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WORLD WIDE FUND FOR NATURE AUSTRALIA PROGRESS REPORT NO. 7

A. Project No and Title

P199: Conservation of Jarrah Forests in WA - the Impact of Prescribed Burning.

B. Report Type

Progress Report No. 7, 28 August, 1996.

C. Authors of Report

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D. Collaborators

Western Australian Museum, Perth.

E. Objectives of Project

a) To examine the effects of spring and autumn prescribed burns on the terrestrial invertebrate fauna (particularly beetles, spiders, wasps and flies) of *Eucalyptus marginata* forests.

b) To compile information on abundance, habitat preferences and life history strategies of the major invertebrate groups, and examine trends in species composition of selected groups (eg. beetles, spiders, wasps and flies).

c) To use data to refine existing guidelines for fire regimes in Jarrah forests.

F. Research Methodology

The work adopts an experimental approach and is being carried out in the Batalling and Nundedine Forest Blocks, 35 km east-north-east of Collie. Six areas, each about 1500 ha, are being sampled six times each year (twice in spring, summer and autumn), with two sampling sites within each area. Two of these areas were burnt in spring 1994, a further two were burnt in autumn 1996, and the remaining two areas will be left as unburnt controls. Two additional sites (ie. 14 sites total) were established in the Fleays Forest Block south-west of Batalling in November 1992, and prescription burnt in autumn 1993. The two controls in the Batalling area were also established in November 1992, while the remaining 10 sites were established in the summer of 1994.

Each sampling site comprises a 15 x 15m grid of 16 pitfall traps (cups 90mm diameter and 110 mm deep) in a 4x4 array at 5m spacing . When operational, traps are 3/4 filled with Galt's solution (preservative) and left open for 10 days. Traps are bulked by four to give four samples per sampling session. Forest structure and habitat parameters which may be of relevance to terrestrial invertebrates (eg. litter depth and cover, understorey height and cover) are being quantified on each site before and after burning. Climatic data, especially rainfall, will also be gathered for the Batalling area.

G. Summary of Work to Date

a) Invertebrate sampling in the two autumn burnt sites (13 & 14) in the Fleays area and two control sites (3 & 11) in the Batalling area took place in November 1992, February 1993, May 1993, June 1993, October 1993, April 1994 , June 1994, August 1994, November 1994, February 1995, March 1995, May 1995, July 1995, September 1995, November 1995, January 1996, March 1996, May 1996 and July 1996.

b) The eight remaining sites in the Batalling area have now been sampled in March 1994, June 1994, August 1994, November 1994, February 1995, March 1995, May 1995, July 1995, September 1995, November 1995, January 1996, March 1996, May 1996 and July 1996.

c) The four autumn 96 burn sites were prescribed burnt on 29 & 30 April 96. A natural experimental design developed with sites 1&2 being burnt at a lower intensity, during the night of the 29th while sites 7&8 were burnt at much higher fire intensities during the day on the 30th. A principal descriptor of fire impact and intensity is the Leaf Scorch Height

which generally did not exceed 2.5m to 3.5m at sites 1&2, while Leaf Scorch Height at sites 7&8 varied from 2.5m to total crown scorch at 25m high in the co-dominant jarrah crowns. Therefore, this favourable situation gave us an opportunity to study the impacts of varying intensities of prescribed autumn fires on the invertebrate community and jarrah forest floor microhabitats (refuge and preferred habitats).

d) Various habitat parameters (litter cover, depth and leaf species; log and large branch size and locations; moss sward area and locations; density of dominant shrubs in flower; spider web types and height in vegetation) continue to be measured and monitored at all sites.

Habitat Structure:

Regrowth of vegetation:
The height recovery of all common species of tree saplings and large understorey shrubs below the height of 2m will be graphically summarised in the December 96 or the final report. My impression to-date is that most understorey shrub species of burnt sites recover to pre-fire heights within 1 to 2 years.

Flowering phenology of dominant shrubs:
The density of flowers on dominant understorey shrubs has been monitored for each sample date and will be summarised and correlated to pollinator insect activity at the completion of this study.

Litter Recovery:
Litter depth and cover have been measured at each of the 16 pitfall traps for all 14 sites. Litter depth and cover was measured in August 94 at the commencement of the study and in the following 2 autumns of March 95 and March 96. Litter depth was measured as height in millimetres from mineral soil to the upper surface of the leaf litter. Litter cover was estimated within a 30cm x 30cm square quadrat adjacent to each pitfall trap and recorded using the following index of litter percentage cover classes;

0: <1% cover.
1: 1 to 25% cover.
2: 26 to 50% cover.
3: 51 to 99% cover.
4: 100% <3cm thick.
5: 100% >3cm thick.

Results from the most recent measurement of litter depth in March 96 indicate that both the autumn 93 burnt sites and the spring 94 burnt sites have built-up mean litter depths to similar mean depths as the control sites (Figure 1). The Autumn 96 mean litter depths, for all sites, are as follows; Autumn 93 burnt sites 20.0mm (n=32); Spring 94 burnt sites 18.9mm (n=64); 'yet-to-be-burnt' in Autumn 96 sites 19.6 mm (n=64) and long unburnt Controls sites 20.2mm (n=64). However the autumn 93 burnt sites have taken 36 months to accumulate to control site litter depth, while the spring 94 burnt sites have accumulated litter to control site depths in only 16 months. This more rapid recovery of litter depth by the spring burnt sites may be due to several factors. Firstly prescribed burning in spring under wetter soil moisture conditions may reduce the combustion loss of the highly decomposed litter or humus layer, and therefore reduce the initial loss of litter depth in these spring burnt sites.

Alternatively, the huge spring 94 and spring 95 increase in the abundance of litter decomposing springtails (Collembola) following the prescribed fire at the autumn 93 burnt sites may have indicated a marked increase in the decomposition rate of the accumulating litter fall, which could have slowed down the build-up of litter depth.

Unlike the litter depth results, the most recent measurements of litter cover, in March 96 suggest that litter cover on both unburnt and burnt sites is quite patchy and has only recovered to half the control site values . The median Litter Cover Class for each fire treatment in March 96 is as follows; Control sites 51 to 99% cover, Autumn 93 sites 26 to 50% cover, Spring 94 sites 26 to 50% cover and 'yet-to-be-burnt' Autumn 96 sites 26 to 50% (see Figure 2). These results indicate that initially there were pre-fire differences in litter cover between sites as the unburnt autumn 96 fire sites had a low median cover class of 26 to 50% as compared to the median cover class of 51 to 99% of the similarly unburnt control sites. The varying density of trees may have a marked influence on the patchiness of leaf litter cover at each site.

Preferred & Refuge Microhabitats :

A number of rare or relict invertebrate species in south west Australia are thought to be dependent on restricted forest floor microhabitats as refuges from fire and harsh environmental conditions. Several of the better studied species include the Midget spiders such as those from the family of Micropholcommatidae which are thought to be dependent on the moss swards on the floor of the jarrah (*E. marginata*) forest for breeding sites. Another of the better known relict spider species is the tiny Lungless spider (*Chasmocephalon sp.*) that constructs minute orb webs in the ends of fallen logs or burnt-out hollow butt trees in the relict Tingle forest (*E. guilfoylei* and *E. jacksoni*) on the extreme south coast of Western Australia. Both these spider taxa illustrate the dependence of a number relict invertebrates on restricted microhabitats that may be created or destroyed by periodic fire or act as refuges during these fires.

Also our earlier pilot BACI analysis of the first 24 months of invertebrate abundance data indicated that some of the more common apterous invertebrates which have low dispersal powers, such as silverfish (Thysanura), woodlice (Isopoda) and centipedes (Chilopoda) survived the spring 94 fire in high numbers. These taxa survived possibly using logs as refuges from the spring fire. Also during the recent autumn 96 fires I observed escaping litter invertebrates using both the cracks in logs and the insulated leaf litter under them as shelter. Therefore logs may be an important microhabitat or refugium from harsh environmental conditions such as periodic fires or seasonal summer and autumn drought.

Therefore I have mapped all 14 sites to determine which forest floor microhabitats are the most restricted in area, their potential as fire refugia, and, also, to determine the role of fire in their creation or destruction. I have mapped the non-living physical structures of the 225 sq.m. area of each of the 14 sites at approximately 2 monthly intervals. The area maps of the 14 sites could be divided broadly into 9 groups of non-living physical structures on the jarrah forest floor that could possibly act as refuges during fire. The 9 broad microhabitat types recognised are as follows; 1) Bare soil; 2) Unburnt litter; 3) Burnt litter; 4) Rocks (>5cm diameter); 5) Logs & branches; 6) Log ashbeds; 7) Dead stumps; 8) Burnt-out stump holes and 9) Termite mounds. Also, since moss swards have been previously identified as possible important microhabitats for relict taxa, such as the micropholcommatid spiders, in the south west forests (Main,1987). I have, therefore, focused specifically on the extent and survival of moss swards (*Funaria hydrogrammetrica*) in the above 9 broad forest floor refuge microhabitats types.

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The role of prescribed fires in the creation or destruction of these refuges or microhabitat types was studied by comparing the changes in microhabitat areas mapped 2 months prior to the spring 94 and autumn 96 prescribed fires with the areas of microhabitats mapped 2 months after these prescribed fires, and also concurrently with the unburnt control sites.

