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Effect of Prescribed Fire and Mechanical Treatments on Northern Bobwhite Occupancy in Mesic Pine Flatwoods

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EFFECT OF PRESCRIBED FIRE AND MECHANICAL TREATMENTS ON NORTHERN BOBWHITE OCCUPANCY IN MESIC PINE FLATWOODS

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ABSTRACT

We examined whether roller-chopping, mowing, and prescribed fire used to restore groundcover in pine flatwoods habitats affected northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) occupancy. We surveyed bobwhites using repeated point counts (n = 3), April–June each year, to determine response to prescribed fire and mechanical treatments on Osceola National Forest (Osceola, 78 plots) and St. Sebastian River Preserve State Park (Sebastian, 11 plots) in Florida, USA, 2013–2019. We measured groundcover each year at randomly placed transects within 200-m radius point-count plots. To assess the importance of management covariates, we fit single season occupancy models to predict occupancy (ψ) and detection (p). Detection probability was 0.12 (standard error [SE] = 0.05) and 0.35 (SE = 0.05) on Osceola and Sebastian, respectively. Modeled occupancy on both sites was best predicted by presence of roller-chopping, years since fire, and year. Predicted occupancy was highest on plots with 1 year since fire (Osceola, 0.22 [SE = 0.10]; Sebastian, 0.67 [SE = 0.18]). Predicted occupancy was higher on roller-chopped plots (Osceola, 0.33 [SE = 0.15]; Sebastian, 0.85 [SE = 0.15]) than on mowed (Osceola, 0.08 [SE = 0.03]) or untreated plots (Osceola, 0.07 [SE = 0.03]; Sebastian, 0.38 [SE = 0.34]). Roller-chopping and fire reduced density of palmetto (*Seranoa* spp.)-shrub vegetation and increased grasses and forbs. To increase bobwhite occupancy and improve habitat suitability of degraded mesic pine flatwoods, we recommend roller-chopping and a 2-year fire frequency.

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Key words*: Colinus virginianus*, habitat, management, mowing, northern bobwhite, occupancy, pine flatwoods, prescribed fire, roller-chopping

Northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) have declined significantly in the southeastern United States, including Florida (Sauer et al. 2008). Changing land use, reduction in fire use and frequency, and habitat loss and fragmentation are thought to be responsible for observed declines in regional bobwhite populations (Brennan 1991, Brennan and Kuvlesky 2005). The decline in the use of frequent prescribed fire is likely to be largely responsible for bobwhite population declines in forest ecosystems in the southeastern United States (Brennan et al. 1998).

Pine flatwood ecosystems are the most extensive ecosystems dominated by longleaf pine (*Pinus palustris*) in Florida (Abrahamson and Hartnett 1990). These ecosystems present a significant opportunity for bobwhite conservation as millions of hectares are in public ownership and most are managed with prescribed fire. Further, restoring habitat suitability for bobwhite would be likely to benefit a suite of declining upland species, thus garnering public and agency support (Miley and Lichtler 2009, Palmer et al. 2011). However, few studies explore the effects of management in pine flatwoods and additional information is needed for bobwhite conservation in these habitats (Miley and Lichtler 2009).

Flatwoods are naturally dominated by longleaf pine or slash pine (*Pinus elliotii*) (or both), a flammable understory of saw palmetto (*Serenoa repens*) and gallberry (*Ilex glabra*), and—in good ecological condition—a high diversity of herbaceous species (Peet and Allard 1993, Platt 1999). While flatwoods were historically maintained by frequent, low intensity fires, most flatwoods in Florida currently exist in a highly degraded state due to fire suppression and reductions in fire frequency. Low fire frequency has resulted in increased height and density of shrubs, particularly saw palmetto, and subsequent declines in herbaceous groundcover (Maliakal et al. 2000). These changes threaten the integrity of pine flatwood ecosystems and

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significantly reduce their suitability for dozens of species of conservation concern, including bobwhite.

