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FACTORS INFLUENCING NORTHERN BOBWHITE HUNTER SUCCESS ON A PUBLIC WILDLIFE MANAGEMENT AREA IN KENTUCKY

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ABSTRACT

Hunter success is a critical measure of northern bobwhite (*Colinus virginianus*) restoration. Understanding the factors influencing hunter success can guide wildlife agencies in efforts to improve success and satisfaction and sustain hunter support of conservation initiatives. We compared use of vegetation types by radiomarked bobwhite ($n = 30$ coveys) and hunting dogs ($n = 241$) equipped with Global Positioning System collars during the 2014–2015 quail hunting season on Peabody Wildlife Management Area in western Kentucky. We surveyed hunting parties ($n = 252$) immediately after their hunt to determine success (flushed bobwhite) and gather hunt-party characteristics. We used associated habitat metrics from the dog track, weather variables, hunter and dog characteristics (e.g., age, experience), and hunt metrics (e.g., hours hunted, no. of dogs) to determine factors that influenced hunt success. Dogs used winter wheat firebreaks more than bobwhite regardless of time of day, forested areas more than bobwhite in the morning (0700–1000 hr) and midday (1000–1300 hr), disked areas more than bobwhite during midday, and open herbaceous areas less than bobwhite during morning and midday. The probability of success was positively influenced by number of dogs and hours hunted and negatively influenced by proportion of the hunt track in disked areas. Also, hunter success was greater in November compared with December and January. Our results indicated some key features associated with bobwhite habitat (open areas) may be underexploited by hunters, whereas other features (disked areas, firebreaks, and forested areas) may be overexploited. However, success was influenced primarily by factors that may be related to covey avoidance behavior resulting from substantial hunting pressure rather than where hunters selected to hunt. Lower bobwhite encounter rates (coveys flushed/hour) could cause hunter support to wane and bias hunting data as an indicator of population abundance.

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Key words: *Colinus virginianus,* hunter success, hunting, Kentucky, northern bobwhite

Sportsmen and women play an important role in the conservation of northern bobwhite (*Colinus virginianus;* henceforth, bobwhite) populations by contributing funding and support for land management (Brennan 2015). Understanding hunter success can have important implications for managing hunter satisfaction and harvest, and identifying factors related to hunter success and effort can help agencies manage bobwhite populations (Palmer et al. 2002, Tomeček et al. 2015). Bobwhite hunter success has been reported to be positively associated with bobwhite

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densities; therefore, success can be used as an inexpensive method to monitor bobwhite population trends (Palmer et al. 2002, Guthery and Mecozzi 2008).

Many factors besides bobwhite density can influence bobwhite hunter success including weather, landscape configuration, hunter and dog ability, and covey avoidance behavior (Michener et al. 2000, Wellendorf et al. 2012). Furthermore, comparing hunter and bobwhite use of vegetation types may further elucidate reasons for lower encounter or success rates (Richardson et al. 2008). By providing sportsmen with information regarding factors influencing success, agencies and managers may increase sportsmen success and satisfaction and therefore sustain future hunting efforts.

Considerable effort has been put forth by the Kentucky Department of Fish and Wildlife Resources to manage northern bobwhite populations on wildlife management areas open to public quail hunting. Monitoring efforts (fall-covey counts and spring-whistle counts) have indicated the population on Peabody Wildlife Management Area (WMA) has increased since 2009 at the onset of habitat management (Peters 2014, Morgan and Robinson 2015), but hunter success (coveys flushed/hour) has not followed the same trend (J. J. Morgan, unpublished data). Disparities in success and population estimates may be related to a multitude of factors but biologists and land managers within Kentucky's wildlife agency and at Peabody WMA have postulated that differences between bobwhite and hunters cover use resulting from hunting in an unfamiliar environment (reclaimed strip-mine vegetation), and covey avoidance behavior resulting from direct (bobwhite hunters) and indirect (rabbit hunters [Leporidae]) hunting pressure, may be the primary causes.

The objectives of our study were to 1) evaluate differences in vegetation types used by bobwhite and hunting dogs, and 2) evaluate the influence of hunt party, weather, and habitat characteristics on northern bobwhite hunter success on a public wildlife management area in west-central Kentucky to better understand the discrepancies between bobwhite populations monitoring efforts and hunter encounter rates.

