WINTER SURVIVAL AND HABITAT SELECTION OF TRANSLOCATED NORTHERN BOBWHITE IN THE NEW JERSEY PINE BARRENS

by

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Bachelor of Science in Wildlife Ecology and Conservation with Distinction

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) ecology has been well documented in its current range, but studies of reintroduced bobwhite are less common. New Jersey historically had bobwhite populations, but due to habitat loss, urbanization, and changed management techniques, they have likely gone extinct in the State. While bobwhite restoration efforts primarily focus on habitat management, translocation has been shown to be successful at restoring populations in certain circumstances. In this study, we translocated 80 birds from Georgia into managed forests in the New Jersey Pine Barrens April 2017. This was the third year of a four-year reintroduction effort. My goal was to compare bobwhite winter survival between sexes and estimate habitat selection between Oct 1- March 31, 2017–2018, on the remaining 18 that survived the breeding season. I used three-element Yagi antenna via the homing method, 2–3 times per week to estimate survival, home range, habitat use including the effects of basal area and canopy coverage density. I used Kaplan-Meier models to estimate survival [S = 0.500, (95% CI = 0.315- 0.794)]. I did not detect a difference in 182-day survival between sex (n = 18, X^2 = 0.03, P = 0.87), age (n = 18, X^2 = 1.37, P = 0.23), and site (n = 18, X^2 = 0.79, P = 0.37). Due to a low sample size, however, it is difficult to assess survival rate differences in a specific class. I assessed covey habitat selection using $\mathcal{X}^2$ tests and forage ratio statistics and found the bobwhite positively selected for grassland (n = 5, $\bar{x}$ = 6.94, SE = 5.63), managed pine ($\bar{x}$ = 3.92 SE = 2.45) and wooded wetland (n= 5, $\bar{x}$ = 12.12, SE = 11.980). Covey 95% LSCV kernel home range's

averaged 9.13 ha (+/- 1.83 SE). For fourth order habitat selection, I found no difference between selected locations and random locations for canopy coverage (t = 0.66, P = 0.75) and basal area density (t=0.44, P = 0.78). Drawing definitive conclusions from our dataset is extremely difficult due to the low sample size, but still important to show potential trends to give base information to managers and researchers who want to implement a full-scale reintroduction of the bird. Providing as much habitat as possible in the form of thinning pine, burning, and planting native early successional species to give the birds the best chance of surviving at the northern portion of their range is quintessential.

Chapter 1

INTRODUCTION

1.1 Background

Northern bobwhite (*Colinus virginianus*; hereafter "bobwhite") are one of the most studied gamebird species in the United States (Guthery 1997). During the non-breeding season, bobwhites are social birds, forming groups called coveys (Stoddard 1931) that are composed of ~12 juvenile and adult birds varying in relatedness (Williams et al. 2003, Miller et al. 2017). Coveys enhance survival by increasing the competitive ability to defend resources on territory, improving population stability through buffering environmental stress, increased feeding efficiencies, and defense against predators (Williams et al. 2003). Bobwhite are a popular hunted species and thus there are large amounts habitat management efforts and money dedicated toward their conservation. However, their numbers continue to decrease throughout most of their range due to landscape-level habitat loss occurring fasting that conservation efforts (Brennan 1991, Hernandez et al. 2013). The mid-Atlantic region, near the northeastern periphery of their historic range, has experienced population declines exceeding the national average during the twentieth century (Lohr et al. 2011, Williams et al. 2012). In New Jersey, the rapid decline of bobwhite is largely attributed to loss and fragmentation of habitat resulting from urban/suburban sprawl, improved farming techniques, and the states' forest management practices (Chandra and Herrighty 2009, Lohr et al. 2011). Ultimately, the species has become functionally extirpated in New Jersey, with recreational harvest and pen-release activities halted while a state recovery plan is implemented. Due to the decline in neighboring potential source populations (e.g., Pennsylvania and Delaware; Sauer et al. 2017), the geographic isolation of New Jersey, and the poor dispersal capabilities of bobwhite, habitat improvement alone will not recover the species within the state. Consequently, translocation has become a key component of bobwhite recovery plans for New Jersey and other mid-Atlantic states.

Translocation describes the capture and movement of wild animals from one site to another and is a promising population restoration technique for bobwhite; however, efforts in the past have reported mixed results and more research is needed to determine what factors limit success (Martin et al. 2017). In the Southeastern United States, translocated bobwhites have shown high site fidelity and no difference in survival between resident and translocated birds (Terhune et al. 2006, 2010). Several translocation projects in the Southeast have documented positive population responses at donor sites following release (Sisson et al. 2017). In contrast, research in Texas reported that survival and reproduction of translocated bobwhites was high, but there was no positive population response in subsequent years (Scott et al. 2013, Downey et al. 2017). The current state-of-knowledge on translocation is limited to a few studies, primarily in southern regions of the United States. One study in Ohio attempted a large-scale translocation effort; however, they found little or no evidence of sustained populations existing after seven years (Wiley and Stricker 2017). No research has been conducted in northern latitudes of the Atlantic coast and therefore basic information regarding survival rates and habitat use patterns for this region are lacking. This knowledge gap must be filled through field research studies in an effort to further develop bobwhite translocation practices and to achieve national/regional recovery objectives (Sisson et al 2017).

It is widely recognized that a critical component of any successful translocation is that release sites must have large contiguous tracts of bobwhite habitat (Martin et al. 2017). Because bobwhite are primarily ground-dwelling, ground cover structure and species composition are important considerations. Ground cover vegetation provides thermal protection, concealment, forage, and nesting substrate for bobwhites (Stoddard 1931, Rosene 1969). Along the Atlantic coastal plain, bobwhite are typically associated with low basal area (e.g., 40-60 ft^2), open canopy forests where sunlight can reach the ground level to promote grasses and forbes that in turn provide high nutrient and protein foods as well as nesting and escape cover (Palmer and Sisson 2017). Fires are a fundamental ecological driver maintaining open canopy forests and thus influence groundcover composition. Additionally, grasslands and shrublands are often similar in their groundcover makeup to open canopy pine forests on the Atlantic coastal plain and provide usable space for bobwhites.

Unfortunately, such forest conditions have become increasingly scarce in the eastern United States as land use changes over the past century have shifted toward more profitable alternatives, such as agriculture, even-aged pine monocultures, or climax forests (Brennan 1991). Consequently, much of the historic bobwhite landscape has been altered to such a degree that active habitat management is required to recover populations. Habitat management in pine upland systems typically involves stand thinning, clear-cutting, and/or prescribed fire (McComb 2008).

To recover bobwhite in an economically efficient manner, prioritization must occur based on an area's potential for recovery given habitat management (Morgan et al. 2017). The National Bobwhite Conservation Initiative (NBCI) produced such a prioritization, highlighting areas with varying degrees of potential for recovery (Morgan et al. 2017). In New Jersey, the Pine Barrens were identified as a focal area for bobwhite recovery because it contains large contiguous tracts of public and privately-owned land and once supported populations of bobwhite (Leck 1998). Reintroduction of this species to the New Jersey Pine Barrens should be guided by the most current and accurate information available so that it may serve as a case study for future reintroduction efforts in the mid-Atlantic region and nationally. Thus it is the goals of this research project to 1) estimate winter (1 October 2017 – 31 March 2018; 181-day) survival rates of translocated northern bobwhite at two New Jersey release sites including evaluation of sex, site, and age effects, and 2) estimate northern bobwhite covey home range size and habitat selection during winter 2017, including comparison of landcover type at covey use points to available landcover within the study area (3^{rd} order) and comparison of canopy closure and basal area at covey use points to unused points (4^{th} order).

