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Fire Ant Response to Management of Native Grass Conservation Buffers

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Abstract.—Native grass conservation buffers established for grassland birds require periodic disturbance, but disturbance of vegetation and soil may increase abundance and activity of imported fire ants (*Solenopsis* sp.). This is a concern because fire ants are invasive, often respond positively to disturbance and can be a major cause of nest losses in grassland birds. We experimentally tested if fire ant mound density and foraging activity increased after burning and disking in native grass buffers. In 2008, fall disking increased mound density and foraging activity during the first growing season post-disturbance, but burning did not. In 2009, disking had no effect, but effects of disking the previous season persisted into the second growing season. Prescribed fire, which tends to maintain or increase perennial grass cover, may be a better option than disking for managing native grass buffers where fire ant densities are high.

Introduction

Approximately 11 million ha of potential wildlife habitat are currently under contract in the USDA's Conservation Reserve Program (USDA, 2010), which provides a variety of financial incentives (rental agreements, cost share, signup incentives, etc.) for landowners to convert cropland to primarily grassland or forest habitat. To increase environmental benefits, including wildlife habitat, of the CRP (Hohman and Halloum, 2000), successive farm bills have increasingly emphasized targeted conservation practices to address specific resource concerns and regional conservation initiatives. For example, Conservation Practice 33 (CP33) – Habitat Buffers for Upland Birds was created to ameliorate declines of northern bobwhite (*Colinus virginianus*) and other grassland birds (Burger *et al.*, 2006). Because ≈80% of CRP lands are enrolled in grass-based conservation practices (USDA, 2008), the program has the potential for conserving many birds and other wildlife species that require early successional herbaceous habitat. Over 60% of North American grassland bird species are declining (Brennan and Kuvlesky, 2005; Sauer *et al.*, 2008), and the CRP has the potential to ameliorate habitat-related declines for many of these species (*e.g.,* Veech, 2006; Riffell *et al.*, 2008).

CRP grasslands (like CP33 Habitat Buffers) must be disturbed periodically during the contract period (*i.e.,* mid-contract management) to promote habitat diversity and maintain early successional herbaceous habitat required by many grassland birds (Hamrick *et al.*, 2006; Negus *et al.*, 2010), and this is required in some contracts. Over the life of the contract, perennial grasses increase, bare ground declines and litter accumulates, diminishing habitat quality for specific seasonal biological processes of focal species (McCoy *et al.*, 2001; Harper *et al.*, 2007). The only way to eliminate buildup of dead vegetative material and inhibit encroachment of woody vegetation is to use some form of planned, periodic disturbance like prescribed fire or light-strip disking (Greenfield *et al.*, 2003; Harper *et al.*, 2007).

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A potential drawback to mid-contract management is that fire ants (*Solenopis* sp.) may increase with disturbance (Stiles and Jones, 1998; Williamson *et al.,* 2002; Zettler *et al.*, 2004; Todd *et al.*, 2008). Fire ants can be a major source of nest loss for ground- and shrub-nesting grassland birds (Lochmiller *et al.*, 1993; Allen *et al.*, 1995; Pedersen *et al.*, 1996; Mueller *et al.*, 1999; Williamson *et al.*, 2002; Stake and Cimprich, 2003; Allen *et al.*, 2004; Campomizzi *et al.*, 2009; Conner *et al.*, 2010). Fire ants may also decrease abundance and diversity of native arthropod species (Porter and Savignana, 1990; Forys *et al.*, 2001; Epperson and Allen, 2010) that provide ecosystem services like pollination that fire ants themselves cannot provide. Thus, wildlife and ecosystem benefits of periodically disturbing native grass buffers could be indirectly sabotaged by the disturbance itself.

To provide information about how fire ants respond to mid-contract management, we measured fire ant mound density and foraging activity in prescribed burned, disked and undisturbed controls in CP33 native grass buffers in northeastern Mississippi. We tested two hypotheses: (1) mound density and foraging activity of fire ants would be different in disturbed buffers compared to undisturbed controls; and (2) foraging activity and mound density would be greater in disked buffers compared to burned buffers.

METHODS

STUDY AREA

B. Bryan Farms (West Point, MS) has approximately 2000 ha of row crops and cattle pasture. In spring 2004, 79 ha of cropland were enrolled in CP33 Habitat Buffers for Upland Birds and planted with native warm season grasses and forbs including: big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), partridge pea (*Chamaecrista fasciculata*), black-eyed susan (*Rudbeckia hirta*) and maximilian sunflower (*Helianthus maximilianii*) (Burger *et al.*, 2006; Harper *et al.*, 2007). CP33 buffers were planted in the outer 36.6 m margin of crop fields (4–23 ha in size). Bryan Farms is located in the upper coastal plain (Hamrick *et al.*, 2006) and blackland prairie region of Mississippi (Moran *et al.,* 1997).

