Cost and Forage Production of Food Plots, Prescribed Fire, and Roller Chopping for Northern Bobwhite at Babcock-Webb Wildlife Management Area, Florida

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Abstract: Management of northern bobwhite (*Colinus virginianus*) commonly focuses on creating cover and food for bobwhite throughout the year. Numerous studies have addressed these management practices and their impacts on bobwhite, but few have assessed the quantity of resources they produce or the associated management cost per unit of production. My study assesses three common bobwhite habitat management practices (prescribed fire, roller chopping, and food plots) on the Cecil M. Webb-Babcock Wildlife Management Area in Charlotte County, Florida. I estimated production of the most common natural bobwhite forage (slough grass [*Scleria* spp.]) and the most common planted species (sesbania [*Sesbania* spp.]) in 80 wildlife exclosures located in areas that had been managed with prescribed fire only, in those that had been managed with both prescribed fire and roller chopping, and in food plots. I documented substantially higher production yields (i.e., dry weight of seed) of sesbania in food plots (3,627.3 kg ha^{-1}) than other forage species and under different management practices. Slough grass was much more widespread across management practices and the study area than sesbania, which was documented only in food plots. Based on yield estimates, production was more cost-effective for sesbania in food plots than slough grass in roller chopping areas ($0.88 kg^{-1} and $23.91 kg^{-1}, respectively). Although production and management costs of sesbania food plots are much lower than those associated with management for slough grass, environmental factors such as flooding, seed degradation, and the small effective spatial extent of food plots may limit any positive benefits for bobwhite populations.

Key words: northern bobwhite, *Sesbania* spp., habitat management, supplemental forage, management cost

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Management for northern bobwhite (*Colinus virginianus*; hereafter bobwhite) frequently involves prescribed fire and mechanical habitat manipulations such as roller chopping, disking, brush piles, food plots, and supplemental feeding. Numerous studies have examined the biological outcomes of these management practices, with highly variable results within and across the activities (see Doerr and Silvy 2002 for a summary). The use of food plots and supplemental feeding continues to be popular with bobwhite managers to provide additional winter food resources for bobwhite (Doerr and Silvy 2002, Madison et al. 2000). In addition, food plots are a visible and tangible use of funds dedicated to wildlife management, unlike other management practices less obvious to the public. However, food plots typically are more costly to managers than other practices such as prescribed fire or roller chopping because of specialized equipment requirements, personnel time, and seed costs. Food plots have been shown to benefit target wildlife species by providing cover and supplemental food sources during food-stressed periods (Robel et al. 1974, Porter et al. 1980, Guthery 1999, Smith et al. 2007), but the spatial extent of habitat improved by food plots can be small for bobwhite (Robel et al. 1974). Guthery (1997) concluded that such practices were beneficial to bobwhite populations only when paired with quality habitat at spatial scales larger enough to benefit the birds year-round. Therefore, bobwhite managers often attempt to balance the use of food plots with other management practices that create habitat that bobwhite need for cover, reproduction, and other facets of their lifecycle.

Managers must also incorporate the cost of practices into bobwhite management plans, which can constrain how they manage habitat. For example, the Florida Fish and Wildlife Conservation Commission (FWC) estimates that prescribed fire costs approximately US$74.10 per hectare burned, whereas roller chopping and food plots can cost as much as $123.55 and $494.21 ha^{-1}, respectively (A. Pope, Florida Fish and Wildlife Conservation Commission, personal communication). For a manager responsible for ensuring a sustainable population of bobwhite and adequate opportunity for hunters, these costs must be considered relative to their biological benefits and the spatial extent of the managed property.