Chapter 2

STUDY AREA

The New Jersey Pine Barrens covers just under 567,000 ha of flat, acidic, and sterile soils which constitute a major part of the Outer Coastal Plain of the Atlantic Coastal Plain in South-Central New Jersey (Boyd 1991)**.** The soil, developed from sandy, sedimentary deposits, are unusually porous and acidic (pH ranging from 3.6–5.5), leaving the surface very dry and leached of nutrients, encouraging species that favor acidic wetland and forest systems. Within the Pine Barrens, over 80,000 ha of bog and swamp lands are scattered throughout the landscape. As a result, much of these areas have been cleared for commercial cranberry production (Boyd 1991). The climate is continental in nature, distinguished by cold winters and hot summers, so the temperature can range from below freezing in the winter to nearly 38° C at peak summer times (Boyd 1991).

This research was conducted on private property located within Burlington County, New Jersey and the surrounding public lands. The property is a cranberry farm (Pine Island Cranberry Company, LLC.) and is the largest privately-owned tract in the state (~6,000 ha). Additionally, it is centrally located within the New Jersey Pine Barrens. Pine Island has been operating under a state-approved forestry management plan since 2005, which aims to improve watershed health through timber thinning, clear cutting, and prescribed burning. Upland forest dominates the study sites, with pitch pine (*Pinus rigida*), short leaf pine (*Pinus echinata*), and scrub oak (*Quercus ilicifolia*) dominating the overstory. The understory consists of various shrub and fern species including black huckleberry (*Gaylussacia baccata*), lowbush blueberry (*Vaccinium angustifolium*), bracken fern (*Pteridium aquilinum latiusculum*), and teaberry (*Gaultheria procumbens*) (Boyd 1991). Annual and perennial grass species in the understory, where higher sunlight reaches the forest floor, include panic grasses (*Panicum spp.*), indian grass (*Sorghastrum nutans*), and little bluestem (*Schizachyrium scoparium*) (Boyd 1991). Hardwood drains and Atlantic white cedar (*Chamaecyparis thyoides*) swamps bisect the upland forests.

There are two study sites on the property where bobwhites were released in March 2017, referred to as Home Farm (HF) and Sim Place (SP; Figure 1). These sites are ~8 km apart, separated by Penn State Forest. HF is predominantly dense stands of immature pitch pine. Within this are several large dispersed-retention cuts with planted short leaf and pitch pine regeneration varying in age from 10–12 years. Additionally, there are production blueberry fields. Atlantic white cedar swamps border the site to the west, cranberry bogs border the south, and Penn State Forest borders the east. SP is centered around a ~5 ha grassland, dominated by warm season grasses, and fringed by young natural pine regeneration. To the north is expansive densely stocked pine-oak upland forest. Cranberry bogs dominate the site reducing dispersal to the south, east, and west.

CHAPTER 3

METHODS

3.1 Translocation

Bobwhites were captured between 24–26 March 2017 at anonymous privately-owned source sites in southwest Georgia using baited funnel traps (Stoddard 1931). Birds were handled by technicians to determine age, sex, and weight; contour feathers were collected for disease testing prior to translocation. Those weighing >150 g were collared with pennant-style VHF radio transmitter (7.5 g) and banded with a uniquely-numbered aluminum leg band less than 24 hours before translocation. A total of 80 bobwhite (40 male and 40 female) were released in New Jersey between 26–28 March 2017. Of the original 80 birds released in the Spring, 18 bobwhites with collars (11 male, 7 female) survived to the beginning of the winter study season (1 October 2017).

3.2 Radio Telemetry

Between 1 October 2017 – 31 March 2018, I located individuals 2–3 times per week using a VHF telemetry receiver and three-element Yagi antenna (Advanced Telemetry Systems, Inc., Isanti, MN) via the homing method (White and Garrot 1990). I approached bobwhites to 25–50 m to limit location error and marked on a customized smart-phone application (Avenza PDF maps) with high-resolution spatially referenced (UTM zone 18N) aerial imagery. Additional, I recorded observational data for each location, including understory density (heavy, intermediate, sparse, none), bird activity (active, inactive), and other associated birds (i.e. covey membership). If a mortality was suspected, I approached the location for evaluation of the mortality cause as determined using diagnostic signs (following Dumke et al. 1973). I eliminated locations of birds that were found depredated from data analysis (e.g., home range estimation) because of the possibility that predators moved the bird or transmitter from the kill sight (Terhune et al. 2006). Location data was uploaded as comma-separated value documents for analysis.

3.3 Microhabitat Data Collection

For a subset (75%) of covey locations, I collected microhabitat information to compare use points and paired non-use points. Basal area and canopy closure were targeted, as these variables are known to influence bobwhite habitat use and can be readily manipulated through forest management. To avoid affecting bobwhite behavior, I only collected these data once coveys moved more than 100 m from the location. I collected microhabitat measurements within a month of covey use; because this study occurred during the dormant season, it is unlikely that basal area and canopy closure varied to any significant degree throughout the season (i.e. between time of use and subsequent measurement). I collected basal area (UNITS?) density using a Jim-gem factor 10 prism (Doggett and Locher 2018) and canopy closure (UNITS?) via a convex spherical densitometer (Forestry Suppliers, Inc., Jackson, MS, USA), averaging four measurements taken in each cardinal direction. I collected basal area and canopy closure data at the point of the covey, as well as a random non-use point 125 m away within the same patch. I determined non-use points in the field using a randomly-generated azimuth from each use point, and another azimuth was selected if the first occurred within non-habitat (e.g., open water, paved road, etc.).

3.4 Data Analyses

I estimated winter season (182-day, 1 October 2017 – 31 March 2018) survival using the package SURVIVAL (Therneau et al. 2018) in R (R development Core Team 2018). This package uses a right-truncated time-to-event approach for survival estimation in which the event is either bird mortality or censor. I assessed sex, site, and age as categorical variables potentially affecting survival via the Kaplan-Meier model. The package SURVMINER (Kassambara and Kosinski 2018) in R was used to visualize the survival probability over the winter season, due to its graphical flexibility and additional built-in diagnostics.

I determined covey home ranges using the package ADEHABITATHR in R (Calenge 2015). I defined coveys as unique groups of bobwhites that remained together for >3 consecutive tracking days (Lohr et al. 2011). I excluded coveys with <25 locations from analysis to reduce estimation bias, as is typical with bobwhite studies (Terhune et al. 2010). I excluded points at which a mortality occurred. For all coveys, a 95% kernel home range was calculated (Worton 1989, White and Garrott 1990) using least square cross validation procedure to estimate the smoothing parameter (Seaman and Powell 1996). Due to the irregular sampling frequency of covey locations, incorporating temporal autocorrelation (e.g. autocorrelated KDE, Fleming et al. 2018) into analyses biased estimates and were therefore not used.

