The Journal of the Iowa Academy of Science: JIAS

Volume 115 | Number 1-4 Article 7

2008

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Jour. Iowa Acad. Sci. 115(1–4):28–32, 2008

Ant Diversity in Two Southern Minnesota Tallgrass Prairie Restoration Sites

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There is little basic information about ant species richness and abundance in tall grass prairie restorations despite the importance of ants to plant community structure and function. We compared ant abundance and richness, vascular plant cover and richness, and soil compaction at two southern Minnesota grassland restoration sites, a prairie reconstruction and a prairie remnant undergoing rehabilitation. We collected a total of 3,523 ants from 12 different species. Plant species richness ranged from 45 in the prairie reconstruction to 95 in the remnant prairie. We found five more species of ants and significantly higher mean ant species richness per plot in the more heterogeneous prairie remnant with higher plant diversity, especially forbs, than in the prairie reconstruction where plant species diversity was lower. Our study found 10 new ant species records in Le Sueur and Nicollet counties, Minnesota. Because of the paucity of information about ant species in the upper Midwest, it is difficult to fully compare our results to those of other restored or natural areas in the area. Our study provides an important baseline census for two different types of tallgrass prairie restorations.

INDEX DESCRIPTORS: ants, forbs, Formicidae, grasses, Minnesota, restoration, prairie reconstruction, species richness, tallgrass prairie.

Ants (Formicidae) are one of the most abundant, species-rich insect families on earth (Hölldobler and Wilson 1990). In addition to serving important structural and functional roles (Beattie 1989, Blomqvist et al. 2000), ants are responsive to environmental changes (Majer 1983, Cabrera et al. 1998) and can be used as indicator species when monitoring restoration or conservation sites (Underwood and Fisher 2006). Thus, cataloging ant species richness and abundance as well as determining fidelity to specific habitats provides baseline information to further investigate species interactions and community ecology (Trager 1998).

In the Midwestern U.S., less than 1% of tallgrass prairies remain (Samson and Knopf 1994, Tester 1995). Conservation initiatives such as C.R.E.P. (Conservation Reserve Enhancement Program) have focused on sowing native prairie vegetation on marginal cropland or pasture. Throughout southern Minnesota small, patchily distributed prairies have been reconstructed from agricultural fields (less than 50 ha) or are remnants in the process of rehabilitation; in both types of sites little monitoring occurs after restoration is initiated. Despite the importance of ants to plant community structure and function, relatively little basic information exists about ant diversity in these restoration areas, especially in Minnesota (Trager 1990, 1998).

Our two study sites represent two different types of prairie restoration possible, a prairie reconstruction on a former agricultural field and a prairie remnant that was never plowed and currently is undergoing rehabilitation (burning, mowing and invasive species control). We hypothesized that the two sites would have different ant communities. Our objectives were to contrast ant abundance, species richness and diversity between the prairie reconstruction and the remnant rehabilitation using fast, repeatable, quantitative methods. Our secondary goals were to determine if ant diversity was associated with plant richness and soil bulk density.

METHODS

Two tallgrass prairie sites were selected for this study: a remnant prairie undergoing rehabilitation called Kasota Prairie in LeSueur County, Minnesota (T 109N, R 26W, S 06) and a prairie reconstruction at the Linnaeus Arboretum in Nicollet County, Minnesota (T 110N, R 26W, S 20). Kasota prairie (Kasota) is approximately 36.5 ha; it was never plowed, but experienced grazing for 100 years prior to rehabilitation. Domestic grazers were excluded in 1984 and the site is actively managed (e.g. controlled burns, seeding, mowing and weeding). Kasota contains a diverse assemblage of tallgrass prairie species dominated by big bluestem (*Andropogon gerardii* Vitman), Indian grass (*Sorghastrum nutans* Nash), purple prairie clover (*Dalea purpurea* Vent) and bee balm (*Monarda fistulosa* L.; see Results). The Linnaeus Arboretum prairie (Arb) was converted from an agricultural field to six prairie 'islands' (14–140 m^2) by broadcast seeding and planting a mixture of native forbs and grasses in 1988, 1990 and 1994; a total of 74 species were planted in the prairie reconstruction (Gustavus Adolphus College Linnaeus Arboretum unpubl. data). Since 1999, the sections of the Arb alternate between a fall burning, a year of no treatment followed by spring mowing. Big bluestem and Indian grass predominate while native forbs are rare (see Results). Arb islands are surrounded by a turfgrass lawn (*Poa pratensis* L. and *P. annua* L.). County surveys indicate that both sites historically supported similar dominant upland, mesic tallgrass prairie flora on the loamy gravel and sand soils of the Minnesota River valley bluffs (Soine and McMiller 1954, Arneman et al. 1958, Minnesota Natural Heritage Program 1993), only the large embedded rocks at Kasota made farming less feasible.