MID-CONTRACT MANAGEMENT TREATMENTS

Beginning in fall 2007, 14 buffered fields were randomly assigned to one of three disturbance treatments (disked, n = 5; burned, n = 5; control, n = 4). Only one buffer along a field edge was disturbed each year (assigned randomly) with either prescribed burning or light strip-disking. Control fields were left undisturbed (4 fields). Over the duration of the study, this created a successional sequence allowing us to observe fire ants at different post-disturbance time periods. Because ants may have dispersed from treated buffers into attached buffers scheduled for disturbance later in the sequence, we refer to untreated buffers within treated fields as in-field controls. Entirely untreated fields will be referred to as whole-field controls. For 2008 analyses, treatment levels were: no treatment (whole-field control), disked fall 2007 (disk 2007), in-field controls of disked fields (disk control), burned spring 2008 (burn 2008) and in-field controls of burned fields (burn control). For 2009 analyses, treatment levels were the same as 2008 plus disked fall 2008 (disk 2008) and burned spring 2009 (burn 2009).

Buffers were disked in fall (Sept.–Oct.) prior to the growing season (2007 and 2008) or burned in spring (Mar.–Apr.) of each growing season (2008 and 2009). Burning in the spring leaves overwinter cover for grassland wildlife and stimulates rapid growth of native warm season grasses (Harper *et al.*, 2007). Disking occurred in the fall because spring disking encourages agronomic weeds like Johnsongrass (*Sorghum halepense*; Harper *et al.*, 2007).

FIRE ANT SPECIES IDENTIFICATION

We collected two samples of fire ants from a mound in each study field in 2008 (n = 28). We chose mounds that were 5–25 m outside buffers so we did not cause unnecessary disturbance in our study area. Black imported fire ants (*Solenopsis richteri*), red imported fire ants (*S. invicta*) and *richteri* × *invicta* hybrids were distinguished using extracted venom alkaloid and cuticular hydrocarbon profiles (Menzel *et al.*, 2008) sent to the USDA-ARS, National Biological Control Laboratory (Stoneville, MS; David C. Cross, Department of Entomology and Plant Pathology, Mississippi State University, pers. comm.). Random amplified polymorphic DNA (RAPD) marker test (Shoemaker *et al.*, 1994) and a restrictive fragment analysis of mitochondrial DNA (Goodisman *et al.*, 1998) were performed to determine fire ant species by using genetic markers. When markers of both species were present, the colony was determined to be hybrid. To determine social form of a colony, polymerase chain reaction (PCR) was used to determine if the allele ($Gp\text{-}9^b$) associated with polygyny (multiple queens) was present in each sample (Menzel *et al.*, 2008).

FIRE ANT SAMPLING

We collected fire ants in native grass buffers around all 14 fields in May and Aug. of 2008 and 2009. Our sampling schedule bracketed the grassland bird nesting season. In 2008, we sampled the newly disturbed buffer and two in-field controls (untreated buffers attached to the treated buffer) in each field. We also sampled three buffers in whole-field controls (untreated fields). In 2009, we re-sampled the same buffers as in 2008, except that in treatment fields only one buffer remained as an in-field control (the other was now disturbed). We used whole-field controls in addition to in-field controls because in-field controls may have been potentially influenced by dispersal of fire ants from treated buffers connected to in-field controls. In this manner, we tested for both buffer- and field-level effects of disturbance.

To measure mound density, we positioned three 50 transects along a 200 m section of each buffer. We counted all active fire ant mounds (determined by light disturbance of each mound) found within 5 m on each side of the 50 m transect. We measured foraging activity on mornings (0630–1200 CST) of dry days by placing three consecutive lines of 10 bait cups (50 ml test tubes with small, hot dog pieces inside; Williamson *et al.*, 2002) on the ground in each 50 × 10 m transect. We used the same transects used to estimate mound densities. Bait cup lines were 50 m long, and bait cups were spaced 5 m apart. Bait cups were collected after 30 min of exposure, capped and frozen for later counting and identification.

STATISTICAL ANALYSIS

To test for differences in mound density and foraging activity among disturbance treatments, we used general linear mixed models (Littell *et al.*, 2006). We included field as a random effect to account for sampling multiple, connected buffers in the same fields. Connected buffers may not have been completely independent because ants might disperse from treated buffers into attached, undisturbed controls. For each buffer, response variables were mound density (mounds/1500 m^2) and foraging activity (average ants/vial). We used an F-test to test the null hypothesis that treatments did not differ. If there was a difference, we used least squared means for multiple comparisons among treatments. We used an *a priori* $\alpha = 0.10$ for all tests to increase our statistical power because we deemed Type II errors (failing to detect actual differences in fire ant metrics) more serious than Type I errors.

