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Original Article

Population Demographics of Translocated Northern Bobwhites on Fragmented Habitat

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ABSTRACT Habitat fragmentation is considered a contributing factor to declining populations of northern bobwhite (*Colinus virginianus*). Some population strongholds exist within large expanses of habitat; however, many regions of the species' range have become fragmented and populations therein have become nearly extirpated. Our objectives were to determine whether combined habitat management and bobwhite translocation could restore bobwhite populations in habitat patches within a fragmented landscape. We translocated 550 bobwhites to 2 sites ($\geq$660 ha; Caldwell and Fayette counties) in the Post Oak Savannah ecoregion of Texas, USA, during 2004–2006. We compared survival, home-range size, and reproduction between translocated bobwhites in a fragmented landscape and resident bobwhites in contiguous habitat (Brooks County). Pooled over the 3-year study, translocated bobwhites had lower survival (6 Apr–15 Aug, 2004–2006; $\hat{S} = 0.35$; $n = 165$ bobwhites) than did resident bobwhites ($\hat{S} = 0.56$; $n = 224$ bobwhites; $P < 0.001$). Translocated bobwhites also had larger home ranges ($\bar{x} = 398.1$ ha; $n = 55$ bobwhites) than resident bobwhites ($\bar{x} = 10.9$ ha; $n = 28$ bobwhites; $P = 0.003$). Moreover, percent of hens nesting (95% CI = 36 ± 16.4%) and nesting rate (95% CI = 1.1 ± 0.2 nests/hen) were lower for translocated bobwhites than for resident bobwhites (79 ± 12.4% and 1.6 ± 0.3 nests/hen, respectively). Our restoration efforts were unsuccessful; relative abundance of bobwhites remained low ($\leq$1.0 covey heard/point) on translocation sites despite intensive translocation efforts. Restoring bobwhite populations in areas with few remaining bobwhites may be beyond the realm of practical management in this fragmented ecoregion. © 2012 The Wildlife Society

KEY WORDS bobwhite, *Colinus virginianus*, habitat fragmentation, northern bobwhite, survival, translocation.

Habitat loss and fragmentation are major factors influencing the decline of grassland birds (Brennan and Kuvlesky 2005), including northern bobwhite (*Colinus virginianus*; Brennan 1991, Terhune et al. 2010). Habitat fragmentation is the division of contiguous habitat into smaller, disconnected habitat fragments that are of smaller total area (Wilcove et al. 1986). Wildlife populations can persist in fragmented landscapes if the populations inhabiting habitat patches remain connected through immigration and emigration (Levins 1970). Populations experiencing low survival and/or reproduction can escape extinction by supplementation due to immigration from neighboring populations through a process described as "dispersal rescue" (Martin et al. 2000). However, isolated populations that lack immigration and experience low survival and/or reproduction are especially vulnerable to extinction.

Northern bobwhites may be particularly sensitive to the negative effects of habitat fragmentation given their life history. Daily movements of bobwhites generally do not exceed 1 km and typical home-range size is small (<20 ha; Roseberry and Klimstra 1984, Brennan 1999). In addition, bobwhite populations sustain high annual mortality (approx. 80%; Brennan 1999) and experience variable reproduction in response to weather, particularly in the southwestern portion of the species' range (Lehmann 1984; Hernández et al. 2005, 2007). Consequently, bobwhite populations may become more vulnerable to extinction with increasing fragmentation due to their limited movements, high mortality, and variable reproduction.

Texas, USA, traditionally has been a population stronghold for northern bobwhite (Brennan 1991, 2007; Sauer et al. 2007). A primary reason for these relatively stable

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(i.e., non-trending) populations is the vast expanse of contiguous habitat that exists throughout the southern, northern, and western parts of the state (Brennan 2007). Urbanization and ranch subdivision, however, have resulted in increased habitat fragmentation and decreased property size in some regions of central and eastern Texas, such as the Post Oak Savannah (Wilkins et al. 2000). Thus, bobwhite populations in this ecoregion have decreased dramatically and occur primarily as isolated populations (Silvy 2007).

Restoring bobwhite populations on fragmented landscapes involves practices beyond mere habitat management (Terhune et al. 2010). Improving conditions on habitat fragments may not be sufficient for bobwhite restoration because a population source may not exist nearby to provide immigration onto the managed lands. Effective restoration efforts in these circumstances therefore may involve translocations of wild conspecifics in addition to habitat management (Brennan 1991, Terhune et al. 2010). This tandem approach to species restoration has been used for various other galliforms, including mountain quail (*Oreortyx pictus*; Pope and Crawford 2004), wild turkey (*Meleagris gallopavo*; Miller et al. 1985, Leif 2001), ruffed grouse (*Bonasa umbellus*; White and Dimmick 1978, Kurzejeski and Root 1988), and prairie grouse (*Tympanuchus* spp.; Toepfer et al. 1990).

