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ABSTRACT

Quail translocations are becoming increasingly popular in regions of suitable habitat where local quail populations have declined. In northeastern Texas, USA, northern bobwhite (*Colinus virginianus*) populations have drastically declined for over a century and have reached undetectable levels in many areas. As a result, the number of quail hunters and quail conservation funding have also declined. California valley quail (*Callipepla californica*; hereafter, valley quail) have increased across their range and have been translocated to many states and countries. Thus, the goal of this study was to determine whether translocating wild valley quail to Texas was feasible, and evaluate their survival, dispersal, roost location preference, and potential predator impacts. We translocated 748 wild valley quail from Idaho, USA to northeastern Texas in 2019 and 2020. We collected quail location data from very high frequency (VHF) and digital transmitters. Motion-triggered cameras, scent stations, simulated nests, and raptor transects were used to record predator presence and potential predator impacts. Survival of birds with tracking devices was 63% (VHF) in 2019, and 38.8% (VHF) and 92.5% (digital tag) in 2020. Survival was greater for quail with digital transmitters. Median dispersal distance was 633.5 m in 2019 and 246.6 m in 2020 for valley quail with VHF transmitters, and 310.4 m for quail with digital transmitters. Minimum convex polygon area medians were 4.3 ha in 2019 and 3.1 ha in 2020 for quail with VHF transmitters, and 16.1 ha in 2020 for quail with digital transmitters. Roost sites were primarily in young stands of oak trees. Median simulated nest survival was 2 days (minimum [min] = 1, interquartile range [IQR] = 2–5.4, maximum [max] = 23) in 2019, and 7.5 days (min = 2, IQR = 4.5–15.2, max = 23) in 2020. The most frequent mammalian predators observed were raccoons (*Procyon lotor*), feral hogs (*Sus scrofa*), and white-tailed deer (*Odocoileus virginianus*). Red-tailed hawks (*Buteo jamaicensis*) were the most frequent aerial predator. We completed the first documented translocation of wild California valley quail to Texas, demonstrating it is feasible. Future translocation may benefit from translocating more birds over a longer period of time, with more consistent methodology. The establishment of a sustainable population may require ≥7 years of translocation at a rate of 500 birds per year with >2,000 ha of suitable habitat.

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Key words: California valley quail, *Callipepla californica, Colinus virginianus*, dispersal, mesomammal, nest camera, nest predation, northern bobwhite, predator-prey, radio-telemetry, radio handicap, survival, scent stations, translocation, Texas

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Quail translocations are becoming increasingly popular in regions of good habitat where local quail populations have declined (Martin et al. 2017). Northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) populations in the United States have declined 3.1% annually since 1966 (Sauer et al. 2020). Bobwhite populations have declined to undetectable levels in northeastern Texas, USA, the focal region of this study. With declining quail populations, quail hunter numbers in Texas have decreased from 127,451 in 1999–2000 to 49,752 in 2017–2018 (Purvis 2018). Fewer hunters results in less funding for quail conservation (Brennan 2015). Thus, landowners and wildlife agencies are looking for novel approaches to restore quail and quail hunter numbers.

Population restoration techniques (PRTs) are used to restore quail populations in areas of restored habitat where resident populations do not exist. Landowners have implemented PRTs, such as releasing captive-reared bobwhites and translocating wild birds, with little documented long-term success (Whitt et al. 2017, Reyna and Newman 2018, Reyna et al. 2021). The failure of bobwhite PRTs has been attributed to bad source stock (Reyna and Newman 2018), poor timing of releases (Sisson et al. 2012), stress (Martin et al. 2017), severe weather (Chavarria et al. 2012*b*), and improper predator response (Stephenson et al. 2011, Reyna and Newman 2018). Additionally, predators are major stressors for newly translocated bobwhites and can adversely impact survival and translocation success (Martin et al. 2017). Predation losses are responsible for ≥89% of nest failures and 93% of adult mortalities (DeVos and Mueller 1993). Recent studies have investigated methods to improve bobwhite translocation success, and recommend release just prior to breeding season, a large area of high quality habitat on the recipient site, and short handling and transport times (Liu et al. 2002; Terhune et al. 2006*b*, 2010; Sisson et al. 2017; Reyna et al. 2021).

Bobwhites are not the only quail species to have been widely translocated. California valley quail (*Callipepla californica*; hereafter, valley quail) have been successfully translocated to ≥8 U.S. states and to Canada, New Zealand, Australia, Chile, Germany, and France (Phillips 1928, Schwartz and Schwartz 1950, Williams 1952, Leopold 1977, Pietri 1995). Many of these translocations resulted in increased hunting opportunity and revenue (Leopold 1977). While bobwhite populations have declined range-wide, valley quail populations have increased, particularly in regions where they were introduced (Sauer et al. 2020). Valley quail inhabit temperate to subtropical regions and have demonstrated high adaptability to new environments and tolerance of anthropogenic influences (Leopold 1977). Valley quail are less dependent on insects than bobwhites (Glading et al. 1940, Crispens et al. 1960, Hurst 1972) and are considered "suburban adaptable" (Blair 1996). Unlike most quail, which roost at ground level, valley quail roost in trees or elevated positions at night (Sumner 1936, Leopold 1977). There is a dearth of scientific literature on the utility of these adaptations to improve translocation success. For example, roost site selection is in part due to predator avoidance (Weatherhead 1983), and roosting in trees could decrease night predation. Because of their previous long-term translocation successes, ability to adapt to a wide variety of new environments, and increasing population numbers, valley quail appear to be good candidates for translocations to restored habitat.

We investigated the feasibility of translocating wild valley quail to Texas. A recent attempt by James et al. (2017) to translocate valley quail was unsuccessful. Therefore, our objectives were to translocate wild valley quail from Idaho, USA to Texas and evaluate their survival, dispersal, roost site selection, and potential predator impacts.

STUDY AREA

We focused on a ~500 ha privately owned ranch in Fannin County, Texas (Figure 1). Surrounding private land was also evaluated as translocated quail dispersed. The study area was in the Blackland Prairie ecoregion (Griffith et al. 2004) and was a mixture of grasslands interspersed with densely wooded areas. Average annual rainfall for Fannin County was 117 cm and mean annual temperature was 17° C (Arguez et al. 2011). The study area was managed primarily for white-tailed deer (*Odocoileus virginianus*), ducks (family Anatidae), and quail, although no quail were known to be present prior to the study. Predator control consisted of trapping and shooting, which, for this study, began in July 2019 and continued through the end of this study. Grasslands were interspersed with supplemental food plots, including oats (*Avena sativa*), legumes (family Fabaceae), and *Sorghum* spp. to attract and support deer and other wildlife. The ranch was managed through mechanical means (e.g., disking, mowing), prescribed burning, and periodic grazing of cattle to maintain early-successional grasslands and woodlands. The grasslands on the study area were mostly tallgrasses (*Panicum* spp., *Schizachyrium* spp., *Sorghastrum* spp.) intermixed with sections of briars (*Rubus* spp., *Smilax* spp.) and stands of young trees (*Quercus* spp.,

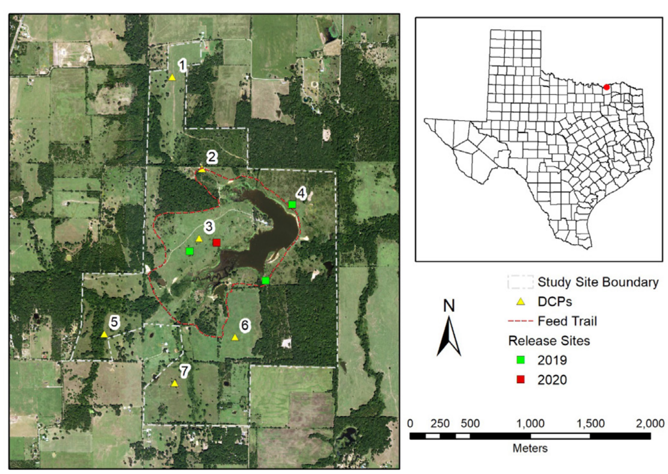

Fig. 1. California valley quail (*Callipepla californica*) translocation study area with data collection points (DCPs), feed trail, and quail release locations for 2019 and 2020.