Covey third-order habitat selection (sensu Johnson 1980) was determined by comparing the landcover types at use locations to the aerial proportion of landcover types over the entire study area using a GIS (ArcMap 10; ESRI, Inc., Redlands, CA, USA). The entire study area was defined by the minimum convex polygon encompassing all covey locations. I identified individual coveys and available resources at the population level, thus adopting Manley et al. (2002)'s study design II, sampling protocol A. Censusing available landcover involved digitizing predetermined landcover categories over high-resolution orthoimagery within the study area and subsequent ground-truthing. I defined the following 8 landcover categories based on the criteria described herein: 1) pine woods, defined as pine-dominated upland within which no timber operations occurred within the preceding 10 years; 2) managed pine, defined as pine-dominated upland in which pine thinning or clearing occurred within the preceding 10 years; 3) grassland/cropland, characteristically dominated by early seral stage herbaceous vegetation, warm season grasses, or perennial crops (e.g., blueberry field); 4) wooded wetland, defined as wetlands dominated by hardwoods; 5) herbaceous wetland, defined as wetland dominated by herbaceous vegetation; 6) cedar woods, defined as wetland dominated by Atlantic white cedar; 7) cut cedar, defined as cedar woods that have been clear cut during commercial harvest; 8) barren land, defined as areas dominated by exposed substrate (e.g., sandpits).

To calculate third order habitat (i.e. landcover type) selection, I used chi-squared tests and selection ratios. These multiple complementary metrics were used to determine if selection of landcover types was occurring and whether or not selection differed among coveys. Chi-squared tests will assess deviations from expected values for covey landcover selection based on the assumption of no error in sampling either used or available resources. First, I tested the null hypothesis that coveys used landcover types in the same proportions to each other, independent of whether or not selection was occurring, following:

$$X_{L1^2} = 2\sum_{j=1}^{n}\ \sum_{i=1}^{I} u_{ij}\, log_e\{u_{\underline{ij}} E(u_{ij})\}$$

where u_{ij} is the frequency of use by covey *i* of landcover type *j* and $E(u_{ij}) = u_{i+}u_{+j}/u_{++}$ is the expected frequency of use for landcover type *i* by covey *j* if that covey selects landcover in the same way as the other coveys (Manly et al. 2002). Second, I tested if individual coveys used landcover types in proportion to availability, following:

$$X_{L2^2} = 2\sum_{j=1}^{n}\ \sum_{i=1}^{I} u_{ij}\, log_e\{u_{\underline{ij}} E(u_{ij})\}$$

where $E(u_{ij}) = \pi_i u_{+j}$, π_i is the known proportion of type i habitat available to the population, in this case is the expected frequency of use for landcover type *i* by covey *j* if use is proportional to availability (Manly et al. 2002). These chi-squared test statistics were assessed at a significance level of α = 0.05 (Manly et al. 2002).

I calculated the selection ratio statistic ($\hat{w}_{ij}$, Savage 1931, Manly et al. 2002) for each covey (*i*) and each landcover type (*j*), following:

$$\hat{w}_{ij} = (u_{ij} / u_{+j}) / \pi_i$$

where u_{+j} is the frequency of use of all landcover types by covey *j* and π_i is the proportion of available area of landcover type *i*. This statistic ranges from 0-1 for negative selection, and 1 to ∞ for positive selection (Ivlev 1961, Jacobs 1974). This was the baseline statistic used for selection ratios; moreover, I have used a modified version to calculate the ratios for the j_{th} covey for the type i_{th} landcover type based on my study design. When 95% Bonferroni confidence limits for a selection ratio did not overlap with 1, it was concluded to be significant (Manly et al. 2002).

To determine fourth-order habitat selection, I compared basal area and canopy coverage at use and paired non-use points within entire home ranges, using a paired t-test (Microsoft Excel, α = 0.05). Additionally, I further examined whether basal area and canopy coverage difference between used and random points within each habitat type (Cedar Woods, Grassland, Managed Pine, Unmanaged Pine, and Wet Woody) within a home range (paired t-test, α = 0.05).

Chapter 4

RESULTS

Winter (181-day) survival was 0.500 (95% CI = 0.315- 0.794, Fig 3*)*. There were 9 mortalities and no birds had to be censored due to collar failure or loss. Five of the deaths were confirmed to be killed by a mammal, 2 were from exposure, 1 from a raptor, and 1 with an unknown cause of mortality. Three of the deaths were females, 6 were males, 4 were adults, and 5 were juveniles at time of release. During a short period between 30 November 2017 – 30 December 2017, there were 5 deaths, 28% of the original population. There was no difference in 182-day survival between sex ($\chi^2 = 0.03$, $P = 0.87$), age ($\chi^2 = 1.37$, $P = 0.23$), and site ($\chi^2 = 0.79$, $P = 0.37$); however, a low sample size may have limited my power to detect differences between these groups.

I tracked five unique coveys, each established prior to the initiation of the winter study period (1 October 2017). Covey size ranged from 1–8 individuals; however, two coveys coalesced on one occasion, creating a group of 10 individuals that then broke up within the week. Two coveys were within Home Farm and 3 were within Sim Place (Fig. 4). I excluded one covey (covey 1) from home range calculation because it had <25 locations. Mean 95% kernel density covey home range size was 9.13 ha (range = 4.06–12.50 ha, n = 4, Fig. 5-9).

Individual coveys used landcover types (third-order) at a frequency different than expected based on availability (χ^2_{35}= 618.3, $P < 0.001$) (Fig.10). Additionally, use of landcover types differed among coveys (χ^2_{28} = 331.4, $P < 0.001$). Specifically, bobwhite selected for managed pine and grassland/cropland landcover types more than expected at random, while wooded wetland, herbaceous wetland, cedar woods, cut cedar, and barren landcover types were selected less than expected based on availability over the study area (Table 2). Bobwhite selected for pine woods equal to random use.

Fourth order canopy coverage did not affect selected (49.1%) versus random (47.5%) points (t = 0.66, P = 0.75). Fourth order basal density did not affect used (54.7 ft^2/acre) versus random (58.9 ft^2/acre) points (t = 0.44, P = 0.78, Table 3). Additionally, after subdividing the habitat types for canopy coverage: cedar woods (t = 0.14, P = 1.56), grassland (t = 1.92, P = 0.06), managed pine (t = 0.50, P = 0.62), unmanaged pine (t = 0.50, P = 0.57), and wet woody (t = 0.36, P = 0.72), I found no significant variation in use versus non-use points and 95% confidence. For basal area density of each habitat type: cedar woods (t = 1.04, P = 0.31), grassland (t = 1.53, P = 0.14), managed pine (t = 0.70, P = 0.48), unmanaged pine (t = 0.90, P = 0.36), wet woody (t = 0.67, P = 0.51), I found no significant variation (Table 3).

