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Assessment of Northern Bobwhite Survival and Fitness at Felsenthal National Wildlife Refuge, Arkansas

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Assessment of Northern Bobwhite Survival and Fitness at Felsenthal National Wildlife Refuge, Arkansas

Jacob W. Doggett

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DEDICATION

Dedicated to those who have never given up on their dreams

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BACKGROUND

The northern bobwhite (*Colinus virginianus*); hereafter, bobwhite, is a popular upland game bird associated with the grassland shrub ecosystems of the eastern United States (Stoddard 1931, Brennan 1991, Kozicky 1993, Dimmick et al. 2002). Like other gallinaceous birds, bobwhites are classified as an "r-selected" species (Brennan 1999) which means they rely on early-successional vegetation (Spears et al. 1993) maintained by frequent disturbances such as fire, weather catastrophes, grazing and low intensity agricultural practices (Stoddard 1931, Ellis et al.1969, Rosene 1969, Wilkens and Swank 1992, Brennan et al. 1998). Bobwhites are also dependent on the ability to disperse between suitable habitats across the landscape (Harrison 1991, Roseberry 1993, Fies et al. 2002). In particularly, the native habitat bobwhites historically occupied likely supported the mobility required to seek out naturally disturbed areas (Roseberry 1993). Because of this unique life history, bobwhites are particularly vulnerable to maturing ecosystems (Roseberry et al. 1979). Unless proper habitat is maintained, bobwhites can disappear as quickly as they colonize (Roseberry et al. 1979, Burger 2002).

In the late 1800's and early 1900's, early land use practices increased the amount of suitable habitat across the landscape and therefore bobwhite abundance (Dimmick et al. (2002). Landscapes were comprised of small scale agricultural operations and older forests, intermixed with idle fields and small forest clearings (Stoddard 1931, Rosene 1969, Burger 2002, Dimmick et al. 2002). Habitat was characterized by small fields, weedy fencerows, fallow fields, recently burned forests and grass patches that provided suitable nesting cover (Stoddard 1931, Kabat and Thompson 1963, Dimmick 2002). Over large areas, these landscapes likely enhanced dispersal and consequently bobwhite abundance (Brennan 1991, Roseberry 1993, White et al. 2005, NBCI 2011). Such dynamics illustrate how bobwhites can thrive under appropriate land use practices, but they also illuminate the opposite effects seen when specific quality habitat components become limited (Ellis et al.1969, Kozicky 1993, Burger 2002, Brennan and Kuvlesky 2005).

Today, bobwhites are experiencing imperiling declines across much of their range (Brennan 1991, Dimmick et al. 2002). Results from the 2010 National Breeding Bird Survey, indicate nationwide bobwhites have declined 3.8% annually since 1966 (Sauer et al. 2011). Declines have been linked with large-scale, landscape-level changes in land-use associated with intensified agricultural and silvicultural practices, increased urbanization, and offset predator population dynamics (Roseberry and Klimstra 1984, Brennan 1991, Guthery et al. 2000, Veech 2006, Rollins and Carroll 2001). Modern day practices have increased field sizes, removed fencerows, eliminated prescribed fire and replaced mature mixed forests with intensively managed monocultures of pine (Lagner 1985, Helsinki 2000, Burger 2002, Jones et al. 2010). As a result, many local and regional populations have suffered a downward trend (Dimmick et al. 2002, Brennan and Kuvlesky 2005). Because bobwhite hunting represents a century old tradition and generates economic impacts for many local areas (Burger et al. 1999, Burger 2002), declining bobwhite numbers have become a major concern for hunters and conservation advocates alike (Stoddard 1931, Roseberry 1993, Brennan 1999, Brennan and Kuvlesky 2005).

At present time, bobwhites are likely one of the best studied avian species in the world and research has uncovered a tremendous understanding of their life history, demographics (Sandercock et al. 2008, Folk et al. 2007), habitat requirements (Stoddard 1931, Rosene 1969, Roseberry and Klimstra 1984, Guthery 2006) and management practices (Guthery 1997, Guthery 2000, Williams et al. 2004, NBCI 2011). The enormous amount of literature generated over the last 40 years has allowed biologists and managers to create nation-wide conservation initiatives (Dimmick et al. 2002, NBCI 2011), grass-root conservation organizations, and educational programs (Rollins et al. 2000). These initiatives have been successful at coordinating management strategies between states, researchers and within federal policy, but since range-wide declines are associated with large-scale changes in landuse, many of these practices come up short (NBCI 2011). Economic trade-offs between land management practices (Burger et al. 1999, Huang 2008) as well as increasing commodity prices for crop and timber products- do not always result in proper management for bobwhites (Huang 2008). Therefore the loss of quality habitat leads to smaller and smaller populations of bobwhites (Twedt 2005, Roseberry 1993), negatively affects hunter constituency, and in turn, results in economic loss for both rural communities and state wildlife agencies (Wallace et al. 1991, Burger et al. 1999, Burger 2001). Without lands set aside for conservation, bobwhites would quickly become extirpated across large portions of their range (Dimmick et al. 2002, NBTC 2011).

Lands set aside for conservation are becoming increasingly more important for bobwhite recovery (Dimmick et al. 2002, NBCI 2011). Aside from providing high recovery potential, focusing management goals on conservation areas is a cost–effective strategy for maintaining the healthy bobwhite populations needed to rejuvenate local support from sportsmen (Burger 2001), landowners, and educational groups (NBCI

2011). Examples of conservation areas include state- and federally–owned lands such as public use wildlife management areas (Hunter et al. 1994, U.S. Dep. Agric, For. Serv. 1993, Reed et al. 1988), state and national wildlife refuges, and private lands that have potential to become enrolled in government farm bill programs like the Conservation Reserve Program (CRP) (Johnson et al. 2000, White et al. 2005, Blank et al. 2013). Bobwhites tend to thrive on state and federal lands managed for openings, edges and early successional vegetation (Bowman et al. 1999, Cram et al. 2002); however, not all public lands are managed specifically for bobwhites. Many state and federally managed lands in bobwhite range do not specifically manage for bobwhites (Ellis 1972). Rather, some lands may be managed for a specific species or guilds of species requiring very similar habitats (Wilson et al. 1995, Cram et al. 2002, Masters et al. 2002, Wood et al. 2004). Such species are labeled umbrella species and though many species like the bobwhite will thrive under management for umbrella species (Cram et al. 2002, Wood et al. 2004), the management conducted may not directly provide all of the requirements for bobwhite (Burke et al. 2008). In terms of reversing the trends throughout bobwhite range, these areas are becoming increasingly more important to bobwhite research (Cram et al. 2002, Wood et al. 2004). Therefore, lands set aside for wildlife conservation are critical for maintaining source populations (Hunter et al. 1994, NBCI 2011) and can provide a safety net for preventing local extinctions (Guthery et al. 2000, Twedt et al. 2007).

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ABSTRACT

In the West Gulf Coastal Plains (WGCP) northern bobwhite (*Colinus virginianus)* numbers are declining faster than range-wide averages and such declines have been linked to the consequences of land management within the region. Management for the endangered red-cockaded woodpecker (*Picoides borealis*) has benefitted northern bobwhite by restoring mature pine-grassland ecosystems in some areas of the region; however, at Felsenthal National Wildlife Refuge, Crossett, Arkansas, USA, the bobwhite population was not increasing despite the availability of seemingly suitable habitat from management for the endangered species. To understand factors that may be affecting bobwhite survival on Felsenthal National Wildlife Refuge I conducted a telemetry study and assessed summer survival, brood survival, and nest success during 1 April – 11 August in 2013 and 1 April – 15 August in 2014. I also calculated homerange sizes and measured microhabitat characteristics around nests. Summer survival rates were 71% (SE=0.17) and 47% (SE=0.14); while nest success was 47% (SE=0.02) and 100% for 2013 and 2014, respectively. Between years, both 95% and 50% kernel homeranges were not significantly different (pooled, 63.92±6.07 ha and 14.94±1.75 ha); however minimum convex polygon home-range sizes were (113.8 ± 20.1 ha in 2013; and 393.1 ± 49.0 ha in 2014, $P < 0.001$). Only numerical differences in microhabitat vegetation characteristics of nest sites and non- nest sites were observed. I suggest management for red-cockaded woodpeckers supports bobwhite populations but only as a buffer against more severe declines. Since bobwhites are declining range-wide, I believe areas federally managed for red-cockaded woodpeckers will become increasingly more important for sustaining regional bobwhite population levels.

INTRODUCTION

In the West Gulf Coastal Plains (WGCP), an ecoregion covering parts of Louisiana, Arkansas, Texas and Oklahoma, bobwhites are experiencing declines steeper than range-wide averages (Dimmick et al. 2002, Twedt et al. 2007). In 2010, the Breeding Bird Survey (BBS) showed regional indices had declined 5.2% annually since the 1960s (Sauer et al. 2010). Restoration in the WGCP is constrained by industrial/corporate ownership of forestlands, past introduction of sod-forming grasses, and private land ownership patterns that are fragmented into small parcels (NBTC 2011). In their 2011 report, the Northern Bobwhite Technical Committee (NBTC; 2011) suggested the best opportunities for restoring bobwhite populations in the WGCP include pine and oak savanna restoration, increased use of prescribed fire, restoration of warm season grasses, and improved management of existing conservation lands.

Many state and federally–owned lands occur throughout the WGCP; however, not all of them are managed specifically for bobwhites. Several of the national wildlife refuges and forests in the WGCP are managed for red-cockaded woodpeckers (*Picoides borealis*; hereafter RCW, USFWS 1985); a federally endangered species endemic to the mature pine ecosystems of the southeastern United States (USFWS 1970, Jackson 1994). Lands under RCW management are important because management for RCWs is designed to restore mature pine-grassland ecosystems (USFWS 1985) and has been reported to benefit early successional species like RCW and northern bobwhite (Lucas 1992, Brennan 1998, White et al. 1999, Hunter et al. 2001). Chamberlain and Burger (2005) suggested that connecting isolated patches of suitable habitat through RCW management practices could lead to increased bobwhite abundance and regional population stability; thus where RCW management is occurring, bobwhite populations could potentially be conserved. Several conservation areas across the WGCP, support populations of bobwhites (Cram et al. 2002, Liu et al. 2002, Burke et al. 2008); however, not all of these populations are growing (see Burke et al. 2008).

In southeast Arkansas, Felsenthal National Wildlife Refuge, hereafter Felsenthal NWR, reported declining bobwhite populations despite seemingly ideal habitat conditions. Mention of decline on Felsenthal was surprising because bobwhites are considered a species of concern under the management actions appropriated for RCW (USFWS 2010) and such management is known to benefit them. Management practices conducted at Felsenthal NWR are not specifically tailored for bobwhites; however, the refuge can indirectly support populations of bobwhites in areas managed for RCW (Chamberlain and Burger 2005). If RCW management indeed benefits bobwhites, management for RCW may not only provide refuge for declining populations; but also, restrictions resulting from the legal ramifications of land stewardship responsibilities for RCW could become more easily accepted when the popular upland game bird species is also supported (Brennan 1991). Thus, evidence suggesting bobwhites are not responding to RCW management on Felsenthal NWR warranted an investigation.

For bobwhites, site specific, descriptive data on survival and mortality are generally prerequisite for the development of sound management strategies (Cox et al. 2004). In declining populations of bobwhites, survival comprises the greatest contribution to variation in rates of population change (Folk et al. 2007, Sandercock et al. 2008). Specifically, summer survival, nest success and chick survival are important metrics to understand bobwhite population dynamics (Klimstra and Roseberry 1975, Folk et al. 2007, Rollins et al.2010). In addition to fecundity and nest success, bobwhites require a unique subset of habitat characteristics to thrive. The most important characteristics are those required for nesting and brood rearing (Burger et al. 1995, Puckett et al. 1997, Dimmick et al. 2002). The overarching goals of the project were to understand the current status of the bobwhite population at Felsenthal NWR in response to management practices for RCW, and understand specific vegetation structure and composition contributing to nest success. My specific objectives were to 1) quantify northern bobwhite survival rates during the nesting and brood-rearing periods; 2) quantify vegetation conditions associated with bobwhite nest success; and 3) identify other potential factors contributing to declines in southern Arkansas. Understanding bobwhite population dynamics at Felsenthal NWR is not only useful for managing bobwhites and RCW together, it also may enhance understanding of the current population dynamics in the West Gulf Coastal Plains – an area where research is lacking and bobwhite declines have been reported as severe.