STUDY AREA

We conducted our study on the Sinclair Unit (4,018 ha) of Peabody Wildlife Management Area (Peabody) in Muhlenberg County, Kentucky. Peabody is owned and managed by the Kentucky Department of Fish and Wildlife Resources and consists primarily of reclaimed strip-mine land. Open areas on Peabody were managed specifically for bobwhite; management practices included disking and herbicide application to control sericea lespedeza (*Lespedeza cuneata*). Disked open areas (open herbaceous or native warm-season grass) represented 1.9% of our study area and averaged 0.5 ha in size (Brooke et al. 2015). Firebreaks were 7–9 m wide and were disked and planted to winter wheat (*Triticum aestivum*) in August–September.

Forested areas comprised 51% of the study area and consisted of eastern cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), and red maple (*Acer rubrum*) with an understory of brambles (*Rubus* spp.) and Japanese honeysuckle (*Lonicera japonica*). Open herbaceous areas dominated by sericea lespedeza, tall fescue (*Schedonorus arundinaceus*), field brome (*Bromus arvensis*), goldenrod (*Solidago* spp.), and common ragweed (*Ambrosia artemisiifolia*) comprised 20% of the study area. Areas dominated by shrubs and small trees (shrub cover), including black locust (*Robinia pseudoacacia*), sumac (*Rhus* spp.), autumn olive (*Elaeagnus umbellata*), and brambles, comprised 14% of the study area. Areas dominated by planted native warm-season grass comprised 1% of our study area. These 4 vegetation types made up 86% of our study area, with the remaining 14% in water (10%), firebreaks (2%), roads (1%), and developed areas (<1%).

METHODS

Field Methods

We captured bobwhite from August 2014 through December 2015 and radiotracked them from August 2014 through February 2015. We captured bobwhite using baited Stoddard (1931) funnel traps. We also used modified cast-nets at night to capture multiple individuals from radiomarked coveys (Truitt and Dailey 2000). We recorded sex, age, and body mass (g) of all captured individuals following protocols approved by the University of Tennessee Institutional Animal Care and Use Committee Permit 2042-0911. Individuals weighing >120 g were fitted with an approximately 6-g necklace-style very high frequency radiocollar (American Wildlife Enterprises, Monticello, FL, USA).

We tracked each covey ≥1 day/week throughout the hunting season (Nov–Feb). We monitored coveys throughout the day, obtaining 1 location/hour from 0700 hours to 1500 hours to determine daily temporal changes in bobwhite habitat use. We tracked each bird to ≥30 m and circled the bird to confirm the bird's location. We stayed ≥30 m from the covey to limit the observer biasing covey movements. We then recorded the Global Positioning System (GPS) location of the observer and azimuth and distance to the bird based on signal strength and direction and the vegetation type where the covey was located. Using the GPS location of the observer and the estimated azimuth and distance to the radio signal, we were able to determine the location of the covey. We assigned individuals to a covey based on their association with other radiomarked individuals. If a radiomarked individual was not located with its original covey on 3 consecutive days, we assigned that individual to a new covey. We used covey as the sampling unit rather than individual because locations from individuals within the same covey were not independent. We randomly selected one individual from each covey to represent the entire covey's location.

Quail hunting was permitted on Peabody Monday–Saturday, 0700 hours to 1500 hours. All hunting parties checked in and out at the WMA office and upon checking out parties were required to fill out a hunting log with information about their hunt party and hunt success. We collected the following information for each hunt party: group experience hunting quail (years), numbers of hours hunted, number of dogs used, coveys flushed, singles flushed, birds shot at, birds killed, and birds crippled. We also gathered information about dogs within each hunting party, including their age and experience hunting wild quail (years).

We acquired spatial data from hunting parties via Garmin Astro (Garmin Ltd., Olathe, KS, USA) collars attached to dogs within the hunting party to represent use of vegetation types by hunting parties. We asked hunters to voluntarily participate in our study upon arrival. We gave participants GPS collars to attach to hunting dogs used during the hunt, and set collars to record 1 location every 5 seconds. Units were returned upon the completion of the hunt and we downloaded data to the computer as text files. We manually checked each text file and identified and removed from the hunt track data the locations taken when the dog was not hunting (e.g., vehicle driving, at truck, in dog box). We gathered weather data for the day of each hunt from a weather station in the same county as our study site via Kentucky Mesonet (Western Kentucky University 2016).

