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EFFECTS OF NORTHERN BOBWHITE HABITAT MANAGEMENT PRACTICES ON RED IMPORTED FIRE ANTS

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Abstract

Management practices that create early successional plant communities through disturbance (discing and prescribed fire) often are prescribed for restoration of declining northern bobwhite (*Colinus virginianus*) populations. Because disturbance may facilitate invasion of exotic flora and fauna such as red imported fire ants (RIFA, *Solenopsis invicta*), we hypothesized that habitat management practices commonly used to enhance bobwhite habitat might have the unintended consequence of increasing local abundance of RIFA. During 1999, we tested effects of 4 treatments (spring discing, spring prescribed burning, spring mowing, and no management), in a randomized complete block design ($n = 10$) on RIFA abundance in Conservation Reserve Program (CRP) fields in central Mississippi. We surveyed RIFA abundance using 3 measures: 1) mound density, 2) a population index based on worker ant and brood estimates, and 3) foraging activity as indexed by attraction to protein bait cups. During May 1999, mound density ($P = 0.0136$) and population index ($P = 0.0078$) differed among treatments, with abundance values greatest in plots treated with fire, and lowest in disced plots. The index of foraging activity did not differ among treatments ($P = 0.6637$). During October 1999, mound density ($P = 0.0334$) and population index ($P = 0.0451$) differed among treatments with abundance values greatest in plots receiving fire and disc treatments, and lowest abundance in control plots. The index of foraging activity did not differ among treatments ($P = 0.9079$). Disturbance tools such as prescribed fire and discing are essential to maintain plant communities to which bobwhite are adapted; however, they may have the unintended consequence of facilitating invasion of RIFA and increasing local RIFA populations.

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Key words: *Colinus virginianus*, discing, fire ant, habitat management, northern bobwhite, prescribed burning, *Solenopsis invicta*

INTRODUCTION

During the last 3 decades, northern bobwhite populations have declined rangewide, and the decline has been particularly steep in the southeast (Brennan 1991, Sauer et al. 1997). The decline has been attributed to large-scale deterioration of bobwhite habitat quality through advanced natural succession, monoculture farming, and intensive timber management (Exum et al. 1982, Brennan 1991). Furthermore, Allen et al. (1995) implicated the RIFA as an additional factor that might contribute to declining bobwhite populations in the southeastern United States.

Effects of RIFA on bobwhite populations have been a contentious issue in the scientific literature (Allen et al. 1993, Brennan 1993). Some studies have deemphasized effects of fire ants on bobwhite popula-

tions (Johnson 1961, Komerack 1980, Brennan 1993). Yet Allen et al. (1995), Pederson et al. (1996), Mueller et al. (1999), and Giuliano et al. (1996) presented compelling evidence that RIFA can negatively affect bobwhite populations under some circumstances. Red imported fire ants can affect bobwhite populations through direct and indirect effects on chicks. Red imported fire ants can directly affect bobwhite populations through predation on pipping chicks (Johnson 1961). Exposure to RIFA can reduce survival and weight gain of chicks (Giuliano et al. 1996). Moreover, RIFA may alter time and energy budgets of chicks, affecting weight gain and survival (Pederson et al. 1996). Red imported fire ants may reduce foraging efficiency of bobwhite chicks by simplifying invertebrate communities through competition and depredation (Fillman and Sterling 1983, Porter et al. 1988, and Porter and Savignano 1990). Mueller et al. (1999) demonstrated that RIFA abundance in the vicinity of the nest influenced survival of bobwhite chicks to an age of 21 days.

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Effects of RIFA on bobwhite and other native animals, including arthropods and vertebrates, are greatest in the presence of polygyne colonies (Lofgren 1986, Porter and Savignano 1990, and Allen et al. 1995). Polygyne colonies have multiple fertile queens, exhibit less territoriality, and consequently occur in very dense concentrations (300–2000 mounds/ha) (Glancey and Lofgren 1988, Porter et al. 1988, and Lofgren and Williams 1984). In contrast, monogyne colonies exhibit territoriality and generally stabilize at densities of 40–80 mounds/ha (Vinson and Sorensen 1986, Porter and Tschinkel 1987).

Red imported fire ants prefer the open and semi-open vegetation structure characteristic of early successional plant communities (Porter and Tschinkel 1987). Anthropogenic activities often create and maintain disturbance-dependent ecosystems (Banks et al. 1985), potentially facilitating colonization by RIFA. Disturbance promotes RIFA colonization in 2 ways: 1) by opening canopy or dense herbaceous layers allowing light penetration, and 2) by removal of competitive native ant species. Native ants generally do not colonize as rapidly or exhibit the rapid population growth of the RIFA (Tschinkel 1993, Allen et al. 1998).