Given the continuing decline of bobwhite populations and the concurrent fragmentation of habitat, the need exists to determine the efficacy of habitat management and translocation for population restoration on fragmented landscapes. Our objectives were to 1) document survival, home-range size, and reproduction of wild bobwhites translocated onto managed habitat fragments and 2) compare the demographics of these bobwhites with non-translocated bobwhites in contiguous habitat.

STUDY AREA

We conducted our study in 2 ecoregions of Texas: Post Oak Savannah and Rio Grande Plains (Gould 1975). The Post Oak Savannah is an ecoregion that has become fragmented by urbanization, small-scale agriculture, and "improved" pastures (i.e., pastures sown to non-native forage species for grazing improvement; Wilkins et al. 2003). Bobwhite populations in the ecoregion are declining (Silvy 2007). In contrast, the Rio Grande Plains is an adjacent ecoregion that is characterized by large, contiguous tracts of native rangeland with relatively stable bobwhite populations (Hernández et al. 2002). We evaluated bobwhite translocations in the Post Oak Savannah and used the Rio Grande Plains for a comparison site.

Post Oak Savannah

The Post Oak Savannah ecoregion was characterized by gently rolling to hilly topography at 91 m–244 m above sea level (Correll and Johnston 1979). Annual rainfall ranged from 89 cm to 114 cm, with the highest rainfall occurring during May and June. Soils were acid sandy loams or clays that were light colored in the uplands and light brown to dark gray in bottomlands. Trees were predominantly post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*). Small farms were common in the ecoregion, and an increasing amount of area had been converted to improved pastures that were seeded to bermudagrass (*Cynodon dactylon*), bahiagrass (*Paspalum notatum*), and similar species (Scifres 1980). The most notable land-use trends in the ecoregion were the conversion of croplands to improved pastures and proliferation of small properties (Wilkins et al. 2003). These land-use changes have caused habitat loss and fragmentation and have resulted in small, isolated populations of bobwhites (Silvy 2007). Historically, the Post Oak Savannah held modest populations compared with the 10 other ecoregions of Texas. Roadside surveys conducted by Texas Parks and Wildlife Department during 1978–1987 ranked the Post Oak Savannah as fifth of 10 ecoregions in the state in terms of bobwhite abundance (Silvy 2007). There are no current data for quail abundance for this ecoregion. However, quail hunter and harvest numbers have declined drastically during 1981–2001 from about 30,000 quail hunters harvesting around 200,000 bobwhites to about 5,000 hunters harvesting around 25,000 bobwhites (Silvy 2007). Bobwhites are projected to become extinct in the ecoregion unless additional habitat is created (Silvy 2007).

Our translocation study involved 2 study sites (1 in Caldwell County and 1 in Fayette County) within the Post Oak Savannah. The site in Caldwell County was a private ranch (900 ha). Habitat management practices on the ranch included livestock grazing to reduce herbaceous cover and increase bare ground and aeration to reduce woody-plant cover. Predominant grasses included silver bluestem (*Bothriochloa laguroides*), Texas wintergrass (*Nassella leucotricha*), brownseed paspalum (*Paspalum plicatulum*), and Kleberg bluestem (*Dichanthium annulatum*). Common forbs were sunflower (*Helianthus* spp.), western ragweed (*Ambrosia psilostachya*), and croton (*Croton* spp.). The site in Fayette County was a property (660 ha) owned and managed by the Lower Colorado River Authority. No grazing occurred on this property. Habitat management included discing and prescribed burning to create or maintain suitable bobwhite habitat. Predominant grasses included little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), silver bluestem, and Kleberg bluestem. Common forbs were partridge pea (*Chamaecrista fasciculata*), croton, Illinois bundleflower (*Desmanthus illinoensis*), and western ragweed.

The landscape surrounding both of the translocation sites included agriculture fields and small- to medium-sized (<400-ha) cattle farms dominated by improved pastures. We used 2006 U.S. Geological Survey national land-cover data to determine landscape composition surrounding the study site within an 8-km buffer. Landscape composition within an 8-km buffer of each study site consisted of 14% improved pasture, 20% agriculture, 50% rangeland, 6% forest, 3% water, and 8% urban for the Caldwell County site and 41% improved pasture, 1% agriculture, 22% rangeland, 18% forest, 12% water, and 7% urban for the Fayette County site. Habitat management plans for each translocation site were developed by Texas Parks and Wildlife Department wildlife biologists working in the Post Oak Savannah and were implemented in 2004 prior to this study.

