with VHF transmitters to assess mortality rates between transmitter types. I hypothesized birds equipped with both VHF and GPS transmitters would have equal daily survival probabilities. Similar studies using both GPS and VHF transmitter on SCQU showed no differences in mortality related to transmitters (White 2020). My second objective was to evaluate adult overwinter survival over 2 winter field seasons (2018−2019 and 2019−2020) between intermittent and stable populations, age, and sex. I defined ranches that are composed of large grassland tracts (45% of total) with relatively low woody cover percentage (25−30%) and have relatively abundant SCQU populations as determined from annual surveys from Quail Tech (B. Dabbert, Quail Tech Alliance, unpublished data) as stable population ranches. I defined ranches with small, fragmented tracts of suitable cover, grassland tracts <45% and woody vegetation densities >25-30%, as intermittent population ranches. Intermittent populations usually consisted of small groups or sometimes isolated coveys of SCQU in areas that were less likely to support extensive increased population densities. I defined my field season, and the overwinter season, as 01 October to 15 March, for 2 seasons 2018-2019 and 2019-2020. I predicted SCQU in stable populations will have higher overwinter survival rates than SCQU in intermittent populations because of decreased escape cover and increased predation rates often associated with dense woody cover and fragmentation. My third objective was to compare survival among patch size, patch type, and any additive or interactive effects for each study area. I predicted adult survival rates would be positively related to grassland patch size, and a threshold grassland patch size exists at which the relationship disappears. My fourth objective was to assess if vegetation and microclimate data at fine scales (i.e., data collected at used sites by GPS-tagged SCQU) influenced daily survival probabilities (DSP).

Understanding overwinter survival rates of SCQU among stable and intermittent populations will provide critical information for long-term conservation and management, as well as aid our understanding of the factors associated with the decline of SCQU. Combined, my objectives will facilitate a better understanding of the impact of new transmitter types on SCQU while simultaneously assessing the role of woody vegetation cover and other land use/land cover metrics on overwinter survival at three spatial scales (study area, landscape, fine scale) in Texas.

Study Area

The TRP and THP of Texas encompass 67 counties in northwest Texas, which make up the Texas Plains (Modala et al. 2017). The THP and TRP regions are the southern end of the Great Plains of the central United States. The TRP occurs just below the level plateau of the High Plains Caprock separated by steep slopes and canyons that comprise the escarpment transitions between the two ecoregions. Formation of the Texas Plains ecoregions is a result of alluvial deposits from Rocky Mountain river origins (Modala et al. 2017). Elevations for the THP range from 914 m– 1.371 km m above sea level whereas Rolling Plains elevations range from 243−914 m above sea level. Average annual rainfall for the THP is between 36 - 61cm inches, slightly lower than the 46−76 cm average annual rainfall seen in the TRP (Modala et al. 2017).

Scaled quail were monitored on four study sites, two with stable populations and two with intermittent populations throughout the TRP and THP. Sites with stable populations include a ranch in Potter County, a ranch in Dawson County, and the two study sites with intermittent populations include a ranch in Dickens County and a ranch in Mitchell County (Fig. 1.2).

The ranch in Potter County is in the THP-TRP north of Amarillo. This ranch is primarily used for cattle and horse grazing and oil production. Soils classes on this ranch include Acuff-Palo Duro-Olton, Mobeetie-Tascosa, Veal-Mobeetie, Weymouth-Vernon, and Likes-Tivoli, these are a mix of loamy, clayey, calcareous and non-calcareous soils (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The Vegetation community consists of native grasses and woody shrubs. Although mostly shortgrass rangeland, this site consists of patches of shrubs, trees and succulents such as prickly pear (*Opuntia spp*.) and walking stick cholla (*Cylindropunta imbricata*). This site is known for year-round supplemental feeding of milo on maintained roads which may be a factor in high abundance observations.

The Dawson county study site is located east of Lamesa, Texas. This study site is primarily used for cattle grazing. Soils on this site include: Alibates loam, Ady fine sandy loam, Amarillo fine sandy loam, Acuff sandy clay loam, Midessa fine sandy loam, Plemons loam, Portales loam, Veal loam, and Vernon clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this ranch consists of native grasses, woody shrubs, and forbs along with patches of trees and succulents such as prickly pear and walking stick cholla.

The site in Dickens County is located near the town of Spur, Texas. This Ranch is also primarily used for cattle grazing. The soils on this ranch include: Abilene clay, Colorado Loam, Latom gravelly fine sandy loam, Mansker loam, Miles fine sandy loam, Olton clay loam, Veal fine sandy loam, Vernon clay loam, and Weymouth clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this study site consists of native grasses and woody shrubs (e.g., yucca (*Yucca filamentosa*), lote bush (*Ziziphus obtusifolia*), catclaw acacia (*Senegalia greggii*)) and forbs along with patches of trees and succulents such as prickly pear and walking stick cholla.

The Mitchell County ranch is just south of Colorado City, Texas. This ranch is used for farming and grazing. The soils on this study site include: Burkreek loam, Miles fine sandy loam, Colorado loam, Snyder loam, Sagerton clay loam, Pyron clay loam, Spade fine sandy loam, Spade-Latom fine sandy loam, Stamford clay, and Vernon clay loam (WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed August 2020). The vegetation community at this study site consists of native grasses and woody shrubs (e.g. yucca, lote bush, catclaw acacia) and forbs along with patches of trees (e.g. honey mesquite, soapberries (*Sapindus saponara*), and Junipers) and succulents such as prickly pear and walking stick cholla.

Methods

Capture

To collect SCQU geospatial data for this analysis , I captured SCQU using modified Stoddard quail funnel traps (Smith et al. 1981, Figure 1.3). The traps are built with 14-gauge, 2.54 cm x 5.08 cm galvanized mesh wire. Using a 122 cm x 30.5 m roll, roughly twenty 61 cm x 61 cm x 20 cm funnel traps can be assembled. Funnel traps were hinged together with J hooks in order to collapse the traps for ease of transport and storage. Trap locations were selected based on SCQU sightings and suitable habitat containing the various cover types. Traps were then placed in areas with substantial loafing or escape cover such as shrubs, trees, and succulents.

Funnel traps were baited with milo and covered with available surrounding vegetation to reduce thermal stress and to reduce risk of predation. I set traps at or before sunrise, checked them at solar noon and again at sundown. Once checked, traps were flipped over to prevent inadvertent overnight captures of target and non-target species. All non-target species were immediately released upon arriving to the trap. Captured SCQU were removed from traps and placed into mesh bird bags and taken to the field vehicle to be processed. All birds were trapped under the authority of a Texas Parks and Wildlife Department Scientific Collecting Permit and processed within 30 minutes of being removed from the trap as per Texas Tech University Institutional Animal Care and Use (Protocol No. 19007-01).

Captured SCQU were fitted with aluminum butt-end leg bands (National Band and Tag Co., No. 8 bands, Newport, KY.) on the left leg of each bird and location

(Universal Transverse Mercator Coordinate System; UTM) at the capture site along with age, sex, wing cord (mm), weight, time of capture, and date of capture were recorded. Gender was determined using the (Wallmo 1956) technique by identifying the absence or presence of longitudinal streaking down the throat accompanied with a dirty bluish grey color associated with females. Juveniles were differentiated from adults by examining the tips of the 1-7 primary wing coverts whereas sub adults older than twenty weeks display a buff-colored edge while adult primary tips were all gray (Cain and Beasom 1983, Smith et al. 1984, Figure 1.4).

Survival Monitoring

Fall/Winter trapping efforts began in October and continued through mid-March. We fixed and maintained a total of twenty, 6-gram necklace style VHF radio transmitters (American Wildlife Enterprises, Monticello, FL) at each site for movement and mortality assessments. The VHF transmitters had an 11-month lifespan capable of enduring the fall-winter field season. Mortality assessments were conducted on a weekly basis via radio telemetry and recording UTM locations where the last live signal was detected. Deceased SCQU were retrieved using telemetry homing and UTM locations were recorded at the mortality site along with time and date of retrieval.

GPS Monitoring

The advanced GPS transmitters used in this study provide precision instrumentation to overcome temporal and spatial scale issues restricted by VHF technology and field observer limitations. I collected fine-scale habitat selection data from sampled SCQU at each site (See Chapter 2) using Ecotones PICA 5.5-gram solar powered backpack style data loggers (hereafter GPS, Fig.1.5). The GPS store on board data logger (Ecotone, Gdynia, Poland) was attached using a backpack style attachment on at least one SCQU per captured covey (Hansen et al. 2014). The backpack data loggers were fixed with 2.0 g VHF (American Wildlife Enterprises, Monticello, Florida, USA) piggyback transmitters for retrieval. The GPS units had a reflective solar panel with an area of approximately 3.08 cm^2. The weight of the combined GPS and VHF ranged between 7.9 g – 8.9 g which was below the 5% body mass limit on tagged birds weighing ≥165 g. I fit the GPS to the SCQU using black elastic string allowing a ~1.3 cm space between the bird's back and the transmitter to allow the wings to move freely and sill snug enough to remain attached to the bird during flight or moving through dense brush. The GPS loggers were remote user programmable to allow for selection of location intervals, number of positions recorded during each interval, maximum time for the GPS to attempt a location (work time limit), and the time frame in which the logger recorded each day. Data collection settings were loaded and transmitted to the data loggers using the Ecotone Tracker (v. 20181124) software. The data loggers were set to collect one SCQU location at one-hour intervals and programmed to shut off at night during roosting in order to preserve battery voltage in low light hours.

I deployed 10 GPS data loggers on SCQU throughout each field season at each study area. After a period of fourteen days, the data loggers were retrieved via telemetry, hand nets, and spotlights. Given the SCQU's affinity for running rather flushing, the retrievals were significantly more efficient at night. Once the initial roosting covey was broken up, individual tagged birds could be held in place with a spotlight upon locating the bird. After manually retrieving a tagged bird the data logger was removed and the bird was evaluated for signs of injury or distress. No manual recaptures resulted in mortalities and likewise showed no signs of injury. Geospatial locations were downloaded using an Ecotone P5-2xSD Base station and Ecotone logger analyzer 271216 software. I converted locations from the GPS to .csv and .kml files, then uploaded the .kml file into eMotion 3.5.0 (senseFly SA, Route de Genève 38, 1033 Cheseaux-sur-Lausanne, Switzerland) drone flight software to create flight paths over used GPS location areas. I then deployed the drone over each study area to photograph the use areas at 3.0 mega pixel resolution.

Drone Mapping

See Chapter 1 for Methods and Results.

GIS/FRAGSTATS Analysis

I used drone imagery paired with ground vegetation surveys to establish Land Use Land Cover Data (LULCD) and quantify cover types for all study areas (Fig.3.1).

I created four cover types for my assessment: woody vegetation, grassland vegetation, bare ground, and succulent vegetation. For each study area, I calculated class area (CA), largest patch index (LPI), and Percent Land (PLAND) for each cover type for each study area using FRAGSTATS (v. 4.2, Figure 3.2).

Accuracy and Precision Estimation

See Chapter 1 for Methods and Results.

Vegetation Sampling

I quantified vegetation structure using a variety of metrics and sampling techniques: woody tree species density, stems per hectare density, exotic plant species composition, visual obstruction reading (VOR) estimate using a Robel pole, and percent canopy cover using a Daubenmire frame to at 2 selected locations and 2 random locations for each GPS-tagged SCQU for the first winter field season. I sampled 100 individual used and random points for the stable and intermittent population sites over 2 winter field seasons and collected >11,500 individual vegetation readings. I changed the vegetation sampling from 2 selected and 2 random points to 3selected and 3 random points for the second field season for more robust data collection as well as to mitigate for ibutton failures. I randomly selected used locations from SCQU GPS points and paired them with random points T using a free-floating dial spinner. Field technicians were instructed to spin the dial for a directional heading, walk 15 meters in that direction then spin the dial once more and proceed another 15 meters with the new heading and begin the randomly selected vegetation analysis in that location.

I conducted vegetation habitat sampling at used and random paired locations and all Daubenmire measurements were collected at 5-m, 10-m, and 15-m intervals to account for GPS error for each location downloaded from the GPS unit. I used a modified 30.5 cm square Daubenmire frame to estimate the percent ground cover of grass, shrubs, forbs, litter, and bare ground (Daubenmire 1959) at the center GPS point, and intervals above, and in each cardinal direction. I measured the tallest plant within each Daubenmire frame to assess the vegetation structure (cm).

