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SHORT TERM EFFECTS OF A PRESCRIBED BURN ON INVERTEBRATES IN GRASSY WOODLAND IN SOUTH-EASTERN AUSTRALIA

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Abstract

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The effect of fire on invertebrates in a remnant undisturbed white box woodlandwith a *Themeda* understorey is reported. The woodland was burnt experimentally in May 1994 with half the plots fenced against grazing. Invertebrates were sampled every four months for 16 months using a suction sampler. Initially, lower numbers of invertebrate individuals were collected on the burnt compared with the unburnt plots but after sixteen months this difference had disappeared for all higher taxa. However there were differences in composition of collembolan fauna and relative abundance of species caught between burnt and unburnt plots and between fenced and unfenced plots.

Introduction

Although some Australian plant communities are adapted to fire, the frequency, timing and intensity of burning influences the rate of recovery of structure and function to the prefire state (Cheal, 1996; Tolhurst, 1996). Too frequent fires or a total absence of fire are both likely to result in loss of species and for each community type, the interval between burns which is optimum for sustainability will differ (Gill, 1996). In some plant communities there is evidence to suggest that the altered intensity and frequency of burning since European settlement is affecting invertebrate abundance and even causing local extinctions (York, 1996; Lowe, 1995). Alternatively in grasslands, the absence of fire may be reducing floristic diversity (Prober 1995). It may also affect invertebrates dependant on early successional plants for food or shelter.

The aim of most fuel reduction burning is to reduce the risk of wildfire, so the optimal conditions required for different plant communities are not usually considered (Gill, 1996). It is now increasingly recognised however, that fire management plans should be based on knowledge of the responses of all components of the fauna and flora to burning, so that as much of the biodiversity of the ecosystem as possible can be preserved (Anon, 1992). Fire management plans which protect floristic diversity and vegetation type will not necessarily protect invertebrate diversity, since invertebrates respond to abiotic factors differently from plants. They are also an order of magnitude more diverse, so larger number of species exhibit small scales of distribution. Cho et al. (1995), in a report on Jervis Bay National Park, NSW, state "the assumption that if all habitats are conserved then all invertebrates are conserved is generally well founded" and quote Nadoly (1984). However this assumption has been shown by a number of studies to be false (Greenslade and New, 1991 and included references). Until the invertebrate fauna has been surveyed and macro and microhabitats requirements determined, any fire management plan based on vegetation communities alone cannot guarantee to conserve the invertebrate fauna.

A review of previous work on fire and invertebrates has been published by Friend (1996) and more recently discussed by Greenslade et al. (1996). In many studies on effects of wild fires and prescribed burns on invertebrates in Australia, identification has been to the level of order (Neumann and Tollhurst, 1991; Abbott, 1984; Coy, 1996; Hutson and Kirkby, 1985) and these studies have tended to show a rapid recovery in abundance and representation of all orders after fire. Moreover some studies indicated that invertebrate responses to season and site were greater than to the fire itself (Friend, 1996). Consequently some authors have concluded that the effect on invertebrates of prescribed burning is short term and insignificant (Abbott et al., 1984; Neumann and Tolhurst, 1991).

A high proportion of the studies have been on ants (Majer, 1980; Andersen and Yen, 1985), a group which generally has a preference for open habitats and high temperatures so are favoured by fire, which is not typical of the responses of invertebrates of more humid habitats to fire. Other higher taxa which could be appropriate "indicators" of fire effects were recommended by Friend (1996) in a review of research on fire and invertebrates in Australia. He concluded that five higher taxa were "sensitive to fire". These were Araneae, Lepidoptera, Isopoda, Blattodea and Thysanura. However Blattodea, Thysanura and Isopoda are not usually present in high enough numbers for data on them to be sufficiently informative, the taxonomic difficulties and high diversity of Araneae make their use as an "indicator group" problematical and the problems in sampling Lepidoptera quantitatively are well known. Greenslade and Rosser (1984) and Coy (1996) showed that Dermaptera and Amphipoda respectively were very sensitive to fire in having high abundances before burning and not having returned for a year after the burn. Where present, they are clearly taxa to be considered as candidates for "indicators."