Management practices commonly prescribed to enhance bobwhite habitat, such as disking and fire, create and maintain early successional characteristics and may have the unintended consequence of increasing RIFA abundance or activity. Although RIFA are known to inhabit early successional plant communities, potential effects of bobwhite habitat management practices on RIFA have not been investigated. Therefore, we tested the null hypothesis that disking, prescribed fire, and mowing did not affect indices of RIFA abundance and foraging activity during 1999 in central Mississippi.

METHODS

This research was conducted on Cameron Plantation, a 4,048-ha private property in Madison County, Mississippi. Cameron Plantation is characterized by a mostly flat topography with 0–12% slopes. The predominant soil type is Loring silt loam, with minor occurrence of Calloway and Grenada silt loams (Scott 1984). These soils are moderately well drained and contain a fragipan. Soil pH is strongly acidic to very strongly acidic (Scott 1984). Vegetative communities on Cameron Plantation include mature bottomland hardwood, mixed pine/hardwood, and pine forests, CRP fields enrolled as CP10 (existing grass) and CP3 (pine trees), and agricultural fields planted to soybeans or corn. Red imported fire ant populations were estimated on Cameron Plantation and adjacent properties during May 1998 by complete census of mounds in 35 randomly located, 0.10-ha circular plots (Lofgren and Williams 1984 and Allen et al. 1995). Mean RIFA mound density was 395 (SE = 38.01) mounds/ha and mean population index was estimated following the methodology of Lofgren and Williams (1984) at 581 (SE = 52.17).

Table 1. Population index used to assess relative abundance of red-imported fire ants (RIFA) on Cameron Plantation, Mississippi, 1999.

Estimated No. of Worker Ants	Mound Index	
	Worker Brood Absent	Worker Brood Present
<100	1	6
100 to 1000	2	7
1000 to 10,000	3	8
10,000 to 50,000	4	9
>50,000	5	10

We established treatment blocks (n = 10) in March 1999 on 10 grass CRP fields with similar soil and vegetative characteristics distributed throughout the property. Grass stands in these fields had previously been maintained by annual mowing and were dominated by broomsedge (*Andropogon virginianus*). Treatment blocks had not been burned or disced for ≥3 years prior to the initiation of the study. All treatment blocks consisted of Loring soils (Scott 1984). Each block was divided into 4, 30m × 50m plots. Each plot was randomly assigned a treatment: burning, mowing, disking, or no treatment. Prescribed burn plots were burned 2–4 March 1999. Burn plots were encircled by a 2-m wide, disced fire break. Disking was performed on 2 March 1999 for all selected plots. Plots assigned a mowing treatment were bush-hogged to a height of 10 cm on 10 March 1999. We separated plots by a 10-m wide, non-treated buffer to minimize residual effects of treatments on adjacent plots.

Treatment plots were sampled for RIFA during 2 periods: 19–20 May 1999 and 21–23 October 1999. Only 6 blocks were sampled in October due to inadvertent destruction of 4 plots by land management activities. We used a complete count of mounds and the population index method as modified by Lofgren and Williams (1984) to index fire ant abundance within treatment plots. Mound surveys were conducted by a careful, systematic search throughout each 0.15-ha plot by a team of 5 trained observers. Observers positioned themselves 3 m apart and followed a 50-m transect, recording all active mounds to their right between themselves and the next observer allowing the team to cover the entire plot in 2 passes. To assess presence and relative abundance of RIFA in all mounds, we used a shovel to dig down to soil moisture where ants would be, if present (Mueller et al. 1999). Active mounds received a score based on estimated number of worker ants present, and the presence of worker brood (all mounds possessed worker brood). The population index was then calculated for each plot using the following equation:

$$\text{Population index (PI)} = s_6 \times 5 + s_7 \times 10 + s_8 \times 15 + s_9 \times 20 + s_{10} \times 25$$

where s was the number of mounds, with brood, within a given size class (estimated number of ants). The weighting factor increased with mound size (Table 1; Lofgren and Williams 1984). A foraging index was used in conjunction with mound counts to index fire

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Table 2. Mean mound density of red-imported fire ants, population index, and foraging index for 0.15-ha plots treated with fire, discing, mowing, and no treatment during May and October, 1999, Cameron Plantation, Madison County, Mississippi.