For consistency, each litter measurement was recorded in the northwest corner of each Daubenmire frame. Within each 15-cm square quadrant of the Daubenmire frame, I also inventoried the overall woody vegetation species as well as recorded any exotic and succulent species. I estimated VOR at each survey location using a Robel pole at a distance of 4 m from the center with eye-height at ~1 meter (Robel et al. 1970). I recorded visual obstruction at 100% and 0% intervals, where 0% was the location on the Robel Pole that was completely blocked by vegetation (recorded to the nearest dm), and 100% was the location on the Robel Pole where the tallest piece of vegetation was located (recorded to the nearest dm).

Microclimate

Microclimate data were collected at each vegetation survey location using Maximum Integrated Semiconductor data loggers (otherwise known as and here after ibutton; Maximum Integrated Products, Sunnyvale, CA). I programed ibuttons to record relative humidity and ambient temperature every 10 minutes for 14 days. I deployed ibuttons at selected and random paired locations where the fine scale habitat data were collected. Time and date were recorded during the deployment and retrieval of each ibutton.

I attached ibuttons on 15.24 cm steel spike fasteners with clear quick drying all weather adhesive so each sits exactly the same way at the soil surface. Each spike was carefully driven into the ground, so as not to dislodge the data logger, at exactly 12.7 cm relative to the body mass surface area of the adult SCQU. I placed the spike and ibutton at point center of each selected and random location. Ibuttons from each replicate vegetation survey sight were retrieved approximately 14 days from initial date of deployment. After retrieval I downloaded relative humidity and temperature data and exported each to a .csv file for statistical analysis. Techniques for ibutton microclimate data analysis were derived from Grisham et al. (2016). I calculated the vapor pressure deficit (VPD), the difference between the amount of moisture in the air and how much moisture the air can hold when saturated (mmHG), by using the paired temperature and relative humidity measurements from each data logger (Anderson 1936). Vapor pressure deficit is a better measure of aridity than relative humidity, which is not a reliable measure of atmospheric moisture unless the temperature and relative humidity measurements are identical (Anderson 1936).

Survival Analysis

I assessed DSP for all analyses using the logit-link function in the nest survival model (Dinsmore et al. 2002) in Program MARK (White and Burnham 1999). My data met the assumptions of the nest survival model because we used radiotelemetry to monitor and check both VHF and GPS-tagged SCQU fates. I used the first date of capture of the first VHF tagged bird as the first day active (i); the day the bird was last checked or known alive (j); and the day of mortality event or transmitter retrieval was the last day the SCQU was checked (k; Dinsmore et al. 2002). Telemetry checks likely did not influence SCQU survival because I only flushed GPS-tagged SCQU approximately 14-days after release and I assumed fates of GPS or VHF-tagged SCQU were independent (Dinsmore et al. 2002). I monitored SCQU from 1 October to 15 March, which resulted in 172 estimates of daily survival for all analyses.

GPS vs. VHF Transmitter Survival Assessment

I grouped SCQU by either VHF-tagged or GPS-tagged and then 1) modeled DSP as a function of transmitter type 2) modeled DSP independently of transmitter type, 3) a null model with no variation in DSP among groups or covariates. I also included one model that compared GPS and VHF with the influence of additive mass. I used VHF and GPS-tagged SCQU for this overwinter survival assessment.

Stable vs. Intermittent Ranch Survival Assessment

I grouped SCQU by population type: stable or intermittent and then modeled overwinter survival as a function of 1) stable and intermittent populations had similar

DSP, 2) stable and intermittent populations did not have similar DSP, 3) each study area had unique DSP, and 4) there was no difference among DSP among study areas to assess which model had the most support. I used both VHF and GPS-tagged SCQU for this overwinter survival assessment.

Land use/Land cover Overwinter Survival

I calculated class area (CA), largest patch index (LPI), and Percent Land (PLAND) for each cover type for each study area using FRAGSTATS for each GPS-tagged SCQU and included these metrics as covariates in this assessment. I then developed 15 *a priori* models using combinations of CA, LPI, and PLAND, as additive or interactive effects to assess which, if any, and to what extent, landscape configuration of woody or grassland cover influenced overwinter survival (Table 3.1). I only used GPS-tagged SCQU for this overwinter survival assessment.

Fine-Scale Vegetation/Microclimate Overwinter Survival Assessment

I estimated woody tree species, stems per hectare, exotic plant species, visual obstruction, and percent canopy cover at two selected locations for each GPS-tagged SCQU (See Chapter 2) and included these data as covariates in Program MARK. Likewise, I calculated maximum, minimum, and other important microclimate parameters from each ibutton and paired it with the vegetation data from the same location. These data were included as covariates for each GPS-tagged SCQU in my assessment. I then developed 10 *a priori* models using combinations of vegetation and microclimate parameters to assess which, if any, vegetation and microclimate components influenced overwinter survival for GPS-tagged SCQU (Table 3.2). I only used GPS-tagged SCQU for this overwinter survival assessment. I averaged all values for vegetation and microclimate parameters in instances where multiple used locations were used for any one GPS-tagged SCQU.

I used second order Akaike's Information Criterion for small sample sizes (AIC_c), Δ AIC_c values, and Akaike weights (w_i) to select the best-approximating model (Burnham and Anderson 2004) for my four analyses. I considered any model with Δ $AIC_c < 2$ to be competitive. I model-averaged parameter estimates across competing models and used the delta method (Powell 2007) to calculate standard errors and 95% confidence intervals (CIs) in instances with multimodel support (no single model with $w_i > 0.90$). I then compared daily survival rate between/among groups using the DSP, and associated SE and 95% CI from the top-ranking model (top model $w_i > 0.90$) or between or among models (top model $w_i < 0.90$). I considered DSP statistically different if 95% CIs among groups did not overlap. I considered any covariates statistically significant to DSP if the 95% CIs for the beta estimate did not overlap zero, where a positive, significant beta estimate indicated a positive correlation between the covariate and DSP and a negative significant beta estimate indicated a negative correlation between the covariate and DSP. Finally, I calculated the probability of a SCQU surviving 14, 21, 28, and 35 days for each group by raising the DSP to the 7^{th}, 14^{th}, and 21^{st}, 28^{th}, and 35^{th} power, respectively.

Results

Capture

I captured 186 SCQU, 2018 – 2020 and of those I GPS and radio tagged 135 SCQU. I deployed 42 GPS and 93 VHF transmitters, respectively, on SCQU, 20189 – 2020. Captured scaled quail averaged 197 g (range 129 – 251 g), but I only deployed transmitters on quail ≥ 165 g to be within the 5% guideline (Fair et al. 2010).). I captured 117 adult and 18 subadult SCQU and 59 male and 76 female SCQU, 2018-2020. Exposure period for birds combined from first capture date to last date of last SCQU monitored via telemetry was 172 days.

GPS vs. VHF Transmitter Survival Assessment

Daily survival probabilities among years for GPS-equipped SCQU were not different (2018: DSP = 0.98, SE = 0.02 n = 62; 2019: DSP = 0.98, SE = 0.001, n = 57; 2020: DSP = 0.97, SE = 0.03, n = 23), so I pooled SCQU across years for subsequent analysis. There was a small degree of model–selection uncertainty across our suite of 4 candidate models. The top competing model ($S_{GPSvVHF+Mass}$) received 57% of the AIC*c* weight. In this model, there was no difference in DSP for SCQU equipped with GPS transmitters (DSP = 0.98; SE = 0.002; 95% CI = 0.98 – 0.99) compared to those equipped with VHF transmitters (DSP = 0.98; SE = 0.001; 95% CI = 0.98 – 0.99), and mass had a positive effect on survival (β_{mass} = 0.01; SE = 0.001; 95% CI = 0.001 – 0.02). The model that incorporated transmitter and attachment types without the additive effect of mass had some model support (ΔAIC_c = 1.97), but DSP between groups did not differ from the top competing model. There was no evidence of a seasonal difference in DSP (ΔAIC_c = 2.30) or an interactive effect of season and transmitter type in daily survival probabilities (ΔAIC_c = 5.16).

Stable vs. Intermittent Ranch Survival Assessment

I pooled SCQU across years and transmitter type and grouped each SCQU by study area (stable vs. intermittent), and then included age and sex as covariates. Study area vs. different sex (ΔAIC_c = 2.25) and ranch vs constant age (ΔAIC_c = 6.83) had no model support. The top competing models were 1) survival varied between age and among study areas and 2) survival varied among study areas, which received 39% and 34% of the AIC*c* weight, respectively. I then compared daily survival rate between study area and age using the DSP, SE, and associated 95% confidence intervals. Overwinter survival probabilities for study areas classified as stable was 0.32 (0.09 SE; 95% CI =0.17-0.52) compared to 0.16 (0.04 SE; 95% CI = 0.09-0.26) for study areas that were classified as intermittent. My results also indicated variability in DSP between age among the 4 ranches. Age classes of SCQU at intermittent study areas were composed of mostly adults in Dickens county and mostly sub-adults in Mitchell county whereas 2 mutually exclusive study areas that have stable populations were composed of a mixture of adults and sub-adults. Study areas that were biased to one particular age class (Ranch 1 and 2) had DSPs that averaged 0.98 compared to the stable population study areas that did not show bias to one particular age class (DSP =0.99), but the results were only marginally dissimilar due to model uncertainty with the AICc selection process (Table 3.3).

Land use Land cover Overwinter Survival

For this assessment, I only used LCLU cover data from GPS-tagged SCQU (*n* = 23), and I combined the data between stable and intermittent ranches due to low sample size of GPS-tagged SCQU at each ranch. There was a model selection uncertainty among my 15 *a-priori* models, and the models that incorporated total area, percent landscape, and total area of woody vegetation and bare ground as well as largest patch of woody vegetation and bare ground received support (Delta AIC_c range = 0.00 – 0.91; Table 3.4). However, only two covariates were significant: total area of woody vegetation within the home range and percent of landscape within home range that was bare ground. Both factors negatively influenced overwinter survival of scaled quail (Table 3.5). The model averaged overwinter survival estimate among the three top competing models was 0.52 (Exposure Period = 172 days; SE=0.52, UCL = 0.24, 95 % 95% LCL = 0.67).

Fine-Scale Vegetation/Microclimate Overwinter Survival Assessment

For this assessment, I only used fine scale habitat and microclimate data from GPS-tagged SCQU (*n* = 21), and I combined the data between stable and intermittent ranches due to low sample size of GPS-tagged SCQU at each ranch. There was a model selection uncertainty among my 10 *a-priori* models, and the null model received the most support, and then the model that incorporated density of woody species and percent composition also received support (Delta AIC_c range = 0.00 – 1.15; Table 3.6). However, neither density of woody species or percent composition were significant. The model averaged overwinter survival estimate among the three top competing models was 0.56 (Exposure Period = 172 days; SE=0.13, UCL = 0.32, 95% LCL = 0.79).

Discussion

My major findings for this study were 1) survival did not differ by transmitter type, 2) overwinter survival was correlated to age among ranches, 3) ranches with stable populations have mixture of age classes whereas ranches with intermittent populations tend to favor a particular age class, 4) woody vegetation within the home range and percent of landscape within home range that was bare ground both negatively influenced overwinter survival of scaled quail, and 5) fine scale vegetation and microclimate had no negative effects on overwinter survival. Landscape composition influences scaled quail overwinter survival, but survival estimates are within ranges reported in other studies. The two covariates that were significant were total area of woody vegetation within the home range and percent of landscape within home range that was bare ground. Both factors negatively influenced overwinter survival of SCQU. The various lines of evidence suggest that thresholds exist for 1) establishment of home ranges and core areas in areas with too much bare ground and woody vegetation (Chapter 1), 2) SCQU avoided areas with dense woody vegetation and abundant bare ground (Chapter 2), and 3) and the total area of woody vegetation and percent landscape composed of woody vegetation can have population level impacts on overwinter survival of SCQU.

