HABITAT USE BY ENDANGERED MASKED BOBWHITE QUAIL (*Colinus virginianus ridgwayi*) ON THE BUENOS AIRES NATIONAL WILDLIFE REFUGE, ARIZONA

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EXECUTIVE SUMMARY

The masked bobwhite (*Colinus virginianus ridgwayi*) is currently restricted geographically to 2 sites: one population occurs in southeastern Arizona on the Buenos Aires National Wildlife Refuge and the other occurs on a privately-owned ranch in central Sonora, Mexico. Despite the presence of a self-sustainable population of masked bobwhites in Sonora and persistent restoration efforts in Arizona, the status of wild populations of masked bobwhites remains tenuous at best. In order to implement effective management strategies, basic questions regarding masked bobwhite life history, ecology, and habitat use must be answered. Specifically, information concerning basic habitat requirements and the demographics associated with specific habitat conditions represent immediate needs. We studied masked bobwhite habitat relationships on the Buenos Aires Refuge during 1994-96. Our objectives were to (1) quantify habitat components used by masked bobwhites during 2 biologically relevant seasons (pair formation/breeding season and covey season) and (2) compare bobwhite habitat use with available habitat on the Buenos Aires Refuge. We used several methods to obtain locations of bobwhites, including radio telemetry associated with releases of captive-reared birds and capture of free-ranging birds, use of trained bird dogs, random line transects, taped call playbacks to elicit breeding and assembly calls, and chance encounters. We then measured a variety of habitat-related variables at each of these points designed to describe the structure and species compostion of forbs, grasses, subshrubs, shrubs, and trees. Specific variables included forb and grass richness, herbaceous biomass, percent bare ground, and percent forb, grass, subshrub, shrub, and tree cover. We compared these measurements of habitat collected at quail use points to random points distributed throughout the Refuge in a use-availability framework. Masked bobwhites appeared to select sites with greater vegetative structual diversity than what was available at random throughout the Buenos Aires Refuge. This was most evident when we compared the variables vegetation structure and percent bare ground between quail points and random points. We found no strong association for specific plant species by masked bobwhites during any season and, in general, plant species were used in proportion to their availability on the Refuge. This indicates that vegetation structure is of greater importance to masked bobwhite than the specific species involved. This does not preclude the importance of specific plant species that may provide critical food sources for masked bobwhite adults and young. Despite this, there may be some evidence that masked bobwhites actually showed disproportionate use of areas with higher composition of nonnative than native grasses on BANWR, particularly during covey seasons. This could be because nonnative grasses such as Lehmann lovegrass provided denser stands of cover, and thus more protection and more favorable microclimatic conditions (e.g., warmer microsites during the colder months) during a time of year when temperatures are cool to cold and peak raptor migration occurs. Adequate cover is also undoubtedly important to newly released captive-bred quail. Mortality of newly released birds to raptors can be relatively high on BANWR, perhaps up to 50% of released birds in some areas. Although the data we collected at release sites was probably inadequate to examine quantitative aspects of vegetation structure in a rigorous manner, it appears that habitats close to release sites that offer protective cover for newly released quail could improve survival and thus establishment of a self-sustaining population on the Refuge.

INTRODUCTION

Background

The masked bobwhite (*Colinus virginianus ridgwayi*) is related to bobwhite quail in the eastern and mid-western United States, but more closely resembles bobwhite forms of southern Mexico (Aldrich 1946). Masked bobwhites were first reported by European settlers in southern Arizona and Sonora, Mexico in 1864 (Coues 1903:6). The subspecies was a permanent resident from southeastern and south-central Arizona south to southern Sonora. By the mid-1880's, masked bobwhite populations declined sharply, probably because of overgrazing and several years of severe drought. By the turn of the century, masked bobwhites were extirpated from Arizona (U. S. Fish and Wildl. Serv. 1995).

Ligon (1952) reported that masked bobwhites were "fairly" numerous locally as late as 1937 in central and southern Sonora, where habitat destruction was not as severe as Arizona. After the 1930's, habitat degradation from overgrazing became more widespread in Mexico. The subspecies was listed as endangered in 1973 by the U. S. Fish and Wildlife Service (USFWS) under the Endangered Species Act (U. S. Fish and Wildl. Serv. 1995).

A reintroduction program was initiated in the United States during the 1940's and 1950's. Wild masked bobwhites from Sonora and some propagated stock (about 200 birds) where released in eastern Arizona and western New Mexico, where native populations had never been known to occur (Tomlinson and Brown 1970). Range conditions were considered unsuitable for reintroductions to historic habitat in southern Arizona (Tomlinson 1972). These early attempts to establish a wild population were unsuccessful.

By the early 1950's, masked bobwhite populations in Sonora declined dramatically and ornithologists feared that the bird might already be extinct (Ligon 1952). In 1964, a population of masked bobwhites was rediscovered on a ranch in central Sonora (Gallizioli et al. 1967). Renewed interest resulted in attempts to reestablish populations of the species in their historic range in southern Arizona. A captive propagation program for masked bobwhites was initiated, and in 1968 and 1970, 57 wild birds were collected in Sonora and sent to the Patuxent Wildlife Research Center for breeding stock (Tomlinson 1972).

Identifying suitable habitat for releases of captive-reared stock was critical. In 1969, the USFWS, in cooperation with the Arizona Game and Fish Department, began a search for suitable release sites within historic range in Arizona. In 1970, 4 experimental release sites were selected in the Altar Valley. However, habitat conditions for most sites were not adequate because elevations were too high and grazing continued to occur (U. S. Fish and Wildl. Serv. 1995). Results from experimental releases indicated that the birds preferred bottomland habitat along riparian areas and washes. Therefore, the 465-ha Buenos Aires Ranch, located along the Altar Wash, was leased by the USFWS to provide for bobwhite habitat studies from 1978 to 1981.

Captive birds that were released onto the Buenos Aires study site were prepared for survival in the wild by use of foster parent Texas bobwhites (Brown 1989). This may have attributed to a population increase of short duration in 1979. Thereafter, uncontrolled grazing on release site pastures, combined with summer drought, resulted in sharply reduced population levels (Brown 1989).

Because a protected area was critical for reestablishment of a masked bobwhite population in Arizona, the USFWS purchased the Buenos Aires Ranch and established the Buenos Aires National Wildlife Refuge (BANWR) in 1985 (Brown 1989). From 1985 to the present, >20,000 masked bobwhites have been released on BANWR (U. S. Fish and Wildl. Serv. 1995). The main goal of the captive release program was to establish self-sustaining populations and ultimately remove the masked bobwhite from the endangered species list. Survival of released chicks has been low and recovery of the population has been slow.

Historic Habitat Conditions

Brown (1982) suggested that grasslands of the Altar Valley were similar to the Sonoran savanna grassland communities of the plains of Sonora, Mexico, but this was before overgrazing by livestock and invasion of mesquite (*Prosopis velutina*) and exotic grasses such as Lehmann lovegrass (*Eragrostis lehmanniana*) and Johnson grass (*Sorghum halepense*). Historical records describe masked bobwhites as occupants of grassy plains and foothills of Sonora, and early references and recent observations in Sonora indicate that dense stands of perennial grasses were an important component of habitat (Gallizioli et al. 1967). Other accounts describe masked bobwhites as inhabiting mesquite-grassland habitat at elevations of approximately 250-1,200 m above sea level (Tomlinson 1972). Quantitative data on habitat use by masked bobwhites is scarce (U. S. Fish and Wildl. Serv. 1995).

Some earlier studies have described habitat features that may be essential to the survival and successful reproduction of masked bobwhites. These features include areas with a high diversity of grasses and forbs and the following minimum amounts of standing biomass and canopy cover: a standing grass crop of 397 kg/ha with 12-15% grass canopy cover, a standing forb crop of 265 kg/ha with 10-15% forb cover, and 15-30% overstory cover of shrubs or brush (Goodwin 1982). Johnson and Stephen (1980) believed that habitat conditions for masked bobwhites in Arizona and Sonora have been degraded and may not currently support a self-sustaining population. Others theorize that masked bobwhites were never as abundant as other endemic species of quail, nor were they as widely distributed because of their restricted habitat requirements (Ligon 1952, Tomlinson 1972).

The historic range of masked bobwhites overlapped, at least in part, with the ranges of 4 other species of quail: Gambel's quail (*Callipepla gambelii*), which ranged throughout Arizona and Sonora; scaled quail (*C. squamata*), which was found only at the extreme northern edge of masked bobwhite range in southeastern Arizona; elegant quail (*Lophortyz douglasii*), which was common in the eastern and southern parts of the bobwhite's range in Sonora; and Mearn's quail

(*Crytonyx montezumae*), which was present at higher elevations throughout masked bobwhite habitat (Tomlinson 1972).

Brown (1885) observed 3 of these quail species in southern Arizona and reported that Gambel's quail were found in rough canyon-like country, scaled quail in wide grassy plains, and masked bobwhites on mesas and in the plains, but not in canyons. Goodwin and Hungerford (1977) conducted a study on habitat use by native quail in the Altar Valley during 1975-76. Their study indicated that Gambel's preferred dense overstory cover of mesquite, hackberry (*Celtis* spp.), wolfberry (*Lycium fremontii*), and catclaw (*Acacia greggii*) with an understory of snakeweed (*Gutierrezia sarothrae*) and burroweed (*Aplopappus tenuisectus*), while masked bobwhites preferred habitat with dense ground cover and a high diversity of forbs and grass species. Goodwin and Hungerford (1977) reported that masked bobwhites moved into Gambel's habitat when their preferred habitat was limited. They also reported that, at the northern limits of masked bobwhite range in the Altar and Santa Cruz Valleys of Arizona, semidesert grassland replaced Sonoran savanna grassland and masked bobwhite were replaced by scaled quail (Goodwin and Hungerford 1977). Scaled quail prefer low grasses and shrubs with 10-50% ground cover (Brown 1989).

Current Status and Conditions

The masked bobwhite is currently restricted geographically to 2 sites. One population occurs in southeastern Arizona on the Buenos Aires National Wildlife Refuge, approximately 97 km (60 miles) south of Tucson, and the other occurs on a privately-owned ranch in Sonora, Mexico, approximately 137 km (85 miles) south of Nogales.

Current estimates of numbers of masked bobwhite on BANWR range from 500 to 800 individuals. This existing population on the Refuge does not represent birds that originally inhabited Arizona. Rather, these birds were produced by the captive population, formerly housed at the Patuxent Wildlife Research Center and now on BANWR near the town of Arivaca, and are descendents of the Mexican population. The BANWR population was established through chick releases, aided by livestock exclusion, prescribed burning, and other habitat management. Though limited success has been achieved at restoring a wildlife population on the Refuge, restoration efforts have been disappointing as a self-sustaining population has not yet been realized. Additional data and measures are clearly needed if a viable population is to be established in Arizona.