The results of the refugia-microhabitat mapping (see Table 1) indicate (at this pre-statistical analysis stage) that the 9 forest floor microhabitats and their associated moss microhabitats can be ranked in a similar order, by percentage area, for each of the four fire treatment groups.

Rocks:
The most restricted of the microhabitats types was the surface of large rocks which generally occupied less than 0.07% (1575 sq.cm. per site) of the area of any of the groups of sites. The upper surfaces of lateritic rocks, which partly protrude above the covering soil, are an harsh microhabitat with relatively few cracks and fissures to act as environmental refuges, particularly in summer months, and only at the post-fire autumn 93 sites did moss colonise rock surfaces and then only with a trace mean percentage area of 0.01% (225 sq.cm. per site) of the sites.

Termite Mounds:
The next most restricted microhabitat was the surface of termite mounds (*Nasutitermes sp.*), another harsh microhabitat with little potential as a source of environmental refuges, which generally occupied less than 0.07% of the area of sites . Termite mounds colonised by moss occupied 0.03% (675 sq.cm. per site) of the area of both pre and cool post burnt autumn 96 sites 1&2.

Stump Holes:
Shallow stump holes, in the surface of the ground created by the partial or complete burning of dead tree stumps and their underground root systems, were the third most restricted microhabitat type with a general percentage area of equal to or less than 0.17% (3825 sq.cm. per site) of the area of all sites. The post autumn 93 burnt sites 13&14 were the only sites to have stump holes colonised by moss at 0.02% (450 sq.cm.per site) of the area, which is an unexpected low result, as the combustion of the stump wood produces a nutrient rich ashbed in the bottom of the hole. Also unburnt upright portions of stumps create a more sheltered environment. These conditions would seem to favour moss colonisation.

Dead Stumps:
The deep sheltered cracks and holes burnt in the root systems of stumps by previous fires could, also, act as important refuges for invertebrates during times of seasonal temperature and water stress and also during the acute impact phase of periodic fires. Dead stumps occurred at the majority of sites but were very restricted with a mean percentage area of less than or equal to 0.4% (9000 sq.cm. per site). Dead stumps were colonised by moss prior to the prescribed fires with a mean percentage area of 0.01% (225 sq.cm. per site) at four of the sites. Two months after the prescribed fires the area of stump moss had expanded three fold to a mean percentage area of 0.03% (675 sq.cm. per site), possibly due to increased moss colonisation of nutrient rich ashbeds created by the burning of these stumps. This is also supported by the fact that the area of dead stumps at these sites was reduced by approximately one quarter to 0.18% (4050 sq. cm per site) mean area, as a result of a small number of the dead stumps partially or completely burning to create stump holes.

Moss at the base of tree trunks:

At the base of the trunks of live jarrah (*Eucalyptus marginata*) and marri (*Eucalyptus calophylla*) trees there is often a small bare patch of soil that seems to be protected from the accumulation of leaf litter. This small bare patch provides a favourable microhabitat that is often colonised by small moss swards, particularly on the shaded southern side of the trunk. As live trees are abundant at all sites, this trunk moss microhabitat is widespread, occurring fairly evenly across all sites and therefore maybe a readily available refuge for relict invertebrates. The size of these moss swards is often quite small and hence the low combined mean percentage area of 0.03% (675 sq.cm. per site) for all the pre-fire spring 84 and autumn 96 sites. After the spring 84 and autumn 96 prescribed fires the combined mean percentage area for all these sites had increased to 0.04% (900 sq.cm. per site). However this was not consistent across all prescribed burnt sites, as both the cool and hot spring 84 sites had post-fire decreases in the area of this microhabitat, while the hot autumn 96 burnt sites had a doubling in the area of this microhabitat. I can only speculate at the reasons for the variable fire impacts between the spring burnt and autumn burnt sites, but one explanation is that at the time of the spring 84 fire the moss was still partly green and not yet fully dried out for its summer dormancy and so may have been more susceptible to damage from the radiant heat of the fire front. In contrast, I observed at one of the high intensity autumn 96 burnt sites, that several of the brown and dry moss swards had not been burnt, despite this being the most intense of the all the fires. As these dry swards at the base of each tree trunk were all surrounded by a small bare patch of gravel they remained unburnt in obvious contrast to the burnt and blackened leaf litter surrounding them. One month later these unburnt moss swards were sprouting many new green shoots in response to the autumn rains. The release of nutrients from the surrounding burnt litter may have also stimulated an increase in size of these trunk swards. The widespread survival of these trunk mosses highlights the importance of these small patches of microhabitat as refuges during high intensity fires.

Logs & Fallen Branches:
Logs and fallen branches is a broad microhabitat type that contains many refuges of extreme importance to both invertebrate and vertebrate species in the jarrah forest community. The relict mygalomorph spider (*Chenistonia villosa*), for example, unlike other burrowing species of this genus constructs silk tubes under logs, as well as in bark and moss (Main,1987). Refuges created by logs, that are available to surface active invertebrates, include unshed bark, old borer galleries, cracks, long heartwood hollows and unburnt litter under or behind the overhanging sides of logs. I have frequently observed quite small dead branches (approx. 3 cm. diameter) with strips of unburnt litter protected under them following the Batalling prescribed fires.

Prior to the spring and autumn prescribed burns this microhabitat only occupied a small percentage of the total area of each site, ranging from a mean percentage area of 4.58% at the control sites to 0.54% at the pre-burn spring 94 sites. Although the range of mean percentage areas of the log and branch microhabitat is quite small relative to the total area of each site, there are large pre-fire differences in the area of this microhabitat between sites. Therefore it is important to compare relative post-fire changes in the area of this microhabitat at each site, and not compare absolute post-fire changes between sites of different fire treatments.

In general cool and hot spring 94 fires resulted in no change in the mean percentage area of the log and branch microhabitat. However, the cool autumn 96 prescribed fire resulted in an approximate one tenth net reduction in the area of logs and fallen branches to a post-fire mean percentage area of 3.06% (68,850 sq.cm. per site). The hot autumn 96 fire, also, resulted in an approximate one half net reduction in the area of this microhabitat to a post-fire mean percentage area of 2.74% (61,650 sq.cm. per site).

It is important to note that resulting post-fire area of the log and branch microhabitat at each site is the net result of the dynamic process of prescribed fires both creating new logs and fallen branches due to dead and damaged lives trees burning down and, while also, partially reducing previously fallen logs and tree branches to ashbeds. The log and branch microhabitat is an important refuge to surface active invertebrates, which is in relatively short supply. The availability of this refuge microhabitat is significantly reduced, but only partly eliminated, by autumn prescribed burning under dry soil conditions.

Large logs also create several restricted microhabitats that are more frequently colonised by mosses. The first of these is the charcoaled upper surface of intact logs or the upper surface of large charcoaled fragments of logs, both of which are occasionally colonised by moss . The upper log surface moss microhabitat, only occurred, in measurable quantities at the autumn 96 burn sites, both before and after the prescribed autumn fire. The autumn 96 fires did not reduce the area of this microhabitat at either the cool or hot burnt sites with the mean percentage area remaining at 0.02% (450 sq.cm. per site) for all sites.

Moss under logs:
The second microhabitat often created by large logs is the patches of shaded bare soil directly under these logs, where long sections are raised up off the soil surface. These shaded patches of bare soil are not uncommonly colonised by long narrow strips of moss. However, the only two fire treatment groups to contain measurable areas of this microhabitat were the control sites group and the post-fire hot autumn 93 burn sites group with a mean percentage area of moss of 0.09% (2025 sq.cm. per site) for the control sites and 0.2% (4500 sq.cm per site) for the post-fire hot autumn 93 burn sites. Since no pre-fire data are available, for the hot autumn 93 burn sites on the extent of moss swards under logs, it is difficult to assess the impact of this intense prescribed autumn fire on the extent of this microhabitat. However, because the autumn 93 burnt sites have the highest mean percentage area at 0.2%, it appears that the high intensity of this fire did not reduce the distribution of this microhabitat type relative to the the unburnt control sites. Release of nutrients from the hot autumn fire may have increased the extent of the colonisation by mosses of this microhabitat under large fallen logs.

Log Ashbeds:
The results of the impact of fire on the extent of the "Log and Branch" microhabitat indicates that autumn prescribed fires reduced the area of this microhabitat to one half of its pre-fire area. However, the partial loss of this microhabitat by the combustion of logs resulted in the creation of long narrow nutrient rich ashbeds. These ashbed microhabitats are extremely important as they support the major area of moss swards found on the jarrah forest floor. The mean percentage area of moss colonised ashbeds after the spring 94 and autumn 96 prescribed fires was 0.29% (6525 sq.cm. per site) which was three quarters of the total area of moss found in all jarrah forest floor microhabitats in this study area. The "Log and Branch" microhabitat, in contrast, is approximately ten times more extensive in area than these moss colonised ashbeds, even following the autumn 96 prescribed fires, which reduced the mean percentage area of the log microhabitats at all spring 94 and autumn 96 sites to 2.79% (62,775 sq.cm. per site). Therefore the autumn prescribed fires play an important role in maintaining the dynamic balance between the important but spatially restricted moss ashbed microhabitats and the log microhabitats that are relatively far more widespread. This is particularly important when the spatially restricted moss microhabitats are important breeding or refuge sites for relict invertebrates.