STUDY AREA

Felsenthal NWR lies across portions of Ashley, Bradley and Union Counties (33°7'52.4437"N, 92°11'26.3253"W) in southeastern Arkansas. The refuge comprises approximately 16,000 ha of bottomland hardwood forests, 4,000 ha of upland forest and a fluctuating 6,000 to 14,000-ha lock and dam-controlled reservoir. Land use surrounding the refuge has been heavily managed for timber production including pulpwood, poles and saw logs (USDA 2010); soil types in the upland areas range from Una silty clay loam to Guyton loam (USFWS 2010*b*). The area I choose for the assessment represented the largest spatially distinct upland area on Felsenthal NWR and comprised approximately

60% of the upland area on the refuge and 10% of Felsenthal NWR's total area (approximately 3,100 ha, Figure 1). The study area was dominated by loblolly pine (*Pinus taeda*) intermixed with white oak (*Quercus alba),* post oak (*Quercus stellata*), southern red oak (*Quercus falcata*), cherry bark oak (*Quercus pagoda),* common persimmon (*Diospyros virginiana*), and sweet gum (*Liquidambar styraciflua*). Hardwood canopy cover in areas managed specifically for RCW represented < 30% overall composition. Management consisted of prescribed burns every 3–5 years, even-aged timber management (100-year rotation), and single tree harvests to attain a basal area between 13.7–16.1 m^2/ha (Bill Burchfield, U.S. Fish and Wildlife Service, personal communication, Weil 2012). Understory plant communities included a variety of woody and herbaceous species. Woody species included dewberry (*Rubus* spp.), deerberry (*Vaccinium angustifolium*), greenbrier (*Smilax* spp.), American beauty berry (*Callicarpa americana*), and smooth sumac (*Rhus glabra*). Common graminoids were slender wood oats (*Chasmanthium laxum*), indian wood oats (*Chasmanthium latifolium*), broomsedge bluestem (*Andropogon virginicus*), switchgrass (*Panicum virgatum*), and various sedges (Family Cyperaceae).

I chose the area because of its potential for holding sufficient bobwhite numbers to conduct the study. Weil (2012) created a habitat suitability model that described the area as having distinct spatial patterns of low to medium–density pine as well as grass components that predicted the highest chances for bobwhite presence on the refuge. In addition, reports and observations by both Weil (2012) and refuge staff suggested the area supported several coveys which we would be able to monitor (Rick Eastridge, U.S.

Fish and Wildlife Service, personal communication). Based on the management practices for RCW, these upland areas were thought to be suitable for bobwhite as well.

METHODS

Trapping

In order to find nests and assess survival on Felsenthal NWR, I trapped wild bobwhites continuously from March through August in 2013 and from March through May in 2014 using baited funnel traps (checked ≥ 2 times daily) and mist nets (Figure 2). Mist nets were deployed in two different fashions to either, call in individuals using audio and decoy lures, or to opportunistically capture individuals whose location was already known (Wiley et al. 2012). Captured birds were banded with two aluminum leg bands and fitted with 6.5-g pendulum style radio-transmitters equipped with 14-hr mortality censors (American Wildlife Enterprises, Monticello, FL). During primary capture events, I recorded each individual's sex, age, weight and condition and fitted them with transmitters if they were in visually good condition and weighed ≥ 130 g (Tehrune et al. 2007). All birds captured together were released together from their capture location. All of my capture, handling and release methods were approved by the Institutional Animal Care and Use Committee through Grand Valley State University (Project # 12-06-A), Arkansas Game and Fish Commission (AGFC Code 15-30), and the U.S. Fish and Wildlife Service.

To improve trapping success in 2014, I released 60 radio-marked, pen-reared northern bobwhite in addition to normal trapping efforts in the month of March. Research suggested that during large releases of pen-reared bobwhites, resident wild bobwhites would occasionally be attracted to the area (Roseberry et al. 1987, DeVos and

Speake 1995). Pen-reared birds were purchased and transported from Ozark Quail Farms (Republic, MO) and consisted of an equal sex ratio of 13–16-wk old flight-capable individuals. Prior to release, all pen-reared quail were kept in an approximately 9.29-m^2 holding pen covered in 2.54-cm nylon mesh and fed a mixture of game starter, cracked corn, milo and wheat. Because of the coordination involved with processing (i.e., banding, weighing, and transmitter fixing) as well as releasing pen-reared bobwhites, I randomly selected individuals that were acclimated to transmitters for a range of (1–20 days) before being released. I released all of the pen-reared bobwhites in groups of 6–9 individuals (9 groups) and varied group composition by sex ratio, age ratio, and transmitter acclimation. I chose release sites containing an arbitrarily high probability of holding wild bobwhites while at same time providing suitable cover. All of these sites were scattered with 0.45–2.27 kg of feed prior to release and monitored for approximately 30-min post release. Once radio-marked pen-reared quail were released, I tracked them via telemetry almost daily and made efforts to visually observe the group from approximately 10-m during each visit (Figure 5).

Tracking

In both 2013 and 2014, I used a procedure different from that of the pen-reared bobwhites, to track wild radio-marked individuals. Rather than visually observing wild bobwhites, I tracked all marked birds ≥ 5 times per week via the homing method (White and Garrot 1990). The homing method consists of approaching marked birds to a distance between 10–50 m and then circling the individual to accurately estimate its location. I estimated each individual's daily location using a 2-step protocol whereby I recorded the Universal Transverse Mercator (UTM) coordinates from a Garmin GPSMap

62sc Global Positioning System (GPS) receiver (Garmin GPS, Garmin International, Inc., Olathe, KS) at the observers' position, and then measured the azimuth and estimated distance to the radio-marked individuals (Figure 3). I also recorded date, and time. During each observation, I made every effort to minimize flushing radio-marked individuals except when it was useful to identify unmarked individuals with radio-marked bobwhite. When mortality signals were triggered I approached the location to investigate cause of death. In instances where marked birds were found dead, I assessed the cause of mortality based on transmitter damage, remains, and physical evidence at the site (Curtis et al. 1988, Dumke and Pils 1973).

When bobwhites were tracked to the same location ≥ 2 consecutive days during the nesting season I assumed that there was a nest present (Taylor et al. 1999, Lusk et al. 2006). I noted potential nest locations and visited them immediately the next day to confirm the location and presence of the marked bird. Potential nest sites were investigated only when the bird was determined to be temporarily away (Ellis-Felege et al. 2012); and since bobwhites typically do not spend much time at the nest until the onset of incubation, I assumed the parent's daily presence on the nest marked the end of the egg laying period and beginning of incubation (Klimstra and Roseberry 1975, Burger et al. 1995, Potter et al. 2011). When visiting nests for the first time, I installed either one or two motion-activated cameras at the site (Primos Ultra-blackout Truth Cam). In the event of a failed nest, these cameras allowed identification of the cause, and date and time of failure. I placed all cameras between 1-m and 5-m away from the nest and camouflaged them to avoid attracting predators (Staller et al. 2005).

To accurately record nest success, I tracked incubating adults to the nest daily. During this time, I made visual observations of the nest only when the nest was suspected to have been predated, or to exchange batteries and SD cards. Routine camera maintenance was necessary about every two to four days, but was only completed when the incubating adult was temporarily away. During visits to the nest sites, I wore rubber boots and gloves to avoid leaving scent that might attract potential predators. I documented nests as active, successful or failed. I visited hatched nests only when telemetry indicated the adult and brood were away from the nest >50 m and documented nests as successful if the incubating adult remained at the nest throughout the incubation period and hatched ≥1 egg. During occasions when the incubating adult did not remain at the nest and/or in which ≥1 egg was predated, I documented these nests as abandoned or failed respectively. When nests were predated, I recorded the predator species responsible for the nest predation based on camera photos as well as the diagnostic guidelines described by Fies and Puckett (1999) and Staller et al. (2005).

To monitor brood survival, I tracked brooding parents daily and to within 50 meters. Since bobwhite chicks are unable to fly until 14 days of age (Stoddard 1931), I did not flush chicks until 14 days after they hatched. In addition, I conducted follow-up flushes at 21, 28, 35 and 42 days post-hatch, respectively (DeMaso et al. 1997). Because bobwhite chicks typically become independent between 21 and 42 days post hatch and brooding parents are known to abandon chicks during this time as well (Burger et al. 1995), these procedures allowed me to record the number surviving until brooding was complete.

Vegetation

For our microhabitat sampling, I measured microhabitat characteristics at nest sites within one week after the nest had been vacated to avoid creating negative consequences for the brood. For every nest plot I also sampled one equally sized non-nest plot within a randomly chosen distance between 0 m and 200 m away and in a random direction using. Sampling vegetation at random points allowed for vegetation at the nest site to be compared with available vegetation conditions throughout the rest of the study area (Lusk et al. 2006, Radar et al. 2007). For each plot, I described vegetation characteristics by percent ground coverage, horizontal ground cover density (i.e. vertical structure), tree basal area, stem density, tallest vegetation height over the nest and percent overstory tree canopy cover. Plot sizes measured 0.04 ha in area and established using a11.28-m radius circle.

To estimate percent ground coverage at each location I took 13 visual estimates from a 1-m^2 quadrat. Readings were taken over the nest and also 1.5, 3.5 and 5.5 m from the nest in each of the four cardinal directions. I based these measurements off of Daubenmire’s (1959) midpoint values which consisted of categorizing cover types into five coverage classes to estimate the categorical frequency and composition of available vegetation (Daubenmire 1959). For each of these measurements, I chose the categories: graminoids, forbs, bare ground, litter and woody vegetation because they are critical components for bobwhite nesting habitat (Stoddard 1931, Schroeder 1985, Wilkins and Swank 1992, Taylor et al 1999b). Each percent ground coverage measurement was visually estimated from height of approximately 1.37 m above the ground.

To assess nest cover suitability, I measured horizontal ground cover density using a vertical profile cloth sheet with a 10-cm grid, 1-m wide by 2-m tall. I recorded measurements from heights of 15.24 cm and 137.16 cm above the nest with the grid at a distance of seven meters away from the nest in each of the four cardinal directions. I quantified nest concealment and vertical structure by taking the percentage of cells per grid (i.e., 200) containing vegetation structure from each location and averaging the four readings in each plot. To measure percent overstory canopy cover, I took digital pictures at 15.24 cm above the ground directly over the nest or plot center depending on plot type. These pictures were then uploaded into the image software program Image J (Rasband 1997–2012; U. S. National Institutes of Health, Bethesda, Maryland, USA) and converted to a binary color format. From this format I calculated canopy cover percentage values by calculating the ratio of black to white pixels within the image.

For overstory basal area measurements, I used a breakpoint DBH (diameter at breast height) of 2.54 cm and defined saplings as trees less than the breakpoint diameter but taller than 1.37 m. Seedlings were defined as those trees less than 1.37 m in height. Within each plot, I identified all trees greater than the breakpoint diameter by species and measured their circumference to calculate the basal area of the plot. For stem density measurements, I counted all sapling stems within the 11.28-m radius plot, and seedlings only within a 3.54-m radius plot (Keane 2006). I classified each sapling and seedling as either pine or hardwood species (see Table 1 for definitions of microhabitat measurements).

Analysis

To calculate summer survival and nest success I used two different analyses. For summer season survival estimates, I used the Kaplan-Meier staggered entry method (Kaplan and Meier 1958, Polluck et al. 1989b) followed by a log rank test to check for differences between years. In both years, I extrapolated the rates to reflect a longer, more typical breeding season (i.e., 183-d; Guthery and Lusk 2004, Sandercock et al. 2008). The Kaplan-Meier staggered entry method allows for captured bobwhites to be entered over an extended period of time as well as the data from censored individuals to be used for more accurate estimates. The method requires fairly easy-to-follow assumptions including random sampling procedures, independent fates, accurate mortality times, homogeneity of survival, attainable consistent locations, and unbiased radio-transmitter effects. Similarly, I used the Mayfield Method (Mayfield 1961, Johnson 1979) to calculate estimates of nest success. The Mayfield Method allows the total number of bird exposure days to be incorporated into final estimates and also for estimates to be generated for nests only partially monitored. To calculate confidence intervals for the Mayfield estimates I used the procedures outlined in Johnson (1979). The Mayfield Method follows the assumptions that survival rates are constant over the nesting cycle, all nests visits are recorded, observer effects are inconsequential, successes can be measured accurately and every nest exposure day is independent of each other. Though Mayfield estimates are sometimes argued to be biased because of the inability to find bobwhite nests earlier than the incubation period of the cycle; both Mayfield and Kaplan Meier methods are commonly used across the quail literature.