Fire can also effect decomposition processes. For instance, by reducing populations of litter decomposing invertebrates fire can, even in the short term, result in a more rapid build up of fuel after a prescribed burn because of reduced rates of decomposition. Hodda (1991) found fewer and smaller harvester termite mounds in annually burnt areas compared to unburnt areas at Kakadu and in annually burnt areas there was also a reduced loss of leaf litter compared to unburnt areas and this was directly linked to a slower rate of removal of plant material by termite.

It has been shown that species composition of faunas from plant communities of different ages since fire can differ markedly (Friend and Williams, 1993 — beetles; Little and Friend, 1993 — spiders; Abensperg-Traun and Milewski, 1995 — termites; Hodda, 1991 -termites; Greenslade, 1994a — springtails) and that these differences in composition can persist for many years after the fire. Moreover there is some evidence to show that inappropriate fire regimes can cause local extinction of some species. One example is Leichhardt's grasshopper, *Petasida ephippigera* in Kakadu National Park (Low 1995) and in eucalypt forest north of Sydney, Alan York (1994, 1996) has shown that there is a suite of fire sensitive ant species which are lost from areas under an intensive burning regime. It is clear therefore that it is essential to identify the fauna to species and morphospecies to adequately demonstrate the real effect of fire on invertebrate communities.

Most work on fire and invertebrates in Australia has been carried out in eucalypt woodland and forest. There has only been one previous study in grassland (Greenslade, 1994b). Here we identify the most abundant group collected, the Collembola, to species and in another study of fire in coastal heath (Greenslade et al., 1996) the total fauna was identified to morphospecies.

Site description

Woodstock cemetery, 33°45′S, 148°51′E, 20 km E of Cowra, NSW, is an isolated remnant patch of white box woodland with a dense understorey dominated by *Themeda* grassland. This site had never been cleared and had not been mown, grazed by stock or burnt for over 50 years. It is floristically diverse with 66 native vascular plants having been recorded from it (Prober and Thiele, pers. comm.) In 1994 an experimental site was established within the remnant by botanists from CSIRO Division of Plant Industry (Fig. 1) with the aim of investigating responses of plant species richness of the ground layer to fire. The total area of the remnant vegetation was about 5 hectares.

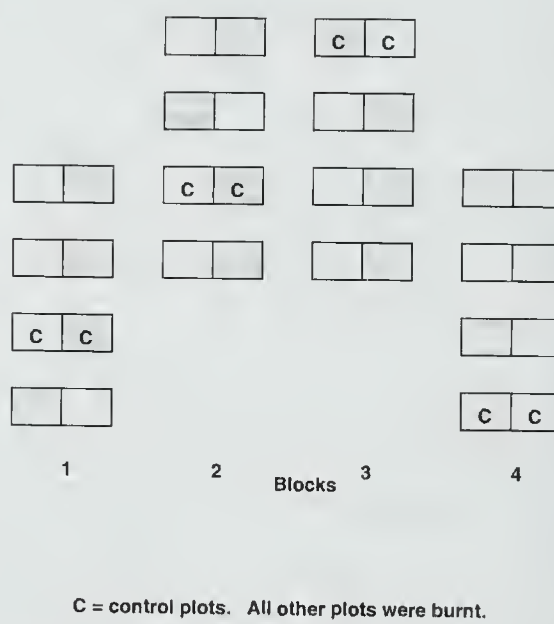

Figure 1. Details of experimental layout at Woodstock (after Prober, 1995). Each plot is 5 × 5 m. One of each pair is fenced. Adjacent pairs of plots are separated by a 5 m strip. The area between pairs of plots was slashed before burning.