Month	Treatment	Mounds/plot		RIFA Index		Foraging Index	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
May	BURN	45.10 A	7.09	556.00 A	262.43	42.40 A	8.44
	MOW	42.40 AB	8.79	529.00 A	117.41	35.10 A	7.86
	CONTROL	30.30 BC	4.33	402.50 AB	37.52	39.40 A	8.24
	DISC	24.00 C	3.729	274.5 B	44.12	34.10 A	6.16
October		M ^b		M ^b		— ^a	SE
	BURN	53.0 A		633.5 A		49.17 A	21.90
	DISC	50.5 A		546.5 A		52.50 A	12.74
	MOW	45.5 AB		530.0 AB		60.83 A	24.76
	CONTROL	37.5 B		433.5 B		46.50 A	17.19

^a Means within the same season with same letter are not significantly different, LSD $P < 0.05$.^b During the October sampling season, medians reported for total mound density and population index. Mean ranks compared using Fisher's LSD $P < 0.05$.

ant foraging activity in each treatment. Foraging RIFA were sampled using 21, 30-ml baitcups containing approximately 1 g of protein bait (hot dog) (Porter and Tschinkel 1987, Mueller et al. 1999). Bait cups were distributed on a 10m $\times$ 30m grid in the center of each plot with 5 m spacing between cups. We left baits exposed for 30 minutes, then capped (Summerlin et al. 1977) and froze them at -20°C (Mueller et al. 1999). Specimens in each cup identified as RIFA were counted and recorded.

We tested effects of disturbance treatments on mound density and RIFA index using a randomized complete block analysis of variance (ANOVA) within each sampling interval. The assumption of normality was tested using the Shapiro-Wilk's test for each sampling procedure and interval (SAS Institute Inc. 1989). Within each interval and sampling technique, we tested for homogeneity of variance using Levene's test (Snedecor and Cochran 1980). If the data did not meet the normality assumption, we used a Friedman 2-way analysis of variance on ranks (Daniel 1978). Following a significant F test, we used Fisher's LSD ($\alpha = 0.05$) for multiple comparisons among treatments (Peterson 1985). All analyses were conducted in SAS version 6.12 (SAS Institute Inc. 1989).

RESULTS

During the May sampling interval, residuals were normally distributed for total mound density ($W = 0.983$, $P = 0.878$), population index ($W = 0.963$, $P = 0.305$), and foraging index ($W = 0.978$, $P = 0.616$). Similarly, we observed homogeneity of variance across treatments for total mound density ($F_{3,36} = 0.71$, $P = 0.519$), population index ($F_{3,36} = 0.66$, $P = 0.582$), and foraging index ($F_{3,36} = 1.55$, $P = 0.218$). We observed block effects for the total count ($F_{9,27} = 3.87$, $P = 0.003$), population index ($F_{9,27} = 4.00$, $P = 0.002$) and foraging index ($F_{9,27} = 5.54$, $P < 0.001$), suggesting significance among block variation. Total mound count ($F_{3,27} = 4.28$, $P = 0.014$) and population index ($F_{3,27} = 4.87$, $P = 0.008$) differed among treatments, whereas foraging index did not differ among treatments ($F_{3,27} = 0.53$, $P = 0.664$). During May,

prescribe burned plots had more mounds than control or disced treatments ($P < 0.05$), but did not differ from mowed ($P > 0.05$; Table 2). Mowed plots had greater mound density than disced plots, but did not differ from fire or control. Mound density in disced treatments did not differ from control. Red imported fire ant population index exhibited an identical rank order with minor differences in mean separation. Prescribe burned and mowed plots had a higher population index than disced plots ($P < 0.05$), but did not differ from control plots ($P > 0.05$). Population index in control plots did not differ from disced ($P > 0.05$). Foraging index did not differ among treatments; however, rank ordering of means differed only slightly from that of total mound count and population index (Table 2).

During the October sampling interval residuals for total mound density ($W = 0.852$, $P = 0.002$) and population index ($W = 0.879$, $P = 0.007$) deviated from normality. Levene's test suggested a tendency toward lack of homogeneity of variance for both total mound density ($F_{3,20} = 2.47$, $P = 0.092$) and population index ($F_{3,20} = 2.55$, $P = 0.085$). Therefore, for these 2 metrics, we used Friedman's non-parametric 2-way analysis of variance on ranks to test for differences between treatments. October foraging index exhibited normal residuals ($W = 0.950$, $P = 0.272$) and homogeneity of variance ($F_{3,20} = 0.81$, $P = 0.505$). Total mound count ($F_{3,20} = 3.50$, $P = 0.034$) and population index ($F_{3,20} = 3.21$, $P = 0.045$) differed among treatments, but the foraging index did not ($F_{3,15} = 0.18$, $P = 0.908$). Pairwise comparisons yielded an identical pattern for total mound count and population index during October. Median values for fire, discing, and mowing did not differ, but fire and discing exhibited greater mound density and population index than controls. Mowing did not differ from the control (Table 2).

DISCUSSION

All management practices affected RIFA abundance, as indexed by mound counts and population indices, relative to undisturbed plots. However, the direction and magnitude of response varied among prac-

tices and over time. During the brief interval between implementation of the treatments and measurement of spring mound density (2 months), RIFA populations increased in response to prescribed fire. Burning reduces litter accumulation, increases sunlight reaching ground, releases nutrients, and stimulates growth of new vegetative material, all of which might improve the foraging environment and food resources for RIFA. In contrast, discing initially reduced RIFA density. Discing might temporarily destroy mounds and foraging tunnels causing short-term dispersal and apparent reduction in local mound density and foraging activity.