The largest population of masked bobwhites occurs on Rancho El Carrizo in Sonora, Mexico. This property is owned and operated by Mr. Gustavo Camou of Hermosillo, Sonora, and encompasses approximately 1,620 ha (4,000 a) of rangeland, most of which is historic masked bobwhite habitat. In addition to Rancho El Carrizo, Mr. Camou's family owns another 20,235 ha (50,000 a) of land that is either masked bobwhite habitat or potential habitat, if subjected to improvements. A recent census indicated that about 2,000 birds currently exist on Camou family land in Mexico. This population appears to be in better demographic condition than the population on BANWR because it has apparently increased slightly or has at least remained stable despite recent years of drought.

Objectives

Despite the presence of a self-sustainable population of masked bobwhites in Sonora and persistent restoration efforts in Arizona, the status of wild populations of masked bobwhites remains tenuous. Extended drought, a severe outbreak of disease, or other natural catastrophe could result in extirpation of either population. It is therefore imperative that aggressive management be implemented as soon as possible to circumvent the demise of this species. In order to implement effective management strategies, questions regarding masked bobwhite life history, ecology, and habitat use must be answered. Specifically, information concerning basic habitat requirements and the demographics associated with specific habitat conditions represent immediate needs. If the essential habitat requirements of masked bobwhite populations can be identified clearly, management and ultimate recovery of the species in Arizona and Sonora would be greatly facilitated.

Therefore, the specific objectives of this research were to (1) quantify habitat components used by masked bobwhites during 2 biologically relevant seasons (pair formation/breeding season and covey season) and (2) compare bobwhite habitat use with available habitat on the Buenos Aires Refuge. This information could then be used as a aid to managers for improving and managing cover and other aspects of bobwhite habitat to improve the distribution, survival, and reproduction of masked bobwhites on the Refuge.

Our general hypotheses of interest were:

H_O: masked bobwhites use selected vegetative components of the grassland community in equal proportions to their availability on the Buenos Aires Refuge.

H_A: at least some of these habitat components were used in higher or lower proportions than their availability on the Refuge.

All other research and statistical hypotheses were subsets of this general paired null and alternative hypotheses. Components used in higher proportions to their availability were considered to be preferred by masked bobwhites, while those components used in equal or lower proportions to their availability were considered to be not preferred or avoided, respectively.

STUDY AREA

Location and Physical Description

This study took place on the Buenos Aires National Wildlife Refuge in southeastern Arizona (Fig. 1). The Refuge is managed by the U. S. Fish and Wildlife Service and encompasses about

48,000 ha. It is located 97 km southwest of Tucson and lies mostly within the Altar Valley east of the Baboquivari Mountains.

Elevations on the Refuge range from 925 to 1,400 m and topography is comprised mainly of rolling hills, several major washes, and many smaller washes. Climate is characterized by low precipitation, low humidity, and high summer temperatures. Mean annual temperature is 15 C, with temperatures ranging from a low of -11 C in winter to 41 C in summer. Annual precipitation averages 40 cm and falls in a bimodel pattern on an annual basis: about 40% occurs as summer rains during July and August, with the remaining occuring as rain and occasionally snow during the winter months (U. S. Fish and Wildl. Serv. 1995).

Vegetation

Vegetation on BANWR is predominately semidesert grassland with remnants of Sonora savannah grassland (Brown et al. 1979). European settlement of the region has created a mixture of native and exotic plant species throughout much of southern Arizona (McClaran and Van Devender 1995). Dominant native grasses include dropseeds (*Sporobolus* spp.), grammas (*Bouteloua* spp.), threeawns (*Aristida* spp.), Arizona cottontop (*Digitaria californica*), plains lovegrass (*Eragrostis intermedia*), and wild buckwheats (*Eriogonum* spp.) (McLaughlin 1990, U. S. Fish and Wildl. Serv. 1995). The deeper soils of wash basins are characterized by a mixture of Johnson grass, sacaton (*Sporobolus* spp.), and Russian thistle (*Sallsola kali*). The foothills and higher elevations at the extreme east and west boundaries are dominated by rocky outcrops and a mixture of half-shrubs such as snakeweed and burroweed, grasses, prickly pear (*Opuntia* spp.), cholla cacti (*Opuntia* spp.), and ocotillo (*Fouquieria splendens*) (McLaughlin 1990).

Among exotic grass species, Lehmann lovegrass is prevalent on most upland areas and Johnson grass dominates many of the floodplains along major washes. Native grasses are most prevalent along the eastern edge of the Refuge in areas of higher elevations, steeper slopes, and variable soils where grasslands are less disturbed and more diverse. These areas are dominated by native perennial grasses and have not been invaded extensively by woody plants (McLaughlin 1990). On much of the Refuge, lack of natural wildfires has increased the distribution and density of mesquite trees and other woody growth, and scattered to dense stands of mesquite are present throughout BANWR.

Vegetation Associations

In order to facilitate restoration and management of native grassland habitat, Refuge staff have identified 8 vegetation associations based on unique features and dominant plant species. These vegetation associations are: (1) mesquite, (2) mesquite-Lehmann, (3) Lehmann, (4) Lehmann-native grass, (5) native grass, (6) subshrub-grass, (7) subshrub, and (8) Johnson grass-Sacaton-Russian thistle (Kuvlesky and Madsen 1995).

The mesquite association (1) is dominated by mature mesquite trees (>30 yrs.). The majority of this association is restricted to the deeper soils of washes and floodplains. Canopy cover throughout much of this association exceeds 80% and often approaches 100%. The mesquite-Lehmann (2) association is characterized by a mixture of mesquite trees, with canopy cover ranging between 30-60% distributed within a matrix of Lehmann lovegrass.

The Lehmann association (3) is dominated by Lehmann lovegrass and occurs primarily on uplands with shallow soils. Small mesquite trees (<15 yrs.) may be distributed throughout this association, although canopy cover is typically <10%. The Lehmann-native grass association (4) consists of a mixture of lovegrass (35-65%) and native grasses (35-65%), with mesquite and catclaw acacia distributed throughout. Canopy cover is <30%.

Native grass associations (5) are composed of at least 65% native species. The subshrub-grass association (6) occurs primarily on uplands and is composed of a mixture of snakeweed and burroweed (35-65%) and grass (35-65%). The grass component may be either native species or Lehmann lovegrass. Subshrub associations (7) occur primarily on uplands and are composed of >65% burroweed and snakeweed. The Johnson grass-sacaton-Russian thistle association (8) occurs almost exclusively in the deeper soils of wash basins. A few woody species, such as mesquite, catsclaw acacia, and desert willow (*Salix* spp.) occur within this association, though few native species are present.

METHODS

Use-availability Framework

Adequate quantities of resources, such as cover, water, and food, are necessary to sustain wildlife populations. Determining which resources are selected by a species more often than other resources is important for answering fundamental questions about the ecology and management of that species. This is especially true for endangered species, such as the masked bobwhite, where habitat availability and management practices are critical components to recovery and delisting.

A use vs availability framework has been used by biologists to examine how wildlife species use or select among a variety of habitat and/or food resources (Neu et al. 1974, Marcum and Loftsgaarden 1980, Byers et al. 1984). Manly et al. (1995) have reviewed the literature on resource selection and have summarized and unified the methodology for use-availability studies. They state that it is often assumed that a species will select resources that are best able to satisfy its requirements, and that high quality resources will be selected more than low quality ones. The availability of various resources is not generally uniform, and use may change as availability changes. Therefore, used resources should be compared to available (or unused) resources in order to reach valid conclusions regarding resource selection (Manly et al. 1995:1).

We applied these principles to our study of habitat use by masked bobwhites on BANWR. We measured habitat as a series of vegetative and non-vegetative characteristics, and defined habitat "use" as those areas of the Refuge where we found masked bobwhites. "Available" habitat was defined by a collection of points distributed at random throughout the Refuge. We collected the same data and made the same measurements on vegetative and non-vegetative variables at both quail (used habitat) and random (available habitat) points. When habitat was used by masked bobwhites disproportionately to its availability on BANWR, we concluded that bobwhites were selecting for those habitat characteristics (Manly et al. 1995).

Identifying Quail and Random Points

Locating quail. Masked bobwhites are difficult to locate because of their elusive nature, reluctance to flush, and low population densities. We, therefore, used several methods to obtain habitat use data, including radio telemetry associated with releases of captive-reared birds and capture of free-ranging birds, use of trained bird dogs, random line transects, taped call playbacks to elicit breeding and assembly calls, and chance encounters.

Refuge staff released captive-reared masked bobwhites onto the Refuge during our study (Fig. 2). Funnel traps were used to capture quail during the latter part of covey season (Oct-Mar), when birds could be lured into baited traps. At least 1 quail in each group released was fitted with a radio transmitter, which was equipped with a mortality signal. Signals on newly released birds were monitored for the first 3 consecutive days after release, but these individuals were not approached (flushed) unless a mortality signal was detected. After the third day, radioed birds were located at least once a week during one randomly selected time period: morning (sunrise - 0930 hrs), midday (0931 - 1730), or evening (1731 - sunset). Once we located a signal, we approached until it or the group was flushed. The point of flush for an individual or the center of the group was then used as our center plot for our habitat plots. Telemetry continued as long as a signal was transmitted (up to 6 months), until the bird died, or until the radio signal was lost.

We used trained bird dogs to assist us in locating and flushing groups of masked bobwhites during the covey season. During this time of year, quail are present in larger groups and thus leave stronger scents for the dogs to track and locate, and temperatures are cooler and scenting conditions better, increasing the stamina and efficiency of the dogs. During most of the pair formation/breeding season, temperatures are often much higher and the dogs are more susceptible to heat exhaustion, more at risk to bites from venomous reptiles, less likely to detect quail because of poor scenting conditions, and more likely to cause disturbance to breeding pairs if quail are located. During most of the study, we used 2 dogs (a setter and a pointer), but at other times we had access to and used several other breeds of dogs. Bird dogs worked in areas where masked bobwhites were released prior to the covey season, where quail were seen or heard, and in randomly chosen areas.

We also located quail by walking line transects located at random throughout the Refuge. For each transect, we randomly chose an area from our study area grid map in a manner similar to that used for locating random points for habitat analysis (see below). Once we determine the accessibility to the selected area, we chose a random distance and direction (which was usually limited in choice) with which to drive into the area. This procedure helped us to randomly select a starting point to begin the transect. We then chose a random compass bearing to determine the direction of the transect, and began walking for 20 minutes. At 5 minute intervals, we stopped and walked in a circle about the line for 3-5 minutes; this was done because masked bobwhite often hold tight and do not flush readily. If no birds were flushed, we continued with this procedure until the line was completed. We then moved 75-100 m to the right or left and continued on a line transect for 20 minutes in the opposite direction.

