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Abstract

We studied the effect of a late growing-season fire on the plant and foliar arthropod communities in a naturally occurring grassland. In central Arkansas, these grasslands are common on south-facing slopes where shallow soils and hot/dry weather conditions during the summer cannot support the growth of a forest community. Patches of grassland were burned in the autumn (4 November, late growing season), often the time of natural fires in Arkansas, and compared to unburned areas. Fire increased the biomass of forbs and decreased the biomass of grasses, although overall biomass was not different between treatments. Among the foliar arthropods, herbivores were significantly reduced by burning, especially the Homoptera. Carnivorous arthropods as a whole were not affected by burning, although spiders showed a small but significant reduction. The response of arthropods to fire occurred almost one year after the burn, showing that fire effects can be delayed for a substantial period of time. This experiment shows that fire occurring during the natural burning period in Arkansas can have substantial effects on grasslands communities. The response of plants in Arkansas is similar to that of plants in nearby grasslands on the Great Plains and southeastern United States which also show a great increase in forbs under late growing season burning regimes. The changes seen in this experiment demonstrate that the suppression of fire by humans has probably modified the structure of Arkansas grasslands. With the increasing use of fire as a management tool in Arkansas, changes to grassland systems are likely to be profound.

Introduction

Fire is the major abiotic disturbance event that is important in structuring North American prairies (Bragg, 1982). In the absence of fire, many prairie habitats undergo succession to forests (Bragg and Hulbert, 1976; Collins and Wallace, 1990; Knight et al., 1994; Sparks et al., 1999). In addition to preventing the encroachment of trees, fire has profound effects on other components of grassland plant communities, and it can alter nutrient cycles (Collins, 2000; Briggs and Knapp, 1995; Blair, 1997). For instance, in the tallgrass prairies of central North America, frequent fire tends to increase the dominance of C_4 grasses at the expense of C_3 grasses and forbs (Collins et al., 1998; Knapp et al., 1998). However, the timing of fire can cause substantial variation in this response. In North American tallgrass prairies, fire in the spring, the traditional season of burning by cattle producers, tends to reduce forbs and promote the growth of grasses (Gibson and Hulbert, 1987; Svejcar and Browning, 1988; Biondini et al., 1989), whereas summer fires tend to do the opposite, increasing the abundance of forbs at the expense of grasses (Pfeiffer and Steuter, 1994). In the southeast United States, growing season fires appear to be more effective than dormant-season fires in maintaining prairie habitat (Boyer, 1990; Glitzenstein et al., 1995) including the pine-grassland communities of the western Ouachita Mountains (Sparks et al. 1999), which are near our field site.

Fire also has varied direct and indirect effects on animals. The most ubiquitous macroscopic animals in most grassland communities are arthropods (Redak, 2000). Studies investigating fire effects on grassland arthropods have found both positive (Evans, 1984, 1988; Moya-Raygoza, 1995) and negative (Amburg et al., 1981; Seastedt, 1984; Anderson et al., 1989; Fay and Samenus, 1993) effects. Anderson et al. (1989) found a significant decline in insects immediately after a burn whereas Swengel (1996) found that infrequent fire promoted butterfly abundance. It is known that some arthropods such as fire beetles (Buprestidae) are promoted by fire (Whelan, 1995), but others may be at greater risk of predation in burned habitat due to exposure. Nagel (1973) found an increase in herbivore biomass after a spring grassland burn, but above-ground arthropod species fared worse than the more abundant soil arthropods.

In Arkansas, fires historically tended to occur during the late summer and early autumn (Foti and Glenn, 1991; Masters et al., 1995) when high temperatures and low rainfall (National Weather Service, Little Rock) increase the potential for ignition and fire spread. Sparks et al. (1998) studied the effects of fire season on vegetation in a western Arkansas grassland. Species diversity and stand species richness were greater in burned stands than in unburned control stands. Although they set out to determine the effects of fire season on plant communities, no overall community attributes differed between late growing-season and late dormant-season burns. However, late growing-season fires decreased density of warm-season (C_4) plant species (Sparks et al., 1998).