Data Analysis

We estimated bobwhite habitat use by calculating the proportion of each covey's locations within each vegetation type. We also estimated the average distance from each vegetation type and access point for each covey. We defined access points (roads and firebreaks) as features that provided hunting parties easy access to potential hunting areas. For hunt parties, we estimated the length of the dog's hunt path in each vegetation type and divided it by the total path length, similar to Richardson et al. (2008). We also measured the average distance of locations on the hunt path to each vegetation type and access point. We were not able to attach collars to every dog in each hunt party. Therefore, for parties with multiple dogs, we randomly selected a track from one dog to represent the vegetation types used by the hunting party. We split the data into 3 time periods, morning (0700–1000 hr), midday (1000–1300 hr), and afternoon (1300–1500 hr) based on previously documented covey activity periods (Sisson and Stribling 2009, Crouch 2010) to capture temporal variation in bobwhite and hunter habitat use. We compared the proportions of quail locations and distance-to features with the proportions of dog hunt paths and distances-to features using 2-sample *t*-tests. We evaluated each variable for normality prior to analysis and transformed the data when appropriate (Shapiro and Wilk 1968). We used Mann–Whitney *U* nonparametric tests when normality could not be achieved with transformations (Kasuya 2001). The data reported are the untransformed means and confidence intervals. Significance for all tests was determined at an alpha of 0.05. For variables with significant relationships across time periods, we tested for significant differences in bobwhite and hunter cover use for each of the 3 time periods.

We determined the influence of hunt-party characteristics, weather, and habitat characteristics on hunt success (encountering ≥ 1 bobwhite) using binomial logistic regression. We used the glm function within the stats package of Program R (R package version 3.1.1, www.r-project.org, accessed 1 Dec 2015) to compare logistic regression models. We defined the dependent variable (hunt success) as flushing ≥ 1 bobwhite during the hunt (covey or single). We compared models using an Akaike Information Criterion (AIC_c) framework (Burnham and Anderson 2002). We first fit models using only weather, hunt, and hunt-party characteristics because we did not have habitat characteristic data for all hunts. Hunt and hunt-party variables included hours hunted, number of dogs used, group hunting experience (years), dog hunting experience (years), dog age (years) for all dogs used by the party, and the month the hunt occurred (categorical variable). Weather variables including maximum temperature, average wind speed, and total daily precipitation. Models included a null model (intercept only), single-variable models, models built based on experience hunting at Peabody, and a global model containing all variables. We used the top model from our first analysis as the base model for our habitat characteristic modeling exercise. We fit models containing habitat use variables using only hunting parties for which dog hunt tracks were recorded. We built models based on our habitat use data and data gathered previously on bobwhite selection from our study area (Brooke et al. 2015, Unger et al. 2015). We considered variables influential to hunt success if 95% confidence intervals for the beta estimate did not overlap zero.

RESULTS

We captured 251 individual bobwhite and tracked 30 coveys during the 2014–2015 quail hunting season, yielding 5,094 telemetry locations. We recorded hunt success information for 252 hunting parties, 143 of which also had associated dog track data. In total, we tracked 241 dogs from those 143 hunt parties, resulting in >500,000 locations. The average hunting party used 2.50 ± 1.74 (SD) dogs during the hunt and hunted 4.16 ± 1.38 hours. The maximum number of dogs used during a hunt was 12 dogs. Eight hours was the maximum amount of time hunted. The average dog covered 19.03 ± 8.57 km. Hunters harvested 222 birds, 31 of which were radiocollared, and 71.4% of hunt parties flushed ≥ 1 bobwhite. Hunting parties averaged encounter rates (coveys flushed/hour) of 0.25 ± 0.27 coveys/hour but averaged 0.58 ± 0.66 flushes/hour when including coveys and singles.