Chapter 5

DISCUSSION

My research goal was to determine survival rates and habitat use of translocated northern bobwhite quail in the winter months to determine if the methodology would be a viable population recovery tool for New Jersey extirpated bobwhite. Winter survival rates can be extremely variable (0.02–0.73, Sandercock 2008) because of factors including predation, disease, malnutrition, harvest, and exposure to the elements (Holt et al. 2009). Extreme winter weather (e.g., snow accumulation) has been shown to influence bobwhite survival in northern latitudes (Janke et al. 2017) and may be a limiting factor in population persistence in New Jersey (Williams et al. 2012). Winter survival has been shown to be the most influential demographic parameter in its effect on bobwhite population growth (Sandercock et al. 2008, Williams et al. 2012). I observed similar survival rates (0.5) to research conducted in the Southeastern Coastal Plain (e.g. Sisson et al. 2009 [0.541], Terhune et al. 2009 [0.469], and Terhune et al. 2007 [0.240-0.730]) over the non-breeding season. This is interesting to see because even in colder winter climates, the bobwhites had similar non-breeding season survival rates as more robust populations in the Southeast, suggesting the potential for the bobwhite in the pinelands. Unfortunately, with only 18 birds total, it was difficult to provide robust results regarding subcategories of survival including age, sex, and site differences. Never-the-less, my overall estimates of adult winter survival rate following translocation to New Jersey provide an important demographic rate targeted in this research.

Habitat selection in pine-savanna ecosystems is well documented during the non-breeding season (Oct-Mar), where early successional and heavily managed areas dominate preference. Much of this selection is directly dependent on frequency, spatial extent, and seasonality of disturbance (Jones et al. 2010, McGrath et al. 2017). Studies on selection in the northern portion of their range during breeding season have been researched (Collins et al. 2009); however, breeding season versus non-breeding season selection is vastly different due to variation in factors such as, predation pressure, cover, nesting requirements, brood-rearing, covey dynamics, etc. (Terhune et al.2007). Winter habitat selection in northern latitudes has been well documented, but mostly on agricultural lands. Grassland and forest ecosystems have been documented as habitats coveys most likely select in the winter months in New Jersey (Lohr et al. 2011). Therefore, habitat selection of coveys within a heterogeneous landscape is important to advancing our understanding of bobwhite winter ecology in New Jersey.

For my covey home range analysis, the LSCV 95% kernel density estimation (average = 9.13 ha) was much smaller than other studies (e.g. Lohr et.al 2009, Janke and Gates 2013, range = 26.1–29.2 ha) focused around agricultural based habitats. Within these agricultural based systems, home ranges can increase as quail actively use tree/shrub/road corridors which do not as readily exist in a monoculture pine system. Pine forest habitat studies seem to have a large range in non-breeding season home ranges like Dogget and Locher 2018 where the mean was 63.9 ha, or McGrath et al. 2017, where the mean was 16.1 ha, similar to our 9.1 average. In a monoculture forest, it is likely coveys find all their daily resource needs in a relatively small area versus needing to travel via corridors to different habitat types to meet specific resource needs (Parnell et al. 2002, Sisson et al. 2000). It is possible that in northern latitudes where winter weather conditions may be more extreme, more confined home ranges in a monoculture environment may prove to be an advantage (assuming energy expenditure and predator avoidance are met).

Further examining habitat selection within the covey home ranges indicated preference for sub-habitat types within the study areas. The habitat types that coveys showed the greatest selection preference for were managed pine and grassland (Figure 10). For example, Covey 5 (Table 1) went back and forth between an open grassland mixed with shrub-scrub, and an area with early successional grasses and woody vegetation as the understory, with scattered pine trees moving in from the adjacent forest. Past research has documented that active management, promoting early successional species to grow in grasslands and managed pine forest, provides habitat for northern bobwhite (Cram et al. 2002, Guthery et al. 2002, Ransom et al. 2008). Further it supports the preference for early successional grass and scrub-shrub in New Jersey, similar to the findings of Lohr (2009).

Interesting, one of the 5 coveys showed preference for the wooded wetland habitat type. What is interesting is that this covey had unmanaged pine woods within 100 yards on most occasions and they still selected the wooded wetland habitat. While this is an unusual habitat preference, perhaps the shrub and wet woody area available for the covey provided the best opportunity for cover against predation and the elements available to them (Janke 2011, Unger et al. 2015).

Despite the macro habitat preferences observed, I did not find any microhabitat preference for a different canopy coverage or basal density against random points (Figure 11). However, this was only because I defined $\alpha = 0.05$. This was similar to the results of Doggett and Locher (2018) and Unger et al. (2015); however, our vegetation data was not collected at as fine of a scale. Additionally, studies in the Southeast have shown that a basal area density and bobwhite population densities have an inverse relationship (Little et al. 2009). This could be attributed to the higher volume of light reaching the ground, promoting early successional grasses to grow (Engstrom and Palmer 2005). Our data might not have shown significant trends, but the early successional habitat types in regard to basal area density and canopy coverage displayed the largest variation.

The data I collected in the Pine Barrens of New Jersey, while small in sample size, still provides valuable preliminary knowledge about bobwhite translocation ecology at the northern portion of their range. The New Jersey Pine Barrens have the potential to be a fruitful habitat for northern bobwhite quail restoration; however, our results indicate the need for forest management to improve population stability. Bobwhite rely heavily on early successional habitat, and by preventing fire and unnaturally burning in the winter seasons will not give the annual and perennial grass, forb, and woody species enough time to grow. Another important aspect of quail habitat is the need for pine forests thinning, as New Jersey pine forests provide an unnatural monoculture of climax species where the understory has difficulty attaining efficient amounts of light. Because the New Jersey Pine Barrens have largely had little forest thinning and fire management over the last 30 years, and I found translocated bobwhite selected for managed forests, I recommend public and private lands engage in more habitat management to increase bobwhite restoration success.

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Table 1. Use of landcover types by northern bobwhite coveys (n = 5) in the New Jersey Pine Barrens during winter (1 October 2017 - 31 March 2018). Available proportion calculated as the aerial proportion of landcover types over study area.

Landcover	Available proportion	Use of landcover by covey					
		1	2	3	4	5	Total
Pine woods	0.408	14	4	24	57	8	107
Managed pine	0.068	0	49	0	2	31	82
Grassland/cropland	0.012	0	4	0	0	23	27
Wooded wetland	0.222	1	2	14	0	2	19
Herbaceous wetland	0.035	1	0	0	0	0	1
Cedar woods	0.190	0	0	17	0	0	17
Cut cedar	0.020	0	0	0	0	0	0
Barren land	0.045	0	0	1	0	2	3
Total	1.000	16	59	56	59	66	256

Table 2. Selection of landcover types by northern bobwhite coveys (n = 5) in the New Jersey Pine Barrens during winter (1 October 2017 - 31 March 2018). Observed frequency of use determined from radio telemetry location data and expected frequencies calculated using aerial proportion of landcover types over study area.

Landcover	Observed frequency of use	Expected frequency of use	$\hat{w}_i$	Bonferroni confidence limits	
				Lower	Upper
Pine woods	107	104.45	1.02	0.84	1.21
Managed pine[+]	82	17.41	4.71	3.64	5.78
Grassland/cropland[+]	27	3.07	8.79	4.79	12.79
Wooded wetland[-]	19	56.83	0.33	0.15	0.52
Herbaceous wetland[-]	1	8.96	0.11	0.00	0.39
Cedar woods[-]	17	48.64	0.35	0.15	0.55
Cut cedar[-]	0	5.12	0.00	0.00	0.00
Barren land[-]	3	11.52	0.26	0.00	0.63

[+] Bonferroni confidence limits greater than 1 with no overlap
[-] Bonferroni confidence limits greater than 1 with no overlap

Table 3. Mean (SE) of basal area and canopy coverage across all habitats within home ranges from points coveys were fixed at versus a random point 125 m away during winter season (1 October 2017 – 31 March 2018).