In addition to survival analyses, I compared microhabitat characteristics between nest sites and random sites using both descriptive statistics and a principle components analysis (PCA). Aside from the value in comparing means and standard errors, the PCA allowed me to narrow down the variables considered most influential to the variation between nest plots from random plots. Additionally, the PCA biplots provide an illustration of the relationship between plot types and variables. In order to reduce the number of variables used in the PCA, I created Spearman rank correlation matrices and removed one of each pair(s) of highly correlated variables, keeping the variable with the highest eigenvectors within the first two PC axes. With these results, I created distance biplots to visually compare relationships between variables as well as amongst sites.

Lastly, because telemetry data allowed me to easily estimate the home-range size of individuals; I calculated home range sizes of each individual with greater than 24 locations. For home-range estimates, I used two different techniques: minimum convex polygon (MCP) and two fixed kernel density estimators (Worton 1989, White and Garrott 1990). For kernel estimates, I followed the methods outlined in Janke and Gates (2013) to first compare bandwidth estimators for individual birds in the program Animal Space Use (Version 1.3; Horne and Garton 2009); and then used the selected value in the Hawth's tools extension of ArcGIS (version 9.3, ESRI, Redlands, CA) for the computations. For each individual, the graphical displays in Animal Space Use suggested the least squares cross validation smoothing parameter (LSCV; Seaman and Powell 1996) estimate was the best fit and I therefore used this parameter in Program R. Horne and Garton (2006) suggested sample size limitations to consider when choosing between the likelihood cross validation (LCV) and LSCV methods for deriving the smoothing parameter. My data fit the sample size recommendations for number of bird locations used for LSCV ($\bar{x}$ = 77.35 ± 6.07, range = 24–121, n=20); and locations were adequately dispersed to allow the use of LSCV. For marked individuals that nested during the monitoring period, I used the nest location only once in each of my estimates. Once estimates were calculated I compared them by sex and year using pair-wise t-tests corrected with Bonferroni adjustments. All estimates of summer demographics (survival and home-range) were based on the seasons 1 April–11 August and 1 April–14 August in 2013 and 2014, respectively. All primary statistical analyses were conducted in the open-source program R (Version 3.0, R Development Core Team 2008, Vienna, Austria).

RESULTS

Across both field seasons, I was only able to identify six distinct coveys; two in 2013, and four in 2014. Covey size ranged from 6–13 individuals/covey and averaged 9.17 ± 0.95 individuals. Out of nine groups of pen-reared birds released in 2014, one amalgamated with a covey approximately 4-days after release, while another lead us to a wild covey just before mortality occurred also 4-days post-release. Out of the wild birds I was able to detect in 2013, I captured 17 individuals of which only 10 (5 males, 5 females) were fitted with transmitters. In 2014, I captured 21 individuals and radio-marked 19 (7 males, 12 females; Table 4). Trap predation accounted for the loss of seven individuals across both years while one individual died from trap related injuries. Two of the 17 individuals captured in 2013 were juveniles of unknown sex, and because they weighed < 130g, I did not fit them with a transmitter. In total, I captured 66 bobwhites (including recaptures) at 717 funnel traps sites and across 11 mist nets occasions (Figure 2). Based on the number of capture events per trap night, trap success was 0.41% (21 birds / 5165 trap nights) and 2.9% (44 / 1517 trap nights) in 2013 and 2014, respectively. All traps were open for an average of 9.3 (range = 0–33) nights.

Of the ten radio-marked birds in 2013, eight were right censored because of broken collars (n=2), capture mortality (n=1); and surviving past the end of the study period (n=5). In 2014, eight were right censored because of broken collars (n=3) and surviving past the end of the study period (n=5). Only one individual was left censored across both years and this occurred in 2014. Mammalian and avian predation accounted for the only two cases of natural mortality in 2013; however in 2014, mammalian predation accounted for 6 out of 10 cases of natural mortality. Avian (n=2), snake (n=1), and unknown (n=1) predation accounted for the other cases (Table 4). There was only one instance in which a radio-marked bird was found dead within a one week period after marking and since it occurred before 1 April 2014, I excluded it from survival estimates.

Kaplan Meier estimates of summer survival were 0.714 (95% CI = 0.45–1.00) and 0.476 (95% CI = 0.27–0.85) in 2013 and 2014, respectively (Figure 6). Kaplan Meier estimates were based on a 128-day period from 6 April – 11 August in 2013, and a 136-day period from 1 April – 14 August in 2014; and were not significantly different between years ($X_1^2 = 1.6$, P = 0.21). When I pooled the estimates; 0.502 (95% CI = 0.30–0.83); and extrapolated rates to reflect a 183-d period, the new rates became 0.618, 0.368, and 0.396 for 2013, 2014 and the pooled rate, respectively**.** While many studies include a 1–2 week acclimation period before including birds in survival estimates, I did not because of the limited field season length and also small sample size (Polluck et al. 1989b).

In total, I found ten nests across both years of the study; seven in 2013 and three in 2014; Figure 4). In 2013, two of the five nests I was able to follow the entire incubation period, hatched; whereas in 2014, all three nests hatched. As a result, Mayfield estimates of nest survival were 0.478 (95% CI = 0.201−1) and 1.00 in 2013 and 2014, respectively. Across both years, nests were initiated between 6 May and 26July and hatched between 3 July and 9 August (Table 4). In 2013, one nest was found on 6 August and appeared to be in the early stages of incubation; because the field season ended before it hatched I could not document its laying start-date. In total there was only one instance of both renesting and male-incubation and both occurred in 2013. Mean clutch size for all nests was 14.0 (14.0 ± 0.7, range 9−16, n=10) eggs and hatchability was 0.86 (51/59 eggs hatched).

Across both years of the study, predation accounted for all failed nests (Table 4). In 2013 my cameras detected a raccoon destroying one of the nests but failed to document the other two in which I attributed the events to snake predation. Upon visiting these two nests, I found no sign of nest bowl disturbance or missing eggshell fragments. In 2014, the last nest I observed began with a clutch size of 12 eggs, but only ended up hatching one egg upon completion. While monitoring this nest, I observed two events in which 4 and 6 eggs were depredated from the nest within the incubation period. I attributed these events to snakes as well do to the inability of my cameras to detect such instances and also because there was lack of vegetation disturbance at the nest site.

In short, I was only able to completely monitor three broods for brood survival estimates across both years. In 2013, I followed only one brood before the end of the field season and when flushed at 14, 21, 28 and 36 days post hatch, this brood contained only one chick. In 2014, I observed two of the three broods that hatched. Of the older of the two, I failed to observe any chicks on the 14 day flush attempt, but did observed 2 chicks during the 21-d and 28-d flushes. When I attempted to flush the latter brood at 14-d, I observed chicks chirping but could not make a count because of the difficulties in rounding up and flushing the chicks. During the event, the incubating female flushed only a short distance away (approximately 10-m) and proceeded to display distress calls. The field season ended two days after this event and on the last day, the incubating adult's mortality switch was triggered. I tracked the signal to a mature loblolly pine but could not retrieve the transmitter because it was in the tree's canopy.

When I initially conducted the PCA with all 20 variables, 44.4% of the variance was explained within the first two principle components and 88.4% within the first six principle components (Table 6). With all 20 variables, broken stick eigenvalues suggested the first 6 axis were the most meaningful. When I reduced the number down to just five variables using Spearman correlation matrices, the variables: total basal area, pine stem density, pine sapling density, total seedling density and percent overstory canopy cover, explained 81.6% of the variance across the first two principle components (Table 7). Broken stick eigenvalues suggested these two axes were the most meaningful. Out of the remaining five variables, pine sapling density, pine stem density and percent overstory canopy cover fell along the first axis while total seedling density and basal area had the highest eigenvectors along the second axis. Pine stem density along with pine sapling density showed an inverse relationship with percent canopy coverage as did total seedling density and total basal area. With the exception of three random plots and one successful nest plot, most plots (both random and nest) appeared relatively clumped along the central vertex and the eigenvector representing total basal area (see Figures 7 and 8).

When I compared the microhabitat variables by their means and standard errors, only the percent ground cover of forbs and detritus between successful nests and failed nests appeared to be significantly different (Table 2). A higher percentage of forb cover and lower percentage of detritus was present at successful nests compared to failed nests. In general, nest concealment and percent grass, forb and woody cover were all higher at nests and successful nests compared to random plots and failed nests respectively. Nests and successful nests had lower overstory tree stem density, but higher sapling density than random plots and failed nests. Successful nests had lower basal area on average than failed nests.

For each of the home-range estimates, there was an average of 77.4 (range = 24–121) locations per individual. All but one individual had greater than thirty locations; therefore sample size did not influence either 95% kernel estimates ($P = 0.239$, $r^2 = 0.0248$), 50% kernel estimates ($P = 0.167$, $r^2 = 0.536$) or MCP estimates ($P = 0.596$, $r^2 = -0.0387$). Out of the three estimates, only the MCP estimates across years were significantly different (Table 3). MCP estimates in 2013 ($\bar{x} = 113.8 \pm 20.1$) were significantly lower than those in 2014 ($\bar{x} = 393.1 \pm 49.0$; $P < 0.001$). Mean 95% kernel home-range size was 63.9 ha (95% CI = 48.7-79.2) and mean 50% kernel home-range size was 14.9 ha (95% CI = 11.28 - 18.6) pooled across years, respectively. Though not significantly greater, both the 95% and 50% kernel estimates were larger in 2013 than 2014.

DISCUSSION

Weil (2012) reported several bobwhite coveys on Felsenthal NWR during his research in 2010 and 2011, suggesting that habitat on Felsenthal NWR could support bobwhites. In addition, he predicted future management directed towards improving already good areas on the refuge could result in a sizable population. Unfortunately, however, the number of birds observed in my study suggests the population on Felsenthal NWR has not grown since then. Only six distinct coveys were identified across both field seasons despite extensive searching, calling, trapping and the release of pen-reared bobwhites.

In a study area of approximately 3,000-ha in size, six coveys equates to 0.0020 birds/ha; which is considerably low compared to very low densities reported in Ohio (0.0025–0.0163 birds/ha, Janke et al. 2013). Janke et al. (2013) also noted densities from other research (i.e. Williams et al. 2004, DeMaso et al. 1992, Leif and Smith 1993, and Roseberry and Klimstra 1984) ranging from 0.012–0.58 birds/ha and reported an average distance of 0.96 km between radio-marked coveys in highly fragmented habitat. On Felsenthal NWR, distance between coveys ranged from 1.42– 4.29 km and their size and movements indicated they were likely the only coveys in the area (J. Doggett, personal observation). Past research has illustrated that distance between coveys increases as density decreases (Guthery 2000:140); thus, the large distances in my study suggests the number of individuals on the refuge was indeed small and reflective of a low-density population (Janke et al. 2013).

Given that management for RCW has been shown to increase bobwhite abundance (Bowman et al. 1999, Cram et al. 2002), the population on Felsenthal NWR could be experiencing problems with recruitment. Janke et al. (2013) postulated that the negative impacts of large distances between coveys could decrease survival during the non-breeding season and impact population growth rates. Other reports suggest that as distance increases between coveys in low density populations (Guthery 2000:140), so does the infrequence of individual transfers between coveys (Yoho and Dimmick 1972, Janke et al. 2013). Even further, Williams et al. (2003) reported that individual survival tends to decrease as covey size fluctuates above or below an optimal size of 11 individuals. On Felsenthal NWR, mean covey size during March and April was only 9.2 individuals and lower than reported averages (Dimmick et al. 2002). Thus, large distances could have inhibited the transfer of individuals among coveys on Felsenthal NWR and resulted in covey sizes below the optimal level. If optimal covey size was higher than 9.2 individuals on Felsenthal NWR, bobwhites were likely experiencing reduced survival (Williams et al. 2003). Reduced winter survival translates into a smaller breeding population and reduced recruitment potential.