Dogs used areas farther from open herbaceous compared with coveys (Table 1). Furthermore, dogs used disked areas, firebreaks, and forested areas more than bobwhite coveys and open herbaceous and roads less than bobwhite coveys (Table 1). Throughout the day, dogs used firebreaks and forested areas 3.6 and 2.17 times more

Table 1. Mean cover type use by northern bobwhite covey and hunting dogs and associated 2-sample *t*-test results for cover types on Peabody Wildlife Management Area, Kentucky, USA, 2014–2015.

	Covey		Dog		*t*-test	
Variable	$\bar{x}$	95% CI	$\bar{x}$	95% CI	*t*-value	*P*-value[a]
Distance[b]						
Disked area	204.8	170.3–239.2	468.5	374.6–562.3	−2.00	0.05
Firebreak	115.1	92.7–148.4	223.2	163.2–283.3	−1.98	0.05
Forest	246.5	201.4–271.9	202.0	185.4–218.5	1.77	0.08
Native grasses	557.3	474.1–665.6	730.4	604.6–856.2	1.26	0.21
Open herbaceous	17.0	13.1–24.3	34.9	27.0–42.8	−3.30	<**0.01**
Road	130.6	106.4–144.9	188.0	174.5–201.4	−5.26	<**0.01**
Shrub	47.0	39.1–54.2	56.9	50.7–63.0	−1.71	0.09
Proportion[c]						
Disked area	3.2	1.5–4.8	6.6	5.6–7.5	0.36	<**0.01**
Firebreak	3.5	2.2–4.8	12.6	11.4–13.9	−7.49	<**0.01**
Forest	5.2	2.7–7.7	11.3	9.5–13.1	9,771[d]	<**0.01**
Native grasses	3.3	1.6–5.1	3.7	3.0–4.4	−0.71	0.71
Open herbaceous	54.9	48.8–61.0	42.8	40.4–45.3	3.68	<**0.01**
Road	3.4	1.9–4.9	0.7	0.5–0.8	11,302[d]	<**0.01**
Shrub	26.5	20.7–32.3	22.3	20.2–24.5	1.35	0.18

[a] Bold represents significant results at an alpha of 0.05.
[b] Distance (m) from bobwhite or dog location to each cover type.
[c] Proportion (%) of covey locations or proportion of dog track in each cover type.
[d] Represents Mann–Whitney *U* nonparametric test.

than bobwhite, respectively. Conversely, dogs used open herbaceous areas 1.28 times less than bobwhite. During the morning and midday, dogs used areas farther from open herbaceous compared with bobwhite (Table 2). Dogs used firebreaks more than bobwhite regardless of time of day, forested areas more than bobwhite during morning and midday, and disked areas more than bobwhite during midday (Table 2). Bobwhite used open herbaceous more than hunters during the morning and midday (Table 2). There were statistical differences in the distance from and use of roads by bobwhite and hunters; however, given the minimal use of roads by both hunters and bobwhite ($\leq$3% of locations), these differences are likely not biologically important.

Model ranking to determine factors related to bobwhite hunter success (Table 3) revealed time spent hunting, number of dogs used during the hunt, and month of the hunt influenced hunter success (Table 4). The addition of each dog to a hunt party resulted in a 6% increase in the probability of success compared with an 8% increase in success for each additional hour hunted (Fig. 1). Hunters were less likely to encounter a covey when hunting in December or January compared with hunting in November (Fig. 1). Although success was lower in February compared with November, the confidence intervals for the beta estimate overlapped zero, indicating success was indistinguishable between the 2 months (Table 4). Additionally, 4 habitat models explained variation in hunt success and included the proportion of disked area, shrub cover, and firebreaks in the hunt path (Table 3). The top model for habitat characteristics contained only disked area (β = –5.42, 95% CI = –10.6 to –0.36), suggesting amount of time a dog spent in disked areas had a negative relationship with success (Fig. 2). Shrub cover was included in 3 of the competing models and had a positive relationship (β = 2.13, 95% CI = –1.64–5.90) with success but the confidence intervals indicated the relationship was not significant. Conversely, firebreaks had a negative relationship (β = –2.81, 95% CI = –7.71–2.09) with success but the relationship was also not significant.

