Influence of Fire and Trapping Effort on Ground Beetles in a Reconstructed Tallgrass Prairie

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ABSTRACT -- The effects of fire on communities of ground beetles (Coleoptera: Carabidae) were investigated between 9 April and 28 October 1996 in Anderson Prairie, a reconstructed tallgrass prairie in Decorah, Iowa. We collected ground beetles in pitfall traps from prairie plots burned in the spring of 1994, 1995, or 1996. We collected a total of 1,772 beetles representing 45 species. Recently burned plots (burned in 1996) had a lower diversity and evenness of carabid assemblages than plots burned in 1994. However, species richness was greatest in the most recently burned plots. Short-term sampling, consisting of three one-week exposures during the peak beetle activity period, yielded similar abundance, species diversity, and evenness trends to biweekly, full-season sampling.

Key words: Carabidae, Coleoptera, fire, pitfall traps, tallgrass prairie.

INTRODUCTION

Fire is a natural component of the grassland ecosystem (Collins and Wallace 1990) and is regularly used as a prairie management technique. However, little information is available on the effects of fire on prairie insects including the Coleoptera (Eyre and Rushton 1989). As many species of ground beetles (Coleoptera: Carabidae) are highly selective and often restricted to a particular habitat (Thiele 1977, Evans 1983), some species may be useful indicators of biological disturbance (Dufrêne et al. 1990, Maelfait and Desender 1990). Therefore, our study is part of an ongoing project using ground beetles (see Purrington and Larsen 1997) to explore the effects of tallgrass prairie management techniques such as fire on prairie insects.

We evaluated the effects of fire on the ground beetle community in Anderson Prairie, a reconstructed tallgrass prairie in Decorah, Iowa. Our objectives were to 1) identify the carabid species, which inhabit this reconstructed tallgrass prairie, 2) determine the peak adult activity periods of these carabids, 3) quantify the impact of spring burning on the ground beetle fauna, and 4) clarify if short-term sampling with pitfall traps can be an adequate substitute to season-long sampling for quantifying the effects of fire on ground beetles of tallgrass prairies.

MATERIALS AND METHODS

Study Site

Our study was conducted from 9 April to 28 October 1996 on Anderson Prairie, a 7.7-ha reconstructed tallgrass prairie located on the Luther College campus in Decorah, Winneshiek County, Iowa (43°18'57"N, 91°48'01"W; 345 m above sea level). During this period, the mean temperature was 16.1°C, with a range of -5°C to 35°C. Soils within the prairie vary from sand to sandy loam.

Anderson Prairie was initially planted with a variety of prairie grasses and forbes in May 1988 and burned in its entirety on an annual basis before 1994. In 1994, the prairie was divided into 14 plots at least 30 by 115 m in size (Fig. 1). Plots are burned in the spring between early-April and early-May and managed as follows: two plots are burned annually (plots 5 and 6), with the remaining 12 plots divided into three year burn cycles. Plots used in our study included plots 2, 4, and 12, which were burned in 1994; plots 1, 7, and 9, which were burned in 1995; and plots 3, 11, and 14, which were burned in 1996.