		Basal Area (ft^2/acre)		Canopy coverage (%)	
Habitat type	N	Selected Mean (SE)	Random Mean (SE)	Selected Mean (SE)	Random Mean (SE)
Cedar Woods	13	149.0 (12.4)	130.0 (14.3)	94.8 (0.8)	89.8 (3.1)
Grassland	24	9.0 (2.8)	19.1 (5.5)	7.3 (2.7)	21.6 (6.9)
Managed pine	59	15.8 (4.2)	14.9 (5.3)	19.2 (4.4)	14.9 (3.6)
Unmanaged pine	81	63.5 (6.2)	77.7 (8.2)	63.7 (5.1)	64.5 (5.3)
Wet woody	15	112.0 (12.6)	127.0 (18.9)	83.5 (5.2)	80.4 (7.0)
Combined habitat types within home ranges	192	54.7 (0.4)	58.9 (0.4)	47.5 (2.6)	49.1 (2.7)

Figure 1. Location of study sites (Home Farm and Sim Place) within the New Jersey Pine Barrens.

Figure 2. Winter (1 October 2017 - 31 March 2018) survival curves for translocated northern bobwhite in the New Jersey Pine Barrens. Sex (male vs. female), site (HF vs. SP), and age at release (adult vs. juvenile) compared over the 181-day exposure period.

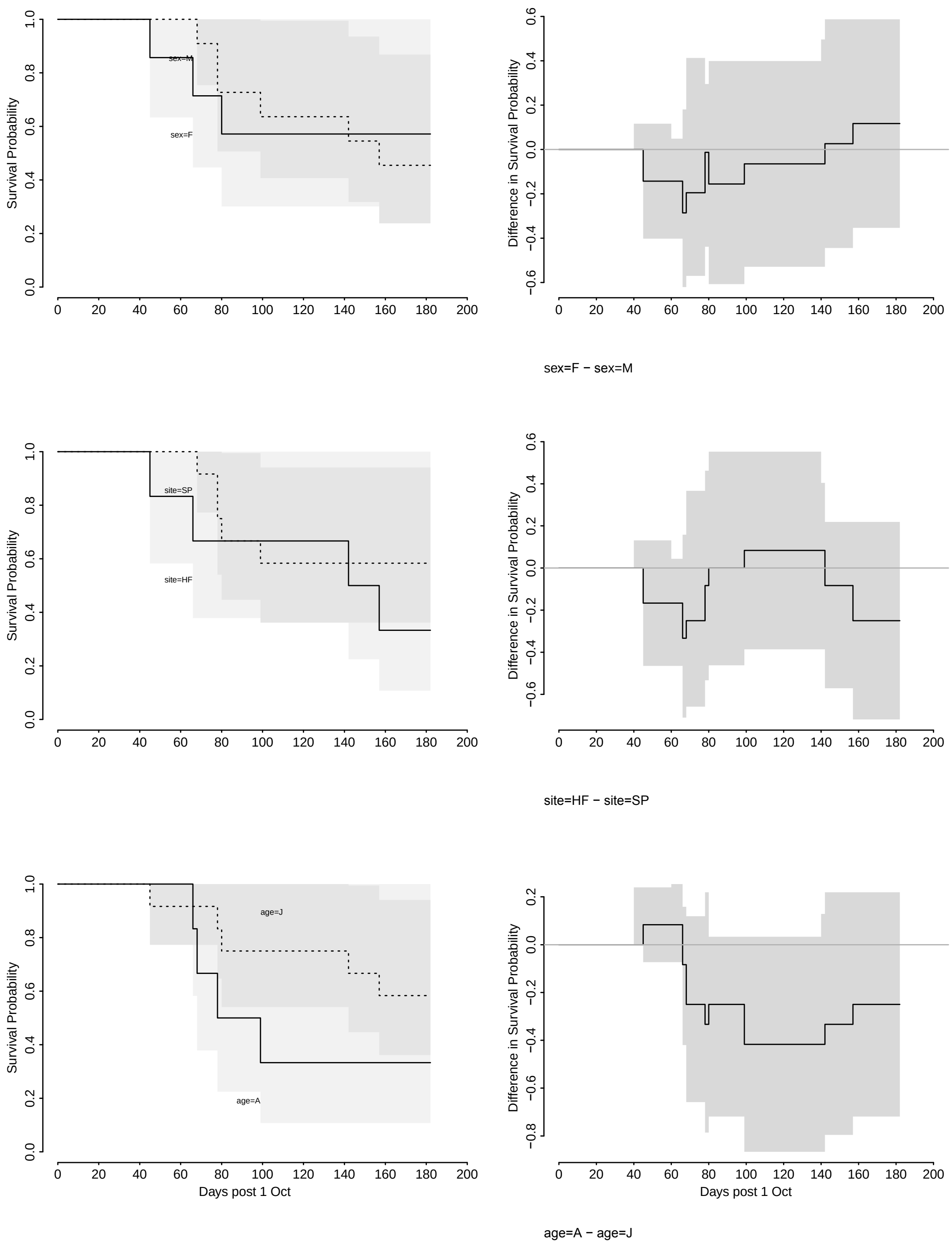

Figure 3. Pooled winter (1 October 2017 - 31 March 2018) survival curves for translocated northern bobwhite in the New Jersey Pine Barrens. The dashed line indicates the number exposure days at which survival reaches 50% of the starting sample.