The Fred C. Babcock-Cecil M. Webb Wildlife Management Area (hereafter, Webb WMA) is Florida's oldest wildlife management area, and historically this south Florida rangeland has been managed for bobwhite. Webb WMA uses a combination of *Sesbania Exaltata* (hereafter sesbania), a non-native to Charlotte County, Florida (USDA 2006), food plots, roller chopping, and prescribed fire to managed bobwhite habitat. Historically, food plots were not present on Webb WMA, and bobwhite subsisted on a combination of native wax myrtle (*Myrica cerifera*) and slough grass (*Scleria muhlenbergii, verticillata,* and *reticularis*) seeds during late fall and winter (October–January; Lassle and Frye 1956, Singh et al. 2010). Lassle and Frye (1956) found that slough grass seeds provided adequate to higher nutritional benefits than what was then assumed to be the ideal bobwhite diet (Nestler 1949). They also found that seeds of slough grass and wax-myrtle were consumed at different times of year but were the staple of bobwhite winter diets on Webb WMA. Approximately 25 years ago, the first sesbania food plots were planted on Webb WMA; sesbania is still used to provide bobwhite with winter food and to increase hunting opportunities. Rolland et al. (2010) and Singh et al. (2010) provided some evidence for the use of food plots for bobwhite management on Webb WMA, indicating that bobwhite preferred food plots when selecting nest sites and winter ranges. But neither those two researchers nor others found that the presence of food plots improved winter natural survival or reproductive parameters of bobwhite (Madison et al. 2000, Rolland et al. 2010). Moreover, Madison and Robel (2001) found that of 12 commonly planted forage species for bobwhite winter forage, sesbania was one of the poorest in nutritional value.

Because increased winter forage is the reason food plots are provided on Webb WMA, I sampled forage production at Webb WMA in 2016 to determine whether the food plots provided more winter forage for bobwhite than natural food sources. I also assessed the amount of forage (i.e., seeds) produced by roller chopping and prescribed fire, both of which are less expensive management practices than food plots. Accordingly, the four objectives of my study were to: 1) estimate the average amount of winter forage for bobwhite (kg ha^{-1}) produced in three management treatments (food plots, roller chopping, prescribed fire); 2) estimate the amount of forage produced by slough grass (*Scleria muhlenbergii, verticillata,* and *reticularis*) and planted sesbania; 3) assess the cost of forage production among the three management treatments; and 4) estimate the densities of wax myrtle in the three management treatments because of its documented importance to bobwhite on Webb WMA (Lassle and Frye 1956).

Methods

Study Area

Babcock-Webb Wildlife Management Area (Webb WMA; 26,611 ha) comprises mesic flatwoods, wet flatwoods, dry prairie, and wet prairie (37.4%, 18.6%, 12.5%, and 6.4%, respectively), with the remainder in disturbed grasslands/shrublands, hardwood hammocks, cypress swamps, and open water. Webb WMA is located approximately 8 km east of Punta Gorda, in Charlotte County. At the time of this study, (2016), Bobwhite was a focal species therein, and its management included an approximately 18-month prescribed-fire rotation over most of the area, herbicide and mechanical treatments to promote bobwhite habitat, and food plots to supplement natural bobwhite forage and increase hunting opportunity. Some recently burned areas also received mechanical treatments such as roller chopping and were the focus of this study. Food plots on Webb WMA represented <1% (approximately 16 ha) of the total area and were typically 3-m-wide linear plots planted with sesbania and fertilized annually. Webb WMA was also divided into 5 management units where managers surveyed and set harvest quotas of bobwhite according to annual covey call counts. Aside from management for bobwhite, Webb WMA was also actively managed for threatened and endangered species such as the red-cockaded woodpecker (*Picoides borealis*) and the Florida bonneted bat (*Eumops floridanus*).