Bare Ground:
In the jarrah forest there are patches of bare soil or lateritic gravel that have not been covered by accumulating leaf litter. These litterless patches are created in a variety of ways including the upheaval of soil by up-rooted trees, wind or water erosion on sloping ground or gaps in the overhead tree canopy resulting in little leaf fall. As a result of this lack of litter accumulation, even quite small patches of bare soil may act as refuges from very intense fires. Bare soil, although a harsh microhabitat, particularly during summer and autumn, is preferentially colonised by a number of jarrah forest floor organisms including both common and rare invertebrates such as burrowing mygalomorph spiders, antlion larvae (Neuroptera), burrowing spider-hunting pompilid wasps and also mosses that may act as refugia for other relict invertebrates. Bare soil was one of the relatively more common microhabitats with a mean percentage area ranging from 8.97% (201,825 sq. cm. per site) at the control sites to a mean of 3.36% (75,600 sq.cm. per site) for all the post-fire sites burnt in spring 84 and autumn 96. The colonisation of bare soil by moss, however, was patchy amongst the 14 study sites. About half of the sites had no measurable moss colonisation of bare soil, while both the control sites and the hot fire sites of autumn 93 and spring 94 had small areas of moss colonised bare soil ranging from a mean percentage area of 0.02% (450 sq.cm. per site) at the autumn 93 sites to 0.12% (2700 sq.cm. per site) at the hot burnt spring 84 sites (see Table 1). This microhabitat has, therefore, a less reliable occurrence and hence may be of lesser importance as a refuge for relict invertebrates than moss colonised ashbeds or the moss swards of shaded soil under large logs.

Unburnt & Burnt Litter:
During the intervening years between prescribed fires in the jarrah forest the most widespread microhabitat on the forest floor is the mixed jarrah and marri leaf litter. Within this litter layer, and on its surface, the jarrah forest litter invertebrates can reach densities of 3,000 individuals per square metre. These litter invertebrates are comprised of guilds of decomposers, herbivores, predators and parasitoids which may have seasonal patterns of activity and vertical movement within the litter layer, thus avoiding harsh environmental conditions such as autumn drought and periodic fire. The litter layer consists of two structurally distinct sub-layers, the uppermost coarse litter fraction and the lower humeric, well-decomposed fine litter fraction, overlaying the mineral soil. The lower, well decomposed, darkly-coloured and relatively moist humus layer, known as the fine litter fraction, may be up to 10mm or 20mm deep.

This fine litter layer is formed and further decomposed by the combined action of micro and meso invertebrates such as bacteria, fungi, earthworms (Class:Oligochaeta), mites (Order:Acarina), entomobryid, sminthurid and neanurid springtails (Order: Collembola), pauropods (Order: Pauropoda) and many larvae of fly and beetle families . Above this humeric lower layer is piled the upper coarse litter fraction which on average is approximately 20 mm. to 30 mm. deep and is largely constructed of the loosely stacked, flat dry and little decomposed, intact jarrah and marri leaves. In the large shaded interstitial spaces, within this loose stack of eucalypt leaves, the decomposer guilds of meso and macro invertebrates move and feed, breaking up the leaves into smaller particles, which are further broken down by a succession of guilds of smaller sized decomposers. The larger macro decomposers, active both in the interstitial spaces and above on the exposed upper surface of the leaf litter, include a small number of species of acridid and gryillid orthopterans, blattid cockroaches and slaters(Order: Isopoda). The decomposers of the meso guilds are mostly comprise of extremely abundant springtails (Order: Collembola) and mites (Order: Acarina).

Also moving and hunting within the shaded spaces of this loose leaf stack are varying sizes of predator guilds. Guilds of predators that are very small in size maybe able to hunt deep down in the litter stack in search of the extremely abundant but very small decomposer invertebrates such as the ubiquitous springtails and mites. Such very small predators include the pseudoscorpions, predatory mite species, tiny predator pselaphid beetles and several relict spider families including the micropholcommatids. The intermediate sized predator guilds may in turn prowl the interstitial leaf spaces in search of larger prey, these predators include such taxa as opilionids, lygaeid and reduviid predatory bugs, dermaptera, spiders of many families, centipedes, coleoptera families such as staphylinids, small carabids, acanthocnemids and intermediate-sized ant species of the genera *Iridomyrmex*, *Melophorus*, *Rhytidoponera* and *Camponotus*. Overhead on the exposed surface of the leaf litter the relatively huge macro invertebrate predators prowl, such as the large nomadic lycosid, gnaphosid, ctenid and zodariid spiders, large scorpion species, huge predator beetles such as carabids, clerids and tenebrionids and large solitary ants of the *Myrmecia* genus.

Many of these invertebrates become inactive during the moisture-limited autumn season, which may have preadapted them to environmental disturbances, such as fire. Main (1987) suggests that some of the relict spider taxa found in the south west forests retreat deep into the litter and may, therefore be, more resistant to fire at this time of year. Unburnt litter patches protected by areas of lower fuel quantity, on the up-wind side of large logs or insulated under recently fallen branches, are possibly one of the most important fire refuge microhabitats for both common and relict invertebrate on the jarrah forest floor. Prior to the prescribed fires at the Batalling study sites the mixed jarrah-marri litter was the most abundant forest floor microhabitat with a mean percentage area of 86.11% (193.74 sq. metres per site) at the control sites and a mean percentage area of 92.23% (207.52 sq. metres per site) at the spring 84 and autumn 96 sites. Following the prescribed fires the mean percentage area of unburnt litter had been reduced to 19.27% (43.36 sq. metres per site) for all the burnt sites. This ranged from the least area of remaining unburnt litter of 10.03% (22.57 sq. metres per site) at the cool autumn 96 burnt sites to the most remaining unburnt litter of 26.97% (60.68 sq.metres per site) at the cool spring 84 burnt sites. The proportion of litter left unburnt, following the spring and autumn fires, showed no clear pattern of correlation with the season or intensity of the prescribed fires (see Table 1). The prediction of the acute impacts of fires, such as the amount of litter fuelbed consumed, the depth of soil heating, the height of crown scorch, is inherently difficult because of a complex interaction of biotic and abiotic factors (Burrows,1995). However, because the lowest mean percentage area was 10.03% litter remaining unburnt, for any of the sites, then the litter microhabitat occupied no less than one tenth of the burnt sites which is a relatively huge refuge area in comparison to the post-fire area of the other refuge microhabitats of the jarrah forest floor.

Preliminary Conclusions on the of Fire Impact on Refuge Microhabitats:
To date the limited amount of research on the rare and relict invertebrates of southwest forests indicates that restricted refuge microhabitats may be important in maintaining the current distribution of these relics. The preliminary analysis of the microhabitat data collected during this study indicates that the impact of prescribed fires on the restricted refuge microhabitats of the jarrah forest floor is a complex chain of dynamic processes which partly destroys relatively more common refuge microhabitats in the process of creating refuge microhabitats that are far less common and of possibly of greater importance to the rare and relict invertebrates. Both spring and autumn prescribed fires burn large areas of leaf litter, leaving relatively large pockets of unburnt litter as refuges for the more common invertebrates. Fire damage to trees during these prescribed fires may result in the formation of large logs and dead tree branches on the forest floor. Fallen logs are a limited and possibly important fire refuge for vertebrates, larger

invertebrates and relict spider species. These fallen logs, although limited in area, are partly reduced to ashbeds, particularly by autumn fires. Moss swards, a restricted refuge for relict spiders on the dry and infertile jarrah forest floor, mostly occur on these nutrient rich ashbeds. The autumn prescribed fires, therefore, may play a greater role in enhancing the structural diversity of refuge microhabitats and maintaining the balance between relatively common and more restricted refuge microhabitats.

This part of the study indicates that the impacts of prescribed fires on the biodiversity of the jarrah forest floor invertebrate community may be more effectively determined by further research on both the microhabitat extent and requirements of rare and relict invertebrates throughout their life cycle. Also further research should be undertaken on creation of more structurally diverse invertebrate microhabitats and mosaics of burnt and unburnt fuels through the use of a diversity of prescribed fire seasons, frequencies and intensities. Further research should also be undertaken on the impact of varying intensities of autumn prescribed fires on invertebrate communities and microhabitats over a broad range of jarrah forest plant communities.

Impact of fire on Invertebrate Orders:

e) Sorting to the level of order has been completed at all sites for the following samples: November 1992, February 1993, May 1993, June 1993, October 1993, April 1994, June 1994, August 1994, November 1994, February 1995 and November 1995. To date approximately 90,000 individual specimens have been sorted and identified to order level.

f) Preliminary analyses of the data, mainly at the Order level, have been carried out on the first 36 months of data. In a previous report, over 30 BACI analyses were conducted on the first 24 months data as a pilot study of data management and the sensitivity of this type of analysis. It should be appreciated that it would not be cost effective to rerun this type of analysis until the complete data set is collected at the end of this study, particularly with my limited funds and the huge number of specimens to sort (approx. 15,000 per sample date) and then analyse. Therefore when sorting time permits data is graphically summarised. The following parameters are continuing to be examined:

- Community structure at the Order level
- Seasonal Changes
- Impact of fire on selected Orders.