Rio Grande Plains

The Rio Grande Plains ecoregion was characterized by level to rolling land that was dissected by streams flowing into the Rio Grande or the Gulf of Mexico (Scifres 1980). The average annual rainfall in this area was 40 cm–76 cm, with the highest amount in May and June (Correll and Johnston 1979). Predominant soils ranged from clays to sandy loams and varied from basic to slightly acidic (Correll and Johnston 1979, USDA Soil Conservation Service 1993). The region was characterized by large ranches with cattle production as a primary land use (Hernández et al. 2002). It has experienced an increase in woody-plant coverage over the past 150–200 years (Scifres 1980). The ecoregion was renowned for bobwhite hunting and historically supported stable bobwhite populations (Hernández et al. 2002). Consequently, fee-lease hunting emerged, and commercial hunting supplanted livestock production as a primary land use on some ranches (Hernández et al. 2002).

Our comparison site was a private ranch (42,448 ha) located within the Rio Grande Plains. We selected 3 pastures (1,000 ha each) that were contained within a commercial hunting lease (approx. 13,000 ha) on the ranch. The lease was managed specifically for bobwhites. Important management practices included grazing management, brush management, prescribed fire, discing, and harvest management (Howard 2007). Vegetation on the study sites consisted predominately of honey mesquite (*Prosopis glandulosa*), live oak (*Quercus virginiana*), granjeno (*Celtis pallida*), prickly-pear cactus (*Opuntia lindheimeri*), and huisache (*Vachellia farnesiana farnesiana*). Common grasses consisted of little bluestem, paspalum (*Paspalum* spp.), threeawn (*Aristida* spp.), red lovegrass (*Eragrostis secundiflora*), gulf cordgrass (*Spartina spartinae*), Kleberg bluestem, King Ranch bluestem (*Bothriochloa ischaemum*), buffelgrass (*Cenchrus ciliaris*), and sandbur (*Cenchrus incertus*). Predominant forbs included croton, dayflower (*Commelina erecta*), partridge pea, and sunflower.

METHODS

Trapping

Translocation sites.—Our goal was to translocate 300 bobwhites into each translocation site (100 bobwhites/site/yr; 600 total) during 3 field seasons (Jan–Aug 2004–2006). Source populations of bobwhites occurred 95 km–221 km from these translocation sites on public and private lands within Atascosa, Frio, Goliad, Matagorda, McMullen, Refugio, Victoria, and Wharton counties (Fig. 1). These counties occur within the Gulf Prairies and Marshes (Matagorda, Refugio, Victoria, and Wharton) and Rio Grande Plains (Atascosa, Frio, Goliad, and McMullen) ecoregions. We selected these counties because they contained ranches or Texas Parks and Wildlife Department wildlife management areas with relatively high densities of bobwhites and represented the closest population sources to the translocation sites.

We trapped bobwhites using baited funnel traps during January–March of each year (Stoddard 1931). Our goal was to have all bobwhites trapped and translocated by 1 April before the beginning of the breeding season. We weighed bobwhites and classified them by age and gender. We banded all bobwhites and attached a 6-g–7-g pendant-style transmitter (American Wildlife Enterprises, Monticello, FL) to females weighing >150 g (Hernández et al. 2005). We preferentially radiocollared females (although both M and F were translocated) because reproductive effort is integral to population restoration. Our radiocollaring goal was 50