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Table 1. Abundance for each treatment (H = honey, T = tuna, A = alcohol) and relative abundance (R.A.) for each site; * denote three rare species.

	Arb				Kasota			
	H	T	A	R. A.	H	T	A	R. A.
Aphaenogaster rudis Emery	117	129	301	0.348	62	26	1381	0.753
Solenopsis molesta Say	–	–	574	0.365	11	2	1	0.007
Lasius neoniger Emery	96	74	194	0.231	38	49	33	0.062
Paratrechina parvula Mayr	5	44	16	0.041	48	101	13	0.083
Formica neogagates Emery	11	1	–	0.008	2	–	51	0.027
Formica subsericea Say	–	–	11	0.007	–	–	–	–
Formica incerta Buren	–	–	–	–	24	14	67	0.054
Formica pallidefulva Latrielle	–	–	–	–	5	2	7	0.007
Monomorium minimum Buckley	–	–	–	–	–	–	5	0.003
Temnothorax ambiguus Emery*	–	–	–	–	–	–	4	0.002
Formica obscuripes Forel*	–	–	–	–	1	–	1	0.001
Ponera pennsylvanica Buckley*	–	–	–	–	–	–	2	0.001

At each site, we randomly placed two 100-m transect lines through the interior of the site. Ten 1-m^2 plots per transect line were established every 10–12 m (n = 20 plots per site). At each plot, two plastic pit traps (8 cm diameter × 9 cm tall) were sunk so the lip was flush with ground (a total of 40 traps/site). To determine which trap type would yield the best results over a short period of time, we collected ants using three methods. In the first trap approach, isopropyl alcohol was mixed with a small amount of ethylene glycol. The pit traps were collected after 24 hours and the ants were preserved in vials containing isopropyl alcohol; this unbaited pitfall method is likely to provide a relatively unbiased sample of the ants in grassland communities (Andersen 1990). The other two methods employed two types of bait: a tablespoon of honey or a small portion of canned tuna. To prevent living, dominant ant species from destroying other species in the trap we collected and preserved all ants after 30 min. At each site, we collected 40 samples of each bait treatment on four dates between 6 June to 20 July 2001 (n = 480 traps per site).

We identified each individual to species using Creighton (1950) Trager et al. (2007) and a web-based identification (http://www.antweb.org); species identifications also were verified by Richard Carter (Black Hills State University, South Dakota). Voucher specimens were deposited in the entomology museum at Gustavus Adolphus College. Ant abundance and richness were tallied for each trap and for each plot. Relative abundance of each species over the course of the study was calculated as the sum of the number of individual ants of a species at a site divided by the total number of individuals of all species at the site. Local species diversity (α; alpha), regional site diversity (γ; gamma, this value also equals species richness for each site) and how species change among plots (ie. turnover or β, beta diversity) were calculated following Ricklefs and Miller (2000). For each site we also calculated evenness (E) and Shannon Index of diversity (H'; Stiling 1999). Diversity indices such as the Shannon Index combine elements of species richness and species abundances (i.e. evenness). Finally, we calculated a Jaccard similarity coefficient for both the ant and plant communities to examine the extent of species overlap between the two communities (Krebs 1999).

To estimate plant diversity we measured richness and percent cover by placing 1-m^2 quadrats over each of the 20 1-m^2 ant plots and in an additional 20 1-m^2 randomly located plots (total n = 40 per site). In each quadrat every plant was identified (following Gleason and Cronquist 1991), and we estimated percent cover of each plant at the base (Mueller-Dombois and Ellenberg 1974), as well as the amount of bare ground to the nearest 1%. In the final analysis, we also grouped all forbs and grasses together since these two groups are important functional components of prairie systems. Soil cores were collected at every ant plot using a soil auger (volume = 22 cm^3). Soil samples were placed in plastic bags until wet and dry masses were recorded in the lab. Soil bulk densities (g/cm^3) were calculated from oven-dry (110° C) soil samples (Brady 1990).