Field Methods

I used steel posts and wire fencing to establish 80 wildlife/livestock exclosures approximately 1.5 m high and 1.5 m in diameter to prevent wildlife and livestock from browsing on study species before sampling. I placed 40 of the exclosures within established food plots that had been disked approximately 14 days prior, 20 in areas that had been roller-chopped the previous summer or fall and treated with prescribed fire, and 20 in areas where prescribed burning had occurred in the same season of the previous year. I placed the exclosures in June 2016 immediately following the disking of food plots by Webb staff and sampled each exclosure in mid-September 2016. Due to high water in 2016, food plots were not planted and samples consisted of volunteer recruitment from the 2015 planting. Not planting food plots in 2016 potentially could bias food plot yields low when compared to normal years where planting occurs normally. Sampling consisted of collecting all stems of each study species from a 0.5- × 0.5-m^2 placed in the center of the exclosure. Sesbania and slough grass were placed in separate paper bags for storage and transport. Wax myrtle stems were counted within a 10-m radius from the center of the exclosure and classified into two categories, large and small. Large wax myrtle stems were those >1 m in height; small stems were ≤1 m in height.

I air-dried samples at approximately 21°C for 60 days. I then removed all seeds for the target species from any other plant materials, keeping Sesbania and slough grass seeds separate. I further dried the seeds in a drying oven at 65°C for at least 8 hrs. I then weighed each sample and recorded the seed mass collected from each exclosure for each target species using a Ohaus DV215CD analytical balance, Ohaus Corporation, Pine Brook, New Jersey.

Analysis

After weighing each sample, I calculated the mean and standard error for yield (kg ha^{-1}) and stem density of sesbania and slough grass measured from exclosures in each management practice. I also reported the highest yield and stem density from any single exclosure for sesbania and slough grass as a representative of potential maximum yield for each management practice. I tested for differences in yield between management practices for each forage species and between forage species yields within management practices using the non-parametric Kruskal-Wallis test and made pairwise comparisons between management practices within each forage species using a Wilcox Rank Sum test. All analyses were conducted using the R statistical Software (R Core Team 2013). For wax myrtle, I calculated the mean and standard error for the stem density of total stems, small stems, and large stem within 10 m of each exclosure. Lastly, using the mean yield per species by management practice and the cost per ha for each management practice implemented on Webb WMA, I calculated the cost per kg of yield for each species by management practice to provide perspective of the financial cost of producing more winter forage for bobwhite.

Table 1. Mean yield (kg ha^{-1}) and standard error () of exclosures for the two target species (sesbania, Sesbania spp.; slough grass, Scleria spp.), the maximum yield from a single exclosure, and the number of exclosures, from fall 2016 on Babcock-Webb Wildlife Management Area, Charlotte County, Florida.

	Mean yield (kg ha^{-1})	Production cost (cost kg^{-1})	Max yield (kg ha^{-1})	Mean stem density (stems/m^2)	*n*
Sesbania spp.					
Food plot	535.1 (155.1)	$0.92	3627.4	49.2 (7.9)	39
Scleria spp.					
Roller chopping	3.4 (1.1)	$36.34	17.9	130 (75)	20
Food plot	1 (0.3)	$494.21	8.0	26.5 (7.7)	39
Prescribed fire only	0.02 (0.02)	$370.50	0.3	11.8 (10.4)	20

Table 2. Mean (SE) stem density (stems ha^{-1}) of wax myrtle (*Myrica* spp.) in two size classes, small (height <1 m) and large (height ≥1 m), measured within a 10-m radius circle around wildlife exclsoures in fall 2016 on Babcock-Webb Wildlife Management Area, Charlotte County, Florida.

	Mean stem density	Mean small stem density	Mean large stem density	*n*
Roller chopping	6.4 (5)	6.4 (5)	0 (0)	20
Food plot	84.1 (14.2)	8.2 (5.7)	75.9 (14.2)	39
Prescribed fire only	33.4 (12.7)	20.7 (9.9)	12.7 (6.3)	20

Results

Sesbania and Slough Grass Production

I documented sesbania stems only in food plots and found at least one stem in 37 of 39 exclosures (one of the 40 exclosures was destroyed during the study) even though food plots were not planted in 2016. Sesbania production was entirely due to volunteer recruitment from the 2015 planting. I documented a mean yield of sesbania from food plots of 535.1 kg ha^{-1} (SE = 155.1 kg ha^{-1}) with a maximum single exclosure yield of 3,627.4 kg ha^{-1} (Table 1). The mean stem density of sesbania within exclosures was 49.2 stems/m^2 (SE = 7.9 stems/m^2). Sesbania production in food plots was significantly greater than production in all other management practices ($P < 0.001$) based on a non-parametric Kruskal-Wallis and pairwise comparison using a Wilcox Rank Sum tests.