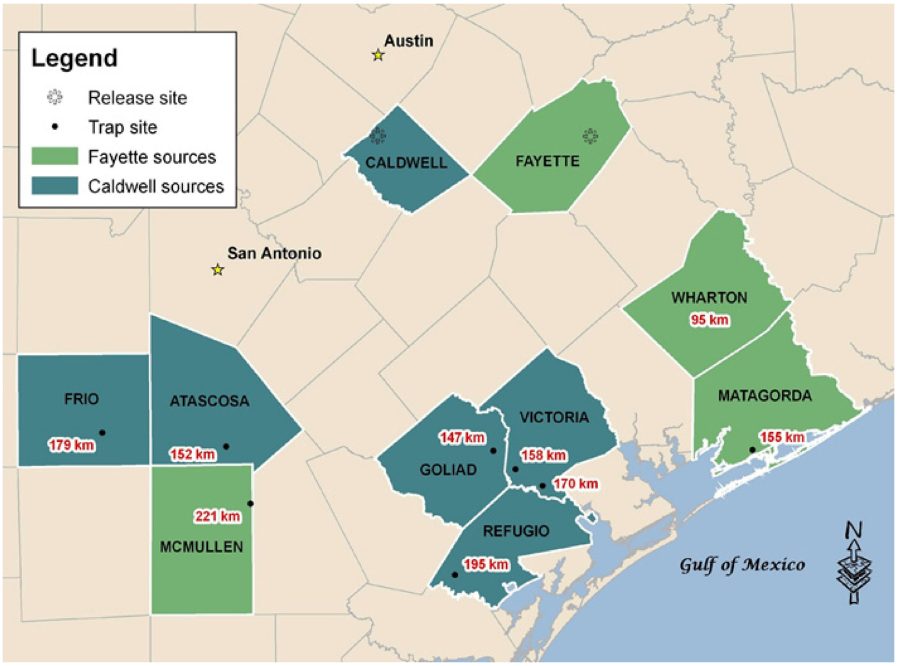

Figure 1. Approximate distance (km) between source and release sites of northern bobwhite (*Colinus virginianus*), Texas, USA, January–August, 2004–2006.

radiocollared females/site/year. However, we radiocollared males opportunistically when the target sample of females had not been reached and the conclusion of the trapping season was near.

We placed bobwhites in holding pens (122 cm × 61 cm × 40 cm) to facilitate translocation and allow them to acclimate to transmitters. We held bobwhites caught as coveys together in order to release them as a covey. We combined partial coveys (e.g., singles and pairs) with other partial coveys to form complete coveys (8–12 bobwhites). We only used bobwhites caught within a 2-km radius to form complete coveys. We provided bobwhites with food (milo + laying ration) and water ad libitum during their holdover period. Given the large distances between and among translocation and source sites, we initially planned (because of logistical efficiency) to hold bobwhites and translocate them when >30 bobwhites had been captured. This resulted in an average holding period of 7 days during the first year of study (2004). However, although we never observed overt signs of stress, we decided to translocate bobwhites as soon as possible in subsequent years, regardless of numbers caught to minimize potential stress. Average holding periods were 1–2 days during 2005 and 2006.

We established release points within translocation sites by creating a 500-m × 500-m grid overlaid onto a map of the area. The intersection points of the grid represented potential release sites within the study area. We randomly selected points (without replacement) for bobwhite release to uniformly distribute translocated coveys and provide adequate spacing among them. Once a release point was selected, we placed the holding pen in a brush motte nearest to selected grid points and used a soft-release technique. We scattered feed near the holding pen's entrance, opened each pen, and left it undisturbed, allowing bobwhites to leave the pen freely. We did not use grid points within 500 m of the area boundary to minimize the probability of movement off the area.

Comparison site.—The comparison site was part of a larger radiotelemetry project on bobwhites (Hernández et al. 2005, DeMaso et al. 2011). Bobwhites were trapped year round (Jan–Dec 2000–2008) using the same methods that were used for the translocation portion of this study, with the exception that bobwhites were not translocated (i.e., released immediately after radiocollaring). This site provided demographic data for resident bobwhites on contiguous habitat. We could not use resident bobwhites on the translocation sites for comparison because few or almost no bobwhites occurred on the habitat fragments. Hereafter, we use the term resident bobwhites to refer to this group of non-translocated bobwhites.

Radiotelemetry

Translocation sites.—We monitored translocated bobwhites once per week during the trapping period (Jan–Mar) to obtain general data regarding movement and survival. We completed bobwhite trapping by 31 March of each field season and began more intensive monitoring of radiomarked bobwhites thereafter. We located translocated bobwhites 2–3 times/week using a hand-held, 3-element Yagi antenna (Advanced Telemetry Systems, Inc., Isanti, MN) during April–August 2004–2006. We located translocated bobwhites by homing unless they traveled onto adjacent properties. In these cases, we estimated locations based on triangulation until private landowners granted trespass privileges. We used a fixed-wing aircraft with telemetry equipment to locate missing bobwhites when necessary. We used Garmin Legend (Garmin, Ltd., Olathe, KS) global positioning system receivers to record coordinates for each bobwhite during tracking sessions.

We assumed radiomarked bobwhites were nesting when we located them on >2 consecutive days in the same location. We used flagging tape to mark vegetation >2 m from the nest in 2 opposite directions to ensure re-location. We checked the presence of incubating females every other day from afar and determined clutch size when females were on an incubation recess. We documented nest fate (successful, depredated, or abandoned) upon indication of a failed or hatched clutch. Successful nests were those in which ≥1 egg hatched (Burger et al. 1995).

Comparison site.—Resident bobwhites were monitored using these same methods, with the exception that tracking occurred 2–3 times/week throughout the year.