We used taped masked bobwhite breeding and covey calls, played through a portable megaphone, to induce responses from quail during the pair formation and covey seasons, respectively. This method was used only to identify the presence of masked bobwhites. When bobwhites were located, we revisited the area with dogs or by walking transects to look for quail. If birds were located on these subsequent visits, we then identified points for habitat data collection.

We defined chance encounters as opportunistic observations of masked bobwhites on the Refuge by project or Refuge personnel. These locations were then used to collect habitat data. Chance encounters included observations of birds feeding, dusting, loafing, roosting, singing, or drinking on the Refuge. We also included observations of quail sign, such as feathers and feces, in our methods for identifying points for habitat analysis.

To avoid the problem of pseudoreplication (Hurlbert 1984), we measured only one point from areas where we located coveys or groups of quail. The center point for our vegetation sampling plot was placed at the approximate center of the covey or group of quail.

Locating random points. We divided a map of BANWR into 191 grids, based on square mile sections that fell partially or entirely within the Refuge boundary. We used a random numbers table to generate a series of 3-digit numbers; these numbers identified the grids were we would locate our random points for determining habitat availability on the Refuge. Once a grid was selected, a random driving distance and direction from the grid boundary into the grid was chosen; in this way, we entered the grid in a random fashion. From this point, a random direction and distance were again chosen so that we could locate a random point that would serve as the center of our random plot for determining habitat availability.

Vegetation Sampling

Both quail and random points were treated in a similar fashion, and we measured the same vegetation and habitat variables in the same way at both sets of points. Vegetative data included the structure and species composition of forbs, grasses, subshrubs, shrubs, and trees. Specific variables included forb and grass richness, herbaceous biomass, percent bare ground, and percent forb, grass, subshrub, shrub, and tree cover.

We used a 0.10 m^2 frame (Daubenmire 1959) to estimate percent herbaceous cover, biomass of herbaceous plants, percent bare ground, and grass and forb richness. The Daubenmire frame was placed at the center point and 1 m from the center point in 4 cardinal directions (N, E, S, W), for a total of 5 frames. We determined biomass from oven-dried weights of grasses and forbs, and converted this to kg/ha.

We used a 2-m Robel pole (Robel et al. 1970) to measure vertical structure of vegetation around quail and random points. The pole was divided into 4 height classes ($\leq$0.15, 0.15-0.5, 0.5-1.0, and 1.0-2.0 m). We estimated vertical structure by the percentage of vegetation covering or obstructing each of the 4 height classes on the pole when viewed from 1 m out in 8 directions (N, NE, E, SE, S, SW, W, NW).

We measured shrub canopy cover (woody cover) with Canfield's (1941) line intercept method. Lines 8 m long radiated out from the center point in 8 directions. Woody cover was estimated as the percentage of line covered by woody canopies.

We estimated woody vegetation density in 2 ways. First, we counted the number of woody stems (stem density) >1 m tall in a 16-m diameter circle centered on the sampling point. Woody plant density was also measure with the point-quarter method (Cottam and Curtis 1956), where we measured the distance from the central sampling point to the nearest shrub and tree in each of four quarters (NE, SE, SW, NW). Distance measurements were converted to densities (shrubs or trees/ha).

Data Analyses

Habitat variables were first plotted and checked visually for normality. Because most variables were positively skewed (due to many low or zero values), we attempted to log-transform the data. The resulting transformations did not normalize the data and thus we used a nonparametric test (Wilcoxon two-sample test) to test for differences between quail and random points (Daniel 1978, SAS 1985).

We considered differences at an alpha level of 0.10 (i.e., $P \leq 0.10$) to be indicative of significant differences between quail and random points. We believe that significance levels $\leq$0.10 are indicative of real biological difference, especially in view of the tremendous variation that can occur in habitat studies in general (Morrison et al. 1992), and particularly with some vegetative variables. By choosing 0.10 vs 0.05, we decreased the probability of a Type II error (accepting a false null hypothesis) but increased the probability of a Type I error (rejecting a true null hypothesis). In order to provide management suggestions with anticipated small sample size, we deemed Type II errors more important than Type I errors (Ockenfels and Brooks 1994). For purposes of interpretation, we state that differences in the range of 0.06-0.10 are suggestive of real biological difference, and those in the range of $\leq$0.05 represent strong inference of a difference.

RESULTS

Quail and Random Points

We collected data on the structure and composition of vegetation around 155 masked bobwhite points (used habitat) and 202 random points (available habitat) (Table 1). These points were distributed among 2 biologically relavent seasons: covey season took place during October-March and the pair formation/breeding (breeding) season took place during April-September. Data collection took place during the covey season 1994-95, breeding season 1995, covey season 1995-96, and breeding season 1996.

We examined the habitat data collected around quail points for between-year differences for the covey season and the breeding season. We found significant differences for 8 of 13 variables during the covey season (range $P \leq 0.001$ to $P = 0.097$), but no differences for any of the 13 variables for the breeding season (range $P = 0.109$ to $P = 0.815$). The latter was probably due to the low number of quail points for breeding season 1996 ($n \leq 6$ points). Low sample sizes for this year were due to the dry conditions and poor scenting conditions for the dogs, and the fact that no captive-reared quail were released by Refuge staff during this time. Because of the differences in habitat variables and climatic conditions, we conducted our analyses separately for the 2 years.

Vegetative Structure

Covey seasons. For both covey seasons (1994-95 and 1995-96), masked bobwhites used habitats with more vertical structure, i.e., taller vegetation (Figs. 3, 4). All 4 height class variables measured with the Robel pole were significantly greater for quail points than random points ($P \leq 0.09$), and most were highly significant ($P \leq 0.04$) (Tables 2, 3). This was especially true of covey season 1995-96, as all 4 height classes were much greater around quail points than random points ($P \leq 0.02$). Sites used by masked bobwhites also had greater vegetation biomass than random points in both years ($P \leq 0.06$) (Fig. 5).

During 1994-95, bobwhite sites also showed lower percentages of herbaceous cover and bare ground, and higher density of woody stem cover than random points (Table 2; Figs. 6-8). These differences were not seen in 1995-96 (Table 3).

No differences were detected between quail and random points for woody cover (canopy cover), numbers of grasses, and grass and forb richness during the covey seasons of 1994-95 or 1995-96 (Tables 2, 3).

Breeding seasons. A similar trend for vertical structure during the covey seasons was seen during the breeding seasons of 1995 and 1996 (Figs. 9, 10). In 1995, all 4 height class variables were greater around quail points than random points ($P \leq 0.02$) (Table 4). In 1996, only the last 2 height categories (structure at 1 and 2 m) were greater at quail points than random points ($P \leq$

0.07), but the trend in greater vegetative height around quail points than random points was similar between 1996 and 1995 (Table 5).

Sites used by masked bobwhites during the pair formation/breeding season also had more woody canopy cover than random points in both years ($P \leq 0.01$) (Fig. 11). During 1996, bobwhite sites also had higher numbers of forbs than random points ($P = 0.06$), but this difference was not detected in 1995 (Tables 4, 5).

No differences were detected between quail and random points for herbaceous cover, percent bare ground, wood per ha, numbers of grasses, grass and forb richness, and biomass during the pair formation/breeding seasons of 1995 or 1996 (Tables 4, 5).

Vegetative Composition

Lehmann lovegrass was the dominant grass species at both quail and random points during 3 seasons (Tables 6-8). The grasses *Vulpia octoflora* and *Aristida* spp. were much more common around random points than quail points. There appeared to be no major differences in shrub or tree species composition between quail and random points (Tables 9, 10). Snakeweed and mesquite were the dominant shrub and tree species, respectively, around quail use points and throughout the Refuge.

Vegetative Characteristics and Quail Survival at Release Sites

Captive-bred masked bobwhite adults and young were released on several sites on BANWR during 1995-96 (Fig. 2). Vegetation was measured at 4 of these sites during breeding season 1995 (Table 11) and 6 sites during covey season 1995-96 (Table 12). In each table, the sample size (*n*) represents the number of times we located quail or a covey of quail, usually through use of radio telemetry, on or near that site.

During the covey season, most of the release sites appeared to have adequate cover, based on amount of vertical structure or mean visual obstruction as measured by the Robel pole method. The amount of structual cover was comparable, although somewhat lower especially in the higher height categories, to what we measured around quail points during covey seasons in 1994-95 and 1995-96 (Tables 2, 3). Our sample of vegetation points at release sites was much smaller during the breeding season 1995, but the Arivaca site appeared to have the best cover available of all the release sites (Table 11).

We collected information on the fates of 36 masked bobwhites that carried radio transmitters; i.e., we recovered the carcasses or radios, or we lost the signals and could not relocate the birds after searching in the field (Table 13). Of these 36 individuals, 39% (14) died of apparent starvation, complications with release, unknown causes, or other non-predator sources of mortality, 36% (13) were killed by raptors, and 25% (9) were attributed to lost radio signals (this latter group could contain some survivors). Raptor predation appeared to be lowest at the Arivaca site (25% of known mortalities or lost signals) and highest at Campartidero (47%). In addition, mean number of days that we recorded an active signal from quail with radios was highest at Arivaca and lowest at Campartidero (Table 13).

DISCUSSION

Habitat Use by Masked Bobwhites

Masked bobwhites selected sites with greater vegetative structual diversity than what was available throughout the Buenos Aires National Wildlife Refuge. This was most evident when we compared the variables vegetation structure and percent bare ground between quail points and random points.

Vegetation structure can be thought of as the mean visual obstruction around a point, which provides cover from terrestrial and avian predators and helps to create microclimatic conditions, such as decrease ground temperatures and increased humidity, that are favorable to quail in hot and arid areas. The mean visual obstruction for the 4 vegetation height classes showed similar patterns among the 4 seasons (covey seasons in 1994-95 and 1995-96, and breeding seasons in 1995 and 1996). In all 4 seasons, the higher height classes (1 and 2 m) were significantly greater around quail points than random points. The lower height classes (15 and 50 cm) were greater in all seasons except breeding season 1996; this lack of significance could have been due to a smaller sample of both quail and random points during this season (see Table 5).