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Ulmus spp., *Juniperus* spp.) that provide cover and shelter for quail (Stoddard 1931, Leopold 1977). Water sources included 4 small creeks that flow into a ~16 ha reservoir near the center of the property, along with 9 small ponds (≤0.4 ha) around the perimeter of the study area.

Seven data collection points (DCPs) were established within the study area (Figure 1). They were marked by a numbered plate on a T-post, placed at the center of an understood 800-m diameter circle (Hansen and Guthery 2001, Whitt 2019), considered the data collection area (DCA).

METHODS

All animal handling methods were approved by the institutional animal care and use committee at Texas A&M University-Commerce (Animal Use Protocol P18-018). Birds were collected under Idaho Department of Fish and Game Wildlife Collection Permit #181220.

Trapping

We captured wild valley quail with modified Stoddard (1931) funnel traps (Smith et al. 1981) baited with a seed mixture (Deluxe Dove and Quail Blend, Chuckanut All Natural Products, Jefferson, OR, USA), which included white millet (*Panicum miliaceum*), safflower seed (*Carthamus tinctorius*), canola seed (*Brassica napus*), canary seed (*Phalaris canariensis*), wheat (*Triticum aestivum*), and cracked corn (*Zea mays*). Trapping occurred during February–March 2019 and 2020. Traps were checked daily and captured valley quail were transferred to the processing site, <10 km away, using a transport coop (COOP-6-Q; KUHL Corp., Flemington, NJ, USA).

Processing

We banded quail with numbered leg bands (1242-8; National Band and Tag Co., Newport, KY, USA) and recorded bird weight, sex, age (juvenile or adult), and general health. We extracted ≤100 µL of blood from the brachial vein of each bird (Owen 2011) using a lancet and 75 µL heparinized microhematocrit capillary tubes (51608; Pulmolab, Northridge, CA, USA) for disease testing.

Disease Testing

Prior to translocating valley quail to Texas, the Texas Animal Health Commission required that 10 birds/flock test negative for avian influenza (Influenza A virus subtype H5N1), and all birds test negative for pullorum disease (*Salmonella enterica* subsp. *enterica* serovar Gallinarum biovar Pullorum) and fowl typhoid (*S. enterica* subsp. *enterica* serovar Gallinarum biovar Gallinarum). A certificate of flock health from a veterinarian was also required. For avian influenza testing, ~50 µL samples of blood from 10 birds/flock were sent to the Idaho State Department of Agriculture Animal Health Laboratory in Boise. For pullorum disease and fowl typhoid testing, 20 µL of the extracted blood was applied to the rapid whole-blood plate test with pullorum typhoid antigen (Charles River Laboratories, Wilmington, MA, USA). Remaining blood samples were stored on labeled blotter cards (Whatman WB120205; Sigma-Aldrich®, St. Louis, MO, USA; Smith and Burgoyne 2004) for future genetic testing. When all tests were returned negative and a veterinarian's health certificate was received from a visiting veterinarian, the Texas Animal Health Commission issued an import permit.

Translocation

We placed birds in shipping boxes (16-Bird Shipping Box; Boxes for Birds, Conway, AR, USA) and shipped them to Texas using Priority Mail Express™ via the U.S. Postal Service. Each bird was supplemented with a ~30–50-g cucumber slice for nutrition and hydration during the 2-day shipping period (L. Webster, Oklahoma Quail Ranch, personal communication) in 2019, and millet sprays in 2021 (Currier 2021).

Quail were transported from the post office in Texas to the study area (~75 km) in the cargo area of a pickup. Shipping boxes were brought into a screened enclosure (Tailgaterz; Wenzel, Boulder, CO, USA) to prevent translocated birds from escaping. Birds were weighed, all demographic data confirmed, and notes made of any injuries or debilitating conditions. In 2019, 100 of the 250 quail were randomly selected and outfitted with very high frequency (VHF) radio transmitters as a necklace (Pip Ag393; Lotek Wireless Inc., Newmarket, Ontario, Canada). For 2020, 50 of the 500 quail were fitted with VHF transmitters as a necklace (A1070; Advanced Tracking Systems, Isanti, MN, USA), and 100 were fitted with a solar-powered digital transmitter (LifeTag™; Cellular Tracking Technologies, Rio Grande, NJ, USA) as a backpack. All birds in each shipment were released on the same day and within 1 week of capture. Quail in 2019 were released in separate locations within the study area. In 2020, all quail were released in the same location near the center of the study area (Figure 1).

In addition to habitat and predator management, the release site was prepared by establishing a ~5.8 km (3.6 mile) supplemental feed trail prior to release, to provide immediately accessible food and reduce mortality (Figure 1; Sisson et al. 2000). Feed was scattered along the feed trail biweekly using an electric feeder (55-Gallon Classic Game Feeder; One and Done Pro, Garland, TX) mounted in the bed of a utility task vehicle (Ranger Crew 570-4; Polaris®, Medina, MN). Feed consisted of ~226 kg (500 lbs) of hen scratch, a mixture of cracked corn, milo (*Sorghum bicolor*), and wheat. Release locations were also supplied initially with a small amount (~10 kg) of hen scratch on the day of release.

Monitoring

We tracked birds with VHF and digital transmitters to determine survival, dispersal, and roost locations. We located birds with VHF transmitters at least once per week. The digital transmitters sent a unique digital ID every 2 seconds in full sun, and every ~30 seconds in partial shade. Signals were relayed by nodes to a base station that recorded time and relative signal strength to estimate location. We also tracked

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digital transmitters by hand using a digital receiver and Yagi antenna. We located VHF transmitters using a combination of triangulation and direct tracking (Millspaugh et al. 2012). While triangulation was the primary method, direct tracking was often more practical when quail were unlikely to flee (Millspaugh et al. 2012), for example, while roosting. We completed direct tracking by walking using a hand-held Yagi antenna to scan for VHF or digital transmitters within the study area. When a VHF or digital transmitter could not be detected within 1 week, we expanded the search radius for the bird from the point it was last recorded. We searched for missing digital transmitters using mobile nodes attached to vehicles. We attempted to locate VHF transmitters from all roadsides in a 2-km radius from the last known point as well as from private land, if permission could be obtained. If the VHF or digital transmitter was not located for 3 weeks, it was considered lost (Liu et al. 2000) and weekly attempts were made to relocate it. If a VHF or digital transmitter did not move for >1 week, the associated quail was flushed to determine status. Recovery dates and locations were recorded and marked with a hand-held Global Positioning System (GPS) device (GPSMap 64st; Garmin Ltd., Olathe, KS, USA).

Indirect quail counts were performed during spring and early summer seasons as an index of breeding potential and to record population trends (Smith and Gallizioli 1965). We conducted call counts at 7 DCPs across the study area (Figure 1). We placed DCPs in locations that did not restrict the observer from effectively hearing calls and avoided areas that were heavily wooded while still remaining ~800 m apart, to avoid double detection (Hansen and Guthery 2001). Call counts were performed starting at sunrise and continued until all DCPs had been visited. We recorded the number and estimated distance of calls, temperature, dew point, wind velocity, and percent cloud cover. Probability of detection was estimated using the double observer method (Nichols et al. 2000). Call counts and visual observations were used as indices for studying population trends.

In addition to radio-telemetry, a hand-held forward-looking infrared device (FLIR; Scout III, FLIR Systems, Wilsonville, OR) was used in combination with a Yagi antenna to detect quail on roost after sunset (Chavarria et al. 2012*a*). Once roosting quail were located, roost locations were marked with GPS coordinates and revisited for evaluation during the day. We recorded roost tree species, estimated age, diameter at breast height using a diameter tape, and estimated height using a tangent height gauge.