While increasing fire frequency may be a logical management prescription for restoring degraded pine flatwood groundstory communities, a return of prescribed fire alone may not result in a shift from perennial woody vegetation to a mixture of woody-herbaceous groundcover (Glitzenstein et al. 2003) more suitable for bobwhite. Application of mechanical treatments in combination with fire have been used to reduce woody groundcover, particularly in areas where high fuel loads inhibit safe prescribed fire application (Brose and Wade 2002). Roller-drum chopping (hereafter, roller-chopping) has been recommended over a single application of growing season fire when reduction in saw palmetto coverage is the objective (Willcox and Giuliano 2010). The combination of roller-chopping and fire may have longer term benefits as well. Watts et al. (2006) found that roller-chopped areas not maintained with burning had more shrubs and less herbaceous groundcover than did roller-chopped sites maintained with burning. Flat mowing is used to reduce the stature of saw palmetto but may not reduce the number of individual plants or their dominance in the groundstory. Flat mowing essentially “top-kills” perennial hardwoods and shrubs and results in increased resprouting of hardwood stems (Welch et al. 2004).

Though bobwhite historically existed at relatively high densities (Frye 1948, 1954), they currently exist in degraded pine flatwood habitats at relatively low densities (S. Brown, unpublished data), but are known to respond to management (Miley and Litchtler 2009). Comparing bird abundance and occupancy estimates over successive years and among areas associated with different management practices provides information on population trends and management effects (Ralph et al. 1995). Therefore, we monitored the response of groundcover and bobwhite occupancy on 2 public lands undergoing habitat restoration in Florida: Osceola National Forest (Osceola) and St. Sebastian River Preserve State Park (Sebastian). To do so, we assessed bobwhite occupancy over a 7-year period and related this to management as applied by the agencies. We modeled bobwhite occupancy in relation to fire use, roller-chopping, and flat mowing. We also measured groundstory condition to determine how vegetation changed following management. We expect this information to be of use to managers interested in restoration of pine flatwood habitats for bobwhite and other species of concern.

STUDY AREA

Osceola National Forest

Osceola, located in northeastern Florida, was composed of a mixture of forested wetlands and mesic pine flatwoods with sandy-acidic soils. Approximately 70% of the pine flatwoods on the Osceola was dominated by slash pine or mixed slash-longleaf pine and the remainder was longleaf pine. Dominant groundcover vegetation types included saw palmetto, gallberry, runner oak (*Quercus minima*), vaccinium (*Vaccinium* spp.), oak (*Quercus* spp.), fetterbush (*Lyonia lucida*), waxmyrtle (*Myrica cerifera*), smilax (*Smilax* spp.), wiregrass (*Aristida* spp.), and bluestem (*Andropogon* spp.). Longer fire-return intervals (4–10 years) on much of the Osceola forest has resulted in a nearly complete coverage of palmetto-shrubs in the groundcover and a decline or absence of many fire-adapted wildlife species. The U.S. Department of Agriculture Forest Service began a Collaborative Forest Landscape Restoration project in 2005 on approximately 25,000 ha of the forest to reduce wildfire threat and increase habitat quality for declining species. Management included increased prescribed fire, roller-chopping and flat-mowing of groundstory vegetation, thinning of younger slash pine stands, and planting longleaf pine.

St. Sebastian River Preserve State Park

The Sebastian study area was on a 1,070-ha portion of the northeast quadrant of the park, located in Brevard County, Florida. The mesic flatwood habitat was dominated by longleaf and slash pine and associated groundcover typical of these ecosystems. Dominant groundcover vegetation types were similar to those on the Osceola. Managers have dramatically increased the use of prescribed fire and roller-chopping over the past 15 years and Sebastian participates in the Upland Ecosystem Restoration Project (Palmer and Sisson 2017). Our study area on Sebastian was managed using frequent prescribed fire, roller-chopping, hardwood control, and some overstory pine thinning. Fires were applied on a 2-year fire frequency and burn size units ranged from approximately 100 ha to 300 ha.

METHODS

Bird Monitoring

We randomly placed 200-m radius survey plots >600 m apart along forest roads within upland habitats (78 plots on Osceola and 11 plots on Sebastian). A single trained observer surveyed bobwhite using point counts at each survey plot during April–June 2013–2019. In order to maximize detection, we visited each survey plot 3 times/year from 15 minutes before sunrise to ≤3 hours after sunrise on days with no rain and low winds. We conducted a 5-minute point count and recorded male bobwhite calls within a 200-m radius. We recorded wind and cloud cover (on the Beaufort scale), date, time, and temperature.