On the contrary, estimates of summer survival were within an acceptable range of a growing population and probably did not impact recruitment. With the exception of the 2013 estimate, my estimates were about average compared to others in the literature; 25.3% and 27.9% in Kentucky (West et al. 2012), 33.2% in Missouri (Burger et al. 1995a), 33% in North Carolina (Puckett et al. 1995), and 34.3% in New Jersey (Lohr et al. 2011). The adjusted pooled rate of 39.6% was considerably lower than an estimate by Sandercock et al. (2008), who showed using life-stage simulation analysis, a summer rate ≥ 79% would be required to support a growing population; however, the estimate was relatively good compared to Sisson et al. (2009) who showed using long-term data; even a summer rate of 35% could support a growing population. Both studies complimented their estimates with winter survival rates of ≥ 50%, which is recommended for accurate population growth rates (Sandercock et al. 2008, Gates et al. 2012); though, considering the small sample size, summer survival alone appeared sustainable on Felsenthal NWR.

Because my sample size was small and small samples can bias survival estimates (Polluck et al. 1989b), I analyzed my estimates of summer survival using another set of criteria outlined by Guthery and Lusk (2004). Within the bobwhite literature, some researchers argue telemetry based survival estimates are biased low do to the potentially negative effects of radio-transmitters (Guthery and Lusk 2004). In particularly, Guthery and Lusk (2004) suggested that for telemetry based survival estimates to be realistic, they should represent a juvenile to adult age ratio less than 7:1. A 7:1 age ratio has been used to represent the maximum reproductive potential theoretically possible for northern bobwhite such that any ratios higher then 7:1 exceeds the limits of bobwhite reproduction (Guthery and Lusk 2004); but also, age ratios < 4 are typically considered low and inadequate for population growth (Roseberry and Klimstra 1984). I tested my rates based on Guthery and Lusk's (2004) assumptions and came up with theoretical age ratios they would consider reasonable: 1.61:1 in 2013; 6.33:1 in 2014 and 5.36:1 for the pooled rate. My calculated ratios were below 7:1 which was good because they suggest summer survival on Felsenthal NWR is acceptable; however, they were also good because they suggest summer survival isn't affecting production and/or recruitment on the refuge.

Similar to breeding season survival, my estimates of nest success were fair and did not indicate a problem with production. The Mayfield estimate during the incubation period (47.8%) in 2013 was about average with respect to values of 49% in Texas

(Hernandez et al. 2007), 45.4% in New Jersey (Collins et al. 2009), 41% in Florida (Rolland et al. 2010), and 31.7% in Kentucky (Tanner 2012). A 100% survival of all nests during the incubation period in 2014 was excellent. Average clutch size on Felsenthal NWR was higher than the assumed range-wide average of 12 eggs (Dimmick et al. 2002); and, with the exception of the hatchability rate in 2013; (77%), the pooled hatchability rate (86%) was in range compared to rates reported in the literature (80% - 96%; Sandercock et al. 2008). Low hatchability rates do not significantly influence bobwhite demography (Sandercock et al. 2008); however, at rates lower than normal, they do suggest odd temperature fluctuations, inbreeding depression or other environmental factors leading to reproductive sterility (Rolland et al. 2010). Such factors should be noted considering the low density on Felsenthal NWR; however, nest success overall was relatively good.

Additionally, when comparing differences in vegetation characteristics measured at nest sites and random sites, my data suggested nesting habitat did not appear to be limiting. The results of the PCA suggested I was able to capture a spread of variation amongst important nesting habitat components (Figure 8). Within the second biplot, most of this variation was explained along the first principle component axis; however, bobwhite nest sites appeared to be grouped within some bounds of the variation along both axes. With the exception of one successful nest, vegetation characteristics at nest plots seemed less variable than random plots. Such a pattern suggests bobwhites were selecting habitat components that were distinguishable from the variety of habitat available. Taking into account the high rates of nest success at nest sites, areas where bobwhites initiated nests likely reflected suitable nesting habitat.

Based on the means and standard errors of the nest microhabitat data, it appeared that bobwhites were selecting for open areas in the forest structure with relatively good woody understory vegetation and a predominance of detritus, woody, and grassy ground cover. Compared to descriptions of nesting habitat in the literature, the characteristics of nest sites within our study area seemed in line with what others have reported. Townsend et al. (2001) reported greater woody cover at nests (20–30%) compared to random sites (10−15%) in Oklahoma while in Texas, Lusk et al. (2006) found nest sites and successful nests had greater percentages of shrub and bare ground exposure and also taller vegetation height over nests in order to provide concealment. These authors and others (Bowman and Harris 1980, Gregg et al. 1994) suggested nest concealment is important because it reduces visual and olfactory predator cues. Thus, since a large portion of the study area was of the same age and in similar stages of management for RCW, the fact that such nest sites were available on Felsenthal NWR suggests nesting habitat wasn't limited for bobwhites, or at least not for such a small population.

Unlike summer survival rates and nest success however, the inability to observe an adequate number of bobwhite chicks during the study suggests the population was experiencing low brood survival. When I compared the estimates to what is theoretically required to sustain a population (i.e. Guthery and Lusk's ratio; Roseberry and Klimstra 1984, Guthery and Lusk 2004), it's apparent that brood survival may in fact be too low on Felsenthal NWR. Across the literature, brood survival ranges from 0.14–0.72 (Sandercock et al. 2008) and is typically regarded as the least understood aspect of bobwhite ecology; however, low brood survival directly translates into fall recruitment and low recruitment can significantly impact a bobwhite population (Folk et al. 2007, Sandercock et al. 2008). A lack of brood production on the study area could be impacting fall population size and consequently reducing population growth rates. Therefore, I suggest low brood survival is likely contributing to the declining numbers on Felsenthal NWR.

Other factors could also be contributing to low recruitment on Felsenthal NWR as well. For bobwhites, the ability to have multiple broods throughout the breeding season as well as the propensity to re-nest after failed attempts is thought to be a mechanism of recovery after years of low annual survival (Burger et al. 1995, Burger et al. 1995b). Theoretically, if bobwhites nested later in summer such instances could reduce recovery potential via a shortage of nests and surviving chicks (Guthery et al. 1988, Guthery and Kuvlesky 1998). Such claims are supported by Dimmick (1974) who suggested the total number of nests built in a breeding season was a good predictor of fall density. On Felsenthal NWR, nest initiation though more typical in 2013, was relatively later than reports of first nest initiation in the literature, especially in 2014. Klimstra and Roseberry (1975) reported first instances of clutch initiation as early as 16 April in southern Illinois; while Simpson (1973) and Lehman (1946) reported even earlier dates in Georgia and Texas. Simpson (1973), Lehman (1946) and Klimstra and Roseberry (1975) found that peak nest initiation was typically associated with the end of May and first two weeks in June, while Cox et al. (2005) reported peak nest initiation at the end of April. Based on the nests I observed during the assessment, first nest initiations ranged between 6 May and 27 June in 2013; but between 3 June and 4 July in 2014. Though it is possible the weather may have impacted nesting in both years, other than high December rainfall in 2013 resulting in the ground being more saturated in March and April of 2013; I didn’t observe or find in the record any extreme climatic patterns that would appear to have been influential (J. Doggett, personal observation, NCDC 2014). Nest predation is by far the most common cause of nest failure (Stoddard 1931, DeVos and Mueller 1993), and prior to incubation usually goes unnoticed in telemetry studies; however, if nesting was indeed delayed it may be responsible for the lack of broods I observed before the end of each field season. Bobwhites rely on several attempts to successfully hatch a nest (Burger et al. 1995, Puckett et al. 1995) and a reduction in those efforts could indirectly impact recruitment (Puckett et al. 1995, Guthery et al. 1988, Guthery and Kuvlesky 1998).

Along with late nest initiation, covey break up on Felsenthal NWR seemed unusually late especially in 2014. Though rarely discussed in the literature, late covey break up is intrinsically linked to nest initiation dates. On Felsenthal NWR, covey break up ranged from 15 April−15 May and was considerably later in 2014 than in 2013. For bobwhites, spring pair-bonding is facilitated when suitable mates are within the covey prior to break up, and supplementary covey mixing during winter could facilitate earlier nest initiation (Lehmann 1946). A limited number of breeding pairs on Felsenthal coupled with low annual recruitment could theoretically lead to highly related individuals within coveys. Thus, during years where covey transfers fail to occur, pair bonding could be limited to the members of the covey accrued during the fall or spring shuffle (Lehman 1946, Ellsworth et al. 1989). Over time, it would seem logical that bottlenecking events associated with harsh weather patterns (see Williams et al. 2003) or limited useable space (see Guthery et al. 1997 and 2000) could inhibit genetic mixing between coveys and result in the need to disperse to find suitable mates (Townsend et al. 2003). In addition, if small covey size decreases winter survival then one might expect to find large breeding season home ranges. Assuming weather, habitat or predation had no significant effects on nesting then such mechanisms could account for late nest initiation.

Large breeding season home-ranges were observed on Felsenthal NWR. When I compared the estimates to others in the literature, home-ranges on Felsenthal NWR exceeded most estimates for 95% kernel distributions; 21-ha in GA (Tehrune et al. 2010); 38-ha in NJ (Lohr et al. 2011); 54-ha in Florida (Singh et al. 2010); and 74-ha in Kansas (Taylor et al. 1999). For areas closer and more similar to Felsenthal NWR, Liu et al. (2002) reported a 95% kernel distribution estimate of 61.9-ha in the pine forests of East Texas while Bell et al. (1985) reported home-ranges of 58.4-ha in Louisiana. In both studies, authors suggested their home-range estimates were large mostly because of the poor quality of pine-forest ecosystems in general. Thus, estimates from observations on Felsenthal NWR were relatively high considering the apparent overlap in management practices between RCW and bobwhite (Bowman et al. 1999, Cram et al. 2002, Chamberlain and Burger 2005).

In their study on spring dispersal, Townsend et al. (2003) suggested that greater movements during the early breeding season could be explained by the instinctive behavior of individuals to search for mates or suitable nest sites. Tehrune et al. (2010) appeared to support this argument and added that past research suggests low-density populations yield greater spring movements because of the innate drive to search for mates (Errington 1945, Urban 1972, Roseberry and Klimstra 1984, Townsend et al. 2003). The fact that minimum convex polygon estimates in my assessment were nearly three-times higher than kernel estimates, and MCP ranges were considerably large, suggests quail on Felsenthal NWR were covering large portions of the study area during the dispersal phase of the breeding season. If nesting habitat was indeed available on Felsenthal NWR, it could mean dispersal was more oriented towards finding suitable mates rather than seeking good nesting habitat.

Poor quality habitat could be responsible for large home-range sizes on Felsenthal NWR; however, my observations suggest that the isolated characteristics of the refuge in general, better explain the movement patterns of radio-marked bobwhites. During the study, I failed to observe bobwhites dispersing large distances off of the refuge. Several of the 2014 radio-marked individuals did disperse to adjacent non-federally owned properties which were also managed for RCW's, and stayed there the duration of the summer. However, these properties were juxtaposed uniquely along the refuge boundary and intertwined by other more intensively managed property in a way that they likely appeared to a bobwhite as "connected" to the refuge but also surrounded by intensive timber management (J. Doggett, personal observation). Except for short periods of time, radio-marked birds did not disperse beyond the boundaries of the RCW managed areas such that the limits of the property represented the furthest distances away from the refuge radio-marked birds traversed.

Many researchers would agree that bobwhite movements are dictated by habitat quality (Kabat and Thompson 1963, Fies et al. 2002,) such that limited resources increase home-range size (Sisson et al. 2000), however; the degree to which the site is fragmented from other suitable sites may also decrease home-range size and prevent dispersal (Janke et al. 2013, Tehrune et al. 2010). Janke et al. (2013) documented decreased covey movements in fragmented habitat and suggested the availability of suitable habitat may have restricted movements. Since none of the radio-marked birds in my study were lost due to excessive movements off the refuge, it might be naïve to conclude that habitat quality in the study site was indeed poor (Winker et al. 1995), but rather, dispersal off the refuge appeared to be restricted. The possibility of restricted movement off of the refuge strengthens the possibility that the population may in fact be isolated and those dynamics could explain the low density characteristics I observed (Janke et al. 2013). If the population was indeed isolated or immigration to the refuge was minimal, the population could be experiencing problems associated with reduced gene flow as well (Berkman et al. 2013).