Here we report the results of a study on the effects of fire on the vegetation and associated foliar arthropod community in the growing season following a prescribed burn during the late growing season. We examined the entire plant-foliar arthropod community to determine how different functional groups are affected by burning.

Materials and Methods

In the spring of 1999, 12 2 m x 2 m experimental plots were established within grassland patches in northeastern Conway Co. near Center Ridge, Arkansas. Grassland patches ranged in area from approximately 20 m^2 to 105 m^2 and were surrounded by closed canopy *Quercus – Carya* (Oak-Hickory) forest. Therefore, each larger grassland patch contained one 2 m x 2 m plot that was monitored during the course of the experiment. The grasslands were located on a south-facing slope (elevation 186 m) in an eastern extension of the Ouachita Mountains.

The most common plant species is the native grass, little bluestem (*Schizachyrium scoparius*) which co-occurs with other grasses (mostly dropseeds, *Sporobolus* spp.) and numerous forb species. The most abundant secondary species are lanceleaf coreopsis (*Coreopsis lancolata*), venus looking-glass (*Specularia perfoliata*), false garlic (*Nothoscordum bivalve*), toothwort (*Dentaria laciniata*), and sunflower (*Helianthus* spp.).

To determine the pre-burn conditions of the plots and to verify similar community attributes between treatment and control plots (before manipulation), we classified all plants to species level every two weeks for the entire 1999 growing season (Feb. to Oct.). These measurements were used to determine plant species diversity within the plots. Once per month we also measured arthropod abundance by placing a single 30 cm x 30 cm wooden plate painted with Tangletrap (Tanglefoot Co., Grand Rapids, Michigan) in each plot. Captured arthropods were counted and classified to order and trophic level. Finer classification was not possible with these samples as the Tangletrap tends to severely damage fine structures (e.g., wings, bristles, etc.), which are necessary for identification.

On 4 November 1999, we successfully burned six grassland patches and the experimental plots within those patches with a kerosene drip torch. This date corresponds to the end of the dry season (late growing season). The other six grassland patches (and imbedded experimental plots) remained unburned. The following growing season (2000), we monitored plant and arthropod communities with the same methods as the pre-burn samples. We also employed additional, more destructive, post-burn sampling techniques to more thoroughly measure plant and arthropod parameters. Once in June and once in September 2000, we removed all above-ground plant biomass in a randomly selected 1 m^2 quadrat within each plot. Plants were sorted according to species, dried, and massed. To more thoroughly sample arthropods at the end of the experiment, the entire plots were sampled by D-vac to remove as many arthropods as possible. Arthropods were counted and classified according to order and trophic level.

There was much heterogeneity between plots so that most plants were not found in every sample area, and it was impractical to analyze the treatment response of individual plant species. We therefore analyzed the plants by broad growth form groups (i.e. grasses and forbs) between treatment and control plots.

For dependent variables measured multiple times over the two years of the study, we performed repeated measures MANOVA. If the repeated measures analysis was significant, we analyzed individual dates to determine what time of year the treatment response was occurring. Plant biomass and the final arthropod samples, for which we did not have pre-treatment measurements, were analyzed by one-way ANOVA. Data sets that showed significant heteroscedasticity were log10-transformed prior to analysis, after which no data set violated this ANOVA assumption.

Results

In June 2000, there was no significant effect of fire on total plant biomass, grass biomass, or forb biomass (one-way ANOVA, Fig. 1A). However, by the September sample, grass biomass was reduced in burned plots (one-way ANOVA, $F_{1,10} = 5.87$, $P = 0.036$) whereas forb biomass was greater in burned plots (one-way ANOVA, $F_{1,10} = 7.46$, $P = 0.021$). Total plant biomass was similar between burned and unburned plots (Fig. 1B). There was no change in plant diversity between burned and unburned plots during the course of the experiment.