Experimental design

In order to study fire effects on invertebrates, field experimentation is necessary. However if experimental plots are large enough to simulate natural conditions, site differences can swamp treatment differences (Friend and Williams, 1993; Friend, 1996). Alternatively if small plots are used to reduce variability and provide good replication so that fire effects can be measured independently of site variability, edge effects may influence faunal responses. An alternative method could be achieved by a nested plot design but practical problems made this impossible here. At Woodstock small, well replicated plots were used to study short term effects of an environmental burn on invertebrates in grassy white box woodland and in an alternative study large plotswere used to study effects of a wildfire in coastal heathland and results from it are reported elsewhere (Greenslade et al., 1996).

A uniform area of just under 100 m by 100 m which sloped gently to the south and where trees were largely absent, was selected and divided into sixteen small plots, 5 m by 10 m, the blocks being separated by a 5 m wide strip. Half of each plot was fenced to prevent grazing by kangaroos and rabbits (Fig. 1). Suction sampling was used to survey the invertebrate fauna associated with the ground vegetation within the small plots at this site. The suction sampler used has been shown to take samples which are representative of the fauna present, are reproducible and semi-quantitative (Greenslade, 1994a). Two prefire samples were taken comprising sixteen samples each, one from each main plot, in spring (Nov 1993) and early autumn (1994), just prior to burning. All sampling was carried out between midday and 3 pm. Four post fire samples were taken, one from the unfenced plots at two months post burn and two from each main plot inside and outside the fence, at 5, 10 and 16 months after the burn. The fenced plots were not sampled until five months after burning as effects of grazing were unlikely to be evident earlier. Rainfall was well below average prior to all postfire sampling periods except the last two. Invertebrates were sorted to order and counted. The majority of specimens collected were Collembola which were identified to species. Other taxa were not present in sufficient numbers in the suction samples to be analysed at species level.

Burning

Twelve of the plots were burnt on 14 May 1994. The areas between plots and for a distance of about 5 m around the whole experimental area were dampened to confine burning to the plots themselves. Burning was carried out from the ground with a hand held flame torch, great care being taken to protect the control plots. The intensity of the fire was low with charred tussock bases remaining after the fire and burnt organic material from the grass and leaf litter remaining on the ground after the fire. No tree foliage was burnt.

Data analysis

Results were analysed using the statistical packages MULTISTAT, SYSTAT version 5 and GLIM. The only higher taxa present in any numbers were Collembola and Acarina which were analysed for samples collected in Oct 1994 (Table 4) and Mar 1995 (Table 5), using the program GLIM with a Poisson error and a logarithmic link. Student's t was used to compare taxon abundances between treatments for all sampling dates for which data was sufficient using MULTISTAT and a fully factorial ANOVA using MGLH procedure was conducted for Collembola, Acarina and total invertebrate abundance as dependant variables and the treatment variables, grazing and burning as independant factors for samples from Mar and Sep 1995.

Results

A complete list of taxa collected and numbers in each sample are given in Greenslade and Rowe (1996). The total number of Collembola collected from preburn samples in Nov 1993 was 2434 comprising eight species. Statistical tests (t-tests) for significant differences in individuals caught between vertical and horizontal rows of plots showed no biases across the study area. The second pre-burn sample collected only 18 specimens representing four species. These small numbers are almost certainly caused by the lack of rainfall in the preceding months.

Two months after burning numbers were still too low for analysis at species level. However, over three times as many individuals of all groups were collected from the unburnt plots compared with burnt plots and three times as many taxa on the unburnt compared with burnt plots. Similar results were obtained for Collembola alone. Some taxa were only present on the unburnt plots. Excluding those represented by a single specimen, they were Thysanoptera (24 individuals, 3 species) and Coleoptera (4 individuals, 4 species).

Five months after burning mean numbers of total invertebrates per plot indicated no differences between treatments (Fig. 2). Although only 116 Collembola were trapped, too few for statistical analysis, data for this group did show a slight reduction in numbers on burnt sites both fenced and unfenced, compared with the fenced and unfenced unburnt plots (Fig. 2).