Simulated Nests

Simulated nests were created to mimic valley quail nests and to identify and estimate relative abundance of nest-predator species in the study area (Pietz et al. 2012, Dyson et al. 2020). Nests were constructed under a clump of bunchgrass (e.g., little bluestem; *Schizachyrium scoparium*) >0.3 m in diameter by kicking the toe of a boot under the bunchgrass and creating a nest bowl (Rollins et al. 2005). Each nest contained 14 Coturnix quail eggs (*Coturnix japonica*) since they were readily available and resemble valley quail eggs (Figure 2). Simulated nests were active for 23 days, the incubation period for valley quail, and nests were considered successful at day 23. Nests were terminated either once all eggs had been depredated or after 23 days. Nests were checked weekly for predation. Eggs were replaced at 2 weeks if undisturbed to avoid attracting predators to rotten egg odors (Major and Kendal 1996).

In 2019, simulated nests were placed in random clusters. Clusters consisted of 6 nests inside a 40-m × 40-m area. Four clusters were placed in locations typical of valley quail habitat, determined by the presence of adequate bunchgrass (Arredondo et al. 2007), cover, and proximity to food and water (Leopold 1977), along with radio-telemetry data or visual detection of coveys. Clusters were active on a rotating basis 1 May 2019–20 June 2019. When all nests in a cluster were terminated, the next cluster was initiated. Motion-triggered cameras (Model 119874C; Bushnell Corp., Overland Park, KS) were placed <2 m from each nest, and an orange flag placed behind the camera <1 m away. We checked nests every 1–2 days for predation and checked cameras for battery life and media storage.

Fig. 2. A simulated California valley quail (*Callipepla californica*) nest to determine nest predator impacts on translocated valley quail in Fannin County, Texas, USA, June 2019.

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In 2020, simulated nests were placed in DCAs 1–5 along 300-m transects. We omitted DCPs 6 and 7 due to lack of suitable nesting habitat and lack of quail recorded in the area. We placed transects on DCPs in a randomly selected cardinal direction (Reyna et al. 2012). Six simulated nests were placed per transect, one every 50 m. We placed motion-triggered cameras <2 m from each nest, with remote flagging located ~7 m from a nest (Major and Kendal 1996). Simulated nests were active 1 May 2020–20 June 2020 as cameras were available. Transects 1 and 2 were initiated simultaneously. Transects 3–5 were initiated once 6 cameras were available from earlier transects. We checked nests weekly for predation and checked cameras for battery life and media storage.

We used photographs from simulated nests to identify nest predators and calculate nest survival. Predators returning to simulated nests could be determined by looking at unique markings (Heilbrun et al. 2003), size comparisons, and specific behavioral traits (Bridges and Noss 2011).

Predator Scent Stations

Relative abundance of predator species was assessed using predator scent stations, modified from Sargeant et al. (1998). We constructed predator scent stations at all 7 DCPs, ≥800 m from one another. A predator scent station consisted of a motion-triggered camera and a fatty acid scent tablet (Predator Survey Disks; Wildlife Control Supplies, East Granby, CT, USA) placed ~2 m from the camera and enclosed in a wire mesh envelope (5 cm × 5 cm). Mesh envelopes were secured with cable ties attached to a 10-cm metal stake driven into the ground. Scent stations were active for 5 consecutive days 1 May–20 June 2019 and 2020. We replaced tablets after rainfall.

Evaluation of Raptor Presence

To determine raptor presence and relative species abundance, a ~5.8-km transect was established along the existing supplemental feed trail (Figure 1). Two technicians with binoculars walked the transect twice, once clockwise and once counterclockwise, between 0600 and 1000 or 1600 and 2000 and recorded the date, time, weather conditions, location, quantity, and species type of each raptor observed. Raptor identification experience varied among individuals, so those with little experience reviewed the Merlin Bird ID phone application (version 1.8.2; Cornell Lab of Ornithology, Ithaca, NY, USA) to differentiate raptor appearances, songs, cries, and calls. We conducted surveys only on calm days (Craig 1978) and did not conduct surveys during active precipitation. Surveys were conducted twice monthly in 2020, beginning in February and continuing through June, with the exception of March 2020 due to COVID-19 restrictions and weather conditions (Schlater 2019). Raptors presenting themselves in the same spot every day were not counted each time as an incidental observation, but were counted if present during a raptor survey. We compiled data from raptor surveys with incidental observations.

Motion-triggered Cameras

We activated motion-triggered cameras along the supplemental feed trail (Whitelaw et al. 2009), and at an existing gravity feeder (Quail feeder, 1,000lb; Outback Wildlife Feeders, Gilmer, TX) to record predator presence and prevalence, and to monitor translocated quail. Camera locations were adjusted based on sightings of quail coveys and radio-telemetry location estimates. Cameras were identified by deployment location and date.

Data Analysis

Maximum survival was estimated using confirmed deaths from located tracking devices. Quail and simulated nest survival were analyzed with the Kaplan-Meier (Kaplan and Meier 1958) procedure with a log-rank test to compare survival data between groups (Bland and Altman 2004). Dispersal was quantified by: 1) measuring the maximum linear distance each quail traveled (Terhune et al. 2006*a*), and 2) using GIS software (ArcGIS 10.6.1; Esri Inc., Redlands, CA) to compute minimum convex polygon home ranges (MCPs) and center points (Jones 1999). We created a MCP for each quail that had ≥4 recorded locations. Convex polygons are an estimate of the range that the quail traveled over the study duration. Dispersal data were compared across each group of released birds using Mann-Whitney U test. A chi-square test was used to compare predator frequencies recorded from predator scent stations and simulated nests between years. Relative abundance of visits at scent stations was reported as a scent station index (SSI; Reyna et al. 2012), defined as (total station visits/total station operating nights) × 100. All motion-triggered cameras were checked at least once every 2 weeks. We entered image date and time, predator species, number of individuals present, and camera ID in a spreadsheet (Excel® 16.0; Microsoft® Corp., Redmond, WA, USA). Individuals photographed on a motion-triggered camera could be identified based on coat pattern or behavior and were not counted twice if identified twice on the same day, defined as the 24-hour time period beginning at 0000. Image capture times for the 5 most common predators were visualized in a scatterplot.

RESULTS

Translocation

We translocated 748 wild valley quail from Idaho to Texas (>2,000 km): 248 in 2019 and 500 in 2020. Valley quail were in transit for ~48 hours. All translocated valley quail tested negative for avian influenza and pullorum typhoid disease.

Survival

Due to short battery life and failures of VHF transmitters in 2019, survival estimates were determined at 6 weeks post-release. Maximum survival of quail with tracking devices (without censoring) was 63% (VHF) in 2019, and 38.8% (VHF)

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and 92.5% (digital tag) in 2020; Kaplan-Meier estimates were lower (Figure 3). Survival was greater for translocated valley quail with digital tags than VHF transmitters in 2020 (log-rank test, df = 1, χ^2 = 9.71, 0.001 < P < 0.01).

Among birds without tracking devices, survival rate was less certain. At 60 days following the 2019 release, we estimated the number of surviving birds without transmitters in the study area at ~30 individuals, based on observations and assembly calls. At 120 days after our first release, 5–6 valley quail were regularly observed on the site. However, on 21 August 2019, a separate covey of ~15 birds was flushed and appeared to include at least 2 juveniles, indicating ≥1 successful nesting event by the translocated birds. More birds were observed in October, with ≥20 valley quail, including ≥2 juveniles ~6 months after release, with an unknown number outside the study area.

In April 2020, one translocated quail from the 2019 release was found 30.5 km (18 miles) away in Bells, Texas. In June 2021, 2 males were recorded on video chasing a hen on a neighboring property. As of August 2021, residents still observe translocated valley quail in the region of the study area.