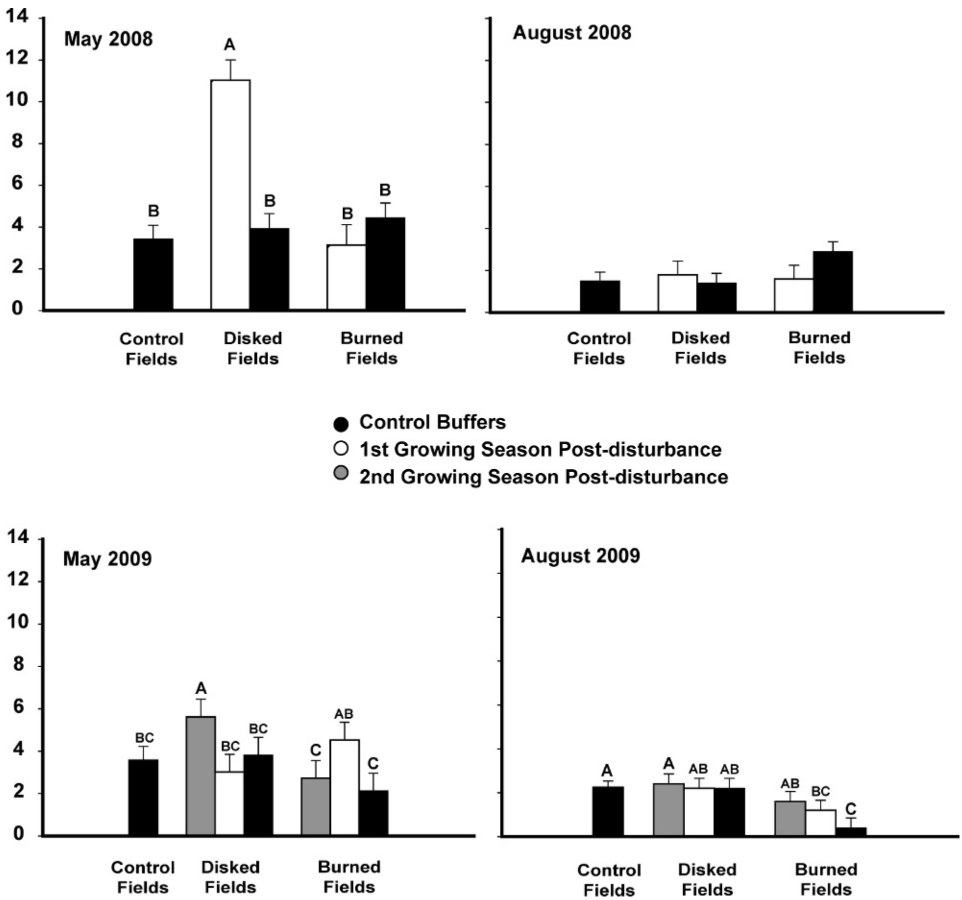

FIG. 1.—Imported fire ant mound densities (#/1500 m^2) in native grass conservation buffers at B. Bryan Farms (Clay County, Mississippi) during 2008 and 2009. In each season, means with the same letter do not differ significantly ($\alpha = 0.10$). Letters are absent where no significant differences occurred

RESULTS

FIRE ANT SPECIES IDENTIFICATION

Fire ants at our study site were primarily monogyne hybrid with the possibility of a small population of black imported fire ants. When considering all tests, 13 of 14 mounds were hybrid fire ants. One was borderline between hybrid and black fire ant ($I = 0.06$ and molecular marker characteristic of *S. richteri*). Two of 14 mounds were polygyne, having multiple queens.

FIRE ANT MOUND DENSITY

In May 2008, mound density differed among treatments ($F_{4,23.4} = 12.49$, $P < 0.001$). Mound density was greatest in buffers disked fall 2007 (Fig. 1), but all differences among treatments had diminished by Aug. ($F_{4,37} = 1.75$, $P = 0.160$). In May 2009, mound density again differed among treatments ($F_{6,26.8} = 2.21$, $P = 0.074$). Mound density in buffers disked fall 2007 ($t = -1.93$–-2.99, $P = 0.005$–0.066) and buffers burned spring 2009 ($t_{24.2} = -2.47$,

