THE EFFECTS OF BURNING ON THE INVERTEBRATE FAUNA OF THE TUSSOCK GRASSLANDS OF THE EAST OTAGO PLATEAU

A preliminary report

by

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TABLE OF CONTENTS

Page

Appendix

LIST OF TABLES

LIST OF FIGURES

Preface

Fire is an important feature of pastoral farming in the tussock grasslands of Otago. Over many years data have been collected on the effects of fire on the tussocks themselves, and to an extent, the intertussock vegetation, most notably by Prof. Alan Mark and associates at the Botany Department of Otago University, but almost no data exist on the other main part of the biota in these habitats, the invertebrates. One of the many reasons for this has been the taxonomic impediment, the vast number of different species, most of them poorly known, that face the investigator. However, this problem has recently been greatly alleviated through the work of Dr Barbara Barrett (MAFTech, Invermay) who in the course of a long term trial to investigate the problem of seed loss in oversown tussock grasslands has established the identity of many of the invertebrate inhabitats of the East Otago Plateau. In fact it was largely through the encouragement and persistence of Dr Barbara Barrett that this research programme was initiated. She also made the preliminary approaches to the Hellaby Trust for financial support and resampled the experimental sites after the discontinuation of the project to provide a whole years data.

I would like to acknowledge the help of Prof. Alan Mark and particularly Dr Barbara Barrett and their respective organisations for personal support and making facilities available for the project. The Otago Catchment Board provided copious information on burning practices and possible experimental sites. Three runholders made available experimental sites on their properties, these were: Mr S. Haughton, Teviot River Downs, Mr K. Heckler, The Burgun Run and Mr J. James, Stonehurst. I would like to thank them for their help and support. Finally this project would not have been possible without the generous financial support of the Miss E.L. Hellaby Indigenous Grasslands Research Trust, and in particular the good offices of Prof. G.T.S. Baylis.

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INTRODUCTION

The history of burning

Fire has always been an important ecological factor responsible for shaping forest and grassland communities worldwide. Origionally, natural ignition sources such as volcanic activity and lightening were responsible for wildfires where suitable conditions prevailed. However, human use of fire during the last 20,000 years has served to intensify the effects of burning in many ecosystems, particularly grasslands. It was recognised that fire could play an important role in perpetuating certain desirable characteristics of ecosystems and consequently prescribed burning became widely used as a management tool. It is practised extensively in forestry situations throughout the world, however, the use of prescribed burning in grassland management is confined to areas that have retained extensive open ranges which are not being intensively utilized or managed (Kozlowski and Ahlgren, 1974). In these areas burning is used to increase forage production, reduce handling costs by increasing visibility of stock, reduce densities of unwanted trees and shrubs and to reduce the risk of wildfire (Martin, 1978). Although not practiced widely in Europe (Morris, 1978) prescribed burning is extensively used in prairieland in North America, Australian rangeland (Leigh and Noble, 1981), Sub-Saharan Africa (Phillips, 1974) and the tussock grasslands of New Zealand (O'Connor and Powell, 1963; Mark, 1965).

Tussock grasslands and fire

Before the arrival of Polynesian cultures around 1,000 AD much of the South Island of New Zealand was covered by forest (Mather, 1982). However, by the time of European settlement early last century vast areas of forest had been burnt and replaced by the tussock grasslands. These consisted of associations of snow tussock, *Chinochloa rigida*, hard tussock, *Festuca novae-zealandicae*, silver tussock, *Poa caespitosa*, and red tussock, *Festuca rubra* (Saxby, 1948). These grasses proved unpalatable to stock and the settlers soon realised that the practice of periodic burning could have immediate rewards. Burning during spring has been shown to induce striking changes in the tussock over the following two seasons. Mark (1965) working with snow tussock showed that burning substantially increased leaf elongation and new tiller production, induced inflorescence production ahead of unburnt plants and increased viable seed production. The young growth comes away rapidly from the crown of the tussock providing acceptable stock feed (O'Connor and Powell, 1963). Fire also serves to open up the crown, thus enabling the smaller more palatable plants to flourish.

The introduction of sheep, rabbits and periodic burning upset the delicate balance of the tussock grass associations and large areas of tussock began to deteriorate. In drier areas, such as Central Otago, only the tops of ranges, moist gullies and least exposed faces managed to maintain the intact tussock associations.

Although quite strictly controlled by the local Catchment Board spring burning is still a regular management practice on the Otago Plateau. It is favoured as a cheap means of opening up areas of rank tussock for mustering and to increase palatability of the vegetation.

Effects of fire on invertebrates

In the field of fire research emphasis has been placed on assessing the effects of burning on the vegetational and soil components of the ecosystem. Comparatively little work has been carried out to study the impact of this disturbance on the invertebrate fauna.

A large proportion of the information available on the effects of fire on invertebrates has come from studies in forestry situations (Heywood and Tissot, 1936; Pearse, 1943; Buffington, 1967; Campbell and Tanton, 1981; Abbott, 1984). From this work it appears that leaf litter faunas show an initial decline in numbers following burning, but that most taxa have recovered numerically within one year.

The response of grassland invertebrates appears to vary greatly. Some authors report no differences in total arthropod densities with respect to burning in American prairiegrass (Steatedt, 1984; Cancelado and Yonke, 1970; Lussenhop, 1976). Others show an initial decline in arthropod density and biomass followed by recovery of most groups, excluding spiders and collembola, within two months (Bulan and Barrett, 1971). Nagel (1973) found that a burnt area of prairie produced significantly more total arthropods than an unburnt site. Herbivores accounted for this increase which was thought to be related to lack of a parallel increase in their predators and parasites.

<u>**Direct and indirect effects of burning**</u>

Fire can have two possible effects on an invertebrate fauna. Firstly, the direct effect of the heat released during burning serves to incinerate those creatures active on the surface or within the vegetation. Anything that cannot burrow, find sanctuary under objects or escape ahead of the flames will suffer direct effects. However, heat released during grass fires is considered to have little effect on below surface soil temperatures. Duration of temperatures above 25°C did not exceed five minutes and a maximum of 75°C was measured at a depth of 1 mm in Norton and McGarity's studies in grassland (1965). These are comparable with those of Heywood and Tissot (1938) who detected negligible increases in soil temperature below a depth of 0.64 cm regardless of soil type. It therefore seems likely that those species with life stages in the soil at the time of burning would be relatively unaffected by the direct effects.

The subsequent effects of a moderate intensity fire on the microhabitat that are considered to have a greater impact on the invertebrate fauna (Buffington, 1967; Ahlgren, 1974; Bulan and Barrett, 1981; Evans, 1983). Soil temperatures are altered by the removal of living shoots and litter that had previously intercepted much of the direct insolation and reduced loss of heat by radiation. Burnt areas are therefore prone to greater temperature fluctuations (Daubenmire, 1968). Following burning the soil surface is left with a deposit of blackened ash which may serve to increase heat absorption (Mallik, Gimmingham and Rahman, 1984). Although this modification of the microhabitat may stimulate plant growth, increase activities of soil microorganisms and the rate of soil chemical reactions (Vogl, 1974) it is not known how this will affect the soil invertwbrate fauna. Nagel (1973) speculated that the higher temperatures should speed up development times and shorten generation times of species with life stages in the soil.

Removal of surface vegetation and litter cover also alters the moisture content of soils by increasing surface evapouration. The incorporation of ash into the soil may reduce infiltration rates, reduce rate of percolation and retention (Mallik, Gimmingham and Rahman, 1984). This alteration of the microhabitat is thought to be responsible for the reduction in earthworm and Collembolan populations which are particularly sensitive to moisture stress (Rice, 1932; Pearse, 1943; Heywood and Tissot, 1963). Buffington (1976) concluded that only those species with adaptations to xeric post-fire conditions would be able to maintain their populations.

One of the more obvious effects of burning is the destruction of the energy supply of an ecosystem by the removal of the living plant material and decaying litter. Buffington (1967) attributed a decrease in soil arthropods following a fire to a reduction in food supply and modification of the microenvironment. Steadst (1984) considered that the increased productivity of roots and microbes on a burnt area would not compensate for the loss of the litter layer and subsequent removal of food sources. Removal of the litter layer by fire was found to effect the survivorship of grasshoppers in prairiegrass by increasing their exposure to predation (Evans, 1983). (Although fire-melanism has been shown in species of African Orthoptera (Hocking, 1963).)

AIMS AND OBJECTIVES

There is a need for information on the effects of burning on the invertebrate fauna of tussock grasslands.

1) Applied need

The East Otago Plateau has been the site of extensive research by the Ministry of Agriculture and Fisheries into the establishment of oversown legumes and grasses in unmodified sub-alpine tussock grassland. Dr B.I.P. Barratt (1982) showed that insects played a role in the failure of oversown legumes in this environment. Four species of broad-nosed weevil (Curculionidae:Leptopiinae) were found to be responsible for the consumption of up to 50% of white clover seedlings. Bremner (1988) found that a significant number of exotic grass seeds were lost due to theft and damage by insects following oversowing. Once again the broad-nosed weevils were responsible, although *Chelaner antarctica* (Hymenoptera:Formicidae), *Oregus aereus*, *Mecodema rectolineatum* and *Agonum* sp. (Coleoptera:Carabidae) and *Pteronemobius bigelowi* (Orthoptera:Gryllidae) were also implicated.

Insect control in this environment is limited, with winter and spring burning being the only practical methods available (Bremner, 1988). An observation following an accidental late spring burn in this area indicated that populations of broad-nosed weevils actually increased in numbers paralleled by a decrease in their predator numbers (Dean, Barratt and Johnstone, 1986). Therefore a thorough understanding of how the invertibrate fauna reacts to a disturbance such as burning will be important in predicting potential pest populations in areas suitable for oversowing.

2) Conservation

Insects have been shown to feed on tussock grasses (Dick, 1940; Kelsey, 1957; White, 1974). Although they are responsible for a certain amount of feeding damage they also play a role in the maintenance of the ecosystem. Their activities recycle nutrients, aerate the soil, remove litter and manure and aid seedling establishment by seedbed preparation as well as being a food source for various tussock dwelling birdlife (Dick, 1940).

To conserve the tussock grasslands as a living system it is necessary to know how the fauna is altered by management practices such as burning. There are also certain species occuring only in this environment which need to be conserved in their own right, such as various species of carabid beetle, grasshoppers, Lepidoptera and weevils.

3) Ecological

Lastly, it is of ecological interest to study the impact of burning on a fauna. If burning does reduce the invertebrate fauna are some species more severely affected than others? How would this imbalance alter the community structure and the food chain? How does recolonisation of a burnt area take place? Is it through survivors acting as a nuclei group or by immigration from unburnt areas? How long does it take for a fauna to recover to prefire density and diversity levels?

It was hoped that this study would answer some of these ecological questions as well as attempting to identify common indicator species which could be used to monitor the impact of burning on the invertebrate community. Lastly, it was hoped that this work would determine how burning alters the populations of potential pest species.

SITES OF STUDY

The study was conducted on the Otago Plateau, which is an area of relatively accessible unmodified tussock grassland close to Dunedin. Initially four sites were selected which together encompassed a range of altitudes, tussock associations, rainfall and management practices on the plateau. However, of the four sites chosen only three were suitably burnt for the purposes of this study. Two were located on the eastern side of the plateau to the southwest of the Rock and Pillar Range and to the north east of the Lammermoor Range. The third site, Teviot River Downs, is to the south west of the Nobby Range above Roxburgh East.

For the purposes of this report only the two sites on the East Otago Plateau will be described and discussed since the data from the Roxburgh site has not been sufficiently analysed.

Site 1- The Burgun Run

This is a property of 6070 hectares. The site has a soil type of Teviot silt loam, pH 4.6, and an annual rainfall of 640 mm (Bremner, 1988). The area used in this study was at an altitude of 914 m above sea level and consisted of snow tussock associations of moderate vigour which had not been burnt since 1975. The average tussock cover in the study area was 8.3% with an average density of 2.3 tussocks per m^2. The intertussock vegetation is dominated by *Anthoxanthum odoratum, Hypochaeris radicata, Pentachondra pumila, Pernettya macrostigma* and dead matter.

A permit was issued by the Otago Catchment Board in 1987 to burn 330 hectares of this property to allow ease of construction of an erosion control fence, remove rank snow tussock from damp gullies and to reduce the risk of escaped fire along the public road.

This area was burnt at 11.00 a.m. on 17th August 1987. The burn was severe in places removing all the tussock vegetation and many intertussock species. The burn was typically patchy along the ridge tops where tussock cover was less dense, but the lower lying areas and gullies were evenly burnt.

Site 2- Stonehurst

Stonehurst Station covers an area of 3035 hectares. The area of study is at an altitude of 820-880 m above sea level with a Teviot silt loam soil, pH 5.0 and 640 mm rainfall per annum. The area runs 2700 ewes from January to April each year. It had not been burnt for over ten years and consisted of dense snow tussock of good vigour with good intertussock vegetation dominated by *Anthoxanthum odoratum, Hypochaeris radiata, Leucopogon fraseri, Poa colensoi* and dead matter. The average tussock density was 2.0 per m^2 with an average cover of 7.6%.

The Catchment Board issued a permit in 1987 to burn 30 hectares, primarily for fuel reduction and to provide ease of stock movement. The area was burnt on 25th September 1987 at 2.45 p.m. with a 1.8 km/hr wind and an air temperature of 11°C. The soil moisture content at the time of burning was 38.5% and the soil temperature 10°C. The burn was of moderate intensity consuming most of the tussock foliage, but not damaging large areas of the intertussock herbs and shrubs. Patches of unburnt tussock remained within the study area.

METHODS

Assessing the impact of burning on the fauna

Six plots were marked out at each site prior to burning. Three were in an area to be burnt and three in a comparable area to be left unburnt as a control. In both cases an access track served as a fire break between the two areas. The plots were marked by a central warretah and sampling took place within a 20 m radius of each marker. Treatment and control plots were paired up as closely as possible using tussock density as the initial factor and later on the dominant intertussock vegetation. soil moisture content and pH. All plots were on areas of similar slope and aspect.

Each site was sampled once prior to burning by taking 20 0.1 m^2 x 0.04 m deep turves between tussocks at each of the six plots and nine tussock plants. Three tussocks were chosen from each of three size groups; 0-15 cm diameter. 15-30 cm diameter and greater than 30 cm diameter giving an area sampled of approximately 0.3 m^2 of tussock. Tussock leaves were clipped down to 15 cm and discarded before shearing the plant roots at approximately 2 cm depth.. Samples were placed in paper sacks and stored at 4°C. No samples remained in the cool store for longer than 14 days before processing.

This method of sampling was suitable for obtaining quantitative measurements of the numbers of soil and surface dwelling invertebrates. It did not provide any information on the densities of the more active groups such as Orthoptera. adult Lepidoptera. wetas and the larger carabid beetles.

The invertebrates were extracted from the turves and the tussocks using a modified Berlese funnel described by Bremner (1988). This uses three 1500W electric heaters to drive the invertebrates from the samples into collecting tubs below over a six hour period. The design of the funnel allows rapid handling of the large numbers of samples required for quantitative studies of grassland invertebrates and can process up to 3 m^2 of turf per run. It has a 97-100% extraction efficiency for most macro-invertebrate species present in the samples (Bremner, 1988). The turf and tussock samples were processed separately to obtain information on the spatial distribution of invertebrates within the heterogenous tussock environment and to assess whether burning affected the two habitats equally.

Following burning, each of the two sites was sampled by the method described above every two weeks for the first two months after burning and then at six weekly intervals until April 1988. On each sampling occassion five 7.5 cm deep soil cores were taken per plot to determine soil moisture by gravimetric analysis.

RESULTS

The species obtained by the sampling methods used in this study are presented in the Appendix. From the data obtained eight groups of the fauna were found to occur on most sampling dates both before and after burning at both sites. These were:

Orchestia sp. (Talitridae:Amphipoda)

These small crustacea, commonly known as hoppers, have evolved from a seashore environment to inhabit forests and grasslands. They feed saprophytically on litter within the tussock plants where the humidity is suitably high. They appear to exhibit no seasonality and overwinter as both juveniles and adults.

Aranaea (Arachnida)

The most commonly occuring families of spiders within the study area were wolf spiders, Lycosidae, dominated by *Lycosa hilaris*, and the jumping spiders Salticidae. Members of both these families are active in the tussock plants and within the intertussock vegetation.

They are present all year round both as adults and juveniles and overwinter in the tussock plants although still actively foraging when conditions are suitable (Bremner, 1988).