The Rolling Plains SCQU population declines are attributed to decreased amounts of grasslands, herbaceous rangelands, and fragmentation of pasture-croplands (Rho et al. 2015, Fulbright et al. 2018). Rho et al. (2015) found that SCQU abundance was negatively correlated with percent cover, patch density (PD), edge density (ED), mean patch size (MPS), and mean shape index (MSI) of forest or woody patches (Rho et al 2015, Fuhlendorf et al. 2017, Fulbright et al 2018). Abundance of edge habitat in the Midwestern United States, particularly agricultural edges, was positively correlated with high populations of medium sized, generalist mammalian predators (Cottam et al. 2009). My results are consistent with the previous literature reported here-in, although I did not collect the data to assess cause-specific mortality to assess if predation in winter was a significant source of mortality. Nevertheless, landscape-level composition affected overwinter survival, and total area inference suggests for every 1 ha of woody vegetation within a SCQU home range, average overwinter probability survival decreased 5% and for every 1% of the home range that is bare ground, overwinter survival decreased 20%. For example, a 200-ha home range = 2 ha of bare ground to decrease survival by 20%. Unscaled, these results clearly indicate that woody vegetation impacts survival more compared to bare ground at the core area and home range level. Removing woody vegetation and decreasing bare ground, even at small scales (1-10ha), can help improve overwinter survival, but my results suggest priority should be placed upon removal of woody vegetation. Bare ground was correlated to warmer microclimates in Chapter 2 and maintaining the landscape to include bare ground juxtaposed within large grasslands that contain low densities of woody vegetation may maximize the establishment of home ranges and core areas (Chapter 1) and improve overwinter survival by moderating thermal extremes.

Microclimates are relevant to ground-dwelling species' habitat selections such as shrub canopy and south facing slopes provide thermal refuge on the landscape (Hovick et al. 2014, Rho et al. 2015, Grisham et al. 2016, Rakowski et al. 2018, Kauffman 2020). Studies suggest that vegetation communities and the thermal environments in which they create are critical components to understanding SCQU overwinter survival and subsequently, population dynamics are ultimately influenced by variations in their characteristics (Kauffman 2020). My results corroborate these findings and add to a growing amount of literature for SCQU and other gallifoms that microclimate and thermal-scapes are an important component to habitat selection and population parameters. For example, Hovick et al. (2014) found grasses alleviated microclimate pitch points at greater prairie-chicken nest sites, and hens selected for nest locations that on average, were cooler and more humid than surrounding random points. Likewise, Grisham et al. (2016) found visual obstruction was capable of moderating microclimates at lesser-prairie-chicken nests, but thresholds existed, and nest survival decreased 10% for every 10-mins when ambient temperature were >37°C. Converse to these studies, my study is the first to quantify the impacts of the thermal environment on overwinter demographics of SCQU.

Natural habitat areas (e.g., corridors, patches) in fragmented agriculture landscapes attract predators and become ecological traps for ground nesting birds (Rollins and Carroll 2001). Survival rates are negatively correlated with nest predation

(Heske et al.1999). In the 1930s with the introduction of aerial photography it became possible to quantify vegetation transitions in larger areas and to parameterize models of woody plant expansion (Asner et al. 1998; Asner & Lobell 2000). Grass establishment has become limited due to competition with woody shrubs for soil water essentially decreasing grass seed production, viability and longevity, while also increasing soil and wind erosion. Shrubland states once established, are highly persistent because of longevity capacity of vegetative regenerative woody plants and feedback loops prefer shrubs to grasses (Bestelmeyer, 2018). My results suggest removing shrubs and other woody vegetation and decreasing bare ground can positively impact SCQU overwinter survival, but the proximate mechanisms associated with mortality may be more affiliated with weather events and subsequent microclimates compared to predation. For example, a large snowstorm resulted in a large-scale mortality event for Northern Bobwhite on a nearby ranch (Brad Dabbert, TTU Quail Tech, unpublished data). Climate change forecasts for the ecoregions suggest C4 pathway plants may benefit from future predicted conditions (Grisham et al. 2016), and most woody vegetation I quantified in Chapter 1 are C4 plants. These results imply removal of woody vegetation at the scales recommended in Chapters 1 and 2 sooner (current-2035), compared to later (>2035), will maximize conditions necessary for SCQU population persistence on the TRP and THP.

Precaution is taken in placing a GPS or VHF transmitter on birds by visually assessing the birds' condition and health. Foster et al. (2018) indicated that survival rates of VHF tagged greater sage grouse (*Centrocercus urophasianus*) during the first year of the study were lower than expected; however, during subsequent years there was improvement in survival regardless of transmitter type and survival estimates began to exhibit ranges of natural variation. My findings support, at least in context of SCQU, the 5% of body mass guideline, as well as using either the backpack or necklace attachment styles. Given that, on average, GPS-equipped SCQU were ~ 197 g, and in general, SCQU are heavier than northern bobwhites, and prefer to walk or run, my data suggests the mass and, as well as location of the transmitter, were as not deleterious to SCQU DSP. Scaled quail equipped with both type of transmitters in our combined assessments also successfully reproduced and raised broods, which suggests both transmitter types and attachment styles did not prohibit successful mating and reproduction (Charlotte Wilson, TXST, Unpublished data). However, we have not evaluated if any differences existed between nest and brood survival rates between transmitter types and attachment styles, so currently we recommend researchers proceed with caution and use transmitter types and attachments based on research objectives for SCQU.

Literature Cited

Anderson, D. B. 1936. Relative humidity or vapor pressure deficit. Ecology 17:277–282.

Arthur, S.M., B.F.J. Manly, L.L. McDonald, and G.W. Gardner. 1996. Assessing Habitat Selection when Availability Changes. Ecology. 77:215-227.

Asner, G.P., C.A. Wessman, D.S. Schimmel. 1998. Heterogeneity of Savannah Canopy Structure and Function from Imaging Spectrometry and Inverse Modeling. Ecological Environments. 8:926-941.

Asner, G.P., S. Archer, R.F. Hughes, R.J. Ansley, and C.A. Wessman. 2003. Net Changes in regional woody vegetation cover and carbon storage in Texas Drylands. Global Change Biology. 9:316-365.

Ault, S.C., and F.A. Stormer. 1983. Seasonal Food Selection by Scaled Quail in Northwest Texas. Journal of Wildlife Management. 47:222-228.

The Audubon Society. 2020. Guide to North American Birds. Scaled Quail. <audubon.org/field-guide/bird/scaled-quail> Accessed 4 April 2020.

Ault, S.C., and F.A. Stormer. 1983. Seasonal Food Selection by Scaled Quail in Northwest Texas. Journal of Wildlife Management. 47:222-228.

Bestelmeyer, B.T., D.P.C. Peters, S.R. Archer, D.M. Browning, G.S. Okin, R.L. Schooley, and N.P. Webb. 2018. The grassland-shrubland regime shift in the southwestern United States: misconceptions and their implications for management. BioScience 68:678-690.

Brennan, L.A., D.L. Williford, B.M. Ballard, W.P. Kuvlesky Jr., E.D Graham, and S.J. Demaso. 2017. The Upland and Webless Migratory Game Birds of Texas. Ecology and Management, Texas A&M University Press, College Station, TX, USA.

Bridges, A.S., M.J. Peterson, N.J. Silvy, F.E. Smeins, and X.B. Wu. 2001. Differential Influence of Weather on Regional Quail Abundance in Texas. Journal of Wildlife Management. 65:10-18.

Bristow, K.D., and R.A. Ockenfels. 2006. Fall and Winter Habitat Use by Scaled Quail in Southeastern Arizona. Rangeland Ecology and Management. 59:308-313.

Brown, D.E., C.L. Cochran, and T.E. Waddell. 1978. Using Call-Counts to Predict Hunting Success for Scaled Quail. Journal of Wildlife Management. 42:281-287.

Cain, J. R., S.L. Beasom. 1983. A Guide for Aging Scaled Quail. Texas Agricultural Experimentation Bulletin. http://hdl.handle.net /1969.1/150034. Accessed 12 July 2019

Campbell, H., and B.K. Harris 1965.Mass Population Dispersal and Long-Distance Movements in Scaled Quail. Journal of Wildlife Management. 29:801−805

Campbell, H., 1968. Seasonal Precipitation and Scaled Quail in Eastern New Mexico. Journal of Wildlife Management. 32:641−644.

Campbell, H.C., D.K. Martin, P.E. Ferkovich, and B.K. Harris. 1973. Effects of Hunting and Some Other Environmental Factors on Scaled Quail in New Mexico. Wildlife Monographs. 34:3−49.

Cottam, M.R., S.K. Robinson, E.J. Heske, J.D. Brawn, and K.C Rowe. 2009. Use of landscape metrics to predict avian nest survival in a fragmented Midwestern forest landscape. Biological Conservation. 142:2464−2475.

Dardanelli, S., M.L. Nores, M. Nores. 2006. Minimum area requirements of breeding birds in fragmented woodland of Central Argentina. Diversity and Distributions. 12:687−693

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science.33:43−64.

Davis, C.A., R.C. Barkley, and W.C. Haussamen. 1975. Scaled Quail foods in Southeastern New Mexico. Journal of Wildlife Management. 39:496−502.

Elmore, R.D., J.M. Carroll, E.P. Tanner, T.J. Hovick, B.A. Grisham, S.D. Fuhlendorf, and S.K. Windels. 2017. Implications of the thermal environment for terrestrial wildlife management. Wildlife Society Bulletin 41:183−193.

Fair, J. M., E. Paul, and J. Jones, editors. 2010. Guidelines to the use of wild birds in research. Ornithological Council, Washington D. C., USA.

Flight evolved.com/sensefly-ebee-drone, Accessed October 2019)

Foster, L. J., K.M. Dugger, C.A. Hagen, and D.A. Budeau. 2018. Potential effects of GPS transmitters on greater sage-grouse survival in a post-fire landscape. BioOne Complete https://doi.org/10.2981/wlb.00479 Accessed 30 August 2020.

Fuhlendorf, S.D., T. J. Hovick, R.D. Elmore, A.M. Tanner, D.M. Engle, and C.A. Davis. 2017. A Hierarchical Perspective to Woody Plant Encroachment for Conservation of Prairie-Chickens. Rangeland Economy and Management. 70: 9−14.

Fulbright, T.E., K. W. Davies, and S.R. Archer. 2018. Wildlife Responses to Brush Management: A Contemporary Evaluation. Rangeland Economy and Management. 71: 35−44.

Giuliano, W.M., R.S. Lutz, and R. Patino. 1996. Reproductive Responses of Adult Female Northern Bobwhite and Scaled Quail to Nutritional Stress. Journal of Wildlife Management. 60:302−309.

Grisham, B.A., A.J. Godar, C.W. Boal, D.A. Haukos. 2016. Interactive effects between nest microclimate and nest vegetation structure confirm microclimate thresholds for Lesser Prairie-Chicken nest survival. The Condor. 118:728−746.

Guthery, F.S., N.M. King, W.P. Kuvlesky, Jr, S. DeStefano, S.A. Gall, and N.J. Silvy. 2001. Comparative Habitat Use by Three Quails in Desert Grassland. Journal of Wildlife Management. 65:850−860.

Guthery, F.S., A.R. Rybak, S.D. Fuhlendorf, T.L. Hiller, S.G. Smith, W.H. Puckett, Jr., and R.A. Baker. 2005. Aspects of the thermal ecology of bobwhites in north Texas. Wildlife Monographs 159:1−36.

Hatch, D.E. 1975. Behavior and Ecology of Bobwhite (Colinus virginianus) and the Scaled Quail (*Callipepla squamata*) in their Area of Sympatry. Dissertation, University of Nebraska, Lincoln.

Hall, L.E., A.D. Chalfoun, E.A. Beever, and A.E. Loosen. 2016. Microrefuges and the occurrence of thermal specialists: implications for wildlife persistence amidst changing temperatures. Climate Change Responses 3:1−12.

Henderson, C.W. 1971. Comparative Temperature and Moisture Responses in Gambel and Scaled Quail. The Condor. 73:430−436.

Heske, E.J., S.K. Robinson, and J.D. Brown. 1999. Predator activity and predation on songbird nests on forest edges in east central Illinois. Landscape Ecology. 14:345−354.

Horne, J.S., E.O. Garton, S.M. Krone, and J.S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology. 88:2354−2363.