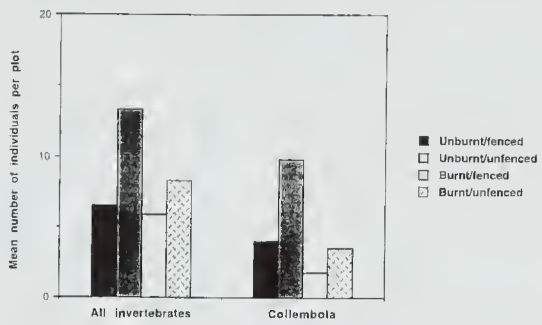

Figure 2. Total invertebrates and Collembola as mean numbers of individuals per plot; five months after burning at Woodstock.

Although total numbers of individuals trapped had increased to over 1000 ten months after burning, numbers of Collembola were still low at 126. However some differences in total numbers between treatments were found to be statistically significant. There was no significant difference between fenced and unfenced control (not burnt) sites. Fenced, burnt plot samples contained twice the number of individuals than the unfenced burnt plots and this difference is statistically significant (*t*-test, $p < 0.02$) although there was no statistical difference in absolute numbers between fenced burnt plots and control plots (*t*-test $p < 0.4$) and unfenced burnt plots and control plots (*t*-test $p < 0.06$) at the level of 5%. Consequently the effect of grazing on total invertebrates at ten months appears to be greater than the effect of fire (Fig. 3A).

Only two species of Collembolan were collected from samples collected ten months after burning, both belonging to the endemic, grass-inhabiting summer active genus, *Corynephoria*. Eighty-eight percent of one species, *Corynephoria* sp. 2, individuals were collected on the burnt plots. Alternatively, *Corynephoria* sp. 1 occurred almost exclusively (95% of invidividuals) on unburnt controls and burnt fenced plots. Unfenced, burnt sites are intermediate.

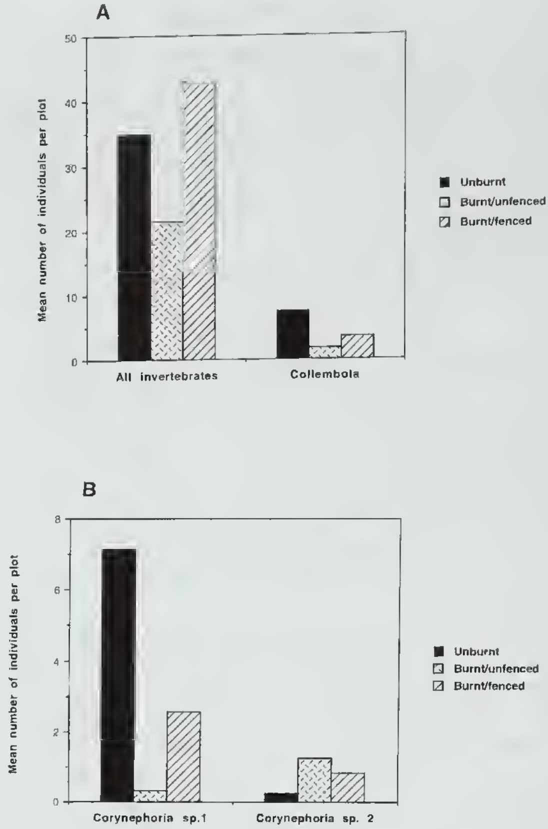

Figure 3. A. Total invertebrates and Collembola as mean numbers of individuals per plot; and B. abundance of 2 collembolan species as mean numbers caught per plot ten months after burning at Woodstock.

