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ABSTRACT

We compared home range sizes and movement patterns of resident and relocated northern bobwhites (*Colinus virginianus*) on an area managed specifically for the species in the Pineywoods of east Texas. During the winters of 1990–1992, 155 south Texas, 136 east Texas, and 139 resident bobwhites were radiomarked, released, and thereafter regularly located. Bird locations were plotted on a digitized map, and home range sizes and movement patterns of each group of birds were estimated. Resident bobwhites moved longer daily distances in March and had larger home ranges during the nesting season (May-Jul) than relocated birds ($P \leq 0.05$). Conversely, no differences were detected among groups in mean of daily distances moved in April or dispersal during the breeding season (Mar-Jun) ($P > 0.05$). Annual dispersal distances ($\bar{x} = 1.43$ km) of birds that survived into November were similar among groups ($P > 0.05$). Managers that elect to relocate northern bobwhites should consider doing so in the fall and only into habitats of ample size.

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Key words: *Colinus virginianus*, movement patterns, northern bobwhite, relocation, Texas, transplant

INTRODUCTION

Historically, bobwhites were present but probably not abundant in east Texas before Europeans arrived. However, early farming and land-use practices favored the species, and populations flourished (Lay 1965). Prior to World War II, east Texas was known for its bobwhite hunting. After World War II, land use practices changed and serious population declines occurred (Lay 1965). By 1987, bobwhite numbers in east Texas were so low that the Texas Parks and Wildlife Department discontinued bobwhite survey routes.

In the late 1980's, Temple-Inland Forest Products Corporation made the commitment to intensively manage a 563-ha area for bobwhites on the South Boggy Slough Hunting and Fishing Club in east Texas. The general objective of the project was to re-establish bobwhites on the area through habitat improvement and relocation of wild-trapped birds. After initial habitat improvement, wild bobwhites were trapped in east and south Texas and released on the area, which had a small remnant population. The corporation also funded a study that examined and compared habitat preferences (Liu et al. 1996), survival (Liu et al. 2000), and reproduction (Nedbal et al. 1997, Parsons et al. 2000*b*) of the resident and relocated bobwhites. This paper reports movement patterns of the 3 groups of bobwhites.

METHODS

The study area was in Trinity County, which is in the Pineywoods Ecological Region of east Texas. Climate in this area is hot and humid, with precipitation ranging 90–150 cm/year (Gould 1975:2). The study area was dominated by upland stands of loblolly (*Pinus taeda*) and shortleaf (*P. echinata*) pines. Hardwoods, primarily sweetgum (*Liquidambar styraciflua*), oaks (*Quercus* spp.), and hickorys (*Carya* spp.) occurred along the small drainages (Liu 1995). Basal areas in these 50–60 year-old pine and mixed pine-hardwood stands ranged 21–28 m^2/ha. Two 10-ha pine plantations, each 5 years old, were on the north end of the area and, as the result of a tornado, a 101-ha portion of the study area was clearcut, site prepared, and replanted in spring, 1989. Also, there were about 10 km of pipeline rights-of-ways and 40 km of roads within the area.

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Habitat modifications were initiated in February 1989. Basal area of merchantable trees was reduced to 9–14 m^2/ha using crown and/or low thinnings. Approximately 20% of the study area was converted into food plots. Cover blocks, both natural and planted, occupied 30% of the area. The study area was initially burned with a prescribed fire in 1989 and was burned again in both 1991 and 1992. Cover blocks, food plots, and young pine plantations were protected during the prescribed burns (Parsons et al. 2000*a*).

In February and March 1990, 50 bobwhites (*C. v. texanus*) from Kenedy County, in south Texas, and 31 from Houston County, which is north of and adjacent to Trinity County, were captured, banded, radiomarked, and released on the study area. Thirteen of the estimated 20 resident birds were captured, banded, radiomarked, and released at the point of capture; both groups of birds captured in east Texas were of the *C. v. mexicanus* subspecies (Johnsgard 1973). In winter 1991, 50 south Texas, 50 east Texas, and 69 resident (i.e., birds hatched and reared on the study area) bobwhites were radiomarked and released. Likewise, in winter 1992, 55, 55, and 57 south Texas, east Texas, and resident bobwhites, respectively, were radiomarked and released on the study area.

During the 3-year study, attempts were made to locate each bird $\geq$ 5 days/week during the late winter, spring, summer, and early fall; numbers of locations were reduced to 2 or 3 days/week during the deer season. Radiomarked birds were tracked until they died, the transmitter failed, or the project ended. Throughout the study, radiomarked birds were recaptured and transmitters replaced as necessary. Searches were conducted daily for missing birds.

