THE EFFECT OF SEASON AND INTENSITY OF FIRE ON POPULATIONS OF GROUND-DWELLING ARTHROPODS

Mark W. Schwartz
Illinois Natural History Survey
607 E. Peabody Drive
Champaign, IL 61820

and

Ron J. Panzer
Northeastern Illinois University
5500 N St Louis Avenue
Chicago, IL 60626

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INTRODUCTION

Habitat degradation is a primary agent causing the loss of biodiversity (Atkinson 1989, Olson 1989, McNaughton 1989, Walker 1989). We usually attribute habitat degradation to misuse of land or development; however, degradation can also become a problem on lands managed to maintain natural diversity. The question of how land use and land management practices influence diversity in dynamic and non-equilibrial biotic systems is critical to conservation (Hobbs and Huenneke 1992) and is considered by many to be a top priority for ecological research (Lubchencko et al. 1991).

Land management activities can, at best, only mimic natural phenomena. Natural areas management is usually directed toward a specific goal, such as maintaining populations of vertebrates (Chamrad and Dodd 1973, Westemeier 1973) or vascular plants (Anderson 1973, Collins and Gibson 1991). For lack of information, the assumption is often made that if a focal group, usually vegetation, thrives as a result of management, the rest of the biota will also respond positively to such management practices (e.g., Dye 1991). Cases have been presented that call this assumption into question with respect to the use of fire in managing tallgrass prairie (Opler 1981, Stannard 1984, Opler 1991).

Fire suppression during the 20th century has resulted in dramatic changes in the vegetation of many regions (Pyne 1982, 1984). The reintroduction of fire through managed burns may not be a good mimic of "natural" fire occurrence (Robbins and Myers 1989) because knowledge of historical fire regimes is often imperfect (Pyne 1982, Anderson 1990). In addition, fire regimes are often chosen to meet specific management goals, such as habitat restoration, and are not necessarily selected on the basis of historic fire frequencies (Anderson 1973). The assumption is appropriate management regimes for the native vascular flora will enhance the community as a whole, including other trophic levels. The effects of fire management on organisms other than vascular plants, however, are often overlooked.

In a general sense, biologists have long been interested in the effects of fire on arthropods (Bouyoucos 1916, Hayes 1927, Shackleford 1929, Rice 1932), particularly as a means of controlling problematic insects (see Warren et al 1987). As one would expect, the effects of fire on arthropods vary, depending on habitat and taxonomic group. For instance, fire can cause a long-lasting depression in diversity and abundance of insects in habitats where natural fire frequencies are low (Buffington 1967). In contrast, in habitats that are maintained by frequent fires, burning results in higher numbers of below-ground arthropods (Lussenhop 1972, 1976, James 1982, 1988, Seastedt 1984a,b). Spring fire in tallgrass prairie also results in higher numbers of most vagile arthropod groups during the subsequent growing season (Cancelado and Yonke 1970, Nagel 1973, Van Amburg et al 1981). Mobile insects may be able to take advantage of the increased vigor, nitrogen content and flowering exhibited by many plants post-burning (Daubenmire 1968, Willms et al 1980, Coppock and Detling 1986).

Unfortunately for conservation biologists, most studies of the effects of fire on insect communities summarize data along broad taxonomic lines (orders or families; see Warren et al. 1987 for review). Few studies have investigated the role of fire on insects at the genus, much less the species, level. This omission is significant for two reasons: first, the direction and magnitude of population response to fire is likely to vary among species within taxonomic groups. Second, conservationists are often concerned with specific groups of insects, such as those associated with particular habitats, or those that are threatened or endangered. Trends within these groups can be obscured by those of more common species.

With this research, we set out to address how controlled burns in high quality, remnant, tallgrass prairie preserves, managed with fire for plant diversity, can affect insect community composition and the persistence of prairie-inhabiting insect species. We used five general questions in which to examine the effects of fire on a variety of taxa at the species level.

Question 1. Are populations of sedentary insects, or insects that are in a sedentary stage (e.g., eggs or caterpillars) at the time of fire, eliminated or severely reduced through fire management of fragmented and isolated prairie preserves?

The response of arthropods to fire seems to vary predictably with respect to life-history (Nagel 1973). Soil arthropods, while relatively sedentary, appear to escape the damaging effects of fire in the soil (Lussenhop 1972, 1976, James 1982, 1988, Seastedt 1984a,b). In contrast, vagile insects appear to avoid fire through flight, and readily recolonize burned sites, where they may take advantage of increased growth rates of plants following fire (Hadley and Kiekhefer 1963, Old 1969, Knapp 1985, Svejcar 1990). In between these two extremes, arthropods that overwinter above-ground (as eggs in duff or embedded in vegetation), or that are in sedentary life stages throughout the growing season (such as some thrips, wingless leafhoppers and larvae of many moths and butterflies), may be sensitive to spring fires. Stannard (1984) hypothesized that these sedentary insects may be particularly threatened by fire because they are vulnerable to fire and do not disperse well.

A population of insects could be extirpated as a result of fire if they all burned, or if populations are driven to such low densities that extinction from other causes becomes likely. Local extinction may be more probable in modern prairie preserves because management recommendations include short fire intervals (2-3 years) and high fire intensities in order to control exotic weed and woody encroachment problems (Heitlinger 1975, Anderson 1973, Hulbert and Wilson 1980). These management recommendations may allow insufficient time for populations depressed by a fire to recover through intrinsic growth. The probability of local extinction may be further increased because many prairie remnants are typically small areas isolated within a sea of agricultural land. The current fragmented landscape may threaten insect species that are not fire-hardy and that rely on vagility and recolonization after fire.

In situ survivorship of fire by insects can depend on several, non-exclusive conditions: the intensity of the fire, the density of the vegetation, and/or the patchiness of the fire.

Some prairie grasses, for example, have extremely dense tussocks that do not burn because dense, sheathing leaves may reduce the amount of oxygen available to fire (Lemon 1949). Such clumps could insulate insects from fire as well. In addition, all fires, both natural and managed, are patchy. Patches of unburned vegetation may provide refugia for resident insects.

We will determine whether sedentary insects, or those at vulnerable stages in their life cycle, are especially prone to local extinction as a result of fire.

Question 2. Do conservative species respond to fire differently from those that are more generalized in their habitat use?

Question 3. Do native species respond to fire differently from insects that are non-native?

In the few studies that have dealt with insects at the species level, fire has been shown to alter species composition of weevils (Bertwell and Blocker 1975), leafhoppers (Mason 1984), grasshoppers (Evans 1987), ants (Andersen 1988), and spiders (Warren et al 1987). Changes in species composition are particularly important from a conservation perspective since most broad arthropod groups contain both native and non-native species as well as both prairie-dependent and generalist species (Panzer and Stillwaugh 1990). Several entomologists have cautioned that fire may have severe adverse effects on arthropod biodiversity (Hessel 1954, Riechert and Reeder 1970, McCabe 1981, Opler 1981, Jackson 1982, Stannard 1984). None have documented proof of species extirpation. Panzer (1988), while urging restraint, finds that managed fire has not eliminated prairie-dependent butterflies and moths in prairie remnants. We might expect that insects endemic to prairies have evolved ways of dealing with fire.

Question 4. What is the source of individuals that replenish populations of insects post-fire?

After fire, insect populations may recover as a result of two distinct phenomena: first, burned areas may be colonized by insects that disperse into the site from other areas and second, populations can rebuild from individuals that were able to survive in situ. Knowing the origin of these insects informs both fire management practices and perhaps also strategies to manage genetic diversity of endangered insect species.

The mechanism of repopulation after fire has important consequences for both insect populations and management strategies. From the standpoint of the genetic structure the population - a matter of concern especially if the species is threatened or endangered - species that rely on colonization from other source areas may have a relatively homogenous distribution of genetic diversity among populations as a result of extensive gene flow. In contrast, species that rely on on- site recovery (i.e. survival as a result of patchiness of fire or ability to withstand fire), may have limited gene flow between sites. While the measurement of genetic diversity is beyond the scope of this study, information we are gathering will measure the dispersiveness for several leafhoppers. Vagility is one component of gene flow, and limited gene flow may facilitate local adaptation by populations to individual sites.

Question 5. How does season of fire affect insect responses to burning?

The season of burning may have a large impact on insect responses to fire. For example, insects that are in immature stages in the spring and unable to fly from fire may be able to escape fire in the fall as winged adults. For most tallgrass prairie regions spring is used as the typical season for managed fire (Pemble et al. 1981). However, historical evidence suggests that fall may have been the more typical season for natural fires (Beckwith 1879, Oakwood 1885, Schwegman and McClain 1985). Thus, fire adapted insects of prairies may do well under fall fires, but not under the spring fire regime predominantly prescribed for current prairie management. We will compare the response of prairie insect species that overwinter as eggs to that of species that overwinter as adults in fall versus spring fires.

From a conservationist's perspective, if life-history is a good predictor of an insect's ability to withstand fire, then land managers may benefit from alternating season of fire to minimize continued losses to fire by groups that are at vulnerable life-stages during any one season. Ultimately, these surveys will allow us to recommend a burning regime that is favorable for the persistence of both native insects and plants.

STUDY AREAS

We have chosen twelve prairie preserves on which to conduct various portions of this research. To examine the potential immediate loss of species from sites with no burning history where fire is introduced (Question 1) we have found 4 sites (Table 1) that meet each of three criteria: 1) they have no recent (past 10 years) fire history; 2) they can be managed with fire; 3) they contain populations of leafhoppers that can be sampled in reasonable densities. To contrast conservative versus generalist species (Question 2), native versus non-native species (Question 3), and other life history traits that may influence a species' ability to recover from fire we use species sampled at all 12 sites (Table 1). To address the source of re-colonizing or rebounding populations (Question 4) we use intensive sampling at Grant Creek Prairie (Will Co.), Gensburg-Markham Prairie (Cook Co.), and Goose Lake Prairie (Grundy Co.) (Table 1). To address season of burn (Question 5) we will be using Grant Creek and Gensburg-Markham prairies.

STUDY ORGANISMS

To assess the affects of fire on prairie insect communities we chose to focus our study on three groups of insects: leafhoppers (Homoptera: Cicadellidae), Butterflies (Lepidoptera) and, in particular, root boring moths (Lepidoptera: Noctuidae: Papaipema), although the broad-based insect sweeps to assess source of recovery in populations include several additional taxa (e.g., froghoppers, planthoppers, walking sticks, grasshoppers, katydids, tree crickets etc). These insects are divided into groups according whether they are conservative (Table 2) or generalists (Table 3). Further, the generalist species are delineated by whether they are native or non-native (Table 3).