Management

We merged management records provided by Osceola and Sebastian with our survey plots using ArcGIS (Esri Inc., Redlands, CA, USA). To assess the effects of mechanical treatments on focal species, we created categorical variables for thinning (Thin), roller-chopping (Chop), and mowing (Mow) and classified each plot as “treated” or “untreated” in each year. We considered a plot treated if 40% or more of a plot received a management treatment. Some mechanically treated plots were burned within the same year or in years following treatment. We calculated the years since burn by determining the number of days since the most recent burn within the plot divided by 365.

Vegetation

We collected vegetation information on 8 randomly placed 10-m transects within each 200-m radius survey plot. Transects were randomly placed at the beginning of the study to track changes over time. Vegetation surveys were conducted from April–June each year, concurrent with bird surveys. At 1-m intervals (11 locations/transect) we placed a 1.5-m pole marked with decimeter increments (modified from Mills et al. 1991) and recorded the presence of each vegetation category (palmetto, shrub, hardwood, vine, pine regeneration, grass, forb, and legume) that was within a 1-dm radius from the pole. For each transect we summed the count for each vegetation category and divided this sum by the total number of decimeters per transect to represent an average "density" for each category. We calculated the density of grass, forb, and legume as a variable (Herbaceous) and density of palmetto, shrub, hardwood, pine regeneration, and vines as a variable (Woody). We assessed each vegetation variable at 2 height levels: above 5 dm (Herbaceous >5 dm, Woody >5 dm) and below 5 dm (Herbaceous ≤5 dm, Woody ≤5 dm).

Bobwhite Occupancy

We fit the single season occupancy model (MacKenzie et al. 2002) to bobwhite presence–absence data to model occupancy (ψ) and detection (p) in relation to covariates using the *occu* function in the R 4.1.0 (www.R-project.org, accessed 5 Aug 2021) package *unmarked* 1.0.1 (Fiske and Chandler 2011). Due to differences in management intensity and management actions, we fit one set of models for Osceola and one set of models for Sebastian. Low detection of bobwhite required us to stack data from all 7 years into a single season and, therefore, we included a year covariate in all models. Year was modeled as a trend variable as we believed management would result in increasing bobwhite occupancy over time. For ease of comparisons and model convergence we standardized all continuous covariates at mean 0 unit variance.

We considered 5 potential covariates for bobwhite detection (p): date, time of day, wind, cloud cover, and temperature. We considered a quadratic term for time of day because we observed a nonlinear relationship between vocalization rate and time of day with more vocalizations in the early and late morning. To examine annual effects on p, we considered interaction terms between date and the other covariates.

We considered 3 potential management-specific explanatory variables for bobwhite occupancy (ψ): roller-chopping, flat-mowing, and years since the last burn within a plot. We did not include thinning because it was not a useful predictor based on preliminary modeling of occupancy. We used Akaike's Information Criterion (AIC) in conjunction with a manual stepwise selection process to identify the best model representing management variables and their interaction with fire. We considered models within 2 AIC units from the most parsimonious model to be plausible (Burnham and Anderson 2002) and we model averaged (Buckland et al. 1997) prediction estimates. We assessed goodness of fit of the global model using a parametric bootstrapping procedure (Dixon 2002) to compute several fit statistics (e.g., sum-of-squared errors, Pearson chi-square, and Freeman-Tukey test), which provided no evidence of lack of fit ($P > 0.323$). We used the best approximating model (lowest AIC) among all models to estimate occupancy of bobwhite. All analyses were done in R 4.1.0. All values are reported as means ±1 standard error unless noted otherwise.

Vegetation Response to Mechanical Treatments

We assessed changes in groundstory composition and structure from mowing and roller-chopping by comparing average vegetation variables prior to and after a management action. For each transect, pre- and post-densities for vegetation categories were calculated by averaging annual densities, before and after a management action was applied. We used paired t-tests to determine whether the difference between pretreatment and posttreatment averages for vegetation categories was different than zero at the 0.05 significance level.

RESULTS

Management

On Osceola, 53 of the 78 plots received a mechanical treatment: mowing occurred within 22 plots, roller-chopping occurred within 22 plots, and 9 plots received both mowing and roller-chopping. Sixty-two plots received prescribed burning during the study. The average years since fire for plots was 3.0 (range 0.0–12.3). On Sebastian, all 11 plots received roller-chopping and burning during the study. The average years since fire for plots was 0.9 (range 0.0–2.0).