When measured over time, herbivorous arthropods were reduced by burning (repeated measures ANOVA, between-subject effects: $F_{1,10} = 9.44$, $P = 0.017$, Fig. 2A), indicating that herbivores were generally greater in control plots over time. Analysis of herbivore abundance only during the 1999 seasons (pre-treatment) was non-significant showing that the response occurred after the prescribed burn. Only the final sample period had significantly higher herbivore abundance (one-way ANOVA, $F_{1,12} = 29.92$, $P = 0.001$, Fig. 2A). Carnivorous arthropod abundance over time was not affected by burning (repeated measures ANOVA, $F_{1,10} = 0.001$, $P = 0.973$, Fig. 2B), although the number of carnivores captured in the sticky traps was small. There were significant time effects for both herbivorous (Wilksí Lambda = 0.052, $F_{5,6}$ = 21.80, P = 0.001) and carnivorous arthropods (Wilksí Lambda = 0.160, $F_{5,6}$ = 6.30, P = 0.022), indicating seasonal changes in abundance (Fig. 2). The final D-vac sample showed that herbivorous arthropods were significantly reduced in burned plots ($F_{1,10}$ = 11.96, P = 0.006, Fig. 3) while carnivorous arthropods were unaffected by burning ($F_{1,10}$ = 1.23, P = 0.293, Fig. 3). Among individual orders of arthropods, only Homoptera and Araneae significantly declined in burned plots (one-way ANOVA, Fig. 3). No taxa or trophic level showed a positive response to burning.

Discussion

The prescribed burn had significant effects on plant growth, with forbs benefiting and grasses being adversely affected. The dominant grass in this system is little bluestem (*S. scoparius*), which accumulates large amounts of litter from previous years that covers the ground. The elimination of this detritus by fire, along with increased nitrogen released and direct fire damage to *S. scoparius*, probably allowed forbs to grow more vigorously (Knapp and Seastedt, 1986). The reduction in grass biomass was opposite from what is seen in many prairie habitats in the Great Plains; there a single burn tends to increase grass growth (Gibson and Hulbert, 1987; Anderson, 1990; Collins and Gibson, 1990). However, many prairie studies used spring burns whereas our burn was in the late growing season. In prairies of the Great Plains, late growing season burns cause similar plant responses as seen in this study (Howe, 1994; Pfeiffer and Steuter, 1994). In other studies in the southeastern United States, the response of a growing season burn appears similar this study with an increase in forb growth (Sparks et al., 1998, 1999). Therefore, it appears that across a large geographic area, late growing season burns have similar effects on plant communities.

Previuos studies of fire effects on arthropods have been equivocal with some positive and some negative responses (see introduction). We found that some arthropod groups were reduced, and this effect was strongest among herbivores. However, no arthropod order or trophic level increased in abundance when burned. Carnivores are generally more mobile than herbivores, as herbivores are more closely associated with their host plant (Bernays and Chapman, 1994). Therefore we suggest carnivores are less affected by disturbance or can recover more quickly. In addition, the areas we burned were relatively small, which could also have allowed mobile carnivores to recolonize quickly.

It is also interesting that the effect on herbivores was not indicated until the final sample period (almost one year after the burn), showing that fire effects can occur well after the disturbance event. The significant negative effect on Homoptera is expected because these groups oviposit on their host plant stems, which would be severely damaged by fire. Other herbivorous groups that oviposit in the ground (e.g. Orthoptera) were not significantly affected.

The link between herbivore abundance and plant growth is important. The increased forb growth may have been caused directly by fire, but also could have been caused indirectly by reduced herbivory in burned plots. Therefore when examining fire effects on plants, the indirect role of herbivores needs to be considered as well. For instance, in tallgrass prairie, bison preferentially graze on areas recently burned (Coppedge and Shaw, 1998), feed exclusively on C_4 grasses, and subsequently change the plant communities in profound ways (Hartnett et al., 1996, 1997; Collins et al., 1998; Knapp et al., 1999). Since arthropod herbivory can also cause significant changes in plant communities (Brown, 1988; Brown at el., 1987; Moran et al., 1996), how fire and arthropods interact to affect plant communities needs to be more thoroughly investigated.