DISCUSSION

Use of vegetation types did differ between bobwhite coveys and hunters on our study area, indicating hunters may be overhunting certain vegetation types and underhunting others. However, these differences, with the exception of use of disked areas, did not influence hunter success; this suggests success is related to factors beyond hunter use of the landscape. Furthermore, the difference in use of features such as roads between coveys and hunters was minimal, suggesting a statistical significance but not a biological significance. Our results suggest factors related to mitigating covey evasion (a result of heavy hunting pressure), such as hunting early in the season, using multiple dogs, and hunting longer periods of time, were more predictive of success compared with habitat variables. Our results compliment the results of Orange et al. (2016), who reported hunters on our study area detected only 29% of available coveys. These results, coupled with those of Orange et al. (2016), provide insight into discrepancies between population estimates and hunter success. However, it should be noted that our study represents 1 year of data and subsequent years of data collection may result in differing conclusions. Nevertheless, these results can be used as a tool to

Table 2. Mean cover type use by northern bobwhite and hunting dogs by time period and associated 2-sample *t*-test results for significantly different ($P < 0.05$) cover types on Peabody Wildlife Management Area, Kentucky, USA, 2014–2015.

	Covey		Dog		*t*-test	
Variable	$\bar{x}$	95% CI	$\bar{x}$	95% CI	*t*-value	*P*-value[a]
Morning[b]						
Distance[c]						
Open herbaceous	16.3	9.0–23.7	26.8	13.5–40.2	−2.05	**0.04**
Road	125.0	90.1–159.9	165.9	132.8–199.1	−2.65	**0.01**
Proportion[d]						
Disk	4.3	1.0–7.7	5.7	3.5–7.8	−1.66	0.10
Firebreak	2.4	0.7–4.1	11.8	8.8–14.9	−7.65	<**0.01**
Forest	4.0	0.2–7.8	9.7	4.8–14.5	1,036[e]	<**0.01**
Open herbaceous	56.0	45.7–66.4	44.7	37.9–51.5	2.35	**0.02**
Road	4.0	0.8–7.1	0.7	0.3–1.0	1,205[e]	**0.04**
Midday						
Distance						
Open herbaceous	19.9	9.0–30.8	41.5	19.8–63.3	−2.40	**0.02**
Road	125.7	91.5–159.9	197.8	164.1–231.5	−3.74	<**0.01**
Proportion						
Disk	2.3	0.3–4.2	5.7	3.7–7.7	−3.50	<0.01
Firebreak	3.5	1.2–5.9	11.7	9.2–14.2	−6.27	<**0.01**
Forest	5.8	0.7–11.0	13.3	9.2–17.4	1,203[e]	<**0.01**
Open herbaceous	53.5	42.6–64.4	42.6	37.2–48.1	2.12	**0.04**
Road	3.4	0.6–6.1	0.7	0.4–1.0	1,508[e]	**0.01**
Afternoon						
Distance						
Open herbaceous	19.9	8.4–31.4	31.6	7.5–55.7	−1.17	0.24
Road	126.3	91.3–161.3	166.3	134.3–198.2	−2.38	**0.02**
Proportion						
Disk	2.9	0.1–6.0	4.3	2.4–6.2	−1.61	0.11
Firebreak	4.5	1.7–7.4	11.4	7.9–14.8	−3.72	<**0.01**
Forest	5.7	1.1–10.4	6.4	3.7–9.0	1,025[e]	0.06
Open herbaceous	55.2	43.5–66.8	46.3	40.3–52.3	1.67	0.10
Road	2.9	0.7–5.1	0.5	0.3–0.7	1,055[e]	0.10

[a] Bold represents significant results at an alpha of 0.05.
[b] Morning = 0700 to 1000 hr, Midday = 1000 to 1300 hr, Afternoon = 1300 to 1500 hr.
[c] Distance (m) from bobwhite or dog location to each cover type.
[d] Proportion (%) of covey locations or proportion of dog track in each cover type.
[e] Represents Mann–Whitney *U* nonparametric test.

educate bobwhite hunters using Peabody Wildlife Management Area.