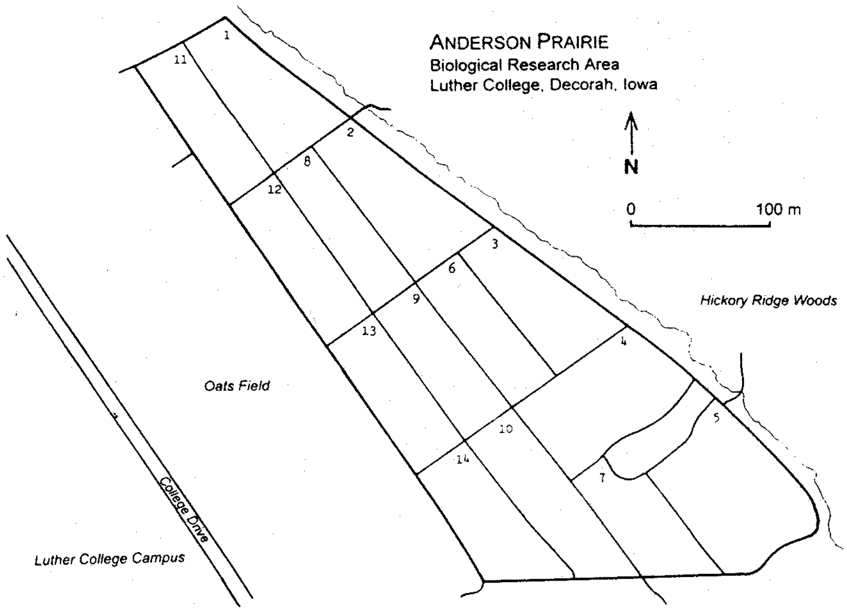

Figure 1. Burn unit layout within Anderson Prairie, a reconstructed prairie in Decorah, Winneshiek County, Iowa. Sampled in our study were plots 2, 4, and 12 burned in 1994; plots 1, 7, and 9 burned in 1995; and plots 3, 11, and 14 burned in 1996.

Beetle Sampling

We collected ground beetles by using pitfall traps for 15 one-week periods during the 1996 field season. Traps were first placed in the prairie 9 April 1996 (Julian date=100) when day-time temperatures were consistently above freezing and sampling continued on a biweekly basis until 28 October 1996 (Julian date=302) when the night-time temperatures dropped consistently below freezing. Each pitfall trap was constructed from one 473 ml plastic cup (9 cm dia) placed into the ground so the lip of the cup was at or slightly below the ground surface. In each cup fitted with a funnel constructed from a 207 ml casual cup insert (Sweetheart® Cup Company, Chicago, Illinois) we placed approximately 50 ml of propylene glycol preservative, diluted at a 1:1 ratio with water. During each trapping period, four traps were placed in each of the nine plots in a transect at 10 to 15 m intervals. After each biweekly trapping period, all traps were removed and the holes left by each trap were filled. Traps, which were damaged and apparently disturbed by large vertebrates, were noted and excluded from the study. We identified ground beetles to species by using keys presented in Lindroth (1961-1969) and Noonan (1991), and standardized names of Bousquet and Larochelle (1993). Voucher specimens are housed in the reference insect collection of the Hoslett Museum of Natural History, Luther College, Decorah, Iowa.

Ground Beetle Faunal Analysis

We determined the total number of ground beetles and species richness for each burn treatment for the entire trapping season. We calculated species diversity (Shannon's diversity index H') and evenness (J) of the ground beetle fauna for each burn treatment (Krebs 1989). Percent similarity among the three treatments, sometimes called the Renkonen index (Krebs 1989), was also determined.

Using only three one-week samples taken during the peak activity periods as determined by both species and numbers of ground beetles collected, we performed a second discrete sampling period analysis. This peak began at the end of June (Julian date=191) and continued to the beginning of August (Julian date=219).

Statistical Analysis

We performed statistical comparisons among burn treatments on the total number of ground beetles, species richness, and average number of ground beetles caught per trap per day by using a two-way analysis of variance (Minitab 1994) for the continuous full season data, with each plot serving as a replicate. We used the non-parametric Friedman test (Minitab 1994) to analyze differences in species accumulation between treatments blocked by date over the sampling season.

RESULTS

We collected a total of 1,772 beetles comprising 45 species of ground beetles from Anderson Prairie during 1996 (Table 1). The greatest beetle activity occurred during a single peak (Fig. 2) from the end of June to early August. The species *Chlaenius platyderus* Chaudoir and *Cyclotrachelus sodalis* (LeConte), constituting 58% of the total beetles collected, were most abundant.