Several other factors besides low juvenile recruitment and population isolation could explain the population dynamics of bobwhite on Felsenthal NWR. For example, compared to summer survival and brood survival, winter survival has been shown to contribute considerably to variation in rates of population change (Williams et al. 2003, Folk et al. 2007, Sandercock et al. 2008 a). Arguably, winter survival is the most important period of survival for bobwhites (Williams et al. 2003, Sandercock et al. 2008). If nesting and brood survival increased significantly the last month of the breeding season and high winter mortality significantly reduced the number of individuals entering the breeding season, low winter survival could be a reasonable explanation for the low-density population on Felsenthal NWR. Low winter survival is typically associated with severe weather, a decline in habitat availability, food shortages, or increased predation rates.

Furthermore, as a national wildlife refuge under constant management, it is possible that predator populations could have excelled in certain portions of the property and negatively affected bobwhites. Seckinger et al. (2008) documented increased winter survival with the reduction of closed canopy pines on an intensively managed plantation in Tennessee; suggesting closed canopy pine may provide refugia for common bobwhite predators. Additionally, Chamberlain et al. (2004) documented smaller raccoon home-ranges in areas managed for RCW while others have documented increased snake and small mammal abundance in areas that were recently burned (Masters et al. 1998, Perry et al. 2009). Because I did not measure winter survival or quantify predation during the study, and since the sample size was extremely small, I cannot eliminate the possibility that low winter survival and/or high predation did not also contribute to constrained population growth on Felsenthal NWR.

Finally, low-quality habitat conditions could also be a reasonable explanation for the metrics I observed. Contrary to previous reports of increased abundance, management for RCW may not be suitable for bobwhites in all areas of bobwhite range. For example, Burke et al. (2008) reported bobwhite abundance declined in pine-forest managed for RCW in north Louisiana despite efforts to improve brood-rearing habitat. He recommended managers should be aware that management for RCW in similar types of forests fails to provide adequate brooding habitat for bobwhites. Similarly, Weil (2012) concluded that habitat on Felsenthal NWR was sub-optimal in terms of producing large quantities of bobwhites. Using a habitat suitability model, Weil (2012) identified several locations where management for RCW resulted in better habitat for bobwhites; however, he concluded that management to improve these areas was necessary to support a larger population. Other than measurements of nest microhabitat characteristics, I did not explicitly quantify habitat quality. Under the constraints of my limited sample size, the variation observed in the PCA could theoretically reflect a narrow range of habitat quality as opposed to a large one. If habitat quality of the study area ranged from very poor to excellent, the variation in the PCA would reflect this range and nest sites could be said to be in rather suitable habitat. However, if habitat quality on Felsenthal NWR actually ranged from only very poor to fair, the quality of nest sites I observed may in fact be lower and nesting habitat may in fact be more limiting. Given that the practices used to manage habitat for RCW intrinsically take time to accomplish, the suitability of the refuge during my study likely had not changed much since Weil's observations. Thus habitat quality within the study area could also be contributing to limited bobwhite abundance on the refuge as well (Weil 2012).

Conclusion

Ultimately, the results of my assessment suggest that bobwhites are experiencing low recruitment during the breeding season on Felsenthal NWR. Throughout the study, I documented relatively good summer survival, good nest success and seemingly good nesting habitat, but failed to document acceptable brood survival rates. I was only able to flush a few broods across both years of the study, and during each of these flushes I documented only a few bobwhite chicks. Because I expected to see more chicks and flush more broods before the end of the field season, I suggest late nest initiation reduced reproductive potential and therefore recruitment on Felsenthal NWR. Nest initiation appeared to be delayed because of the isolated nature of coveys as well as a lack of suitable mates at the beginning of the breeding season. Because nest initiation may be facilitated when suitable breeding partners are already within the covey prior to break up (Lehman 1946), the low-density conditions across the study area could be limiting the availability of suitable mates and therefore impacting the recruitment potential of the population. These observations were supported by seemingly good nesting habitat, large home-range estimates, and the fact that no radio-marked individuals permanently dispersed off of property managed for RCW's. Since management for RCW's and bobwhites overlap considerably and management for RCW's has been associated with increased bobwhite abundance, my observations suggest that bobwhites were isolated to the study area and low reproductive recruitment could be the result of low genetic diversity.

MANAGEMENT IMPLICATIONS

Twedt et al. (2007) found that only 11% of the land area in the WGCP contained habitat suitable enough to support densities of at least 0.14 birds/ha, the recommended restoration goal of the National Bobwhite Conservation Initiative (NBCI 2011). Even further, they also showed only 8% of the land cover within the WGCP supported sustainable populations of 400–700 individuals (Twedt et al. 2007). Given that their model was based on land cover data from the early-to-mid 1990's, trends in the WGCP continue to decline and bobwhite populations in Arkansas likely face similar constraints today (see Dimmick et al. 2002). On Felsenthal NWR, I detected only four coveys and approximately 36 individuals in March of 2014 when the highest numbers of bobwhites were observed. Distance between coveys was high and I also observed later than normal nesting, a relatively few number of individuals successfully raising broods, large home-ranges amongst radio-marked individuals, and movements that appeared restricted to areas managed for RCW. These observations are likely characteristic of a low-density population and could reflect a high degree of isolation between other local bobwhite populations. Since declining, isolated populations are vulnerable to reduced genetic diversity, I recommend conducting a genetics study on and around Felsenthal NWR. A genetics study on Felsenthal NWR may illuminate the degree of relatedness among individuals and confirm whether or not bobwhites on Felsenthal NWR are indeed experiencing problems with isolation.

Twedt al. (2006) recommended against allocating resources to restoration efforts in areas where populations are below sustainable levels while others, recommend restoring areas near already suitable habitat to increase local abundance (Berkman et al. 2013). Since management for RCW already occurs on Felsenthal NWR, I suggest developing management plans to increase connectivity between areas managed for RCW and those in surrounding landscape that have potential to be good bobwhite habitat. As bobwhite numbers continue to decline across the WGCP, concerns of population extirpation will likely become more prevalent and management actions to increase dispersal among isolated populations will be needed. Working with private landowners to increase habitat quality on land adjacent to Felsenthal NWR could increase population growth in the landscape and alleviate concerns of isolation between populations of bobwhites, especially areas already in close proximity (NBCI 2011, Berkman et al. 2013).

Lastly, Felsenthal NWR is not the only location in the WGCP that has reported declining populations in the presence of RCW management. Burke et al. (2008) reported declining bobwhite abundance despite efforts to increase brood-rearing habitat in north Louisiana. He concluded that management for RCW in similar types of forests fail to provide adequate brood-rearing habitat for bobwhites despite reports of improved habitat quality elsewhere. Quite similarly, Weil (2012) reported relatively low habitat suitability on Felsenthal NWR and predicted future management directed towards improving already good areas could result in a sizable population. I recommend initiating research that directly addresses the management discrepancies between RCW and bobwhite, perhaps more specifically, research that investigates the dynamics within a loblolly pine-dominated landscape. Goals for managing RCW in different forest types are often site-specific and understanding how those different management practices affect bobwhites would undoubtedly answer detailed questions about habitat quality for both species. Since bobwhites are declining range wide and among different habitats, I suggest areas like Felsenthal NWR will become increasingly more important to restoring bobwhite populations across their range, in particularly the WGCP where declines are severe and regional conservation goals are unique.

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TABLES

Table 1. Definitions of microhabitat vegetation measurements.

Variables	Definition
Basal Area	Area of ground surface covered by the stem or stems of a tree, measured at 1.37 m above the ground
Stem Density	Number of stems per plot
Sapling	A tree greater than 1.37 m in height and less than 2.54 cm in diameter
Seedling	A tree less than 1.37 m
Height	Tallest height of graminoid or woody vegetation within 10-cm radius of plot center
% Canopy Cover	Percentage of sky covered by overstory-tree canopy; measured from 15.24 cm above plot center
Vertical Structure	Percentage of cells containing vegetation on a 1-m wide, 2-m tall 200-cell grid. Average of four readings at 7 m from plot center and 1.37 m above plot center in each cardinal direction
Concealment	Percentage of cells containing vegetation on a 1-m wide, 2-m high 200-cell grid. Average of four readings at 7 m from plot center and 15.24 cm above plot center in each cardinal direction
Ground Cover	Percentage of ground covered in a 1-m^2 plot by the extremities of an undisturbed canopy projected upon the ground, and all such projections on a given area are summed

Table 2. Means and standard errors of vegetation measurements at nest plots (n=8), random plots (n=8), successful plots (n=5), and failed plots (n=3).

	Nest		Random		Successful		Failed	
Variable(s)	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Pine Basal Area (m^2/plot)	0.7	0.1	0.6	0.1	0.6	0.2	0.8	0.1
Hardwood Basal Area (m^2/plot)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total Basal Area (m^2/plot)	0.7	0.1	0.7	0.1	0.6	0.2	0.8	0.1
Pine Stem Density (#/plot)	5.4	1.3	10.3	5.4	4.4	1.0	7.0	3.2
Hardwood Stem Density (#/plot)	4.3	1.6	7.8	3.4	3.2	1.2	6.0	4.0
Total Stem Density (#/plot)	9.6	2.7	18.0	5.1	7.6	1.3	13.0	7.2
Pine Saplings (#/plot)	0.8	0.6	3.9	2.8	1.0	1.0	0.3	0.3
Hardwood Saplings (#/plot)	90.3	13.5	69.4	29.2	92.6	16.8	86.3	27.4
Total Saplings (#/plot)	91.0	13.7	73.3	28.5	93.6	17.3	86.7	27.1
Pine Seedlings (#/plot)	48.3	39.3	57.9	29.4	68.4	63.3	14.7	12.7
Hardwood Seedlings (#/plot)	38.9	11.7	40.3	13.9	51.8	16.3	17.3	5.2
Total Seedlings (#/plot)	87.1	39.0	98.1	33.4	120.2	58.8	32.0	16.3
Graminoid (%)	13.7	1.6	12.6	2.0	14.9	1.9	11.5	2.9
Forb (%)	9.7	2.6	4.5	1.2	14.0	2.6	2.4	0.1
Woody (%)	31.9	4.7	26.8	3.3	36.3	4.7	24.5	9.2
Bare (%)	3.1	1.2	4.8	1.2	3.2	2.0	3.0	0.3
Detritus (%)	49.9	7.2	55.8	6.1	38.7	7.4	68.6	4.9
Vertical Structure (%)	0.7	0.0	0.7	0.1	0.7	0.1	0.7	0.1
Nest Concealment (%)	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
Tree Canopy Cover (%)	0.5	0.0	0.5	0.1	0.4	0.0	0.6	0.1
Tallest Vegetation Height (m)	1.0	0.2	0.8	0.1	0.7	0.2	1.4	0.5

Table 3. Home-range estimates of male and female radio-marked northern bobwhite and radio-marked northern bobwhite in years 2013 and 2014.

	Male		Female		2013		2014	
Home-range type	Mean	SE	Mean	SE	Mean	SE	Mean	SE
95% Kernel	68.0	12.6	59.8	7.8	64.4	16.1	63.6	6.5
50% Kernel	15.8	3.0	14.1	1.9	15.9	3.9	14.3	1.5
MCP	220.2	42.2	342.6	73.0	113.8	20.1	393.1	49.0

Table 4. Survival data for wild radio-marked northern bobwhite on Felsenthal NWR in years 2013 and 2014.

	Wild Radio-marked Northern Bobwhite Survival Data						
Bird ID	Sex	Release Date	Mortality Date	Predator Type	Censored Date	Censored Type	# Days Monitored
Year 2013							
73603	Male	04/06/13	06/27/13	Mammalian	-	-	82
73605	Female	04/06/13	-	Trap	06/17/13	Right	72
73607	Female	04/06/13	-	-	08/11/13	Right	127
73609	Female	04/06/13	-	Broken Collar	07/19/13	Right	104
73611	Female	05/09/13	-	-	08/11/13	Right	94
73613	Male	05/23/13	-	-	08/11/13	Right	80
73615	Male	06/09/13	-	Broken Collar	08/05/13	Right	57
73617	Male	06/09/13	-	-	08/11/13	Right	63
73619	Male	07/17/13	07/29/13	Avian	-	-	12
73621	UNK	07/30/13	-	-	-	-	-
73623	UNK	07/30/13	-	-	-	-	-
73625	Female	08/05/13	-	-	08/11/13	Right	6
Year 2014							
73627	Female	03/08/14	03/08/14	Avian	03/08/14	Left	0
73629	Male	03/09/14	03/19/14	Mammalian	03/19/14	Left	10
73631	Female	03/09/14	03/30/14	Mammalian	03/30/14	Left	21
73633	Female	03/09/14	-	Broken Collar	04/08/14	Right	30
73635	Male	03/09/14	04/10/14	Mammalian	-	-	32
73637	Female	03/09/14	06/17/14	Avian	-	-	100
73639	Male	03/10/14	-	-	08/14/14	Right	157
73641	Female	03/10/14	08/13/14	Unknown	-	-	156
73643	Male	03/11/14	05/15/14	Mammalian	-	-	65
73645	Female	03/13/14	03/28/14	Mammalian	03/28/14	Left	15
73647	Male	03/14/14	06/23/14	Snake	-	-	101
73649	Female	03/17/14	04/09/14	Mammalian	-	-	23
73651	Female	03/18/14	-	-	08/14/14	Right	149
73653	Female	03/22/14	06/21/14	-	-	-	91
73655	Male	03/23/14	-	Broken Collar	08/05/14	Right	135
73657	Female	03/25/14	-	-	08/14/14	Right	142
73659	Female	03/25/14	-	Broken Collar	07/07/14	Right	104
73661	Female	03/27/14	-	-	08/14/14	Right	140
73663	Male	04/03/14	-	-	08/14/14	Right	133

Table 5. Demographic data for nesting radio-marked northern bobwhite in years 2013 and 2014.