Community Structure of Orders:

Total abundance of all orders:

The mean total abundance of all invertebrates from 31 invertebrate orders was calculated for the 36 month period from November 1992 to November 1995 (Figure 3). The prefire sites and the unburnt control sites highlight several important temporal trends in the mean total abundance of jarrah litter invertebrates. Firstly, all sites have a marked seasonal trend with the abundance of litter invertebrates reaching a peak in late spring, then declining rapidly to a annual low in late summer or early autumn. As moisture possibly becomes less limiting, in early winter, total abundance again begins to climb towards the late spring peak. Prior to the November 94 fires the unburnt spring 94 fire sites reached a peak of mean abundance in November 92 of 248.37 litter invertebrates this then declined, rapidly, by one half to a mean abundance of 127.75 invertebrates in March 93. By June 93 mean abundance had climbed to 267.87 and ultimately reached a peak of 327.75 invertebrates in November 93. The annual low, following the spring 93 peak, was a mean abundance of 156.50 invertebrates which was reached quite late in June 94, possibly because of a dry early winter. In general the oscillations in mean abundance of invertebrates per sample at the unburnt spring 94 fires sites were quite similar and predictable between the 1992 and 1993 seasons. In autumn 93 mean abundance was 51.4% of spring 92 abundance and in winter 94 mean abundance was 47.7% of spring 93 abundance. These seasonal changes also were similar at the control sites in the 1994 season with the low February 95 mean abundance being 44.5% of the November 94 abundance. These seasonal oscillations maybe the combined result of broadly similar annual life cycles in many species of jarrah forest invertebrates. These annual life cycles can be very broadly characterised by the following life history in which adult invertebrates copulate and lay eggs in late autumn and early winter followed by emerging juveniles feeding and growing through late winter and spring, then when fully grown in late spring or early summer these last instar juveniles seek protected refuges in which to shelter during a resting diapause stage as a prepupae, often through late summer and autumn, then pupation takes place at the end or during this resting stage and the sexually mature adults emerge during early winter.

Overlaying these annual seasonal oscillations, there appears to be a long term increase in the peak spring abundance of litter invertebrates at the unburnt sites. At the unburnt spring 84 fire sites the November 92 mean abundance was 248.37 invertebrates which increased by 31.9% to 327.75 invertebrates in November 93. At the unburnt control sites, in the following spring of November 94, mean abundance was 393.62 invertebrates which increased by 33.0% to 523.75 invertebrates in the spring of November 95 (see Figure 3). Therefore, over the first 36 months of the study, all unburnt sites, had peak spring abundances increasing by roughly 30% per year, possibly in response to favourable climatic conditions such as above average minimum winter or spring temperatures.

Abundance Within Common Orders:

A) Seasonal Trends in Total Abundance:
The abundance of the orders within the jarrah forest litter invertebrate community, have predictable seasonal oscillations and the community structure appears quite stable at the unburnt sites (see Figures 4&6). Seasonal trends have also been identified for the jarrah forest canopy invertebrate community (Recher et al, 1995) and litter invertebrates of messmate stringybark (*Eucalyptus obliqua*) dry sclerophyll forest of central Victoria (Neumann et.al.,1995). In the jarrah forest the spring peaks of litter invertebrate abundance tend to be primarily dominated by ants with secondary domination shared equally between the collembolans, flies, beetles, spiders and wasps. The annual low abundance in autumn is largely due to a marked drop in the abundance or activity of ants, although maintaining their primary dominance, with lesser declines in the secondarily dominate orders. The wasps tend to increase slightly during this autumn period to become the second most abundant group, after ants. From early winter to late spring the rapid increase in jarrah forest litter invertebrates is primarily dominated by the litter decomposing collembolans, which tend to have greatly decreased in number by the onset of late spring.

At the unburnt spring 94 fire sites, the peak spring abundance in November 92 was primarily dominated by ants with a mean abundance of 96.25 (38.7% of total abundance) with secondary dominance shared by flies with mean of 26.12 (10.5%), collembolans at 25.0 (10.0%), beetles at 22.6 (9.1%), wasps at 19.1 (7.7%) and spiders at 15.6 (6.3%) (see Figure 6). In March 93 the mean abundances at the spring 84 sites had declined to ants at 34.75 (27.2%), wasps at 29.37 (23.0%), collembolans at 15.75 (12.3%), spiders at 8.62 (6.7%), hemiptera at 8.37 (6.6%), beetles at 8.12 (6.4%) and flies at 7.5 (5.8%), indicating a loss of numerical dominance by the ants and an upsurge in the dominance of predatory and parasitoid wasps. By June 93 the mean abundances at these sites had climbed rapidly due primarily to a large increase in the activity of collembolans at 138.25 (51.6%), followed by rapid increase in flies to 53.75 (20.1%), beetles to 21.25 (7.9%) and orthopterans to 7.12 (2.6%). Several invertebrate taxa that tended to dominate in the hot dry summer and autumn continued to decline, such as the ants to 19.50 (7.3%) and the wasps to 9.12 (3.4%), while spider abundance also remained low at 6.75 (2.5%). In November 93 total mean abundance had again peaked with ants primarily dominant at 103.0 (31.4%) with a secondarily dominant group again including beetles at 51.87 (15.8%), flies at 49.75 (15.2%)and collembolans at 35.62 (10.9%). The third most numerically dominant group was composed of wasps at 20.37 (6.2%), hemiptera at 16.62 (5.1%), spiders at 13.62 (4.2%), mites at 12.87 (3.9%) and orthopterans at 6.5 (2.0%). These three numerically dominant groups, in total, made up 94.7% of the individuals in the 20 litter invertebrate taxa captured at the unburnt spring 94 fires sites for this sampling period. In general, at the unburnt sites, the jarrah forest litter invertebrate community exhibits a marked and predictable seasonal structure in the relative abundance of the most common taxa (see Figure 4&6). This seasonal community structure is characterised by an ant-fly-beetle-collembolan dominated peak abundance in late spring, followed by a ant-wasp-collembolan dominated trough in abundance in autumn which is then followed by a collembolan-fly-beetle dominated phase of rapid increase in abundance from early winter to late spring.

B)Long Term Trends in Order Abundance:.

Overlaying these seasonal oscillations maybe a long term shift in community structure , in response to changes in long term cyclic environmental conditions, these may result in a change in the proportional composition of taxa or even a change in the order of numerical dominance. At the control and unburnt spring 94 fire sites , such a long term shift has been observed in the spring peak of total invertebrate abundance. From November 92 to November 95 peak total abundance has increased by approximately 30% per year (see Figure 3). This increase was mainly due to a marked increase in the number of ants and collembola (see Figure 4). The ants, at the unburnt sites, maintained their primary dominance of mean abundance and increased from a mean abundance of 96.25 (n=16, 38.7% of total abundance) in November 92 to 259.06 (49.5%) in November 95. The collembolans increased from 25.0 (10.0%) in November 92 to 130.06 (24.8%) in November 95. On average the 9 most common taxa comprised approximately 95.0% of the total abundance of the 31 taxa captured. The rank position of these 9 taxa in November 92 was 1) ants,2) flies,3) collembolans,4) beetles,5) wasps,6) spiders,7) hemiptera,8) mites and 9) orthopterans. In November 94 the rank position was 1) ants, 2) collembolans,3) beetles,4) wasps,5) hemiptera,6) spiders,7) flies,8) mites and 9) orthopterans. Therefore the community structure parameter of numerical dominance rank remained largely stable with only the flies and hemiptera having large shifts in their rank position. The flies increased then decreased markedly from the second most abundant rank at 26.12 (10.5%) in November 92 to the seventh rank of 15.81 (3.0%) in November 95. While the hemiptera also fluctuated slightly from a rank of seventh at 11.75 (4.7%) in

November 92 to fifth at 17.56 (3.4%) in November 95. Therefore, over the 4 years, the spring peaks in abundance had community structure parameters that were characterised by a little changed numerical dominance rank of the 7 stable taxa and the proportional composition ranges as follows: 1) ants (31.4 to 49.5%),2) collembolans (10.0 to 24.8%),3) beetles (5.9 to 15.8%),4) wasps (4.0 to 7.7%),5) spiders (6.3 to 3.1%), 6) mites (1.7 to 3.9%) and 7) orthopterans (0.8 to 3.3%). The unburnt litter community structure for all spring seasons (1992 to 1995) was, on average, ants (38.9%), collembolans (16.2%), beetles (10.1%), flies (8.6%), wasps (6.0%), spiders (4.8%), hemipterans (4.0%), mites (3.4%) and orthopterans (2.4%) and another 18 uncommon taxa (mostly orders)(5.6%).

C)Impact of Prescribed Fires on Order Abundance:

First Post-fire Springs:

On to the two temporal community structure trends of seasonal oscillation and long term shifts, such as the spring increase in ants and collembolans, and a decrease in flies, were imposed the prescribed fires of autumn 93 and spring 94. In the first springs following both these fires the abundance of invertebrates increased markedly compared to the unburnt and control sites. The total mean abundance of autumn 93 burnt sites in the first post-fire spring of November 93 was 9.3 % higher than unburnt spring 94 sites. The total mean abundance of the spring 94 burnt sites in the first post-fire spring of November 94 was 38.1% higher than the unburnt control sites (see Figure 3).

However, although invertebrate abundance increased in the first spring following both these prescribed fires, the season of burning had markedly different impacts on the two community structure parameters of ordinal proportional composition and numerical dominance rank.