Opiliones (Arachnida)

Two species of harvestman were commonly found during the study. these were *Nuncia obesa* and *Algidia morplesi.* These are nocturnal creatures which feed on a wide range of plant and animal matter either dead or alive. They are mobile scavengers present in both the vegetation and within the tussock plants. Like the spiders the harvestmen overwinter within the tussock plants where they are present as both juveniles and adults.

Parallepsidion inaculeatum **(Blattidae: Dictyoptera)**

This cockroach is another nocturnal scavenger which feeds on a wide range of decaying plant and animal material. This species inhabits the tussock plants all year round and is seldom found in samples taken in the intertussock vegetation.

Pselaphidae (Staphylinoidea:Coleoptera)

This is a largely unidentified group of species commonly found in the intertussock vegetation in spring and summer. although they spent the winter months within the tussock plants. It is thought that they are predatory on members of the litter dwelling microfauna.

Holopsis **sp. (Corylophidae:Coleoptera)**

These minute coleoptera are commonly found in the intertussock vegetation where they are thought to be detritis feeders

Chilopoda

Centipedes are active predators most frequently found in the intertussock vegetation but overwintering beneath tussock plants where they can burrow to a depth of 10 cm (Bremner. 1988).

Niceana cinerea **and** ***Irenimus*** **sp.3 (Leptopiiniae:Curculionidae)**

The larvae of these broadnosed weevils are known to be root feeders whilst the adults feed on foliage and seedlings. *Niceana cinerea* is seldom found beneath tussock plants whereas *Irenimus* sp.3 overwinters in this environment. Both species were most commonly caught in the intertussock samples. Both show activity peaks in

November and December, but there appears to be no seasonality exhibited in their population numbers (Bremner, 1988).

These groups can be separated into tussock dwellers (Amphipoda and cockroaches), turf dwellers (centipedes, Pselaphidae, *Holopsis* sp., *Niceana cinerea*, *Irenimus* sp.3 and Lepidoptera larvae), and those groups that are found in both habitats (spiders and harvestmen). In the following analyses the total numbers of each of these groups from each of these habitats is used, therefore spiders and harvestmen appear twice giving a total of 12 indicator groups.

1) Graphic representation of data

The mean numbers of each indicator group per burnt and unburnt sample (1.8 m^2 turf or 0.3 m^2 tussock) are plotted against sampling date. Standard errors are fitted to each point (n=3).

The mean number of total species and the mean number of total individuals present in the burnt plots and unburnt plots are plotted against sampling date for tussock samples and turf samples. Standard errors are fitted to each point (n=3).

2) Chi-square tests

Chi-square tests were carried out on the total numbers of each of the indicator groups in the burnt and unburnt samples at each sampling date (data from the three plots are pooled to give a sample area of 3.6 m^2 of turf or 0.9 m^2 tussock). This tests whether all groups are equally affected by burning.

Chi-square tests were also carried out on the total number of species and the total number of individuals present in the burnt and unburnt samples of tussock and turf. This tests whether the tussock inhabiting fauna is affected by burning to the same extent as the turf fauna.

Finally, a chi-square test was carried out on the total numbers of the indicator groups separated into trophic levels to determine whether all groups were equally affected by burning.

Predators	Spiders Centipedes Pselaphidae
Herbivores	*Niceana cinerea* *Irenimus* sp. 3 Lepidoptera larvae
Detritivores	Amphipods *Holopsis* sp.
Scavengers	Cockroaches Harvestmen ?

<u>The effect of burning on the number of species present in the tussock and turf habitats</u> (Table 1)

Burgun Run - burning significantly reduced the total number of species present in both habitats. On the two sampling dates immediately following the burn (26.8.87. and 22.9.87.) the lower number of species present in the burnt tussock samples were the major contributing factor towards the significant chi-sqare value ($0.25 > p > 0.10$) indicating that this habitat was more severely affected initially than the intertussock vegetation.

The number of species present in the tussock samples remained below that in the unburnt controls for the duration of this study. However. the species numbers in the turf recovered by the March sampling date (Fig. 1).

Stonehurst - as at the Burgun Run the total number of species present was significantly reduced by burning. with both the tussock and the intertussock habitats being equally affected. In contrast to the Burgun Run the numbers of species present in the turf samples did not recover to the level of the unburnt control area (Fig. 2).

Table 1: EFFECT OF BURNING ON SPECIES DIVERSITY (TUSSOCK VS TURF)

Contingency tables set as shown below (d.f. = 1 for each chisquare test)

	Number of species present	
	Tussock	Turf
Unburnt		
Burnt		

H_0: No relationship between row and column classification

Burgun Run

Date	Chisquare value	Probability
16.8.87 (Pre-burn)	0.23	$p > 0.50$ ns
26.8.87	2.02	$0.25 > p > 0.10$?[1]
22.9.87	1.34	$0.25 > p > 0.10$?[2]
6.10.87	0.09	$p > 0.75$ ns
2.11.87	0.47	$0.50 > p > 0.25$ ns
20.11.87	0.07	$p > 0.75$ ns
27.1.88	0.32	$p > 0.75$ ns
15.3.88	0.59	$0.50 > p > 0.25$ ns

1 Lower numbers in the 'Burnt Tussock' cell are the single largest contributing factor

2 Lower numbers in the 'Burnt Tussock' cell are the single largest contributing factor

Table 1 (continued):

Stonehurst

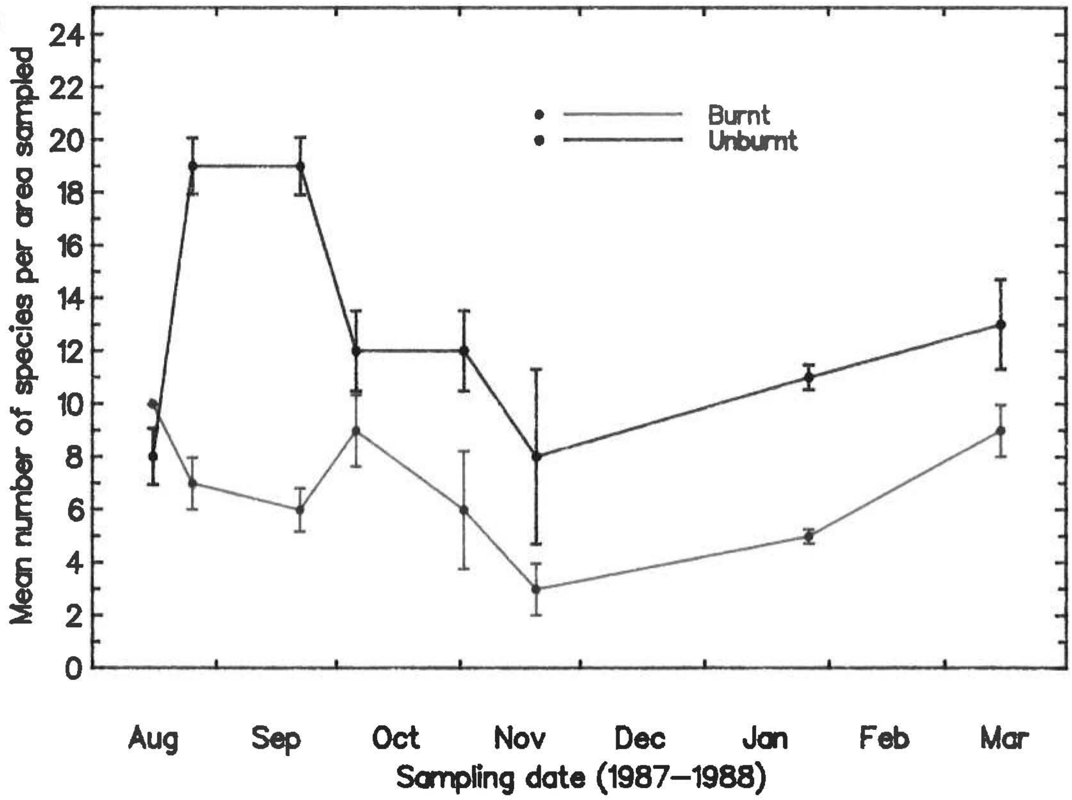
Date	Chisquare value	Probability
17.8.87 (Pre-burn)	0.01	p>0.90 ns
8.10.87	0.07	p>0.90 ns
23.10.87	0.01	p>0.90 ns
4.11.87	0.58	0.50>p>0.25 ns
17.11.87	0.10	p>0.75 ns
27.1.88	1.15	0.50>p>0.25 ns
10.3.88	0.03	p>0.90 ns

Figure 1: **The Burgun Run**

Mean number of species present per area sampled against time.

1. 0.3 m^2 of tussock
2. 1.8 m^2 of turf

1.



2.

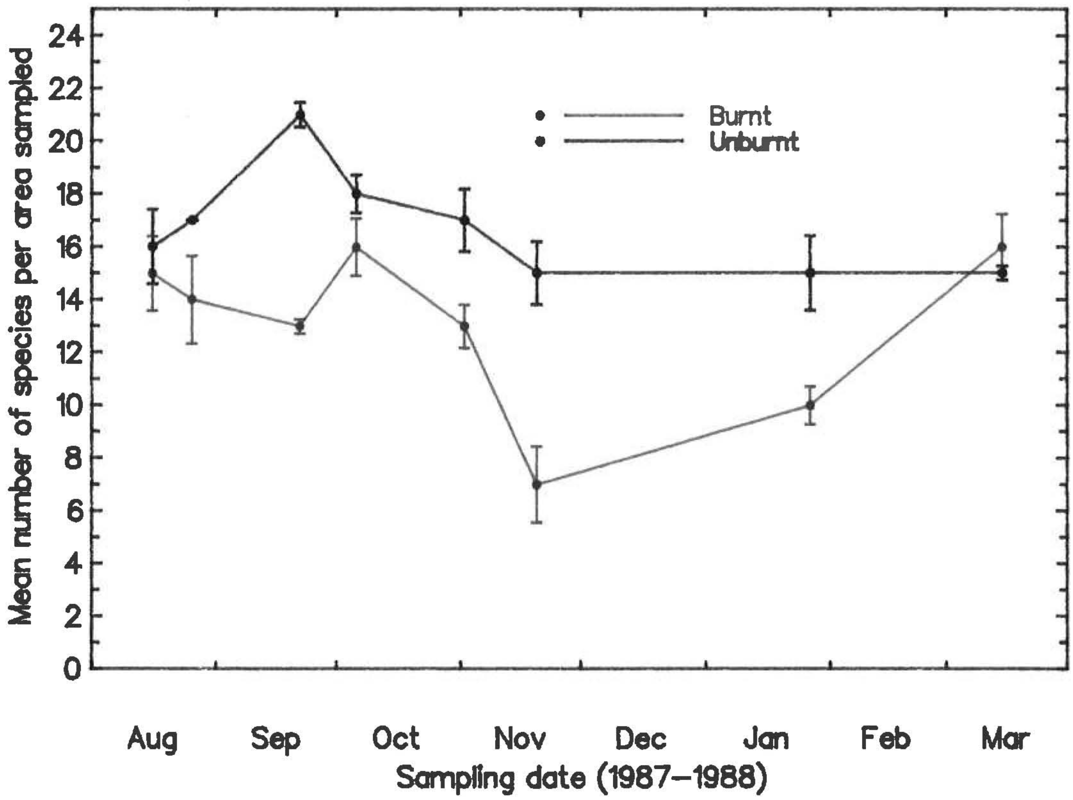
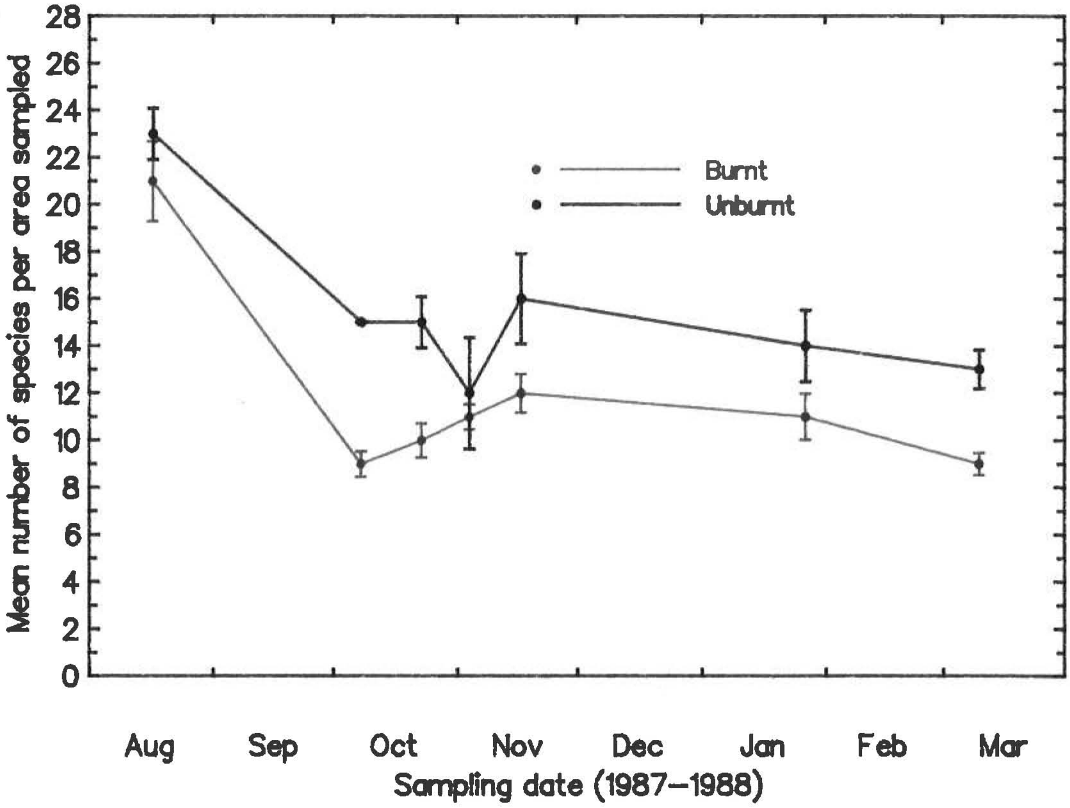


Figure 2: **Stonehurst**

Mean number of species present per area sampled against time.

1. 0.3 m^2 of tussock
2. 1.8 m^2 of turf

1.



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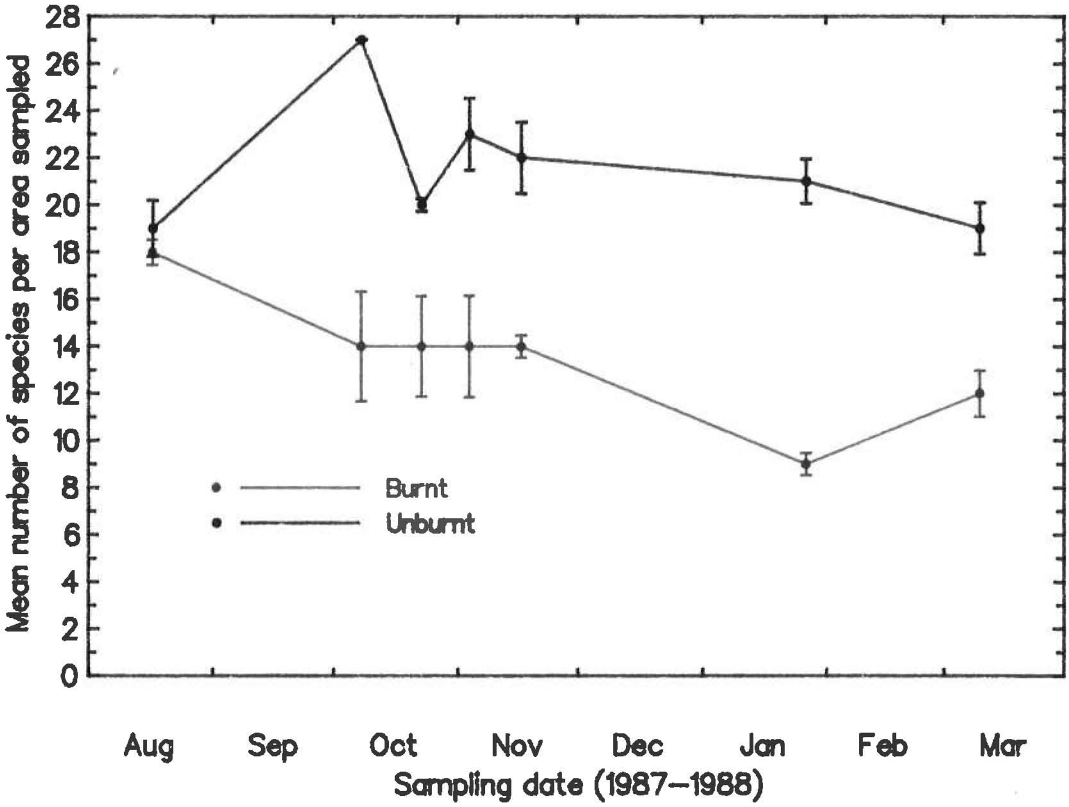


The effect of burning on the total numbers of individuals present in the tussock and intertussock habitats (Table 2)

Burgun Run - burning significantly reduced the total number of individuals present in both the tussock and intertussock habitats with the populations in both environments remaining significantly below the controls for the duration of the study. There were significant chi-square values obtained at each sampling date excluding 6.10.87. Lower numbers in the burnt tussock samples were the consistent contributors to these significant values, although higher numbers in the burnt turf samples contributed on two occassions (26.8.87 and 20.11.87.) (Fig. 3). This indicates that burning has a more severe affect on those individuals present in the tussock environment than the intertussock vegetation.