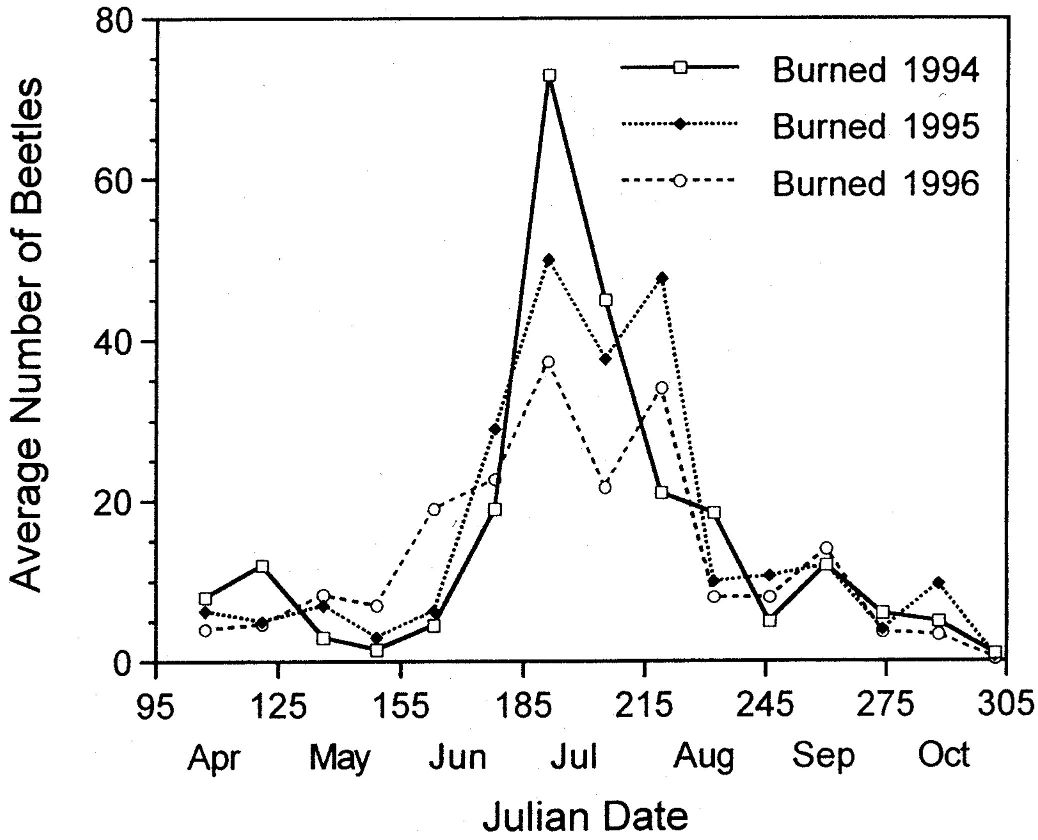

Figure 2. Average total number of ground beetles collected in pitfall traps from 9 April to 28 October 1996 during each biweekly sampling period from Anderson Prairie.

We collected a total of 468 ground beetles in plots burned in 1994, an average of 0.43 beetles per trap per day. Plots burned in 1995 yielded 718 ground beetles, an average catch of 0.59 beetles per trap per day. Plots burned in 1996 produced 586 ground beetles, an average of 0.52 beetles per trap per day (Table 1). Even though there were noticeable differences among the burn treatments, neither numbers of individual ground beetles ($F=0.68$, $df=2, 8$, $p>0.05$) nor beetles captured per trap per day ($F=1.57$, $df= 2, 8$, $p>0.05$) were significantly different.

The overall species richness in the three burn treatments decreased significantly with increasing time since burning from 29 species found in plots burned in 1994, to 32 in plots burned in 1995, to 38 species in plots burned in 1996. By early August, all species collected from the burned 1994 and 1995 treatments had been detected, while new species continued to accumulate until the beginning of October in the burned 1996 treatment (Fig. 3). Species accumulation over time for the three burn treatments showed the burn 1996 treatment had significantly greater species over time than the other treatments (Friedman test $S=17.42$, $df= 2$, $p<0.05$).