SAMPLING METHODS

We censused the leafhopper community using sweep net sampling (50 sweeps per sample). For species directed sampling we focused our sweep samples in a haphazard manner within patches of suitable habitat (e.g., in patches of Sporobolus heterolepis when sampling for Aflexia rubranura). For samples to detect source of population recovery we sampled in transects across burned and unburned units (approximately 30 samples in each unit at 5 m intervals away from the burn line) twice during 1992. All collections from the sweep net samples were preserved in alcohol. Taxonomic identification was conducted during winter 1992/3. All individuals were categorized to species whenever possible. Species were distinguished into categories of prairie-dependent or habitat generalist, introduced or native species.

RESULTS

The results described herein represent a preliminary analysis of the compete study. This report describes the results for the first year of what is planned as a three-year study. As such, results in some areas are preliminary.

Question 1. Preliminary data only on previously unburned sites.

We have no surveyed insect diversity through sweep sampling on four sites with no recent burn history. We are working with the district biologists and site managers in each case to conduct burns on these sites in fall 1993 or spring 1994. We will assess the effects of the burn on diversity on these sites following the fire treatments. Prior to fire treatment we can report two general observations about these sites with no prior burn history: 1) the diversity of leafhoppers is not higher, and is often substantially lower, than in sites with a history of fire management; 2) these sites do not contain any conservative species that unique to unburned sites; and 3) densities of conservative species on long unburned sites are not, in general, higher than on sites with a history of fire management. Thus our pre-fire treatment surveys do not support the predictions of the hypothesis that fire eliminates prairie-dependent sedentary insects.

Question 2.

We sampled several generalist species in sufficient densities to ascertain response to fire in the first year. Among seven beetle species found on Grant Creek Prairie, one significantly increased in the newly burned habitat, one slightly decreased in density, and the other five species did not change appreciably in density (Figure 1). These results were supported for five of these beetles from our results at Gensburg-Markham Prairie, where we observed a similar response for each taxa (Figure 2). Likewise, four other generalist insect species (grasshoppers and beetles) were found to respond favorably to fire at the two primary sites (Figure 3). In contrast, tree crickets (*Oecanthus* sp.) responded negatively to fire at both Gensburg-Markham and Grant Creek, despite being a generalist on wet to mesic grasslands (Figure 4, Table 3). Thus, most generalist species either do not respond to fire, or respond positively to fire.

In contrast, we have analyzed the data for four conservative leafhopper species, one of which we sample at two sites. From these data we see no consistent pattern. There was no apparent effect of fire on *Hecalus grandis*, a conservative leafhopper where only females have wings. The slightly higher densities on unburned habitat at Goose Lake Prairie in May 1992 were equilibrated between burned and unburned units by mid-June (Figure 5). For *Flexamia pectinata* at Lake in the Hills Fen early higher densities on unburned sites gave way to higher second generation densities on the burned habitat (Figure 6). A similar pattern was observed for the closely related *Flexamia prairiana* at Illinois Beach State Park (Figure 7). While for *Aflexia rubranura*, a wingless leafhopper (although we have observed that approximately 10% of first brood adults are winged), fire has a severe negative impact that is persistent through the first brood of the year following the fire. At both Lake in the Hills Fen and Goose Lake Prairie densities in the unburned site far exceeded those in the burned unit throughout the first growing season (Figures 8,9). This decreased density on sites burned in 1992 persisted through the first brood of 1993 at both sites, although they were signs of recovery at Goose Lake Prairie in the second brood of 1992 and in the first brood of 1993 at Lake in the Hills Fen (Figures 10, 11). The second brood of 1993 is just beginning to emerge as this report is written. A preliminary conclusion would be to suggest that this species would benefit from burn cycles longer than at 2-year intervals.

Question 3.

Comparing the response of exotic species we find that among four species all decreased with burning (Figure 12). Two of these species (*Philaenus spumarius*, a froghopper, and *Papilio japonica*, a scarab beetle) had modest declines, however, while the two leafhoppers (*Athysanus argentarius* and *Orientus ishidae*) showed a significant negative responses.

Question 4.

With respect to the question of where the source from rebounding populations comes from we can address this issue by examining population densities with respect to distance away from the burn line. If rebounding populations come from restocking from the unburned habitat, then we would expect to observe populations close to the burn line to recover first, while distant populations recover more slowly. Again, the data is preliminary but this pattern does not meet expectations for observed migration for either *Aflexia rubranura* (Figure 13) or *Papaipema* sp. (Figure 14).

Question 5.

The first fall burns are scheduled for fall 1993. No data is available as of this date.

Additional results.

We also surveyed habitat preference for three species of butterflies to compare relative densities (along measured census routes) within recently burn and not recently burned habitats. For each species densities were higher on the more recently burned habitat patches (Figures 15-17). This data indicates merely a habitat selectivity of adults toward recently burned areas, presumably because of higher densities of flowers. It does not discern survivorship patterns among eggs and larvae on burned and unburned habitat.

In contrast, we censused larval occupation rates of flowering stems of host plants for species in the genus *Papaipema*. In each case, the percent of flowering stems bored by *Papaipema* was higher in unburned sites than recently burned sites (Figures 18, 19). However this effect of higher frequency of flowering stems bored is mitigated by the observation that the recent burn seemed to stimulate the production of flowering stems, at least at Grant Creek (Table 4). Thus, absolute density of moth larvae on the burned side may actually be higher in the more recently burned unit. In examining longer term dynamics of *Papaipema* the issue is further obfuscated. Populations seemed to fully recover to occupy the same proportion of flowering stems in year two at Grant Creek Prairie (Figure 20) while the frequency remained lower at the Goose Lake Prairie site (Figure 21). We do yet not have data on the frequency of flower stem production in plants during this second year.

DISCUSSION

While these results represent a preliminary view of the response of potentially vulnerable insects to fire management, they can lead to several tentative conclusions. First, preliminary indications suggest that long fire free periods do not enhance the insect fauna of prairies by allowing increased diversity or density of conservative species, nor do they appear to provide safe havens for some subset of exceedingly fire sensitive species. Second, while native generalist species may in some cases respond positively to fire, they do not, in general respond negatively. Third, non-native generalist species showed a less favorable response to fire, although fire did not appear to provide a sufficient deterrent to their continued persistence in the habitat. Fourth, conservative leafhoppers, as a group, do not have a predictable response to fire. One species with severely restricted dispersal capabilities, *Aflexia rubranura*, responded negatively to fire and this negative response was persistent into the second growing season after the fire treatment. In contrast, other conservative species, *Hecalus grandis*, showed no response to fire, while others, *Flexamia prairiana*, *F.pectinata* responded favorably to fire. Fifth, adult butterflies appear to select recently burned sites for foraging. Sixth, larval densities of *Papaipema* moths do not decrease as a result of fire management.

FUTURE DIRECTIONS

While these tentative conclusions move us a long way toward the goals stated at the outset of this work, and support continuing current fire management practices, these data need to be supported with increased samples. We are continuing this work by increasing the number of replicates for those species that we have sampled and increasing the number of species we are examining. In addition, we are focusing a great deal of attention toward discerning the population dynamics of *Aflexia rubranura*. As predicted at the outset, this species represents a worst case scenario species given that it is A) prairie-dependent; B) wingless; and C) over-winters aboveground as eggs. Thus it is particularly vulnerable to fire management. We need to refine our ability to predict the long-term response of this rare and potentially endangered species.

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Table 1. Distribution of fire study sites within the Chicago region*

Site	Approximate prairie size (ha)	Insect communities to be examined			
		xeric	mesic	wet	sedge meadow
Cook County:					
Gensburg Markham Prairie	50	x	x	x	x
Sundrop Prairie (Markham)	20		x	x	
Natural Lands Institute Prairie (Markham)†	2		x	x	
Grundy County:					
Goose Lake Prairie	600		x	x	x
Commonwealth Edison Prairie†	50		x	x	x
Lake Heideke Prairie†	3			x	x
Will County:					
Grant Creek Prairie	30		x	x	
Joliet Army Amunition Plant†	2			x	x
Lake County:					
Illinois Beach State Park, North Unit†	400	x	x	x	x
Illinois Beach State Park, South Unit	4	x	x	x	x
Iroquois County:					
Iroquois County State Wildlife Prairie†	300		x	x	x
McHenry County:					
Lake in the Hills Fen	20	x			

* This list will be expanded if we manage to obtain additional funding.

† Preburn baseline data has been gathered. Portions of these sites must be burned if we are to continue.

Table 2. A listing of the conservative prairie insects to be targeted in this study.

Species	habitat description	Midwestern status	apparent degree of conservatism	host plants	replicates to date
Orthoptera:					
family Phasmatidae walking sticks					
*Diapheromera blatchleyi**	wet mesic prairie		moderate	general feeder?	3
Homoptera: hoppers					
family Cicadellidae leafhoppers					
Gypona sp.	mesic prairie		moderate	*Amorpha canescens*	1
Xerophloea major	mesic prairie		high	native grasses	-
Hecalus lineatus †	wet prairie		moderate	*Spartina pectinata*	1
Parabolocratus flavidus	xeric prairie		high	native grasses	-
Parabolocratus viridis	xeric prairie		moderate	native grasses	2
*Parabolocratus grandis**	mesic prairie		high	*Sporobolus heterolepis*	3
Dorydiella kansana†	mesic wet prairie		high	*Scleria* , *Eleocharis*	2
Cloanthanus cinereus	mesic prairie		high	*Amorpha canescens*	2
Flexamia reflexa	mesic prairie		high	*Sorgastrum nutans*	-
Flexamia picta	mesic *prairie*		moderate	native grasses	-
Fexamia prairiana	mesic prairie		high	*Andropogon gerardii*	4
Flexamia pectinata	xeric prairie		high	*Bouteloua curtipendula*	1
Aflexia rubranura *	mesic prairie	C2, E-IL	high	*Sporobolis heterolepsis*	4
Deltocephalus caperatus	mesic prairie		high	*Andropogon scoparius*	-
Laevicephalus acus	wet prairie		high	native grasses	-
Laevicephalus shingwauki	wet prairie		high	native grasses	
Laevicephalus unicoloratus	mesic prairie		high	*Andropogon gerardii*	2
Laevicephalus minimus	xeric prairie		high	*Bouteloua curtupendula*	
Amplicephalus osborni	sedge meadow		high	sedges	
Amplicephalus kansiensis	wet prairie sedge meadow		high	sedges	1
Graminella aureovittata	wet prairie		high	*Panicum virgatum*	
Graminella pallidula	wet prairie		high	*Panicum virgatum*	
Graminella aquaka	wet prairie		high	*Panicum virgatum*	
Euscelis extrusus	mesic wet prairie		moderate	native grasses	
Limotettix cuneatus	sedge meadow		high	*Juncus*	
L. pseudospagmanicus†	sedge meadow		high	*Eleocharis*	1
L. parallelus (*urneolus*)†	wet prairie sedge meadow		high	*Eleocharis*	1

Table 2, continued.