Masked bobwhites also used sites that had lower percentages of bare ground, and thus were less patchy, than random points during covey season 1994-95. Although there was a consistent trend of less bare ground between quail and random points during other seasons, these differences were not statistically different. Precipitation levels during the first winter of study (i.e., covey season 1994-95) were high; this would have stimulated more plant growth (esp. among forbs and grasses), and quail may have had more opportunity to use sites with higher percentages of vegetative cover and less bare ground than during the remaining 3 seasons, when conditions were much drier. The amount and distribution of annual rainfall is undoubtedly extremely important to habitat conditions, and thus to the survival and persistence of quail (Guthery 1986). Densities of masked bobwhites in Sonora have been much greater after years of moderate to heavy rainfall (G. Camou, pers. comm.)

Woody cover (i.e., stems/ha within 8 m of the sampling point) was also important to masked bobwhites during the breeding seasons, but not during the covey season. This growth form may have provided calling perches for male bobwhites, or may have provided an additional level of security from predators during the breeding season.

Vegetative Composition

We found no strong association for specific species of forbs, grasses, or other forms of vegetation for masked bobwhites during any season. Plant species were used in proportion to their availability on the Refuge. This indicates to us that plant structure is of greater importance to masked bobwhite than the specific species involved. The vegetative structure is certainly of great importance to quail for protection from both predation and unfavorable climatic conditions such as heat and aridity. This does not preclude the importance of specific plant species, such as certain native forbs and grasses, that may provide critical food sources for masked bobwhite adults and young. Our analyses may not have been sensitive enough to pick up these more micro-scale aspects of bobwhite habitat. Nevertheless, masked bobwhites evolved in the native arid grasslands of southern Arizona and Sonora, Mexico, and native species of forbs and grasses are likely very important to their survival and reproductive success, and thus to self-sustaining populations.

Despite the above statements regarding the importance of native plant species, there was some evidence that masked bobwhites showed disproportionate use of areas with higher composition of nonnative than native grasses on BANWR, particularly during covey seasons. This could be because nonnative grasses such as Lehmann lovegrass provided denser stands of cover, and thus more protection and more favorable microclimatic conditions (e.g., warmer microsites during the colder months) during a time of year when temperatures are cool to cold and peak raptor migration occurs. This possibility underscores the importance of cover, rather than a preference for one plant species over another. Lehmann lovegrass may provide adequate cover for quail in some areas of the Refuge.

Habitat at Release Sites

Adequate cover is undoubtedly important to newly released captive-bred quail. Mortality of newly released birds to raptors can be relatively high on BANWR, perhaps up to 50% of released birds in some areas. Although the data we collected at release sites was probably inadequate to examine quantitative aspects of vegetation structure in a rigorous manner, it appears that habitats close to release sites that offer protective cover for newly released quail could improve chances for survival and thus establishment of a self-sustaining population on the Refuge.

MANAGEMENT RECOMMENDATIONS

Adequate cover, provided by proper vegetative structure, is a critical factor in the recovery and establishment of a masked bobwhite population on the Buenos Aires National Wildlife Refuge. We recommend that managers attempt to create the structural components that appear to be most used by quail through directed management activities on specific areas of the Refuge. We encourage the continued use of controlled burning to mimic the natural processes that took place in southeastern Arizona before European settlement as beneficial to the goal of aridland grassland ecosystem restoration and management. Other management techniques (soil disturbance) that have met with success for quail species in other parts of the country, particularly Texas, should be examined and evaluated for their applicability for masked bobwhite management on BANWR.

Further analysis of the vegetation at bobwhite release sites would prove useful for improving the chances of survival and successful reestablishment for masked bobwhites on the Refuge. Areas that show the most favorable conditions, based on higher mean days of survival for radioed birds and lower mortality due to raptor predation, should be made priority release sites. Information on habitat characteristics in this and other reports could be used to evaluate potential release sites. Sites that do not provide adequate cover should not be used for releases.

A program of habitat monitoring for masked bobwhites could be initiated on a site-specific basis. For example, the reestablishment of vegetation after burning and other management techniques could be monitored, on both spatial and temporal scales, so that we may learn more about when sites become suitable as habitat. This information could then be applied in a retrospective fashion on sites where, for example, there is documentation of burn history. Sites that provide adequate cover based on some of the key vegetative characteristics outlined in this report could be monitored for quail use and evaluated as potential release sites. The information in this report should be viewed as a general guideline. Vegetative cover on BANWR, as in many areas, is extremely variable, and it is doubtful that we captured the full range of site characteristics that are beneficial (or not beneficial) to masked bobwhites.

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Table 1. Numbers of masked bobwhite and random points, by season and year, on the Buenos Aires National Wildlife Refuge, southeastern Arizona. Covey seasons ran from October to March and pair formation/breeding (breeding) seasons ran from April to September. Data collection took place during the covey season 1994-95, breeding season 1995, covey season 1995-96, and breeding season 1996. Composition and structure of vegetation were measured at quail (use) and random (available) points and compared under a use-availability framework.

	Biological season and year			
Point	Covey 1994-95	Breeding 1995	Covey 1995-96	Breeding 1996
Quail	61	33	55	6
Random	64	88	34	16

Table 2. Means and pooled standard errors for vegetation structure variables collected at quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona for covey season 1994-1995. Means represent mean ranked scores based on arcsine transformed data.

	Masked bobwhite			Random			
Variable	$\bar{x}$	SE	n	$\bar{x}$	SE	n	*P*
% herbaceous cover	56.73	25.92	61	68.98	25.31	64	0.059
% bare ground	56.80	25.92	61	68.91	25.30	64	0.062
% woody cover	60.05	23.05	51	50.56	21.62	58	0.118
Structure 15 cm	71.85	25.62	61	53.44	25.21	63	0.004
Structure 50 cm	72.29	25.92	61	54.15	25.31	64	0.005
Structure 1 m	56.65	20.39	55	46.66	21.83	48	0.091
Structure 2 m	30.23	9.24	34	21.21	12.36	19	0.041
Woody stem density	70.28	25.54	59	54.37	24.53	64	0.013
No. grasses	42.30	14.06	57	49.81	18.76	32	0.147
No. forbs	40.22	15.36	57	53.52	20.49	32	0.019
Grass richness	58.25	24.75	61	67.53	24.17	64	0.134
Forb richness	67.24	25.85	61	58.96	25.23	64	0.200
Biomass	35.50	13.95	15	25.93	8.44	41	0.052

Table 3. Means and pooled standard errors for vegetation structure variables collected at quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona for covey season 1995-1996. Means represent mean ranked scores based on arcsine transformed data.

	Masked bobwhite			Random			
Variable	$\bar{x}$	SE	n	$\bar{x}$	SE	n	*P*
% herbaceous cover	45.02	15.96	55	44.97	20.30	34	0.993
% bare ground	42.85	15.96	55	48.48	20.30	34	0.317
% woody cover	42.35	14.88	50	40.17	18.60	32	0.686
Structure 15 cm	52.97	15.97	55	32.10	20.31	34	0.001
Structure 50 cm	54.57	16.29	55	31.24	20.42	35	0.001
Structure 1 m	47.66	14.16	53	30.24	19.14	29	0.002
Structure 2 m	41.14	11.66	43	21.21	15.60	24	0.001
Woody stem density	47.75	16.01	53	39.57	19.70	35	0.139
No. grasses	42.94	15.06	53	45.65	18.80	34	0.610
No. forbs	33.66	13.39	44	43.13	16.21	30	0.057
Grass richness	43.53	15.77	55	47.37	20.05	34	0.491
Forb richness	44.05	15.87	55	46.54	20.18	34	0.656
Biomass	30.30	8.14	37	17.13	12.78	15	0.005

Table 4. Means and pooled standard errors for vegetation structure variables collected at quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona for breeding season 1995. Means represent mean ranked scores based on arcsine transformed data.

	Masked bobwhite			Random			
Variable	$\bar{x}$	SE	n	$\bar{x}$	SE	n	*P*
% herbaceous cover	62.32	29.32	33	59.11	18.16	86	0.650
% bare ground	55.92	28.49	31	58.77	17.31	84	0.684
% woody cover	62.55	24.57	30	46.12	15.97	71	0.010
Structure 15 cm	69.95	28.45	33	53.95	17.94	83	0.021
Structure 50 cm	69.50	27.27	33	51.07	17.63	79	0.006
Structure 1 m	58.25	23.26	29	44.28	15.30	67	0.024
Structure 2 m	42.76	15.85	21	29.18	10.83	45	0.007
Woody stem density	58.03	29.44	30	60.00	17.19	88	0.785
No. grasses	66.18	26.80	33	56.91	16.70	85	0.152
No. forbs	63.95	28.53	33	57.77	17.78	85	0.370
Grass richness	55.81	29.27	33	62.28	18.03	87	0.359
Forb richness	58.53	29.28	33	60.56	18.14	86	0.773
Biomass	42.83	21.42	21	43.05	12.27	64	0.972

Table 5. Means and pooled standard errors for vegetation structure variables collected at quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona for breeding season 1996. Means represent mean ranked scores based on arcsine transformed data.

	Masked bobwhite			Random			
Variable	$\bar{x}$	SE	n	$\bar{x}$	SE	n	*P*
% herbaceous cover	3.60	1.50	5	6.00	1.93	3	0.180
% bare ground	12.83	5.54	6	11.00	3.39	16	0.555
% woody cover	18.67	5.46	6	8.81	3.39	16	0.002
Structure 15 cm	12.16	5.53	6	11.25	3.39	16	0.768
Structure 50 cm	13.50	4.95	6	9.21	3.24	14	0.138
Structure 1 m	13.17	4.36	6	7.67	3.08	12	0.039
Structure 2 m	10.58	3.45	6	6.28	2.81	9	0.066
Woody stem density	9.00	5.42	6	12.44	3.32	16	0.259
No. grasses	8.67	5.12	6	12.56	3.14	16	0.175
No. forbs	8.70	2.61	5	4.93	2.20	7	0.059
Grass richness	8.83	5.39	6	12.50	3.30	16	0.226
Forb richness	12.92	5.47	6	10.97	3.35	16	0.526
Biomass	7.00	4.16	2	8.15	1.63	13	0.734

Table 6. Frequency (% of total) of grass species identified around quail and random points during covey season 1995-96 on the Buenos Aires National Wildlife Refuge in southeastern Arizona.

Species	Quail	Random
Eragrostis lehmanniana	59.4	36.4
Eragrostis intermedia	8.7	0.4
Cynodon dactylon	6.3	
Aristida spp.	3.8	7.3
Setaria leucopila	3.7	
Leptochola dubia	3.5	
Digitaria californica	2.7	2.5
Vulpia octoflora	2.6	20.4
Unknown spp.	2.5	
Bouteloua spp.	2.4	1.5
Chloris virgata	1.6	
Eragrostis spp.	0.6	
Bouteloua gracilis	0.6	
Bothriochola barbinodis	0.5	
unknown native grass	0.5	
Hilaria spp.	0.4	15.4
Bromus spp.	0.1	
Bouteloua hirsuta		5.6
Bouteloua chondrosoides		4.0
Bouteloua curtipendula		3.5
Sorghum halepense		3.1

Table 7. Frequency (% of total) of grass species identified around quail and random points during breeding season 1995 on the Buenos Aires National Wildlife Refuge in southeastern Arizona.