We employed a t-test to test the null hypotheses that mean per plot ant richness did not differ between the two sites (Systat Software, Inc. 2004). In a second t-test comparing mean ant species richness between the two sites we excluded the last three rare species (denoted * in Table 1) because these species were considered facultative inhabitants of the grasslands (see Discussion). We also did five additional t-tests to examine if per plot: 1) mean cover of grass; 2) average forb % cover; 3) average percent bare ground; 4) mean plant richness, and; 5) average soil bulk density differed between sites (Systat Software, Inc. 2004). Assumptions of t-tests were met after species numbers were log transformed; soil bulk densities did not require transformation. To test if ant richness was correlated with plant richness a Pearson Product Moment correlation was performed on the 20 samples per site where both variables were measured (Systat Software, Inc. 2004).

RESULTS

At the two sites, we identified and counted a total of 3,523 individuals from 12 species of ants representing eight genera (Table 1). Of the 480 total traps at Kasota 175 were occupied by ants compared to only 71 traps at the Arb. Alcohol traps generally contained the most ants because they typically captured 4–8 times more individuals than the tuna or honey baits (Table 1). With the exception of three rare species at Kasota and one in the Arb, the tuna and honey baits caught the same species as the alcohol pit traps (Table 1).

Kasota had higher ant species richness and regional diversity (γ; S = 11) than Arb (γ, S = 6), and higher ant density (n = 1,950 in Kasota vs. n = 1,573 in Arb). There were six species found only at Kasota: *Formica pallidefulva* Latrielle, *Monomorium minimum* Buckley, *Formica incerta* Buren, *Temnothorax ambiguus*

Table 2. Total abundance of each ant species, ant species richness (i.e. regional γ diversity), local alpha diversity, species turnover among plots (beta diversity), Shannon Diversity (H′) and evenness (E) indices are listed for each site. Mean richness per plot (± S.D.) is for all species and for all but the last three rare species (denoted * in Table 1). Means with a different subscript are significantly different (t-test; P < 0.001).

	Arb	Kasota
Number of Individuals	1,573	1,950
Species Richness (S; Regional γ Diversity)	6	11
Local Diversity (α)	3	5.8
Species Turnover among Plots (β diversity)	1.9	1.9
Shannon Diversity (H?′)	1.3	1.0
Shannon Evenness (E)	0.7	0.4
Mean Richness per Plot (all species)	1.9 (0.3)^a	3.7 (0.5)^b
Mean Richness per Plot (three rare visitor species * excluded)	1.7 (0.3)^a	3.2 (0.4)^b

Emery, *Ponera pennsylvanica* Buckley, *Formica obscuripes* Forel. *Formica subsericea* Say was only found at the Arb. Evenness (E) was 0.4 at Kasota and 0.7 in Arb. The Shannon Diversity Index (H′), which combines species richness and evenness was 1.0 in Kasota and 1.3 in the Arb.

Average ant richness per plot differed significantly between the two sites (t-test, df = 18, t = 5.7, P < 0.001; Table 2). Arb plots had an average of 1.9 ant species, while Kasota had an average of 3.7 ant species, 95% more on a per plot basis (Table 2). Average ant richness per plot remained different even after we excluded three more rare visitor species (t-test, df = 18, t = 5.3, P < 0.001; Table 2). Average per plot local diversity also was lower in the Arb (α = 3.0) than Kasota (α = 5.8); as we sampled across plots we encountered different ant species assemblages, approximately 1.9 species changed from plot to plot (β~1.9) at each site. Ant species richness was 42% similar between the two communities (Jaccard similarity coefficient, J_s).

Kasota had higher absolute vascular plant species richness; 95 species of grasses and forbs were found in Kasota plots (Table 3), whereas Arb had fewer than half that number of species (S_{Arb} = 45). Kasota had a significantly higher average number of plant species per plot, between 1.5 to 2 times more species than in any one plot at the Arb (t-test, t = 10.1, df = 38, P < 0.001; Table 3). Plant species at the two sites were only 23% similar (J_s = 0.23). Kasota forb cover was on average five times higher than at the Arb (t-test, t = 7.8, df = 38, P < 0.001; Table 3). Kasota plots had significantly less overall average grass cover (60%), whereas 81% of Arb plots, on average, were covered with grasses (t-test, t = 4.8, df = 38, P < 0.001; Table 3), and only two species of grasses comprised 78% of all ground cover in Arb plots (Table 3). Arb plots also averaged significantly more bare ground (t-test, t = 12.1, df = 38, P < 0.001; Table 3), with an average of 11% of 1-m^2 being devoid of plant cover. Kasota soils had significantly lower bulk density than Arb soils (t-test, t = 7.8, df = 18, P < 0.001; Table 3). Finally, mean richness of ants was positively correlated with per plot average plant species richness for the two sites combined (Pearson's r = 0.85, P < 0.001, n = 40).