Stonehurst - a similar trend was shown to the Burgun Run (Fig. 4). A significant chi-square value was obtained on two occassions (4.11.87 and 10.3.88.). A higher number of individuals in the burnt tussock samples is a major contributing factor on 4.11.87 possibly accounted for by the higher numbers of spiders and cockroaches present.

The effects of burning on the 12 indicator groups (Table 3)

Amphipoda *Orchestia* sp. (Fig. 5)

Burning significantly reduced the numbers of amphipods present in the tussock samples at both sites. Their numbers remained below those on the unburnt control areas for the duration of the study. Fewer amphipods than expected were a consistent contributor to significant chi-square values obtained on each sampling date at each site. This indicates that amphipods are more severely affected by burning than other indicator groups.

Spiders (Figs 6, 7)

The number of spiders present in both the tussock samples and turf samples were significantly reduced by burning at the Burgun Run site. However, at Stonehurst there were significantly more spiders present in the burnt tussocks and turf in the pre-fire samples than in the controls. The numbers were reduced by burning, but significant differences were not obvious on several sampling occassions. There was a rapid decline in numbers following burning, but this was paralleled by a similar

Table 2: EFFECT OF BURNING ON TOTAL INSECT NUMBERS (TUSSOCK VS TURF)

Contingency tables set as shown below (d.f.=1 for each chisquare test)

	Total number of insects present	
	Tussock	Turf
Burnt		
Unburnt		

H_0: No relationship between row and column classification

Burgun Run

Date	Chisquare value	Probability
16.8.87 (Pre-burn)	9.24[1]	p<0.005 ***
26.8.87	40.59[2]	p<0.005 ***
22.9.87	8.09[3]	p<0.005 ***
6.10.87	0.87	0.50>p>0.25 ns
2.11.87	8.10[4]	p<0.005 ***
20.11.87	9.69[5]	p<0.005 ***
27.1.88	7.94[6]	p<0.005 ***
15.3.88	11.00[7]	p<0.005 ***

[1] Lower numbers in the 'Unburnt Tussock' cell are the single largest contributing factor

[2] Lower numbers in the 'Burnt Tussock' cell are a major contributing factor
Higher numbers in the 'Burnt Turf' cell are also a contributing factor

[3] Lower numbers in the 'Burnt Tussock' cell are the single largest contributing factor

[4] Lower numbers in the 'Burnt Tussock' cell are the single largest contributing factor

[5] Lower numbers in the 'Burnt Tussock' cell are a major contributing factor
Higher numbers in the 'Burnt Turf' cell are also a major contributing factor

[6] Lower numbers in the 'Burnt Tussock' cell are the single largest

Table 2 (continued):

contributing factor

7 Lower numbers in the 'Burnt Tussock' cell are the single largest contributing factor

Table 2 (continued):

Stonehurst

Date	Chisquare value	Probability
17.8.87 (Pre-burn)	5.33[1]	$p<0.025$ *
8.10.87	0.47	$0.50>p>0.25$ ns
23.10.87	0.52	$0.50>p>0.25$ ns
4.11.87	11.50[2]	$p<0.005$ ***
17.11.87	0.21	$p>0.50$ ns
27.1.88	0.01	$p>0.90$ ns
10.3.88	11.00[3]	$p<0.005$ ***

[1] All cells contribute equally to the significant chisquare value

[2] Higher numbers in the 'Burnt Tussock' cell are a major contributing factor
Lower numbers in the 'Burnt Turf' cell are also a major contributing factor

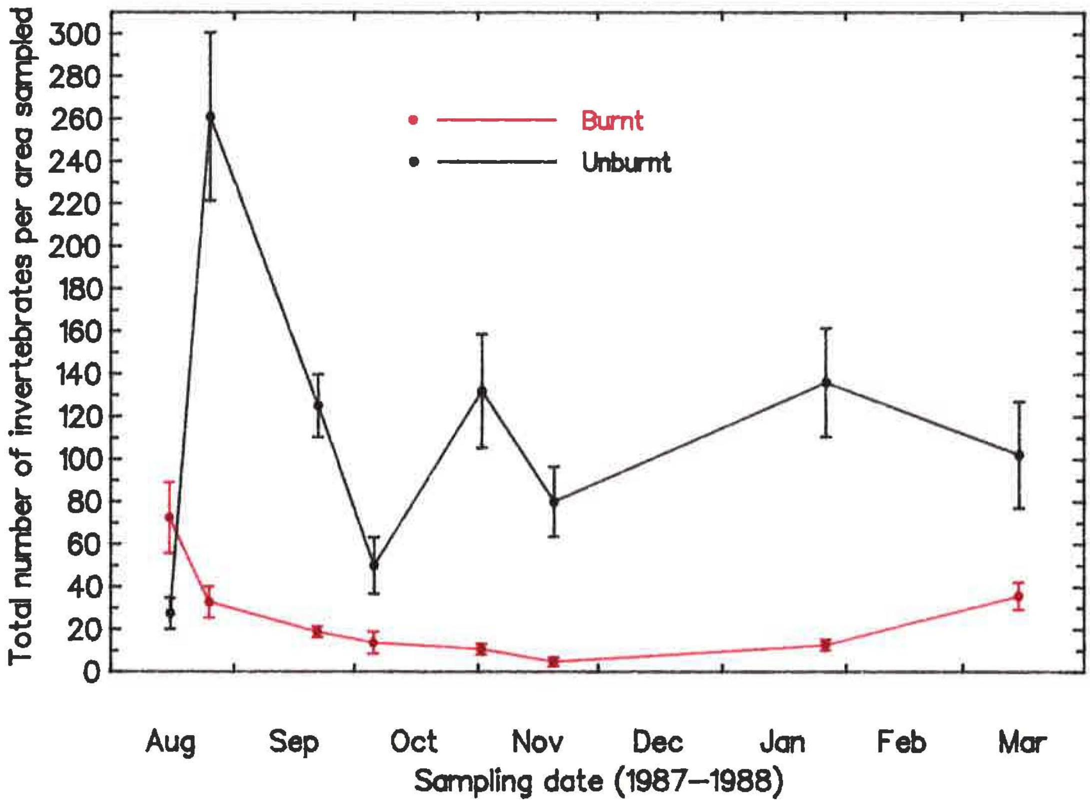
[3] Lower numbers in the 'Burnt Tussock' cell are a major contributing factor
Higher numbers in the 'Burnt Turf' cell are also a major contributing factor

Figure 3: Burgun Run

Mean number of individuals per sample against time.

1. 0.3 m^2 tussock
2. 1.8 m^2 turf

1.



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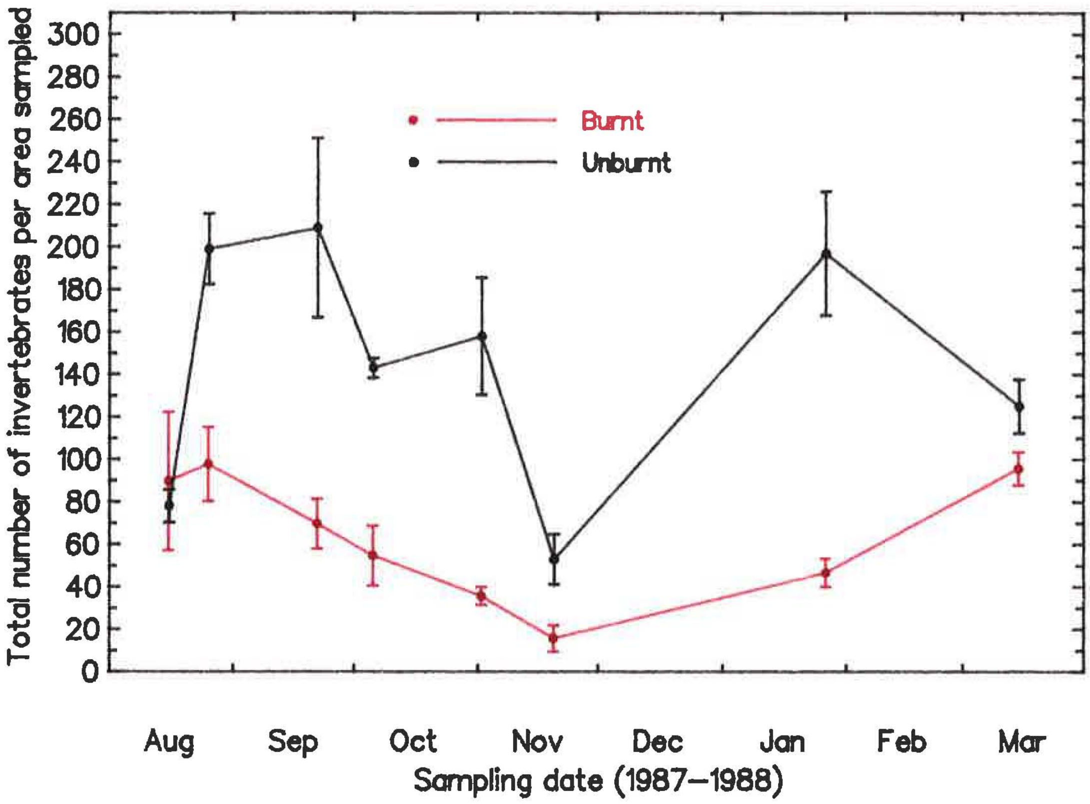
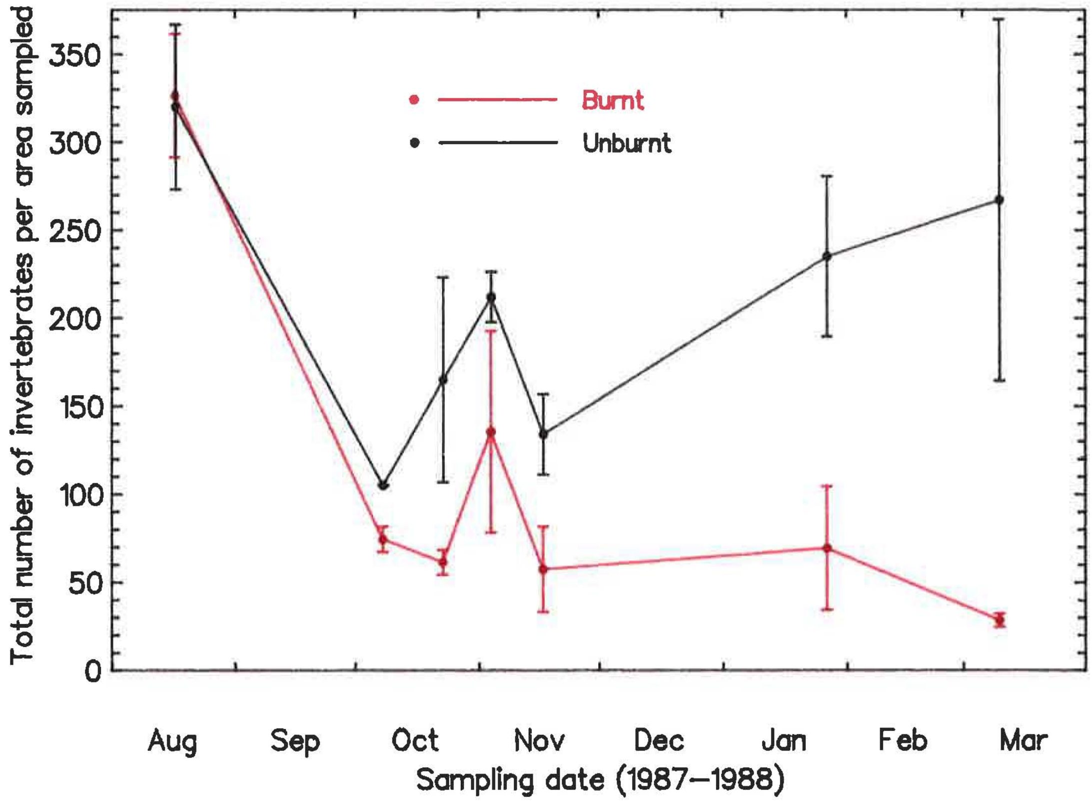


Figure 4: Stonehurst

Mean number of individuals per sample against time.

1. 0.3 m^2 tussock
2. 1.8 m^2 turf

1.



2.

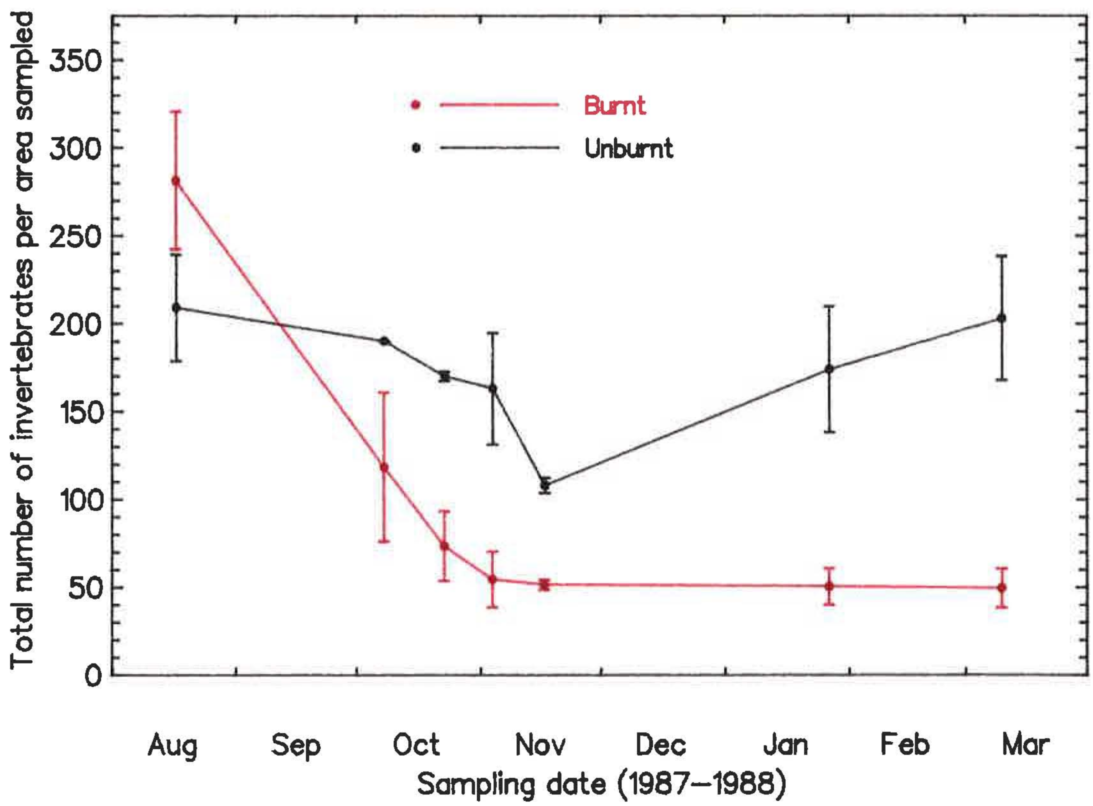


Table 3: **EFFECT OF BURNING ON THE NUMBERS OF EACH OF THE 12 SPECIES GROUPS**

Burgun Run

Date	N		Chisquare value	Probability
16.8.87[1]	10	No cockroaches (turf) No *Niceana cinerea*	57.2691	$p<0.005$
26.8.87[2]	11	No *Niceana cinerea*	24.9516	$p<0.005$
22.9.87[3]	11	No *Niceana cinerea*	35.5702	$p<0.005$
6.10.87[4]	11	No *Niceana cinerea*	36.8405	$p<0.005$
2.11.87[5]	11	No *Niceana cinerea*	62.8569	$p<0.005$
20.11.87[6]	10	No *Niceana cinerea* No harvestmen (turf)	80.6520	$p<0.005$
27.1.88[7]	11	No *Niceana cinerea*	61.7591	$p<0.005$
15.3.88[8]	11	No *Niceana cinerea*	80.4399	$p<0.005$