Relative Abundance

Translocation sites.—We used morning covey-call counts to estimate relative abundance of bobwhites on translocation sites during autumn (Oct–Nov). We established 3 survey points/site, with the restriction that points were not within 500 m of each other. We surveyed each point during autumn 3 times/field season and waited ≥3 days between repeat surveys. We arrived at survey points 45 minutes before sunrise and, when covey-calling began, recorded the number of coveys calling and their approximate location. Counts were continued for 10 minutes beyond the last call heard. We used these data to calculate mean number of coveys heard at each point and calculated an overall mean over the 3 points for each site and each year.

Comparison site.—We estimated relative abundance of bobwhites on the comparison site using the same methods described above.

Statistical Analyses

Survival, movement, and relative abundance.—We used the staggered-entry Kaplan–Meier estimator (Pollock et al. 1989) and Program STAGKAM (Kulowiec 1989) to estimate survival distributions of translocated and resident bobwhites during each field season (6 Apr–15 Aug). We censored from analysis bobwhites surviving ≤14 days post-release (Cox et al. 2004). We used log-rank Chi-square tests to compare survival distributions between translocation sites and between translocated and resident bobwhites (Pollock et al. 1989).

We obtained movement data using ArcView 3.3 and ArcGIS 9. We classified translocated bobwhites as dispersers or non-dispersers following guidelines similar to Townsend et al. (2003). Townsend et al. defined dispersers as bobwhites that traveled >2 km from their release point and

Table 1. Kaplan–Meier survival rates ($\hat{S}$; 6 Apr–15 Aug) of translocated northern bobwhites (*Colinus virginianus*; Caldwell and Fayette counties) and resident northern bobwhites (Brooks County), Texas, USA, 2004–2006.

Category	**2004**				**2005**				**2006**			
Site	***n***	$\hat{S}$	**SE**	***P*-value**	***n***	$\hat{S}$	**SE**	***P*-value**	***n***	$\hat{S}$	**SE**	***P*-value**
Translocated												
Caldwell	33	0.44	0.11		23	0.37	0.11		20	0.29	0.17	
Fayette	37	0.42	0.13	0.44[a]	33	0.27	0.08	0.98	19	0.34	0.14	0.57
Pooled	70	0.41	0.08		56	0.30	0.07		39	0.30	0.10	
Resident												
Brooks	75	0.60	0.05	0.08[b]	93	0.54	0.05	0.01	56	0.53	0.06	0.08

[a] *P*-value is for the comparison of survival between translocation sites.

[b] *P*-value is for the comparison of survival between the pooled estimate of translocated bobwhites and resident bobwhites.

non-dispersers as those that remained within 1 km of their release point. We evaluated the existence of an acclimation period of translocated bobwhites to translocation sites by measuring the distance from the release point to each consecutive location during the initial 90-day post-release period. We also documented maximum distance from release point by measuring the distance from the release point to the farthest location point for bobwhites that survived $\geq$30 days and had $\geq$5 locations.

We used the Animal Movements extension and the fixed-kernel method (with 5% outlier removal) for ArcView 3.3 (Hooge and Eichenlaub 1997) to calculate home ranges for bobwhites with $\geq$30 locations (Haines et al. 2009). We used analysis of variance (ANOVA; SAS Institute, Cary, NC) to compare home ranges of translocated bobwhites using year and site as main factors (Zar 1999).

We used 95% confidence intervals to compare relative abundance between translocation and comparison sites (Johnson 1999).

Reproduction.—We calculated percentage of hens nesting, nesting rate (nests/hen), apparent nesting success (%), clutch size, and egg hatchability (%) for translocated and resident bobwhites. We identified hens with complete nesting histories (alive 1 May–15 Aug) and used this sample to calculate percentage of hens nesting and nesting rate. We only used hens alive during this time period because we could account for their entire nesting effort throughout the duration of the season (Hernández et al. 2005). We used all nests to estimate apparent nest success, clutch size, and egg hatchability.

We used 95% confidence intervals to compare productivity variables between translocated and resident bobwhites (Johnson 1999). We calculated 95% confidence intervals using ($\bar{x} \pm t_{0.025,\, n-1}$ SE) for nesting rate, clutch size, and egg hatchability. For variables involving percentages (i.e., percentage of hens nesting and apparent nest success), we calculated 95% confidence intervals using ($p \pm Z_{0.025}$ SE[p]) where p is the proportion and SE(p) is the square root of ($p[1 - p]/n$). We evaluated the cumulative effect of these reproductive measures using a deterministic model to estimate chick production for translocated and resident bobwhites. Our model was:

$$Y = p \times \text{nr} \times \text{ns} \times c \times \text{eh}$$

where Y, estimated production (chicks/hen); p, percentage of hens nesting; nr, nesting rate (nests/hen); ns, nest success (%); c, clutch size (eggs/nest); eh, egg hatchability (%).