Autumn 93 prescribed fire:

In November 93 the first spring following the autumn 93 prescribed fires the activity or abundance of ants (146.19, n=8, 41.9% higher than unburnt sites) and collembolans (82.37, 131.2% higher) had increased markedly (see Figure 5&6) compared to the unburnt spring 94 sites. The doubling of the post-fire collembolan activity or abundance suggests that the litter decomposition rate had greatly increased, possibly in response to the release of litter nutrients following the autumn 93 fire. The majority of the other 7 common taxa decreased markedly in mean abundance in comparison to the unburnt spring 94 sites by the following proportions: flies at 44.87 (9.9% lower than unburnt), beetles at 23.12 (55.5% lower), wasps at 10.5 (48.5% lower), spiders at 11.60 (14.8% lower), hemipterans at 11.62 (30.1 % lower), mites at 5.87 (54.4% lower) and orthopterans at 9.30 (43.1% higher). The autumn 93 fires resulted in the following first spring community structure parameters of numerical dominance rank and ordinal composition: 1) ants (40.8%), 2) collembolans (23.0%), 3) flies (12.5%), 4) beetles (6.5%), 5) hemipterans (3.2%), 6) spiders (3.2%), 7) wasps (2.9%), 8) orthopterans (2.6%) and 9) mites (1.6%). The acute impacts of the autumn 93 fires on the first post-fire spring community structure could therefore be characterised by an increase in total mean abundance and a changed ordinal composition favouring ants, collembolans and orthopterans and disfavouring beetles, flies, wasps, spiders, hemipterans and mites.

Spring 94 prescribed fires:

In contrast, in November 94 the first spring (ie. 2.5 months post-fire) following the spring 94 prescribed fires the activity or mean abundance per sample of ants (228.7, n=16, 47.1% higher than control) had sharply increased, while collembolans (53.87, 28.6% lower) had markedly decreased, flies (28.31, 21.4% higher) had increased, beetles (127.0, 240.4 %

higher) had increased very sharply, wasps (16.56, 32.5% lower) had decreased, spiders (20.37, 5.8% lower) had decreased very slightly, hemipterans (11.56, 3.7% lower) had decreased very slightly, mites (27.81, 80.9% higher) had increased markedly and orthopterans (3.56, 75.2% lower) had markedly decreased (compare Figures 4&6, Nov.94). The spring 94 fires resulted in the following spring community structure parameters of numerical dominance rank and ordinal composition: 1) ants (42.0%), 2) beetles (23.3%), 3) collembolans (9.9%), 4) flies (5.2%), 5) mites (5.1%), 6) spiders (3.7%), 7) wasps (3.0%), 8) hemipterans (2.1%) and 9) orthopterans (0.6%). The acute impacts of the spring 94 fires on the first post-fire spring community structure, therefore, could be characterised by an large increase in total mean abundance and a changed ordinal composition favouring ants, flies, beetles, mites and disfavouring collembolans, wasps, spiders, hemipterans and orthopterans.

Summer-Autumn-Winter(Abundance Trough) After the First Post-fire Spring:
Autumn 93 prescribed fires:
In the next early winter and the second spring the activity or abundances at both the autumn and spring burnt sites declined to levels similar to or slightly above those of the control sites (see Figure 3). The community structure in this early winter at both prescribed burnt sites was , however different to the control sites. In June 94 the winter following the first post-fire spring at the autumn 93 fires the activity or mean abundance of ants (36.37) was 27.6% higher than control sites, collembolans (32.00) 11.8% higher, flies (37.00) 24.4% higher, beetles (5.87) 65.5% lower, wasps (1.25) 84.7% lower, spiders (1.5) 74.2 lower, hemipterans (0.75) 55.3% lower, mites (2.5) 59.2% lower and orthopterans (2.75) 50.5% lower. This resulted in the following winter community structure of numerical dominance rank and ordinal composition: 1) flies (30.4%), 2) ants (29.9%), 3) collembolans (26.3%), 4) beetles (4.8%), 5) orthopterans (2.3%), 6) mites (2.1%), 7) spiders (1.2%), 8) wasps (1.0%) and 9) hemipterans (0.6%)(see Figure 5, June 94). The acute impacts of the autumn 93 fires on the post-fire early winter community structure , therefore could be characterised by a mean abundance approximating that of the control sites, but with a changed ordinal composition favouring decomposer and seed collecting groups such as flies, ants, collembolans and disfavouring large dead leaf feeders and predatory groups such as beetles, orthopterans, mites, spiders, wasps and hemipterans. This may reflect a lower quantity of accumulated large litter, harsher conditions in the shallower litter, a lack of parasitoid hosts and fewer large prey invertebrates.
Spring 84 prescribed fire:
In the first post-fire late summer (seasonal trough) following the spring 94 fires the activity or mean abundance of ants (136.37) was 82.7% higher than control sites, collembolans (27.43) 98.6% higher, flies (3.12) 22.0% lower, beetles (29.31) 6.6% higher, wasps (7.56) 45.3% lower, spiders (4.56) 41.7% lower, hemipterans (3.75) 34.8% lower, mites (20.00) 10.7% higher and orthopterans (0.31) 87.0% lower. This resulted in the following late summer (seasonal trough) community structure of numerical dominance rank and ordinal composition: 1) ants (56.8%), 2) beetles (12.2%), 3) collembolans (11.4%), 4) mites (8.3%), 5) wasps (3.1%), 6) spiders (1.9%), 7) bugs (1.6%), 8) flies (1.3%) and 9) orthopterans (0.1%) (see Figure 6, Feb.95). The acute impacts of the spring 94 fires on the first post-fire late summer (seasonal trough) community structure , therefore could be characterised by a mean abundance approximating that of the control sites, but with a changed ordinal composition favouring decomposer, seed collecting and predatory groups such as ants, beetles, collembolans, mites and disfavouring large dead

leaf feeders, predatory, parasitoid and herbivore groups such as flies, wasps, spiders, hemipterans and orthopterans. Also this composition may reflect the greater availability of nutrients and a more rapid litter decomposition rate as well as a patchy accumulation of large leaf litter, fewer large prey invertebrates and fewer eggs and larvae available for parasitism.

Second Post-fire Springs:

In the second post-fire springs, although the mean abundance at both prescribed burnt sites were similar to the unburnt control sites, the community structure was markedly different from that of the control sites. The community structure at both the autumn and spring prescribed fires sites, were now quite similar as the differing impacts due to the different burning seasons seemed to have come into phase having similar impacts on the ordinal composition. In these second post-fire springs both the prescribed fires sites had ordinal composition that had shifted in a similar direction with collembolans increasing markedly, ants decreasing (against all seasonal and long term trends).

Autumn 93 prescribed fire:

In November 94 the second post-fire spring following the autumn 93 fires the activity or mean abundance of ants (115.62) was 25.8% lower than control sites, collembolans (123.25) 63.4% higher, flies (32.75) 40.5% higher, beetles (29.12) 22.0% lower, wasps (14.0) 42.9% lower, spiders (14.9) 31.1% lower, hemipterans (9.75) 12.8% lower, mites (19.37) 26.0% higher and orthopterans (22.12) 54.6% higher (Figure 5, Nov.94). This resulted in the following second spring (seasonal peak) community structure of numerical dominance rank and ordinal composition: 1) collembolans (31.8%), 2) ants (29.8%), 3) flies (8.4%), 4) beetles (7.5%), 5) orthopterans (5.7%), 6) mites (5.0%), 7) spiders (3.8%), 8) wasps (3.6%) and 9) hemipterans (2.5%). The acute impacts of the autumn 93 fires on the second post-fire spring (seasonal peak) community structure , therefore could be characterised by a mean abundance approximating that of the control sites, but with a changed ordinal composition favouring decomposer, parasitoid, small bodied predators and large dead leaf feeder groups such as collembolans, flies, wasps, mites and orthopterans and disfavouring seed collectors, large predators and sap-sucking groups such as ants, beetles, spiders and hemipterans. Also this suggests a higher availability of nutrients, a higher litter decomposition rate, an increase in the accumulation of large litter, a greater quantity of nutrient rich new plant growth, fewer seeds available, an increase in the eggs and larvae available for parasitisation and a lower number of large prey invertebrates available.

Spring 84 prescribed fire:

In the second post-fire spring following the spring 94 fires the activity or mean abundance of ants (166.93) was 35.6% lower than control sites, collembolans (206.68) 58.9% higher, flies (16.68) 5.6% higher, beetles (39.5) 27.4% lower, wasps (11.31) 46.3% lower, spiders (12.68) 23.2% lower, hemipterans (11.68) 33.5% lower, mites (16.62) 82.2% higher and orthopterans (2.5) 36.4% lower (Figure 6, Nov.95). This resulted in the following second spring (seasonal peak) community structure of numerical dominance rank and ordinal composition: 1) collembolans (41.2%), 2) ants (33.3%), 3) beetles (7.9%), 4) flies (3.3%), 5) mites (3.3%), 6) spiders (2.5%), 7) wasps (2.3%), 8) hemipterans (2.3%) and 9) orthopterans (0.5%). The acute impacts of the spring 94 fires on the second post-fire spring (seasonal peak) community structure , therefore could be characterised by a mean abundance approximating that of the control sites, but with a changed ordinal composition favouring decomposer and small bodied predators groups such as collembolans, flies and mites and disfavouring seed collectors, large predators, parasitoid, sap-sucking and large dead leaf feeder groups such as ants, beetles, wasps, spiders, hemipterans and orthopterans. Also this suggests a higher availability of nutrients , a higher litter decomposition rate, a slower accumulation of large litter, a lesser quantity of nutrient rich new plant growth, fewer seeds available, an increase in the eggs and larvae available for parasitisation, a greater number of small prey invertebrates and a lower number of large prey invertebrates available.