	Nesting Demographics							
Bird ID	Sex	Laying Start	Incubation Start	Hatch Date	Failure Date	Clutch Size	# Eggs Hatched	Predator Type
Year 2013								
73607	Female	05/06/13	05/25/13	-	06/16/13	16	-	Mammalian
73605	Female	05/24/13	06/11/13	-	06/15/13	15	-	Snake
73611	Female	05/24/13	06/10/13	07/03/13	-	14	12	-
73609	Female	06/21/13	07/09/13	-	07/18/13	15	-	Snake
73617	Male	06/27/13	07/16/13	08/08/13	-	16	11	-
73625	Female	-	-	-	-	15	-	-
73607	Female	07/26/13	08/06/13	-	-	9	-	-
Mean First Attempt	-	05/26/13	06/13/13	07/03/13	06/26/13	15.2	11.5	-
Year 2014								
73651	Female	06/03/14	06/20/14	07/13/14	-	14	14	-
73641	Female	06/22/14	07/07/14	07/29/14	-	14	-	-
73657	Female	07/04/14	07/18/14	08/09/14	-	12	1	Snake
Mean First Attempt	-	06/19/14	07/05/14	07/27/14	-	13.3	7.5	-

Table 6. Importance of components of initial principal component analysis and species scores.

	Principal Components	
	1	2
Eigenvalue	4.69	4.18
Standard Deviation	2.17	2.05
Proportion Explained	0.23	0.21
Cumulative Proportion	0.23	0.44
Eigenvectors		
Total Basal Area	-1.63	-0.20
Pine Basal Area	-1.44	-0.61
Hardwood Basal Area	-0.31	1.43
Total Stem Density	1.47	0.59
Pine Stem Density	1.36	0.01
Hardwood Stem Density	0.32	0.93
Total Sapling Density	0.21	-1.33
Pine Sapling Density	1.51	0.66
Hardwood Sapling Density	0.06	-1.36
Total Seedling Density	0.81	0.75
Pine Seedling Density	0.75	0.65
Hardwood Seedling Density	0.27	0.34
Canopy	-1.39	0.54
Concealment	0.93	-1.14
Vertical Structure	1.14	-1.39
Grass	-0.28	-0.53
Forb	-0.41	-0.91
Woody	0.60	-1.28
Bare	0.27	-0.16
Detritus	-0.06	1.48

Table 7. Importance of components of initial principal component analysis and species scores.

	Principal Components	
	1	2
Eigenvalue	2.85	1.23
Standard Deviation	1.69	1.11
Proportion Explained	0.57	0.25
Cumulative Proportion	0.57	0.82
Eigenvectors		
Total Basal Area	1.26	-1.28
Pine Stem Density	-1.48	-1.12
Pine Sapling Density	-1.57	-0.23
Total Seedling Density	-0.57	2.30
Overstory Canopy Cover	1.45	0.63

Table 8. Family names, species names, and common names of food producing plants for northern bobwhite on Felsenthal NWR.

Family	Species	Common Name
Anacardiaceae	*Rhus glabra*	Smooth Sumac
Apiaceae	*Doucus carota*	Queen Anne's Lace
Asclepiadaceae	*Asclepias tuberosa*	Butterfly Milkweed
Asteraceae	*Ambrosia artemisiifolia*	Common ragweed
Asteraceae	*Bidens bipinnata*	Spanish needles
Asteraceae	*Helianthus divaraicatus*	Woodland sunflower
Asterales	*Vernonia lettermannii*	Narrowleaf ironweed
Clusiaceae	*Hypericum gentianoides*	Pineweed
Clusiaceae	*Hypericum hypericoides*	St. Andrew's-cross
Cyperaceae	*Carex glaucescens*	Southern waxy sedge
Ericaceae	*Vaccinium stamineum*	Deerberry
Euphoribiaceae	*Croton capitatus*	Woolly croton
Fabaceae	*Chamaecrista fasciculata*	Showy partridge pea
Fabaceae	*Lespedeza cuneata*	Chinese lespedeza
Fabaceae	*Lespedeza virginica*	Slender lespedeza
Fabaceae	*Strophostyles umbellata*	Trailing fuzzybean
Fabaceae	*Vicia sativa*	Narrowleaf vetch
Fagaceae	*Quercus stellata*	Post Oak
Fagaceae	*Quercus falcata*	Southern Red Oak
Fagaceae	*Quercus nigra*	Water Oak
Fagaceae	*Quercus phellos*	Willow Oak
Linaceae	*Linum medium*	Stiff yellow flax
Oxalidaceae	*Oxalis stricta*	Yellow woodsorrel
Pinaceae	*Pinus echinata*	Shortleaf Pine
Pinaceae	*Pinus taeda*	Loblolly Pine
Poaceae	*Andropogon virginicus*	Broomsedge bluestem
Poaceae	*Andropogon gerardii*	Big bluestem
Poaceae	*Chasmanthium latifolium*	Indian woodoats
Poaceae	*Chasmanthium laxum*	Slender woodoats
Poaceae	*Dichanthelium scoparium*	Velvet panicum
Poaceae	*Panicum virgatum*	Switchgrass
Poaceae	*Paspalum notatum*	Bahiagrass
Poaceae	*Paspalum urvileie*	Vaseygrass
Poaceae	*Saccharum alopecuroidum*	Silver plumegrass
Poaceae	*Setaria faberi*	Giant foxtail
Poaceae	*Setaria parviflora*	Knotroot foxtail
Poaceae	*Sorghastrum nutans*	Indiangrass
Rosaceae	*Rubus trivialis*	Southern dewberry

FIGURES

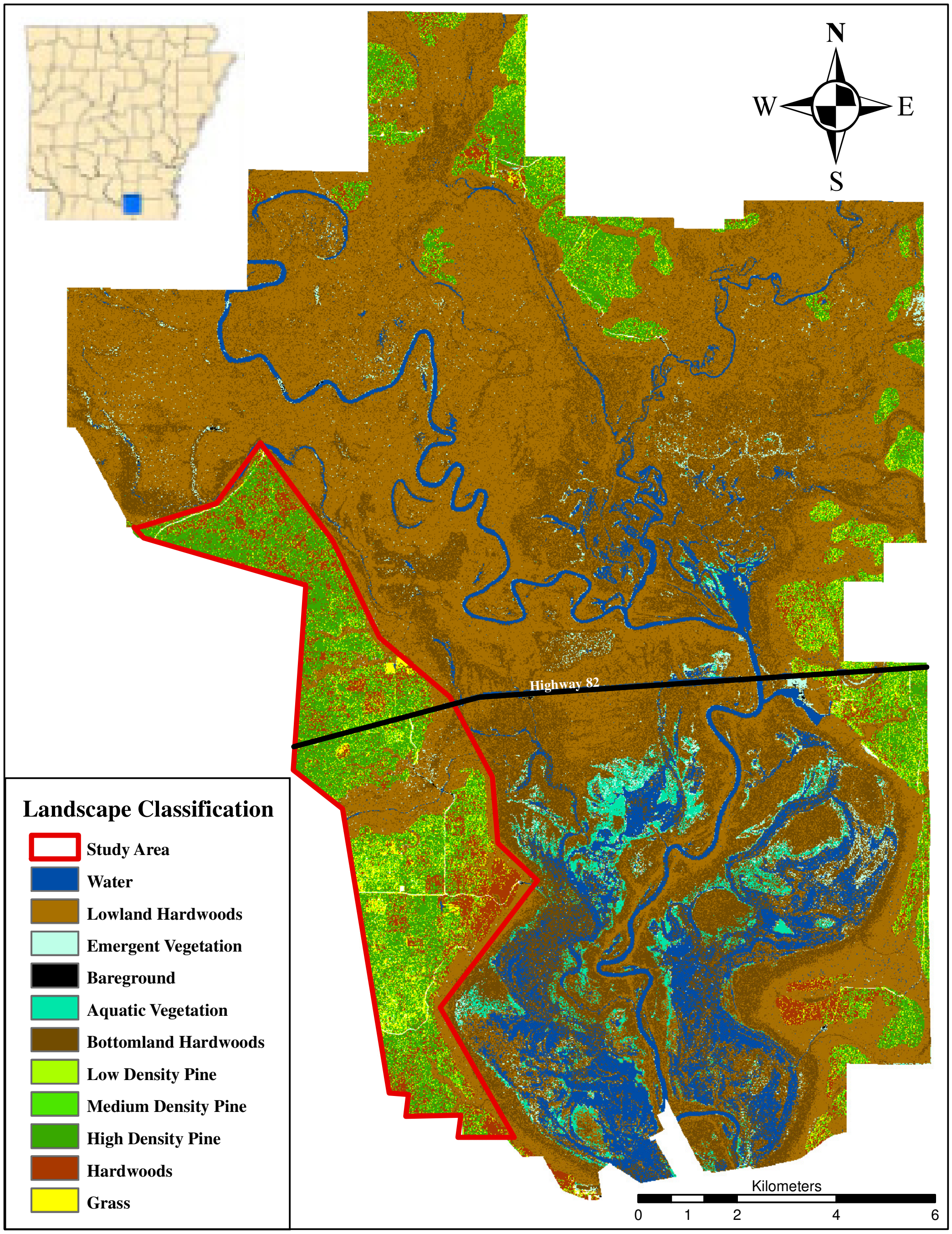

Figure 1. Study Area location on Felsenthal National Wildlife Refuge. Land cover classification utilizing 2006 color-infrared imagery and 2010 4-band imagery, both at 1-m resolution created by Weil (2012).