I documented slough grass in 14 of 20 (70%) roller chopping exclosures, 13 of 39 (33%) food plot exclosures, and 2 of 20 (10%) prescribed-fire-only exclosures. In exclosures in which slough grass was present, I documented a mean yield of 1.4 kg ha^{-1} (SE= 0.3 kg ha^{-1}) and a maximum single exclosure yield of 17.9 kg ha^{-1} (Table 1). The mean stem density of slough grass within exclosures was 49 stems/m^2 (SE = 20 stems/m^2). Slough grass production was highest in exclosures located in roller chopping areas (3.4 kg ha^{-1}; SE = 1.1 kg ha^{-1}) followed by food plots and prescribed fire only areas (1 kg ha^{-1}; SE = 0.3 kg ha^{-1} and 0.2 kg ha^{-1}; SE = 0.02 kg ha^{-1}, respectively). Slough grass production was significantly greater in roller chopping areas than prescribed fire areas and food plots ($x^2 = 15.9$, df = 2, $P < 0.05$) based on a non-parametric Kruskal-Wallis and pairwise comparison using a Wilcox Rank Sum tests. Additionally, non-parametric Kruskal-Wallis tests indicated significant higher sesbania production than scleria production within exclosures located in roller chopping and food plot treatments (x^2=44.6, df = 1, $P < 0.001$) but not in random areas ($x^2 = 2.1$, df = 1, $P = 0.15$).

Wax Myrtle Density

Mean stem density of total wax myrtle (large and small) was greatest around food plots, followed by prescribed fire only and roller chopped areas (Table 2). I observed no large wax myrtle stems in roller chopped areas, but large stems were common around food plots. Prescribed fire areas consisted of a mixture of large and small wax myrtle stems as would be expected without the effects of fire breaks on fire intensity and the effects of roller chopping on woody shrubs such as wax myrtle.

Cost Analysis of Management Practices

At the time of this study, FWC estimated the approximate cost of food plots as $494.00 ha^{-1}; roller chopping, $123.50 ha^{-1}; and prescribed fire, $74.10 ha^{-1} (A. Pope, Florida Fish and Wildlife Conservation Commission, personal communication). Managers at Webb WMA provided approximately 16 ha of food plots, roller-chopped approximately 250 ha year^{-1} (A. Pope, Florida Fish and Wildlife Commission, personal communication), and burned approximately 10,521 ha. Based on yield estimates and implementation costs for each of these three management practices, sesbania food plots at \$0.88 kg^{-1} of forage produced were substantially more cost-effective in producing winter forage than were the other management practices (Table 1). The next most cost-effective method was roller chopping at \$23.91 kg^{-1} of slough grass forage produced, followed by food plots for slough grass production at \$169.22 kg^{-1}, and prescribed fire only at \$330.00 kg^{-1}.

Discussion

A successful bobwhite management regime on public lands is dependent on managers selecting cost-effective practices that produce positive biological outcomes with a large effective footprint. In a study of bobwhite plantations in the Red Hills region of Georgia, Sisson et al. (2017) estimated the average habitat-management costs to be \$232.18 ha^{-1} $year^{-1}$. This estimate, however, incorporates multiple types of management activities and provides little information on the cost per unit of resources provided by each one. On private lands, funding for management may be more plentiful, and managers may be more likely to focus on just one species. But managers striving to optimize biological outcomes for bobwhite while working with limited funding and on other species as well require information on the biological outcomes and associated costs of management practices to apply the most cost-effective practice in different situations. My study provides cost estimates for three of the most common bobwhite management activities used in south Florida and the rest of the southeastern United States based on three of the most common forage species on the study area. Although the target forage species of this study may be specific to central and south Florida the concept of managers weighing available resources versus their potential biological impact from management practices translates across regions and species. Additionally, my estimates of cost per unit of forage produced should provide managers with a better starting point when attempting to optimize the biological outcomes of their management activities while covering the largest possible spatial extent with limited financial resources. This paradox for the managers on my study area is similar to situations managers encounter throughout the Southeast where management decisions must be made with resources at hand.