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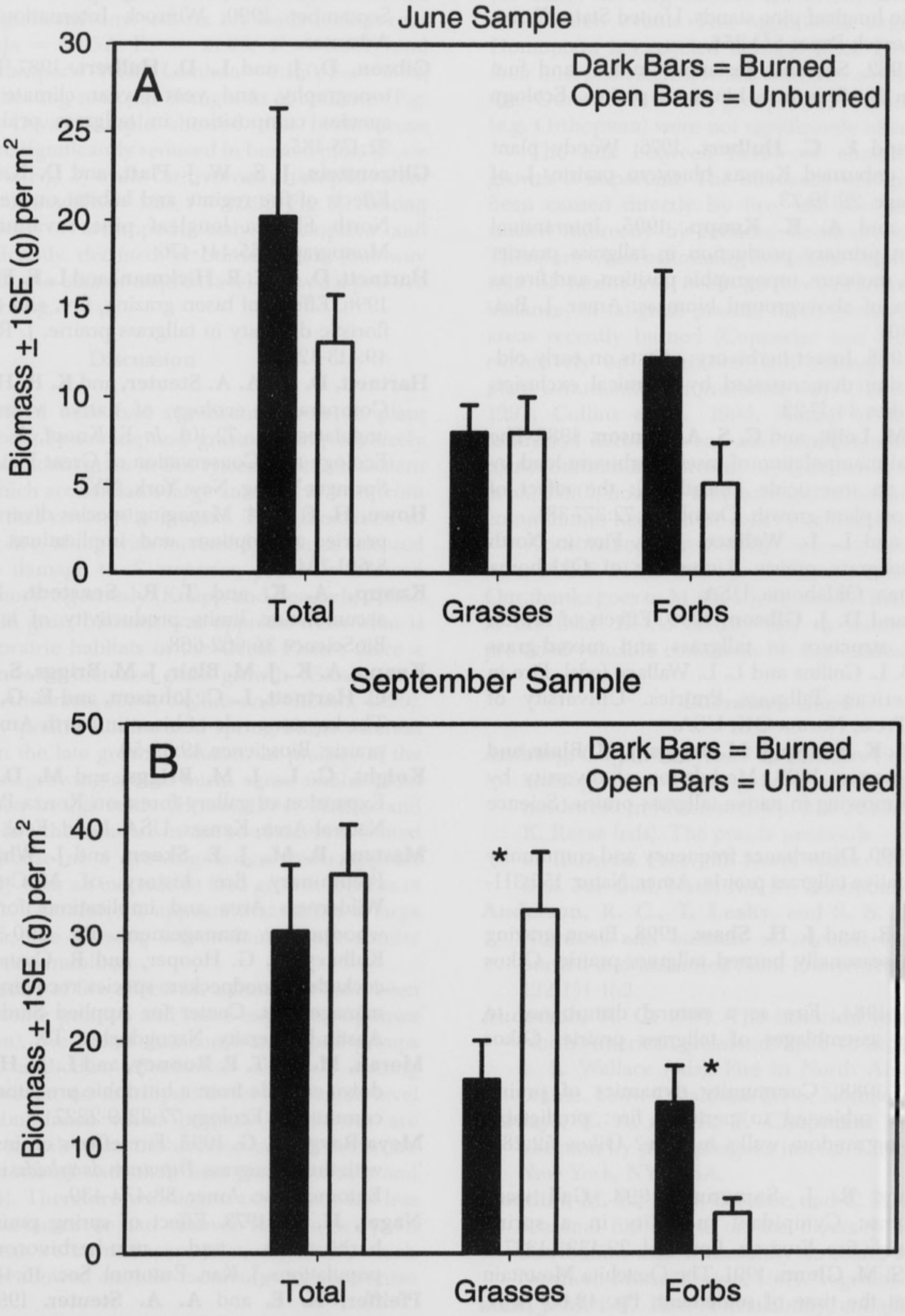

Fig. 1. Effects of fire on total plant biomass, grass biomass, and forb biomass in A) June and B) September following an autumn burn. * indicates significant differences (one-way ANOVA).