Bobwhite Surveys

On Osceola, we detected 39 bobwhite during point-count surveys (n = 1,638). In 2013, we detected 4 bobwhite (0.02 quail/plot) with detections in 2/78 (2.6%) of the plots; in 2019, we detected 6 bobwhite (0.03 quail/plot) with detections in 5/78 (6.4%) of the plots (Table 1). Occupancy probability of bobwhite adjusted for detection probability indicated an increasing trend in occupancy, from 0.06 ± 0.03 in 2013 to 0.31 ± 0.18 in 2019.

On Sebastian, we detected 72 bobwhite during point-count surveys (n = 231). In 2013, we detected 17 bobwhite (0.51quail/plot) with detections in 6/11 (54.5%) of the plots; in 2019, we detected 7 bobwhite (0.21quail/plot) with detections in 6/11 (54.5%) of the plots (Table 1). Occupancy probability of bobwhite adjusted for detection probability indicated an increasing trend in occupancy, from 0.51 ± 0.33 in 2013 to 0.91 ± 0.11 in 2019.

Bobwhite Occupancy and Management

For Osceola, model selection results indicated support for 2 models based upon ΔAIC <2.0 (Table 2). The top model included roller-chopping, years since fire, and year (w = 0.66). Only parameter estimates for roller-chopping and fire frequency were significant ($P \leq 0.009$). Bobwhite occupancy was negatively related to years since fire. Predicted occupancy probability, ignoring yearly and roller-chopping effects, was greater on plots with 1 year since fire (0.22 ± 0.10) than on plots with 4 years since fire (0.07 ± 0.04). Bobwhite predicted occupancy was 4 times greater on roller-chopped plots (0.33 ± 0.15) than on mowed plots (0.08 ± 0.03) and 4.7 times greater than on plots that were not roller-chopped or mowed (0.07 ± 0.03; Figure 1). An additive effect between date and time of day was included in all top models, indicating detection was positively related to the day of the year and negatively related to time of day. Overall detection probability was 0.12 ± 0.05 when date and time were set to their mean values.

On Sebastian, model selection results indicated support for 2 models based on ΔAIC <2.0 (Table 3). The top model included roller-chopping, years since fire, and year (w = 0.67) and was 1.40 AICs below the second-best approximating model, which included years since fire and year. Only parameter estimates for years since fire were significant ($P \leq 0.013$).

Bobwhite predicted occupancy was highest on plots with 1 year since fire (0.67 ± 0.18) and declined after 2 years since fire (0.09 ± 0.10). Predicted occupancy was 2.2 times higher on roller-chopped plots (0.85 ± 0.15) than on untreated plots (0.38 ± 0.34; Figure 2). An additive effect between wind and year was included in all top models, indicating detection was negatively related to wind and year. Overall detection probability was 0.35 ± 0.05 when wind and year were set to their mean values.

Vegetation Response to Mechanical Treatments

On Osceola, roller-chopping significantly increased the density of herbaceous groundcover above 5 dm (t_{117} = 7.63, p < 0.001) and below 5 dm (t_{117} = 8.03, p < 0.001) and significantly decreased the density of woody groundcover above (t_{117} = −12.75, p < 0.001) and below 5 dm (t_{117} = −6.95, p < 0.001; Table 4). Mowing significantly increased the density of herbaceous groundcover below 5 dm (t124 = 4.50, p < 0.001), but not above (t_{124} = 0.51, p = 0.611), and significantly decreased the density of woody groundcover above 5 dm (t_{124} = −12.10, p < 0.001), but not below (t_{124} = −1.27, p = 0.206). Posttreatment density of herbaceous vegetation below 5 dm was two-fold greater on roller-chopped sites than mowed sites.

On Sebastian, roller-chopping significantly increased the density of herbaceous groundcover above 5 dm (t_{69} = 14.68, p < 0.001) and below 5 dm (t_{69} = 19.10, p < 0.001) and significantly decreased the density of woody groundcover above (t_{69} = −9.23, p < 0.001) and below 5 dm (t_{69} = −8.44, p < 0.001; Table 5).