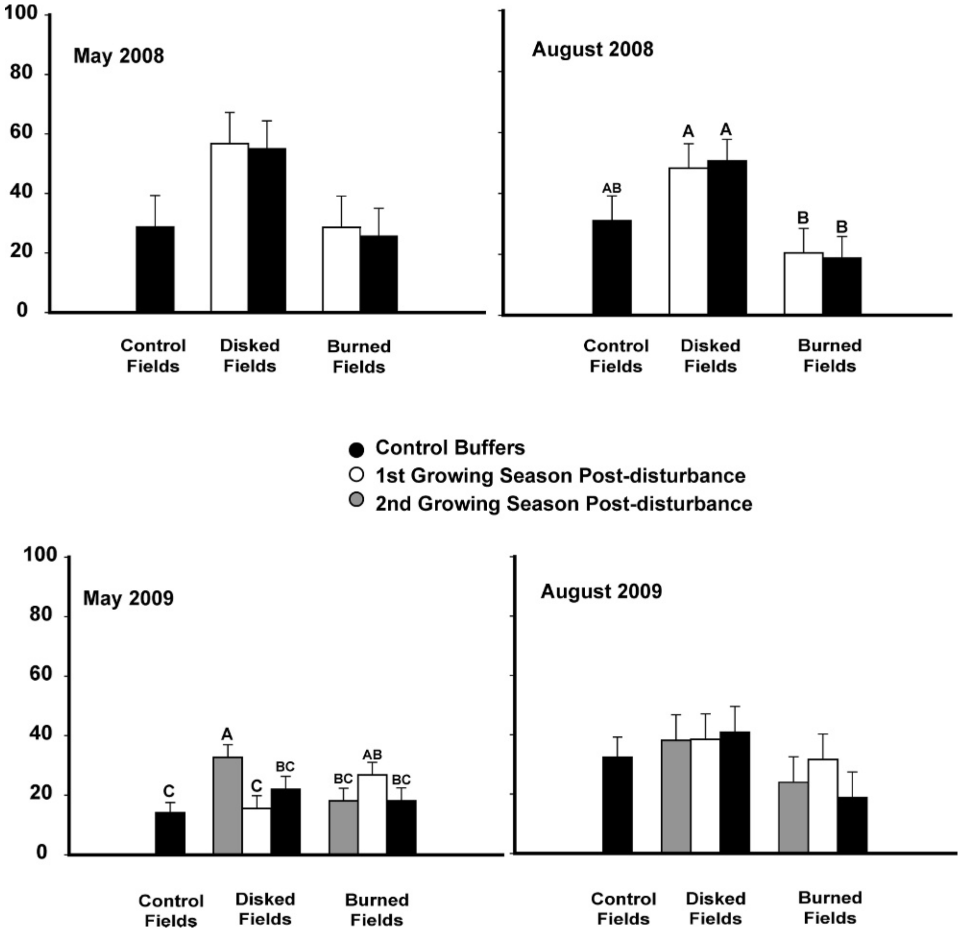

FIG. 2.—Imported fire ant foraging activity (# ants/vial) in native grass conservation buffers at B. Bryan Farms (Clay County, Mississippi) during 2008 and 2009. In each season, means with the same letter do not differ significantly (α = 0.10). Letters are absent where no significant differences occurred

P = 0.018) were greater than control buffers (Fig. 1). But unlike the previous year, mound density was not greater in recently disked buffers (1st growing season post-disturbance). Although there were differences among treatments in Aug. 2009 ($F_{6,35} = 2.83$, $P = 0.024$), none of the disturbed buffers had mound densities greater than control buffers (Fig. 1).

FORAGING ACTIVITY

In May 2008, there were no differences in foraging activity ($F_{4,15.7} = 1.71$, $P = 0.197$) In Aug. 2008, foraging activity differed among treatments ($F_{4,22.2} = 3.69$, $P = 0.019$). Foraging activity was greatest in buffers disked fall 2007 and associated infield controls (Fig. 2). In May 2009, foraging activity differed among treatments ($F_{6,27} = 3.07$, $P = 0.020$). Similar to what we observed for mound density (see above), foraging activity in buffers disked fall 2007 and buffers burned spring 2009 was greatest than on control buffers, but unlike the previous year, fire ant foraging activity was not greater in recently disked buffers (Fig. 2). In Aug. 2009, there were no differences ($F_{6,24.4} = 0.75$, $P = 0.614$) in foraging activity (Fig. 2).

DISCUSSION

RESPONSE TO MID-CONTRACT MANAGEMENT

Disking increased fire ant mound density and foraging activity the first year of our study, but burning did not. Fire ants were not affected by disking that occurred in the second year, but increased fire ant mound density and foraging activity persisted in buffers that had been disked 2 y earlier. Burning increased fire ant mound densities during the second study season only (2009), but this response was small and disappeared by Aug.