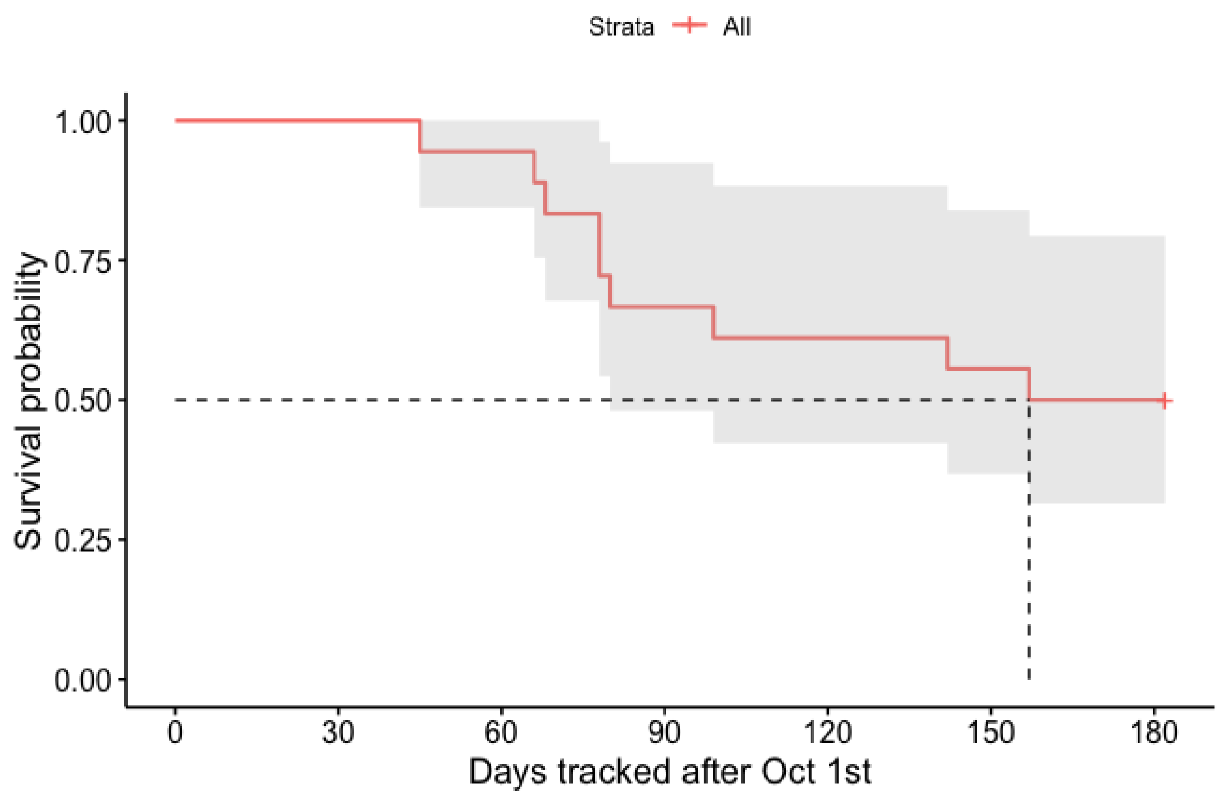

Figure 4. Telemetry locations of five radio-tracked northern bobwhite coveys during winter season (1 October 2017 - 31 March 2018) in the New Jersey Pine Barrens. Pine Island Cranberry property boundaries, with Home Farm portion on west (coveys 1 and 2) and Sim Place on the east (coveys 3–5).

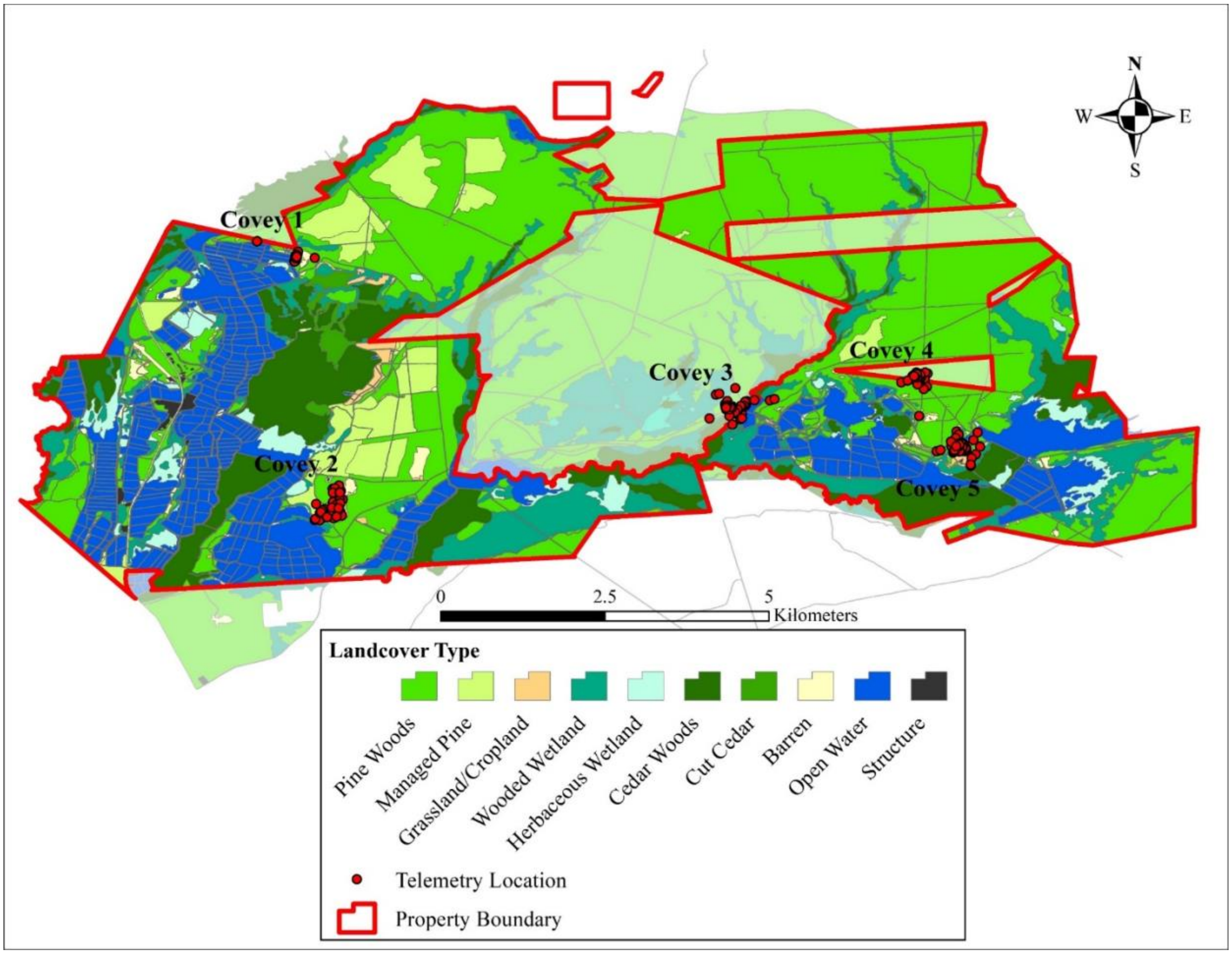

Figure 5. Telemetry locations of northern bobwhite covey 1 during winter season (1 October 2017 - 31 March 2018) overlaid with landcover types in the New Jersey Pine Barrens. I collected fewer than 25 locations, so home range was not calculated.