Dispersal

Median dispersal for translocated valley quail with VHF transmitters was 633.6 m (minimum [min] = 36.3 m, interquartile range [IQR] = 397.5–833.4, maximum [max] = 2,029.2) in 2019, and 246.6 m (min = 12.6, IQR = 149.8–628.6, max = 1,696.3) in 2020. Median dispersal for translocated valley quail with digital transmitters in 2020 was 310.4 m (min = 34, IQR = 176.6–538.6, max = 975.9). Median dispersal in 2019 was greater for birds with VHF transmitters than in 2020 (Mann-Whitney *U*, *P* < 0.001) and for birds with digital transmitters (Mann-Whitney *U*, *P* < 0.001). There was no difference in dispersal distance between quail with VHF and digital transmitters in 2020 (Mann-Whitney *U*, *P* = 0.24).

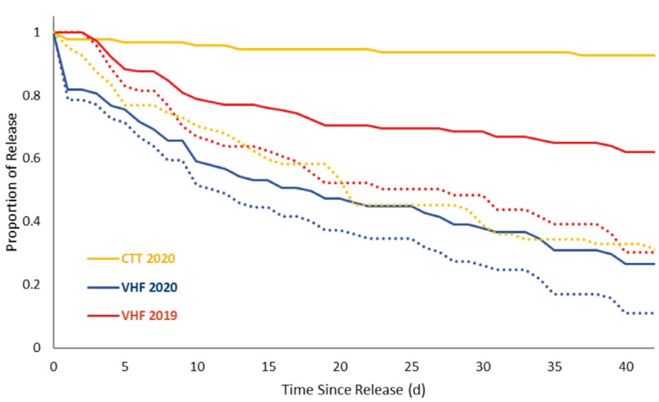

Fig. 3. Estimated survival for California valley quail (*Callipepla californica*) translocated from Idaho, USA to Texas, USA with very high frequency transmitters in 2019 (red) and 2020 (blue), and digital transmitters in 2020 (gold) based on recovered tags (top solid line) and Kaplan-Meier survival estimations, in which tags with an unknown location are censored (bottom dotted lines).

Sufficient location estimates were obtained to generate MCPs for 35 translocated valley quail with VHF transmitters in 2019 and 24 quail in 2020. There were 82 MCPs generated for translocated valley quail with digital transmitters in 2020. Median MCP area was greater for valley quail with digital transmitters than for birds with VHF transmitters in 2019 and 2020 (Mann-Whitney *U*, *P* < 0.001). Median MCP area for translocated valley quail with VHF transmitters was 4.3 ha (min = 0.1, IQR = 0.9–12.2, max = 44.1) in 2019, and 3.1 ha (min = 0.1, IQR = 0.7–12.5, max = 42.8) in 2020. Median MCP area for translocated valley quail with digital transmitters was 16.1 ha (min = 1.4, IQR = 7.6–26.9, max = 78.5) in 2020. There was no statistical difference in median MCP area for translocated valley quail with VHF transmitters between 2019 and 2020 (Mann-Whitney *U*, *P* = 0.99). There was no difference in MCP area of male and female quail (Mann-Whitney *U*, *P* = 0.14).

One quail from 2019 was found 30 km away from its release site. This datum was considered an outlier and excluded from dispersal analysis. In 2019, there were ~300 quail locations recorded from VHF transmitters. In 2020, there were 144 quail locations recorded from VHF transmitters, and >25,000 quail locations from digital transmitters.

Spring Call Counts

We conducted two call counts in June 2019 and recorded 0 quail. In 2020, we recorded 2 calls in May and 2 calls in June. Both observers reported the same number of calls.

Fig. 4. An oak tree (*Quercus* sp.) used as a roost site for California valley quail (*Callipepla californica*) translocated from Idaho, USA to Fannin County, Texas, USA. Surrounded by cover for quail and partially covered with briars (*Smilax* sp.), this tree is representative of the majority of roost sites for the translocated quail.

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Roosts

We documented 27 roost sites, >60% in oak (*Quercus* spp.) and elm (*Ulmus* spp.) trees. Of the 14 roosts in 2019, 9 consisted of multiple young trees that grew close together, providing dense cover for the birds (Figure 4). Tree mean diameter at breast height (DBH; ±standard error) was 9.0 ± 2.9 cm, with a mean height of 5.5 ± 1.6 m. The remaining roosts for 2019 included single eastern redcedars (*Juniperus virginiana*; $N = 2$) and ground roosts ($N = 3$). For 2020, 10 roosts were recorded in trees with a mean height of 8 ± 1.5 m and DBH of 22.7 ± 7.6 cm. All sites were <15 m from escape cover, such as *Rubus* spp. and *Smilax* spp. At least 3 roost sites were used ≥1 night.

Simulated Nests

Median simulated nest survival time in 2019 was 2 days (min = 1, IQR = 2–5.4, max = 23). Median simulated nest survival time in 2020 was 7.5 d (min = 2, IQR = 4.5–15.2, max = 23). Nest survival time was greater in 2020 than 2019 (Figure 5; $\chi^2 = 7.95$, df = 1, $P = 0.005$). One nest (4%) survived 23 days in 2019. Four nests (16%) survived 23 days in 2020.

Predator Scent Stations

Predator scent station cameras recorded 7 mammalian and 1 avian species (Table 1). In 2019, the most common visitors were raccoons (SSI = 48.6), followed by feral hogs, white-tailed deer, and armadillos (please see Appendix A for scientific names of predator species). In 2020, the most common visitors were feral hogs (SSI = 31.4), white-tailed deer, and raccoons. Species frequencies did not differ between years ($\chi^2 = 11.296$, df = 7, $P = 0.126$).

Evaluation of Raptor Presence

Nine species were detected during 8 raptor surveys conducted 16 February 2020–30 June 2020 (Figure 6). March was excluded due to weather and COVID-19 exposure protocols. Sixty percent of raptors were recorded during raptor surveys, and 40% were recorded from incidental observations. Species could not be determined for 6 raptors.

Motion-triggered Cameras

Motion-triggered cameras recorded ≥20 species of quail predators (13 mammalian, 6 avian, and 1 reptile). The most common nest predators were raccoons (33%), feral hogs (24%), and white-tailed deer (20%). Including species not considered quail predators, 45 vertebrate species were recorded on the study area through motion-triggered cameras and visual detection by technicians (Appendix A). Of note, 2 quail were photographed during copulation in 2019 (Figure 7).

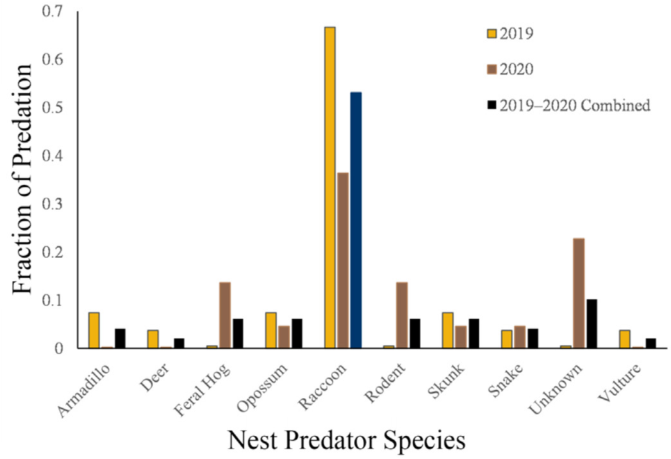

Fig. 5. Proportion of simulated California valley quail (*Callipepla californica*) nest predations per species within a quail translocation study area in Fannin County, Texas, USA, May–June 2019 and 2020.

Table 1. Scent station index (SSI) for species identified on motion-triggered cameras deployed at predator scent stations in Fannin County, Texas, USA, May–June 2019–2020.

Species	Scent station index[a]	
	2019	2020
Raccoon	48.6	14.3
Feral hog	20.0	31.4
White-tailed deer	11.4	17.1
Armadillo	11.4	2.9
Coyote	8.6	5.7
Bobcat	5.7	0.0
Skunk	2.9	2.9
Roadrunner	0.0	2.9

[a] Scent station index estimates number of predator visits (total station visits/total station operating nights) × 100.