[1] Burnt: More amphipods (tussock) than expected
Unburnt: Fewer amphipods (tussock) than expected

[2] Burnt: More *Irenimus* sp. 3 (turf)
More total spiders (turf)

[3] Burnt: More centipedes (turf)

[4] Burnt: More centipedes (turf)
More Lepidoptera larvae (turf)*
More total spiders (tussock)

[5] Burnt: Fewer amphipods (tussock)
More centipedes (turf)
More total spiders (tussock)*

[6] Burnt: Fewer amphipods (tussock)
More Lepidoptera larvae (turf)*
More total spiders (tussock)*

[7] Burnt: Fewer amphipods (tussock)
More *Irenimus* sp. 3 (turf)*
More total spiders (turf)

[8] Burnt: Fewer amphipods (tussock)
More *Irenimus* sp. 3 (turf)*

*N.B. Expected values less than 5.00

Table 3 (continued):

Stonehurst

Date	N	Chisquare value	Probability
17.8.87[1]	12	123.981	$p<0.005$
8.10.87[2]	12	114.753	$p<0.005$
23.10.87[3]	12	132.582	$p<0.005$
4.11.87[4]	12	76.7897	$p<0.005$
17.11.87[5]	12	92.4235	$p<0.005$
27.1.88[6]	12	115.026	$p<0.005$
10.3.88[7]	12	325.115	$p<0.005$

[1] Burnt: Fewer cockroaches (tussock) than expected
Unburnt: More cockroaches (tussock) than expected

[2] Burnt: Fewer cockroaches (tussock)
More centipedes (turf)
Fewer *Niceana cinerea* (turf)
More Lepidoptera larvae (turf)
More total spiders (turf)
Unburnt: More *Niceana cinerea* (turf)
Fewer Lepidoptera larvae (turf)

[3] Burnt: Fewer amphipods (tussock)
More Pselaphidae (turf)
More total spiders (tussock)
More total spiders (turf)

[4] Burnt: More cockroaches (tussock)
Fewer *Irenimus* sp. 3 (turf)
More total spiders (tussock)
Unburnt: Fewer cockroaches (tussock)

[5] Burnt: More Pselaphidae (turf)
More total spiders (tussock)
More total spiders (turf)
Unburnt: Fewer total spiders (tussock)

[6] Burnt: Fewer amphipods (tussock)
More Lepidoptera larvae (turf)
More total spiders (tussock)
More total spiders (turf)

[7] Burnt: Fewer amphipods (tussock)
More cockroaches (tussock)

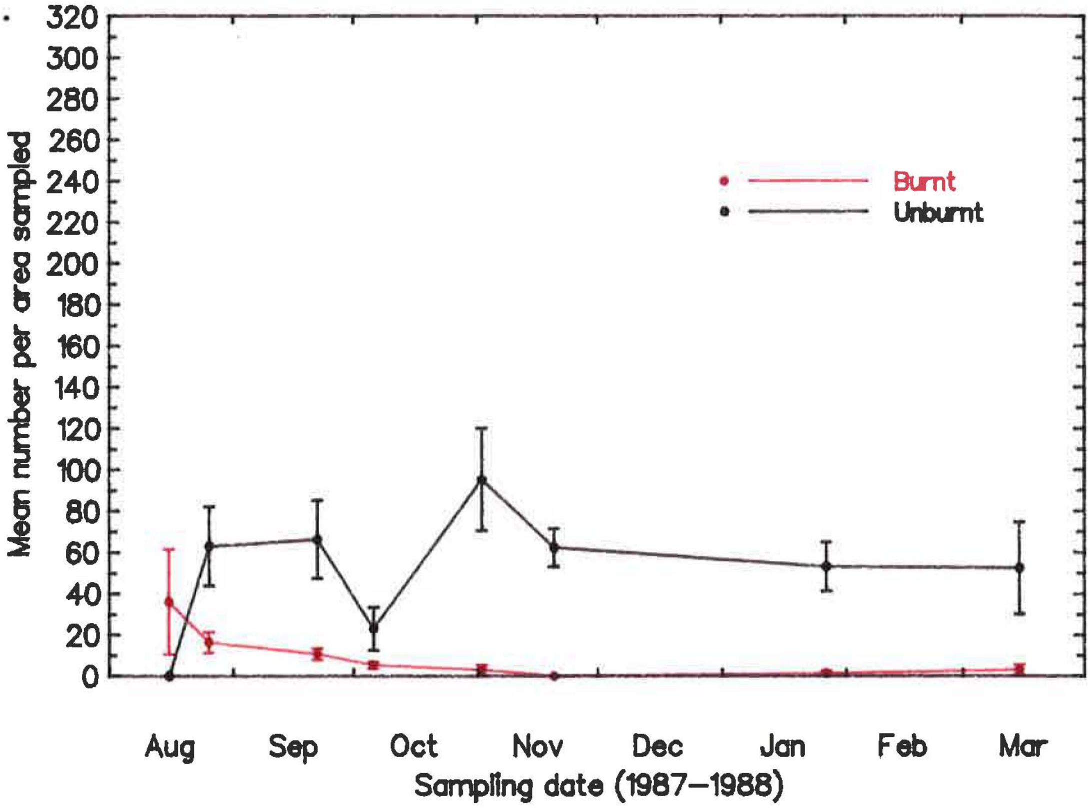
Table 3 (continued):

More cockroaches (tussock)
More Pselaphidae (turf)
More total spiders (tussock)
More total spiders (turf)

Figure 5: Mean number of amphipods (<u>Orchestria</u> sp.) per 0.3 m^2 tussock against time.

1. Burgun Run
2. Stonehurst

1.



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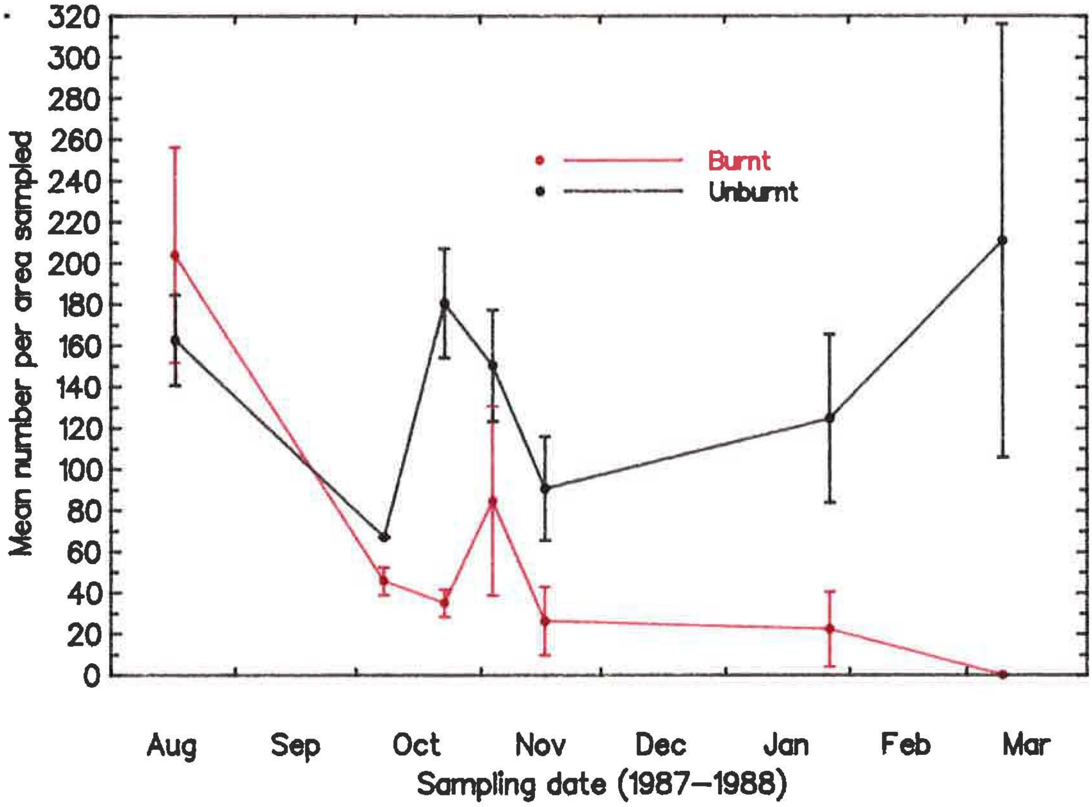
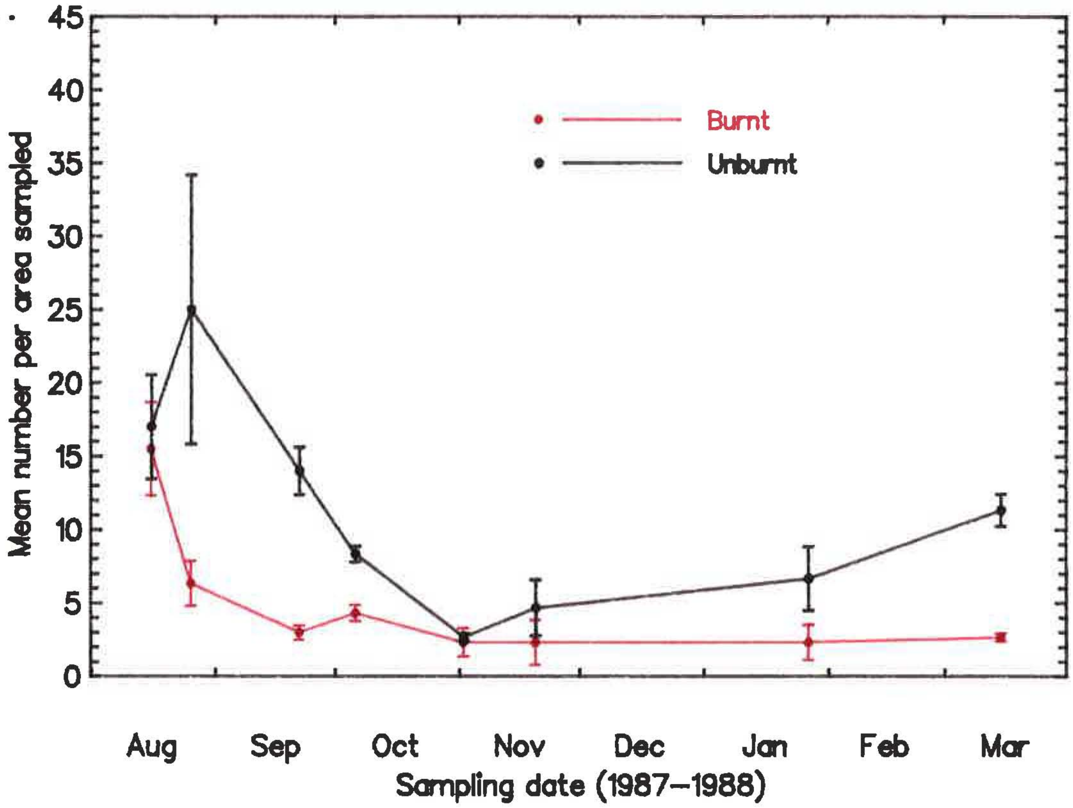


Figure 6: Mean number of spiders per 0.3 m^2 of tussock against time.

1. The Burgun Run
2. Stonehurst

1.



2.

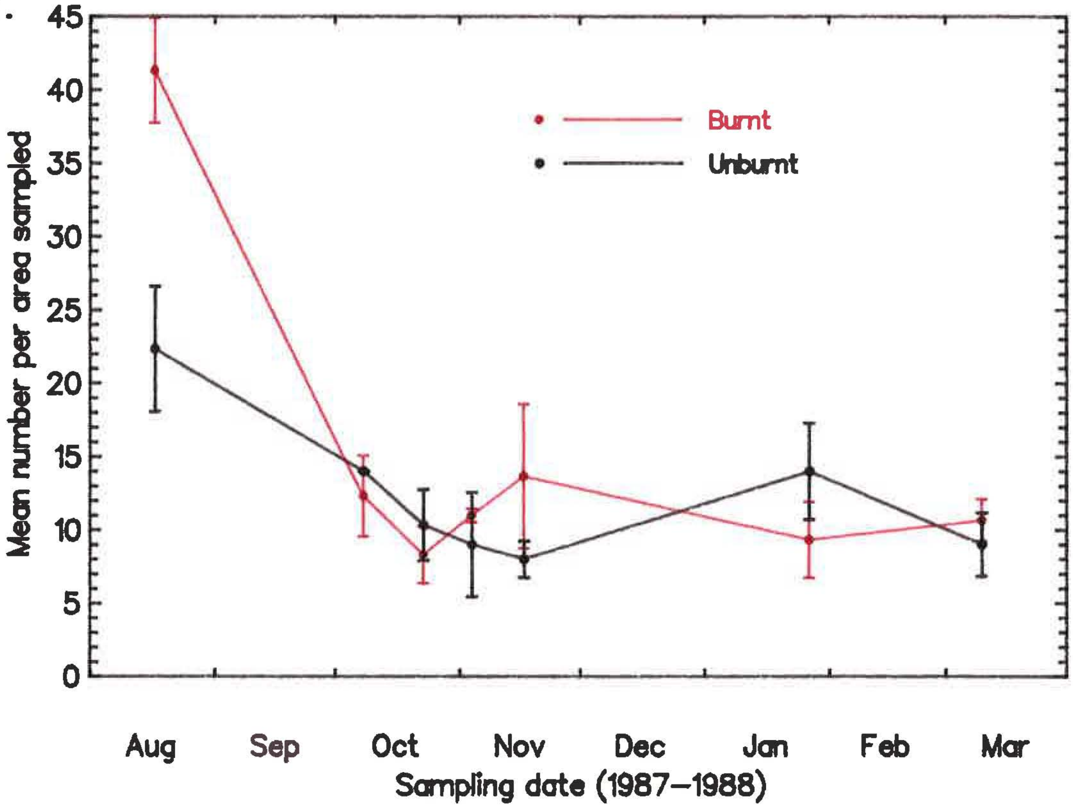
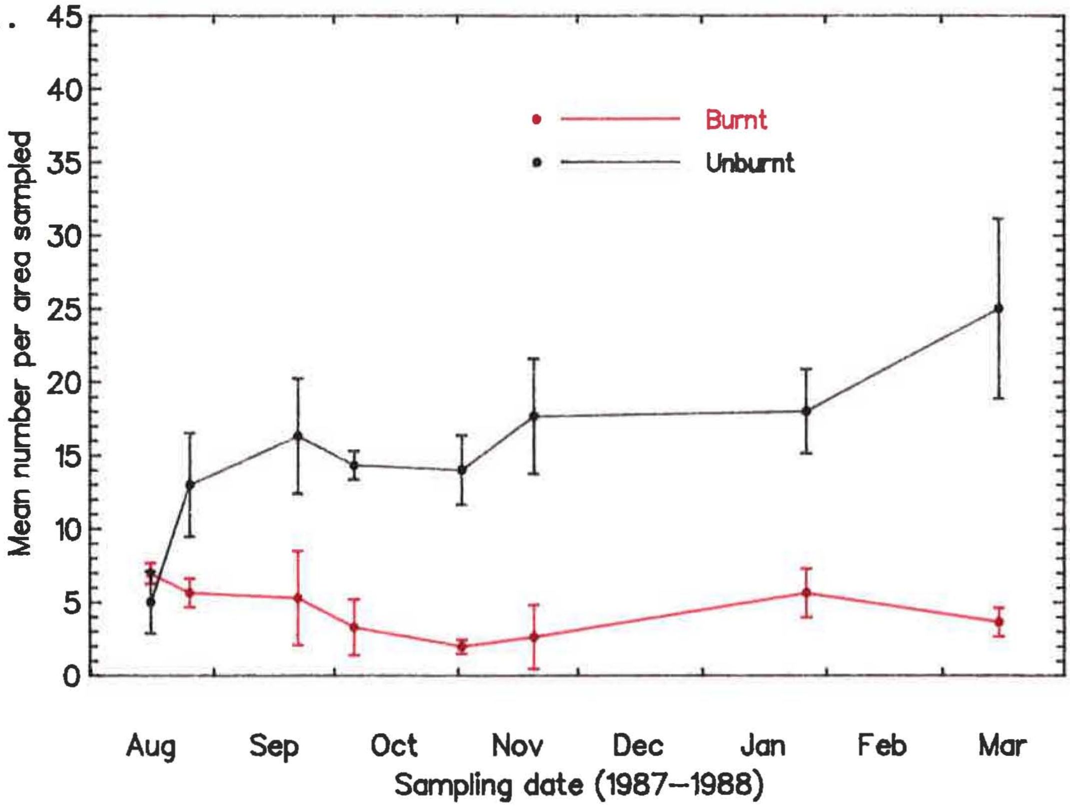