RESULTS

Survival, Movements, and Relative Abundance

We trapped and translocated 550 bobwhites ($n = 232$ bobwhites, Caldwell County; $n = 318$ bobwhites, Fayette County) during January–April 2004–2006. Of these, we radiomarked and monitored 252 bobwhites ($n = 117$ bobwhites, Caldwell County; $n = 135$ bobwhites, Fayette County) during April–August 2004–2006. Bobwhite survival did not differ between translocation sites for any year ($P > 0.44$; Table 1). Thus, we pooled across translocation sites. Survival was numerically lower for translocated bobwhites than resident bobwhites in all years; however, survival only differed significantly during 2005 (Table 1).

We were able to regularly locate 44 translocated bobwhites during the 90-day post-release period. Of these, 18 (41%) bobwhites were classified as dispersers. Dispersers settled into a core area of use at approximately 9 weeks following release (Fig. 2). We documented no significant difference in home-range size among years for dispersers and non-dispersers ($P > 0.15$); thus, we pooled across years for each group. Dispersers had home ranges that were about 10 times larger than those of non-dispersers (Table 2). Translocated

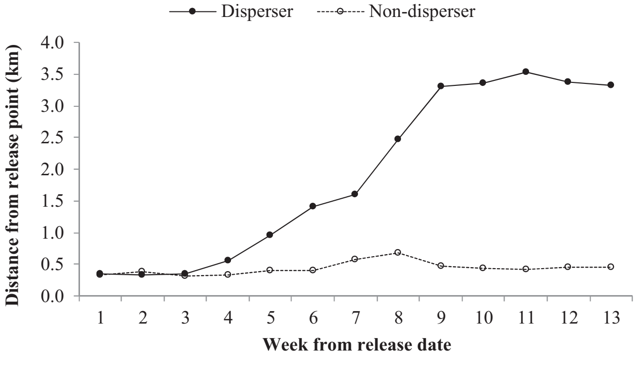

Figure 2. Average distance (km) from release point to subsequent location points for dispersing and non-dispersing, translocated northern bobwhites (*Colinus virginianus*) during 90-day post-release period, Caldwell and Fayette counties, Texas, USA, April–August, 2004–2006.

Table 2. Fixed-kernel home-range size (ha) of translocated northern bobwhite (*Colinus virginianus*) in Caldwell and Fayette counties and resident bobwhites in Brooks County, Texas, USA, April–August, 2004–2006. Translocated bobwhites that moved >2 km from release site were classified as dispersers and those that remained within 1 km of release site were classified as non-dispersers.

Category	Non-disperers			Disperers		
Site	*n*	$\bar{x}$	95% CI	*n*	$\bar{x}$	95% CI
Translocated						
Caldwell	12	39.2	24.9–53.6	8	385.1	21.0–749.2
Fayette	14	108.5	71.4–145.6	10	911.4	295.1–1,527.8
Resident						
Brooks	28	10.9	8.5–13.3			

bobwhites had larger home ranges at the Caldwell ($P = 0.001$) and Fayette site ($P < 0.001$) than those of resident bobwhites (Table 2).

We identified 123 bobwhites that met the criteria for calculation of distance traveled (i.e., survived ≥30 days for which we obtained ≥5 locations). Most (71%) translocated bobwhites remained within 2 km of the release site (Fig. 3). However, we observed several long-distance movements (Fig. 3). The farthest distance traveled by a translocated bobwhite from the point of release was 40 km.

Relative abundance of bobwhites during autumn on the translocation sites was low throughout the study (Fig. 4). Relative abundance of bobwhites was greater on the comparison site than translocation sites (Fig. 4).

Reproduction

We located 24 nests for translocated bobwhites and 169 nests for resident bobwhites. Percent of hens nesting (95% CI = 36 ± 16.4%) and nesting rate (95% CI = 1.1 ± 0.2 nests/hen) were lower for translocated bobwhites than for resident bobwhites (79 ± 12.4% and 1.6 ± 0.3 nests/hen, respectively; Table 3). However, nest success, clutch size, and egg hatchability were similar ($P > 0.05$) between translocated and resident bobwhites (Table 3). Substituting the means of these variables in the deterministic model, we estimated that translocated bobwhites were about 3 times less productive (1.9 chicks/hen) than were resident bobwhites ($n = 6.9$ chicks/hen).