Species	habitat description	Midwestern status	apparent degree of conservatism	host plants	replicates to date
Limotettix truncatus†	wet prairie sedge meadow		high	*Eleocharis*	2
Limotettix utahnus (brisoni)	wet prairie sedge meadow		high	*Eleocharis*	
Limotettix nigrax †	savanna sedge meadow		high	*Eleocharis*	
Paraphlepsius lobatus †	wet prairie		moderate	*Andropogon scoparius*	1
Paraphlepsius solidaginis†	mesic prairie		high	*Solidago*	-
Paraphlepsius nebulosus †	mesic prairie		high	?	-
Paraphlepsius lupalus†	panne		high	?	-
Chlorotettix fallax†	sedge meadow		high	native grasses	
Chlorotettix brevidus†	sand prairie		high	native grasses	
Chlorotettix spatulatus	mesic wet prairie		moderate	native grasses	2
Cicadula cyperacea	sedge meadow		high	sedges	
Cicadula melanogaster	wet/sedge mdw		moderate	sedges	1
Cicadula smithii	sedge meadow		high	sedges	
Homoptera: Froghoppers					
family Cercopidae					
Lepyronia gibbosa†	xeric prairie		high	native grasses	1
Philaenarcys killa†	xeric prairie		moderate	*Andropogon scoparius*	
1					
Homoptera: Planthoppers					
family Issidae					
Bruchomorpha extenda	mesic prairie		high	*Sorgastrum nutans*	-
family					
Neacoryphus bicruicus	wet prairies		moderate	*Spartina ?*	1
Lepidoptera: butterflies					
family Hesperiidae					
Euphyes dion†	sedge meadow	V-PA, W-IL, IN	high	*Carex*	2
Euphyes bimacula †	mesic/wet pr.	E-OH, W-IL, SC-IN,	high	*Carex?*	3
Satyrium acadica†	wet prairie		moderate	*Salix*	1
family Nymphalidae					
Boloria selene myrina	wet prairie	T-OH	high	*Viola* spp.	3
Speyeria aphrodite†	mesic prairie		high	*Viola* spp.	5

Table 2, continued.

Species	habitat description	Midwestern status	apparent degree of conservatism	host plants	replicates to date
family Satyridae					
Cercyonis pegala olympus†	mesic prairie		moderate	native grasses	6
Lepidoptera: moths					
family Noctuidae					
Papaipema nepheleptena†	mesic wet prairie & fen		high	*Chelone glabra*	-
P. eryngii †	prairie	C2, E-IL SC-IN	high	*Eryngium yuccifolium*	3
P. silphii†	prairie	E-OH, SC-MI *L-WS*	high	*Silphium* spp.	1
Papaipema spp:				facultative *Cacalia* -feeders	3
P. maritima†	prairie		high		
P. baptisiae†	prairie		moderate		
P. beeriana†	prairie	E-OH, SC-MI	high		
P. cerrusata†	prairie		moderate	*Vernonia* spp.	-
P. sciata†	prairie		high	*Veronicastrum virginicum*	-
P. unimoda†	prairie		high	*Thalictrum revolutum*	-
P. rigida†	prairie		high	*Zizea aurea*	-

* Wingless

† Univoltine

- -

Table 3 . A partial listing of the nonconservative prairie genera and species to be examined in this study.

Species	habitat description	attributes of interest
Orthoptera:		
family Acrididae: Grasshoppers		
Melanoplus spp.	mesic grassland	dominant spur throats (Crytacanthacridinae)
Orphulella spp.	mesic grasslands	common slant-face species (Acridinae)
Chorthippus curtipennis	wet grasslands	common slant-face species
Arphia zanthoptera	mesic grasslands	uncommon banded-wing (Oedipodinae)
family Tettigoniidae: katydids		
Conocephalus spp.	wet & mesic grasslands	large herbivores
Orchellimum spp.	wet & mesic grasslands	large herbivores
family Oecanthidae: tree crickets		
Oecanthus spp.	wet & mesic grasslands	common herbivores
Heteroptera: True bugs		
family pentatomidae: stinkbugs		
Euschistus variolaris	all grasslands	super tramp herbivore
family Nabidae: broadheaded bugs		
Nabis americofera	all grasslands	common predator
family Berytidae: stilt bugs		
Jalysus spinosus	all grasslands	common predator
family Issadae: planthoppers		
Bruchomorpha dorsata	mesic grasslands	common herbivore
family Acanalonidae: planthoppers		
Acanalonia bivitatta	all grasslands	super tramp herbivore
family Delphacidae: planthoppers		
Liberniella ornata	all grasslands	common herbivore
family Membracidae: treehoppers		
Campylenchia latipides	all grasslands	wide-ranging forb-feeder
Stictocephala spp.	wet & mesic grasslands	wide-ranging shrub-feeders

Table 3, continued

Species	habitat description	attributes of interest
family Dictyopharidae: planthoppers		
Scolops sulcipes	all grasslands	wide-ranging herbivore
family Cicadellidae leafhoppers		
Endria inimica	all grasslands	super tramp herbivore
Strellus bicolor	wet & mesic grasslands	super tramp herbivore
Draeculacephala sp.	all grasslands	abundant herbivores
Neokolla hieroglyphica	wet & mesic grasslands	shrub-feeder
Gyponana spp.	all grasslands	shrub-feeders?
Helochara communis	wet & mesic grasslands	common herbivore
Hecalus (Parabolocratus) major	all grasslands	common herbivore
Scaphytopius argutus	all grasslands	super tramp
Scaphytopius frontalis	all grasslands	super tramp
Flexamia inflata	wet & mesic grasslands	uncommon herbivore
Latulus missellus	xeric grasslands	common herbivore
Latulus sayi	xeric grasslands	common xeric herbivore
Latulus configuratus	xeric grasslands	common xeric herbivore
Ohiola osborni	wet & mesic grasslands	uncommon herbivore
Doratura stylata	all grasslands	ubiquitous exotic
Limotettix striolus	wet grasslands	wide-ranging *Eleocharis*-feeder
Paraphlepsius irroratus	all grasslands	super tramp
Orientus ishidae	wet & mesic grasslands	ubiquitous exotic
Chlorotettix tergatus	wet & mesic grasslands	common herbivore
Chlorotettix unicolor	all grasslands	super tramp herbivore
Athysanus argentarius	all grasslands	ubiquitous exotic
family Cercopidae: Froghoppers		
Lepyronia quadrangularis	wet & mesic grasslands	uncommon shrub-feeder
Philaenus spumarius	wet & mesic grasslands	exotic herbivore

Table 3, continued

Species	habitat description	attributes of interest
Coleoptera		
famil Scarabidae: scarab beetles		
Papilio japonica	all grasslands	ubiquitous exotic
family: Cantharidae		
Chauliognathus pennsylvanicus	wet & mesic grasslands	super tramp flower-feeder
family Chryomelidae: leaf beetles		
Cryptocephala sp.	wet & mesic grasslands	
Diabrotica unidecimpunctata	all grasslands	super tramp herbivore
Diabrotica sp.	all grasslands	super tramp herbivore
Microrhopala vittata	wet & mesic grasslands	goldenrod-feeder
Exema sp.	wet & mesic grasslands	case-bearing larvae
Family Meloidae		
Epicauta spp.	all grasslands	predatory larvae
family Coccinellidae		
Coccinella novemnotata	all grasslands	common predator
Diptera		
family		
Tritoxa sp	wet & mesic grasslands	onion-feeders
Tritoxa sp.	wet & mesic grasslands	onion-feeders

Table 4. Frequency of flowering for three prairie plants on burned and unburned portions of Grant Creek Prairie.

A) *Cacalia tuberosa*

	Flowering	Not Flowering	
Burned	64	13	chi square = 90.0; 1 d.f.
Unburned	3	65	$p<.001$

B) *Eryngium yuccifolium*

	Flowering	Not Flowering	
Burned	145	31	chi square = 209.5; 1 d.f.
Unburned	7	155	$p<.001$

C) *Silphium laciniatum*

	Flowering	Not Flowering	
Burned	14	13	chi square = 21.4; 1 d.f.
Unburned	20	141	$p<.001$

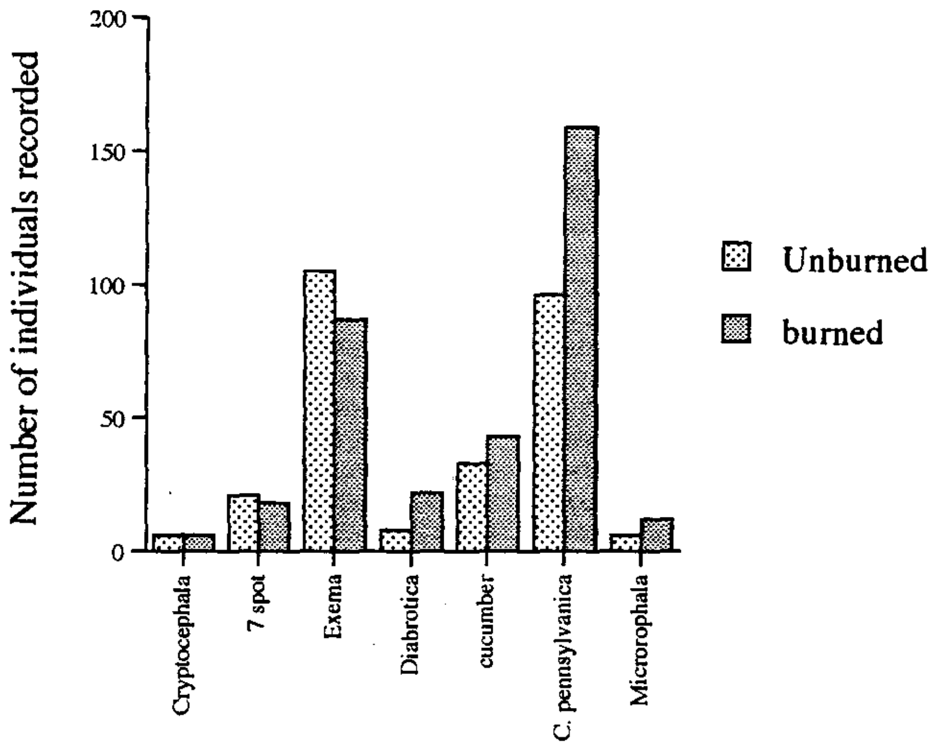


Figure [illegible]. Beetle abundance in burned and unburned sections of the Grant Creek Prairie in 1992