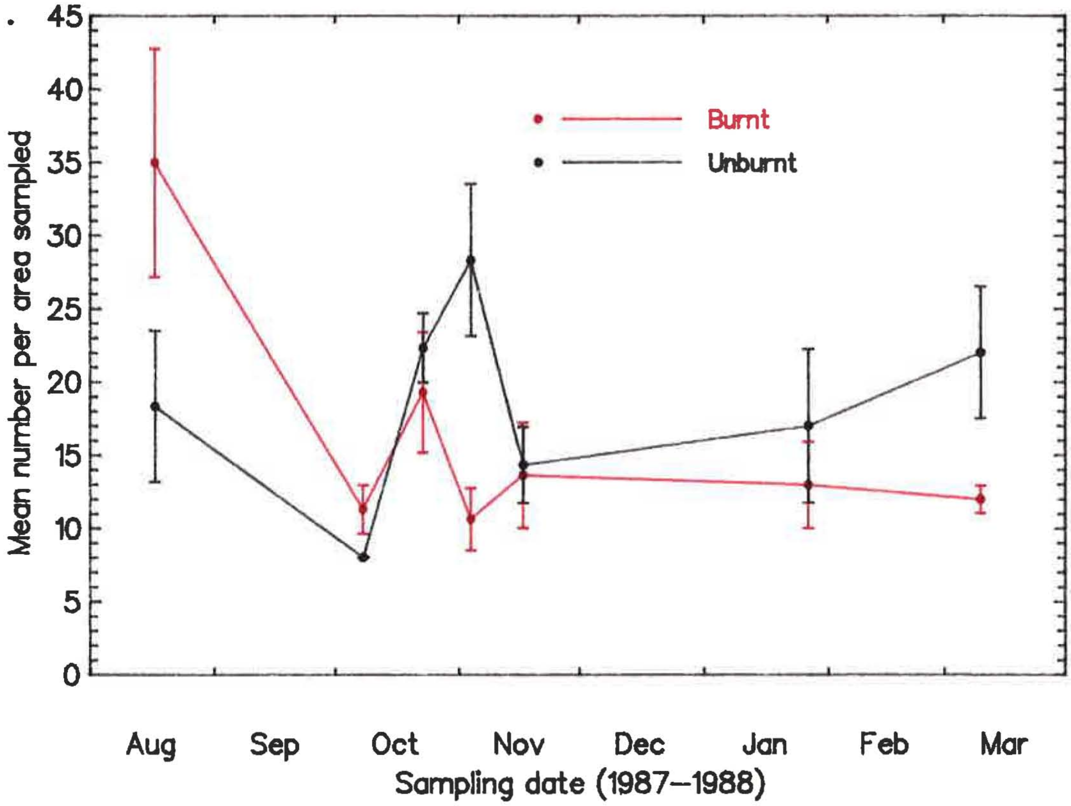
Figure 7: Mean number of spiders per 1.8 m^2 of turf against time.

1. The Burgun Run
2. Stonehurst

1.



2.



decline in the numbers in unburnt samples. The numbers of spiders present in the turf in the March sample were significantly lower than the unburnt samples. No such trend was seen in the tussock habitat where numbers appeared to recover relatively quickly. More spiders than expected were a consistent contributer to the significant chi-square value at both sites. This implies that they may have the ability to recolonise burnt areas at a faster rate than the other indicator groups.

Harvestmen (Figs 8, 9)

The numbers of harvestmen in the tussock and turf habitats were significantly reduced by burning. Numbers present in the burnt turf samples were dramatically lower than those in the unburnt samples at the end of the study. This group was not a contributor to the chi-square values indicating that they are neither more or less affected than expected.

Cockroaches *Parallepsidion inaculeatum* (Fig. 10)

The number of cockroaches present in the tussocks were significantly reduced by burning at both sites. Populations remained below those in unburnt tussock for the duration of the study. excluding 4.11.87. at Stonehurst when there was an unaccountable drop in the control population numbers.

However. there were significantly more cockroaches present in the pre-fire control tussock samples than the burnt samples which makes it difficult to draw any conclusions from the trends shown.

Pselaphidae (Fig. 11)

Burning significantly reduced the populations of Pselaphids in the immediate post-fire samples at both sites. The Burgun Run showed consistently lower numbers on the burnt areas throughout the study. In contrast the Stonehurst burnt populations show no significant difference to the unburnt except on the final sampling date when they were lower.

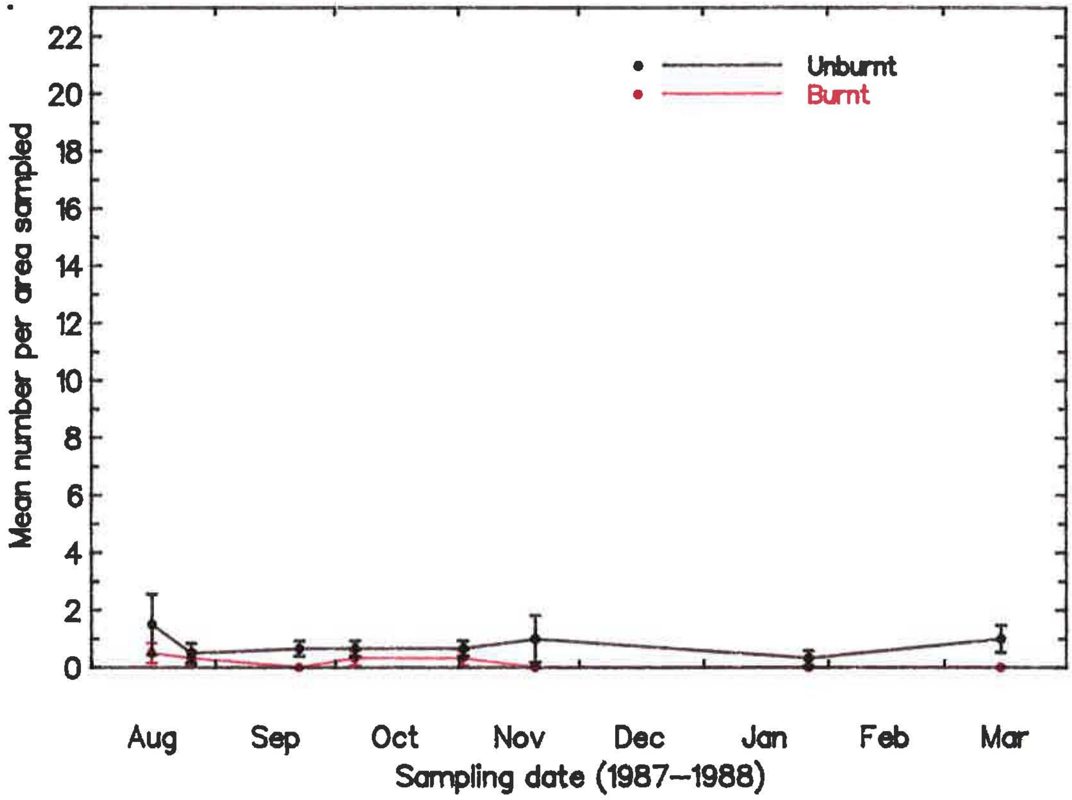
Corylophidae *Holopsis* sp. (Fig. 12)

These small Coleoptera were significanty reduced by burning and remained at consistently lower numbers throughout the study.

Figure 8: Mean number of harvestmen per 0.3 m^2 tussock against time.

1. Burgun Run
2. Stonehurst

1.



2.

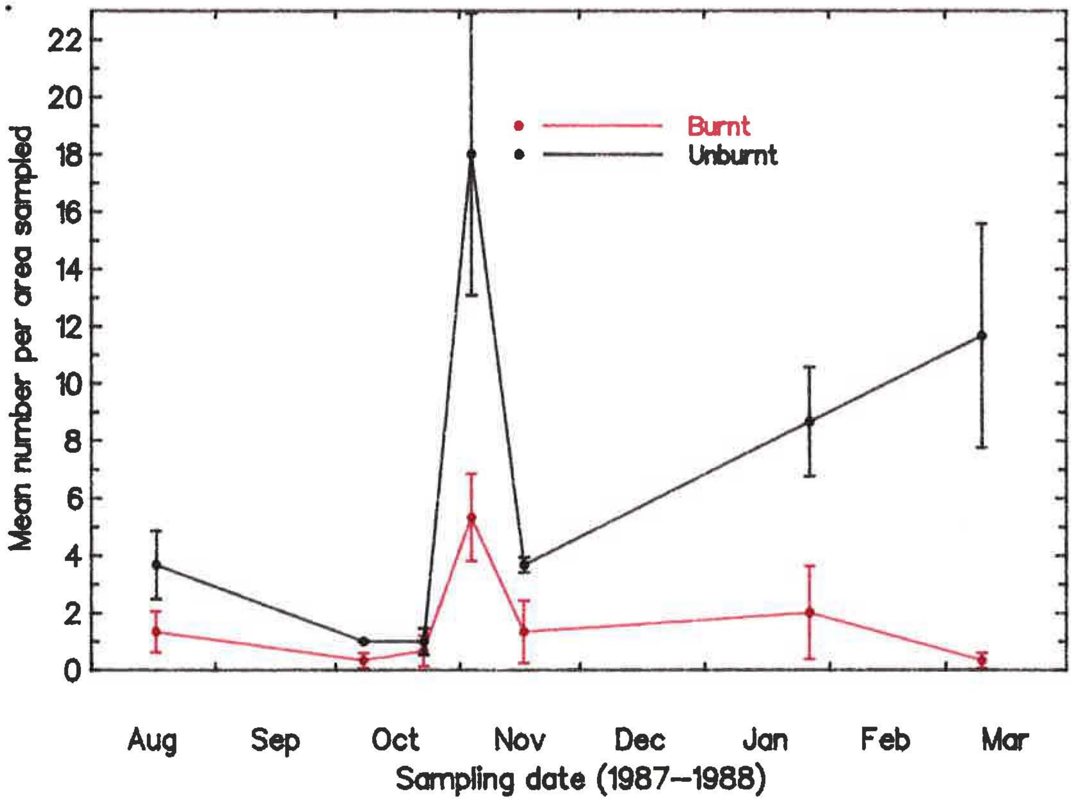
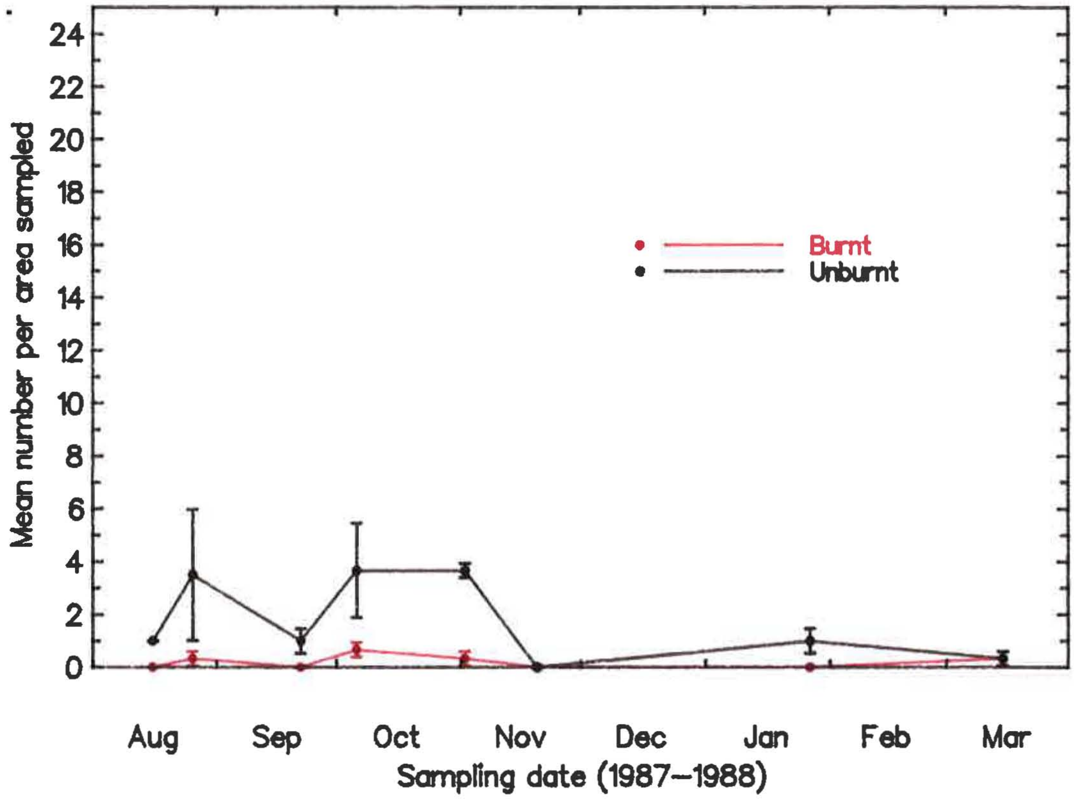


Figure 9: Mean number of harvestmen per 1.8 m^2 turf against time.

1. Burgun Run
2. Stonehurst

1.



2.

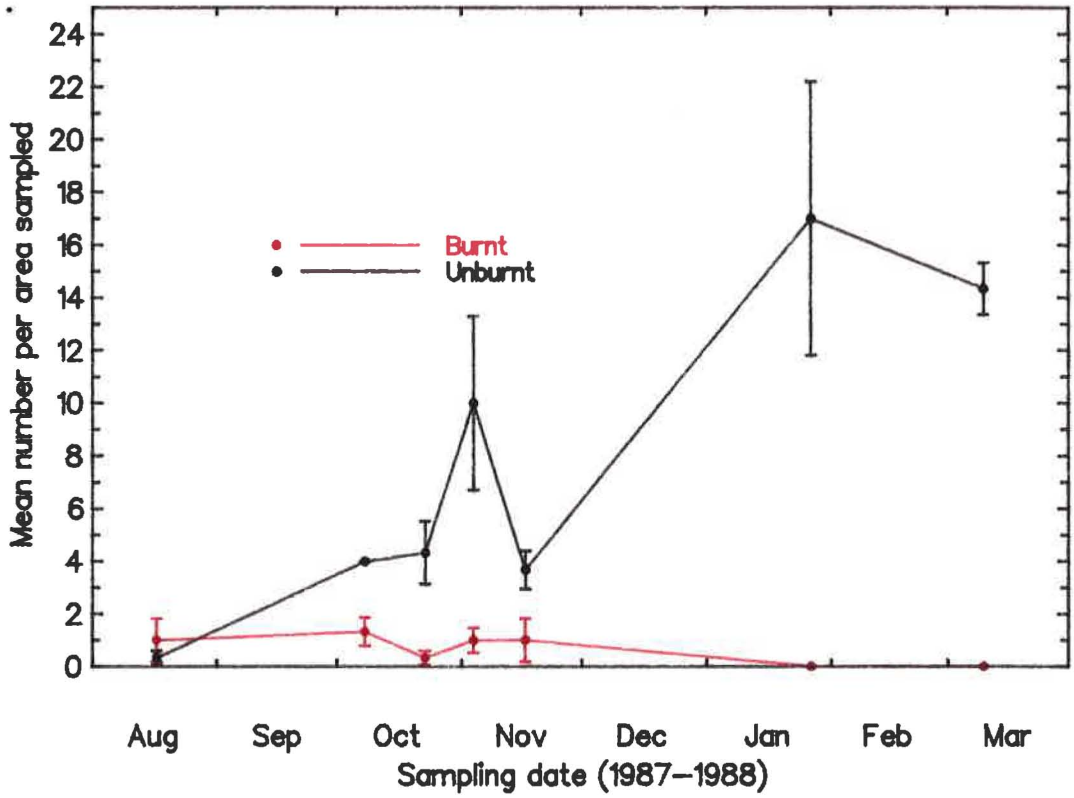
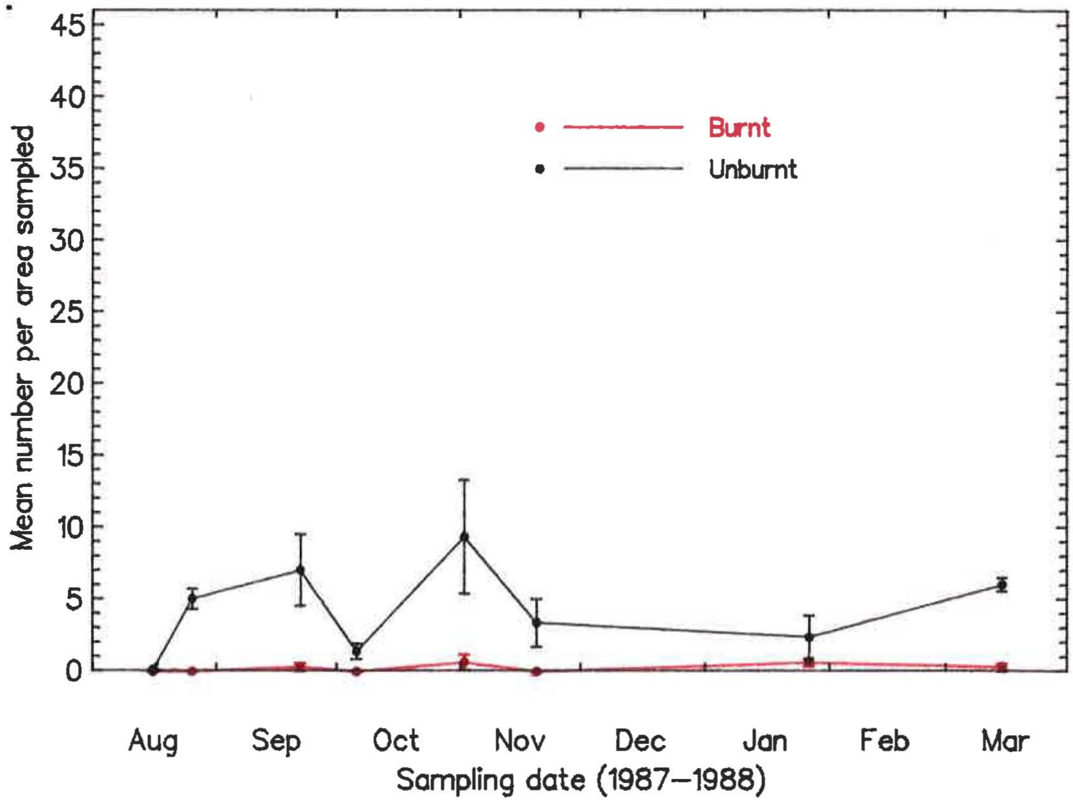