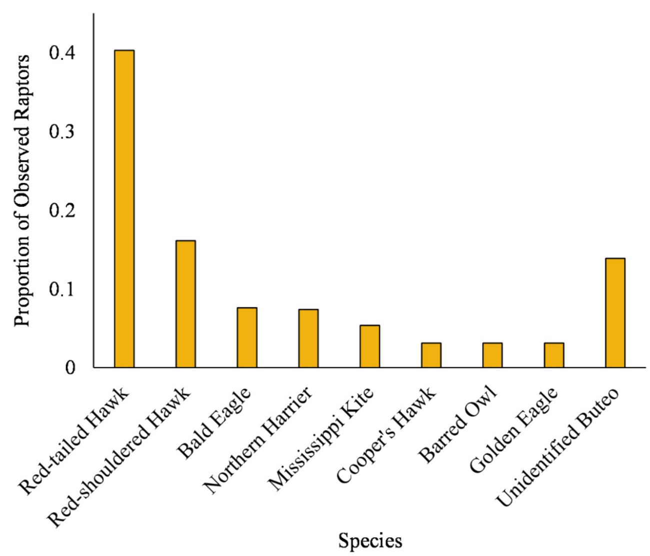

Fig. 6. Proportions of raptors recorded during raptor surveys and incidental observations within a California valley quail (*Callipepla californica*) translocation study area in Fannin County, Texas, USA, February–June 2020.

Fig. 7. Wild California valley quail (*Callipepla californica*) copulating in Fannin County, Texas, USA, 2019, after translocation of birds to the region.

DISCUSSION

This was the first documented translocation of wild California valley quail to Texas, demonstrating that translocating wild valley quail to Texas is feasible. This study improved on previous efforts by James et al. (2017) by: 1) translocating wild birds; 2) selecting a release area with a sufficient quantity and quality of escape, loafing, and nesting cover; 3) preparing the release area for translocations; and 4) recording roost selection.

Survival

Comparable survival estimates >6 weeks were difficult to obtain due to the lack of performance of tracking devices. The longer life of quail with digital transmitters was likely due to the difference in mass between digital and VHF transmitters (Guthery and Lusk 2004). Digital transmitters weighed ~0.45 g, and VHF transmitters weighed ~3.3 g. However, we are unclear if some of this advantage was offset by harness type. Digital transmitters were attached as a backpack to allow exposure for the solar power source, whereas the VHF transmitters were attached as a necklace. Pheasants (family Phasianidae) with backpack harnesses had a lower recovery rate through shooting or trapping than those with a necklace of equivalent mass, suggesting a lower survival rate (Marcström et al. 1989).

The 2020 translocation was more successful than the 2019 translocation in terms of number of birds recorded on the study area >5 months and in the region >12 months after release. This may be due to the increased number of birds released in 2020, conspecifics in the area (Martin et al. 2017), or the introduction of lighter transmitters.

In the first year of the study, birds copulating were captured in a photograph, and a fertilized egg was found in front of a camera in early June. Despite evidence of at least one successful reproductive event, no valley quail nests were located in this study. This could be due to a majority of quail with tracking devices being censored or depredated prior to nesting season. Expected breeding times for valley quail are from April to August (Raitt 1960).

The study area in Texas was different in both climate and vegetation than the Idaho trapping site. In Boise, Idaho, summer months have average daily high temperatures above 28 °C. The warmest month, July, has average high temperatures of 34 °C and lows of 17 °C. In July in Bonham, Texas, ~10 km from the study area, the average high is 35 °C and the average low is 23 °C (Arguez et al. 2011). There is some evidence that valley quail eggs may be more susceptible to extreme heat than bobwhite eggs (Reyna and Burggren 2012, Moser 2021), and it is not known how well valley quail will survive in a drought year in Texas. Future studies would benefit from evaluating the impacts of Texas drought conditions on the development and survival of valley quail and determining lethal and sublethal temperatures (Reyna and Burggren 2012, 2017; Tomecek et al. 2017; Reyna 2019).

Dispersal and Detection

The 3.1–4.3 ha MCP for quail with VHF transmitters was likely biased low, since we used few location (≥4) to generate the MCPs. Other studies used ≥25 (Coppola et al. 2021) or ≥30 locations (Terhune et al. 2006*a*). Our MCP size for birds with digital transmitters was 18.7 ha, comparable to home ranges of 3.9–22.1 ha for wild valley quail in Oregon (Kilbride et al. 1992), 17.4 ha for translocated bobwhites in Georgia, USA (Terhune et al. 2006*a*), and 20.40–20.85 ha for translocated bobwhites in Texas (Yancey 2019). The larger MCP size for translocated valley quail with digital transmitters is likely due to more locations recorded (~260 per bird), allowing for more complete estimates of movement. While the digital transmitters produced more locations, the location data were not as accurate as those recorded from quail with VHF transmitters. Mean difference between estimated and recovery locations of digital transmitters was 85.9 ± 16.2 m (n = 11).

Some studies incorporate detection in addition to location (Downey et al. 2017). Tracking data are lacking for quail that left the study area, especially in areas where vegetation was thick and impenetrable. The grid of nodes that detected digital transmitters covered ~390 ha. However, the system required line-of-sight and, in some regions of the study area, vegetation was too thick for digital transmitter signals to be consistently detected. Additionally, a quail with a digital transmitter outside of the grid's range could be detected only by a technician with a hand-held Yagi antenna or a portable node. Due to dense forest vegetation along roads, these efforts produced <10 additional locations. Most off-site observations were reported by nearby residents. Coveys of translocated quail were frequently recorded outside the perimeter of the study area. Future studies using VHF transmitters would benefit from obtaining more location points for each bird. For future use of digital transmitters, deploying more nodes and base stations is likely to improve detection range. A digital transmitter that

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is both solar and battery powered could alleviate some of the detection difficulties of solar-powered digital transmitters.

Spring Call Counts

Few valley quail were heard during spring call counts. Unlike bobwhites, which produce audible calls 15–45 minutes prior to sunrise (Wellendorf et al. 2004), translocated valley quail call times were inconsistent. Some days, no quail were detected in the morning, but quail were heard in the same location later in the day; thus, this method of census was not a reliable metric representation of the local quail population. Future studies may be able to reduce the potential for false negatives at low densities by increasing detection time (Delaney and Leung 2010, Riddle et al. 2010). Quail calls did help determine whether quail were present in a given area.

Simulated Nests

Mesomamamals accounted for 70% of simulated nest predation. A camera study of bobwhite nests in North Florida, USA and South Georgia (Thornton 2003) showed mesomammals responsible for 11–53% of nest depredations, with raccoons, armadillos, and opossums the most common predators. The landowner began predator control July 2019 and continued through the end of this study, resulting in the removal of ~25 raccoons, 2 otters, and >60 feral hogs prior to the 2020 simulated nest predation experiment. While nest survival was greater in 2020 than 2019, it cannot be conclusively attributed to predator control. The change in nest placement methods in 2020 meant that simulated nests were both less common in high quail activity areas as measured by radio-telemetry and less densely spaced, which can influence predation rate (Reitsma 1992).

This ambiguity is common in predator control studies. Predator control did reduce predator activity and improve bobwhite nest success in an 8-year study in Florida, Georgia, and Alabama, USA (Jackson et al. 2018). However, predator control efforts had no impact on simulated nest survival in the Rolling Plains of Texas (Lyons et al. 2009), and inconsistent effects on chick production rates in north-central Texas (Jackson 1951). Thornton (2003) also found predator control efforts had inconsistent results on bobwhite nest predation in North Florida and South Georgia.