Second Post-fire Summer-Autumn:
Autumn 93 prescribed fire:
In February 95 the second post-fire late summer(seasonal trough), the autumn 93 burnt sites suffered a much lower decline in the total mean abundance relative to the unburnt control sites (37.0% higher than control)(see Figure 3). This reduced decline was due to a markedly higher abundance of collembolans, ants and wasps which went against the seasonal trends in the control sites which were experiencing rapid decreases in these taxa.

In the second post-fire late summer following the autumn 93 fires the activity or mean abundance of ants (98.62) was 32.2% higher than control sites, collembolans (52.87) 282.8% higher, flies (5.25) 31.2% higher, beetles (8.5) 69.1% lower, wasps (27.87) 101.8% higher, spiders (8.9) 14.02% higher, hemipterans (9.62) 67.3% higher, mites (13.62) 24.6% lower and orthopterans (6.5) 174.3% higher (Figure 5, Feb.95). This resulted in the following second post-fire late summer (seasonal trough) community structure of numerical dominance rank and ordinal composition: 1) ants (41.4%), 2) collembolans (22.2%), 3) wasps (11.7%), 4) mites (5.7%), 5) hemipterans (4.0%), 6) spiders (3.7%), 7) beetles (3.6%), 8) orthopterans (2.7%) and 9) flies (2.2%). The impacts of the autumn 93 fires on the second post-fire late summer (seasonal trough) community structure , therefore could be characterised by a mean abundance markedly higher than the control sites and also with a changed ordinal composition favouring seed collectors, decomposer, parasitoid, large predators, sap-sucking and large dead leaf feeder groups such as ants, collembolans, flies, wasps, spiders, hemipterans and orthopterans and disfavouring small bodied predator groups such as beetles and mites. This higher abundance of litter invertebrates at these sites may have been the result of the amelioration of the harsh summer conditions in the litter layer due to the accumulation of the litter to a depth of 12.6mm and the shading effect of the dense shrub regrowth and thicker tree canopies. Also this suggests a higher availability of nutrients, a higher fine litter decomposition rate, a higher decomposition of accumulated large litter, a higher quantity of nutrient rich new plant growth, more seeds available, an increase in the eggs, larvae or pupae available for parasitism, a lesser number of small prey invertebrates and a higher number of large prey invertebrates available.

Third Post-fire Spring:
Autumn 93 prescribed fire:
In November 95 the third post-fire spring, the autumn 93 burnt sites had a large decrease (49.4% lower) in the total mean abundance relative to the unburnt control sites (see Figure 3). This large decrease was due to the a marked reduction in the abundance of both collembolans and ants, which went against the seasonal and long term trends in the control sites which were experiencing increases in these both these taxa.

In the third post-fire spring following the autumn 93 fires the activity or mean abundance of ants (48.75) was 81.2% lower than control sites, collembolans (77.75) 40.3% lower, flies (12.87) 18.6% lower, beetles (50.00) 61.3% higher, wasps (14.87) 29.4% lower, spiders (13.75) 16.7% lower, hemipterans (16.25) 7.5% lower, mites (9.75) 6.9% higher and orthopterans (6.87) 74.8% higher. This resulted in the following third post-fire spring (seasonal peak) community structure of numerical dominance rank and ordinal composition: 1) collembolans (29.3%), 2) beetles (18.9%), 3) ants (18.4%), 4) hemipterans (6.1%), 5) wasps (5.6%), 6) spiders (5.2%), 7) flies (4.9%), 8) mites (3.7%) and 9) orthopterans (2.6%) (see Figure 5, Nov.95). The acute impacts of the autumn 93 fires on the third post-fire spring (seasonal peak) community structure , therefore could be characterised by a mean abundance markedly lower than the control sites and also with a changed ordinal composition favouring small bodied predators, herbivore and large dead leaf feeder groups such as beetles, mites and orthopterans and disfavouring seed collectors, small decomposer, wasp pollinators, large predators and sap-sucking groups such as ants, collembolans, flies, wasps, spiders and hemipterans. Also this suggests that the availability of nutrients and the fine litter decomposition rate were beginning to slow, a higher decomposition of accumulated large litter, fewer seeds available, a reduce quantity of plants in flower, a greater number of small prey invertebrates and a lower number of large prey invertebrates available.

Preliminary Conclusions on the Impact of Fire on the Abundance of Litter Invertebrates:

At the unburnt sites the abundance of the orders within the jarrah forest litter community have predictable seasonal oscillations and therefore the community structure appears quite stable. In most years the annual peak in the ordinal abundance occurs in late spring. The strongly seasonal flowering of the shrub layer and the relatively warm moist climatic conditions of late spring tends to favour primary domination by omnivorous seed feeding ants and secondary domination by litter decomposing taxa such as collembolans and flies. Other taxa that reach their peak abundance in late spring are the beetles which include guilds of both small prey and large prey predators and saprophytes; the wasps with mainly pollinating and parasitoid guilds; the spiders with generally large prey predator guilds; hemipterans which have both predatory and sap-feeding guilds; the mites with both decomposer and small prey predatory guilds and also the orthopterans that include both herbivorous and dead leaf feeding guilds. Later in the year as the climatic conditions become extremely harsh particularly in late summer and autumn the seasons of annual maximum temperatures and lowest monthly rainfalls, the ordinal composition of the jarrah forest litter community shifts to favour different taxa. During late summer and autumn the total abundance of litter invertebrates reaches an annual low. This annual low is largely due to a marked decline in the abundance or activity of the ants , which still maintain their primary dominance in abundance. The limited litter moisture and soil moisture at this time of year is also associated with a large decline in the abundance of the decomposing collembolans. Other taxa are more tolerant of these harsh conditions, such as the predatory and parasitoid guilds of the wasps and the large prey predatory guilds of the spiders and beetles.

In winter and early spring, when moisture is no longer limiting the abundance of litter invertebrates rapidly increases. Litter decomposing taxa such as the collembolans and flies then tend to dominate. Other taxa favoured during these seasons are the saprophytic and small prey predator guilds of the beetles and the dead leaf feeding guilds of the orthopterans.

Overlayed on these seasonal oscillations was a long term increase in the peak spring litter invertebrate abundance. At the unburnt sites this long term increase was largely due to an

increase in the abundance of ants and collembolans from one spring to the next. The fly taxon however declined over the four springs sampled to date.
The impacts of the spring 84 and autumn 93 prescribed fires markedly altered these seasonal and long term trends in the abundance of jarrah forest litter invertebrates. The productivity or total abundance of the litter invertebrates at the burnt sites increased markedly in the first post-fire springs possibly in response to the release and increased availability of litter and soil nutrients. The ordinal composition of this increased invertebrate abundance was partitioned differently in response to the different burning seasons. At the autumn 93 burnt sites this boom of invertebrate abundance was largely partitioned between the ants, collembolans and flies. These taxa may have been favoured by the autumn burning season as they are less active at this time of year. They, also, experienced only a short post-fire period of extreme temperature and moisture conditions before the onset of winter and they were then able to increase rapidly during the post-fire winter and early spring as there was a greater availability of nutrients and moisture.
In contrast, the boom of invertebrate abundance following the spring 94 prescribed fires was much larger than that of the autumn 93 prescribed fires. This first post-fire spring boom, however, contained a markedly reduced number of collembolans. This reduction in the abundance of collembolans was probably due to their much higher activity during this burning season making them far more susceptible to the acute impacts at the time of the spring prescribed fire. The ant and beetle taxa of the spring 94 burnt sites made up the majority of this boom in abundance. These taxa were more common after the spring prescribed fire as they may have become more active on the litter surface due to habitat simplification or in the case of the ants were possibly less susceptible to the acute impacts at the time of the prescribed fire due to refuges in the deep litter or soil or in the case of the beetles due to large numbers immigrated from outside the burnt areas.
Following the mild climatic conditions of this first post-fire spring, the litter environment of the burnt sites, during the extremes of late summer and autumn, was possibly the harshest experienced by the litter invertebrates of both the spring 94 and autumn 93 burnt sites. During this autumn the litter was still shallow and the vegetation had not yet completely regrown during this early acute post-fire stage.
At the autumn 93 sites during the harsh conditions of this autumn season the flies, ants and collembolans dominated while the taxa that appeared disfavoured by these harsh conditions were the large dead leaf feeding and herbivorous orthopterans and hemipterans, the parasitoid wasps, the mites, the beetles and the large prey predatory spiders. While, at the spring 94 sites the early spring impacts were now less obvious with the ants, beetles and collembolans dominating and the disfavoured taxa made up of the large dead leaf feeding and herbivorous orthopterans and hemipterans, the parasitoid wasps and the large prey predatory spiders. At both these burnt sites the fine litter decomposing taxa appeared to be favoured possibly due to the availability of soil and litter nutrients. While lack of large leaf litter, plant regrowth, parasitoid hosts and large prey invertebrates maybe the cause of other taxa being disfavoured.
By the time of the second post-fire spring the sites that were prescribed burnt during the differing seasons of spring and autumn had now come into phase having similar ordinal compositions. This indicated that the early impacts of the different burning seasons had largely disappeared. Also at both prescribed sites the total abundance was similar to that of the unburnt control sites. However, the abundance of each taxon at both these prescribed burnt sites was markedly different from the control sites. At these prescribed burnt sites, during the second post-fire springs, the taxa abundance had shifted in a similar direction with collembolans increasing markedly while ants markedly decreased (against all

seasonal and long term trends).The total abundance at both these burnt sites was primarily dominated by collembolans with secondary domination by the ants. Other taxa that were favoured were the flies and mites, while the most disfavoured taxa were the large prey predatory taxa of spiders and beetles.