Hovick, T.J., R.D. Elmore, S.D. Fuhlendorf, and D.K. Dahlgren. 2015. Weather constrains the influence of fire and grazing on nesting greater prairie-chickens. Rangeland Ecology & Management 68:186−193.

http://txwildlifealliance.org/recovering-america-s-wildlife-act/texas-ecoregions.html. Accessed 6 January 2020

Joseph, J., J.L Holechek, R. Valdez, M. Collins and M. Thomas. 2003. Research Observation: Effects of Rangeland Ecological Condition on Scaled Quail Sightings. Journal of Range Management. 56:314−318.

Kauffman, K. 2020. Breeding Season Habitat Use and Survival of Scaled Quail. M.S. Thesis, Oklahoma State University, Stillwater, OK, USA

Kie, J. G. J. Matthiopoulos, J. Fieberg, R.A. Powell, F. Cagnacci, M.S. Mitchell, J.M. Gaillard, and P.R Moorcroft. 2010. The home-range concept: are traditional estimators still relevant with modern telemetry technology? Philosophical Transactions of the Royal Society B. 365:2221−2231.

Long, A.M., W.E. Jensen, and R.S. Matlack. 2014. Influence of Prescribed Burning on Bird Abundance and Species Assemblage in a Semiarid Great Plains Grassland. Western North American Naturalist. 74:396−404.

Lusk, J.J., F.S. Guthery, M.J. Peterson, and S.J. DeMaso. 2007. Evidence for Regionally Synchronized Cycles in Texas Quail Population Dynamics. Journal of Wildlife Management. 71:837−843.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, London, United Kingdom.

Medina, A.L. 1988. Diets of Scaled Quail in Southern Arizona. Journal of Wildlife Management. 52:753−757.

Modala, N.R, S. Ale, D.W. Goldberg, M. Olivares, C.L. Munster, N. Rajan and R.A. Feagin. 2017. Climate Change Projections for the Texas High Plains and Rolling Plains. Theoretical and Applied Climatology. 129:263−280.

Nelson, T., J. L. Holechek, R. Valdez, and M. Cardenas. 1997. Wildlife numbers on late and mid seral Chihuahuan Desert Rangelands. Journal of Range Management. 50:593−599.

Orange, J.P., C.A. Davis, R.D. Elmore, E.P. Tanner, S.D. Fuhlendorf, and E.T. Thacker. 2016. Evaluating the Efficacy of Brood Flush Counts: A Case Study in Two Quail Species. Western North American Naturalist. 76:485−492.

Orange, J.P., C.A. Davis, R.D. Elmore, and S.D. Fuhlendorf. 2016. Temporary Communal Brooding in Northern Bobwhite and Scaled Quail Broods. Western North American Naturalist. 76:122−127.

Peterson, M.J. 2001. Northern Bobwhite and Scaled Quail Abundance and Hunting Regulation: A Texas Example. Journal of Wildlife Management. 65:828−837.

Pleasant, G.D., C.B. Dabbert, and R.B. Mitchell. 2003. Evaluation of the Moisture Facilitated Nest Depredation Hypothesis in a Semiarid Environment. Management Journal of Wildlife. 115:343−346.

Pleasant, G.D., C.B. Dabbert, and R.B. Mitchell. 2006. Nesting Ecology and Survival of Scaled Quail in the Southern High Plains of Texas. Management Journal of Wildlife. 70:632−640.

Powell, R.A., and M.S. Mitchell. 2012. What is home range?. Journal of Mammalogy. 93:948−958.

Rakowski, A.E., R.D. Elmore, C.A. Davis, S.D. Fuhlendorf, and J.M. Carroll. 2018. Thermal refuge affects space use and movement of a large-bodied galliform. Journal of Thermal Biology 80:37−44.

Rea, A.M. 1973. The Scaled Quail (Callipepla squamata) of the Southwest Systematic and Historical Consideration. The Condor 3:322−329.

Rho, P., X.B. Wu, F.E. Smeins, N.J. Silvy and M.J. Peterson. 2015. Regional land cover patterns, changes and potential relationships with scaled quail (Callipepla squamata) Abundance. Journal of Ecology and Environment. 38:185−193.

Riera, J.L., J.J. Magnuson, J.R. Vande Castle, and M.D. MacKenzie. 1998. Analysis of large-scale spatial heterogeneity in vegetation indices among North American landscapes. Ecosystems 1:268−282.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between Visual Obstruction Measurements and Weight of Grassland Vegetation. Journal of Range Management 23:295−297.

Roberts, A.J., C.W. Boal, and H.A. Whitlaw. 2017. Nesting Ecology of Grassland Birds Following a Wildfire in the Southern Great Plains. The Southwestern Naturalist. 62:39−45.

Rollins, D., and J.P. Carroll. 2001. Impacts of Predation on Northern Bobwhite and Scaled Quail. Wildlife Society Bulletin. 29:39−51.

Saiwana, L., J.L. Holechek, A. Tembo, R. Valdez and M. Cardenas.1998. Scaled Quail Use of Seral Stages in the Chihuahuan Desert. Journal of Wildlife Management 62:550−556.

Schemnitz, 1959. Past and Present Distribution of Scaled Quail (Callipepla squamata) in Oklahoma. The Southwestern Naturalist 4:148−152.

Schemnitz, 1961. Ecology of the Scaled Quail in the Oklahoma Panhandle. Wildlife Monographs 2:429−433.

Schemnitz, 1964. Comparative Ecology of Bobwhite and Scaled Quail in the Oklahoma Panhandle. The American Midland Naturalist 2:429−433.

Silvy, N.J., D. Rollins, and W. Whisenant. 2007. Scaled Quail Ecology and Life History.In Texas Quails: Ecology and Management. College Station: A&M Press. 65−68.

Smith, D.S. F.E. Stormer, and R.D. Godfrey Jr. 1981. A Collapsible Quail Trap. Rocky Mountain Forest and Range Experiment Station: USDA Forrest Service. 1−3.

Smith, D.S. and J.R. Cain. 1984. Criteria for age Classification of Juvenile Scaled Quail. Journal of Wildlife Management 48:187−191.

Stohlgren, T.J., K.A. Bull, and Y. Otsuki. 1998. Comparison of Rangeland Vegetation Sampling Techniques in the Central Grasslands. Journal of Range Management. 51:164−172.

Stormer, F.E. 1984. Night-Roosting Habitat of Scaled Quail. Journal of Wildlife Management. 1:191−197.

Suggitt, A.J., P.K. Gillingham, J.K. Hill, B. Huntley, W.E. Kunin, D.B. Roy, and C.D. Thomas. 2011. Habitat microclimates drive fine-scale variation in extreme temperatures. Oikos 120:1−8.

Tanner, E.P., M. Papes., R.D. Elmore, S.D. Fuhlendorf, and C.A. Davis. 2017. Incorporating Abundance Information and Guiding Variable Selection for Climate-Based Ensemble Forecasting of Species Distributional Shifts. PLoS ONE 12(9):e0184316.

Tanner, E.P., R.D. Elmore, C.A. Davis, and S.D. Fuhlendorf. 2017. Evidence in Scaled Quail (Callipepla squamata) Following an Anthropogenic Disturbance. The Wilson Journal of Ornithology. 129:354−359.

Texas Parks and Wildlife [internet].2020. Austin (TX): Quail Forecast 2019-2020; [cited Sep. 16, 2020].Available from: http://www.tpwd.state.tx.us/huntwild/hunt/planning/quail_forecast/forecast/

Texas Parks and Wildlife Department. 2006. Scaled Quail in Texas: Their Biology and manangement.Austin T.X. USA. 1−34.

Tharp, J.E. 1971. A Study of Scaled and Bobwhite Quail with Special Empasis on Habitat Requirements and Brush Control. Thesis, Texas Tech University, Lubbock, TX, USA

Tomacek, J.M., B.L. Pierce and M.J. Peterson. 2015. Quail Abundance, Hunter Effort, and Harvest of Two Texas Quail Species: Implications for Hunting Management. Wildlife Biology 21:303−311.

Wallmo, O.C. 1956. Determination of Sex and Age of Scaled Quail. Journal of Wildlife Management 20:154−158.

WebSoilSurvey.nrcs.gov/app/WebSoilSurvey.aspx. Accessed 01 August 2020.

White, R. 2020. Winter survival and resource selection of GPS equipped northern bobwhite in the Rolling Plains of Texas. M.S. Thesis, Texas Tech University, Lubbock, TX, USA

Williford, D., R.W. Deyoung, R.L. Honeycutt, L.E. Brennan and F. Hernandez. 2014. Phylogeography of the Scaled Quail in the American Southwest. Western North American Naturalist 74: 18−32.

Zornes, M., and R.A. Bishop. 2010. Western Quail Conservation Plan: Association of Fish and Wildlife Agencies Resident Game Bird Workshop Group. Wildlife Management Institute. Cabot, VT, USA.

Figures

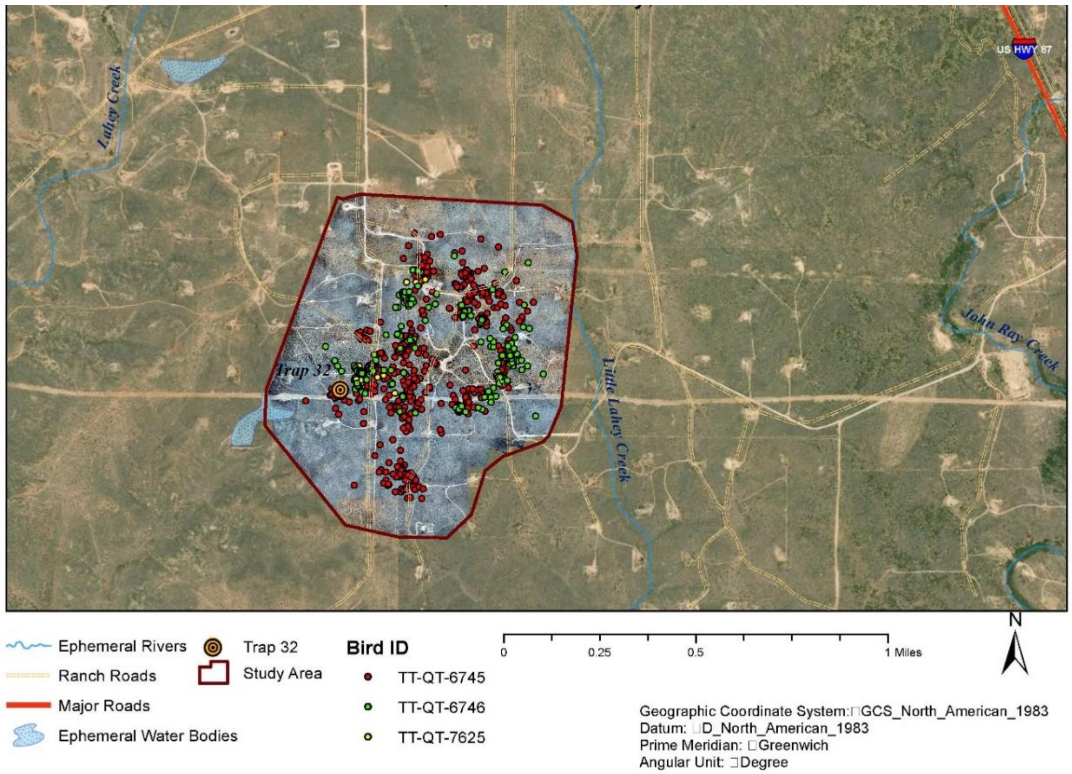

Figure 3.1. Example map of a study area for my assessment of scaled quail (Calipepla squamata) overwinter survival on the Texas Rolling and High Plains, 2018-2020.