Two unexpected nest predators were photographed: turkey vultures and white-tailed deer. Vultures have been recorded predating nests of iguanas, crocodiles, and sea lions (Sexton 1975, Pavés et al. 2008, Platt et al. 2014). Likewise, white-tailed deer are opportunistic eaters and have been reported predating northern bobwhite nests (Pietz and Granfors 2000, Thornton 2003, Ellis-Felege et al. 2008). Khanal et al. (2006) reported 22% of bobwhite nests were depredated by white-tailed deer in an area with heavy predator control.

Predator Scent Stations

Raccoons and feral hogs represented 40 of 65 (61.5%) of our scent station visits and had indices of 31.4 and 25.7 SSN (Table 1). In contrast, feral hogs were the third most common and raccoons the fifth most common predators recorded at scent stations in South Texas (Haines et al. 2004), and coyotes were the most common visitor, with an SSI of 2.9–12.5. While their mean of 7.5 was comparable to our SSI values for coyotes (5.7–8.6), coyotes represented 57% of all scent station visitors over 3 years in South Texas, and their frequencies for all predators combined were lower (SSI = 5.7–20.5) than the 2-year mean frequencies of raccoons alone (SSI = 31.5) in our study. Total predator visit frequencies in this study (SSI = 77.2–108.6) were 3.8–19.1 times higher than those for Haines et al. (2004). This may be interpreted as supporting the mesomammal release hypothesis (Crooks and Soulé 1999). The landscape immediately surrounding the study area is fragmented, with a mean parcel size of ~27 ha, compared with ~179 ha in the Rio Grande Plains in 2003 (Brewster 2005). Lower fragmentation combined with coyotes being relatively more common in South Texas may explain the much lower mesomammal predator numbers in the study by Haines et al. (2004).

Raptor Observations

The most commonly recorded raptors—red-tailed hawks, red-shouldered hawks, Cooper's hawks, and barred owls—are all common, year-round residents in Fannin County, Texas. Bald eagles, golden eagles, and northern harriers are winter residents. Mississippi kites are primarily migrants, but have been observed as summer residents (Dunne et al. 1988, Sullivan et al. 2009).

Motion-triggered Cameras

Raccoons decreased and feral hog populations increased from 2019 to 2020. However, motion-triggered cameras were primarily used for monitoring quail and, as such, were placed along the feed trail and near locations where translocated quail were observed. Four cameras failed in April–July 2020 and were not replaced. Thus, predator observations could not be accurately compared between years.

Skunks, male white-tailed deer, and select feral hogs were the most identifiable species during the study. In general, it was easier to identify individuals from video than from still images, despite the lower resolution, as characteristics like gait and other movements could be observed. In many cases, individual identification was hindered by camera blur, environmental obstructions (e.g., tall grass), or distance from the motion-triggered camera. Probability of identification could be improved by minimizing obstructions, or through use of higher resolution cameras. In some locations, wind-blown vegetation regularly caused motion-triggered cameras to activate without the presence of an animal. Future studies should attempt to keep vegetation trimmed near cameras and consider prevailing winds from multiple directions.

Bobwhites and valley quail share most of the same predator species (Leopold 1977, Rollins and Carroll 2001, Staller et al. 2005). It is reasonable to assume that any predator management and avoidance techniques that work for bobwhites in northeast Texas should work for valley quail. One possible exception is that valley quail often roost in trees (Leopold 1977) and may encounter different predators, or the same predators at different rates than bobwhites.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

We showed that it is feasible to translocate wild valley quail to Texas, but the duration of our project was not sufficient to establish a sustainable population. For example, the establishment of valley quail in New Zealand was completed over ≥10 years (Williams 1952). Nearby sightings of quail >1 year following translocation show there is potential for annual overlap, potentially increasing survival rates for future translocations (Martin et al. 2017).

Northern bobwhites have a population threshold of ~800 birds with 1–2 ha/individual needed for a population to become sustainable (Guthery et al. 2000). Assuming a similar threshold for valley quail, it would take ≥7 years to reach the 800-quail threshold with 500 birds translocated annually, 10% annual survival, and replacement-level reproduction of the surviving 10%. In addition, any sustainable population would have to make use of land outside the study area. Attempts to create a sustainable population through translocation would be best attempted on sites with >2,000 ha managed for quail.

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LITERATURE CITED

Arguez, A., I. Durre, S. Applequist, M. Squires, R. Vose, X. Yin, and R. Bilotta. 2011. NOAA's U.S. Climate Normals (1981–2010): 1981–2010 Station normals of temperature, precipitation, and heating and cooling degree days. NOAA National Centers for Environmental Information, Asheville, North Carolina, USA.

Arredondo, J. A., F. Hernández, F. C. Bryant, R. L. Bingham, and R. Howard. 2007. Habitat-suitability bounds for nesting cover of northern bobwhites on semiarid rangelands. Journal of Wildlife Management 71:2592–2599.

Blair, R. B. 1996. Land use and avian species diversity along an urban gradient. Ecological Applications 6:506–519.

Bland, J. M., and D. G. Altman. 2004. The logrank test. The BMJ 328:1073. doi: 10.1136/bmj.328.7447.1073

Brennan, L. A. 2015. Hunters are a fundamental component of northern bobwhite quail conservation. International Journal of Environmental Studies 72:830–838.

Brewster, E. 2005. Fragmentation. Tierra Grande 12:17–19.

Bridges, A. S., and A. J. Noss. 2011. Behavior and activity patterns. Pages 57–69 *in* A. F. O'Connell, J. D. Nichols, and K.U. Karantl, editors. Camera traps in animal ecology: methods and analyses. Springer, New York, New York, USA.

Chavarria, P. M., A. R. Kocek, N. J. Silvy, and R. R. Lopez. 2012*a*. Use of portable infrared cameras to facilitate detection and capture success of Montezuma quail. National Quail Symposium Proceedings 7:333–338.

Chavarria, P. M., A. Montoya, N. J. Silvy, and R. R. Lopez. 2012*b*. Impact of inclement weather on overwinter mortality of Montezuma quail in southeast Arizona. National Quail Symposium Proceedings 7:346–351.

Coppola, P. M., C. K. Williams, T. M. Terhune, J. Parke, and J. Cecil. 2021. Landscape connectivity influences survival and resource use following long-distance translocation of northern bobwhite. Journal of Wildlife Management 85:369–383.

Craig, T. H. 1978. A car survey of raptors in southeastern Idaho 1974–1976. Journal of Raptor Research 12:40–45.

Crispens, C. G., I. O. Buss, and C. F. Yocom. 1960. Food habits of the California quail in eastern Washington. The Condor 62:473–477.

Crooks, K. R., and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400:563–566.

Currier, S. A. 2021. An analysis of weight loss and stress physiology of captive-reared and translocated California valley quail. Thesis, Texas A&M University-Commerce, Commerce, USA.

Delaney, D. G., and B. Leung. 2010. An empirical probability model of detecting species at low densities. Ecological Applications 20:1162–1172.

DeVos, T., and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. National Quail Symposium Proceedings 3:83–90.

Downey, M. C., D. Rollins, F. Hernández, D. B. Wester, and E. D. Grahmann. 2017. An evaluation of northern bobwhite translocation to restore populations. Journal of Wildlife Management 81:800–813.

Dunne, P., D. Sibley, and C. Sutton. 1988. Hawks in flight: the flight identification of North American migrant raptors. Houghton Mifflin Harcourt, Boston, Massachusetts, USA.

Dyson, M. E., S. M. Slattery, and B. C. Fedy. 2020. Nest predators of ducks in the boreal forest. Wildlife Society Bulletin 44:631–639.

Ellis-Felege, S. N., J. S. Burnam, W. E. Palmer, D. C. Sisson, S. D. Wellendorf, R. P. Thornton, H. L. Stribling, and J. P. Carroll. 2008. Cameras identify white-tailed deer depredating northern bobwhite nests. Southeastern Naturalist 7:562–564.

Glading, B., H. H. Biswell, and C. F. Smith. 1940. Studies on the food of the California quail in 1937. Journal of Wildlife Management 4:128–144.