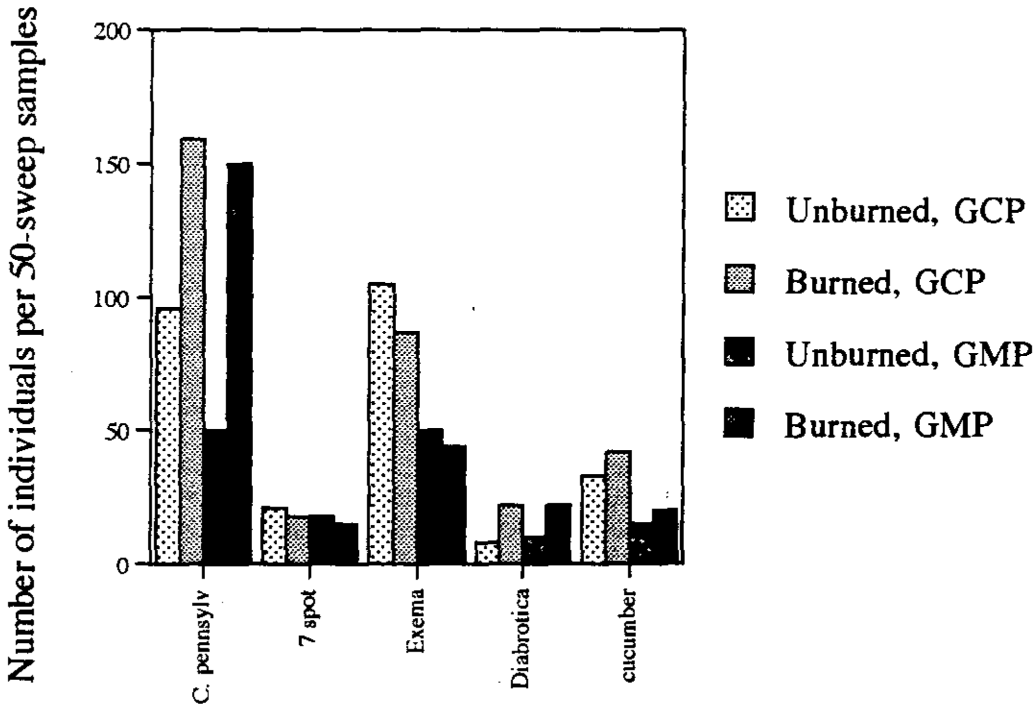


Figure 2 Relative abundance of 5 beetle species within burned and unburned sections of 2 Illinois prairies in 1992

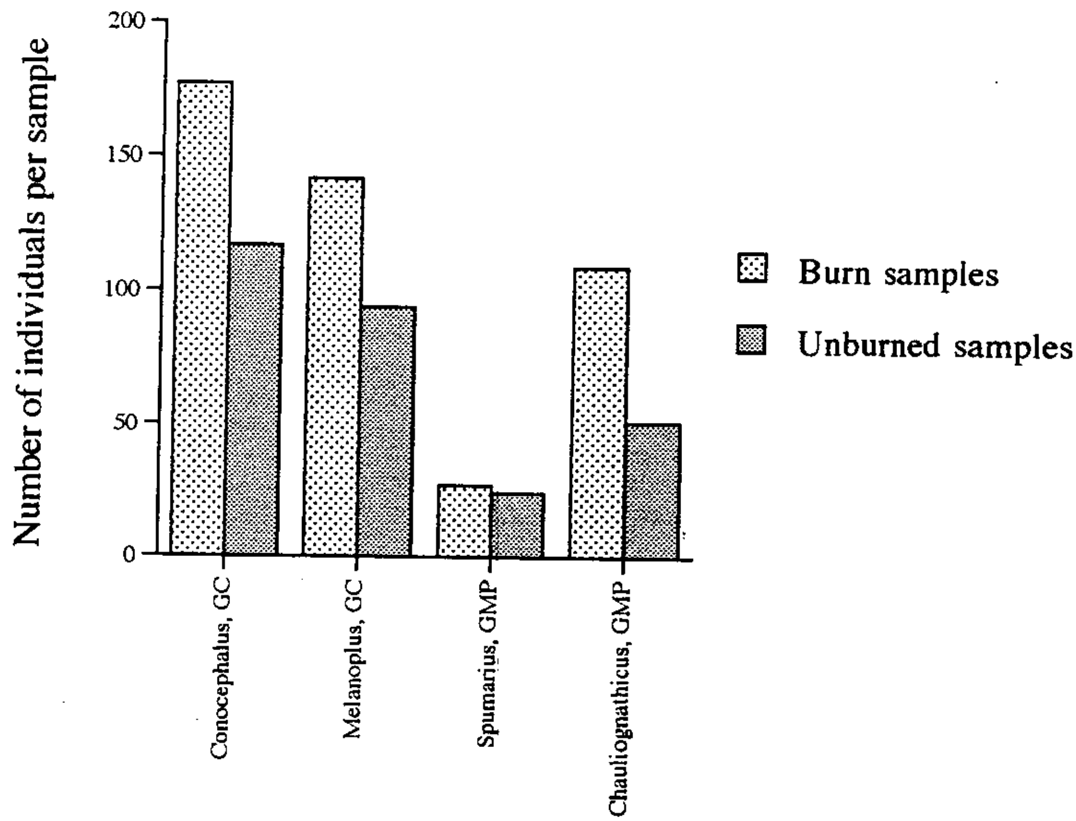


Fig 3 **Abundance of 4 insect species within burned and unburned sections of 2 Illinois prairies**

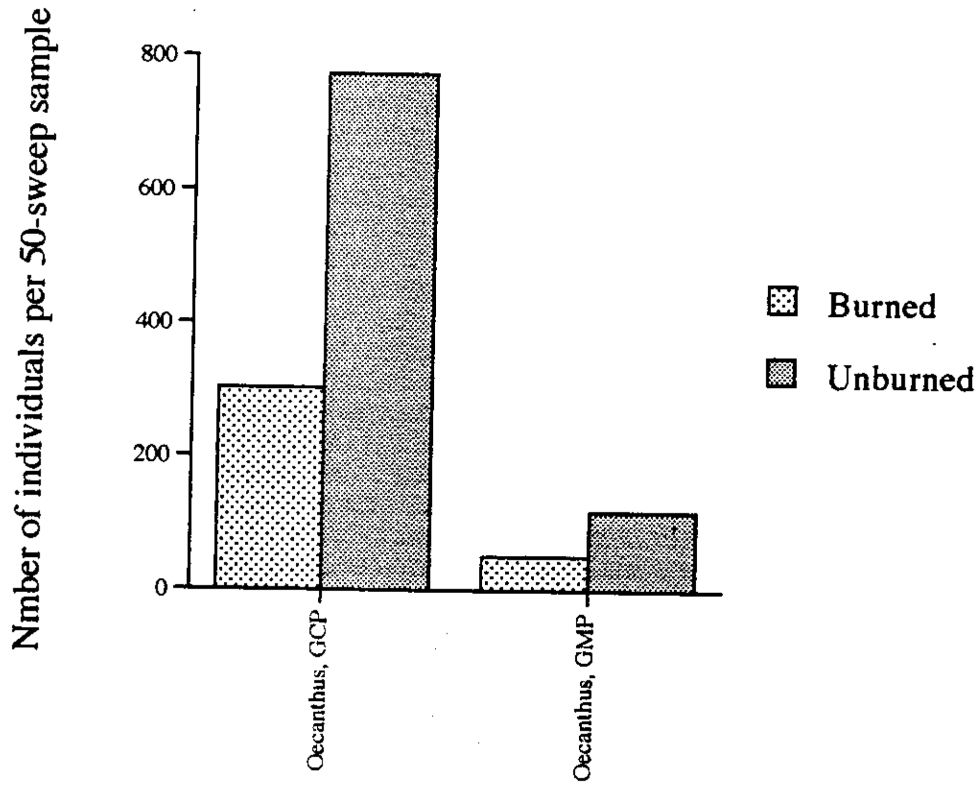


Figure 4. Tree cricket (*Oecanthus* sp.) abundance in burned and unburned sections of 2 prairies in 1992.

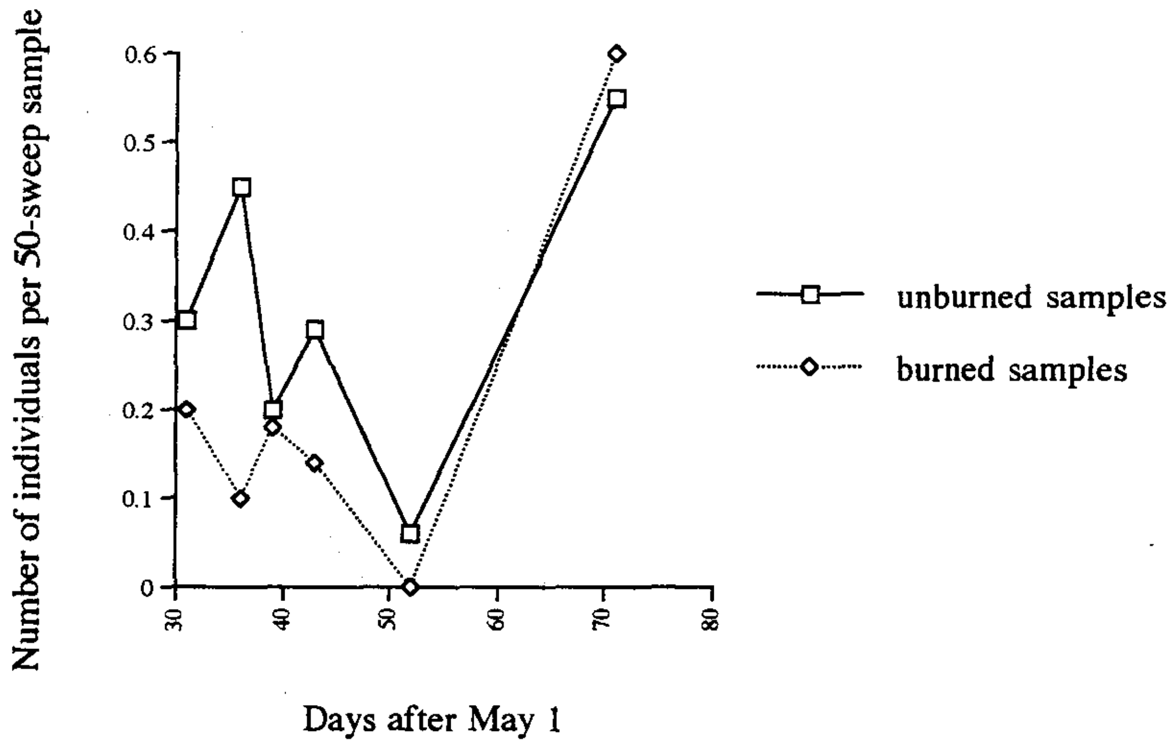


Fig 5 **Relative abundance of *Hecalus grandis* within burned and unburned sections of the Goose lake Prairie (1992).**