In 1990, bird locations were plotted on existing copies of aerial photos of the study area. However, a set of new aerial photos was taken in 1991 and a digitized study area map was made from these photos. A grid system, with each cell representing a 100 $\times$ 100 m area, was imposed on the map. Daily locations of the birds were plotted on the gridded map in 1991 and 1992, and the aerial photos were used to help determine the precise locations of the birds on the map. To minimize plotting error, each person locating bobwhites was given intensive training pertaining to the use of the map and aerial photos and recognition of landmarks.

In order to error test the radio-locating and location-plotting systems, 36 locations were randomly selected in the study area. A transmitter was placed at each location, at approximately the height of a bobwhite, by a person who was not a radio-tracker. Each tracker then independently located these transmitters as if they were birds, including plotting the locations on the gridded map. Actual locations of the transmitters were plotted on the map thereafter. The distances between estimated locations and the actual locations were measured using a Geographic Information System (GIS) (ESRI 1993). Analyses of variance were performed on these data to determine any accuracy differences among trackers. There was no statistical difference among the trackers, therefore the data were pooled for all trackers and the error rates were then estimated (Liu et al. 1996).

March home range sizes, nesting-season home range sizes, means of distances moved daily, breeding-season dispersal distances, and annual dispersal distances were compared among the 3 groups of bobwhites. For these analyses, only birds that were initially radiomarked each year were included (i.e., birds that joined the population after late February were excluded).

March home range was selected because it was before covey break-up, but after relocated birds had time to become acclimated to the study area. The nesting-season home range included all radio locations of a bird during May, June, and July. The mean of distances moved daily by a bird was the average of all distance measurements between radio locations on consecutive days in a month. Breeding-season dispersal distance was the distance between the release site of a bird and the radio location farthest from that site during June. June was selected because by then the spring shuffle was completed and most birds had settled into the breeding-season routine. Annual dispersal distances were calculated for birds surviving into November. These values were obtained for each bird by measuring the distance from the release site to the most distant radio location recorded during the year.

In order to obtain March or nesting-season home range of a bird, digitized radio locations were used to define a polygon and the area of the polygon (excluding obvious outliers) was calculated using the GIS. The process of measuring home range was made interactive by an ARC Macro Language (AML) program (Liu 1995:121) and the measurements were automatically written into the original information (INFO) files.

Movement data were obtained using the GIS. In order to determine the distance a bird dispersed from its release site, a map of the release sites was digitized. Breeding-season dispersal was obtained by calculating the distances between the bird's release site and each of its daily locations in June. These distances were then compared and the greatest distance was obtained. The mean of distances moved daily during each month was calculated using a similar routine. During each month, the first location of a bird was selected and then the location successive to the first was selected. These 2 locations were tested for consecutiveness in dates and, if they were consecutive, the distance between them was calculated. Next, the location successive to the second was selected and the test and measuring process repeated. This process continued until distances between all consecutive locations of the bird in the month were measured. The total of the distance measurements was divided by the number of measurements to produce the monthly average. These processes were customized by an AML program (Liu 1995: 124) and the results were also output to the original INFO files.

Two statistical analysis procedures were used to analyze home range and movement data. March home range sizes, nesting-season home range sizes, breed-

Table 1. Results of multivariate analyses of variance of home range sizes and movements among resident, east Texas relocated, and south Texas relocated bobwhites on the South Boggy Slough study area, Trinity County, Texas, 1990–1992. Means with the same letter within rows do not differ ($P > 0.05$).

	South Boggy residents ($n = 35$)		East Texas relocated ($n = 56$)		South Texas relocated ($n = 41$)		
Variable	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*P*-value
March home range (ha)	10.5a	10.0	5.5b	4.3	6.1b	5.3	0.002
Nesting-season home range (ha)	61.9a	30.1	46.9b	27.1	42.6b	29.8	0.011
Breeding-season dispersion (km)	1.4	0.7	1.2	0.6	1.1	0.7	0.127
Mean distance moved daily in March (m)	182.0a	98.0	123.0b	58.0	134.0b	73.0	0.001
Mean distance moved daily in April (m)	195.0	158.0	209.0	186.0	151.0	82.0	0.178

ing-season dispersal distances, and means of distances moved daily during March and April were compared among groups using MANOVA. When differences were detected among groups, Duncan's multiple range tests were performed to further identify the differences.