Griffith, G. E., S. A. Bryce, J. M. Omernik, and A. Rogers. 2004. Ecoregions of Texas. U.S. Geological Survey, Reston, Virginia, USA.

Guthery, F. S., and J. J. Lusk. 2004. Radiotelemetry studies: Are we radio-handicapping northern bobwhites? Wildlife Society Bulletin 32:194–201.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Haines, A. M., F. Hernández, S. E. Henke, and R. L. Bingham. 2004. Effects of road baiting on home range and survival of northern bobwhites in southern Texas. Wildlife Society Bulletin 32:401–411.

Hansen, H. M., and F. S. Guthery. 2001. Calling behavior of bobwhite males and the call-count index. Wildlife Society Bulletin 29:145–152.

Heilbrun, R. D., N. J. Silvy, M. E. Tewes, and M. J. Peterson. 2003. Using automatically triggered cameras to individually identify bobcats. Wildlife Society Bulletin 31:748–755.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Proceedings of the National Quail Symposium 1:65–89.

Jackson, A. L., W. E. Palmer, D. C. Sisson, T. M. Terhune, and J. A. Martin. 2018. Partial meso-mammal predator removal positively affects northern bobwhite reproduction. Wildlife Biology 2018(1). 1–8. doi: 10.2981/wlb.00357

Jackson, A. S. 1951. The bobwhite quail in relation to land management in the western Cross Timbers. Division of Wildlife Restoration, Texas Game, Fish and Oyster Commission, Austin, USA.

James, A., C. Purcel, R. Lopez, N. Silvy, and J. Cathey. 2017. Survival of pen reared California valley quail in Central Texas. Texas A&M Agrilife Extension, College Station, USA.

Jones, J. G. 1999. Effects of relocating wild northern bobwhites into managed quail habitat in middle Tennessee. Thesis, University of Tennessee, Knoxville, USA.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53:457–481.

Khanal, P., J. A. Johnson, and K. S. Reyna. 2006. Identification of bobwhite quail predators in Henrietta, Texas by camera trap method. Proceedings of the Sixth Integrative Biology Workshop 6:34.

Kilbride, K. M., J. A. Crawford, K. L. Blakely, and B. A. Williams. 1992. Habitat use by breeding female California quail in western Oregon. Journal of Wildlife Management 56:85–90.

Leopold, A. S. 1977. The California quail. University of California Press, Berkeley, USA

Liu, X., R. M. Whiting, Jr., B. S. Mueller, D. S. Parsons, and D. R. Dietz. 2000. Survival and causes of mortality of relocated and resident northern bobwhites in East Texas. National Quail Symposium Proceedings 4:119–124.

Liu, X., R. M. Whiting, Jr., D. S. Parsons, and D. R. Dietz. 2002. Movement patterns of resident and relocated northern bobwhites in East Texas. National Quail Symposium Proceedings 5:168–172.

Lyons, E. K., J. Frost, D. Rollins, and C. Scott. 2009. An evaluation of short-term mesocarnivore control for increasing hatch rate in northern bobwhites. National Quail Symposium Proceedings 6:447–455.

Major, R. E., and C. E. Kendal. 1996. The contribution of artificial nest experiments to understanding avian reproductive success: a review of methods and conclusions. Ibis 138:298–307.

Marcström, V., R. E. Kenward, and M. Karlbom. 1989. Survival of ring-necked pheasants with backpacks, necklaces, and leg bands. Journal of Wildlife Management 53:808–810.

Martin, J. A., R. D. Applegate, T. V. Dailey, M. Downey, B. Emmerich, F. Hernández, M. M. McConnell, K. S. Reyna, D. Rollins, and R. E. Ruzicka. 2017. Translocation as a population restoration technique for northern bobwhites: a review and synthesis. National Quail Symposium Proceedings 8:1–16.

Millspaugh, J. J., D. C. Kesler, R. W. Kays, R. A. Gitzen, J. H. Schulz, C. T. Rota, C. M. Bodinof, J. L. Belant, and B. J. Keller. 2012. Wildlife radiotelemetry and remote monitoring. Pages 258–283 *in* N. J. Silvy, editor. The wildlife techniques manual. Vol. 1: Research. Seventh edition. The Johns Hopkins University Press Baltimore, Maryland, USA.

Moser, E. 2021. Thermodynamics and upper lethal temperature of California Valley quail eggs. Thesis, Texas A&M University-Commerce, Commerce, USA.

Nichols, J. D., J. E. Hines, J. R. Sauer, J. E. Fallon, and P. J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. The Auk 117:393–408.

Owen, J. C. 2011. Collecting, processing, and storing avian blood: a review. Journal of Field Ornithology 82:339–354.

Pavés, H. J., R. P. Schlatter, and C. I. Espinoza. 2008. Scavenging and predation by black vultures *Coragyps atratus* at a South American sea lion breeding colony. Vulture News 58:4–15.

Phillips, J. C. 1928. Wild birds introduced or transplanted in North America. U.S. Department of Agriculture Technical Bulletin 61, Washington, D.C., USA.

Pietri, C. 1995. Potential habitats for California quail (*Callipepla californica*) and an evaluation of their introductions to Corsica. Gibier Faune Sauvage 12:165–182

Pietz, P. J., and D. A. Granfors. 2000. White-tailed deer (*Odocoileus virginianus*) predation on grassland songbird nestlings. The American Midland Naturalist 144:419–422.

Pietz, P. J., D. A. Granfors, and C. A. Ribic. 2012. 1. Knowledge gained from video-monitoring grassland passerine nests. Studies in Avian Biology 43:3–22.

Platt, S. G., P. Charruau, and T. R. Rainwater. 2014. Scavenging of crocodile eggs by vultures (*Cathartes aura* and *Coragyps atratus*) in Quintana Roo, Mexico. Bulletin of the Texas Ornithological Society 47:37–40.

Purvis, J. R. 2018. Small game harvest survey results 1998–99 thru 2017–18. Texas Parks and Wildlife Department, Austin, USA.

Raitt, R. J., Jr. 1960. Breeding behavior in a population of California quail. The Condor 62:284–292.

Reitsma, L. 1992. Is nest predation density dependent? A test using artificial nests. Canadian Journal of Zoology 70:2498–2500.

Reyna, K. S. 2019. Acute exposure to hyperthermic oscillating temperatures during pre-incubation influences northern bobwhite development, hatching, and survival. PLoS One 14(7):e0219368. doi: 10.1371/journal.pone.0219368

Reyna, K. S., and W. W. Burggren. 2012. Upper lethal temperatures of northern bobwhite embryos and the thermal properties of their eggs. Poultry Science 91:41–46.

Reyna, K. S., and W. W. Burggren. 2017. Altered embryonic development in northern bobwhite quail (*Colinus virginianus*) induced by pre-incubation oscillatory thermal stresses mimicking global warming predictions. PLoS One 12(9):e0184670. doi: 10.1371/journal.pone.0184670

Reyna, K. S., and W. L. Newman. 2018. Comparative analysis of behavioural response of captive-reared and wild-trapped northern bobwhites to simulated predator attacks. Avian Biology Research 11:16–23.

Reyna, K. S., D. Rollins, and D. Ransom, Jr. 2012. The Texas quail index: evaluating predictors of northern bobwhite productivity and abundance using citizen science. National Quail Symposium Proceedings 7:138–146.

Reyna, K. S., J. G. Whitt, and W. L. Newman. 2021. Efficacy of acclimating and releasing captive-reared and wild-translocated northern bobwhites. Avian Biology Research 14:79–86.

Riddle, J. D., S. J. Stanislav, K. H. Pollock, C. E. Moorman, and F. S. Perkins. 2010. Separating components of the detection process with combined methods: an example with northern bobwhite. Journal of Wildlife Management 74:1319–1325.

Rollins, D., J. Brooks, N. Wilkins, and D. Ransom. 2005. Counting quail. Texas AgriLife Extension Bulletin 6173, College Station, USA.