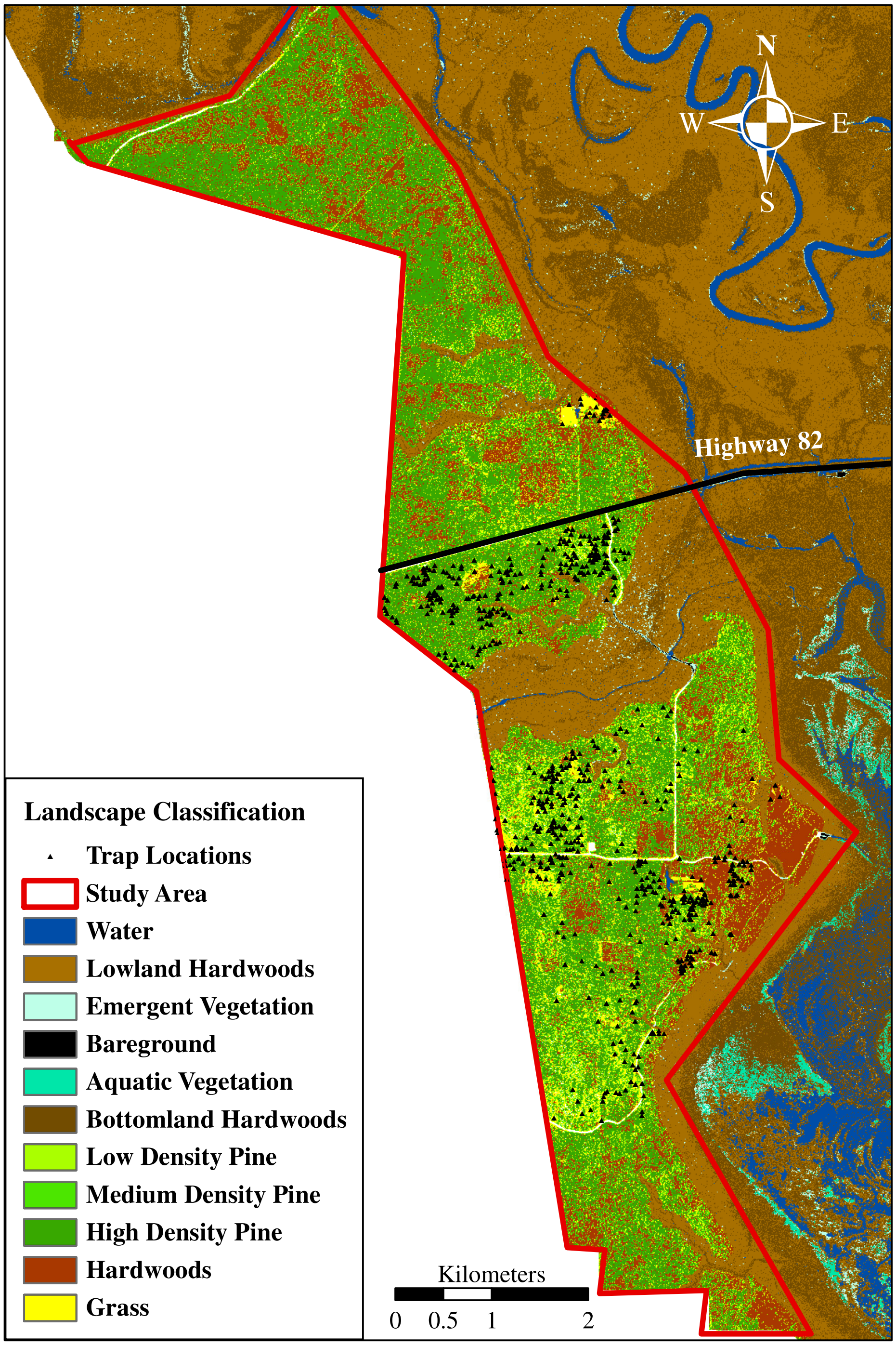

Figure 2. Trap Locations on Felsenthal National Wildlife Refuge in years 2013 and 2014. Land Cover Classification by Weil (2012).

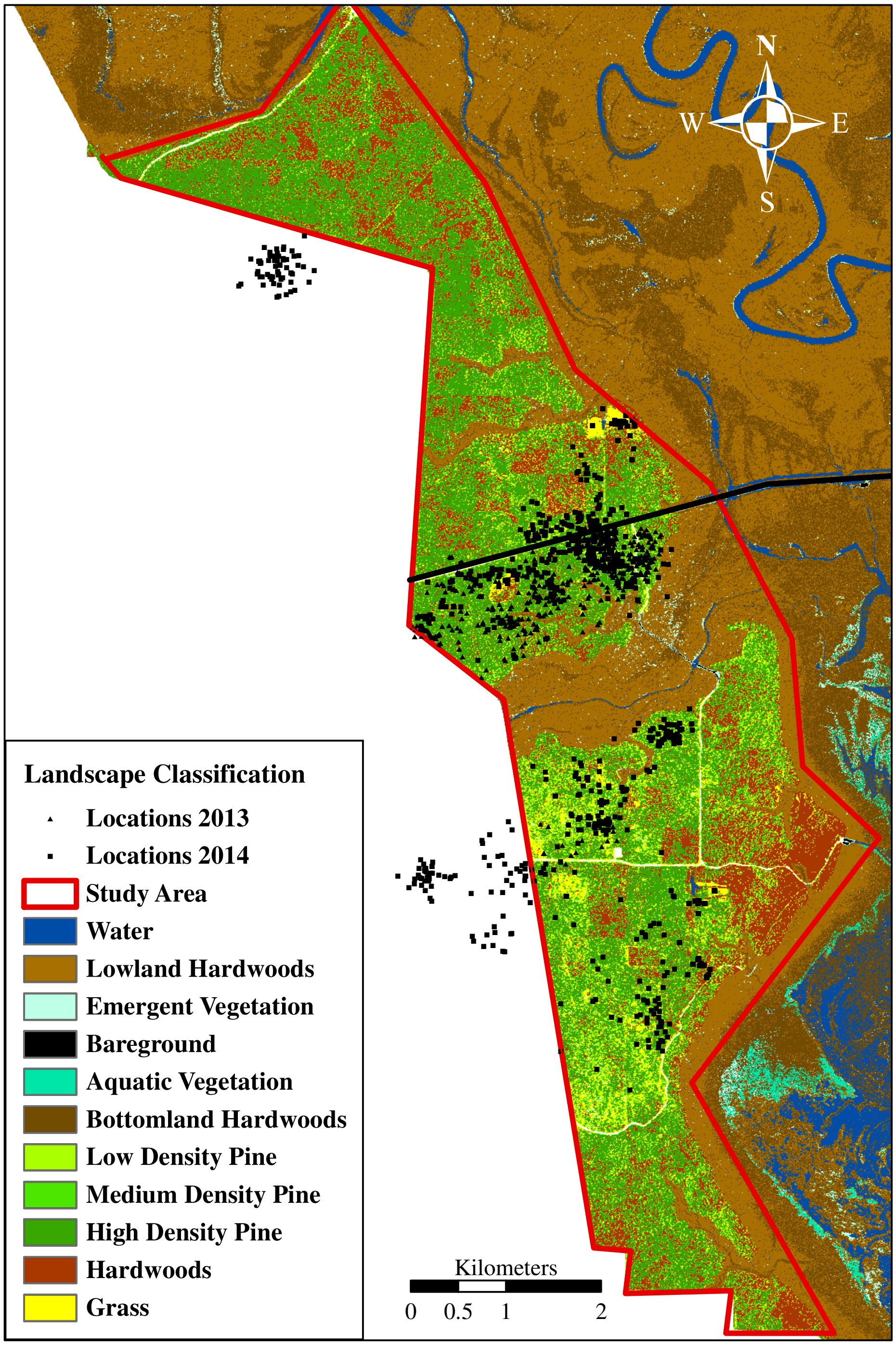

Figure 3. Telemetry Locations of wild radio-marked bobwhites on Felsenthal National Wildlife Refuge in years 2013 and 2014. Land Cover Classification by Weil (2012).

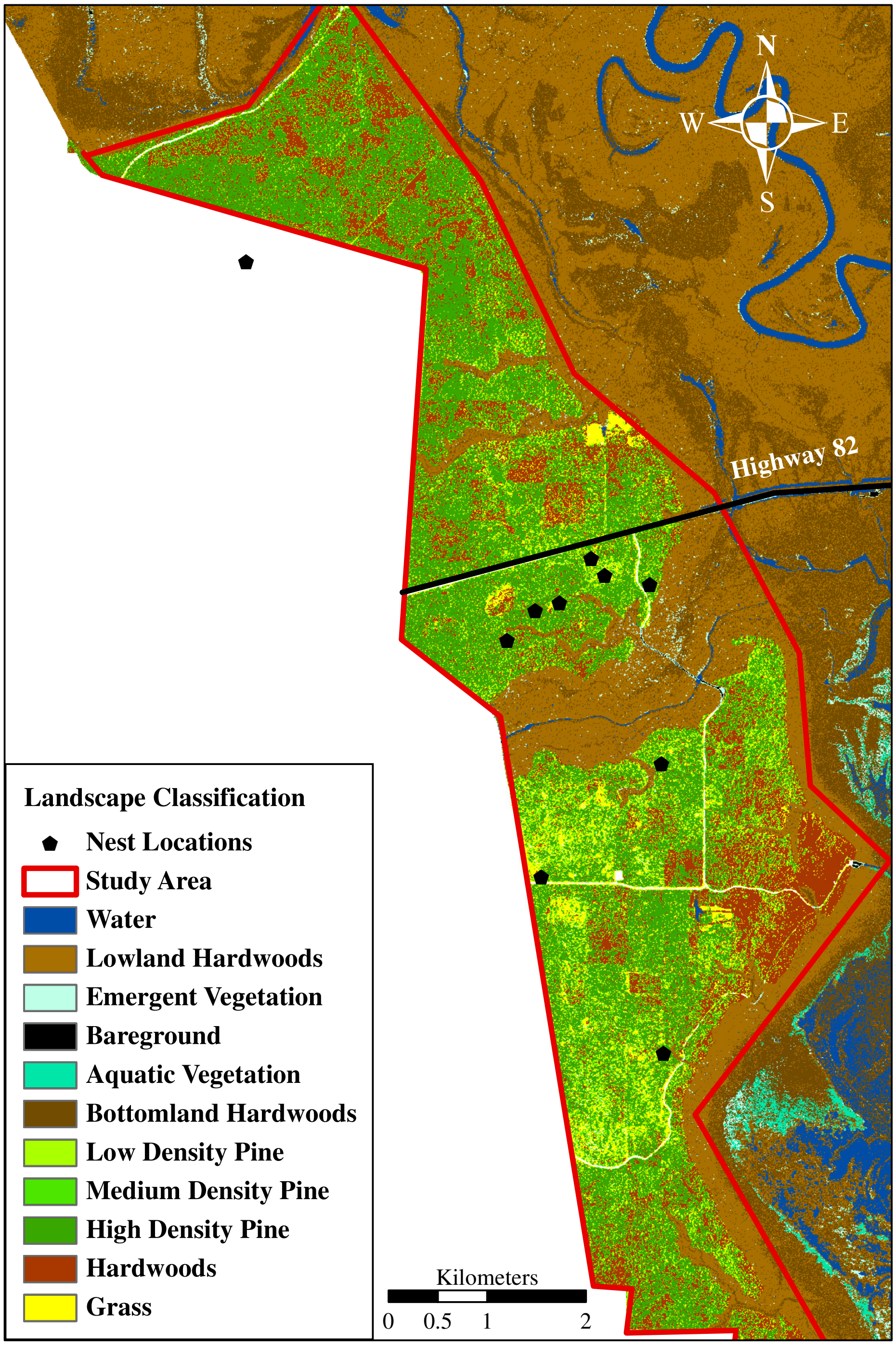

Figure 4. Nest Locations on Felsenthal National Wildlife Refuge in years 2013 and 2014. Land Cover Classification by Weil (2012).