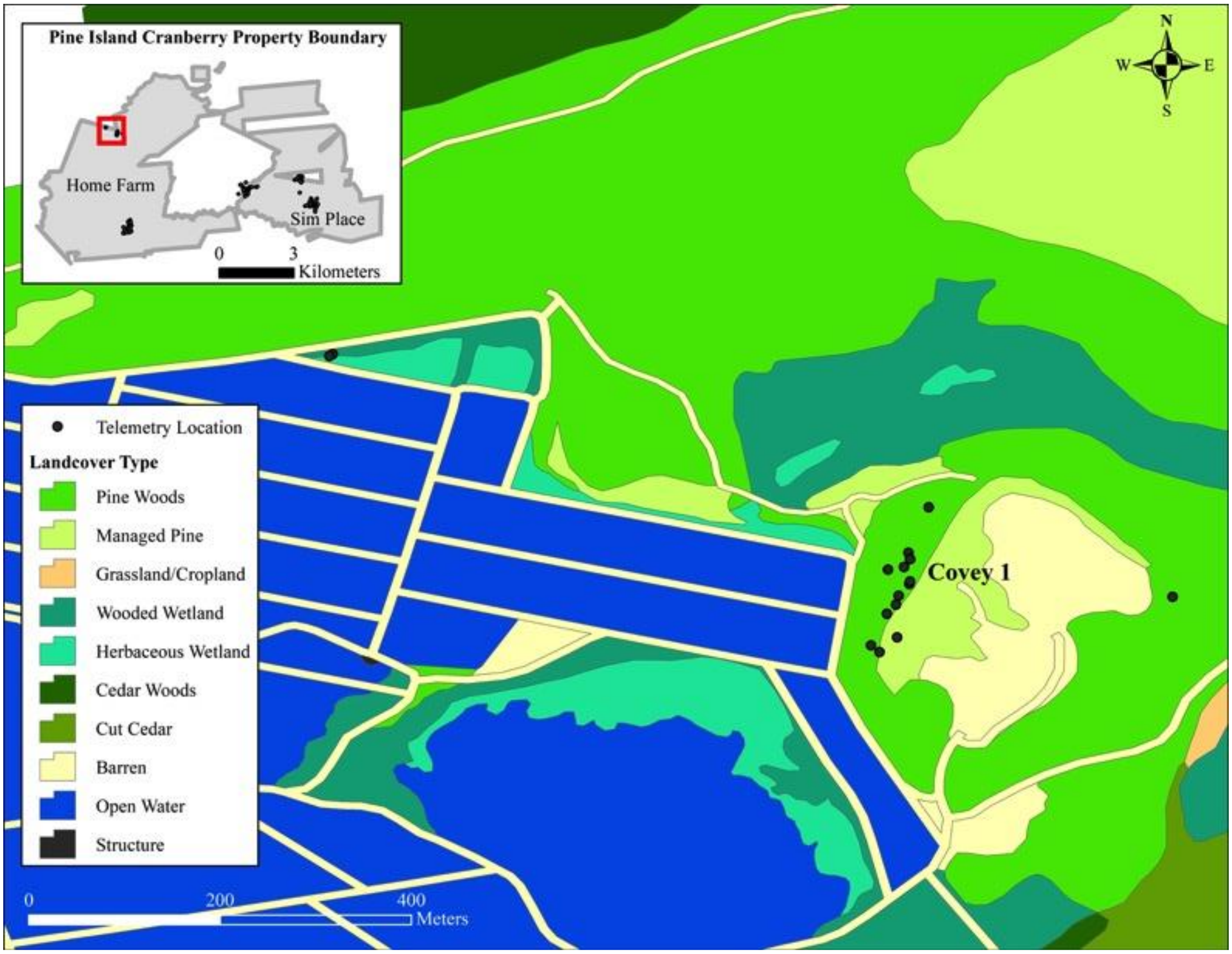

Figure 6. Telemetry locations and 95% kernel home range of northern bobwhite covey 2 during winter season (1 October 2017 - 31 March 2018) overlaid with landcover types in the New Jersey Pine Barrens.

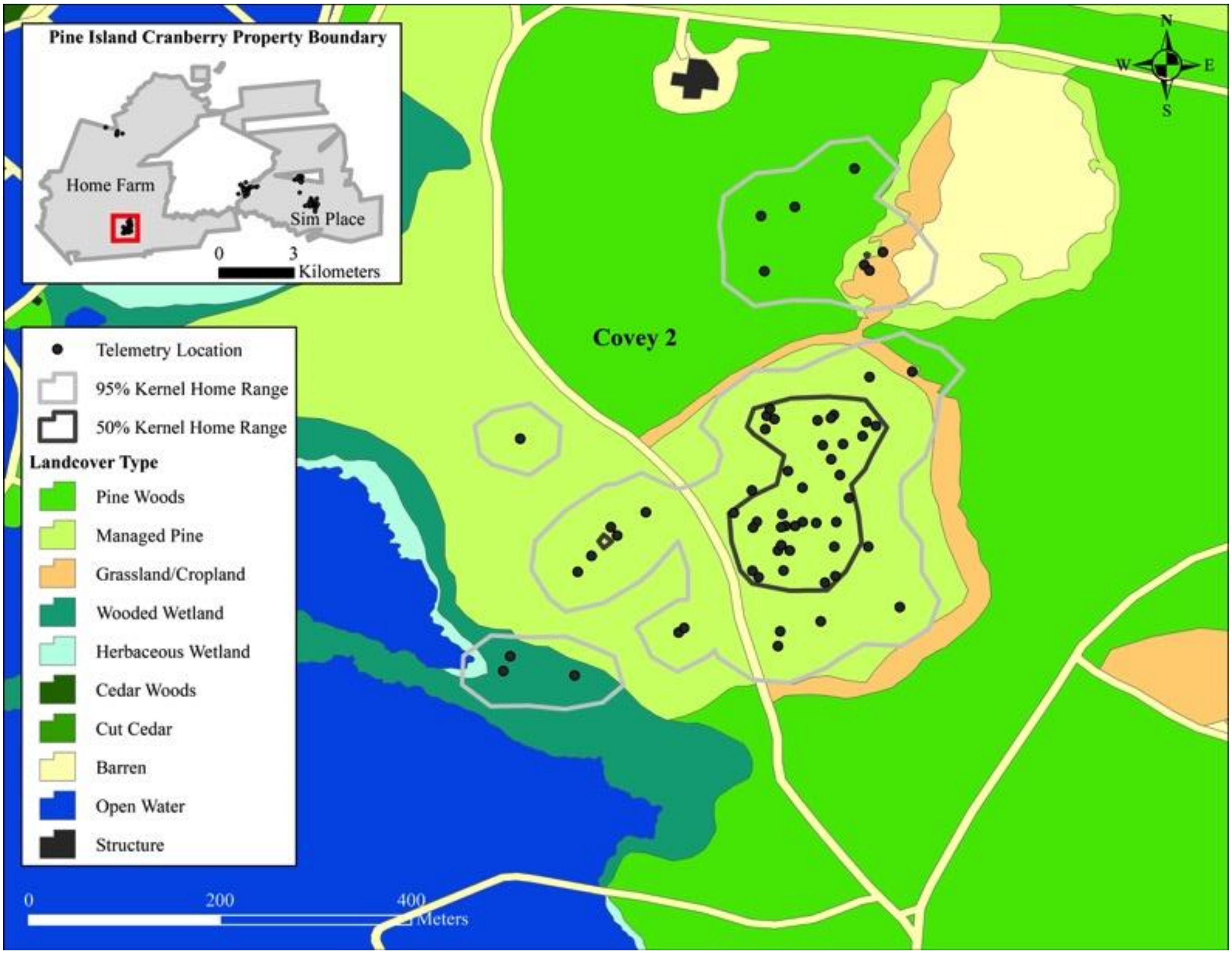

Figure 7. Telemetry locations and 95% kernel home range of northern bobwhite covey 3 during winter season (1 October 2017 - 31 March 2018) overlaid with landcover types in the New Jersey Pine Barrens.