Species	Quail	Random
Eragrostis lehmanniana	31.9	33.7
Vulpia octoflora	19.9	36.5
Bouteloua gracilis	6.9	
Bouteloua spp.	6.4	12.5
Eragrostis intermedia	5.9	
Setaria leucopila	5.0	
Bromus spp.	4.6	4.2
Digitaria californica	4.5	3.3
Aristida spp.	3.8	
Bothriochola barbinodis	2.8	0.8
unknown native grass	2.3	4.2
Aristida purpurea	1.8	
Eragrostis spp.	1.2	0.4
Chloris virgata	0.9	
unknown	0.9	4.4
Bouteloua chondrosoides	0.6	
Bouteloua repens	0.4	

Table 8. Frequency (% of total) of grass species identified around quail and random points during breeding season 1996 on the Buenos Aires National Wildlife Refuge in southeastern Arizona.

Species	Quail	Random
Eragrostis lehmanniana	36.2	40.0
unknown native grass	23.1	
Bouteloua spp.	23.1	3.4
Setaria leucopila	7.7	
unknown	2.3	
Aristida spp.		21.0
Digitaria californica		13.3
Bothriochola barbinodis		10.0
Eragrostis spp.		9.0
Panicum obtusum		3.3

Table 9. Frequency (% of total) of shrub species identified around quail and random points during 3 seasons on the Buenos Aires National Wildlife Refuge in southeastern Arizona, 1995-96.

Species	Quail	Random
	Covey season 1995	
Gutierrezia sarothrae	87.8	68.2
Haplopappus tenuisectus	12.2	31.8
	Breeding season 1995	
Gutierrezia sarothrae	85.3	77.5
Haplopappus tenuisectus	11.0	21.3
Baccharis sarothroides		1.3
	Breeding season 1996	
Gutierrezia sarothrae	80.0	79.2
Haplopappus tenuisectus		4.2
Salsola pestifer	20.0	16.7

Table 10. Frequency (% of total) of tree species identified around quail and random points during 3 seasons on the Buenos Aires National Wildlife Refuge in southeastern Arizona, 1995-96.

Species	Quail	Random
	Covey season 1995	
Prosopis juliflora	90.9	91.0
Acacia greggi	4.4	
Gutierrezia sarothrae	1.7	
Rhamnacea spp.	1.0	
Yucca elata	0.6	
Ziziphus obtusifolia	0.5	
Pinus ponderosa	0.5	
Mimosa biuncifera	0.5	
Cercidium spp.		9.0
	Breeding season 1995	
Prosopis juliflora	96.0	95.5
Acacia greggi	3.3	2.2
Rhamnacea spp.	0.7	
Cercidium spp.		2.3
	Breeding season 1996	
Prosopis juliflora	84.3	96.0
Quercus arizonica	9.6	
Celtis laegigata	3.2	
Acacia greggi	2.9	
Cercidium spp.		4.0

Table 11. Vegetative characteristic of sites where captive-raised masked bobwhites were released on the Buenos Aires National Wildlife Refuge in southeastern Arizona during breeding season 1995.

	Release area							
	Secundino (n = 1)		Arivaca (n = 10)		Triangle (n = 8)		Campartidero (n = 1)	
Variable	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Herbaceous cover	3.8	NA	16.3	2.7	7.6	7.0	33.4	NA
Bare ground	3.6	NA	10.8	2.2	13.7	9.3	6.4	NA
Woody cover	40.0	NA	30.5	5.6	13.8	13.8	1.3	NA
Structure 15 cm	38.8	NA	56.0	4.8	29.4	20.6	67.5	NA
Structure 30 cm	33.8	NA	34.1	6.2	15.0	8.7	11.1	NA
Structure 1 m	17.5	NA	22.4	5.9	32.7	31.7	0.4	NA
Structure 2 m	49.4	NA	16.6	3.9	36.9	36.9	0	NA
Woody stem dens.	3.0	NA	6.3	1.2	5.0	5.0	2.0	NA
No. grasses	0	NA	1.0	0.2	1.0	NA	1.0	NA
No. forbs	2.2	NA	1.2	0.2	1.6	0.0	1.6	NA
Native spp.	0	NA	45.8	10.2	50.0	50.0	99.0	NA
Non-native spp.	0	NA	24.2	9.7	0	NA	1.0	NA
Shrub distance	0	NA	2.1	0.6	11.0	NA	0	NA
Tree distance	7.3	NA	6.6	0.7	25.5	14.7	67.5	NA

Table 12. Vegetative characteristic of sites where captive-raised masked bobwhites were released on the Buenos Aires National Wildlife Refuge in southeastern Arizona during covey season 1995-1996.

	Release area											
	Secundino (n = 11)		Arivaca (n = 21)		Round Hill W (n = 1)		Round Hill E (n = 2)		Triangle (n = 8)		Campartidero (n = 5)	
Variable	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Herbaceous cover	24.7	2.6	21.4	2.7	12.0	NA	34.8	9.2	26.0	7.5	9.5	0.9
Bare ground	9.9	1.8	7.6	1.6	0.6	NA	5.2	0.2	9.3	2.7	11.8	3.7
Woody cover	3.8	0.9	6.3	0.9	3.0	NA	1.0	1.0	4.3	1.9	35.8	21.0
Structure 15 cm	69.5	5.7	58.3	3.7	61.3	NA	60.0	20.0	59.5	8.3	49.6	7.9
Structure 30 cm	36.1	6.4	34.5	2.8	21.3	NA	18.2	9.9	14.3	7.8	43.6	6.0
Structure 1 m	17.4	4.1	18.0	2.4	11.9	NA	5.2	2.9	17.0	7.4	41.9	3.7
Structure 2 m	10.2	3.5	16.6	2.7	11.9	NA	8.1	8.1	14.4	7.6	30.8	8.6
Woody stem dens.	3.8	0.9	6.3	0.9	3.0	NA	1.0	1.0	4.3	1.9	35.8	21.0
No. grasses	1.4	0.1	1.1	0.1	0.2	NA	1.7	0.5	1.3	0.2	0.2	0.1
No. forbs	1.2	0.2	1.1	0.2	1.0	NA	1.2	0.2	0.9	0.3	1.5	0.2
Native spp.	18.6	5.4	24.2	7.0	0	NA	100.0	NA	18.1	8.5	24.0	9.8
Non-native spp.	70.6	8.5	60.6	8.5	0	NA	0	NA	57.6	14.8	0	NA
Shrub distance	5.0	1.0	2.5	0.6	0	NA	0	NA	17.2	5.1	0	NA
Tree distance	8.5	1.2	4.0	0.8	5.6	NA	15.1	0.4	15.7	6.1	3.9	1.6

Table 13. Mean number of days between release and mortality or signal loss and fates of captive-reared masked bobwhites fitted with radio telemetry transmitters and released at 5 sites on the Buenos Aires National Wildlife Refuge in southeastern Arizona, 1995-96.

				Mortality/lost signal		
Site	No. birds	$\bar{x}$ days	SE	Miscellan.	Raptor	Lost signal
Secundino	3	24.3	10.7	1	1	1
Arivaca	8	27.0	11.5	2	2	2
Round Hill	8	8.2	2.2	4	3	4
Triangle	2	26.0	23.0	2	0	2
Compartidero	15	4.2	1.1	5	7	5

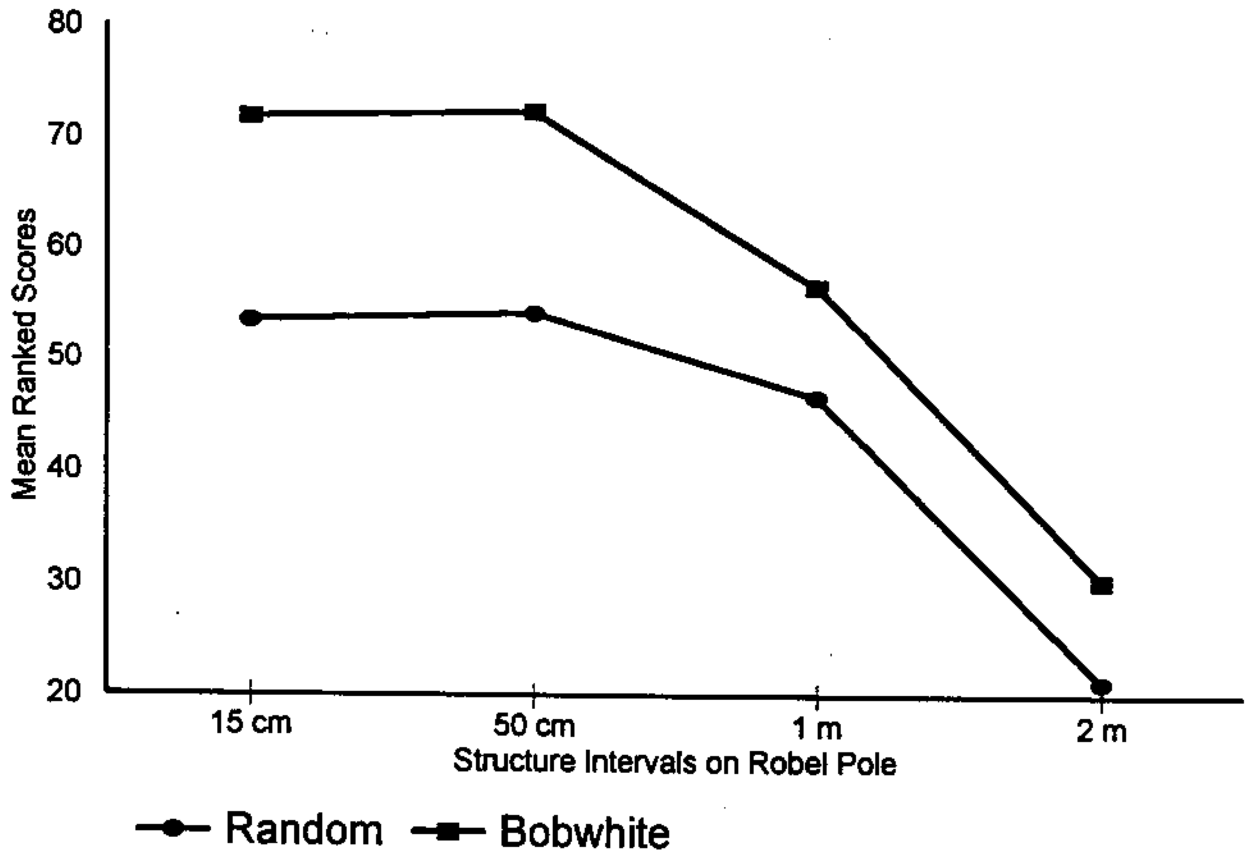

Fig. 3. Vegetation structure or height, based on mean visual obstruction along a Robel pole, for quail and random points during the covey season 1994-95 on the Buenos Aires National Wildlife Refuge in southeastern Arizona. Data are represented as mean ranked scores.