Table 1. Total number of ground beetles (Coleoptera: Carabidae) collected from three different burn treatments by pitfall traps between 9 April and 28 October 1996 from Anderson Prairie, Decorah, Iowa.

Species	**Burned 1994**	**Burned 1995**	**Burned 1996**	**Total**
Chlaenius platyderus Chaudoir	40	234	255	529
Cyclotrachelus sodalis (LeConte)	189	199	108	496
Calathus gregarius (Say)	32	43	33	108
Amara rubrica Haldeman	14	29	26	69
Poecilus lucublandus (Say)	28	17	13	58
Anisodactylus harrisii LeConte	27	26	8	61
Cyclotrachelus seximpressus (LeConte)	16	15	22	53
Anisodactylus rusticus (Say)	11	16	21	48
Harpalus herbivagus Say	13	20	17	50
Agonum cupripenne (Say)	13	16	6	35
Chlaenius emarginatus Say	17	6	8	31
Galerita janus (Fabricius)	7	16	6	29
Dicaelus elongatus Bonelli	12	12	1	25
Amara cupreolata Putzeys	8	10	5	23
Pterostichus permundus (Say)	5	6	6	17
Dyschirius globulosus (Say)	5	10	1	16
Harpalus pensylvanicus (DeGeer)	1	9	6	16
Chlaenius tricolor Dejean	8	6	1	15
Anisodactylus sanctaecrucis (Fabricius)	4	4	4	12
Amara impuncticollis (Say)	0	1	10	11
Pterostichus femoralis (Kirby)	3	2	5	10
Pterostichus stygicus (Say)	3	2	3	8
Stenolophus conjunctus (Say)	3	2	3	8
Selenophorus opalinus (LeConte)	1	5	1	7
Anisodactylus ovularis (Casey)	0	3	2	5

Table 1. Cont.

Species	Burned 1994	Burned 1995	Burned 1996	Total
Pterostichus melanarius (Illiger)	0	3	2	5
Bembidion versicolor (LeConte)	2	1	1	4
Bembidion quadrimaculatum Say	0	1	2	3
Sphaeroderus stenostomus lecontei (Dejean)	2	0	1	3
Cymindis americanus Dejean	0	1	1	2
Amara angustata (Say)	0	1	0	1
Bradycellus rupestris (Say)	0	0	1	1
Stenolophus fuliginosus Dejean	0	1	0	1
Amphasia sericea (Harris)	0	0	1	1
Agonum fidele Casey	1	0	0	1
Agonum nutans (Say)	1	0	0	1
Agonum placidum (Say)	0	0	1	1
Badister notatus Haldeman	0	1	0	1
Calleida punctata LeConte	0	0	1	1
Dicaelus politus Dejean	0	0	1	1
Elaphropus sp.	0	0	1	1
Harpalus somnulentus Dejean	0	0	1	1
Poecilus chalcites (Say)	1	0	0	1
Scarites quadriceps Chaudoir	1	0	0	1
Stenolophus rotundicollis (Haldeman)	0	0	1	1
Number of Individuals	468	718	586	1772
Number of Species	29	32	38	45
Traps Days	1086	1209	1132	3427
Beetles/Trap/Day	0.43	0.59	0.52	
Shannon's Diversity Index (H')	2.38	2.25	2.17	
Evenness (J)	0.71	0.65	0.59	