Bobwhite use of the open herbaceous vegetation type exceeded 50% throughout the day whereas hunter use ranged from 42.6% to 46.3%. Although these unmanaged open areas were dominated by sericea lespedeza and were considered marginal for bobwhite (Brooke et al. 2015), the continuous cover likely served multiple purposes including roosting, feeding, and travel corridors between escape cover. Furthermore, open herbaceous areas included small patches of shrub cover that were too small to map as separate vegetation types but likely offered useable escape cover exploited by bobwhites throughout the day. Hunters likely used firebreaks more than bobwhite throughout the day because these linear features provided access to areas where hunters expected bobwhite to be located. However, these winter-wheat firebreaks did not provide adequate cover for bobwhite during the hunting season and were not selected by coveys (Brooke et al. 2015). Bobwhite use of forested areas was consistently low (<6% of locations) during the day, especially compared with availability of forested areas across our study area (51%), but hunter use of forested areas peaked during midday and was lowest during afternoon. The differences in hunter and bobwhite use of forested areas in morning and midday may be driven by hunters perceiving forested areas as escape cover for bobwhite.

Hunter use of disked areas more than they were used by bobwhite coveys and the associated negative relationship with success is surprising given the importance of these areas to bobwhite during the nonbreeding season on our study area (Brooke et al. 2015). Disking increased cover of food plants for bobwhite during winter (Brooke et al. 2015). Furthermore, Michener et al. (2000) reported both bobwhite and bobwhite hunters used fallow agricultural areas in Georgia similarly, which would be comparable to disked areas on our study area; and bobwhite encounters in Georgia were greater than would be expected in these areas. Temporal patterns indicated

Table 3. Logistic regression model selection results for northern bobwhite hunter success (encountering a covey) from Peabody Wildlife Management Area, Kentucky, USA, 2014–2015. Support for each model is indicated by the log likelihood (log(L)), corrected Akaike's Information Criterion values (AIC_c), the difference in corrected Akaike's Information Criterion values (ΔAIC_c), and Akaike model weights (w_i). All models contain an intercept.

Model	*K*	log(L)	AIC_c	ΔAIC_c	w_i
Hunt-party characteristics[a]					
hours + dogs + month	6	−137.11	286.6	0.00	0.74
hours + dogs + group exp.	4	−141.26	290.7	4.13	0.09
dogs + dog exp. + dog age	4	−142.11	292.4	5.83	0.04
dog exp.	2	−144.27	292.6	6.02	0.04
hours	2	−144.28	292.6	6.06	0.04
hours + dogs + dog exp. + max temp. + group exp. + precip. + wind + month + dog age	11	−135.42	293.9	7.38	0.02
dogs	2	−145.03	294.1	7.54	0.02
dog exp.+ group exp.	3	−144.26	294.6	8.07	0.01
max temp	2	−149.15	302.3	15.79	0.00
intercept only	1	−150.76	303.5	16.99	0.00
Habitat characteristics[b]					
hours + dogs + month + disk	7	−73.954	162.8	0.00	0.36
hours + dogs + month + disk + shrub	8	−73.074	163.3	0.50	0.17
hours + dogs + month + disk + shrub + firebreak	9	−72.431	164.3	1.52	0.15
hours + dogs + month + shrub	7	−74.826	164.5	1.74	0.12
hours + dogs + month	6	−76.154	165.0	2.17	0.09

[a] Hours = no. of hours hunted, dogs = no. of dogs used, month = month of hunt (categorical), group exp. = sum of group quail hunting experience (years), dog exp. = sum of dog experience hunting quail (years), dog age = sum of dogs used age (years), max temp. = maximum daily temperature, precip. = total daily precipitation, wind = average daily wind speed (mph).
[b] Disk = proportion hunt track in disked area, shrub = proportion of hunt track in shrub cover, firebreak = proportion of hunt track in firebreak.

hunters overexploited disked areas during midday. Bobwhite use of disked areas was 87% greater in morning compared with midday. Bobwhite may have shifted from feeding in disked areas in the morning to loafing in nearby cover during midday. Sisson and Stribling (2009) reported covey activity associated with feeding peaks 1–2 hours after sunrise and 1 hour before sunset.