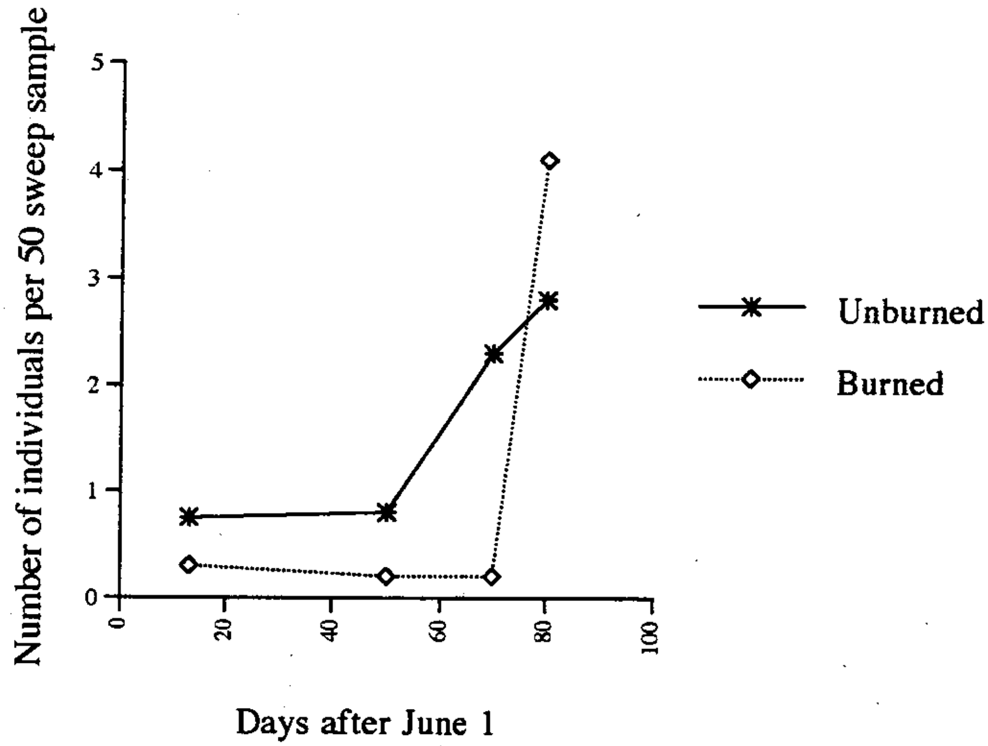


Fig 6 **Abundance of *F. pectinata* within burned and unburned sections of Lake in the Hills Fen**

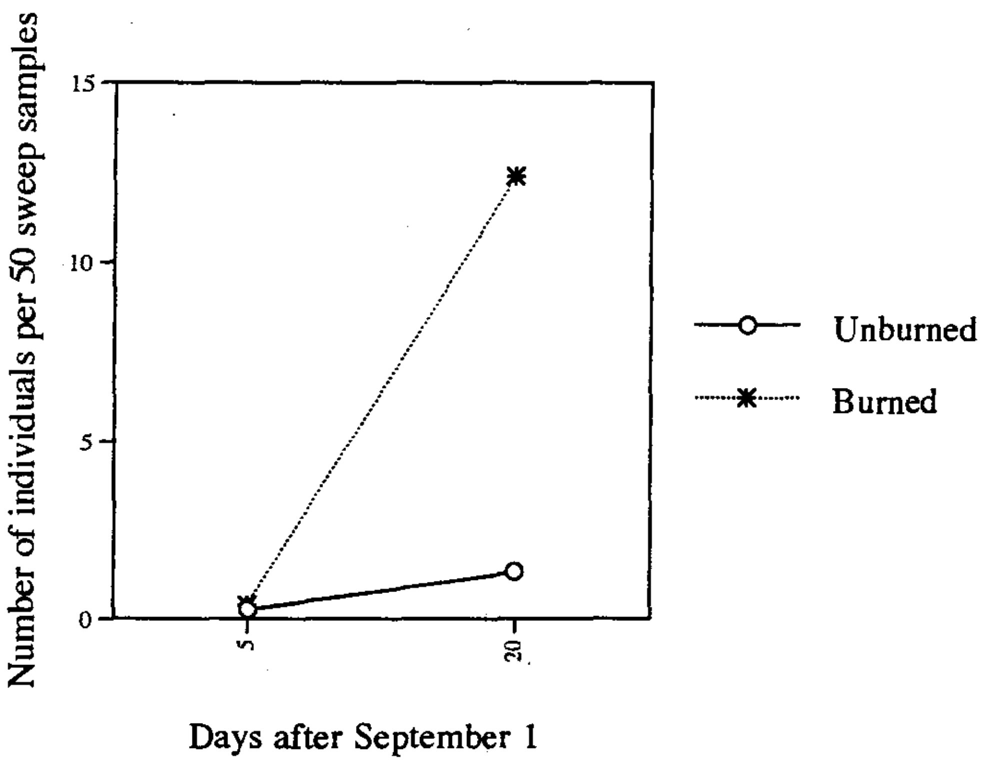


Fig 7

Abundance of *F. prairiana* within burned and unburned sections of Illinois Beach State Park

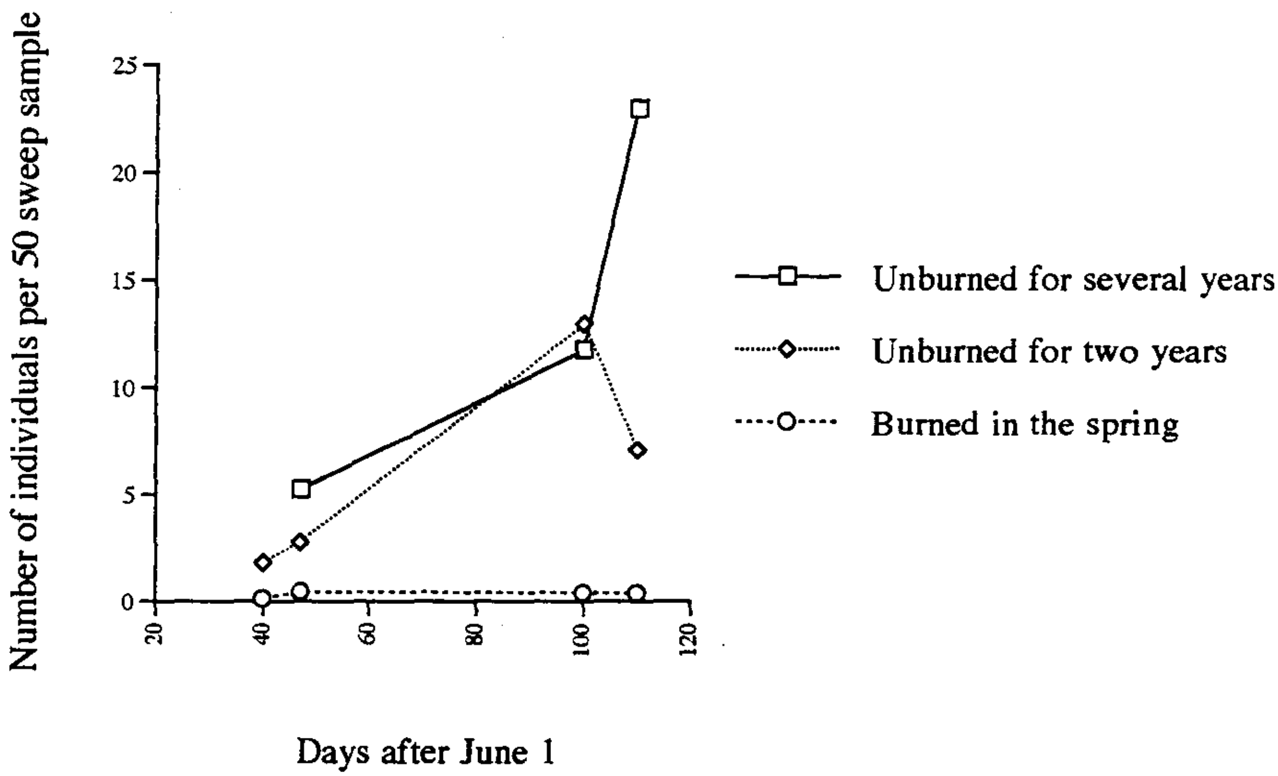


Figure 8 Abundance of *Aflexia rubranura* within burned and unburned sections of Lake in the Hills Fen