Table 1. Northern bobwhite predicted occupancy probability and percentage of 200-m radius plots with a detection, by year. Data are from 78 survey plots located in Osceola National Forest, Olustee, Florida, USA and 11 survey plots located in St. Sebastian River Preserve State Park, Micco, Florida, 2013–2019.

	Survey site					
	Osceola National Forest			St. Sebastian River Preserve State Park		
Year	Detected per plot	% plots with a detection	Occupancy probability	Detected per plot	% plots with a detection	Occupancy probability
2013	0.02	2.6	0.06 ± 0.03	0.51	54.5	0.51 ± 0.33
2014	0.01	2.6	0.08 ± 0.04	0.48	63.6	0.60 ± 0.28
2015	0.03	5.1	0.10 ± 0.05	0.12	27.3	0.69 ± 0.23
2016	0.05	7.7	0.14 ± 0.07	0.27	36.4	0.76 ± 0.19
2017	0.02	6.4	0.18 ± 0.10	0.39	72.7	0.83 ± 0.16
2018	0.02	5.1	0.24 ± 0.13	0.18	54.5	0.87 ± 0.13
2019	0.03	6.4	0.31 ± 0.18	0.21	54.5	0.91 ± 0.11

Table 2. Model selection results with ΔAkaike's Information Criterion [AIC] <2.0 for northern bobwhite occupancy in relation to management covariates[a]. All models include year as a covariate. Data are from 78 survey plots located in Osceola National Forest, Olustee, Florida, USA, 2013–2019.

Occupancy (ψ)	Detection (p)	Number of parameters	AIC	ΔAIC	AIC_{wt}
Chop+YearsSinceFire	Date+Time	7	273.42	0.00	0.66
Chop+YearsSinceFire+Mow	Date+Time	8	274.84	1.42	0.32

[a] Covariates are coded as follows: Chop = roller-chopped, YearsSinceFire = years since fire, Mow = mowed.

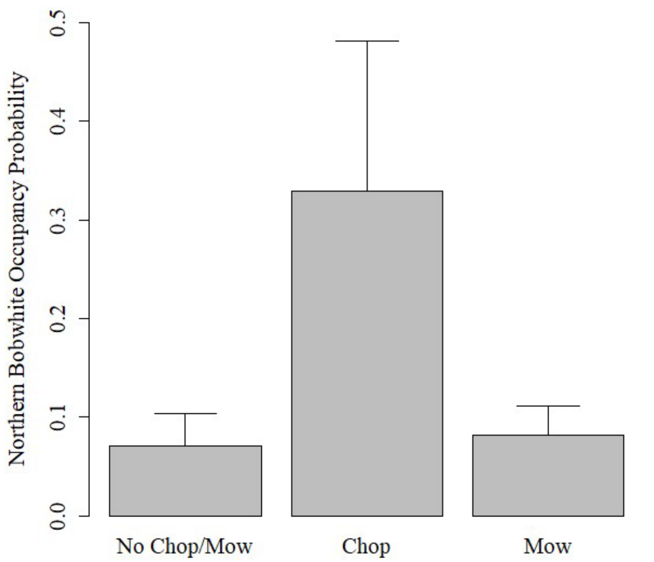

Fig. 1. Northern bobwhite occupancy probability in relation to roller-chopping and mowing on Osceola National Forest, Olustee, Florida, USA, 2013–2019. Error bars are +1 standard error.

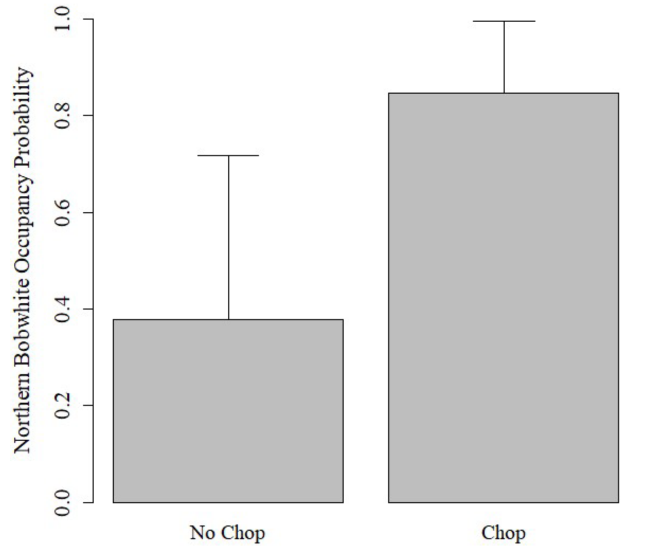

Fig. 2. Northern bobwhite occupancy probability in relation to roller-chopping on St. Sebastian River Preserve State Park, Micco, Florida, USA, 2013–2019. Error bars are +1 standard error.