After April, the numbers of birds rapidly decreased, thus missing values increased. This resulted in the whole record for many birds being rejected by the analysis procedure. Therefore, the means of distances moved daily were not compared among groups for the remainder of the year. However, these means were compared among months within each group using ANOVA, and if appropriate, Duncan's multiple range tests. For similar reasons, annual dispersal distances were not compared in the MANOVA procedure, but in separate ANOVA and Duncan's multiple range tests. The SAS system (SAS Institute 1988) was used for statistical analyses. The alpha levels for all statistical tests were set *a priori* at 0.05.

RESULTS AND DISCUSSION

The mean March home range size of South Boggy residents was larger than those of either east Texas or south Texas relocated birds. Likewise, South Boggy residents had larger nesting-season home ranges than either east Texas or south Texas relocated bobwhites ($P < 0.05$). Conversely, there was no difference among the 3 groups in breeding-season dispersal ($P > 0.05$), which was between the time of release and the end of June (Table 1).

Corresponding to the differences in March home range sizes, the means of distances moved daily in March were also different. Both east Texas and south Texas relocated bobwhites had shorter daily movements in March than did South Boggy residents; the differences were not significant in April (Table 1).

The monthly means of distances moved daily ranged 60 to 299 m; the means were lowest in November, but the sample sizes were also the smallest during that month. Among months, the differences were not significant for either the South Boggy residents or south Texas relocated birds. However, the east Texas relocated bobwhites had significantly longer daily movements in May than in March. For each group, the mean distance that the birds moved daily peaked in May, and the maximum variation (i.e., standard error) occurred in either April or May (Fig. 1). For South Boggy residents and south Texas relocated birds, the standard error values increased in April, reached the maximum in May, and then declined. For east Texas relocated birds, the standard error values were somewhat higher in April than in May. Regardless, it is noteworthy that the standard error values for the month with the highest variation in daily movements was much greater for South Boggy residents than for east Texas or south Texas relocated birds (Fig. 1).

Changes in means of distances moved daily coincided with the breeding season. During fall and winter, bobwhites are in coveys. In early stages of the breeding season, males start whistling, seeking females, and the coveys break up (Rosene 1969:98). During this period, often called the spring shuffle, the birds move extensively. In this study, the spring shuffle began in April and continued into May. After this period of extensive movement, most birds were with mates, hence daily moving distances and variations in these distances were reduced (Fig. 1).

The fact that the South Boggy residents differed from the other 2 groups in average distances moved daily during March and in March home range size suggests that the relocation process had a profound influence on movement behavior of relocated birds during the initial period after relocation. Obviously, the relocated birds were not familiar with the area into which they had been introduced and this may have reduced their movements.

Lack of differences in daily distances moved in April seemingly suggests that the relocated birds had become acclimated to the study area by then. This probably was not the case, however. The impending breeding season probably had more of an impact on the birds' movements than did the lack of familiarity with the study area.

During April and May, birds from all 3 groups often made long-distance movements, seeking a mate. However, movements by South Boggy residents were longer than those of either relocated group during both months. Although the values were smaller, the same was true for June. Finally, the nesting season (May-Jul) home range size of South Boggy residents was