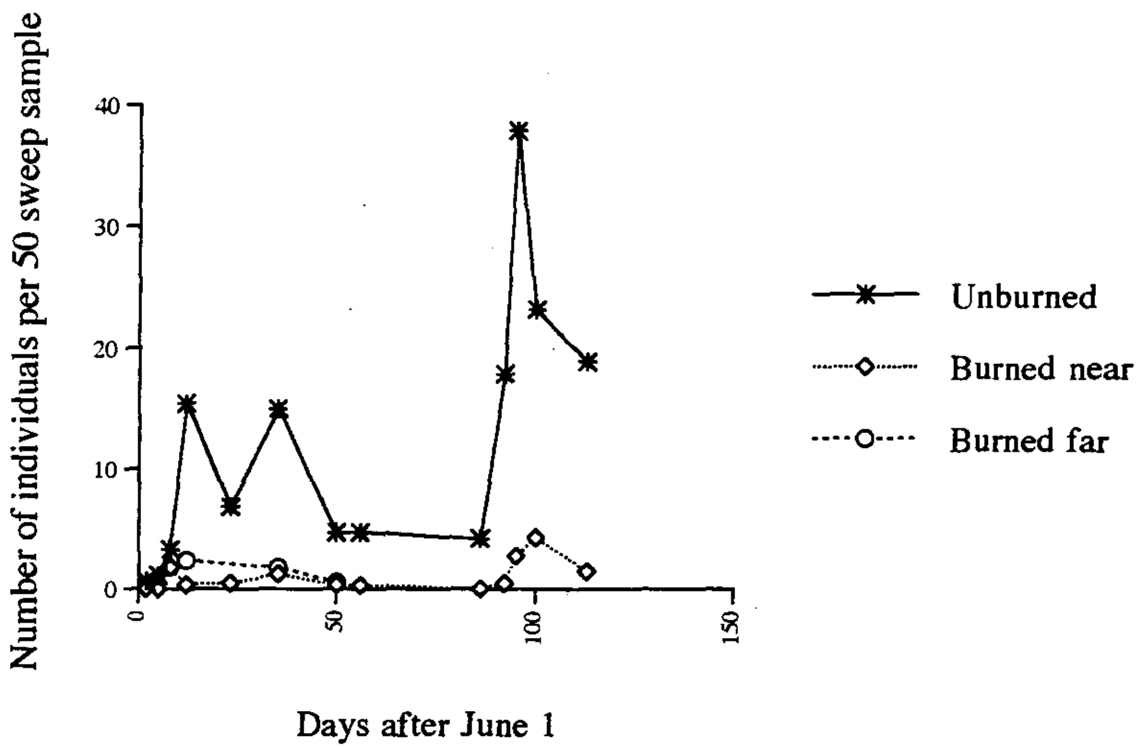


Figure 9. Abundance of *Aflexia* within burned and unburned sections of the Goose Lake Prairie

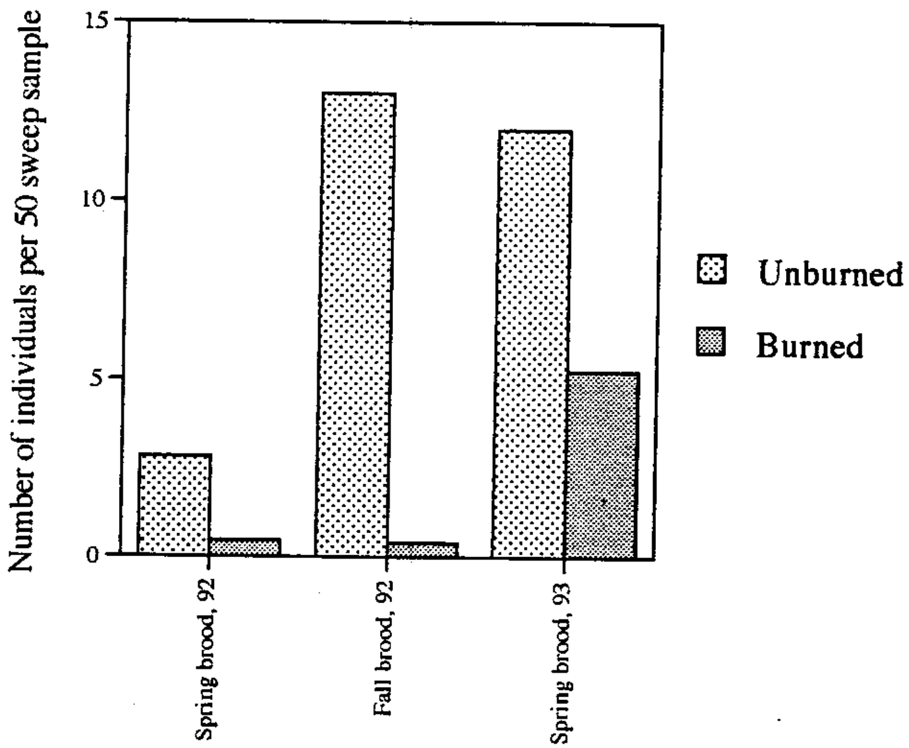


Fig 10

Relative abundance of *Aflexia rubranura* adults in burned and unburned sections of the Lake In the Hills Fen Nature Preserve

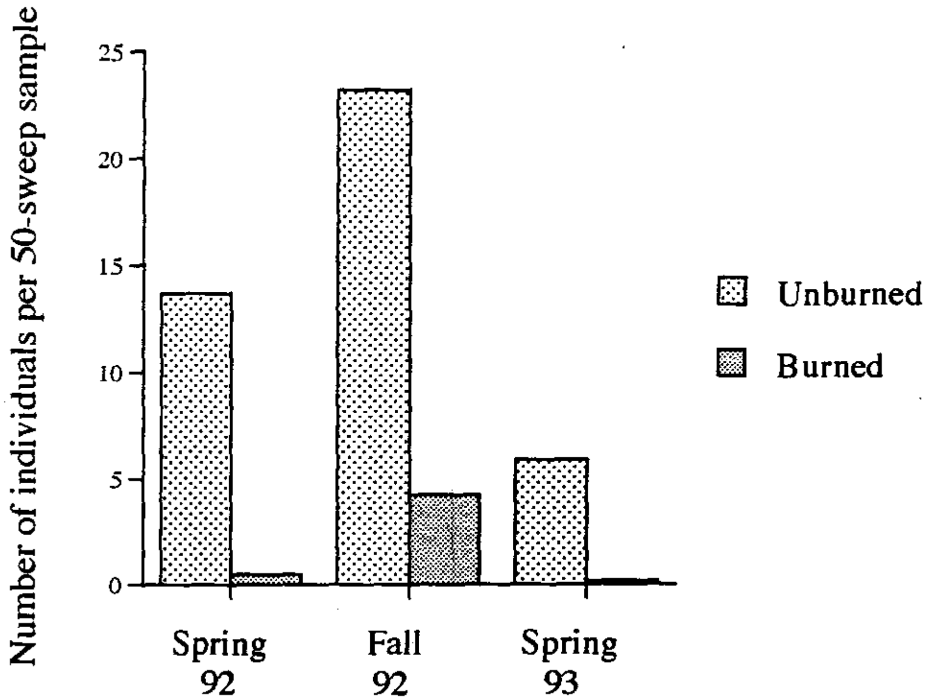


Fig 11 **Relative abundance of *Aflexia rubranura* adults in burned and unburned sections of the Goose Lake Prairie**

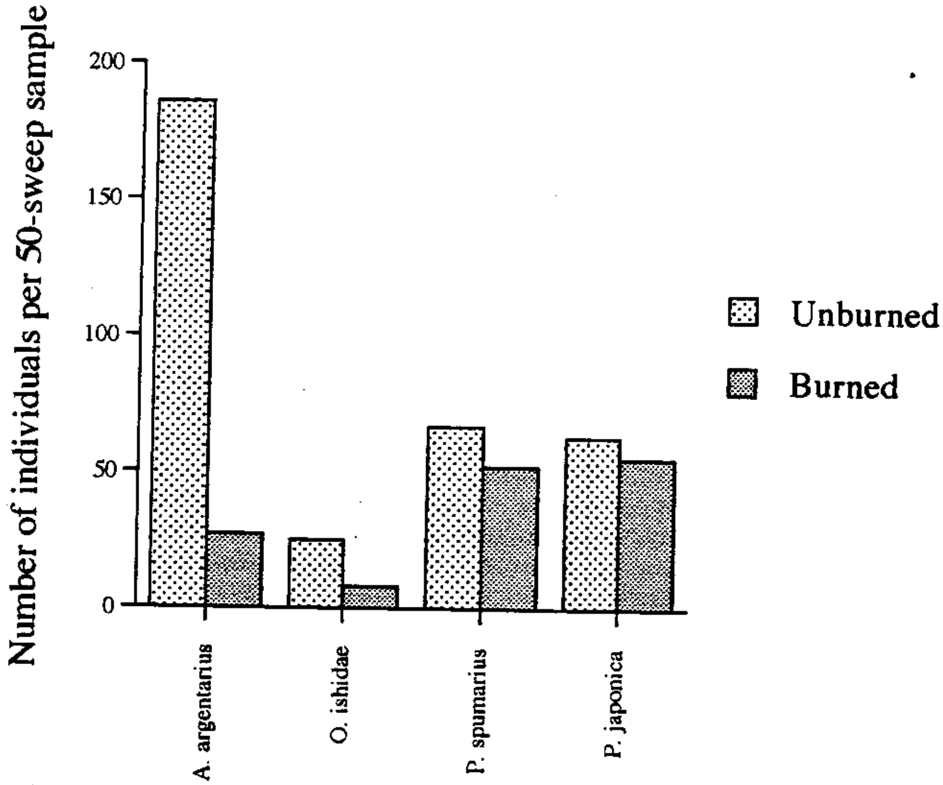


Figure 12. Relative abundance of 4 exotic insect species within burned and unburned sections of the Gensburg Markham Prairie in 1992.

7.