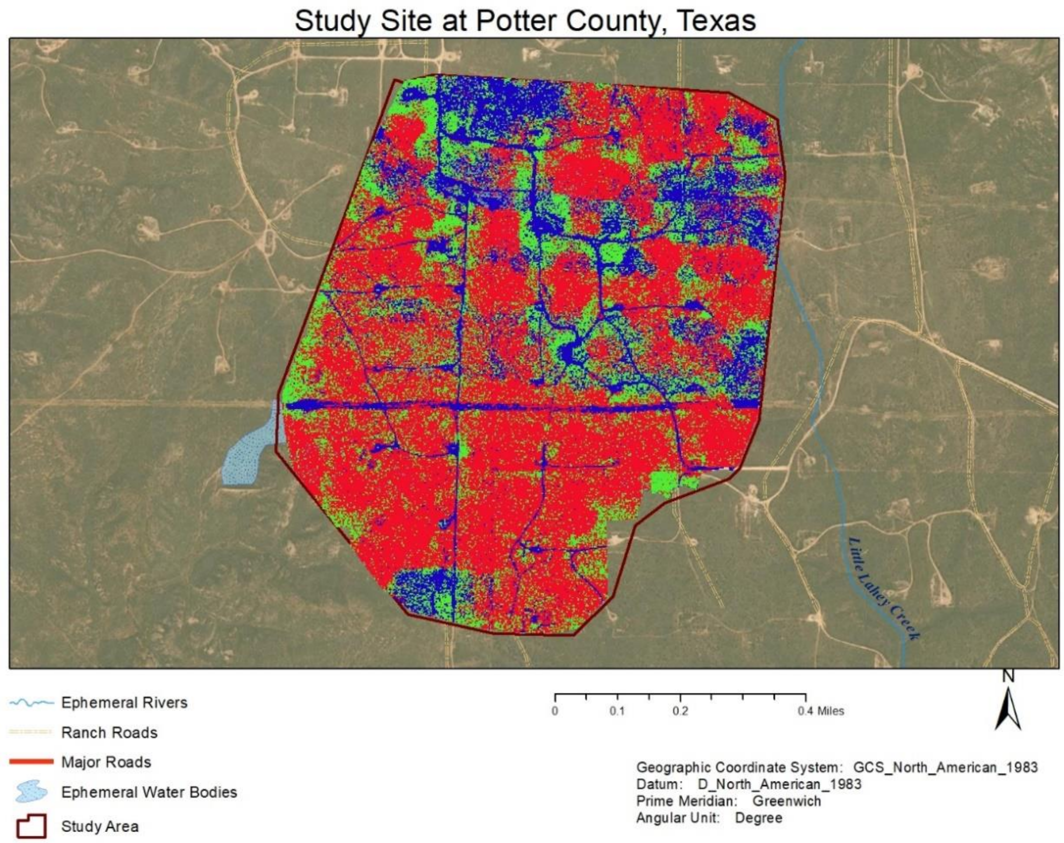

Figure 3.2. An example of a three dimensional land use/land cover classified raster created from each GPS-tagged scaled quail (*Callipepla squamata*), drone imagery, and ground vegetation surveys. These data were incorporated as covariates in my assessment of overwinter survival, 2018-2020.

Tables

Table 3.1. Covariates incorporated into my assessment of landscape composition and overwinter survival of GPS-tagged scaled quail (*Callipepla squamata*) on the Texas Rolling and High Plains, 2018–2020.

Covariate	Metric	Class	BBMM
TASCA	Total Area	Succulents	Core Area
TABGCA	Total Area	Bare Ground	Core Area
TAGCA	Total Area	Grassland	Core Area
TAWVCA	Total Area	Woody Veg	Core Area
TASHR	Total Area	Succulents	Home Range
TABGHR	Total Area	Bare Ground	Home Range
TAGHR	Total Area	Grassland	Home Range
TAWVHR	Total Area	Woody Veg	Home Range
PLSCA	Percent Landscape	Succulents	Core Area
PLBGCA	Percent Landscape	Bare Ground	Core Area
PLGCA	Percent Landscape	Grassland	Core Area
PLWVCA	Percent Landscape	Woody Veg	Core Area
PLSHR	Percent Landscape	Succulents	Home Range
PLBGHR	Percent Landscape	Bare Ground	Home Range
PLGHR	Percent Landscape	Grassland	Home Range
PLWVHR	Percent Landscape	Woody Veg	Home Range
LPSCA	Largest Patch	Succulents	Core Area
LPBGCA	Largest Patch	Bare Ground	Core Area
LPGCA	Largest Patch	Grassland	Core Area
LPWVCA	Largest Patch	Woody Veg	Core Area
LPSHR	Largest Patch	Succulents	Home Range
LPBGHR	Largest Patch	Bare Ground	Home Range
LPGHR	Largest Patch	Grassland	Home Range
LPVWHR	Largest Patch	Woody Veg	Home Range

Table 3.2. Covariates incorporated into my assessment of fine scale vegetation and microclimate variables on overwinter survival of GPS-tagged scaled quail (*Callipepla squamata*), on the Texas Rolling and High Plains, 2018–2020. See Chapter 2 for collection methodologies.

Covariate	**Description**
AVGT	Average Temperature at Used Location
MinT	Minimum Temperature at Used Location
MAXT	Maximum Temperature at Used Location
AVGVPD	Average Vapor Pressure Deficit at Used Location
MinVPD	Minimum Vapor Pressure Deficit at Used Location
MAXVPD	Maximum Vapor Pressure Deficit at Used Location
0VOR	0 Percent Visual Obstruction at Used Location
LP	Percent Litter at Used Location
GP	Percent Grass at Used Location
FP	Percent Forb at Used Location
BP	Percent Bare Ground at Used Location
SP	Percent Shrubs at Used Location
WOODS	Density of Woody Species at Used Location

Table 3.3. Results from my assessment of overwinter survival among Ranch type, age class, and sex class for scaled quail (*Callipepla squamata*) on the Texas Rolling and High Plains, 2018–2020.

Model	**AICc**	**ΔAIC_c[a]**	**w_i**	**£**	**K**	**Deviance**
Ranch Diff AGE	582.70	0.00	0.39	1.00	5.00	572.69
Ranch Diff	582.95	0.25	0.34	0.39	4.00	574.94
Ranch Diff Sex	584.94	2.25	0.13	0.00	5.00	574.93
Ranch Constant Age	589.52	6.83	0.01	-1.04	2.00	585.52
All Same	589.75	7.06	0.01	-1.54	1.00	587.75
Ranch1=Ranch2	591.12	8.43	0.00	-2.04	2.00	587.12
Ranch Constant Sex	591.54	8.85	0.00	-2.54	2.00	587.54

Table 3.4. Model output from 15 *a priori* models in Program MARK used to assess the relationship among landscape level ranch composition and overwinter survival for scaled quail (*Callipepla squamata*) on the Texas Rolling and High Plains, 2018–2020

	AICc	ΔAICc	AICc Weights	Model Likelihood	Num. Par	Deviance	-2log(L)
Total Area, Percent Landscape, Largest Patch of Woody Vegetation Core Area and Home Range	75.58	0.00	0.32	1.00	7.00	61.53	61.53
Total Area of Woody Vegetation - Core Area and Home Range	76.07	0.49	0.25	0.78	3.00	70.06	70.06
Total Area, Percent Landscape, Largest Patch of Bare Ground - Core Area and Home Range	76.49	0.91	0.20	0.63	7.00	62.44	62.44
Total Area, Percent Landscape, Largest Patch of Succulents - Core Area and Home Range	79.96	4.38	0.04	0.11	7.00	65.90	65.90
Percent Landscape of Woody Vegetation - Core Area and Home Range	80.16	4.58	0.03	0.10	3.00	74.15	74.15
Total Area, Percent Landscape, Largest Patch of Woody Vegetation - Home Range	80.75	5.17	0.02	0.08	4.00	72.73	72.73
Total Area - Core Area and Home Range	80.84	5.26	0.02	0.07	9.00	62.75	62.75
Largest Patch - Core Area and Home Range	80.92	5.34	0.02	0.07	9.00	62.83	62.83
Total Area, Percent Landscape, Largest Patch of Woody Vegetation - Core Area	80.94	5.35	0.02	0.07	4.00	72.92	72.92
Percent Landscape - Core Area and Home Range	81.28	5.69	0.02	0.06	7.00	67.22	67.22
Largest Patch - Home Range	81.51	5.92	0.02	0.05	5.00	71.47	71.47
Total Area, Percent Landscape, Largest Patch of Grass - Core Area and Home Range	81.68	6.10	0.01	0.05	7.00	67.62	67.62
Total Area - Home Range	81.99	6.40	0.01	0.04	5.00	71.96	71.96
Largest Patch - Core Area	82.10	6.51	0.01	0.04	5.00	72.07	72.07
Total Area - Core Area	83.55	7.97	0.01	0.02	5.00	73.52	73.52

Table 3.5. Model averaged beta estimates and impact on scaled quail (*Callipepla squamata*), overwinter survival on the Texas Rolling Plains, 2018-2020. "Negative" means the 95%CIs for each beta did not overlap zero.

Covariate	Model Averaged Beta	Direction
TAWVCA	0.82	
TAWVHR*	-0.05	Negative
PLWVCA	-0.06	
PLWVHR	0.06	
LPWVCA	0.13	
LPVWHR	-0.18	
TABGCA	-0.40	
TABGHR	0.08	
PLBGCA	0.15	
PLBGHR*	-0.19	Negative
LPBGCA	0.10	
LPBGHR	-0.01	
Intercept	3.77	

Table 3.6. Model output from 10 *a priori* models in Program MARK used to assess the relationship among fine scale vegetation data, vapor pressure deficit, and temperature on overwinter survival for scaled quail (*Callipepla squamata*) on the Texas Rolling and High Plains, 2018–2020.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance
Null	66.30	0.00	0.27	1.00	1	64.30
Density of Woody Vegetation	67.52	1.22	0.15	0.54	2	63.51
Composition	67.81	1.51	0.13	0.47	6	55.76
Temp Metrics	68.35	2.05	0.10	0.36	4	60.33
VPD Metrics and VOR	68.39	2.09	0.10	0.35	4	60.37
VPD Metrics	68.59	2.29	0.09	0.32	4	60.57
Temp Metrics and VOR	69.39	3.09	0.06	0.21	5	59.36
VPD Metrics and Density of Woody Vegetation	69.63	3.33	0.05	0.19	5	59.59
Composition and Structure	69.78	3.49	0.05	0.18	7	55.72
VPD and Temp Metrics	72.17	5.87	0.01	0.05	6	60.12

APPENDIX A.

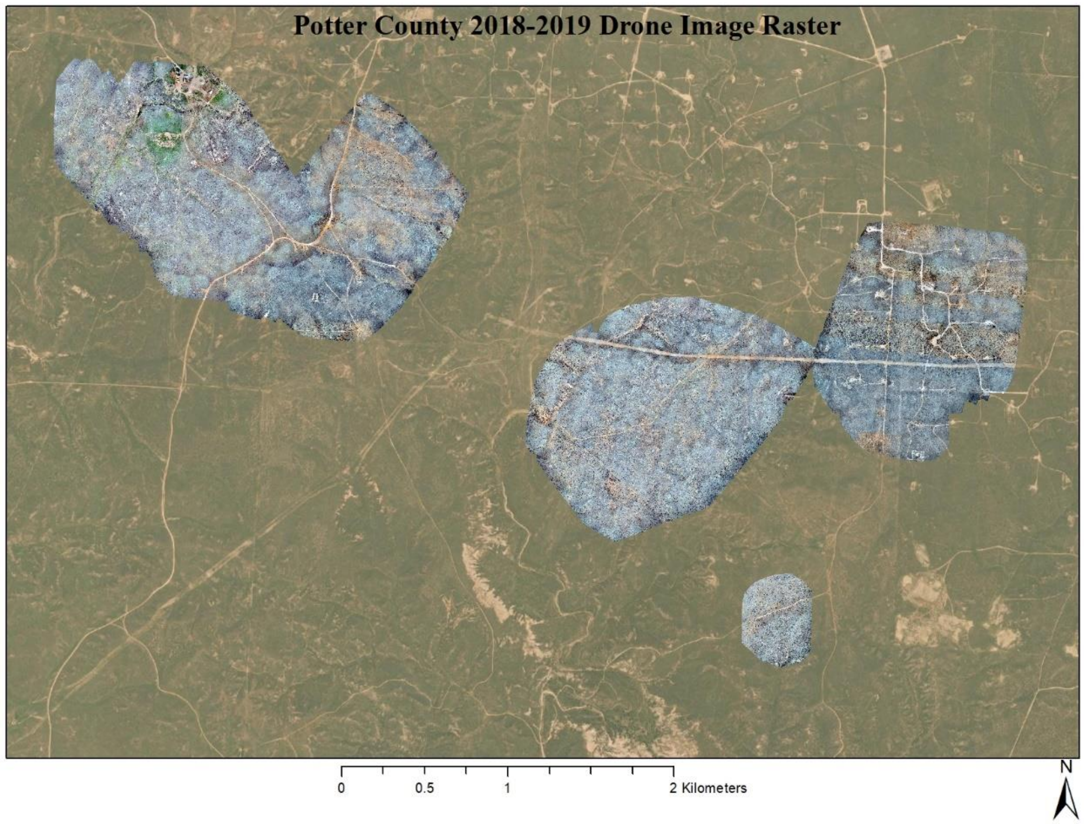

Figure A-1. 18-19 map of Potter County site with red, green, blue, spectral reflectance drone images stitched together in Pix4d.