It is plausible that variables most influencing hunt success on our study area (hours hunted, number of dogs used, and month of hunt) were related to the response of coveys to heavy hunting pressure. Radomski and Guthery (2000) suggested coveys were less likely to flush under heavy hunting pressure. Hunting pressure was not restricted on our study area and our study area also hosted one of the largest densities of rabbit hunters in the state (E. S. Williams, personal communication). Our finding of hunters being more successful in November compared with December and January strongly supports the notion that success decreased with repeated exposure of bobwhite coveys to hunting activity as the hunting season progressed. Orange et al. (2016) suggested hunters only flushed 29% of coveys on our study areas and 60% of coveys that had been missed were observed running from approaching dogs. Repeated contact with hunting dogs, both bird dogs and rabbit dogs, as the season progressed may further elicit this response and reduce the propensity of coveys to flush when encountered by a hunting party.

Table 4. Model beta estimates, confidence intervals, and odds ratios (exp(beta estimate)) for the most-supported model for northern bobwhite hunter success at Peabody Wildlife Management Area, Kentucky, USA, 2014–2015.

Variable	β-estimate	95% CI		Odds ratio
(Intercept)	−0.18	−1.29	0.83	0.93
No. of dogs	0.27	0.06	1.32	0.52
Hours hunted	0.32	0.10	1.38	0.56
Month[a]				
Dec	−1.00	−1.90	−0.17	0.37
Jan	−1.14	−2.03	−0.31	0.32
Feb	−0.79	−1.90	0.32	0.45

[a] Month is a categorical variable; therefore, each month must be compared with a reference month. The beta estimate for each month represents the probability of success compared with Nov (reference month).

Using multiple dogs during the course of a hunt could increase success for multiple reasons, such as allowing a hunt party to search a large area more thoroughly, be more effective in locating single birds from scattered coveys, and allow hunters to replace dogs as they become exhausted. Guthery and Mecozzi (2008) reported redundancy of hunted area (proportion of area in the hunt path searched by multiple dogs) was positively correlated with number of dogs used, suggesting using multiple dogs allowed hunters to more thoroughly search cover. Furthermore, multiple dogs may help mitigate covey avoidance behavior. Coveys were often observed running and scattering in the continuous open cover on our study when hunting dogs approached (J. M. Brooke, personal observation) and when a covey scatters it may reduce the ability of a single approaching dog to track the scent. Guthery and Mecozzi (2008) suggested the distance a hunting dog could detect bobwhite scent was reduced when dogs encountered single and pairs of bobwhite

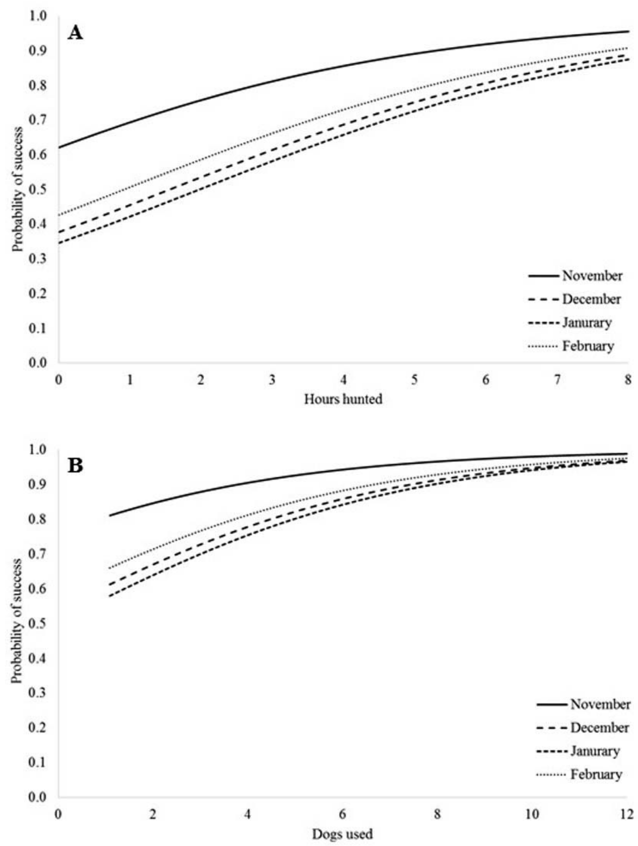

Fig. 1. Probability of success for northern bobwhite hunters on Peabody Wildlife Management Area, Kentucky, USA, 2014–2015. Success was influenced by hours hunted (A) and number of dogs used (B). Different line types represent differences in success based on the month in which hunting occurred.

compared with coveys. Therefore, using multiple dogs may have provided hunters with a larger scenting area to find individuals from scattered coveys or find coveys usually missed by a single dog.