Burning promotes success of species adapted to frequent burning, whereas soil disturbance, like that caused by disking, creates openings for establishment of weedy or ruderal species (Hobbs and Huenneke, 1992). Because fire ants have similar characteristics of invasive species (high dispersal, rapid reproduction, rapid growth), they may have been able to colonize newly disked buffers quickly but did not colonize burned buffers as effectively. The decrease in mound densities in Aug. compared to May could have been due to higher Aug. temperatures driving ants underground where the temperature is lower, hence, causing the above ground portion of the mound to be less visible (Vinson and Sorensen, 1986).

One possible explanation why effects of disking fall 2007 persisted for two growing seasons, and yet disking in fall 2008 had no observable effects on fire ant is that buffers disked in 2007 may have had greater pre-treatment fire ant mound density and foraging. We did not collect pretreatment data for fire ants so we cannot test this directly; but pretreatment vegetation characteristics did not differ among treatment groups, nor did abundance and richness of butterflies (another arthropod taxon) (Dollar, 2011; Adams, 2011). Furthermore, abundance of disturbance-tolerant butterflies demonstrated the same response as fire ants. Butterfly abundance increased significantly in buffers disked fall 2007 (and this difference persisted for two growing seasons post-disturbance), but disking the second year had no effect (Dollar, 2011). Thus, it is unlikely that our results for fire ants represent pre-treatment artifacts.

Persistence of first season disking effects without second season disking effects suggests one of two possibilities. First, buffers may not have been disked at the same depth in both years, influencing response of vegetation and arthropods differently. Second, temporal variation in environmental variables may mediate vegetation and arthropod response. Our study site received more rain the second year (2009 May–Jul. rainfall = 42 cm; Mississippi State Department of GeoSciences) than the first year (2008 May–Jun. rainfall = 22 cm). Fire ants are less active during rain events (Porter and Tschinkel, 1987), so this could explain why there was not a response to disking the second year. However, this still does not explain why effects of disking the first year persisted. Increased rainfall could have possibly influenced vegetation response and recovery and affected indirectly fire ant populations. Persistence of effects in buffers disked the first season also could have been due to fire ants already having colonized those buffers; whereas, the second season, they simply may have been unable to colonize newly disked buffers because rain decreased ant activity. Disturbance may have varied outcomes under different conditions, and environmental stochasticity may influence fire ant response to disturbance. Decisions about efficacy of planned disturbance should not be based on only one or a few years' response. Future research should examine the influences of environmental stochasticity on fire ant response to disturbance over several years.

Persistent effects of disking from the first season could have affected negatively grassland birds because increased mound density and foraging activity of fire ants increases potential for nest failure due to fire ant depredation. Birds avoided nesting in disked buffers the 1st growing season post-disturbance (Adams, 2011), so disking did not likely affect bird nest success via increased fire ants that first year in our study area. However, birds did begin to nest in disked buffers the 2nd growing season post-disturbance (Adams, 2011) when fire ant mound density and foraging activity were still elevated thus increasing potential for nest losses.

Fire ants responded positively to burning in the second study year and so may have increased nest losses in those buffers because nesting birds did not avoid recently burned buffers (Adams, 2011). The extent of this increase is uncertain because fire ant response had diminished by the end of the nesting season, and the magnitude of response to burning spring 2009 was less than response to disking fall 2007.

MANAGEMENT IMPLICATIONS

Using strictly burning as a disturbance tool could potentially increase nest success of grassland birds relative to other modes of disturbance in areas with high fire ant infestations because it had small or no effects on fire ants compared to disking. In contrast, responses to disking persisted throughout two growing seasons, increasing potential for avian nest losses to fire ants. We also observed some positive relations between fire ants and vegetation characteristics associated with more open, forb rich grasslands (Hale, 2010), which further supports the conclusion that vegetation management like disking and burning for birds (and other early successional species) also may make buffers more favorable to fire ants. This is important because if mid-contract management of CP33 buffers increases fire ants, then efforts to provide better habitat for birds could be sabotaged. Although bird nest density and abundance were not negatively related to foraging activity and mound density (Hale, 2010), fire ants were a frequent cause of grassland bird nest failure at our study site (Adams, 2011), so understanding how disturbance influences fire ants in similar systems is important. Because our study and other studies of fire ant response to disturbance have been short term (Williamson *et al.*, 2002; Forbes *et al.*, 2002), long term studies would greatly expand knowledge about whether environmental stochasticity influences year to year variation in fire ant response to disturbance.

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