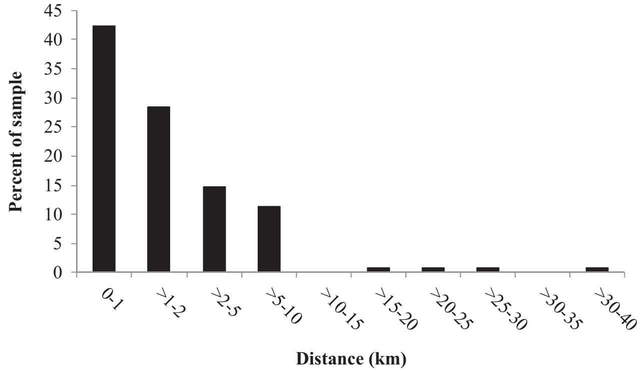

Figure 3. Distance (km) traveled by translocated northern bobwhites (*Colinus virginianus*) from release point to furthest observed location, Caldwell and Fayette counties, Texas, USA, April–August, 2004–2006.

DISCUSSION

We evaluated translocation of wild bobwhites onto managed habitat patches within a fragmented landscape. Overall, this approach proved unsuccessful for bobwhite restoration because relative abundance of bobwhites did not increase on translocation sites through time. Relative abundance of bobwhites remained low (≤1.0 covey heard/point) on translocation sites throughout the study despite intensive translocation efforts. In addition, ancillary data on relative abundance of bobwhites on sites with no translocation but still within the fragmented landscape (i.e., a control) indicated a similar relative abundance (<1.0 coveys/point; F. Hernández, unpublished data).

Translocated bobwhites experienced lower survival and productivity and larger home ranges than did resident bobwhites in contiguous habitat. Our findings contrast prior research (Liu 1995; Jones 1999; Terhune et al. 2006*a*, *b*, 2010). Liu et al. (2000) reported that survival was similar among resident bobwhites and bobwhites translocated from East and South Texas. Terhune et al. (2006*a*, 2010) also documented no difference in survival between resident and translocated bobwhites in Georgia, USA. The distance over which bobwhites were translocated may explain differences between our study and past studies. The nearest bobwhite populations to our translocation sites were 95–221 km away. Thus, we translocated bobwhites over large distances and, by default, held bobwhites over a relatively long period before release ($\bar{x}$ = 1–7 days). Terhune et al. (2006*a*) translocated

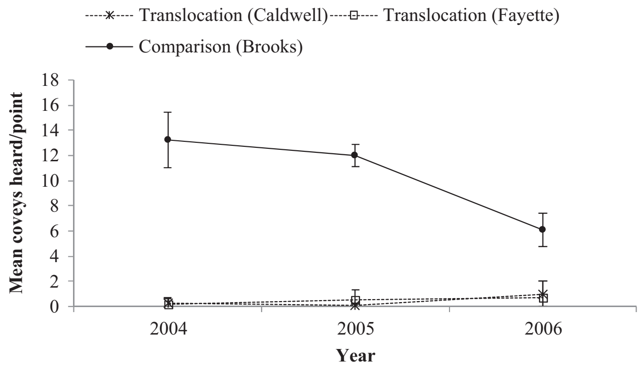

Figure 4. Relative abundance ($\bar{x}$ ± 95% CI; coveys heard/point) of northern bobwhite (*Colinus virginianus*) on bobwhite translocation sites (Caldwell and Fayette counties) and comparison site (Brooks County), Texas, USA, October–November, 2004–2006.

Table 3. Reproductive measures of translocated northern bobwhites (*Colinus virginianus*) in Caldwell and Fayette counties and resident bobwhites in Brooks County, Texas, USA, 2004–2006.

	Translocated			Resident		
Variable	***n***	**Estimate**	**95% CI**	***n***	**Estimate**	**95% CI**
Nesting hens (%)	33	36.4	20.0–52.8	42	78.6	66.2–91.0
Nesting rate (nests/hen)	18	1.1	0.90–1.27	33	1.6	1.34–1.93
Nest success (%)	24	41.7	21.9–61.4	169	50.9	43.4–58.4
Clutch size (eggs/nest)	13	12.3	10.3–14.3	138	12	11.5–12.4
Egg hatchability (%)	10	92.7	80.9–100.0	85	90.1	86.2–93.9

bobwhites over a much shorter distance (approx. 1.2 km) and released bobwhites with 24 hours of capture. Liu et al. (2000) also noted that bobwhites translocated from East Texas (15 km) consistently experienced higher survival than did bobwhites translocated from South Texas (>200 km). They concluded that regional habitat differences may have contributed to lower survival for the South Texas group. An alternative explanation may involve increased stress resulting from longer holding periods. Capture myopathy resulting from trapping and handling is known to occur in bobwhites (Abbott et al. 2005). It is conceivable that longer holding periods (resulting from longer transport distances) increased the severity of capture myopathy of translocated bobwhites and resulted in reduced survival.