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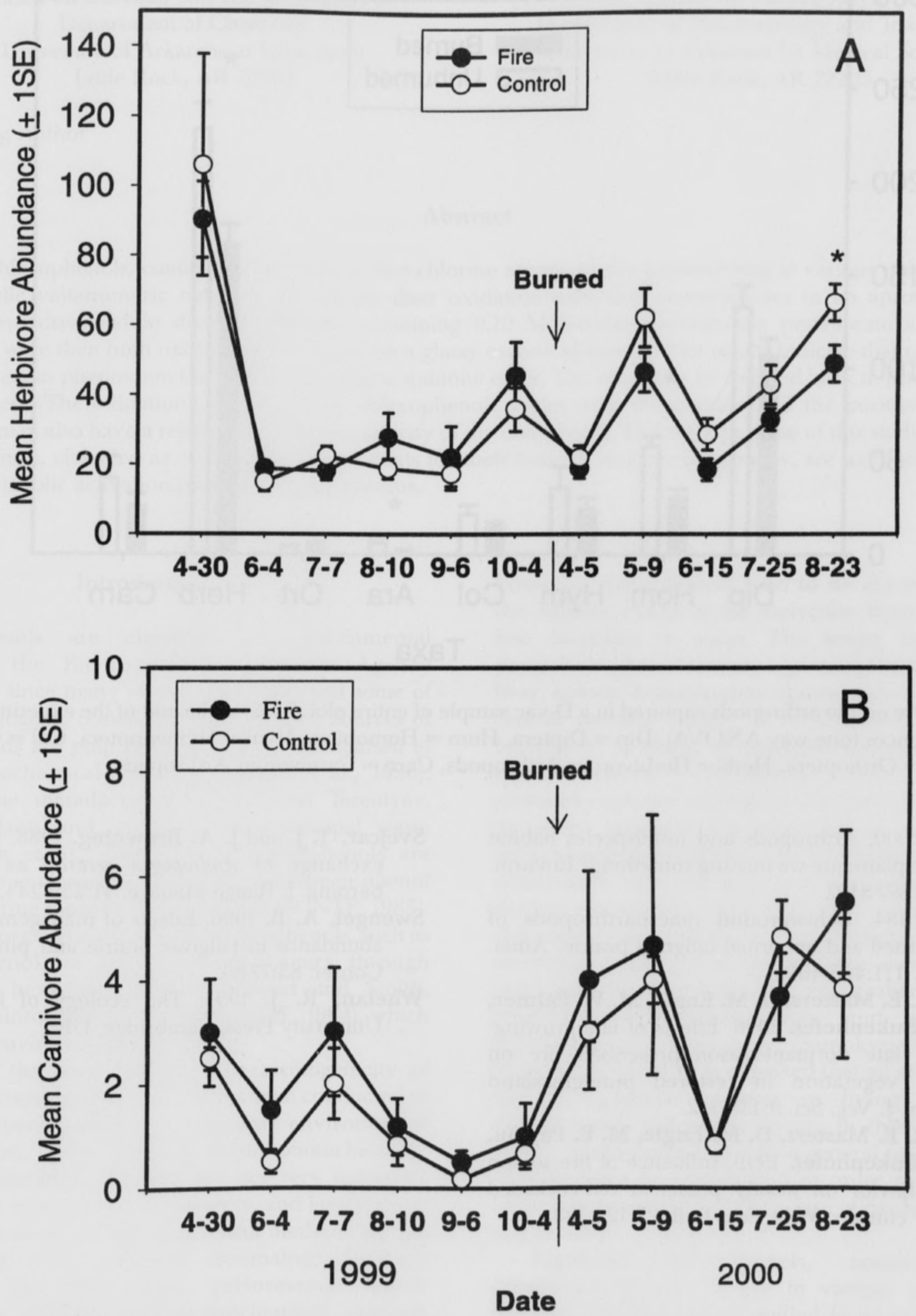