Table 3. Model selection results with ΔAkaike's Information Criterion [AIC]< 2.0 for northern bobwhite occupancy in relation to management covariates[a]. All models include year as a covariate. Data are from 11 survey plots located in St. Sebastian River Preserve State Park, Micco, Florida, USA, 2013–2019.

Occupancy (ψ)	Detection (*p*)	Number of parameters	AIC	ΔAIC	AIC_{wt}
Chop+YearsSinceFire	Wind+Year	7	241.53	0.00	0.67
YearsSinceFire	Wind+Year	6	242.94	1.40	0.33

[a] Covariates are coded as follows: Chop = roller-chopped, YearsSinceFire = years since fire.

Table 4. Average density of herbaceous and woody groundcover[a] on roller-chopped and mowed plots pre-treatment ("Pre") and post-treatment ("Post") and associated p-values from paired t-tests of mean differences. Data are from 78 survey plots located in Osceola National Forest, Olustee, Florida, USA, 2013–2019.

	Treatment							
	Roller-chop				Mow			
Groundcover	Pre average	Post average	Mean of differences	p-value	Pre average	Post average	Mean of differences	p-value
Herbaceous ≤5 dm	0.272	0.460	0.189	<0.001	0.172	0.248	0.075	<0.001
Herbaceous >5 dm	0.030	0.087	0.056	<0.001	0.023	0.025	0.002	0.611
Woody ≤5 dm	1.076	0.919	−0.156	<0.001	1.101	1.079	−0.022	0.206
Woody >5 dm	0.374	0.176	−0.197	<0.001	0.456	0.221	−0.234	<0.001

[a] Groundcover is described by the following: herbaceous = grass, forb, legume; woody = palmetto, shrub, hardwood, pine regeneration, vine.

Table 5. Average density of herbaceous and woody groundcover[a] on roller-chopped plots both pre-treatment ("Pre") and post-treatment ("Post") and associated p-values from paired t-tests of mean differences. Data are from 11 survey plots located in St. Sebastian River Preserve State Park, Micco, Florida, USA, 2013–2019.

Groundcover	Pre average	Post average	Mean of differences	p-value
Herbaceous ≤5 dm	0.855	1.161	0.306	<0.001
Herbaceous >5 dm	0.060	0.241	0.181	<0.001
Woody ≤5 dm	0.638	0.444	−0.193	<0.001
Woody >5 dm	0.111	0.025	−0.086	<0.001

[a] Groundcover is described by the following: herbaceous = grass, forb, legume; woody = palmetto, shrub, hardwood, pine regeneration, vine.

DISCUSSION

Bobwhite occupancy declined with time since fire, indicating that the effects of fire on habitat suitability were temporary. Similar to our study, Miley and Lichtler (2009) found that bobwhite were more abundant in pine flatwoods burned within 1 year and abundance declined in areas >2 years since fire. Other studies have documented the importance of frequent fire to bobwhite habitat suitability (Stoddard 1931, Brennan et al. 1998, Palmer and Sisson 2017, Rosche et al. 2019, Weber et al. 2022, this volume).

Fire frequency has long-term effects that drive pine forest community structure and composition (Glitzenstein et al. 2003, 2012; Rother et al. 2020). In fire-suppressed pine flatwoods, or those with longer fire rotations, groundstory communities become dominated by saw palmetto and shrubs (Glitzenstein et al. 2003) and applying frequent fire may not reduce their dominance. A long-term study on Osceola determined that annual burns, spanning several decades, did not produce herbaceous-dominated groundcover and only slightly reduced the dominance of saw palmetto (Glitzenstein et al. 2003). Therefore, fire alone may not be a viable management technique for improving bobwhite habitat in degraded habitats.