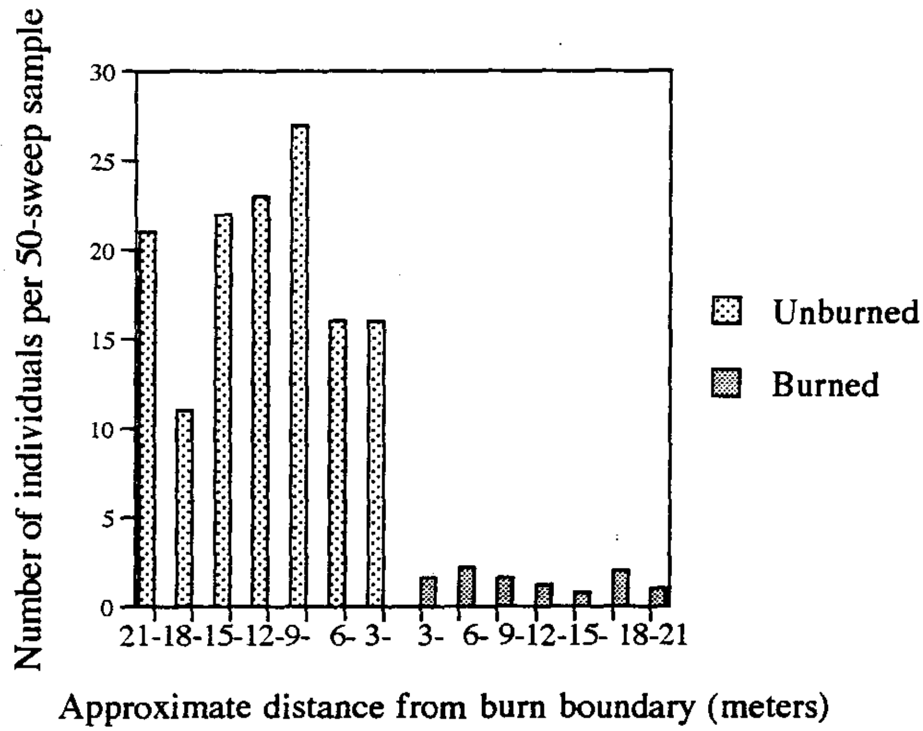
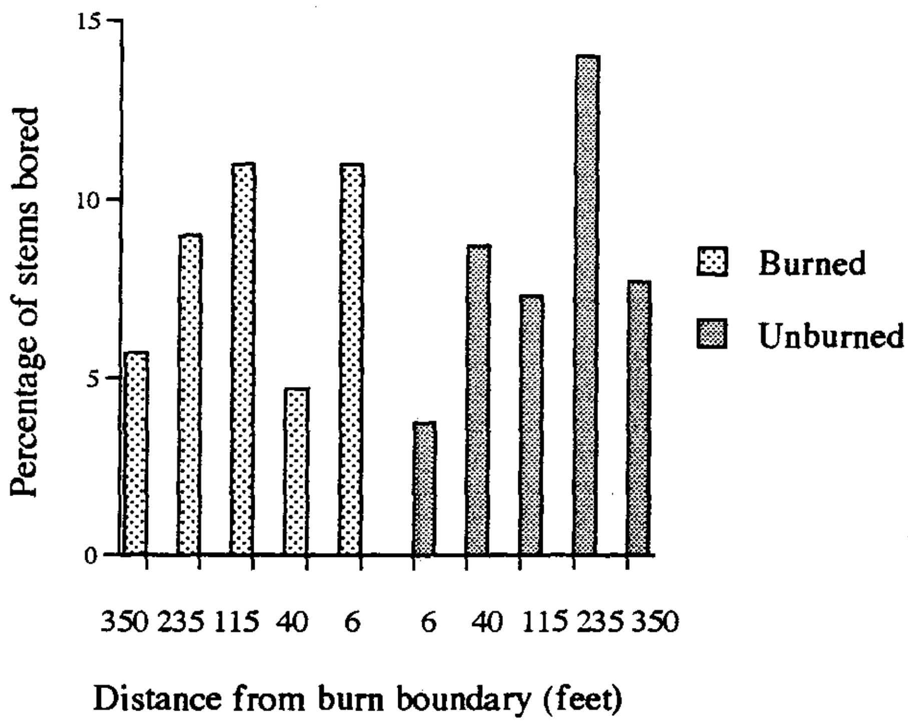
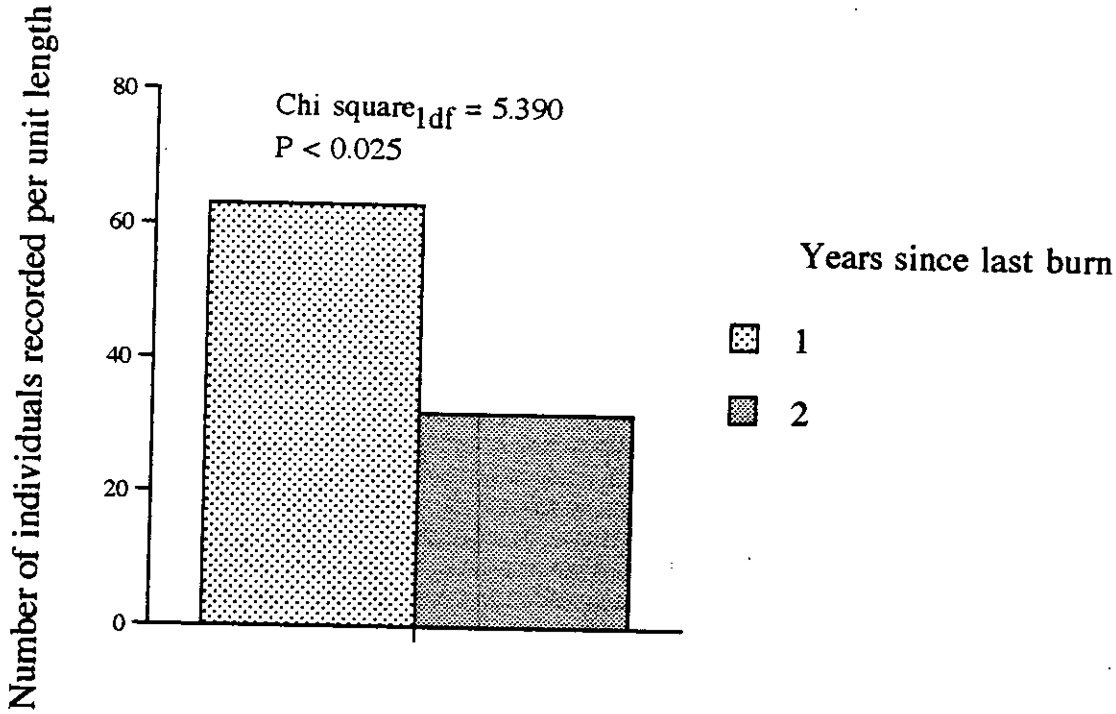


Figure 13 Distribution of *Aflexia rubranura* individuals along a burn/no burn gradient within the Goose lake Prairie on 9-18-92.



Papaipema density along a burn/no burn gradient within the Grant Creek Prairie (1993)

Fig 14



Relative abundance of *Speyeria aphrodite* within 2 burn units on the Gensburg Markham Prairie (1993).

Fig 15

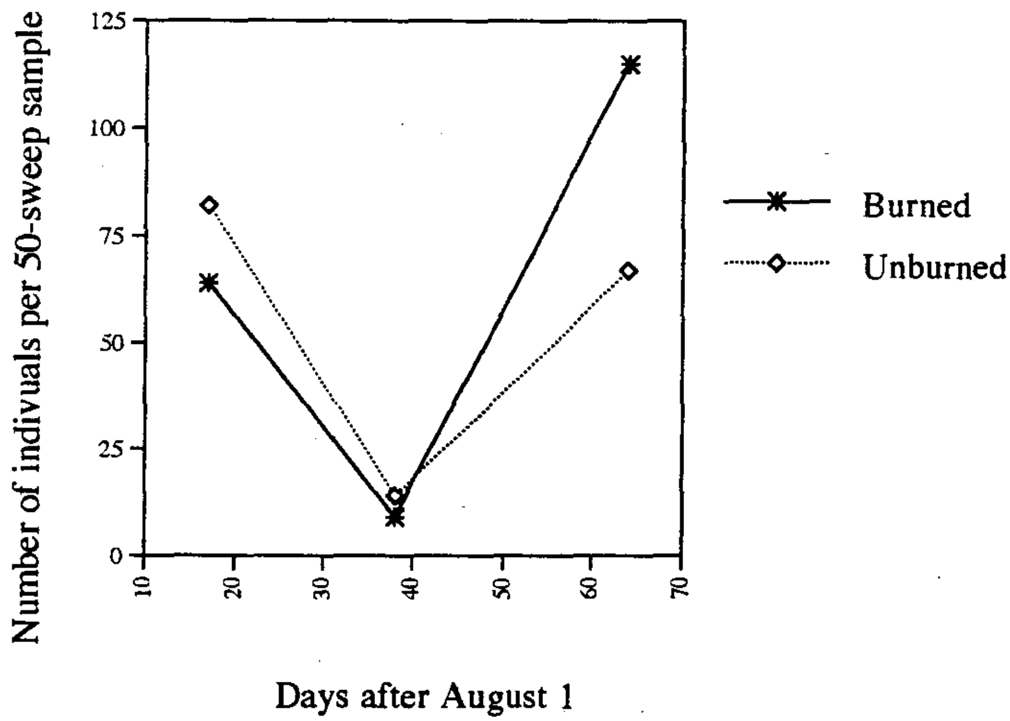


Fig 16

Relative abundance of *Stirellus bicolor* within burned and unburned sections of the Gensburg Markham Prairie (1992).

D in early August.