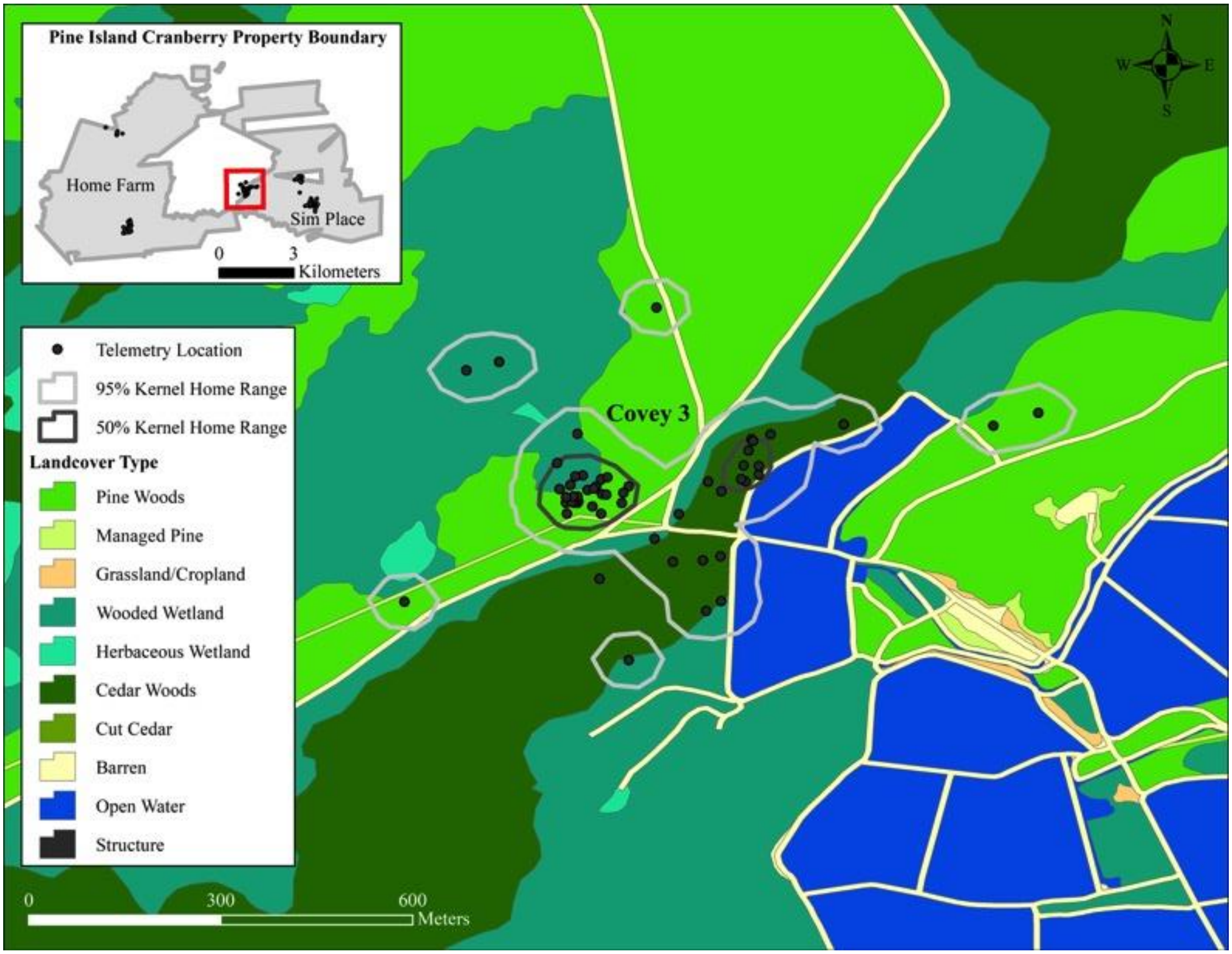

Figure 8. Telemetry locations and 95% kernel home range of northern bobwhite covey 4 during winter season (1 October 2017 - 31 March 2018) overlaid with landcover types in the New Jersey Pine Barrens.

Figure 9. Telemetry locations and 95% kernel home range of northern bobwhite covey 5 during winter season (1 October 2017 - 31 March 2018) overlaid with landcover types in the New Jersey Pine Barrens.

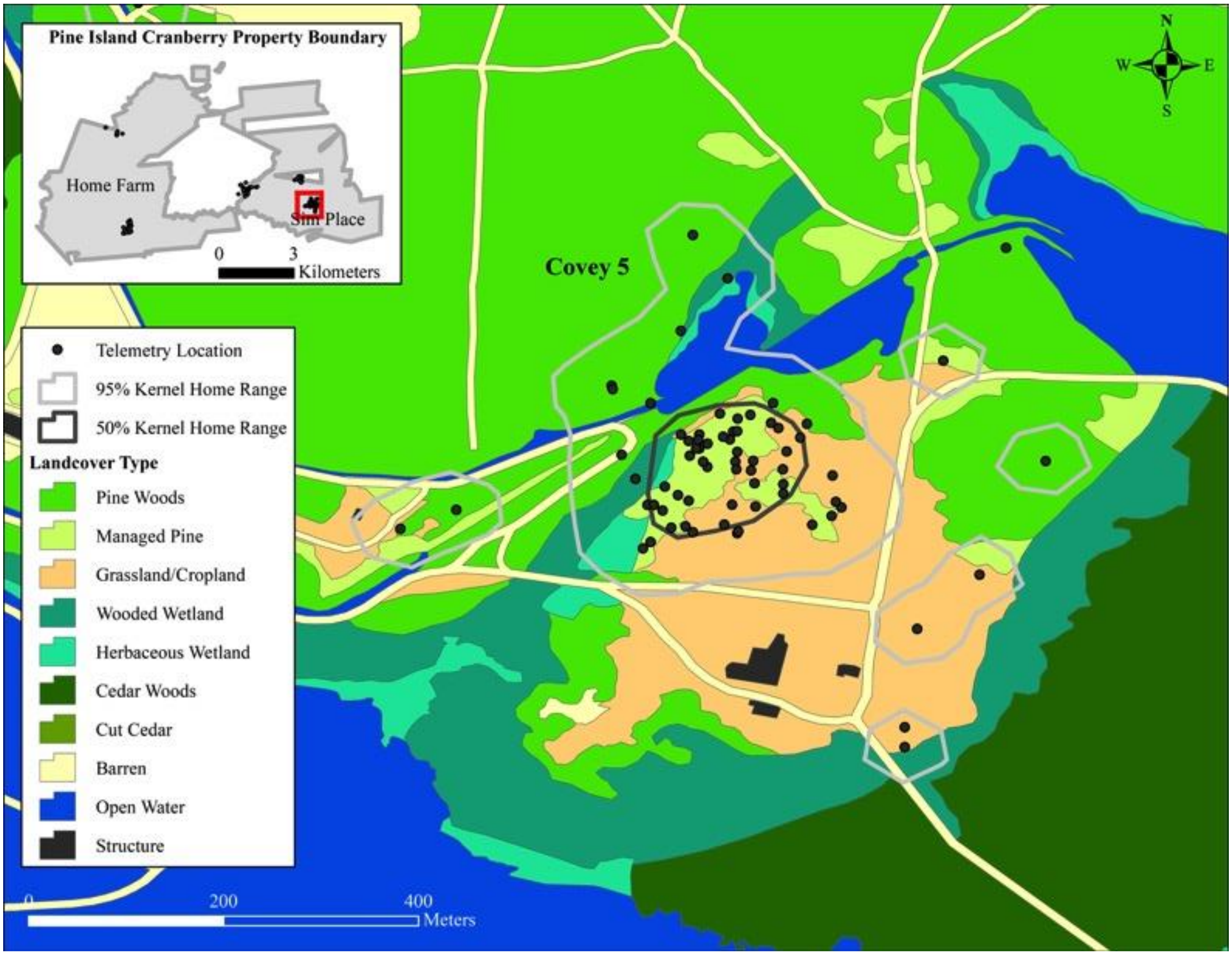

Figure 10. Relative frequencies of available habitat versus habitat used across the landscape of northern bobwhite coveys during the winter season (1 October 2017 - 31 March 2018).