Rollins, D., and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29:39–51.

Sargeant, G. A., D. H. Johnson, and W. E. Berg. 1998. Interpreting carnivore scent-station surveys. Journal of Wildlife Management 62:1235–1245.

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Sauer, J. R., W. A. Link, and J. E. Hines. 2020. The North American Breeding Bird Survey, results and analysis 1966–2019. Volume 6. U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA. <http://www.mbr-pwrc.usgs.gov/bbs/bbs.html>. Accessed 8 Jun 2021.

Schlater, S. M. 2019. Red-tailed hawk (*Buteo jamaicensis*) Space Use across a Highly Fragmented, Agricultural Landscape. Dissertation, University of Nebraska at Kearney, Kearney, USA.

Schwartz, C. W., and E. R. Schwartz. 1950. The California quail in Hawaii. The Auk 67:1–38.

Sexton, O. J. 1975. Black vultures feeding on iguana eggs in Panama. The American Midland Naturalist 93:463–468.

Sisson, D. C., T. M. T. II, W. E. Palmer, and R. Thackston. 2017. Contributions of translocation to northern bobwhite population recovery. National Quail Symposium Proceedings 8:151–159.

Sisson, D. C., W. E. Palmer, T. M. Terhune, and R. E. Thackston. 2012. Development and implementation of a successful northern bobwhite translocation program in Georgia. National Quail Symposium Proceedings 7:289–293.

Smith, H. D., F. A. Stormer, and R. D. Godfrey. 1981. A collapsible quail trap. U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station Research Note RM-RN-400, Fort Collins, Colorado, USA.

Smith, L. M., and L. A. Burgoyne. 2004. Collecting, archiving and processing DNA from wildlife samples using FTA® databasing paper. BMC Ecology 4:4. doi: 10.1186/1472-6785-4-4

Smith, R. H., and S. Gallizioli. 1965. Predicting hunter success by means of a spring call count of Gambel quail. Journal of Wildlife Management 29:806–813.

Staller, E. L., W. E. Palmer, J. P. Carroll, R. P. Thornton, and D. Sisson. 2005. Identifying predators at northern bobwhite nests. Journal of Wildlife Management 69:124–132.

Stephenson, J. A., K. P. Reese, P. Zager, P. E. Heekin, P. J. Nelle, and A. Martens. 2011. Factors influencing survival of native and translocated mountain quail in Idaho and Washington. Journal of Wildlife Management 75:1315–1323.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, New York, USA.

Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. Biological Conservation 142:2282–2292.

Sumner, E. L., Jr. 1936. A life history study of the California quail, with recommendations for conservation and management. California Fish and Game 21:167–253.

Terhune, T., D. Sisson, H. Stribling, and J. Carroll. 2006*a*. Home range, movement, and site fidelity of translocated northern bobwhite (*Colinus virginianus*) in Southwest Georgia, USA. European Journal of Wildlife Research 52:119–124.

Terhune, T. M., D. C. Sisson, W. E. Palmer, B. C. Faircloth, H. L. Stribling, and J. P. Carroll. 2010. Translocation to a fragmented landscape: survival, movement, and site fidelity of northern bobwhites. Ecological Applications 20:1040–1052.

Terhune, T. M., D. C. Sisson, and H. L. Stribling. 2006*b*. The efficacy of relocating wild northern bobwhites prior to breeding season. Journal of Wildlife Management 70:914–921.

Thornton, R. P. 2003. The experimental effect of mesomammal predator removal on nest depredation of northern bobwhite in South Georgia and North Florida. Dissertation, University of Georgia, Athens, USA.

Tomecek, J. M., B. L. Pierce, K. S. Reyna, and M. J. Peterson. 2017. Inadequate thermal refuge constrains landscape habitability for a grassland bird species. PeerJ 5:e3709. doi: 10.7717/peerj.3709

Weatherhead, P. J. 1983. Two principal strategies in avian communal roosts. American Naturalist 121:237–243.

Wellendorf, S. G., W. E. Palmer, and P. T. Bromley. 2004. Estimating calling rates of northern bobwhite coveys and measuring abundance. Journal of Wildlife Management 68:672–682.

Whitelaw, R. E., W. E. Palmer, S. D. Wellendorf, and J. P. Carroll. 2009. Effect of supplemental feeding on winter diet and body mass of northern bobwhites. National Quail Symposium Proceedings 6:282–289.

Whitt, J. G. 2019. The bobwhite population decline: its history, genetic consequences, and studies on techniques for locating and assessing current populations. Dissertation, University of North Texas, Denton, USA.

Whitt, J. G., J. A. Johnson, and K. S. Reyna. 2017. Two centuries of human-mediated gene flow in northern bobwhites. Wildlife Society Bulletin 41:639–648.

Williams, G. R. 1952. The California quail in New Zealand. Journal of Wildlife Management 16:460–483.

Yancey, S. R. 2019. Translocation of northern bobwhite and scaled quail from South Texas to the Rolling Plains of Texas. Dissertation, Texas Tech University, Lubbock, USA.

APPENDIX A

Appendix A. Predator and nonpredator species photographed during 2019–2020 on the valley quail translocation site in Fannin County, Texas, USA. Entries of 0 represent species' presence recorded by technician sightings.

Animals observed	Scientific name	Number of photos
Raccoon	*Procyon lotor*	738
Striped skunk	*Mephitis mephitis*	89
Virginia opossum	*Didelphis virginiana*	50
White-tailed deer	*Odocoileus virginianus*	491
Feral hog	*Sus scrofa*	1630
Nine-banded armadillo	*Dasypus novemcinctus*	15
Coyote	*Canis latrans*	221
Eastern gray squirrel	*Sciurs carolinensis*	0
Eastern flying squirrel	*Glaucomys volans*	0
Fox squirrel	*Sciurus niger*	3
Eastern cottontail	*Sylvilagus floridanus*	>20
Bobcat	*Lynx rufus*	30
River otter	*Luntra canadensis*	1
North American beaver	*Castor canadensis*	0
Cattle	*Bos taurus*	>20
Red-tailed hawk	*Buteo jamaicensis*	5
Red-shouldered hawk	*Buteo lineatus*	3
American crow	*Corvus brachyrhynchos*	>40
Black vulture	*Coragyps atratus*	>50
Road runner	*Geococcyx californianus*	3
Turkey vulture	*Cathartes aura*	>50
Waterfowl	*Anatidae* spp.	0
White-throated sparrow	*Zonotrichia albicollis*	>300
Barn owl	*Tyto alba*	2
Wild turkey	*Meleagris gallopavo*	6
Northern flicker	*Colaptes auratus*	2
Painted bunting	*Passerina ciris*	2
Northern cardinal	*Cardinalis cardinalis*	>50
Cooper's hawk	*Accipiter cooperii*	0
Northern harrier	*Circus cyaneus*	0
Barred owl	*Strix varia*	0
Golden eagle	*Aquila chrysaetos*	0
Bald eagle	*Haliaeetus leucocephalus*	0
Mississippi kite	*Ictinia mississippiensis*	0
Green heron	*Butorides virescens*	0
Great blue heron	*Ardea herodias*	3
Ornate box turtle	*Terrapene ornata ornata*	0
Three-toed turtle	*Terrapene carolina triunguis*	0
Snapping turtle	*Chelydra serpentina*	0
Northern cottonmouth	*Agkistrodon piscivorus*	0
Rough green snake	*Opheodrys aestivus*	0
Eastern copperhead	*Agkistrodon contortrix*	0
Black rat snake	*Pantherophis obsoletus*	3
Ribbon snake	*Thamnophis sauritus*	0
American green tree frog	*Dryophytes cinereus*	0
American bullfrog	*Lithobates catesbeianus*	0
Southern leopard frog	*Lithobates sphenocephalus*	0
Woodhouse's toad	*Anaxyrus woodhousi*	0