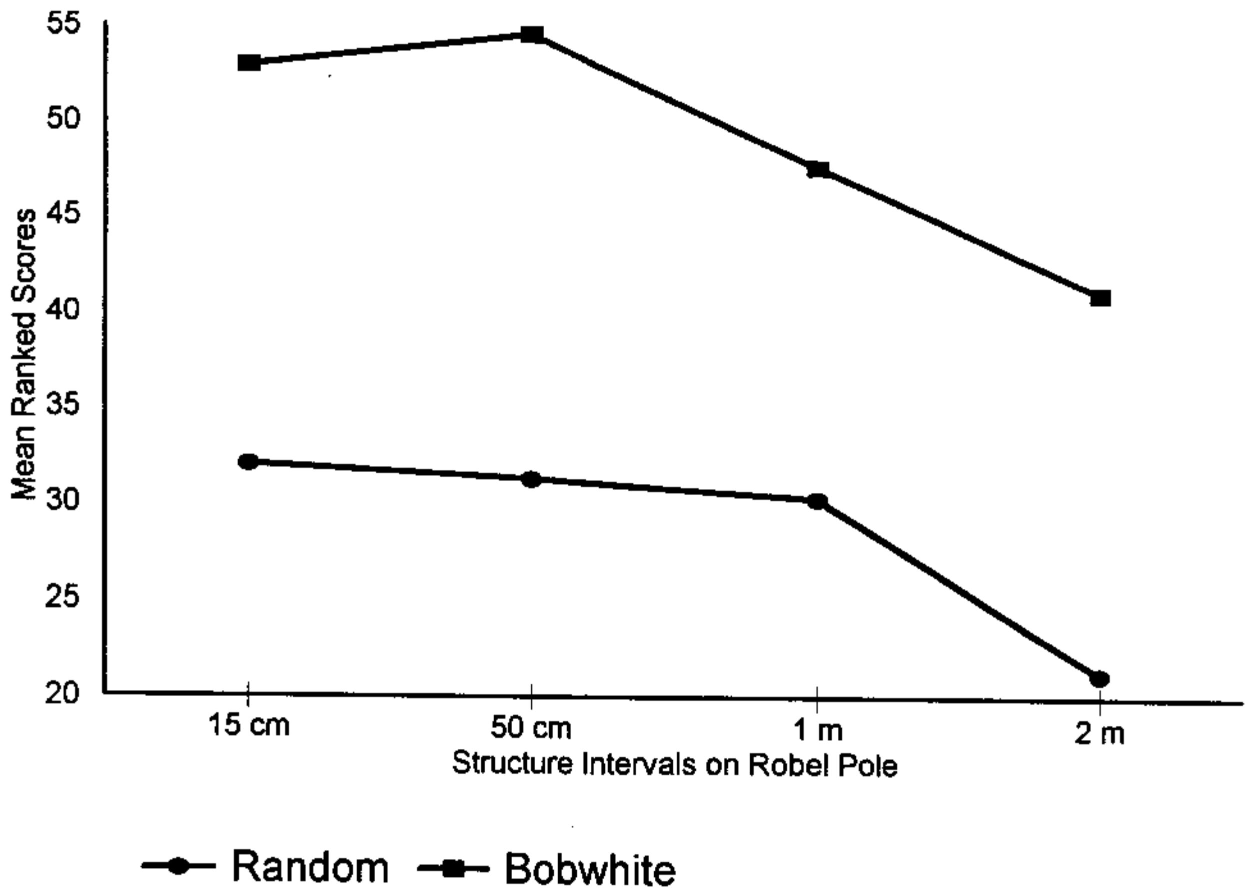

Fig. 4. Vegetation structure or height, based on mean visual obstruction along a Robel pole, for quail and random points during the covey season 1995-96 on the Buenos Aires National Wildlife Refuge in southeastern Arizona. Data are represented as mean ranked scores.

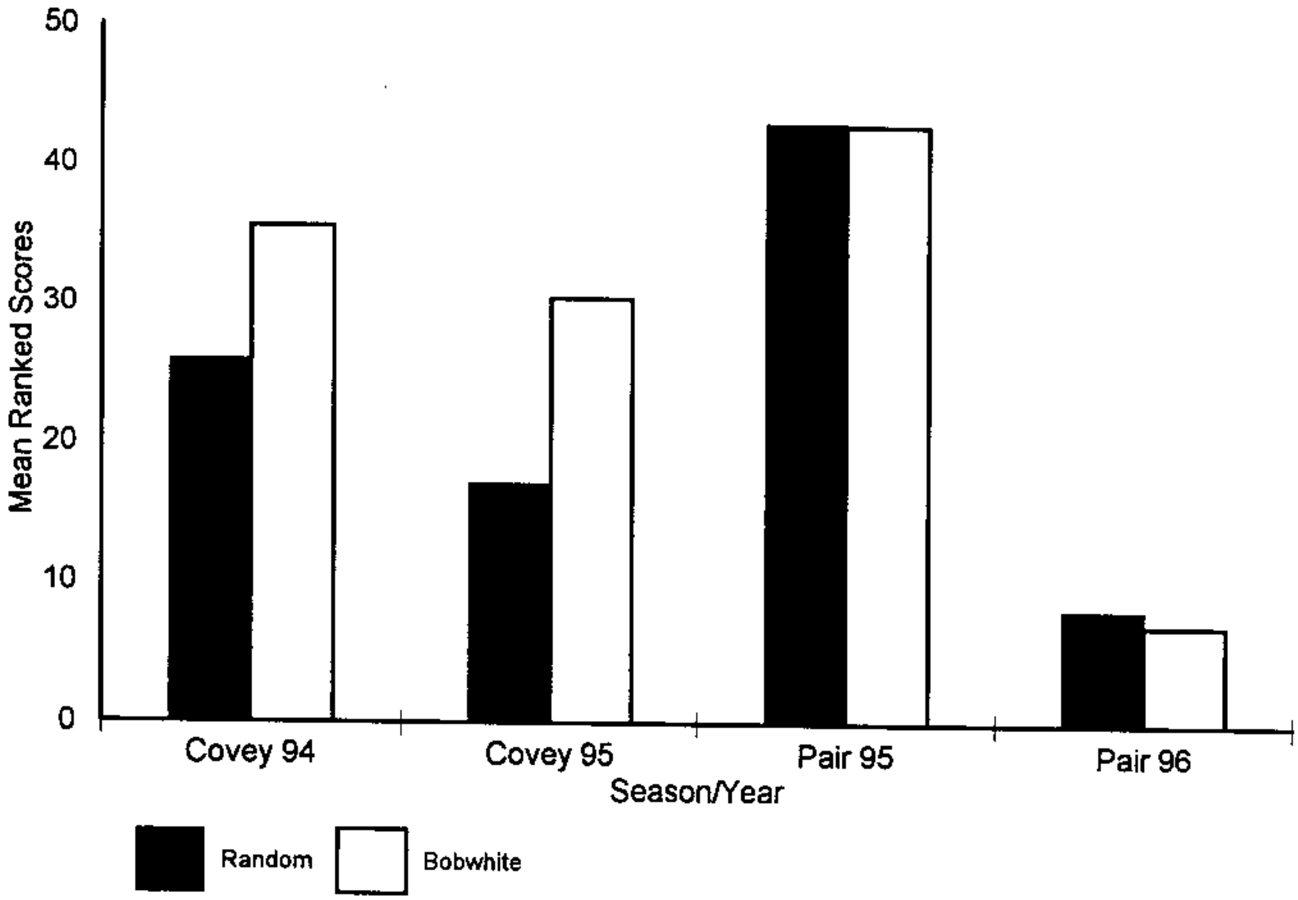

Fig. 5. Vegetation biomass for quail and random points during the covey season 1995-96 on the Buenos Aires National Wildlife Refuge in southeastern Arizona. Data are represented as mean ranked scores.