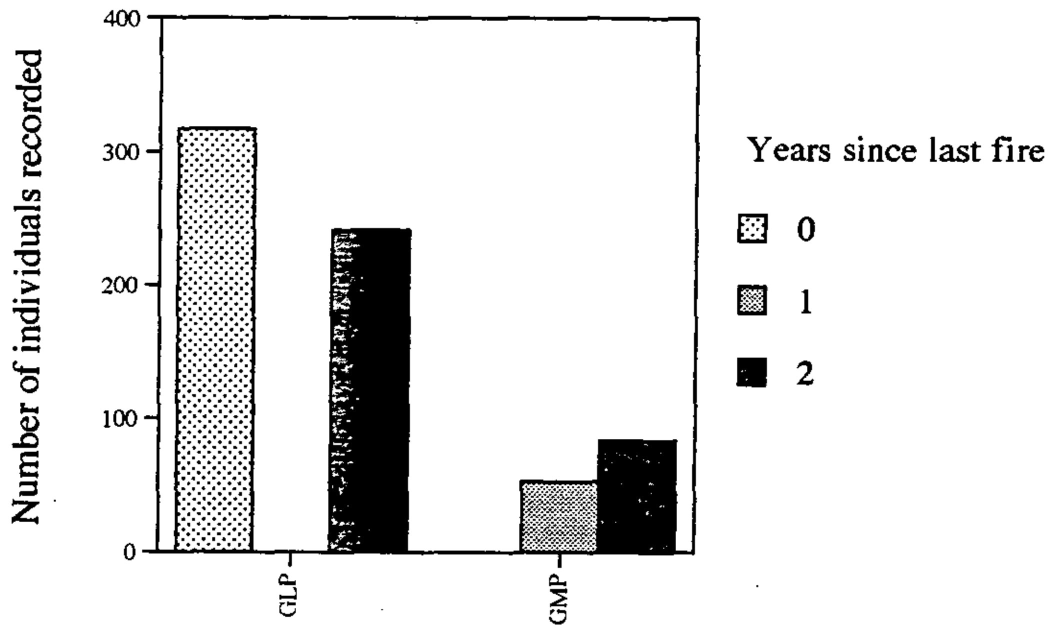
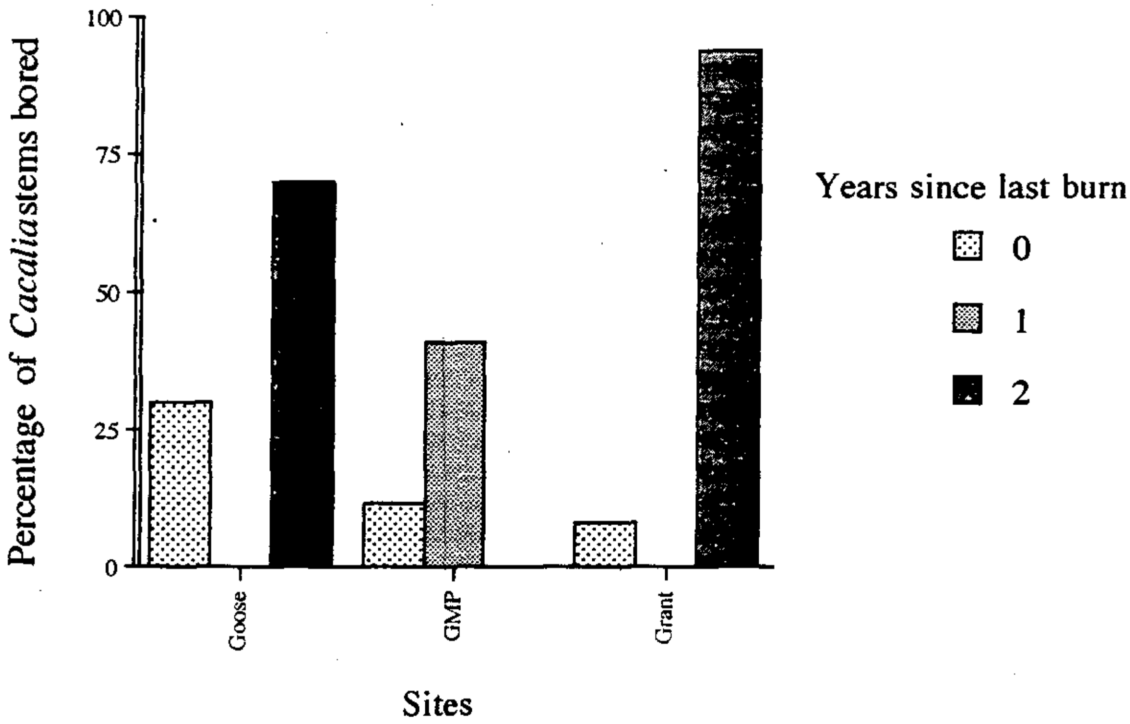


Fig 17

Relative abundance of blue eyed grayling within burned and unburned sections of 2 prairies



Prevalence of *Papaipema* spp. within burned and unburned sections of 3 preserves

Fig 18

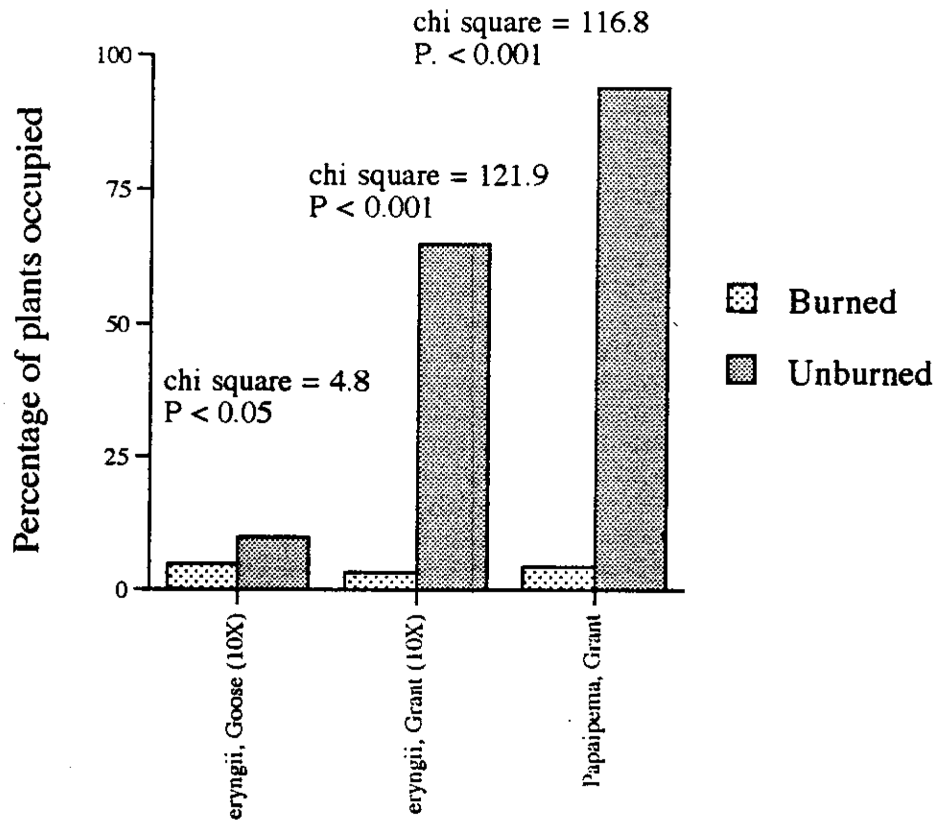


Figure 19 Abundance of *Papaipema* larvae in burned and unburned sections of 2 prairie preserves

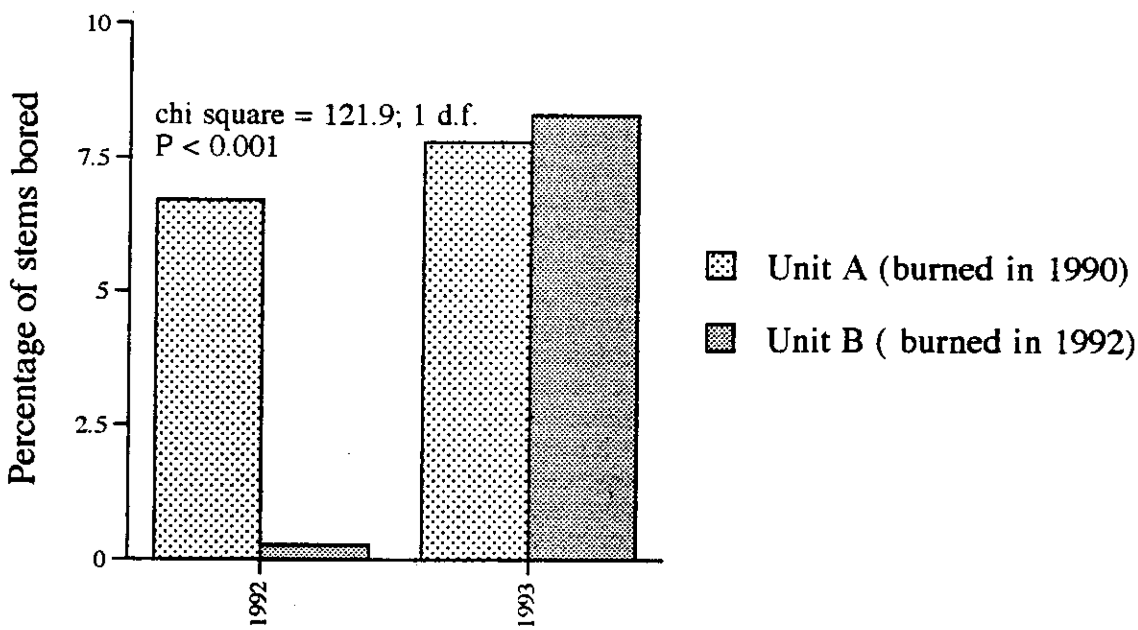
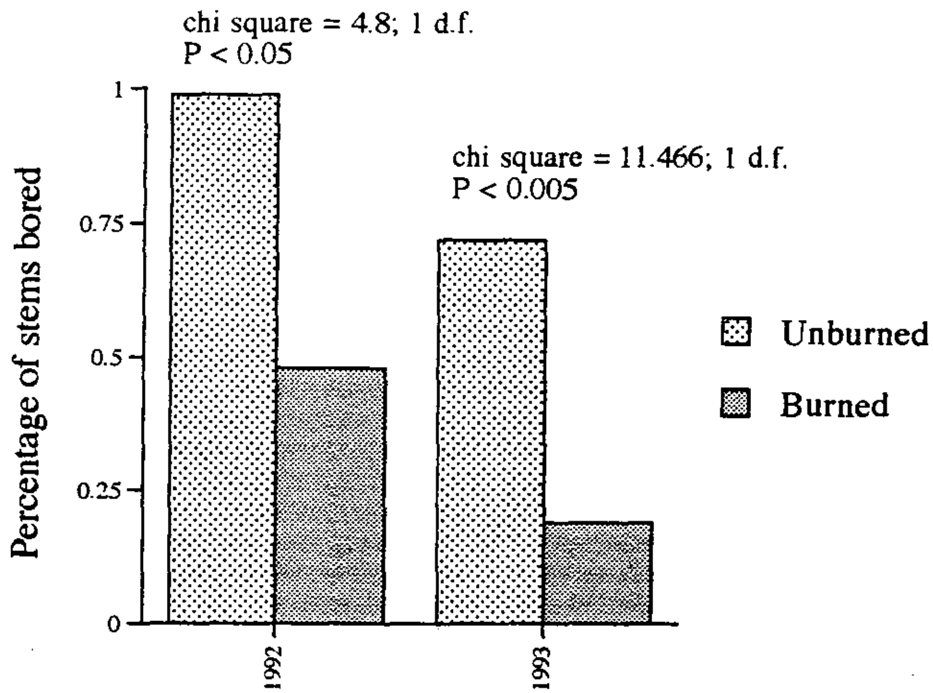


Fig 20

Papaipema eryngii/ silphii densities in burned and unburned sections of the Grant Creek Prairie in 1992 and 1993



Papaipema eryngii densities in burned and unburned sections of the Goose Lake Prairie in 1992 and 1993

Fig 21