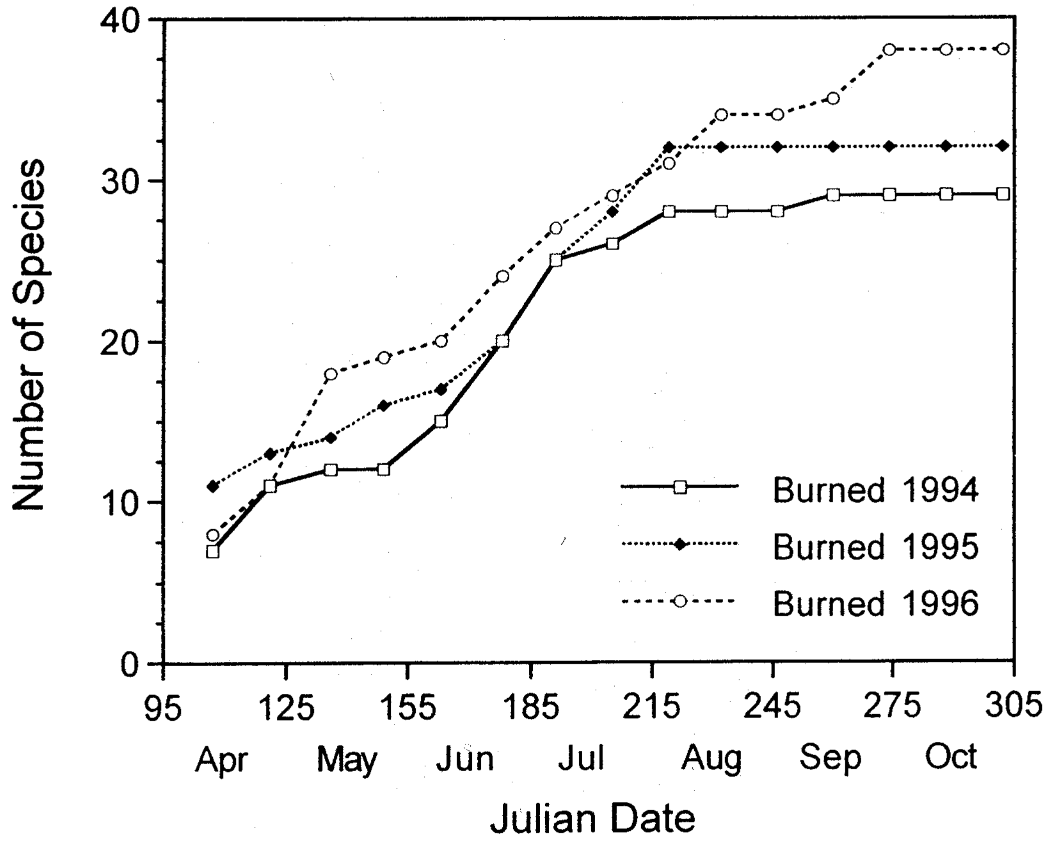

Figure 3. Species accumulation curves from April to October 1996 for ground beetles collected from within each burn treatment in Anderson Prairie.

In contrast to increased species richness in more recently burned plots, species diversity (H') increased with time since burning, with the most diverse carabid fauna in plots burned in 1994, and the least diverse fauna in plots burned in 1996 (Table 1). This trend in species diversity is likely due to the more even distribution of beetles among species from plots burned in 1994 than 1995 and 1996, and is evidenced by the evenness (J) calculated for each treatment (Table 1), which also increased with time since burning. The beetle assemblages of the burned 1995 and 1996 plots were most similar (80.3%), with the burned 1994 and 1995 plots 70.7% similar. Least similar were beetle assemblages in the burned 1994 and 1996 plots, with a similarity of only 56.6%.