At sixteen months the total number of Collembola collected was 2561 but considering control plots alone, this was still only half prefire levels of two years earlier indicating that the some effects of the previous drought were still evident. The winter fauna predominated at this time with no *Corynephoria* species and Katianninae species being present in large numbers as expected (Greenslade, 1986). There were no statistically significant differences in abundance of total invertebrates between control and treatment or between fenced and unfenced plots. Collembola comprised nearly 70% of total fauna collected. As at ten months, there was no statistically significant difference in total individuals caught between fenced and unfenced control plots (*t*-test). However there was a highly significant difference between the combined controls and the fenced/burnt plots ($p < 0.001$) and a significant difference between fenced/burnt plots and unfenced/burnt plots ($p < 0.01$). There was less difference between the controls and the unfenced/burnt plots although this was significant at the 10% level

At the species level further differences were evident in the composition of the collembolan communities. Seventeen species of Collembola were collected 16 months after burning, 12 from unfenced/burnt plots and 14 from fenced/burnt plots. Although the small difference in number of species was not significant, there was a difference in relative species abundance in terms of individuals caught in the two treatments (Fig. 4). The same two species of Collembola were numerically predominant on all treatments but they were relatively more abundant on the fenced plots than on the unfenced plots where the six subsidiary species were more abundant. This is illustrated by the Shannon index of evenness which was 0.356 for the fenced plot and 0.495 for the unfenced plot indicating that the community structure is more evenly distributed among species under grazing.

The comparison "burnt v unburnt" is a comparison between plots, and its mean square

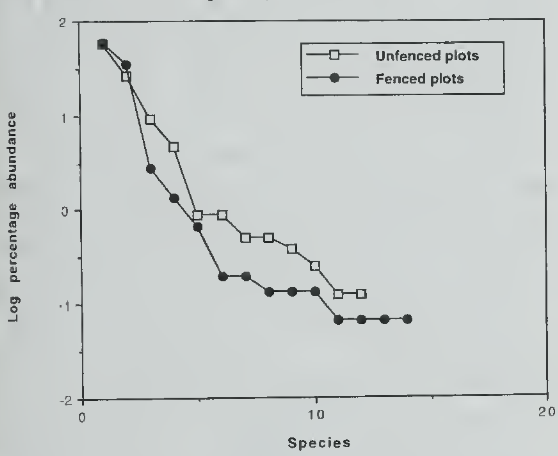

Figure 4. Log percentage species abundance of Collembola caught on fenced and unfenced plots at Woodstock, 16 months after burning.

(m.s.) is therefore compared with the between-plots residual m.s. immediately below it. Similarly, the comparison "grazed v ungrazed" is a within plot comparison, comparable with the within-plots residual. These analyses show no important effects of burning or grazing, except for an effect of grazing on Acarina in 1995, where examination of the data shows that almost invariably there were more Acarines collected on the grazed half plot burnt or unburnt, than on the ungrazed (Table 1). It is not clear whether this is a genuine difference in population density, or merely in sampling efficiency.

Using this analysis based on the Poisson distribution (i.e., random counts), the residual m.s. is expected to equal 1 if there is no heterogeneity. The residual m.s. in the above table show that there is some heterogeneity between plots, but not much within plots. It is therefore not unreasonable to use ordinary χ^2 to examine the effects of grazing (a within plots comparison) on all categories sampled, including those not analysed above, but not effects of burning (a between plots comparison). For example, total Acarines on all ungrazed sub plots in 1995 is 179, on grazed plots is 308; so $\chi^2 = 34.17$ which agrees well with the corresponding m.s. 34.58 in the analysis. Since some within plots heterogeneity does exist, such values of χ^2 should be treated with caution.

Total Collembola, total Acarina and total invertebrates were used as dependant variables in the ANOVA analysis for the two last dates. Several significant values were found as follows. For March 1995, only total Collembola v burning ($p < 0.05$) were significant. In September 1995, for total Collembola both burning ($p<0.005$) and the interaction of burning and grazing ($p < 0.05$) were significant. Also total invertebrates versus burning ($p < 0.005$) was significant in September 95.

Table 1. Analyses of Deviance obtained from GLIM for October 1994 and March 1995.