Table 3. Average basal cover of plant species and bare ground (%), total species richness, average soil bulk density and average species richness for each site. Species comprising less than 1% are not listed. Means with a different subscript are significantly different (t-test, P < 0.001)

	Arb	Kasota
Andropogon gerardii Vitman	51	27
Sorghastrum nutans Nash	27	19
Schizachyrium scoparium (Michx.) Nash	1	11
Bouteloua curtipendula (Michx.) Torr.	–	2
Poa pratensis L.	2	1
Monarda fistulosa L.	1.5	3
Dalea purpurea Vent	–	2.5
Ratibida pinnata (Vent.) Barnh.	–	2
Lespedeza capitata Michx.	1	2
Solidago speciosa Nutt.	–	2
Aster ericoides L.	1	2
Agastache foeniculum (Pursh) Kuntze	1	2
Liatris punctata Hook.	–	1.5
Zizia aurea (L.) Koch.	–	1.5
Achillea millefolium L.	–	1.5
Solidago canadensis L.	–	1.5
Coreopsis palmata Nutt.	–	1.5
Species Richness	45	95
Mean % Grass Cover (± S.D.)	0.83 (0.02)^a	0.67 (0.09)^b
Mean % Forb Cover (± S.D.)	0.06 (0.01)^a	0.31 (0.10)^b
Mean % Bare Ground (± S.D.)	0.11 (0.03)^a	0.02 (0.02)^b
Mean Richness per plot (± S.D.)	4.65 (0.12)^a	8.73 (0.48)^b
Mean Soil Bulk Density (g/cm^3 ± S.D.)	1.31 (0.04)^a	1.05 (0.03)^b

DISCUSSION

Higher ant species diversity, as measured by species richness (S, γ) and alpha diversity, existed in the Kasota prairie remnant, which had higher vascular plant species richness and less disturbed habitats that bordered it. Kasota had a higher absolute number of ant and plant species, and ant traps contained significantly more heterogeneous mixtures of ant species. We also encountered ants more frequently at Kasota. H′ for the Arb was slightly higher (1.3) than the H′ at Kasota (1.0) probably because the evenness was higher in the Arb (E_{Arb} = 0.7, E_{Kasota} = 0.4); there were three species that existed in the Arb at relatively even abundances. At Kasota there were one dominant species, *Aphaenogaster rudis*, seven less common and three rare species, and this pattern in relative abundance can decrease diversity index values (Stiling 1999). As such alpha, species richness (S or regional diversity (γ) are likely better ways to characterize ants diversity at the two sites. Kasota γ and α diversity was 11 and 5.8 respectively whereas Arb γ diversity equaled 6 and Arb α totaled 3.0. Also, the average ant species richness per plot in Kasota was nearly twice that of Arb. Taken together Kasota has a more diverse ant community than the Arb.

Soils at Kasota were less dense, possibly due to the greater abundance and diversity of ants and/or plants mining the soil, adding more organic matter, or because of less compaction or loss of aggregates from not having been cultivated. The diversity of insects was strongly positively correlated with plant diversity probably because more resources, especially forb diversity can support a greater variety of consumers' needs (Strong et al. 1984, Siemann 1998). Plant resources at Kasota were likely more diverse because the site was used as pasture rather than plowed and contained diverse patches of prairie species prior to rehabilitation. Moreover, Kasota has other habitats bordering the area, whereas the Arb did not; on one edge of the Kasota grasslands oak woodland and a floodplain forest exist. Two species of ants at Kasota, *T. ambiguus* and *P. pennsylvanica* inhabit woodlands as well as being found in grasslands near woodlands. The fact that we found only four and two individuals, respectively, of each of these species could suggest that they may have been visitors to the grassland or that their small size and slow, independent foraging habits prevented us from detecting them in higher numbers. Additionally, we trapped only two individuals of another ant species found only at Kasota, *F. obscuripes*. Colonies of *F. obscuripes* contain hundreds to thousands of workers and they are widespread in their foraging activities suggesting that there is a nest in the vicinity of Kasota, but not close enough to be considered residents of the prairie proper. Even when we exclude these three potentially facultative grasslands species from our analyses, the mean number of ant species per plot was still about 90% higher at Kasota than in the Arb (Table 2) suggesting that ant species may exist in more heterogeneous distributions in the remnant prairie.