Trends shown by the short-term samples, i.e., three discrete one-week samples taken during the peak beetle activity period between late-June and early-August, were consistent with full-season biweekly sampling. The numbers of beetles collected showed the same increasing trend as the full year data (Fig. 4). However, the burned 1996 treatment did possess fewer species during the late-June and early-August activity peak than the other treatments (Fig. 5), a trend that differed from the biweekly

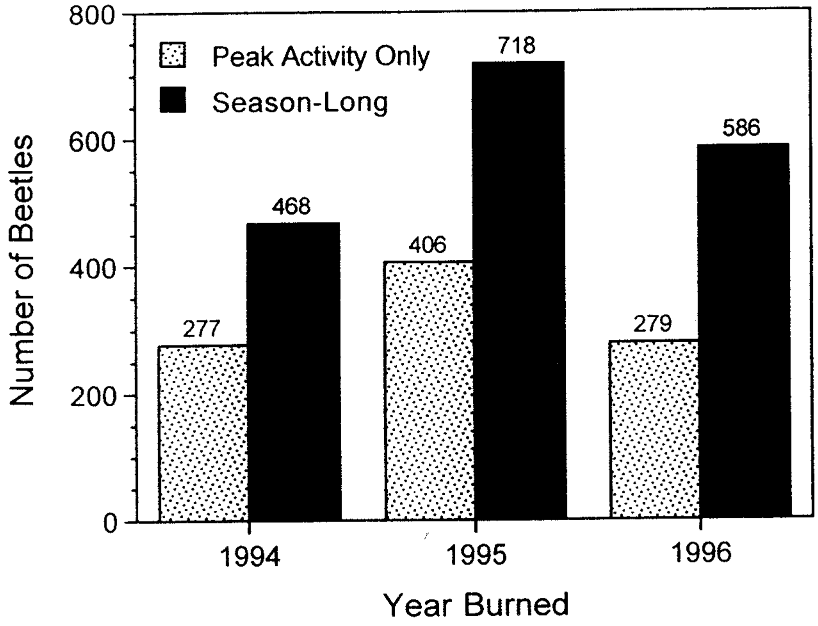

Figure 4. Abundance of ground beetles collected in pitfall traps from treatments in Anderson Prairie burned in 1994, 1995, or 1996. Beetles were collected by either short-term sampling consisting of three one-week samples during the peak beetle activity period, or bi-weekly from April to October 1996.

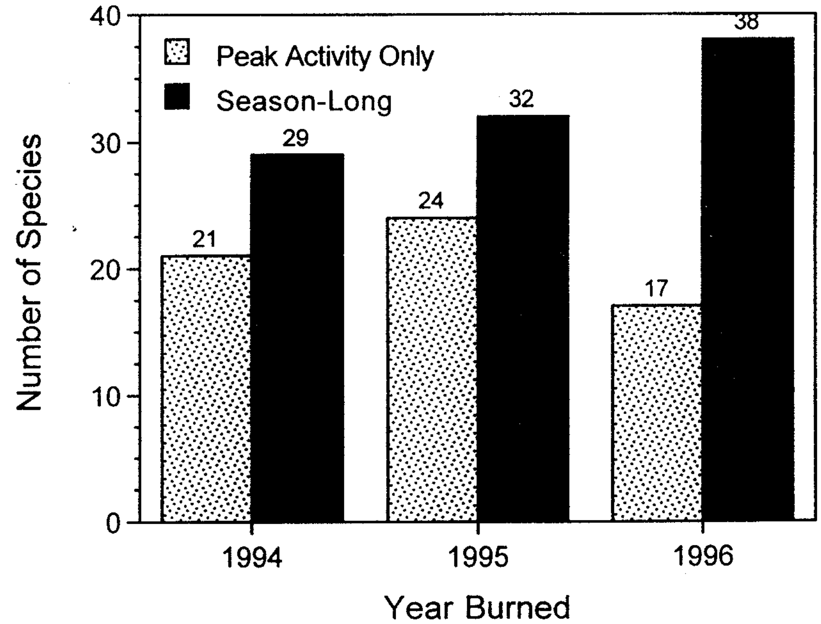

Figure 5. Species richness of ground beetles in Anderson Prairie collected by pitfall traps from treatments burned in 1994, 1995, or 1996. Beetles were collected by either short-term sampling consisting of three one-week samples during the peak beetle activity period, or bi-weekly from April to October 1996.

full-season results. Shannon's diversity index (H') for the discrete peak activity period increased from 1.43 in the burned 1996 treatment to 1.74 in the burned 1994 treatment, a trend similar to the continuous full-season results (Table 1). Likewise, evenness (J) increased from 0.52 in the burned 1996 treatment to 0.57 in the burned 1994 treatment, similar to the full-season results (Table 1).