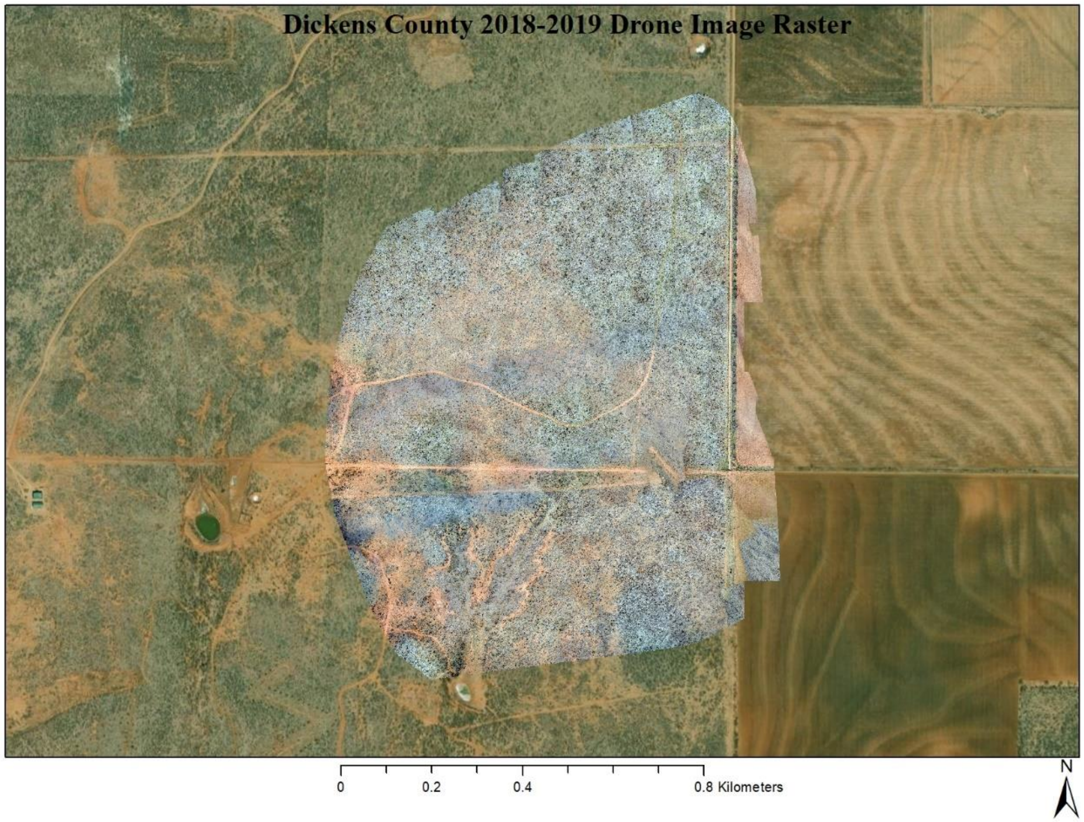

Figure A-2. 18-19 map of Dickens County site with red, green, blue, spectral reflectance drone images stitched together in Pix4d.

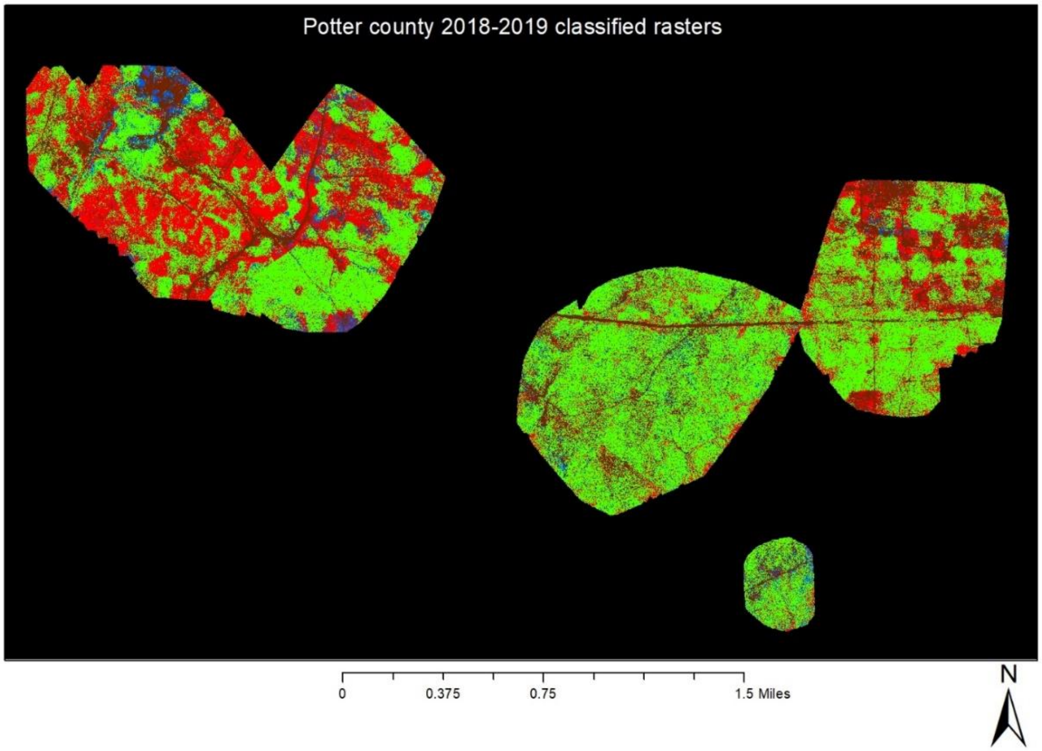

Figure A-3. 18-19 map of Potter County site drone images stitched together with classifications overlaid.

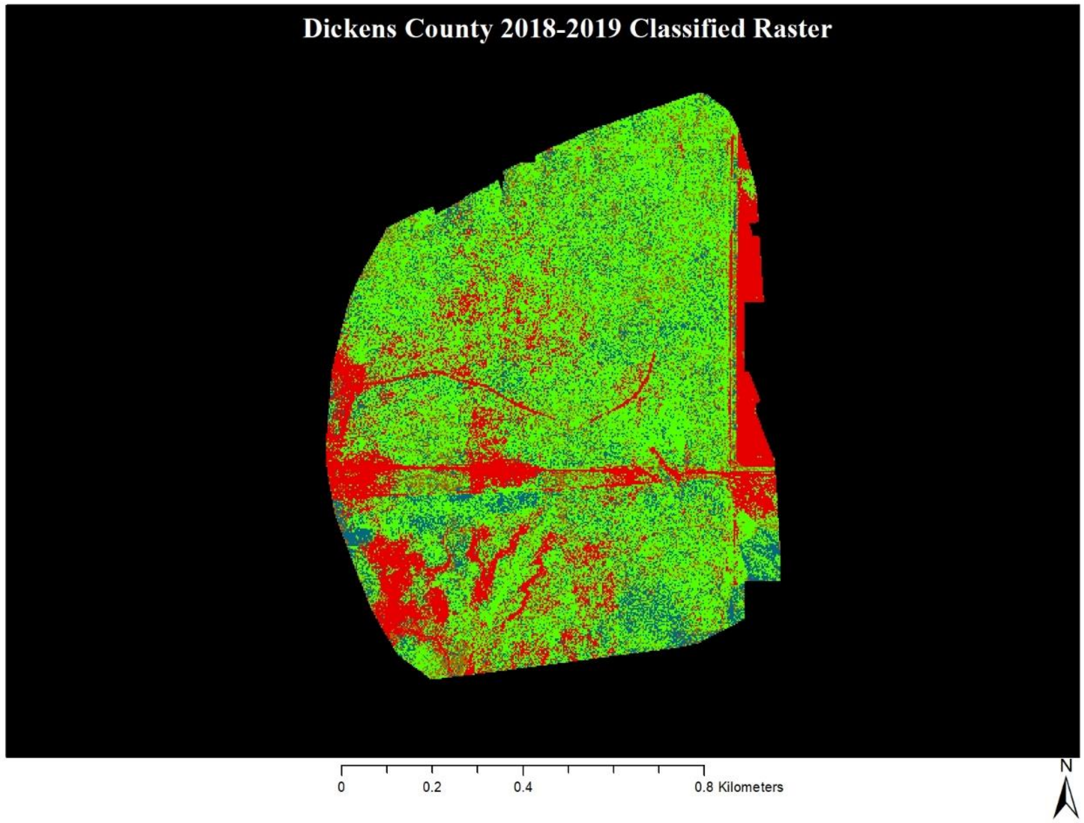

Figure A-4. 18-19 map of Dickens County site drone images stitched together with classifications overlaid.

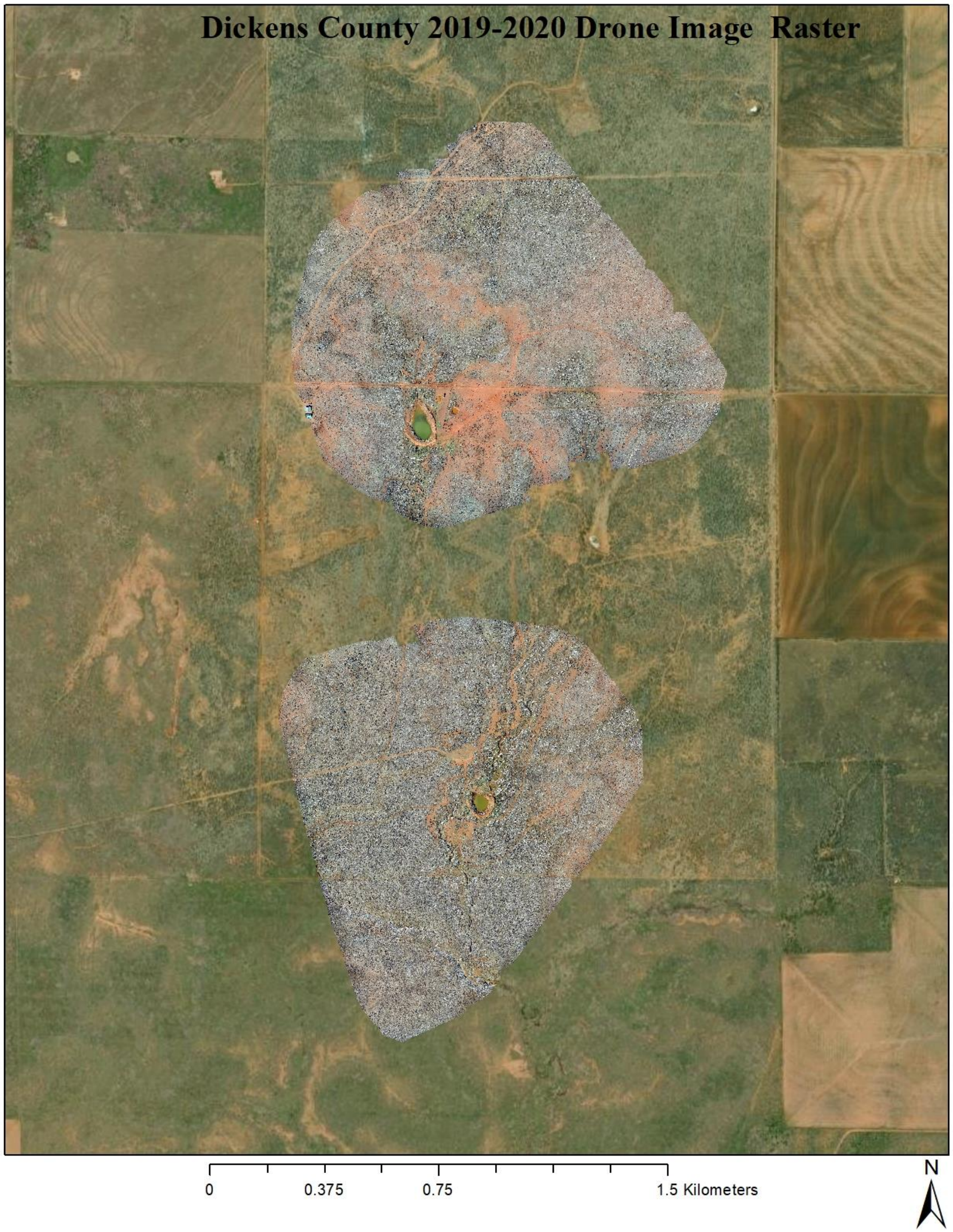

Figure A-5. 19-20 map of Dickens County site with red, green, blue, spectral reflectance drone images stitched together in Pix4d.