Figure 10: Mean number of Cockroaches (Parallepsidian inaculeatum) per 0.3 m^2 tussock against time.

1. Burgun Run
2. Stonehurst

1.



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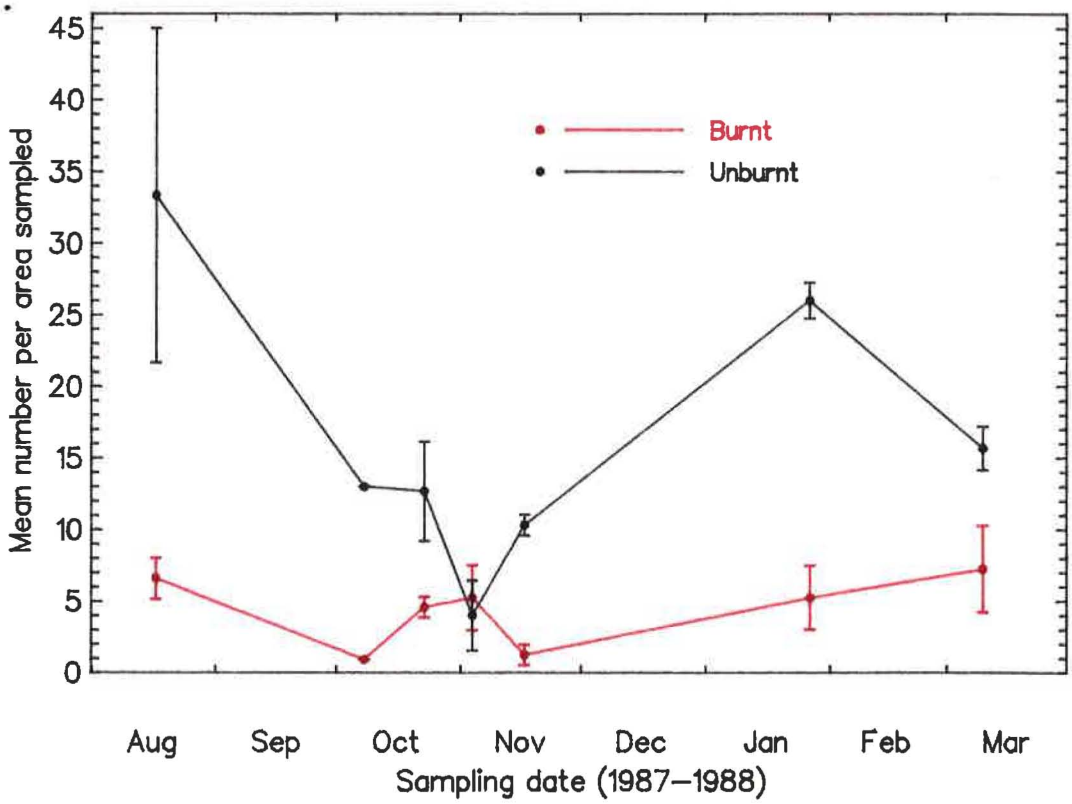
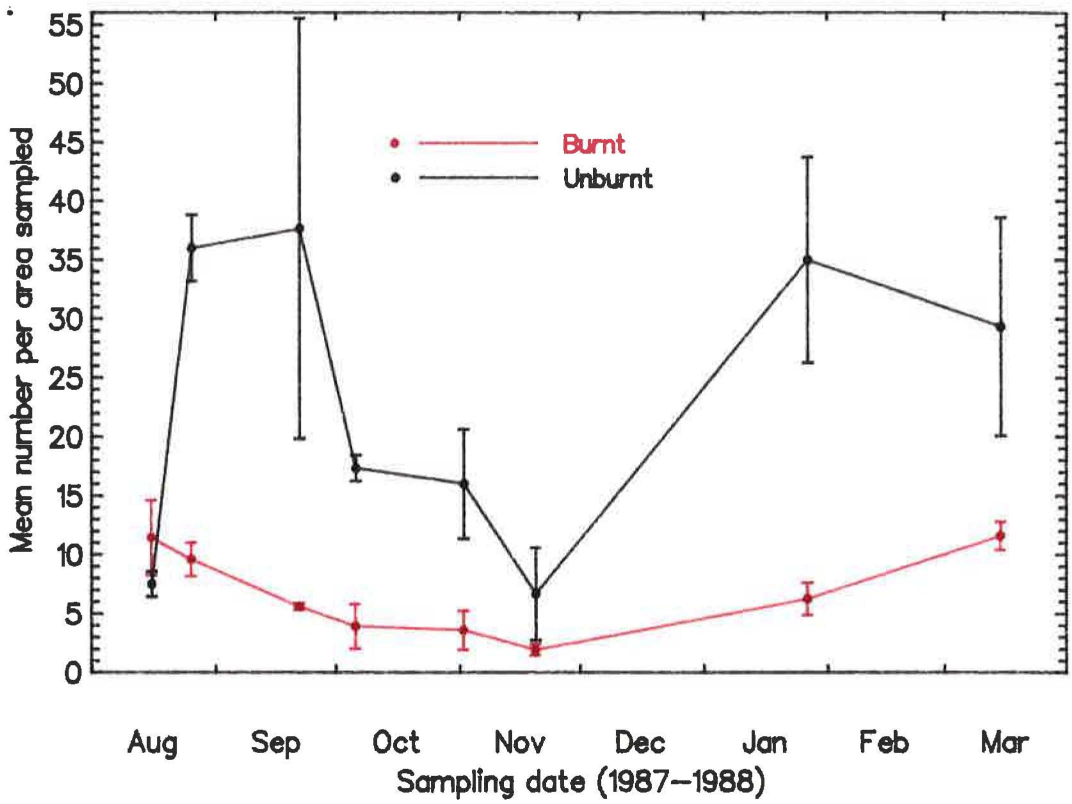


Figure 11: Mean number of Pselaphidae per 1.8 m^2 turf against time.

1. Burgun Run
2. Stonehurst

1.



2.

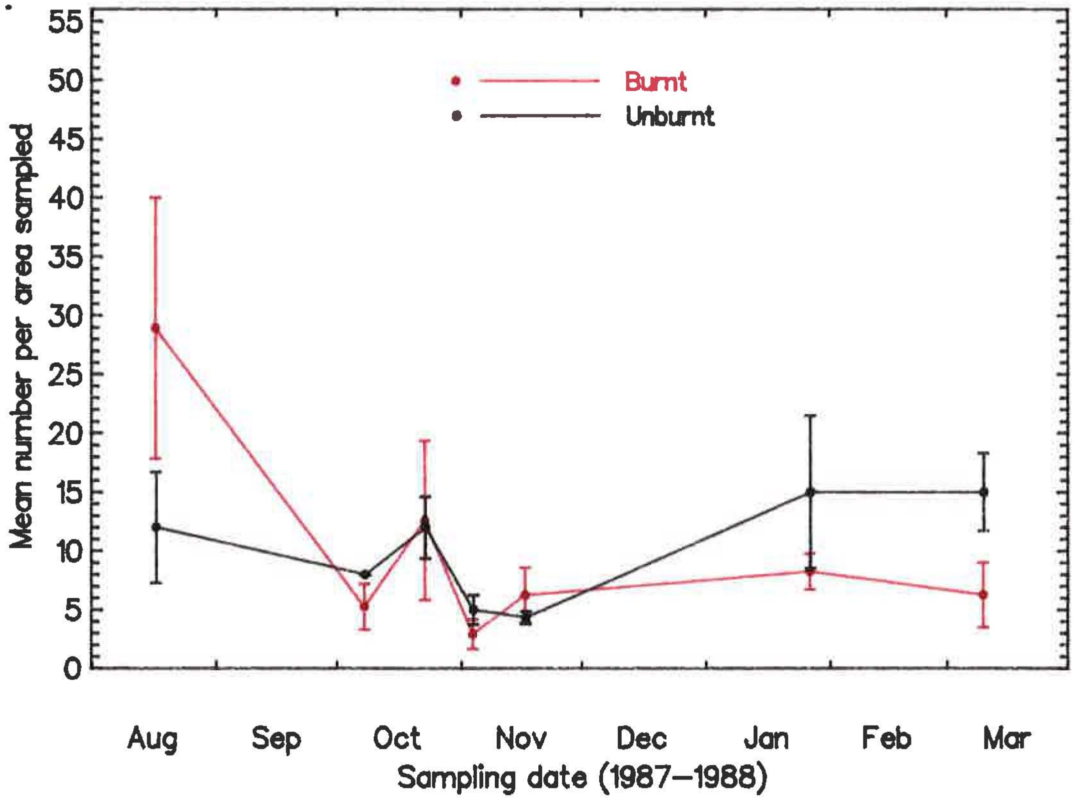
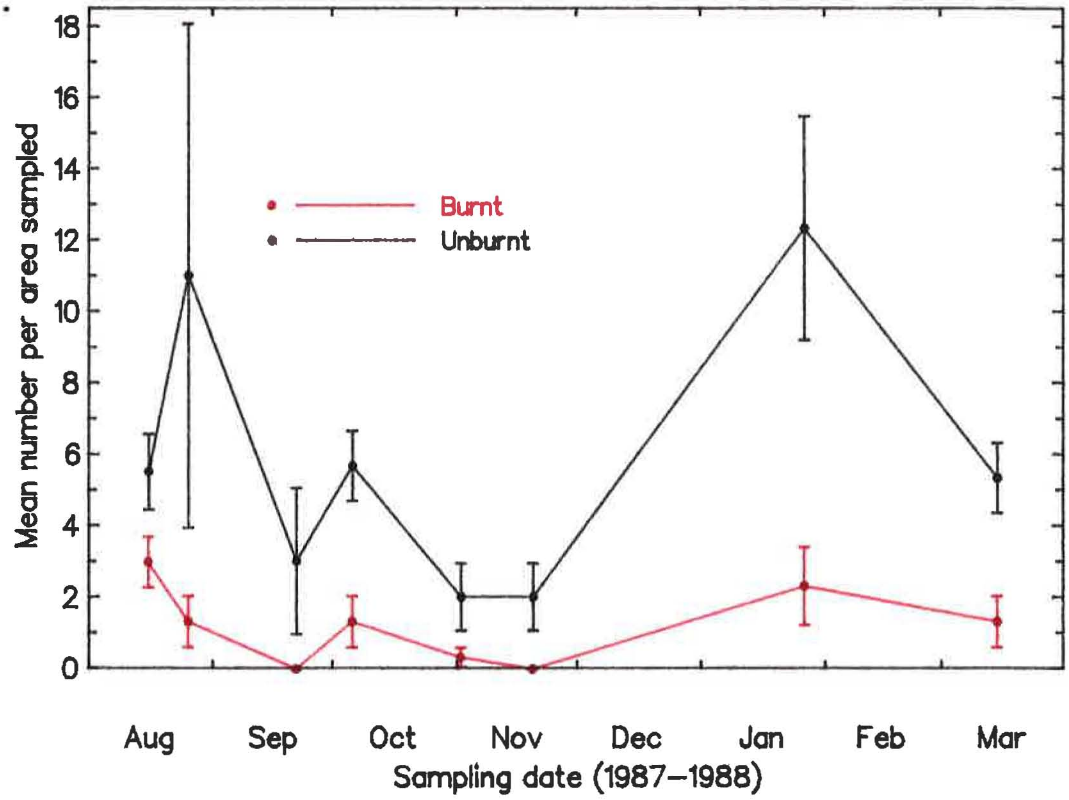


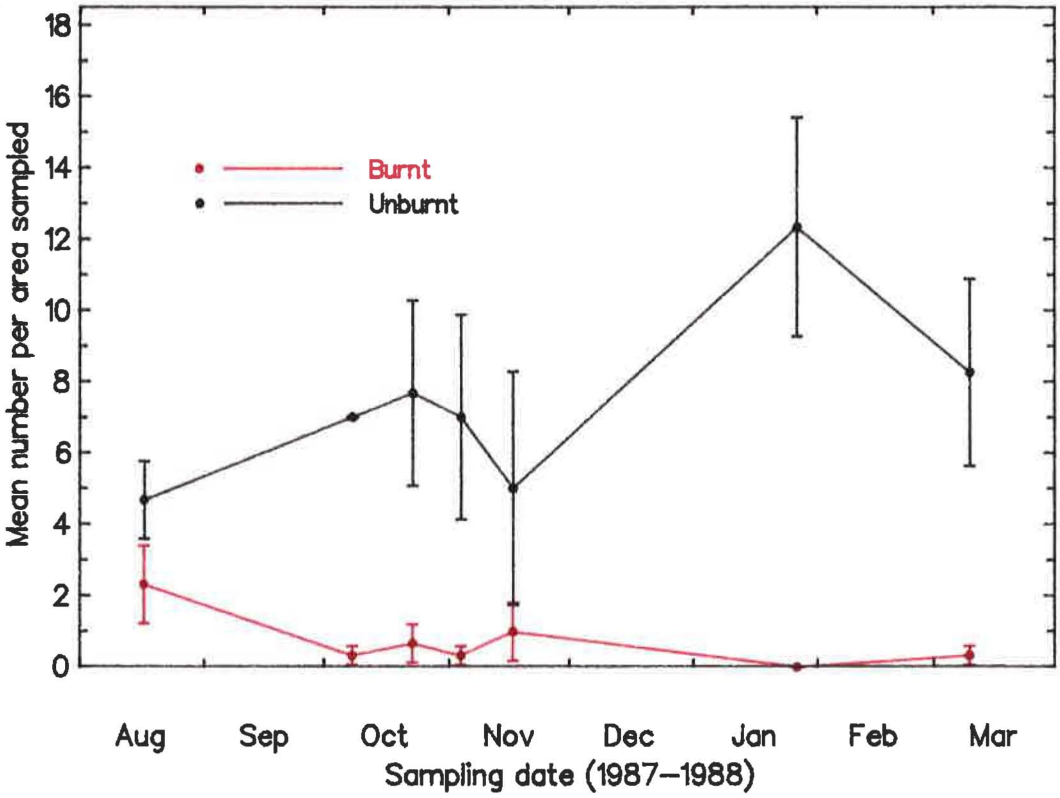
Figure 12: Mean number of Corylophidae (Holopsis sp.) per 1.8 m^2 turf against time.