Unsurprisingly, spending more hours afield increased the probability a hunting party flushing a bobwhite. However, given our encounter rate (0.25 coveys/hr), hunting parties may become discouraged and stop hunting prior to encountering a covey or be less likely to return in the future. Encounter rate is an important factor of hunter satisfaction (Richardson 2006) and low encounter rates may decrease hunter satisfaction and ultimately reduce the number of hunters pursuing bobwhite. Consistent hunting effort is an important consideration if hunter success is used as an index for bobwhite population monitoring. A considerable reduction in hunter effort may preclude use of this index (Palmer et al. 2002). Educating hunters on factors influencing success may be vital to maintain or increase hunter satisfaction and encourage future participation.

One issue hunters raised throughout our project was concern regarding the influence of repeated contact between research technicians and coveys and the potential impact on covey behavior. Technicians did track coveys throughout the day, but flushed the covey on $<1\%$ of tracking events (J. M. Brooke, unpublished data). Perkins et al. (2014) suggested bobwhite flew shorter distances, at slower speeds, and landed in areas with less visual obstruction when flushed by researchers compared with when flushed by hunters or raptors. This suggests bobwhite do not perceive the threat posed by researchers similarly to other threats. Furthermore, our fall covey counts on Peabody suggested there were ≥ 77 coveys on our area but we only radiomarked 30 coveys, indicating more than half of the coveys on our study area may have not had any contact with researchers (E. S. Williams, unpublished data). Therefore, we conclude that researchers had minimal if any effect on covey behavior on our study area.

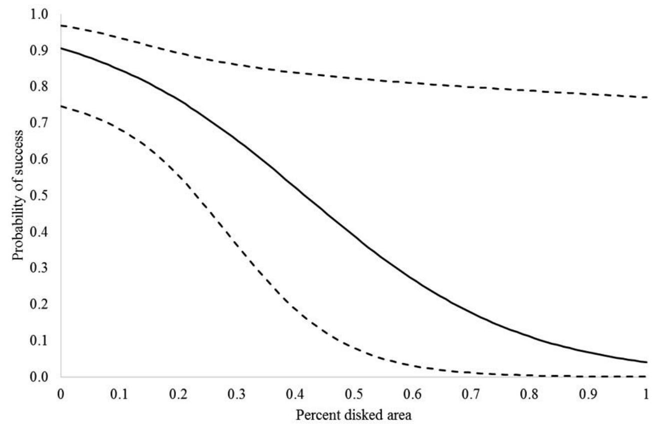

Fig. 2. Probability of success for northern bobwhite hunters based on the proportion of Global Positioning System hunt track within disked areas on Peabody Wildlife Management Area, Kentucky, USA, 2014–2015. Dashed lines represent the 95% confidence intervals around the probability of success.

MANAGEMENT IMPLICATIONS

Our results suggest focusing hunting efforts on disked areas, especially during midday (1000–1300 hr), may decrease hunter success. Therefore, we suggest hunter effort should be focused on cover around disked areas (shrub and open herbaceous), outside of peak feeding times (1–2 hr after sunrise). Furthermore, hunters should avoid venturing into forested cover away from open areas. Factors such as covey-avoidance behavior may strongly influence bobwhite encounters, especially when hunting pressure is unrestricted; and our results suggest using multiple dogs during the hunt, hunting longer periods, and hunting early in the season increase success. Managers may consider reducing hunting pressure in an effort to increase hunter success throughout the hunting season. However, it is important to consider that nonbobwhite hunting on public areas, such as rabbit hunting, also may contribute to unintentional hunting pressure on bobwhite. Our results can be used to educate hunters about factors influencing hunter success and may help sustain future hunter participation, which may have direct implications for future funding or population monitoring efforts.

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