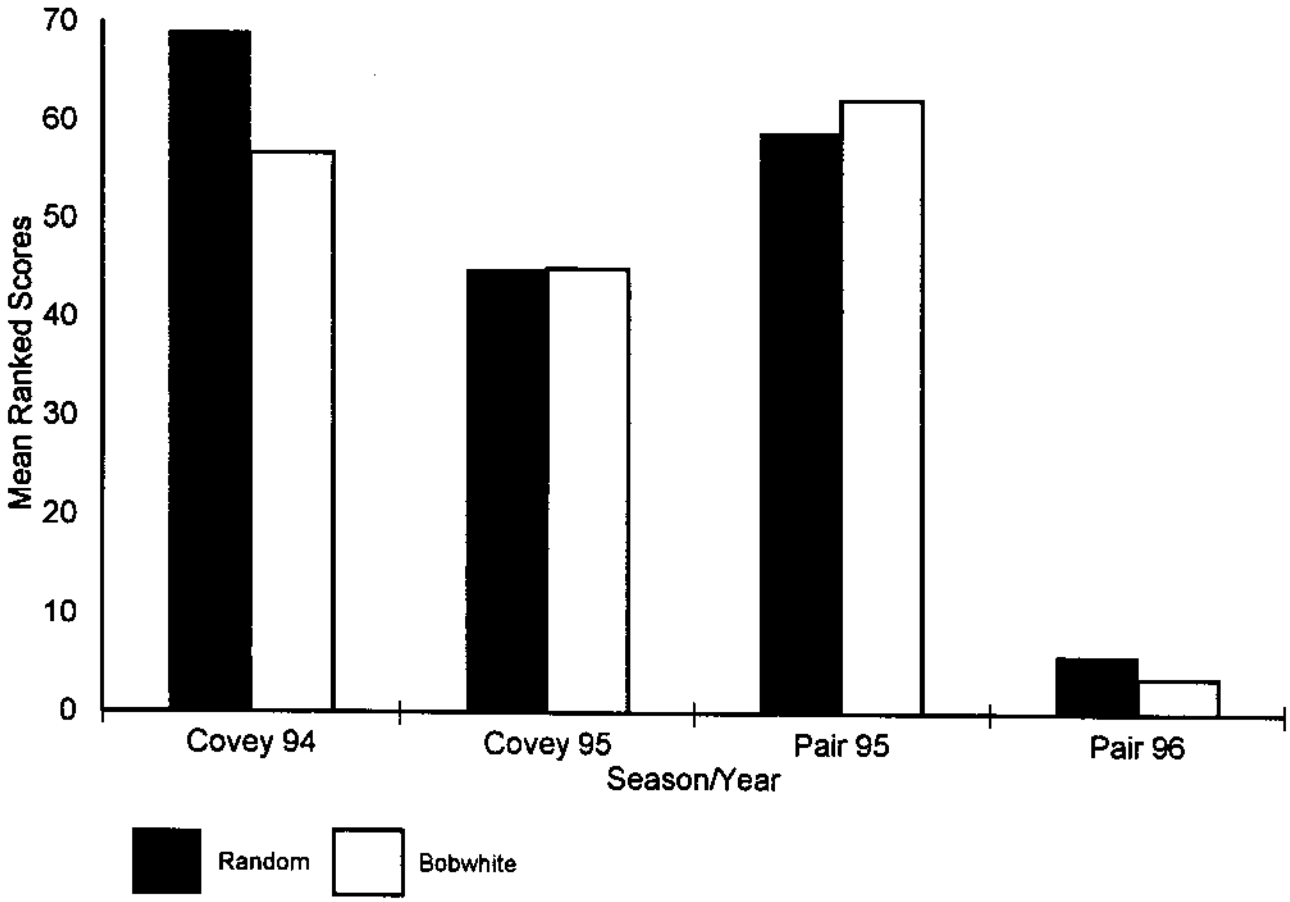

Fig. 6. Percent herbaceous cover measured in 5 Daubenmire frames around quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona during 4 seasons, 1994-96. Data are represented as mean ranked scores.

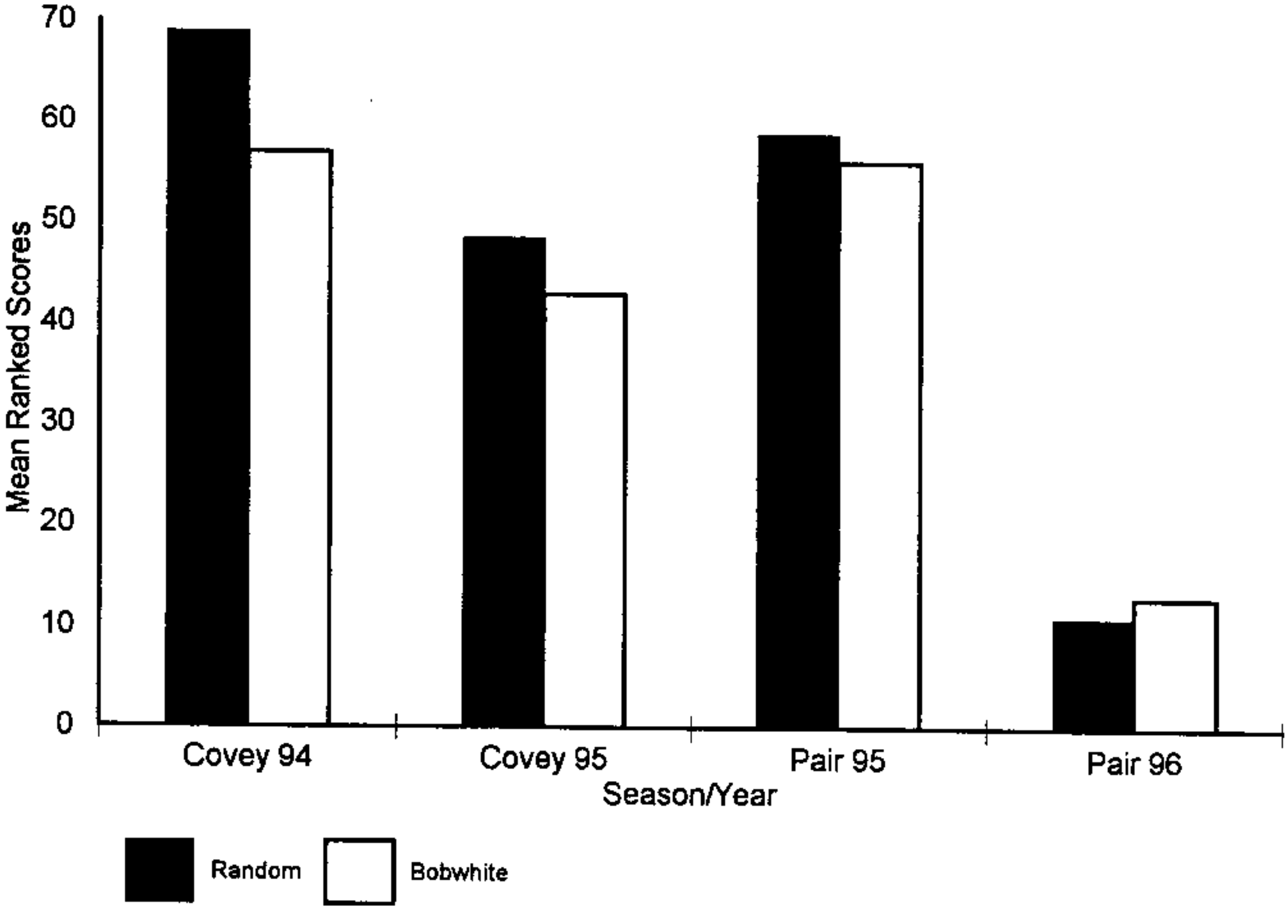

Fig. 7. Percent bare ground measured in 5 Daubenmire frames around quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona during 4 seasons, 1994-96. Data are represented as mean ranked scores.

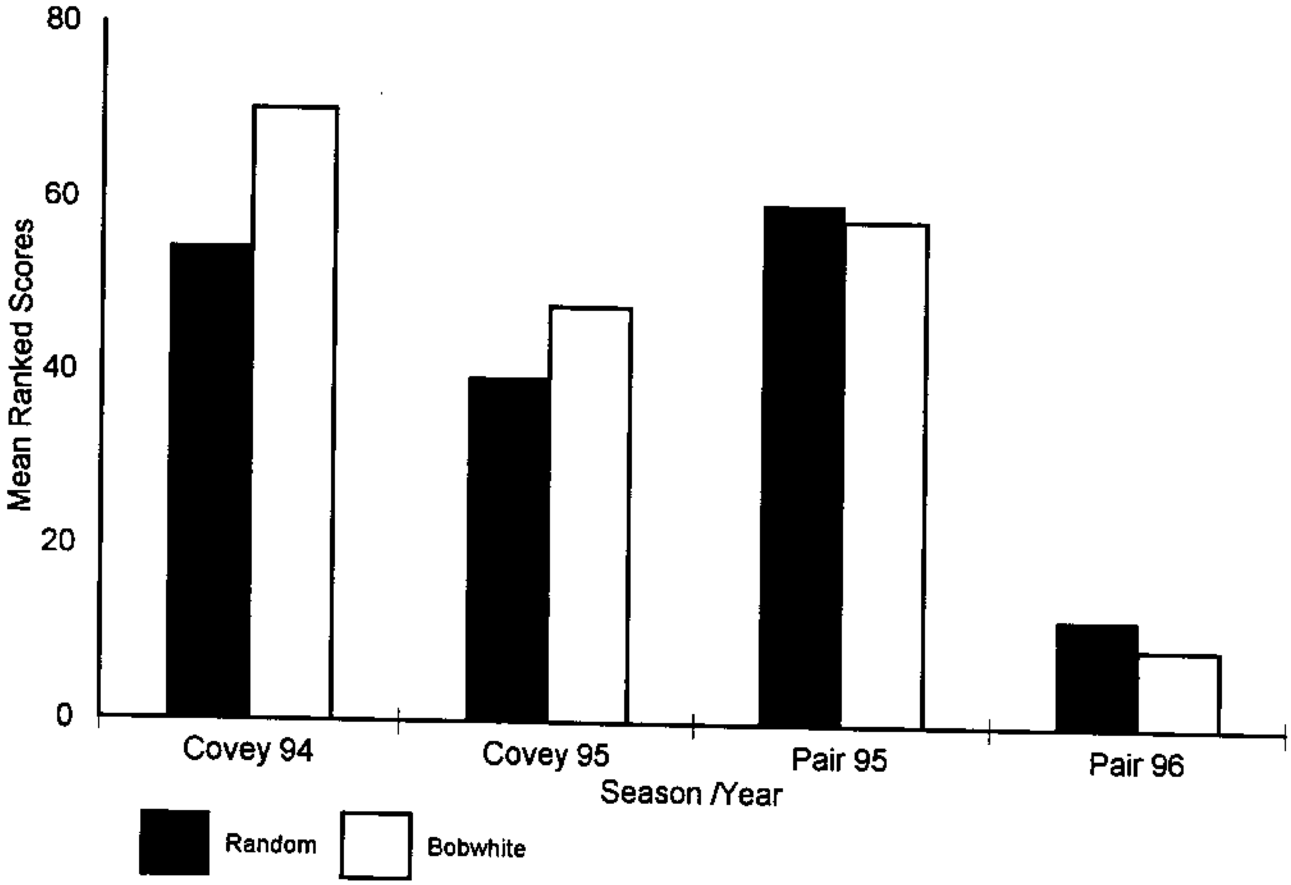

Fig. 8. Density of woody stems measured around quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona during 4 seasons, 1994-96. Data are represented as mean ranked scores.