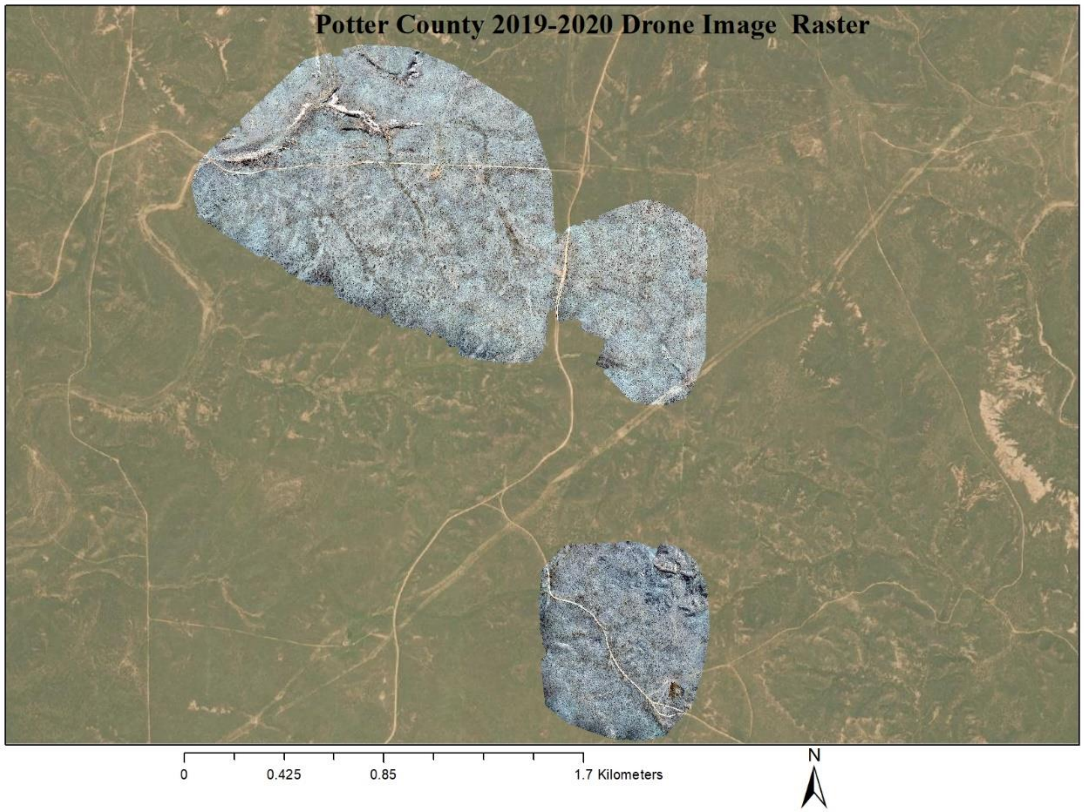

Figure A-6. 19-20 map of Potter County site with red, green, blue, spectral reflectance drone images stitched together in Pix4d.

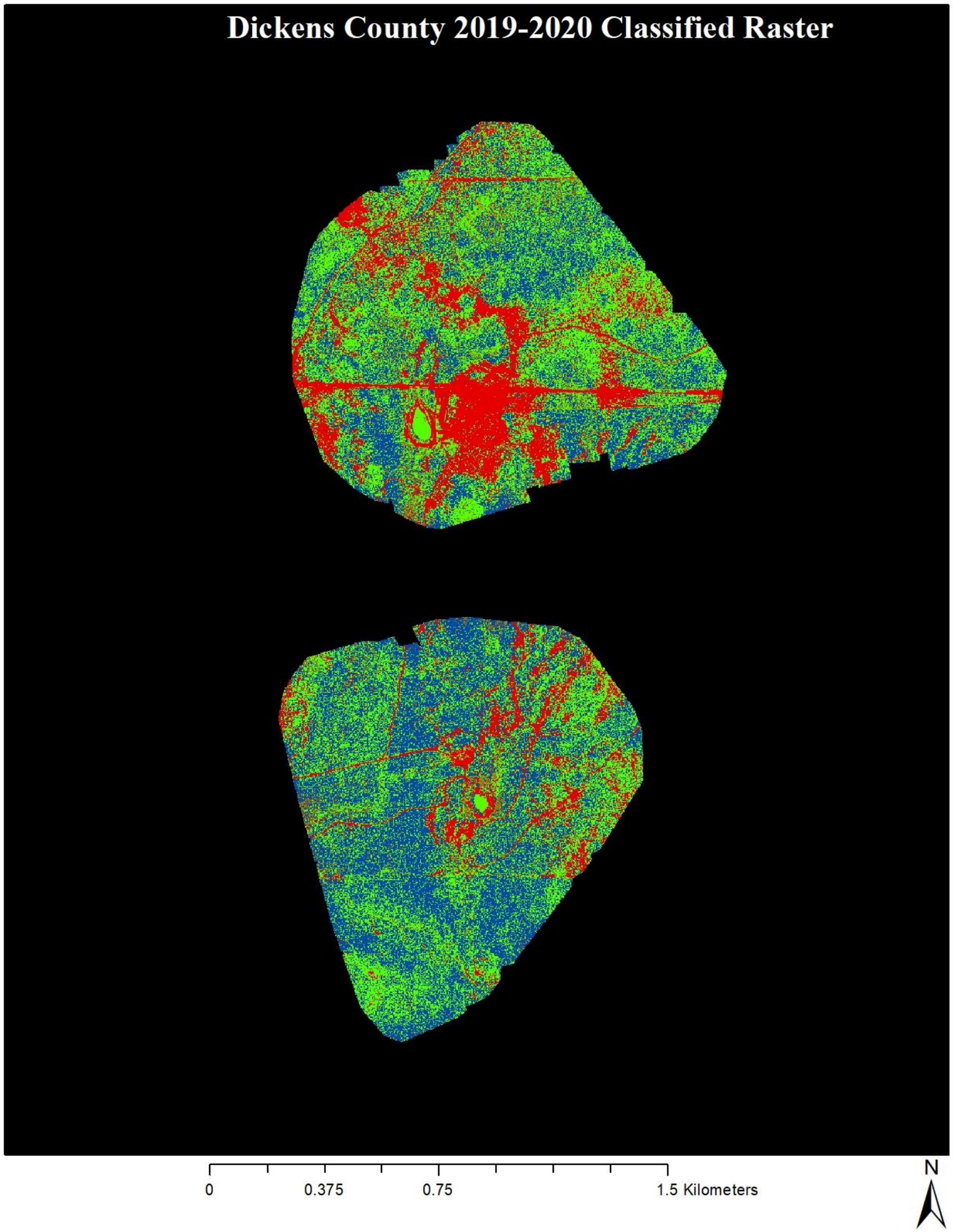

Figure A-7. 19-20 map of Dickens County site drone images stitched together with classifications overlaid.

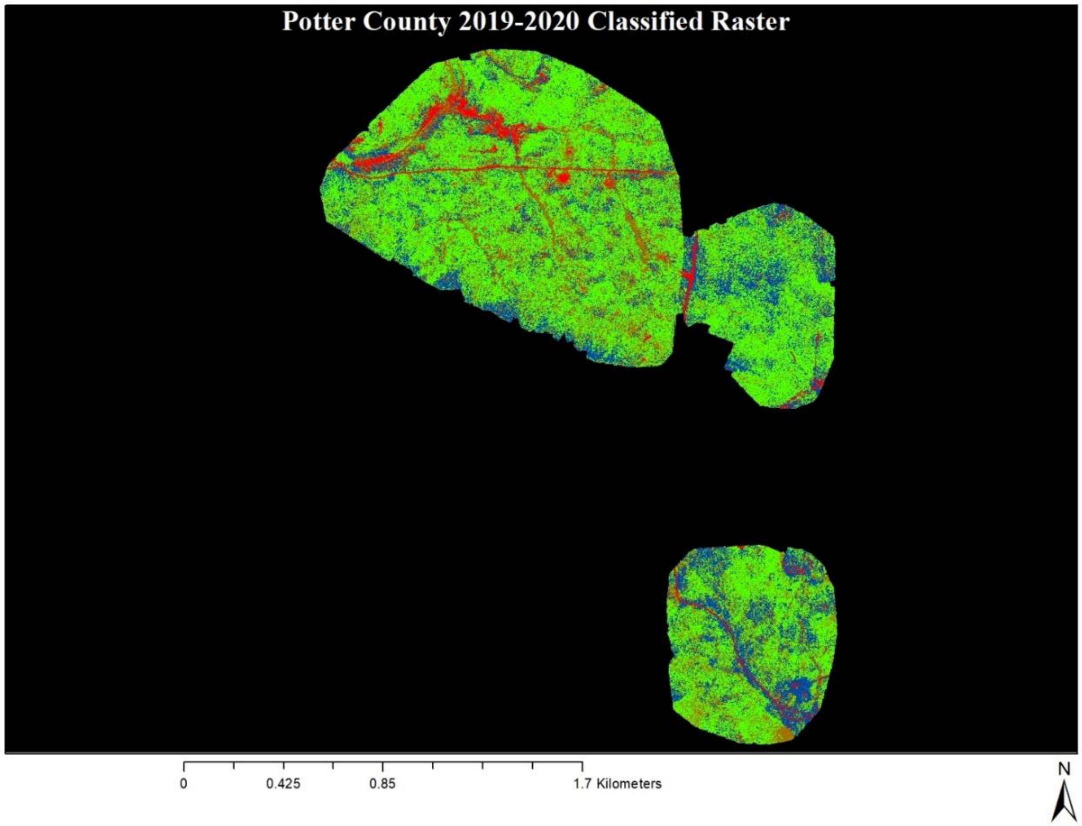

Figure A-8. 19-20 map of Potter County site drone images stitched together with classifications overlaid.