1. Burgun Run
2. Stonehurst

1.



2.



Centipedes (Fig. 13)

Similar trends were shown for the centipede populations at both sites. Their numbers increased immediately following burning then declined to a significantly lower level than the unburnt controls. At the Burgun Run higher numbers than expected in the burnt turf contributed to the significant chi-square value (22.9.87. 6.10.87. 2.11.87).

Niceana cinerea **(Fig. 14)**

This species only occured with regularity at the Stonehurst site. It was dramatically reduced by burning and did not recover throughout the study.

Irenimus **sp.3 (Fig. 15)**

The populations of this species of weevil were reduced to levels significantly below those in unburnt samples where they remained for the duration of the study at the Stonehurst site. At the Burgun run there was no significant difference in populations immediately following burning, but the numbers in the September to December samples were significantly reduced. More *Irenimus* sp.3 than expected contributed to the significant chi-square value obtained on 27.1.88. and 15.3.88.

Lepidoptera larvae (Fig. 16)

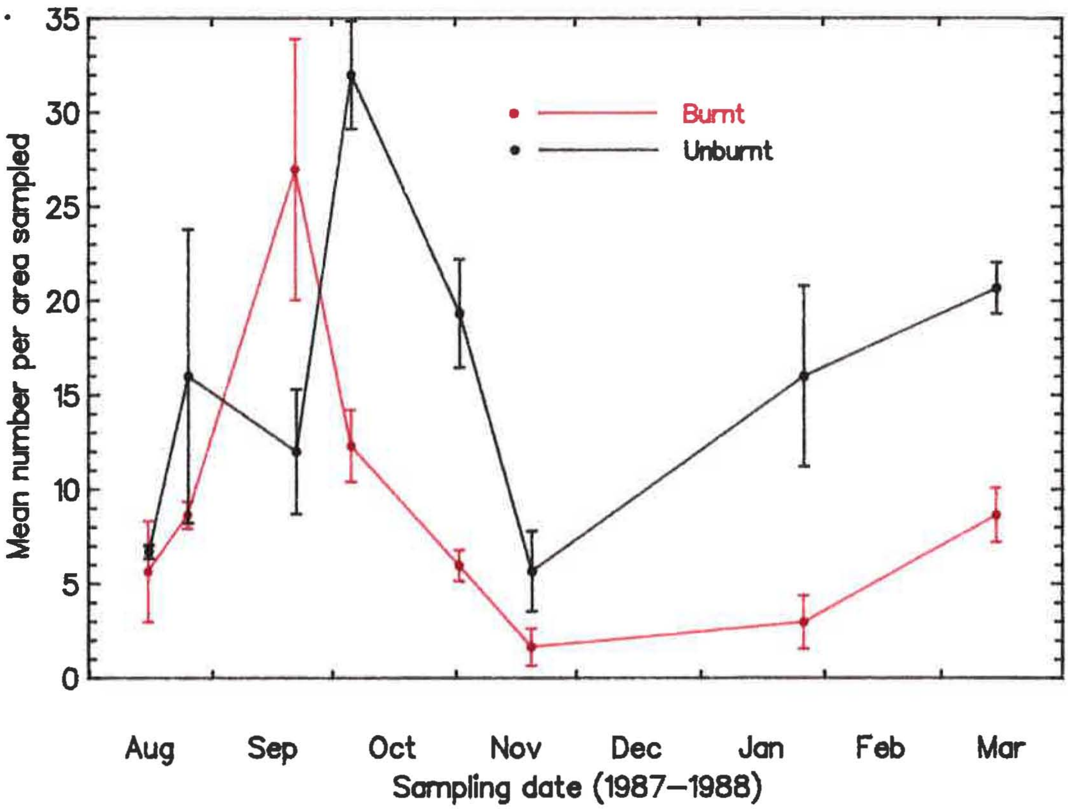
These indicators did not appear to be as severely reduced by burning as some of the other indicator groups. Following an initial decline at the Burgun Run their numbers were not significantly different to those on the unburnt area until January when there was a dramatic peak in numbers in the latter.

Stonehurst showed a larger number of lepidoptera larvae present than expected from the chi-square value immediately after burning coupled with a lower number than expected on the unburnt area.

Figure 13: Mean number of centipedes per 1.8 m^2 turf against time.

1. Burgun Run
2. Stonehurst

1.



2.

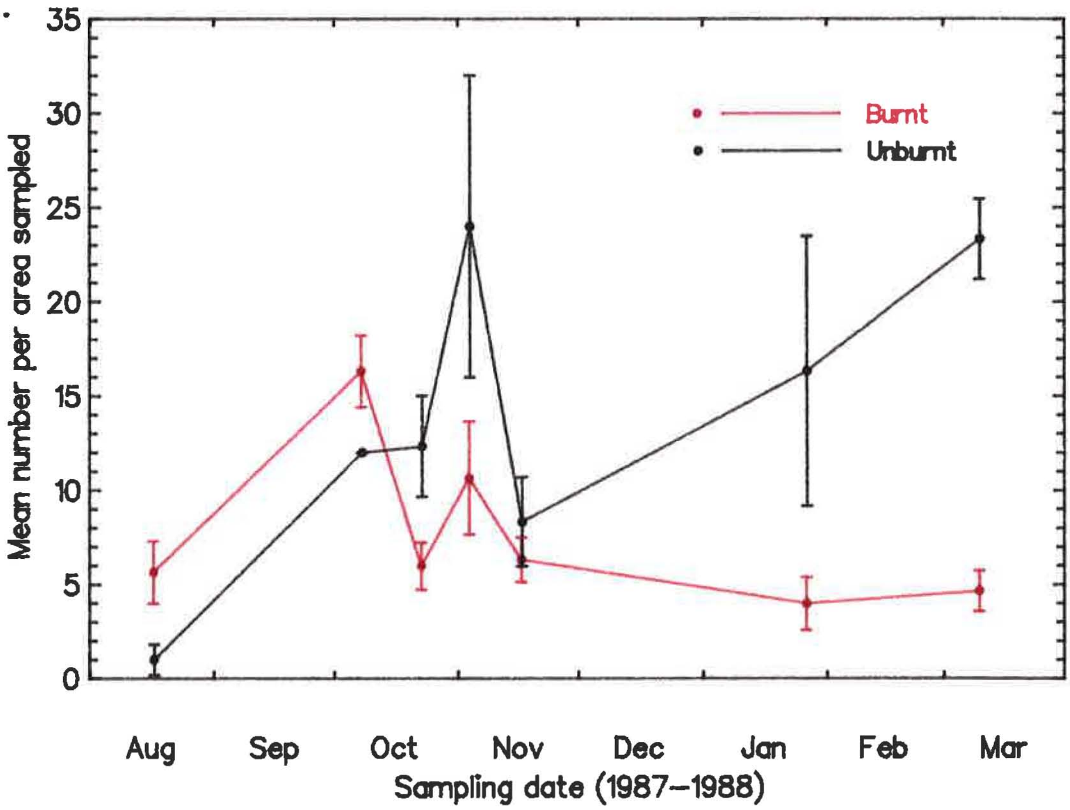


Figure 14: Mean number of Niceana cinerea per 1.8 m^2 turf against time.

Stonehurst

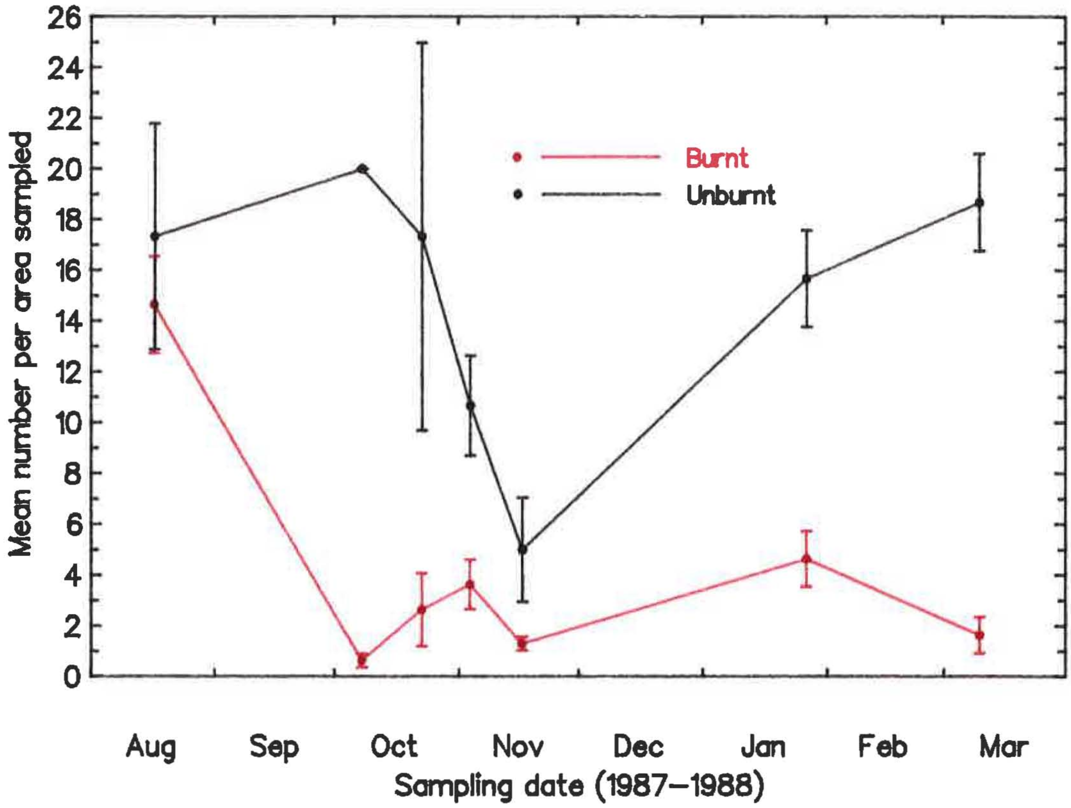
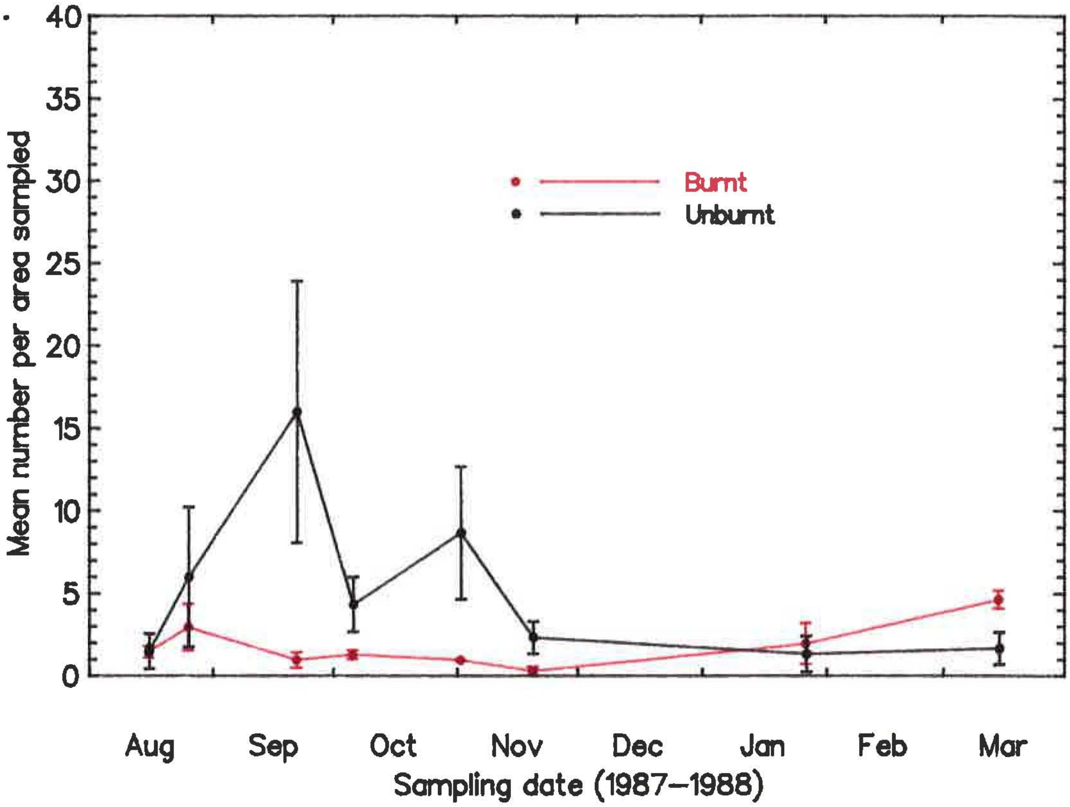


Figure 15: Mean number of <u>Irenimus</u> sp. 3 per 1.8 m^2 turf against time.

1. Burgun Run
2. Stonehurst

1.



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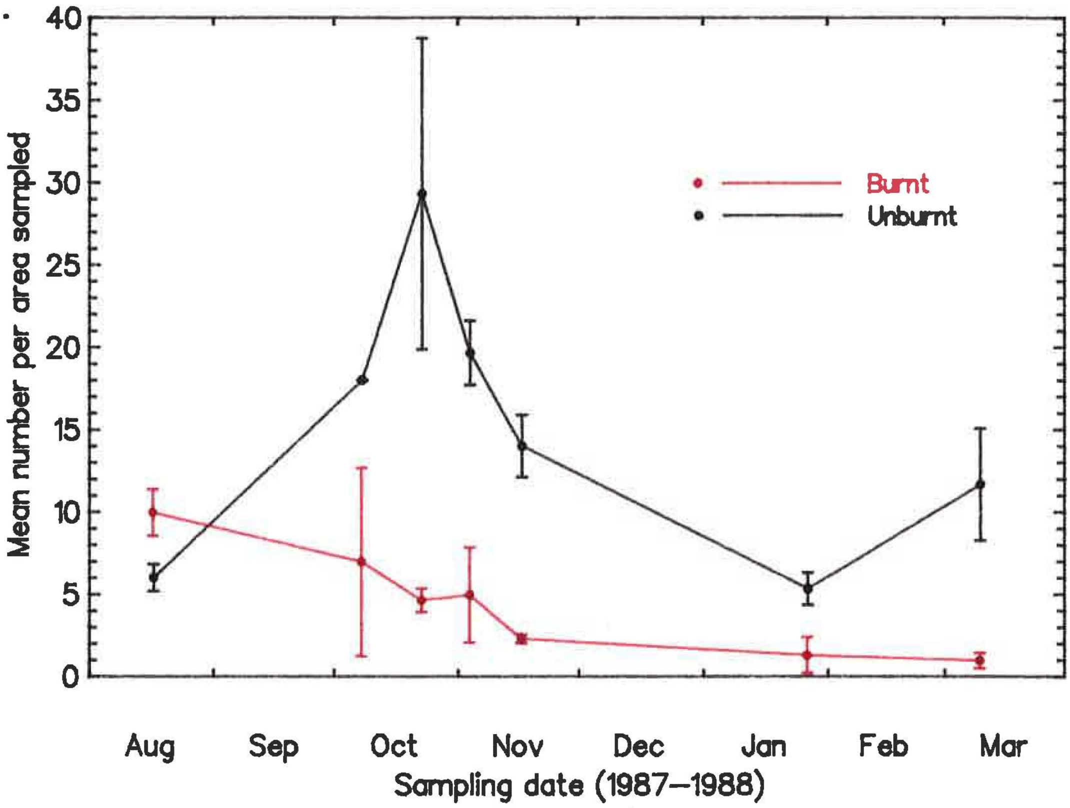
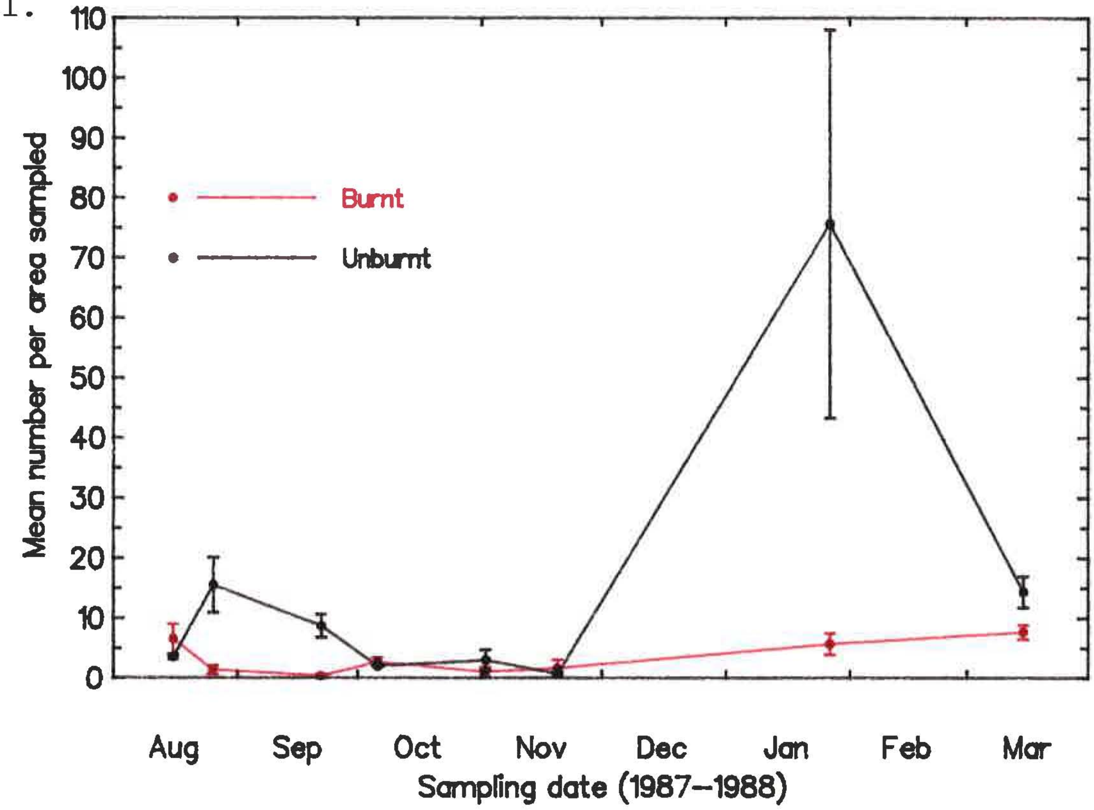