Forage Production

Yield is a readily quantifiable and replicable method of assessing the potential for positive biological outcomes that result from management intended to promote the production of forage. My findings show that planted supplemental sesbania produced considerably more winter forage biomass for bobwhite than did the native slough grass (546.1 kg ha^{-1} vs. 3.73 kg ha^{-1}). Sesbania yield in 2016 resulted only from volunteer recruitment from the 2015 planting but was still an order of magnitude higher than slough grass production. Even in roller-chopped areas intended to promote production of slough grass, production by weight (5.17 kg ha^{-1}) was still considerably less than production in food plots. However, the data presented here represent a snapshot of production and do not account for any other important differences between sesbania and slough grass, such as timing of production, availability to bobwhite, and nutritional value that might limit the benefits of food plots.

Lower amounts of production by slough grass may not correspond directly to a lack of winter forage or negative biological outcomes for multiple reasons. Unlike sesbania, slough grass produces forage for bobwhite throughout the winter (Lassle and Frye 1956). In addition, slough grass is one of a suite of other winter bobwhite foods on Webb WMA consumed during that season (Lassle and Frye 1956). A native species such as slough grass may also be buffered against local inter-annual weather variations that may lead to the failure of a non-native planted species, making it a more stable food source than sesbania within and among years (Jones 2013). Spatially, both sesbania and slough grass that resulted from management in my study had a small spatial extent relative to the landscape. Roller chopping and the resulting increased density of slough grass do, however, cover a substantially larger spatial extent than do food plots. This results in management of a wider range of soils with variable hydrology, which may buffer slough grass production over a larger area against especially wet or dry years.

Although levels of supplemental feed far below those produced by sesbania in this study can still benefit bobwhite through increased winter survival (Sisson et al. 2000, Doerr and Silvy 2002), food plots have not increased survival on Webb WMA (Rolland et al. 2010). The energetic benefits of food plots to bobwhite at Webb WMA may have been negated by increased mortality rates, either through harvest or predation of bobwhite, because the small spatial extent of food plots may concentrate bobwhite, predators, or hunters (Landers and Mueller 1986, Curtis et al. 1988). The neutral effect of food plots on survival and reproduction on Webb WMA observed by Rolland et al. (2010) and Singh et al. (2010) may also result in part from sesbania not being available to bobwhite because of the seasonality of its production. Sesbania must be able to persist on the ground throughout the winter to be a sustaining food source for bobwhite because it is produced once annually and not throughout the winter. Nelms and Twedt (1996) found that in flooded agricultural fields, sesbania took longer to deteriorate than did crops such as corn and soybeans. But due to seasonal flooding on Webb WMA and on mesic flatwoods in south Florida in general, seeds may persist but not be available to bobwhite due to inundation of food plots. Conversely, slough grass produces forage on a much wider spatio-temporal extent than do food plots, making it more likely to have a positive effect on bobwhite even though production is substantially less. Although Rolland et al. (2010) and Singh et al. (2010) did not examine the effect of management practices such as roller chopping that promote the growth and production of natural vegetation such slough grass, it is possible that there are direct positive benefits to bobwhite from roller chopping. For example, Wilcox and Giuliano (2011) found growing season roller chopping in central Florida, similar to that implemented on Webb WMA, did increase avian breeding community abundance. Also in the Red Hills regions of Florida and Georgia roller-chopping has been used as a soil disturbance similar to its implementation on Webb WMA with benefits to bobwhite similar to disking (Engstrom and Palmer 2005).