We documented that translocated bobwhites had larger home ranges than did resident bobwhites. Conversely, Liu et al. (2002) reported that resident bobwhites had larger home ranges than did bobwhites translocated from East and South Texas. Terhune et al. (2006*b*, 2010) reported no differences in home-range size between resident and translocated bobwhites. The translocation sites used in our study were virtually void of bobwhites (i.e., extirpated). We hypothesize that this extremely low density of conspecifics may explain differences among studies. Conspecific attraction is the tendency of individuals of the same species to settle near each other and is documented in birds (Ward and Schlossberg 2004, Ahlering et al. 2006). Translocated bobwhites in previous studies may have benefited from association with resident bobwhite coveys. Bobwhite densities on translocation sites in prior studies have ranged from 0.25 bobwhites/ha to 0.75 bobwhites/ha (Terhune et al. 2010) to 1.5 bobwhites/ha to >7.4 bobbobwhites/ha (Terhune et al. 2006*a*). Terhune et al. (2006*b*) reported site fidelity for 89% of translocated bobwhites. Jones (1999) reported 95% integration of translocated bobwhites into resident coveys within 4 days following release. He also noted that integration into wild coveys reduced home-range size of translocated bobwhites (Jones 1999).

An alternative explanation is that bobwhite movement is greater in fragmented habitat. Liu et al. (2002) reported relatively large home ranges (42.6 ha–46.9 ha) for translocated bobwhites. Liu (1995) noted that ≥17% (>50 of 291) bobwhites dispersed ≥2.5 km. Similarly, Fies et al. (2002) documented that 25% of 198 bobwhites dispersed >2 km in fragmented habitat and suggested that breeding-season movement of bobwhites could be greater in fragmented landscapes than contiguous habitat. We observed home ranges for translocated bobwhites that were about 3–90 times the size of resident bobwhites in contiguous habitat. In addition, 41% of translocated bobwhites in our study dispersed off the study sites. Our findings provide support for the hypothesis of Fies et al. (2002).

We documented no difference in nest success, clutch size, and egg hatchability between translocated and resident bobwhites. However, the percentage of hens nesting and nesting rate were lower for translocated bobwhites. In addition, we estimated that translocated bobwhites would produce considerably fewer chicks/hen than would resident bobwhites. This contrasts with Terhune et al. (2006*a*), who documented no difference in nest initiation rates between translocated and resident bobwhites. Distance over which bobwhites were translocated again may provide an explanation. Parson et al. (2000), in a companion study to Liu et al. (2000, 2002), investigated the reproductive success among resident bobwhites from East Texas and translocated bobwhites from East and South Texas. They reported that bobwhites that had been translocated from South Texas produced fewer nests and fledged fewer broods than the other 2 groups. However, there was no reproductive difference between resident East Texas bobwhites and translocated bobwhites from East Texas. It is plausible that the stress associated with a longer transport distance and, therefore, longer holding period may have affected both survival and reproductive performance.

In summary, translocated bobwhites in our study experienced lower survival, lower productivity, and larger home ranges. We hypothesize that large (>200 km) transport distances (and, consequently, longer holding periods) and low bobwhite densities on translocation sites may explain differences with past research. However, we note that resident bobwhites in our study were not bobwhites inhabiting translocation sites (as occurred in past research) but represented bobwhites from contiguous habitat that had not been subjected to translocation. Thus, it also is possible that the differences in demographic performance between translocated (fragmented habitat) and resident bobwhites (contiguous habitat) in our study may simply be a reflection of bobwhite performance on fragmented versus contiguous habitat.

MANAGEMENT IMPLICATIONS

We were unsuccessful in restoring northern bobwhite on habitat fragments in the Post Oak Savannah of Texas via habitat management and bobwhite translocations. The translocation sites in our study were essentially void of bobwhites. Griffith et al. (1989) stressed the need to initiate translocation efforts prior to low densities or population declines given that both situations resulted in low chances of success. Past research appears to provide some support for this general recommendation (Jones 1999; Liu 1995; Terhune et al. 2006*a*, *b*, 2010). Given our results, translocations on large (>400 ha), vacant habitat fragments may be beyond the realm of practical management, particularly in the Post Oak Savannah ecoregion of Texas.

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