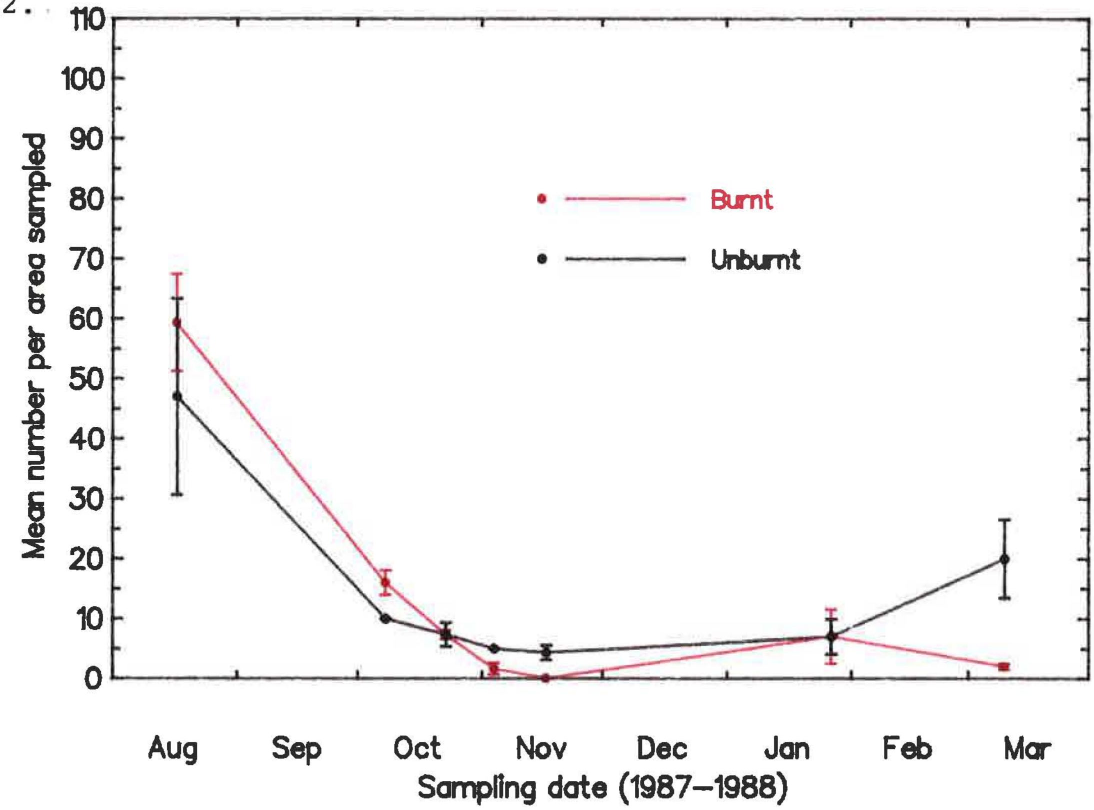
Figure 16: Mean number of Lepidoptera larvae per 1.8 m^2 turf against time.

1. Burgun Run
2. Stonehurst

1.



2.



Effects of burning on the indicator food-type groupings (Table 4)

Burgun Run - Lower numbers of herbivores in the burnt samples were a major contributing factor to the significant chi-square value obtained in the two post-fire samples. Lower numbers of detritivores in the burnt area were significant in the January and March samples. There was a consistently higher number of predators on the burnt area than expected in all the post-fire samples.

Stonehurst - As at the Burgun Run there were higher numbers of predators present on the burnt area after burning than expected. However, there were greater numbers of this group present in the burnt than unburnt area in the pre-fire samples which may account for the higher numbers than expected after burning.

Lower numbers of herbivores and detritivores on the burnt area were factors contributing to the significant chi-square values from November to March.

DISCUSSION

It can be clearly seen that burning of the tussock grasslands in spring significantly reduced the number of species present in both the tussock and intertussock habitats. The total number of individuals present in the burnt area was also significantly reduced below levels on comparable unburnt areas. This obviously results in a less diverse and much depleted fauna after burning. From a conservation point of view this is an important factor to be considered when examining the burning issue. Areas of sub-alpine tussock grassland on the Rock and Pillar Range have been identified in a recent Pastural Lands Assessment survey as being potential reserve areas. The information obtained here on the general short term depletion of the fauna caused by burning may prove useful to the Department of Conservation when arguing the case for conserving the native grasslands of the area.

It is not possibe to determine from this study the length of time required for the species numbers and the total numbers of individuals to recover to pre-fire levels, if indeed they do. This time scale has important implications for conservation. Sufficient time must be left between successive burns to allow recovery of the fauna and prevent extinction of the rarer species. Unfortunately, the methods of sampling and the statistical analyses of the data were not sufficiently detailed to provide information on the effect of burning on species of limited distribution.

Table 4: EFFECT OF BURNING ON INSECT FOOD-TYPE GROUPINGS

Contingency tables set as shown below (d.f. = 3 for each chisquare test)

	Total number of invertebrates			
	Predators	Herbivores	Detritivores	Scavengers
Burnt				
Unburnt				

H_0: No relationship between row and column classification

Burgun Run

Date	Chisquare value	Probability
16.8.87 (Pre-burn)	26.35[1]	p<0.005 ***
26.8.87	4.13	0.25>p<0.10 ns
22.9.87	19.04[2]	p<0.005 ***
6.10.87	7.22[3]	0.10>p>0.05 ns
2.11.87	42.74[4]	p<0.005 ***
20.11.87	56.51[5]	p<0.005 ***
27.1.88	23.08[6]	p<0.005 ***
15.3.88	52.03[7]	p<0.005 ***

1 Lower numbers in the 'Unburnt Detritivores' cell are a major contributing factor
Higher numbers in the 'Burnt Detritivores' cell are also a contributing factor

2 Lower numbers in the 'Burnt Herbivores' cell are a major contributing factor
Higher numbers in the 'Burnt Predators' cell are also a contributing factor

3 Lower numbers in the 'Burnt Herbivores' cell are the single largest contributing factor

4 Higher numbers in the 'Burnt Predators' cell are a major contributing factor
Lower numbers in the 'Burnt Detritivores' cell are also a contributing factor

5 Lower numbers in the 'Burnt Detritivores' cell are a major contributing factor

Higher numbers in the 'Burnt Predators' cell are also a major contributing factor

Higher numbers in the 'Burnt Herbivores' cell are also a major contributing factor (but expected value < 5.0)

[6] Higher numbers in the 'Burnt Predators' cell are a major contributing factor

Lower numbers in the 'Burnt Detritivores' cell are also a major contributing factor

[7] Higher numbers in the 'Burnt Herbivores' cell are a major contributing factor

Lower numbers in the 'Burnt Detritivores' cell are also a major contributing factor

Table 4 (continued):

Stonehurst

Date	Chisquare value	Probability
17.8.87 (Pre-burn)	101.68[1]	$p<0.005$ ***
8.10.87	43.64[2]	$p<0.005$ ***
23.10.87	97.47[3]	$p<0.005$ ***
4.11.87	13.39[4]	$p<0.005$ ***
17.11.87	18.99[5]	$p<0.005$ ***
27.1.88	77.74[6]	$p<0.005$ ***
10.3.88	236.58[7]	$p<0.005$ ***

[1] Higher numbers in the 'Burnt Predators' cell are a major contributing factor
Lower numbers in the 'Unburnt Predators' cell are also a major contributing factor
Lower numbers in the 'Burnt Scavengers' cell are also a major contributing factor
Higher numbers in the 'Unburnt Scavengers' cell are also a major contributing factor

[2] Higher numbers in the 'Burnt Predators' cell are the major contributing factor
Lower numbers in the 'Unburnt Predators' cell are also a major contributing factor

[3] Higher numbers in the 'Burnt Predators' cell are the major contributing factor
Lower numbers in the 'Burnt Detritivores' cell are also a major contributing factor
Lower numbers in the 'Unburnt Predators' cell are also a major contributing factor

[4] Lower numbers in the 'Burnt Herbivores' cell are the major contributing factor
Higher numbers in the 'Unburnt Herbivores' cell are also a major contributing factor

[5] Lower numbers in the 'Burnt Herbivores' cell are a major contributing factor
Higher numbers in the 'Burnt Predators' cell are also a major contributing factor

Table 4 (continued):

[6] Higher numbers in the 'Burnt Predators' cell are the major contributing factor
Lower numbers in the 'Burnt Detritivoress' cell are also a major contributing factor

[7] Higher numbers in the 'Burnt Predators' cell are the major contributing factor
Lower numbers in the 'Burnt Detritivores' cell are also a major contributing factor

All 12 indicator groups showed a decline in numbers following burning but not all were equally affected. Amphipods appeared to be more severely reduced in numbers than the other groups. This could be due to their requirement for a humid environment. The tussock plant provides this microclimate prior to burning but when the tillers are removed and the base exposed to dehydration the amphipods may suffer considerably. The burning also removes the decaying litter material which is a food source for these creatures.

Spiders showed an initial decline in numbers following burning at each site but recovered their populations more rapidly than the other indicator groups. This could be due to their high mobility and fecundity. *Lycosa hilaris* females carry their offspring on their abdomen which would be a means of transport into the burnt area for these otherwise delicate life-stages.

The populations of each indicator group, excluding spiders in tussock at Stonehurst and *Irenimus* sp.3 at the Burgun Run, did not recover to the levels of the unburnt control areas by the end of the study. This inability to regain population numbers following a burn may be due to slow recolonisation by many species. This would appear likely for the smaller, less mobile creatures such as the tiny Holopsis species, Pselaphids,and amphipods. Lepidoptera, Orthoptera and carabid beetles were not sampled in this study , but it might be expected that they would be able to recolonise burnt areas more rapidly due to their high mobility. The numbers of Lepidoptera larvae present after burning did recover to near unburnt levels possibly due to adults moving into sites after burning.

Slow population recovery may also be due to the alteration of the habitat and microclimate in a burnt area. The time between removal of the vegetation by the fire and initiation of new spring growth will be important for survival of herbivorous species. Here the timing of the burn appears significant. A later spring burn will reduce the period when species have to compete for the resources available. Not only does fire reduce the food sources of many species, but it also removes vegetation which had previously offered shelter and protection from predation. In this study it was shown that the predators were not as severely affected by the fire as the other trophic levels. A short period of time between burning and regrowth of the tussock could prove important to survivorship of many species.

Since a large proportion of the fauna overwinter in the tusssocks, burning may increase winter mortality by reducing the thermal protection afforded by these plants. It is recognised that tussock cover prevents the formation of soil ice crystals

(Gradwell, 1954). The effects of a winter on the fauna in a burnt environment was not demonstrated in this study since no samples were taken after March.

There has been interest in the effect of burning on the populations of potential pest species in relation to oversowing native grasslands following burning. Dean, Barratt and Johnstone (1986) observed an increase in the numbers of broad-nosed weevils present following a fire. This present study does not confirm those findings. In this case the numbers of *Niceana cinerea* and *Irenimus* sp.3 were found to be reduced by burning and remained at lower numbers for the duration of the study. However, the burn in Dean, Barratt and Johnstone's study occurred in late spring. This may have altered the survivorship of the weevils in several ways. Firstly, the majority of weevils would have moved out of their overwintering habitat in the tussocks and be active in the intertussock vegetation later in the spring. Secondly, the burn itself was not severe and did not consume any of the intertussock vegetation (Bremner, pers. comm.). The weevils may therefore have escaped the direct fire effects. The two burns carried out in this study occurred in early to mid spring and were more severe, completely removing all tussock cover and much of the intertussock vegetation. It therefore seems likely that many of the species were still present in their overwintering sites in the tussocks and suffered direct incineration.

The results of this study indicate that a spring burn may reduce populations of potential pest species, but that this management practice also has a severe impact on the total invertebrate fauna.

This study is only very preliminary, although certain trends have been identified regarding the immediate effects of burning on the invertebrate fauna. More detailed work is required to determine how long the fauna takes to recover, how this recovery actually takes place, and whether the time of burning in the spring alters the impact of this disturbance on the invertebrate fauna.

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APPENDIX

Species list of invertebrates identified from turfed tussock samples collected on the Bergun and Stonehurst runs, East Otago Plateau

Order	Family	Species
Diplopoda		
Chilopoda		
Amphipoda	Talitridae	*Orchestia* sp.
Aranaeomorpha	Lycosidae	*Lycosa hilaris*
	Salticidae	
	Unidentified sp.	
Chelonethi	Cheliferidae	*Philomaoria pallipes*
Opiliones	Triaenonychidae	*Nuncia obesa*
		Algidia marplesi
Dermaptera	Labiduridae	*Parisolabis* sp.
Dictyoptera	Blattidae	*Parallepsidion inaculeatum*
Hemiptera	Cicadellidae	*Kikihia augusta*
	Schizopteridae	Schizopterid sp.
	Nabidae	*Nabis maoricus*
	Tingidae	*Cyperobia carectorum*
	Lygaeidae	*Hudsona anceps*
		Nysius huttoni
		Metagerra truncata
		Udecoris laevis
	Pentatomidae	*Cermatulus nasalis*
		Dictyotus caenosus
Coleoptera	Carabidae	*Holcaspis placida*
		Holcaspis ovatella
		Agonum otagoense

	Demetrida moesta
	Scopodes edwardsi
Leiodidae	*Isocolon* sp.
	Mesocolon sp.
Scydmaenidae	*Sciacaris* cf. *fragilis*
Pselaphidae	Various species
Scirtidae	*Cyphon* sp.
Byrrhidae	*Epichorius* sp.
Elateridae	Various species
Languriidae	"Genus1" *anthracinus*
Corylophidae	*Holopsis* sp.
Coccinellidae	*Coccinella leonina*
	Coccinella undecempunctata
	Stethorus sp.
	Adoxellus sp.
Lathridiidae	*Corticaria formicaephila*
Colydiidae	*Pristoderus* sp.nr. *discoidens*
Tenebrionidae	*Pheloneis* sp.
Chrysomelidae	*Chaetocnema nitida*
	Chaetocnema sp.aff. *littoralis*
	Adoxia sp.
	Allocharis sp.
Curculionidae	*Bryocatus amplus*
	Bryocatus sp.
	Eugnomus durvillei
	Eugnomus dispar
	Gromilus sp.
	Nestrius sp.
	Catoptes sp.
	Niceana cinerea

	Irenimus sp.1
	Irenimus sp.2
	Irenimus sp.3
	Sitona discoideus
Lepidoptera	Various species (larvae)