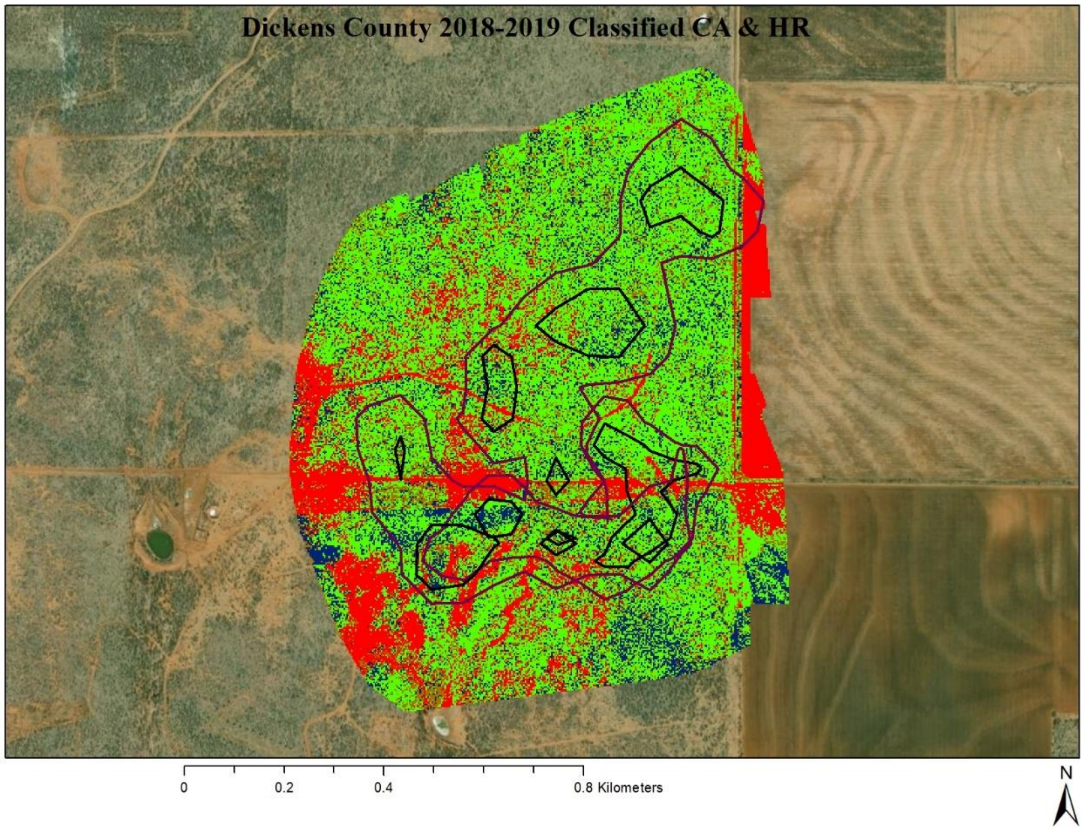

Figure A-9. 18-19 map of Dickens County site drone images stitched together with 50% core area and 90% home range isopleth classifications overlaid.

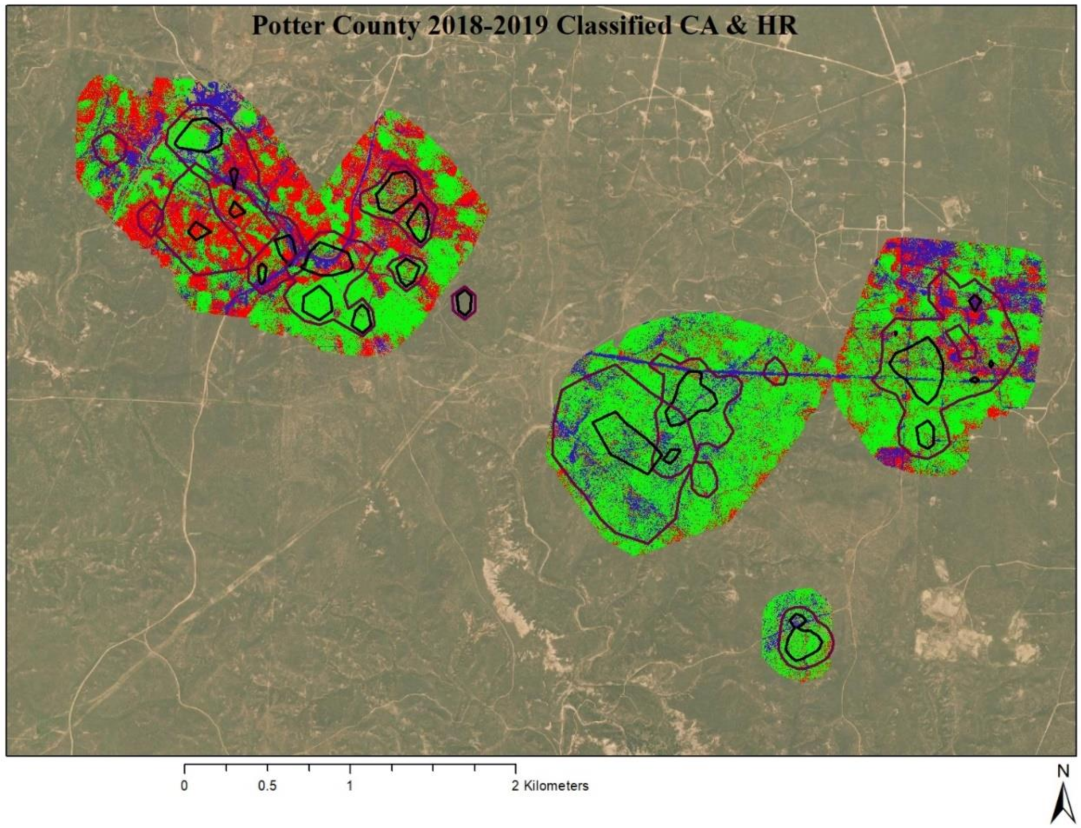

Figure A-10. 18-19 map of Potter County site drone images stitched together with 50% core area and 90% home range isopleth classifications overlaid.

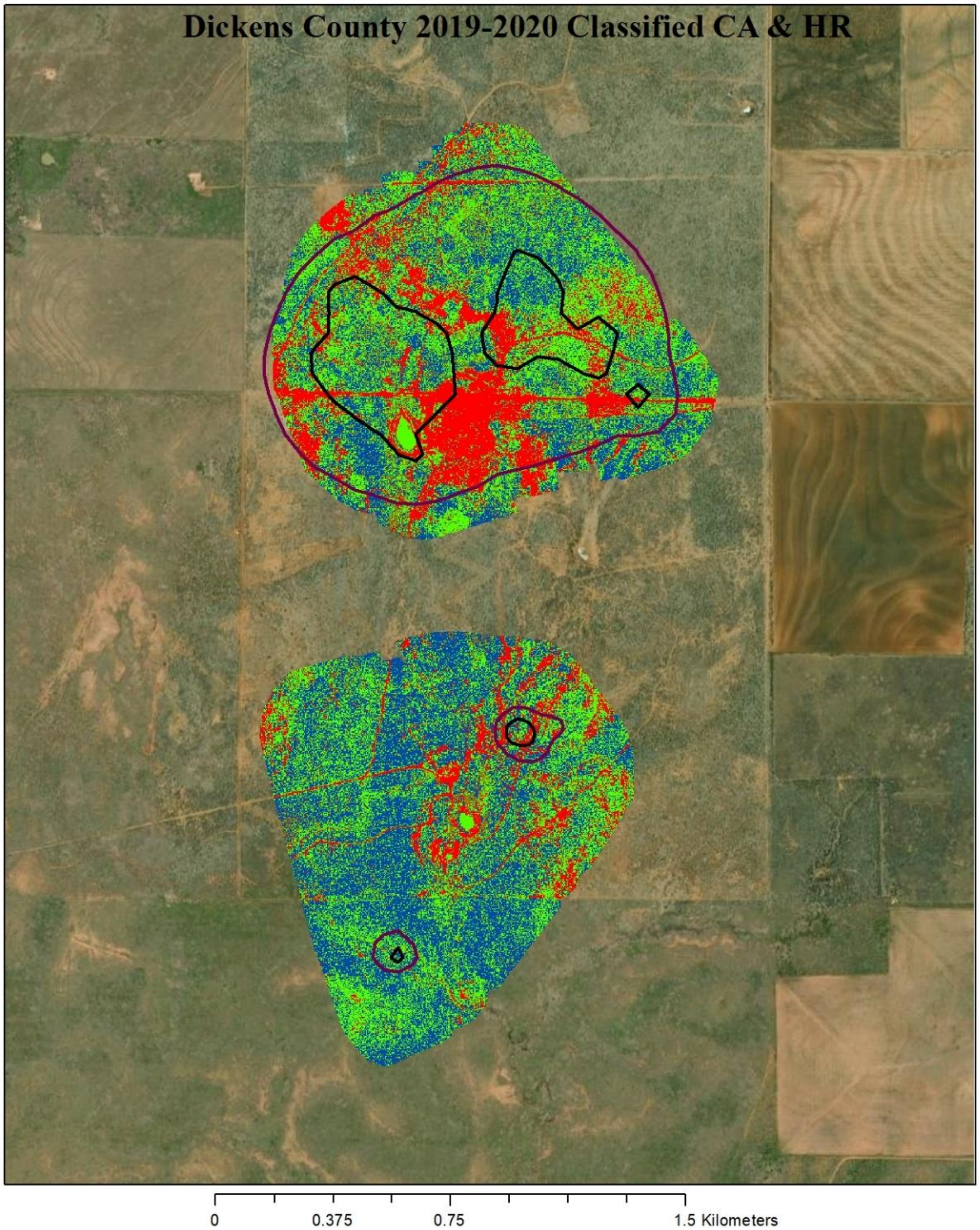

Figure A-11. 19-20 map of Dickens County site drone images stitched together with 50% core area and 90% home range isopleth classifications overlaid.

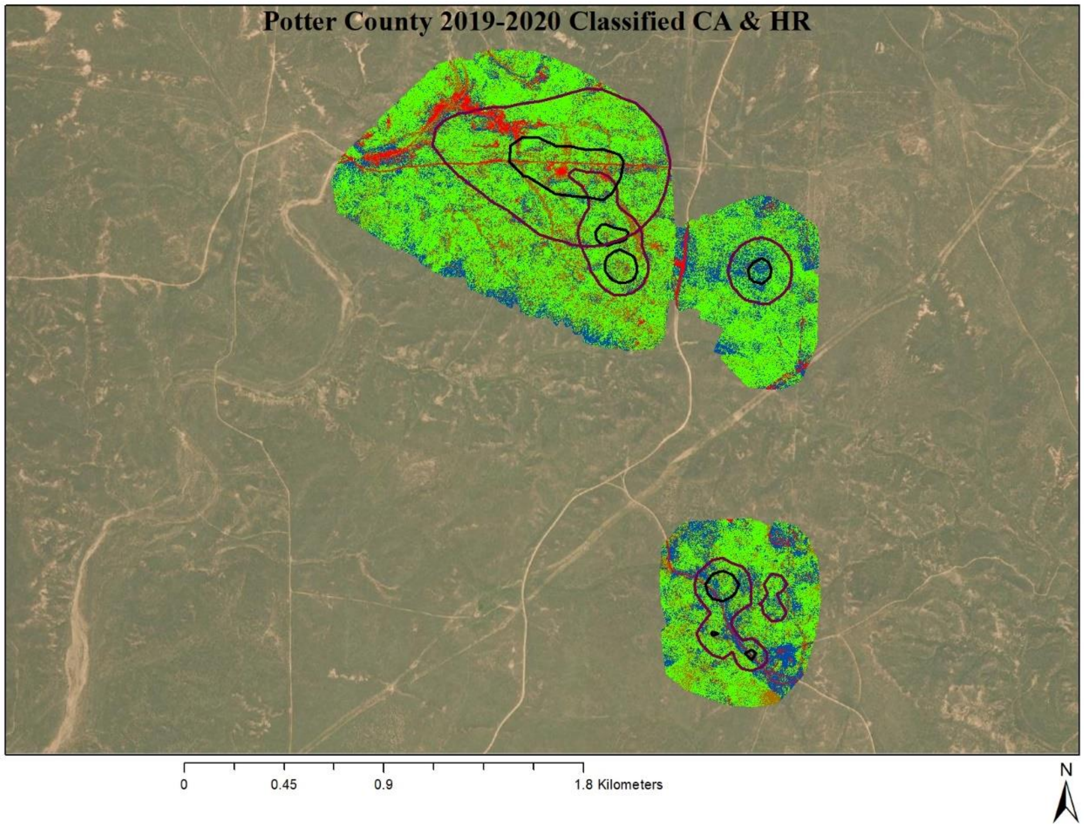

Figure A-12. 19-20 map of Potter County site drone images stitched together with 50% core area and 90% home range isopleth classifications overlaid.

APPENDIX B

Table B. 1 Overall and Kappa coefficient values for cover classification of Scaled quail (*Callipepla squamata*) habitat in the Rolling Plains of Texas in winter 2018-2019 and 2019-2020.

Overall Accuracy and Kappa Coefficient Results for Dickens and Potter County Rasters

Year	Ranch	Overall Accuracy	K
18-19	Dickens	92.46	0.90
18-19	Potter	84.50	0.79
18-19	Potter	90.82	0.88
18-19	Potter	96.25	0.95
18-19	Potter	96.86	0.96
18-19	Potter	81.88	0.76
19-20	Dickens	85.93	0.80
19-20	Dickens	89.38	0.86
19-20	Potter	72.96	0.64
19-20	Potter	91.25	0.88
19-20	Potter	88.75	0.85