In general following the prescribed fires the availability of nutrients seemed to favour the increased litter decomposition rate and continued the burst of productivity of the fine litter decomposers into the second post-fire spring. Also this burst of productivity may have moved up the food web to favour the small prey predators such as some of the mite species. However the taxa that contain a large proportion of large prey predatory guilds still continue to be disfavoured possible due to lack of prey.

Data are not yet available for the impacts of the spring 94 sites during the second post-fire autumn. However preliminary analysis of the autumn 93 site data indicated that the total abundance of these sites was markedly higher than that at the control sites during this harsh season. At these autumn burnt sites the abundance of the primarily dominate collembolans and secondarily dominate ants continued to remain much higher than at the control sites. The other taxa favoured by at this time of year by the impacts of autumn fires were the orthopterans, hemipterans, flies, wasps and spiders. The disfavoured taxa were the mites and beetles. The high total abundance at the autumn 93 sites suggests that the harsh conditions of this season may have been ameliorated by some positive impacts of this fire. By this second post-fire autumn the shrub layer and the tree canopy had largely regrown with a dense cover of new leaves. Also, the leaf litter had accumulated to roughly half the control litter depth. In combination this much denser vegetation cover and the adequate litter depth probably resulted in milder litter conditions during this season at the autumn 93 burnt sites and so favoured the higher total abundance of litter invertebrates.

By the third post-fire spring at the autumn 93 burnt sites the total abundance was markedly lower than the unburnt control sites. This large decline in total abundance was mainly due to a large reduction in the abundance of collembolans and ants. The decline in these taxa suggested that the fine litter decomposition rate had slowed and that nutrient availability was returning to pre-fire levels. The reduced abundance of ants was possible due the lack of seed production by the young regrowth vegetation. Other taxa that were disfavoured during this season were the pollinating flies and wasps and the large prey predatory spiders. The taxa that were favoured during this season were the saprophytic beetles, the decomposer or small prey predatory mites and the herbivorous, large dead leaf feeding or predatory orthopterans.

In conclusion it appears that the both prescribed fires caused a burst of productivity in the first post-fire spring. At the autumn burnt sites the number of fine litter decomposers reached a maximum immediately in the first post-fire spring, while the spring prescribed fires delayed this fine litter decomposer peak by one year. During this first post-fire spring the differing impacts of the burning seasons resulted in greater diversity of taxa between the spring and autumn prescribed burnt sites and also the unburnt control sites.

By the second post-fire spring the impacts of the season of burning had largely disappeared with both burnt sites having a very high component of fine litter decomposers and an increase in the number of small prey predators. By the third post-fire spring at the autumn burnt sites the number of fine litter decomposers and seed feeders had declined, but small prey predators and large dead leaf feeders had increased. Also the taxa although lower in abundance at these sites where more diverse (see Species Richness, Third post-fire autumn). These data suggest that a mosaic of spring burnt, autumn burnt and longer unburnt areas would maximise litter invertebrate biodiversity in the central jarrah forest.

Species Richness of Invertebrate Orders:

A) Seasonal Trends in Species Richness:

The invertebrate orders and lower taxa active in the litter of the jarrah forest show predictable and large changes in species richness with the seasonal cycles. From May 93 to November 95 at the pre-fire sites and unburnt control sites the mean species richness per sample peaked at 89.81 species in late spring and then declined to a minimum in summer, autumn and winter ranging from 54.05 to 55.13 species (see Table 2 & Figure 7&8). Ants (Family: Formicidae) was the most species rich taxa, with the highest mean species richness occurring in late spring. The species richness of the 9 most common taxa occurring in spring at the unburnt sites, can be ranked in the following order: ants (15.27 species), wasps (12.49 species), beetles (11.03 species), spiders (9.06 species), flies (9.03 species), hemipterans (8.06 species), mites (6.99 species), collembolans (6.34 species), orthopterans (1.84 species) and all other 'minor' taxa (9.69 species). In autumn when soil moisture is most limited, the species richness reaches a minimum and is also associated with a shift in the taxonomic composition of the litter community. Predatory and parasitoid wasps then become the most species rich taxa (9.31 species), followed by ants (7.68 species), spiders (6.97 species), beetles (6.1 species), flies (5.87 species), hemipterans (4.52 species), collembolans (4.31 species), mites (3.77 species) and orthopterans (1.67 species), also the 'minor' taxa (5.46 species) had halved in richness. These seasonal trends in species richness appear to parallel the seasonal trends in litter invertebrates' activity or abundance having late spring peaks and summer-autumn-winter troughs (see figures 3). This suggests that life cycles of many jarrah forest litter invertebrate species may have adapted an active developmental phase during the warm moist spring period followed by an inactive resting phase during the hot dry or cold wet periods of summer, autumn and winter.

B) Long Term Shifts in Species Richness:

Overlayed on these seasonal oscillations of the species richness of litter invertebrates may be long term shifts in the species richness in response to long cycle environmental changes. The control sites showed a slight increase (4.9%) in the spring mean species richness from November 94 compared to November 95 (see figure 7). This however is an extremely small change and shows little correlation with the increase in the spring mean abundances of litter invertebrates at an approximate 30% increase per year from November 92 to November 95. At the unburnt control sites the mean species richness of the jarrah forest litter community appears quite stable , with little long term change in the structural parameter of taxonomic composition. The structural parameter of species richness composition may, therefore, be a more stable and predictable indicator, than mean abundance, of cyclic trends in the jarrah forest litter invertebrate community and the impacts of rapid environmental changes (see Figure 8).

C)Impact of Spring and Autumn Prescribed Fires on Species Richness:

Onto the two temporal community structure trends of seasonal oscillations and long term shifts was imposed the prescribed fires of autumn 93 and spring 94 (see Figures 9&10). The impacts of these prescribed fires initially resulted in an increase in the species richness at all the burnt sites in the first post-fire springs. Also the richness or number of all taxa (common and minor) increased from 26 in the pre-fire sites to 31 in the post-fire sites, compared to the 24 taxa captured in the unburnt control sites. Following the initial spring increase at the burnt sites, the species richness declined and remained lower than the control sites until the second post-fire autumn. In the second post-fire autumn burnt sites species richness had returned to and exceeded the richness of the control sites, but had not yet stabilised, as species richness again remained lower than the control sites in the third post-fire spring. The species composition at the post-fire sites, also, changed markedly compared to the control sites, with the capture of many species not previously seen prior to the prescribed fires. Therefore preliminary analysis indicates an increase in the combined species richness of the unburnt control sites and the spring and autumn prescribed burnt sites. This, also, suggests an increase in regional diversity of litter invertebrates as a result of these prescribed fires which form part of a patchwork of varying fire histories in the jarrah forest of the Collie area.

First Post-fire Springs:

The invertebrates sorted to date and the data preliminarily analysed, indicates that prescribed fires caused a large increase in mean species richness per sample in the first post-fire spring (see figure 7, Nov.94), possibly as a result of increased invertebrate activity and also as a result of the immigration of possible acute fire phase pioneer species such as the acanthocnemid beetles. In November 94 the first spring following the spring 94 prescribed fire the mean richness per sample was 101.33 species compared to 87.63 species at the unburnt control sites (see Table 3). This also paralleled the trend in the abundance of litter invertebrates, which also increased in the first spring following both prescribed fires . In the first post-fire spring following the spring 94 fires the species richness increased by 13.7 species which included the capture of an extra 3.43 ant species, 3.12 beetle species and 4.97 'minor' taxa species (see Table 3).The higher richness of ants maybe due to an increase in activity or possibly the loss of the shrub layer which simplified the habitat which may have resulted in the more cryptic ant species being forced to forage on the burnt litter surface. The higher beetle richness may have also been due to higher activity or habitat simplification, as well as the immigration from other forest areas of at least one species of the acanthocnemid beetles, which are known to be attracted to smoke. Also, the higher richness of the 'minor' taxa, many of which are non-winged slow dispersing species, maybe partly due to immigration and partly due to their higher activity after surviving the spring fires in refuge microhabitats. Taxa that were disfavoured in this acute phase following the spring 94 fire included collembolans, reduced by 1.18 species and wasps, reduced by 0.56 species (or 1 less wasp species in 56 traps out of 100 traps) . The collembolans maybe particularly disfavoured in this acute phase immediately after the spring prescribed fires, as pre-fire abundance data from the pre-fire and unburnt control sites suggests that the winter and spring seasons are the periods of highest activity of these invertebrates in the litter layer (see figure 4, Nov. 94). Data on the changes in species richness are not yet available for the autumn 93 fires in this first post-fire spring, but are available for all subsequent seasons.