Arb ant and plant richness was about half that of Kasota suggesting this prairie reconstruction does not fully resemble a remnant tallgrass prairie in either plant or ant diversity. While Kasota was a large site with a continuous habitat distribution, Arb consisted of small habitat islands with many edges. Small habitats tend to support fewer species than comparable larger areas (MacArthur and Wilson 1967, Soulé 1987); moreover, fragmentation and isolation can lead to localized extinction not accompanied by recolonization for grassland insects (Collinge 2000) and plants (Leach and Givnish 1996). Arb was planted with 74 plant species, but we found only 45 and six of these species were not part of the original planting and were non-natives. Moreover, vegetation in Arb is dominated by two grass species and contains very few forbs. Thus, the paucity of resources and lack of heterogeneity in the small Arb patches are likely to restrict ant diversity.

The species we found in the two types of restoration are common throughout the tallgrass prairie region, especially the *Formica* species, *Lasius neoniger Emery*, *M. minimum* and *Solenopsis molesta* Say (Trager 1998). Since our sites were small compared to other prairies (Trager 1998) they would be expected only to support few and the more widespread species (Brown 1995). With the exception of some predatory *Formica*, the species we identified are generalist omnivores and scavengers. When we compared our species list to ant databases, we discovered that 10 species were not listed in Le Sueur and Nicollet counties, Minnesota, yet were pictured in surrounding counties (http://www.acad.carleton.edu/curricular/BIOL/resources/ant/MNants.html; Trager et al. 2007). However all these species are unlikely to be range extensions because only a few studies have examined ant populations in southern Minnesota. Over half of our species of ants were in the subfamily Formicinae (n = 7 species), consistent with other studies that find that *Formica* spp. comprise the highest biomass and species richness in glaciated tallgrass prairies subjected to regular burning (Trager 1990, 1998). Arb also had high numbers of *S. molesta*, a scavenger in the nests of larger ants (Trager 1998, Petersen et al 2002).

Both sites supported a high relative abundance of what we identified to be members of *Aphaenogaster rudis* (75%), an ant characteristic of deciduous woodlands (Trager 1998). However, taxonomy of the *Aphaenogaster* group is uncertain and there are several undescribed grassland species. If the species is *Aphaenogaster rudis*, it may be more common at these sites because the edges of the prairie are dotted with bur oak (*Quercus macrocarpa* Michx.) and deciduous forest species (primarily *Populus deltoides* Marsh, *Acer rubrum*, *A. negundo*, *Fraxinus pennsylvanica*. and *Ulmus* spp.) and because management fires have not eliminated all woody vegetation and debris.

Despite our fairly intensive efforts we only trapped a total of 12 species of ants even though upland prairies can support 25–35 species (Trager 1998), and it is surprising that we did not encounter species such as *Myrmica*. Measured species richness at Arb also was lower than the 11 species Petersen et al. (1998) encountered at a 4-ha prairie recreation in Illinois, but it was similar to a later study at the same location (Petersen et al. 2002). Our low richness relative to Trager (1998) and Petersen et al. (1998) may be a reflection of biological reality or low sampling effort. All of the ants we found have a relatively widespread distribution and were not endemic to tallgrass prairies (e.g. many of the same species can be found in suburban lawns, Kittelson unpubl. data). To improve sampling and ensure capture of all species, sampling should occur for a long period of time and leaf litter sifting, nest searches, aspiration or hand-picking also should be used. Even though tuna and honey baits caught many of the same species as alcohol traps, three of 11 species at Kasota and one of six species at the Arb found only with baiting represent a high proportion of the total richness, so tuna and honey baits were worth the additional effort.

Our study revealed that ant species richness was highest in the prairie remnant where vascular plant species was greatest, likely because Kasota is a forb-rich remnant prairie that is larger, less fragmented and soils were not disturbed by plowing. We found a low diversity of ant and plant communities in the reconstructed prairie. The reconstructed prairie lacked many ant species common to the rehabilitated remnant and only contained a few of the dominant prairie plant species suggesting that this prairie recreation has low potential to ever resemble a remnant prairie. We also found several species not listed in the counties where we worked probably because little has been published about ants in our area; our study serves as a baseline. Ants are ecologically important members of prairie communities and future researchers may find it fruitful to examine interactions among ants (e.g. among similar *Formica* species or between *S. molesta* to its host species) or ant-plant and ant-environment relationships that could influence floral diversity.

ACKNOWLEDGMENTS

We are grateful to: Save the Kasota Prairie Foundation, the Linnaeus Arboretum at Gustavus Adolphus College, Richard Carter who helped us identify ant species, Peter Lesica, Paul Kannowski, two anonymous reviewers and the Associate Editor for improving our manuscript, the Gustavus chapter of the Sigma Xi Society for a Holcomb Research Fund Grant (to MPP and PJG) as well as the Rockefeller Brothers Fund for Environmental Studies student-faculty research (to PMK).

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