The October census provided insight into how RIFA react to disturbance over time. Seven months after disturbances, the pattern of RIFA abundance among treatments differed from that observed in May. During October, total mound count and population index methods suggested that RIFA were most abundant in the prescribed fire treatment, followed by the disced, mowed, and control treatments. All sampling methods suggested that there was a lag time of response to discing disturbance. Discing may have initially disrupted mounds, but by October, the early successional plant communities created by discing had facilitated a positive RIFA response. Similar to prescribed fire, discing reduces litter accumulation, increases bare ground, and stimulates germination of annual grasses and forbs, thereby potentially enhancing foraging environment and food resources for RIFA.

We indexed RIFA response to disturbance regimes using mound density, RIFA population index, and bait cup visitations. Presumably, all 3 metrics index RIFA relative abundance and should reveal similar patterns in population response to habitat management practices. However, at the spatial scale and RIFA population levels of our study, only mound density and population index indicated a RIFA response to habitat alteration. Killion and Grant (1993) reported that measures of RIFA abundance or activity are scale dependent, and that mound density and foraging activity as measured by bait cups may be uncorrelated across a range of spatial scales. We theorize that as mound density increases, foraging activity at bait cups may be asymptotic, such that beyond some threshold, further increases in mound density result in relatively minor or no further increase in foraging activity. Killion and Grant (1993) suggested that mound density or pit trap captures provide a better index to abundance than bait cup visitations.

Regional bobwhite population declines have most frequently been attributed to reductions in landscape heterogeneity and loss of early successional communities. However, increasingly compelling evidence suggests that RIFA can negatively impact bobwhite survival and reproductive success (Allen et al. 1995, Giuliano et al. 1996, Pederson et al. 1996, Mueller et al. 1999) and might exacerbate population declines in some areas. Biologists, operating under the assumption that bobwhite populations are limited by habitat, frequently prescribe management practices that create early successional plant communities through inter-

mediate disturbance (discing and prescribed burning). However, land management practices that disturb soil and vegetation and create early successional habitats, might actually increase RIFA abundance and associated negative effects (Allen et al. 1998). Although correlative associations between disturbance and RIFA have been previously reported (Tschinkel 1988, Allen et al. 1998), no studies have explicitly examined RIFA response to the types of management regimes prescribed for bobwhite habitat enhancement.

Allen et al. (1995) suggested that threats to bobwhite by RIFA were greatest in areas with high infestation. Negative impacts of RIFA on bobwhite have been reported at mean mound densities of 205 mounds/ha (Allen et al. 1995) and 290 mounds/ha (Mueller et al. 1999). Estimated RIFA mound density on our central Mississippi study area in 1999 was 395 mounds/ha (SE = 38.0), considerably higher than levels reported to negatively impact bobwhites (Allen et al. 1995, Mueller et al. 1999). Consequently RIFA populations on our study site are within the range at which negative population consequences might exist for bobwhites.

Red imported fire ants occur in both monogyne and polygyne infestations. Polygyne fire ants exhibit less intraspecific territoriality, and thus may occur at extremely high densities increasing negative impacts on native arthropods and vertebrates (Porter et al. 1991, Allen et al. 1994, Allen et al. 1995, Allen et al. 1998, Mueller et al. 1999). We did not confirm polygyny by floating mounds to identify multiple queens, or dissecting queens to determine if insemination had occurred (Allen et al. 1995). However, polygyne infestations are characterized by extremely high colony densities (Allen et al. 1998). Because monogyne colonies normally do not exceed 99 mounds/ha (Lofgren and Williams 1984, Porter and Tschinkel 1987, Porter et al. 1988, and Allen et al. 1995) and observed densities for all blocks on our study site exceeded 200 mounds/ha, we presumed that colonies were polygyne.

CONCLUSION

Overall, our study provides empirical, experimental evidence that land management practices leading to soil and vegetation disturbance increase infestation by RIFA. More specifically, the 2 habitat management regimes (discing and burning) most frequently prescribed to enhance bobwhite habitat quality increased RIFA mound density and population index. This creates a management conundrum. Maintenance of early successional habitats is essential for bobwhite, yet in areas of high RIFA infestations, these practices can be expected to increase local abundance of RIFA, which could result in associated negative impacts on bobwhite population performance (Allen et al. 1995, Giuliano et al. 1996, Mueller et al. 1999). We acknowledge that this study examined only short-term effects of disturbance practices. Additional research addressing long-term effects of sustained management regimes on RIFA abundance and colonization is needed.

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