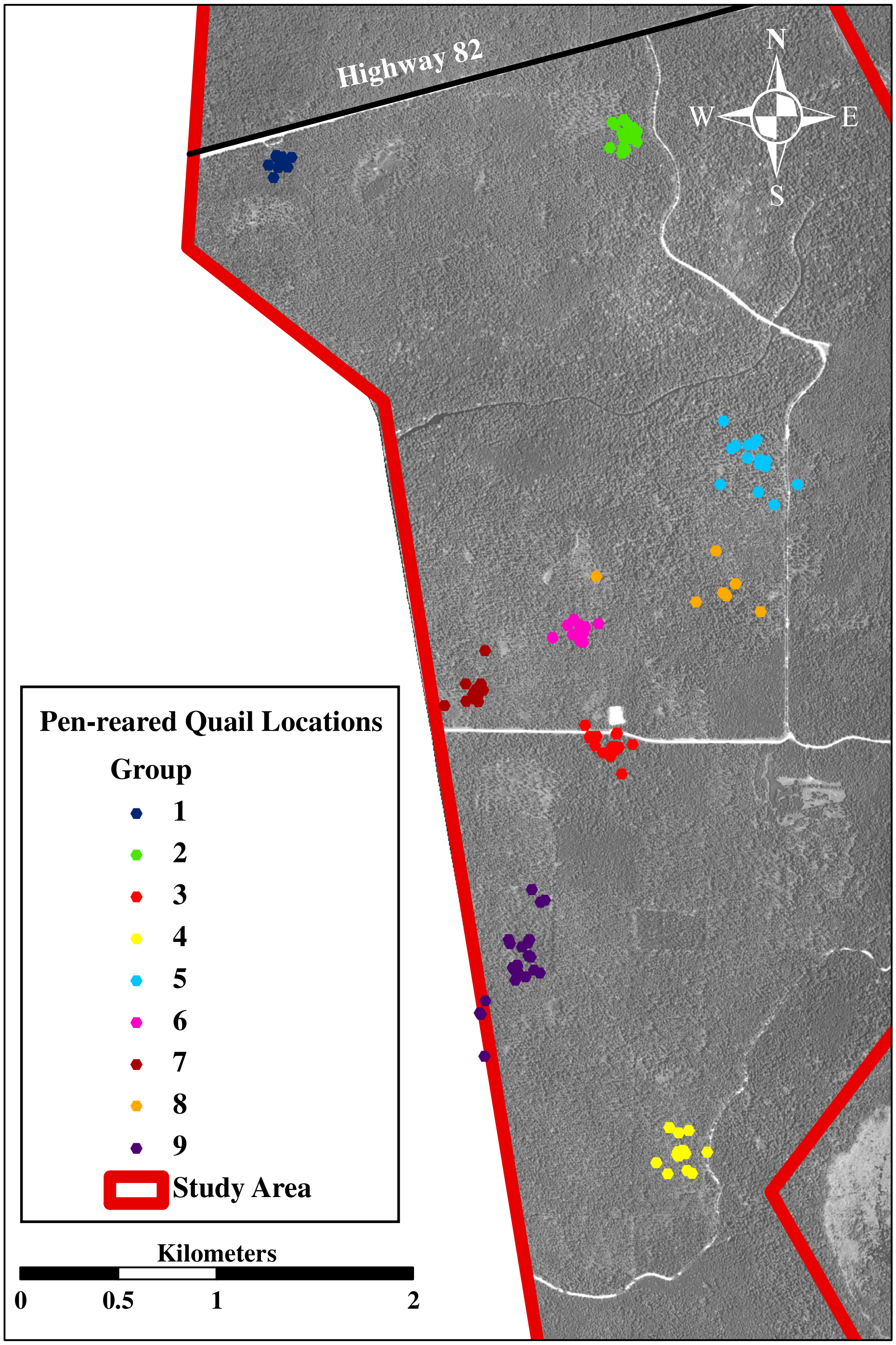

Figure 5. Telemetry Locations of radio-marked pen-reared bobwhites on Felsenthal National Wildlife Refuge in year 2014. Map by Weil (2012).

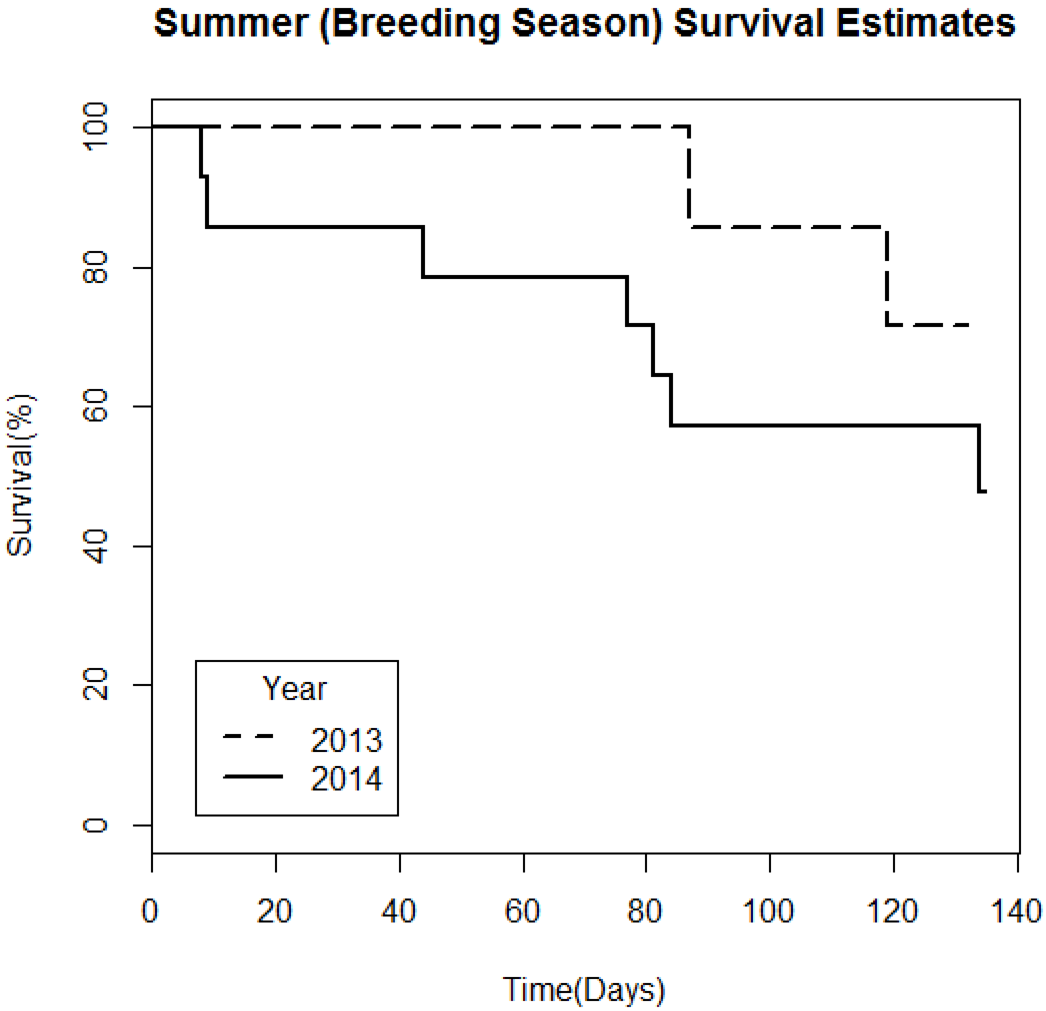

Figure 6. Kaplan Meier Breeding Season Survival Curve for years 2013 and 2014.

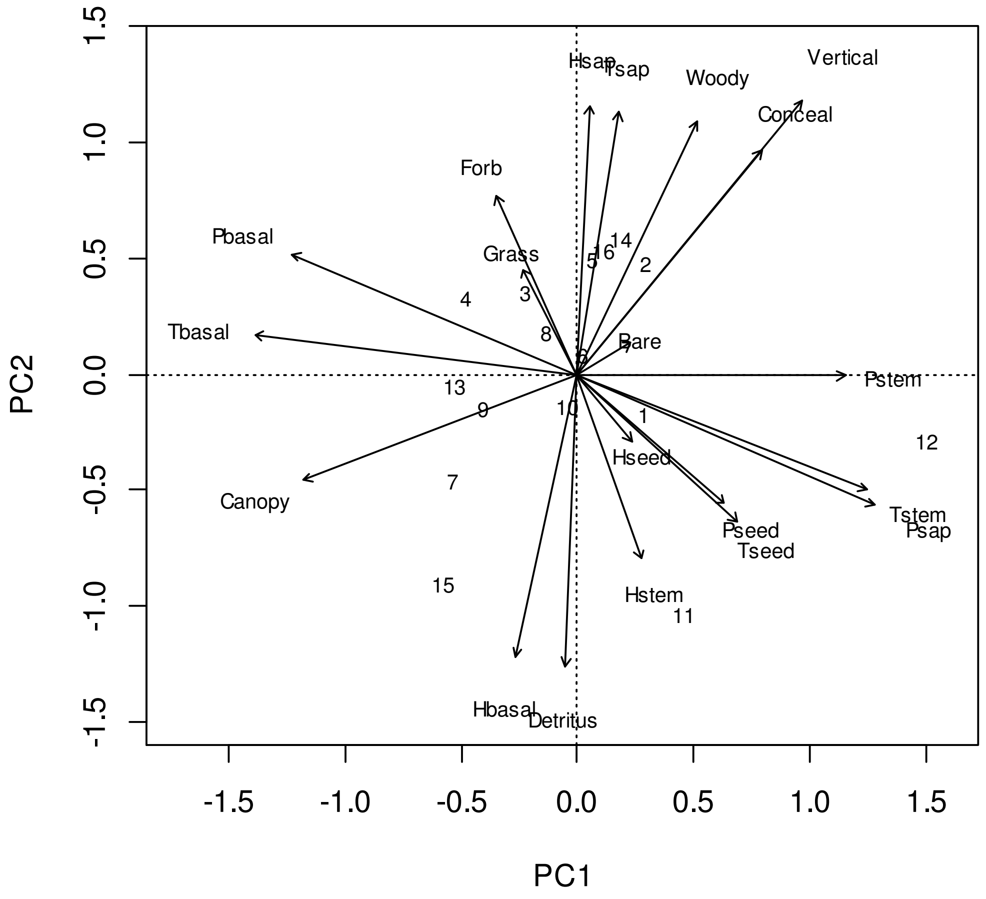

Figure 7. Distance biplot of initial principal components analysis with Scaling 1 for site and species scores. Sites scores are weighted sums of species scores and scaled proportional to eigenvalues. Species are un-scaled with weighted dispersion equal on all dimensions. Variables include Basal Area (Total, Pine, Hardwood), Stem Density (Total, Pine, Hardwood), Sapling Density (Total, Pine, Hardwood), Seedling Density (Total, Pine, Hardwood), Concealment, Vertical Structure, Percent Over-story Canopy Cover, and Ground Cover Composition (Graminoids, Forbs, Woody Plants, Bare Ground, and Detritus). Sites: 1–5 represent successful nests, sites: 6–8 represent failed nests and sites: 9–16 represent random plots.

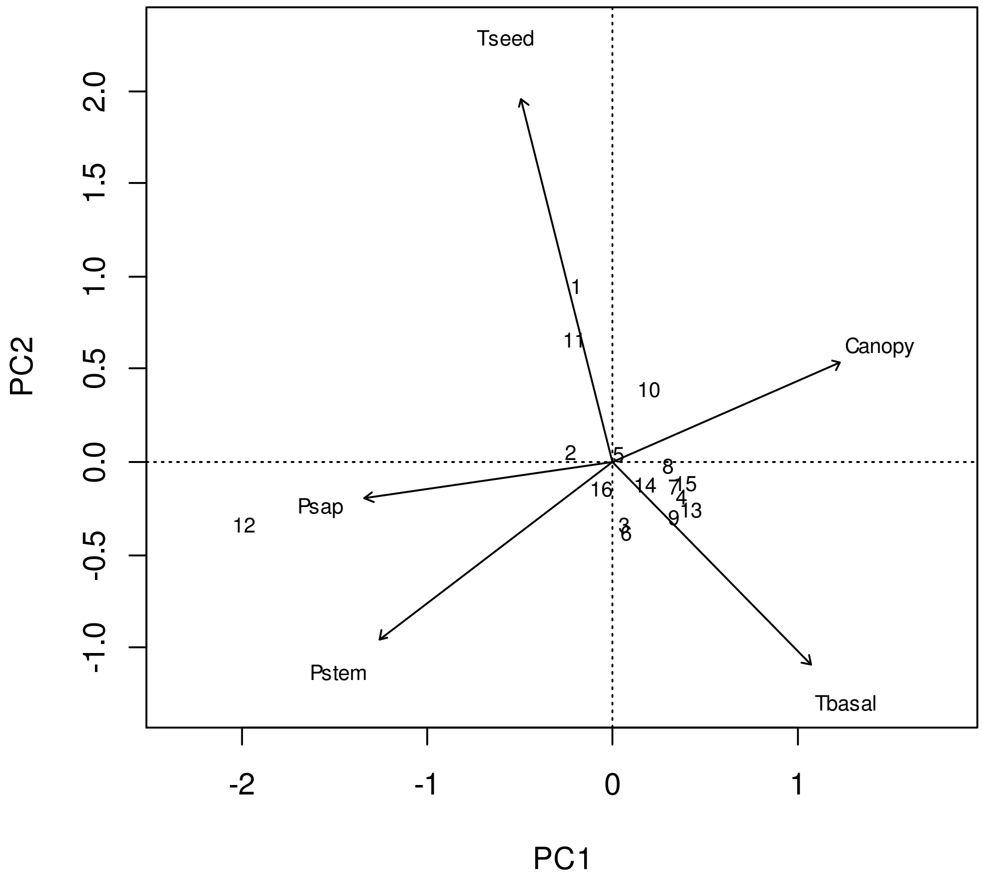

Figure 8. Distance biplot of final principal components analysis with Scaling 1 for site and species scores. Sites scores are weighted sums of species scores and scaled proportional to eigenvalues. Species are un-scaled with weighted dispersion equal on all dimensions. Variables include Total Basal Area, Total Seedling Density, Pine Stem Density, Pine Sapling Density, and Percent Over-story Canopy Cover. Sites: 1–5 represent successful nests, sites: 6–8 represent failed nests and sites: 9–16 represent random plots.