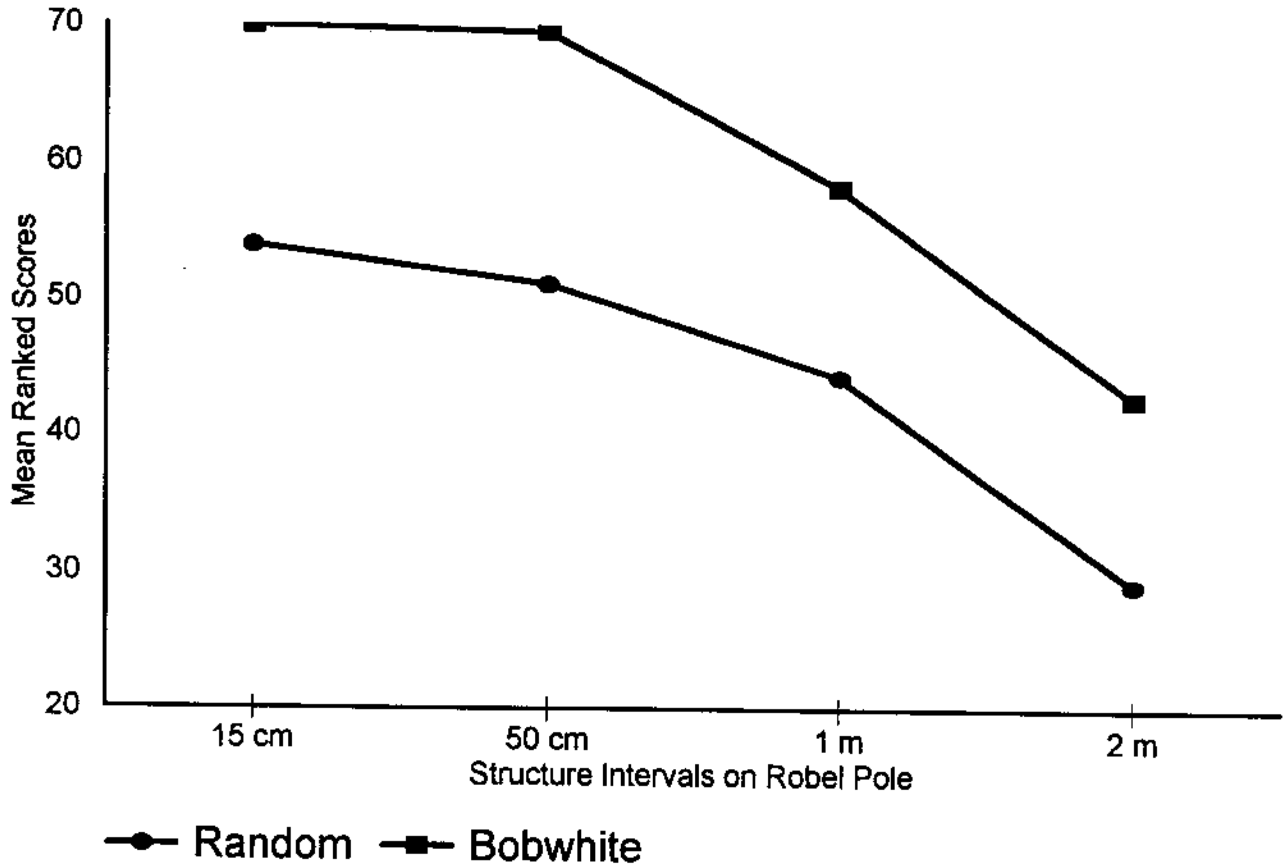

Fig. 9. Vegetation structure or height, based on mean visual obstruction along a Robel pole, for quail and random points during the breeding season 1995 on the Buenos Aires National Wildlife Refuge in southeastern Arizona. Data are represented as mean ranked scores.

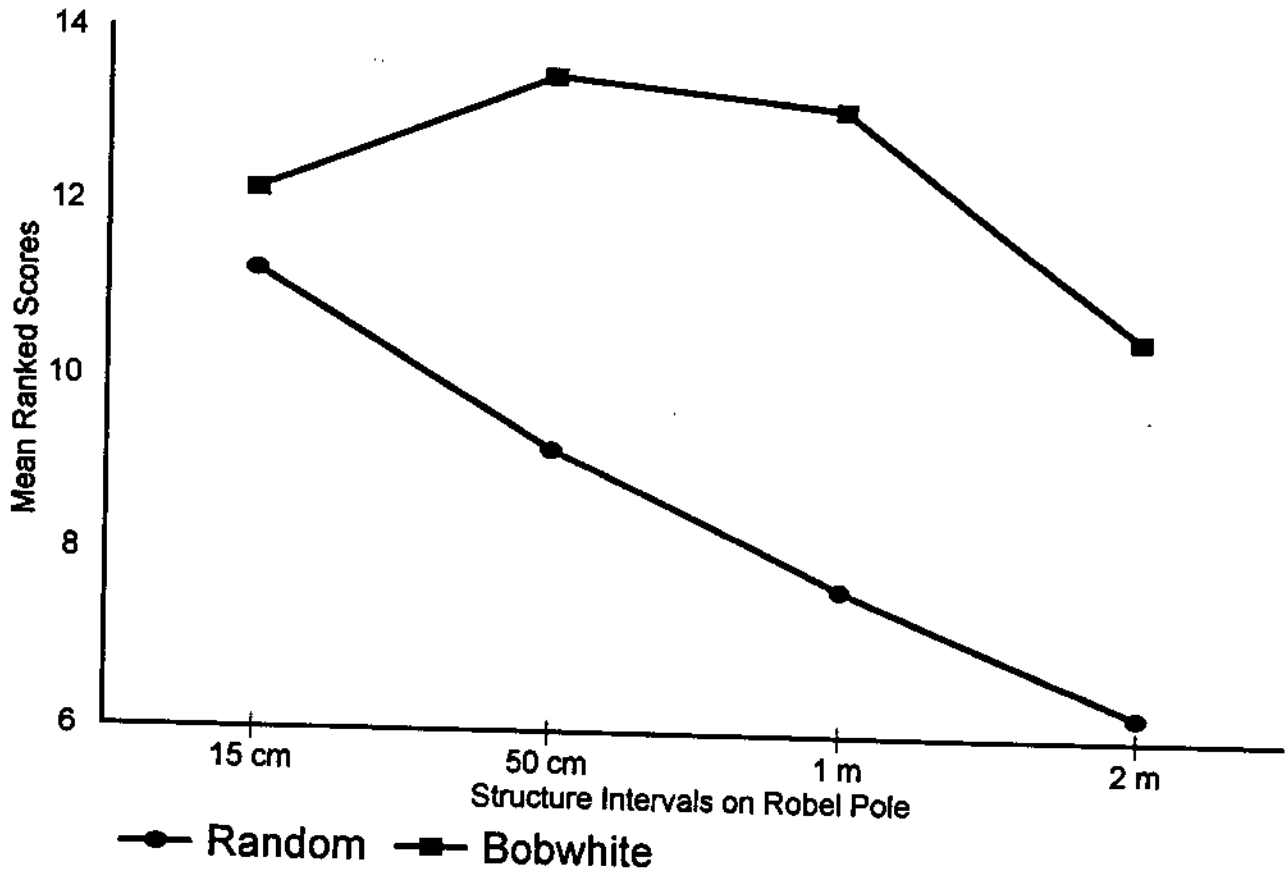

Fig. 10. Vegetation structure or height, based on mean visual obstruction along a Robel pole, for quail and random points during the breeding season 1996 on the Buenos Aires National Wildlife Refuge in southeastern Arizona. Data are represented as mean ranked scores.

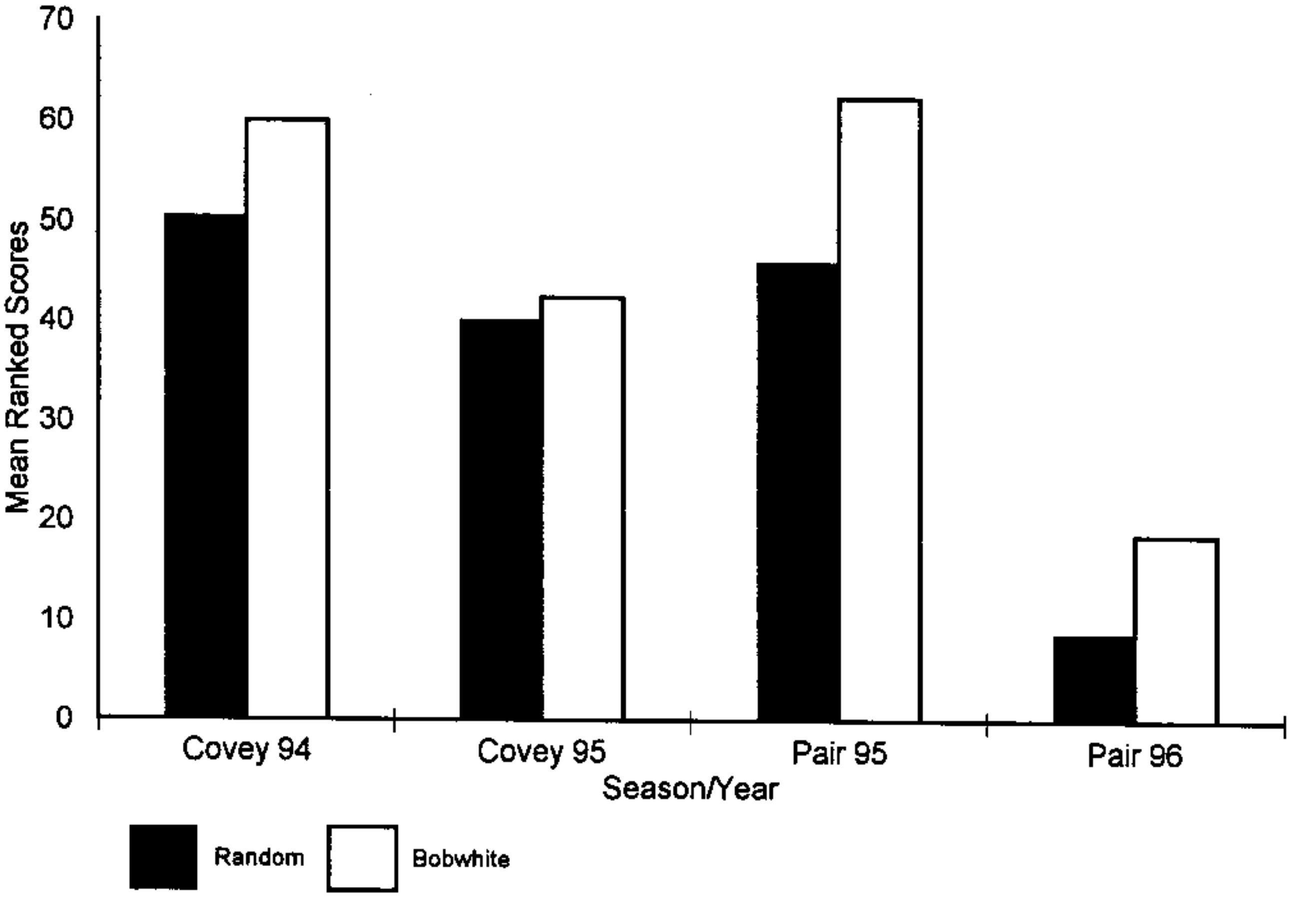

Fig. 11. Percent woody canopy cover at quail and random points on the Buenos Aires National Wildlife Refuge in southeastern Arizona during 4 seasons, 1994-96. Data are represented as mean ranked scores.