Fig. 2. Effects of fire on abundance of A) herbivorous and B) carnivorous arthropods captured in sticky traps over the course of the experiment. Abundance data is presented per trap (0.09 m^2). Effects on herbivorous arthropods were significant (repeated measures MANOVA). * indicates sample period where significant differences exist (one-way ANOVA).

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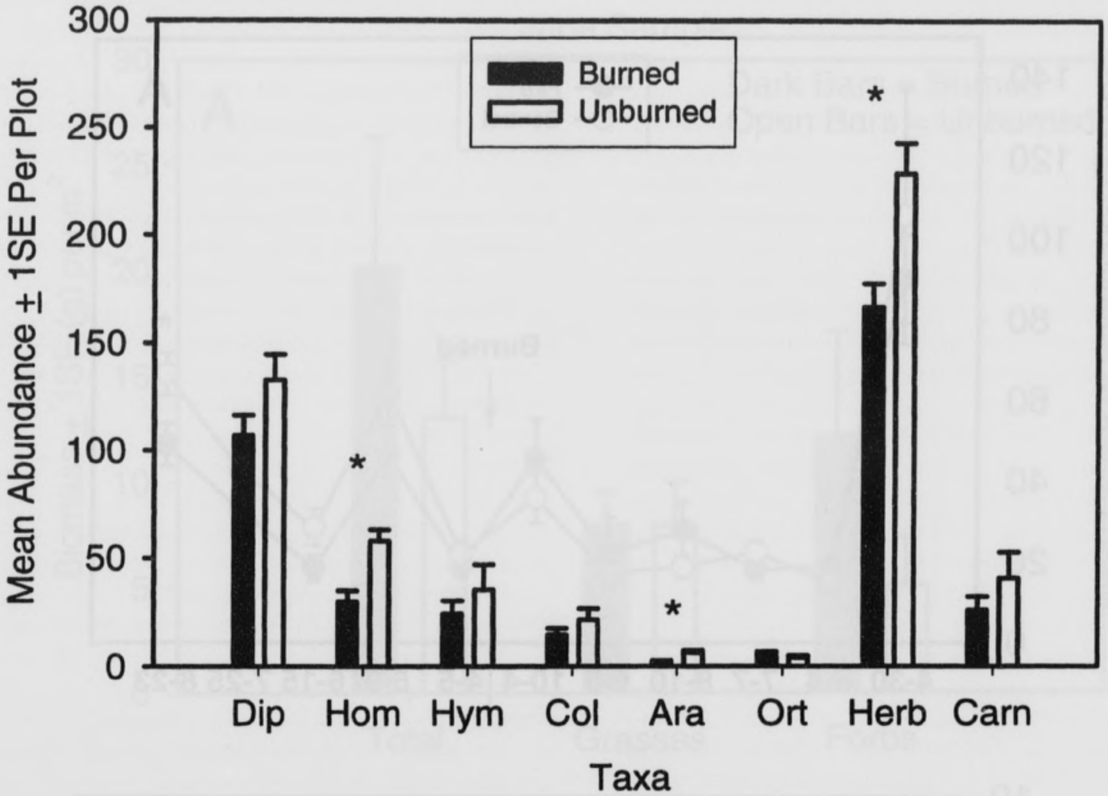

Fig. 3. Effect of fire on the arthropods captured in a D-vac sample of entire plot (9 m2) at the end of the experiment. * indicates significant differences (one-way ANOVA). Dip = Diptera, Hom = Homoptera, Hym = Hymenoptera, Col = Coleoptera, Ara = Araneae, Ort = Orthoptera, Herb = Herbivorous Arthropods, Carn = Carnivorous Arthropods.

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