Nutritional value is another important factor to consider in assessing the utility of food plots to bobwhite. Lassle and Frye (1956) estimate that the crude protein content of slough grass seeds on Webb WMA is 16.5% dry matter (DM), compared with estimates for sesbania seeds of 8.5% DM (Heuzé et al. 2015). Others have also found that sesbania is among one of the nutritionally poorest bobwhite foods used in food plots (Madison and Robel 2001). When compared with the ideal diet of bobwhite as determined by Nestler et al. (1949), sesbania alone is considerably lacking in the crude protein considered necessary for growth and reproduction (14.6% crude protein in sesbania compared to 23%–28% for growth and reproduction). Additionally, Madison and Robel (2001) found that captive bobwhite fed exclusively sesbania lost the greatest amount of body mass compared to bobwhite on diets of other commonly planted food plot seeds. Nutritional values of sesbania seeds may also deteriorate, especially in the warm and humid conditions of south Florida. Preacher (1978) observed seed deterioration in South Carolina, so presumably the warmer and equally humid conditions in south Florida probably means seeds rapidly deteriorated at my study site as well. The combination of a single seed-production event in the fall, decreasing nutritional value over time, and low initial nutritional value lessens the potential for sesbania as a sustaining or supplemental food source. Slough grass produces seed throughout the year and therefore likely loses less nutritional value because new, unweathered seeds are available to bobwhite throughout the year.

Cost Analysis

Bobwhite managers on public lands usually have a limited budget for sustaining or improving the bobwhite population while at the same time providing adequate hunting opportunities and integrating bobwhite management with that of other species. Food plots in general are not only expensive (approximately \$494.00 ha^{-1} on Webb WMA) but often target a single or few species of wildlife in their implementation. Though benefits of forage yield of food plots has been seen to be significantly greater, managers on Webb WMA may favor less expensive practices, such as roller chopping and prescribed fire because of their wider range of positive biological outcomes for bobwhite in particular. However, managers could tailor food plot management to be less expensive than the \$494.00 ha^{-1} cost on Webb WMA. On bobwhite plantations in southwestern Georgia, bobwhite managers used broadcast supplemental feeding at rates of 313 kg ha^{-1} and 283 kg ha^{-1} of two supplemental feeds over the winter season for a total season supplement of 596 kg ha^{-1} (Sisson et al. 2000). Managers at Webb WMA did not plant food plots during 2016 but instead relied on volunteer recruitment from the previous year's planting and still reached yield levels like that of common supplemental feeding practices (546.1 kg ha^{-1} from food plots compared with 596 kg ha^{-1} of supplemental feeding). With such high yields observed in this study from only volunteer recruitment, managers could reduce their planting frequency, reducing costs and making resources available for other management practices.

Management Implications

Although bobwhite food plots are more expensive than roller chopping and prescribed fire to implement each year, they do produce considerably more winter forage by dry weight than natural vegetation such as slough grass. Natural vegetation, however, provides forage year-round (Lassle and Fry 1956). In addition, a single supplemental forage event such as that from food plots may be negatively affected by time through seed deterioration and loss of nutritional value by weathering. Thus, managers should take temporal availability into account when including food plots in their management plans. However, if managers do incorporate food plots into the management regimes, they should pay special attention to the volunteer recruitment of their planted species such as that observed on Webb WMA. By reducing the frequency of planting food plots and only performing maintenance activities, managers could cut cost so that limited funds can be redirected toward other management alternatives that impact a broader range of life history stages, species, or areas. Management that intends to increase a food source should take special care to investigate how the nutritional differences between the resulting food sources may impact bobwhite populations. Roller chopping as a stand-alone management practice appears to stimulate the production of natural forage sources such as slough grass that may be sufficient justification for managers to increase the resources they devote to the practice. Increasing the distances between roller chopping tracks or units to apply roller chopping to a larger area would stimulate at least some natural forage production over a greater spatial extent while using the same resources.

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