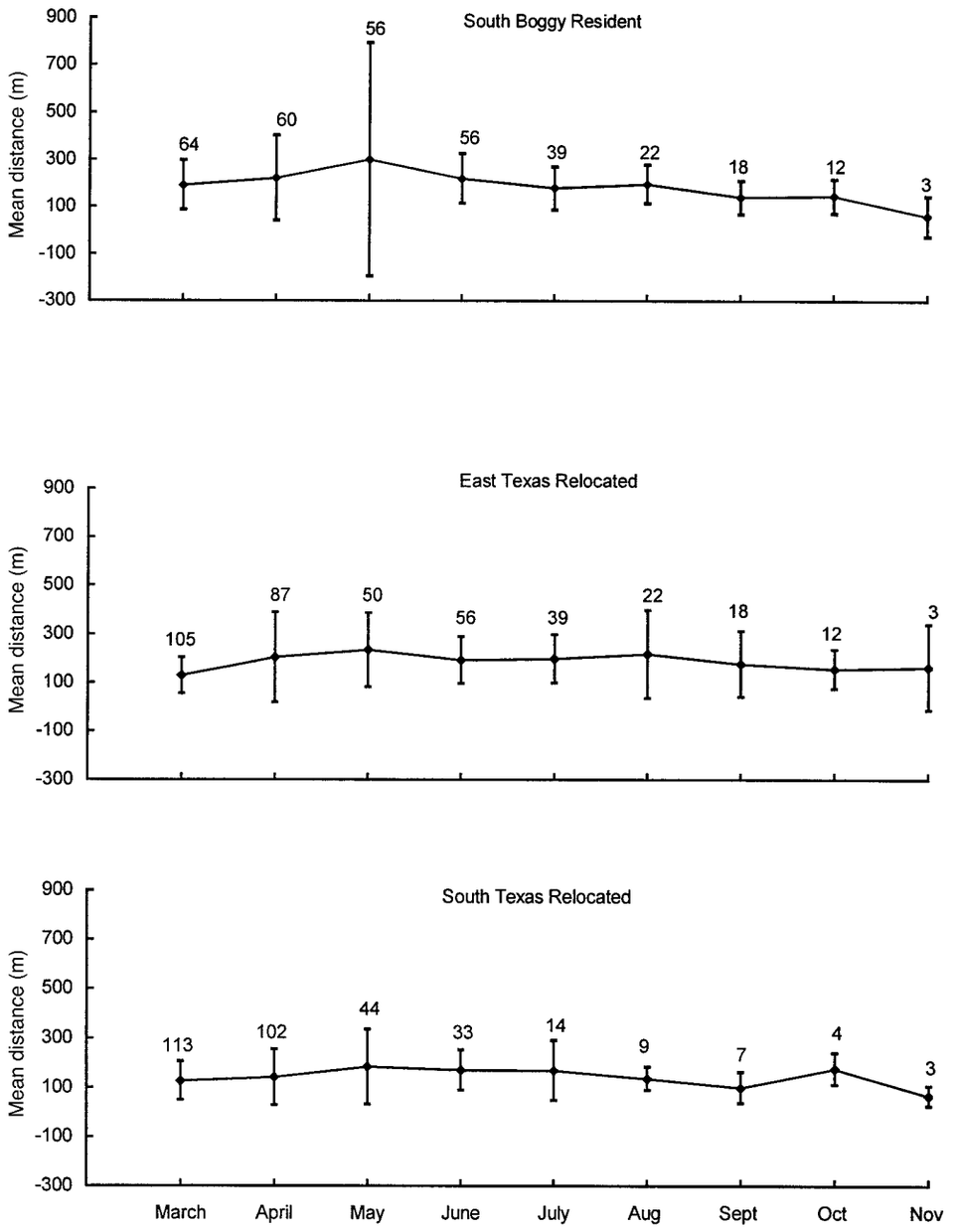

Fig. 1. Monthly means and standard errors of distances moved daily by resident, east Texas relocated, and south Texas relocated bobwhites on the South Boggy Slough study area, Trinity County, Texas, 1990–1992. Numbers presented are sample sizes.

significantly larger than those of the relocated birds (Table 1). These findings indicate that movements of relocated birds were restrained at least through June, or for at least 4 months. If the birds had been relocated in the fall, the impact of the process might have been clearer.

Impact of the relocation process on movement behavior lessened with time and had disappeared by late fall. Among the 3 groups, annual dispersal distances of birds that survived through the breeding seasons into November showed no significant differences ($P = 0.88$). The mean dispersal distance for resident birds was 1.5 km (SD = 0.6 km); for east Texas and south Texas groups, mean dispersal distances were about the same, 1.4 km (SD = 0.5 and 0.4 km, respectively).

MANAGEMENT IMPLICATIONS

Wildlife managers who find it necessary to relocate wild northern bobwhites into habitat created for the species should consider the timing of relocation and size of the modified habitat. Our data indicate that it takes at least 4 months for relocated birds to become familiar with their surroundings, even if the birds are from a similar habitat type. This suggests that relocations should take place in fall rather than winter. Unfortunately, relocation in the fall subjects the birds to a longer period of potential depredation prior to the breeding season than does winter relocation.

Although the annual dispersal distance of the birds averaged 1.4–1.5 km, many birds dispersed much far-

ther than that. However, most of these birds either died or their signals were lost before November, thus they were excluded from that analysis. The greatest known distance was 3.8 km, made by a male South Boggy resident in 1991. It should be pointed out that at least 50 birds dispersed ≥ 2.5 km (Liu 1995:100). This suggests that if a designated relocation area is less than 5.0 km in diameter, at least 10% of the relocated birds may move out of the area, even if all birds are released at its center. This percentage is probably an underestimate because some missing birds in this study probably moved farther than that.

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