		October Collembola 1994		Acarines 1994		March Collembola 1995		Acarines 1995	
	d.f.	deviance	m.s.	deviance	m.s.	deviance	m.s.	deviance	m.s.
burnt v unburnt	1	27.09	27.09	0.67	0.67	29.94	29.94	11.79	11.79
between plots residual	14	122.83	8.77	144.91	10.35	86.06	6.15	271.54	19.40
grazed v ungrazed	1	18.76	18.76	1.58	1.58	0.28	0.28	34.58	34.58
withing plots residual	15	49.74	3.32	46.64	3.11	40.92	2.73	15.83	1.06

Discussion

The immediate effect of fire was to reduce invertebrate diversity and numbers of individuals caught, but after eighteen months, both seem to have regained their prefire levels. However, results indicate that the composition of the postfire community is markedly different from that present before burning. This difference is greatest at the level of species as noted by Friend (1996) and is also in agreement with York's results (1994, 1996) from a long term fire study in forest. York found nearly a quarter of ant species were lost from sites which were regularly burnt at three to four year intervals. The evidence here and from York's work strongly suggests that only studies at species level will provide an adequate understanding of the changes caused by burning.

The differences in species composition may reflect differences between taxa in vagility and hence ability to colonise but the proximity of both control and treatment makes this unlikely to be the main reason. Fire changes vegetation structure resulting in a more open plant community with higher day temperatures and low moisture levels at the surface. Measurements of the physical characteristics of the plots were not made but humidity, light and temperature characteristics of the ground surface were probably more important factors determining species composition than vagility.

Closely related species responded in opposite ways to fire in that two *Corynephoria* species differed in their distributions between treatments. The species found most abundantly on burnt plots is widely distributed in Australia while the other species, found more abundantly on controls, is known from other data to be restricted to sites where grass tussocks are well developed and dense.

When the grassy woodland plots were protected against grazing by kangaroos and rabbits, total numbers of invertebrates caught recovered rapidly to prefire levels and at ten months after fire had regained control levels. These results for invertebrates are similar to those found in south-eastern Australia for plants by Leigh and Holgate (1979). In spring, grazing affected the collembolan fauna on the grassy woodland site resulting in a more evenly distribution of individuals between species. At the sampling occasion the interaction between grazing and burning was significant. No difference in species composition was recorded between controls, fenced or unfenced plots but total Collembola individuals caught increased in fenced plots by increasing numbers of common species caught at the same time as reducing numbers of the subsidiary species. Results from the floristic survey carried out in late 1994 show that the plant cover and hence biomass, was significantly greater on the burnt fenced plots than on burnt unfenced plots and that there were no differences between fenced and unfenced controls (Prober, 1995).

Results must be qualified because of biases caused by the methods used as stressed by Friend (1995). In suction sampling more complex structure and higher density of the vegetation will reduce efficiency of sampling so that the samples from the control plots could be less representative of total populations than those from burnt sites. However a lower number of individuals trapped or caught on the treatment plots, is likely to reflect a real difference in species abundance.

Friend and Williams (1993) studying fire effects on invertebrates in inland heath, found differences between years could be greater than those due to fire. Results here indicated that low rainfall reduced invertebrate numbers for over twelve months to such an extent that data from one preburn sample could not be used, and treatment effects were negligible for five months after burning. In the same experiment Prober (1995) also found that changes in plant species composition were minimal five months after burning and suggested this may have been due to the dry conditions. This indicates that, although obviously desirable (Friend 1995), preburn samples are of value only in detecting variability over the site and can not provide reliable baseline data with with to compare treatment values.

Woodstock cemetery is part of the proposed "Grassy White Box Woodlands Reserve" (Prober, 1995) because of its high conservation value on the basis of floristics and vegetation type. Less than 0.5% of this type of woodland remains in a near-original condition although it once covered several million hectares in the wheat-sheep belt of NSW (Prober and Thiele 1993). As a result of these studies, fire management on this site can take into consideration some of the variable responses of invertebrates to fire and predict the likely consequences of different fire regimes.

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