DISCUSSION

Pitfall traps provided an efficient method of investigating the ecology of adult Carabidae and have been used in a multitude of studies (Greenslade 1964). However, pitfall trap data should be interpreted cautiously when comparing carabid abundances within habitats because insect activity (Thiele 1977, Adis 1979), population density, and weather influence trap catches (Mitchell 1963, Epstein and Kulman 1990). Continuous pitfall sampling over a entire year is thought to produce reliable indices of relative carabid population sizes (Baars 1979, Epstein and Kulman 1990).

Previous studies have reported two periods of peak activity for ground beetles during the year, with the first peak occurring from late-May to June and the second peak from mid-August to late-September (Kirk 1971, Niemelä et al. 1989). We found only one adult activity peak, which began in late-June and lasted into early-August. This single peak may have been due to an unusually cool summer, but in northeastern Iowa apparently the climate allows only this single mid-summer ground beetle activity peak.

When examining short-term sampling periods as a valid representation of full season trends, Niemelä et al. (1990) showed that samples of ground beetle assemblages obtained by trapping periods of 20 days or more are similar enough to a continuous whole season sample to be used in several types of ecological studies. In comparing the full-season and short-term results of our study, many of the same trends relative to the burn treatments were apparent in both the short-term and full-season sampling regimes. Species richness did show dissimilarities between the discrete and full-season results, most likely due to the continued accumulation of species from recolonization detected by continuous sampling not detected during the discrete sample period. We suggest however, that the trends in abundance, diversity, and evenness were most important and agree with Niemelä et al. (1990) that short-term sampling for ground beetles is valid for detecting the effect of management techniques such as fire on ground beetle fauna. We also found that the most recently burned plots contained the richest carabid fauna when sampled throughout the beetle-active season. This species richness was not apparent until August, however, and may be the consequence of recolonization of burned areas the first year after a fire. Although species rich, the most diverse beetle assemblage did not occur until several years after a fire.

Previous research on the effects of burning prairies on ground beetles is mixed.

Rickard (1974) found no significant difference in the abundance of the carabid *Calosoma luxatum* Say between burned and unburned stands of shortgrass prairie. Van Amburg et al. (1981) found a greater abundance of adult carabid beetles in burned tallgrass prairie plots than in unburned plots. In contrast, Seastedt et al. (1986) found carabid larvae were more abundant in unburned plots than burned tallgrass prairie plots.

Our study showed that ground beetle diversity did increase over several years immediately following fire in a tallgrass prairie environment. However, before the effects of burning on ground beetles can be determined, we must identify which species are prairie "specialists" and how these species respond to fire. Some species, such as *C. platyderus*, were "pyrophilic", i.e., are most abundant immediately following a burn, while other species, such as *Chlaenius tricolor* Dejean and *Poecilus lucublandus* (Say) were "pyrophobic", i.e., increasing in their abundance several years post-burn. Although fire may cause a reduction in the abundance of carabid beetles immediately after a burn (Holliday 1984), some species are apparently attracted to recently burned areas (Evans 1971, Holliday 1984). The greater number of species collected in plots burned in 1996 may have been due to increased activity by the ground beetles allowed by the removal of the dense leaf litter, which rapidly builds up in unburned tallgrass prairies. Greenslade (1964) recognized that vegetation impedes ground beetle activity. Possibly ground beetle activity may be affected more by alteration of the vegetation architecture by fire than by the fire directly (McCoy 1987). Continued research should further clarify how disturbance by fire and plant regeneration interact with individual species to influence the ground beetle assemblage found in tallgrass prairies.

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