Roller-chopping reduces dominance of saw palmetto in the groundstory and releases grasses and forbs because it kills the roots of saw palmetto (Hendricks 1983, Willcox and Giulano 2010). Conversely, mowing essentially mimics fire by top-killing individual plants that quickly resprout without a change in species composition (Welch et al. 2004, Menges et al. 2020). On Osceola, where both mowing and roller-chopping occurred, mowing reduced the stature of hardwoods and saw palmetto, but only modestly increased grasses and forbs in comparison to roller-chopping. We believe the positive response of bobwhite to roller-chopping was due to the large changes in habitat structure and composition that it caused; mowing did not elicit a bobwhite response because it did not adequately reduce saw palmetto dominance. Our results indicate that mowing is not an effective, long-term treatment for increasing bobwhite habitat in fire-suppressed pine flatwoods.

Though roller-chopping shifted the plant community and improved bobwhite habitat suitability, the effects of roller-chopping were temporary without the application of frequent fire. We observed increased density of saw palmetto on roller-chopped plots that did not receive adequate fire. Application of roller-chopping requires frequent fire to sustain herbaceous groundcover (Brose and Wade 2002, Watts and Tanner 2004, Watts et al. 2006, Willcox and Giuliano 2010). Watts et al. (2006) observed effects of roller-chopping and burning and found that sites roller-chopped and burned maintained higher forb richness and higher density of grasses even 12–13 years post-treatment. Therefore, long-term frequently applied fire is needed to sustain benefits accrued from roller-chopping degraded flatwood habitats.

Increased management activities improved habitat and resulted in a modest increase in bobwhite occupancy on both our study sites. However, bobwhite occupancy was lower on Osceola than Sebastian. Fire frequency on Osceola averaged nearly 5 years (compared to every 2 years on Sebastian), which resulted in large areas of palmetto-shrub dominance in the groundstory. In addition, less roller-chopping per plot occurred on Osceola than on Sebastian. Finally, the spatial extent and distribution of management on Osceola was determined by an ecological index model, resulting in patches of suitable habitat (this may change with continued management), whereas management on Sebastian concentrated on a focal area, which resulted in more contiguous habitat. We believe the lack of contiguous habitat on Osceola reduced the effectiveness of management actions for eliciting a bobwhite population response (Dunning et al. 1995, Fies et al. 2002, Cox and Kesler 2012).

While bobwhite numbers on Osceola were limited by the extent and distribution of suitable habitats, suitable habitat on Sebastian covered most of the area. However, the number of bobwhites on Sebastian plateaued at a relatively low level (<1 bobwhite detected/plot), while sympatric species, such as Bachman's sparrow (*Peucaea aestivalis*), increased in abundance each year (S. Brown, unpublished data). Bobwhite numbers on Sebastian appeared to be lower than other sites with high fire frequency in central Florida studies (Miley and Lichtler 2009, Johnson et al. 2014). We believe the plateau in bobwhite numbers may be associated with the size and season of fires used on Sebastian. Objectives for management of Sebastian were implemented to benefit a suite of fire-adapted species and therefore fire management was not optimized for bobwhite. Prescribed fires at Sebastian shifted in season over the course of our study from January–May to April–June. Fires occurring in April–June coincide with peak nesting season in central Florida and we suspect that these fires may have impacted nesting success and brood survival, potentially impacting population growth (Kamps et al. 2017). In addition, fires were relatively large in size. The combination of high fire frequency applied during peak nesting season at larger scales (larger than recommended for bobwhite), likely limited the positive response of the population (Weber et al. 2022, this volume).

MANAGEMENT IMPLICATIONS

Roller-chopping followed by fire is an effective technique to increase bobwhite occupancy in degraded mesic pine flatwoods. We suggest that management actions should be directed toward maintaining current areas of high-quality habitat with frequent fire (≤2-year fire rotation) and treating highly degraded areas with roller-chopping followed by fire. We do not recommend the use of mowing on saw palmetto-shrub communities for improving bobwhite habitat suitability. Though mowing may have utility in reducing fuel loads to facilitate burning, roller-chopping has the added benefit of increasing habitat suitability and occupancy of bobwhite. When possible, managers should apply these techniques on large continuous areas to improve bobwhite response.

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