First Post-fire Autumns:

In the first post-fire autumn the species richness for both spring (-0.05 species) fire sites and autumn (-15.38) prescribed fire sites was lower than the unburnt controls as the post-fire species composition remained markedly different. Both seasons of prescribed fire impacted similar litter invertebrate taxa, but the autumn fires resulted in a lower number of species captured within these impacted taxa (see Table 3). During this autumn season at the autumn 93 burnt sites the taxa with the largest reduction in species were the beetles(-4.0), followed by the wasps(-3.56),then by the spiders(-2.93) and then by 'minor' taxa (-2.78). These reductions may be related to the shallow litter depth (<8.4 mm) and more extreme litter surface environmental conditions experienced at these sites in autumn.
At the spring 94 burnt sites during this first post-fire autumn the taxa that had the largest reduction in species richness included the spiders (-2.94), wasps (-1.81), hemipterans (-1.12) and orthopterans (-1.06). While the ants balanced out these reductions with continued higher species richness of 4.56 extra species. A species of mantid (Order: Mantodea) not previously recorded from any of the pre-fire or control sites, was captured at one of these sites during this autumn. In this autumn of 1995 the litter surface environmental conditions may have been less severe as litter depth was 15.6 mm, almost twice the depth of the autumn burnt sites.

Second Post-fire Springs:

In the second post-fire springs the species richness of the litter invertebrate communities at both the spring 94 and autumn 93 remained well below that of the control sites (see Table 3). This suggests that the species composition of these post-fire communities at this mid successional phase was still quite different from the unburnt litter communities. At the autumn 93 burnt sites the ants had 3.12 fewer species suggesting a possible low seed supply due to the lack of seed production in the young regrowth shrub layer and the scorched jarrah crowns above. The wasps also had 2.87 fewer species possibly indicating fewer number or more homogeneous prey such as invertebrate eggs, larvae and pupae. The beetles also had 2.69 fewer species which possibly indicates a shallower litter depth, lack of medium sized prey or a simplification of all of these factors. A possible relict species of flatworm (Order: Tricladida) which had not been captured from any of the sites previously, was captured several times a these autumn burnt sites possibly due to the higher abundance of small invertebrate prey such as collembolans.

In this second post-fire spring the impacts of the spring 94 prescribed fires appear to have intensified with the community becoming more dissimilar to the control sites since the first post fire spring due to a reduced species richness. Wasps, beetles and 'minor' taxa, were fewer in species, as were these taxa at the autumn 93 burnt sites. But spiders, flies, collembolans, mites and orthopterans had species richnesses approximating those of the control sites. While ants still had 1.44 more species than the control sites. Analysis of the November 96 data will indicate whether the species composition of the spring 94 burnt sites has returned to a community structure approximating that of the control sites by the following third post-fire spring. A species of web-spinner (Class: Embioptera) not previously captured from any of the unburnt sites, was capture at one of the spring burnt sites possibly due to higher nutrient availability in the decomposing leaf litter. The trap-door spiders (Mygalomorphae) and midget spiders (Micropholcommatidae) were several relict taxa, which were previously captured in the pre-fire sites and unburnt control sites. Both adult male and female spiders of these taxa were captured at these spring prescribed burnt sites in this second post-fire spring.

Second Post-fire Autumn at Autumn 93 Prescribed Fire Sites:

The autumn 93 burnt sites were in their second post-fire summer-autumn in February 95 and their mean species richness was 6.53 species higher than the control sites. This was also associated with a much higher abundance in February 95 than the controls (see Figure 5). Wasp, hemipteran, fly and cricket species were responsible for the majority of these extra species which possibly responded to the availability of nutrient rich new plant growth and a greater supply of invertebrate hosts. Beetles and mites, however, still had fewer species than the control sites possibly due to the slow accumulation of the leaf litter.

Third Post-fire Spring at Autumn 93 Prescribed Fire Sites:

In November 95 the autumn 93 burnt sites had reached their third post-fire spring. The species richness at these sites was much more similar to the controls than the previous spring, but now was 6.92 species lower. Wasp, 'minor' taxa, fly, ant and mite species made-up the majority of this difference possibly reflecting the lack of early spring invertebrate hosts, low seed production and also the slow rate of litter accumulation due to a high abundance of collembolans in the previous spring (see Table 3). The spiders, beetles, collembolans and hemipterans which previously had low species richnesses had increased in richness by this spring to approximate the richness of the control sites. While the orthopterans had 1.57 extra species possibly in response to the availability of new plant growth. Also a number of taxa were captured at these autumn burnt sites, which had not been captured at the unburnt sites, these were a mantid (Mantodea) species, a flatworm (Tricladida) species, an antlion larva (Neuroptera), a web-spinner (Embioptera) species, a very large predatory long-horned grasshopper (Tettigonidae) species and a relict scorpionfly species (Mecoptera, *Austromerope poultonii* ,to be confirmed). In addition adults of the two relict spider taxa of mygalomorphs and micropholcommatids had been captured frequently at these autumn burnt sites. The micropholcommatids may have been favoured at these higher intensity burnt sites by the creation of log ashbeds that were colonised by large areas of moss swards that are these spiders favoured microhabitat.

Preliminary Conclusions of Fire Impact on the Morphospecies Richness of Litter Invertebrates:

The unburnt control sites have marked seasonal oscillations in mean species richness that peaked in late spring and then declined to half the spring species richness in the harsh summer-autumn season. The warm moist spring season appeared to favour decomposer taxa such as collembolans, flies and many 'minor' taxa and also favoured the seed feeders such as many of the ant species and the herbivorous taxa such as orthopterans and hemipterans. The harsh conditions of summer and autumn tend to favour the predatory and parasitoid taxa such as the spiders, beetles and wasps.

At the unburnt control sites the litter depth in autumn is approximately 20mm, plant growth is slow and the proportion of nutrient rich new growth is low. In contrast the recently prescribed burnt sites had shallow litter, rapid plant growth and a large proportion of nutrient rich new growth.

The spring and autumn fires initially resulted in an increase in both mean abundance and mean species richness. However the spring and autumn fires had differing impacts on the taxonomic composition of the litter invertebrate communities in the first post-fire spring during this acute post-fire stage. These early impacts related to the seasonal activity of particular taxa. The sites burnt in autumn 93 when litter decomposer activity was low was followed by a marked increase during the first post-fire winter and spring of these decomposer taxa, such as collembolans and fly larvae. The high intensity and resultant crown scorch in autumn 93 probably stimulated the immediate release of a large quantity of jarrah seed which may have supported a high ant abundance in the first post-fire spring.

In contrast shortly after the spring 94 prescribed fires the abundance of decomposers such as collembolans was markedly reduced in this first post-fire spring, as these fires occurred during the peak activity season of these decomposer taxa (see Figure 6). While, at these spring burnt sites, the late spring -summer active ants and beetles were both more abundant and more species rich than the unburnt control sites, possibly due to increased surface activity due to the simplification of the habitat as a result of the combustion of the shrub layer and also as a result of the immigration of large numbers of predatory acanthocnemid beetles. Both spring and autumn prescribed fires had markedly different taxonomic composition to the unburnt control sites and this composition appeared to becoming increasingly different with the higher intensity autumn fires which had a number of captures of different taxa. In the harsh first post-fire autumn the autumn 93 burnt sites reached their lowest species richness due to a reduction in species numbers of large prey predators and parasitoids such as spiders and wasps, although total abundance of invertebrates had settled back to approximated that of the control sites. While the spring 94 burnt sites during this first post-fire autumn had a litter invertebrate abundance and species richness that was only slightly lower than the unburnt controls possibly due to the less extreme conditions in the deeper litter layer that was only partly combusted by the spring fires.

By the second post-fire spring the initial differing impacts of the different burning season had virtually disappeared with the mean species richnesses of the spring and autumn prescribed burnt sites coming into phase and both having markedly reduced species richness compared to the control sites. However although the changed taxonomic composition was more simple with fewer species, the abundances of both these prescribed burnt sites approximated those of the control sites. Also the abundances of the prescribed burnt sites were largely composed of collembolans, which although fewer in species were almost twice as abundant as at the control sites, which indicates a much higher litter decomposition rate.(see Figures 4,5&6). The majority of the other taxa of the spring and autumn sites were also impacted in similar ways. The wasp species at both sites were markedly reduced possibly due to lack of juvenile invertebrate hosts. The beetles species were also markedly reduced possibly due to shallow litter depth and lack of medium sized prey. The 'minor' taxa were also reduced in species again possibly due to the shallow litter depth. While the spiders which were also reduced in species, possibly due to a lack of larger sized prey.

By the second post-fire autumn the autumn burnt sites were both more abundant and more species rich than the control sites (see Table 3 and Figure 4&5). Data are not yet available for the second post-fire autumn for the spring 94 burnt sites but I hypothesise that the abundance and richness of these sites will be similar and stay in phase with the autumn burnt sites until they both revert back to a similar community structure found at the unburnt control sites. The higher autumn abundance at the autumn burnt sites was due to a much higher abundance of collembolans than at the unburnt control sites, which probably indicates a continued rapid rate of litter decomposition. The higher species richness at the autumn burnt sites was largely due to the increase in species of wasps, hemipterans, flies and orthopterans possibly reflecting an increase in the number of invertebrate hosts, a greater quantity of nutrient rich new growth and an increase in the litter depth.

In the third post-fire spring at the autumn burnt sites both the abundance and species richness was lower than the control sites. The reduced abundance was largely due to the decrease in the number of collembolans and also ants, possibly due to a decline in the availability of litter nutrients and the low production of seed by the young regrowth vegetation. The reduced species richness was due mainly to fewer species of the wasps, 'minor' taxa and flies. The pollinating wasps were possibly reduced due to the lack of flowers on the young regrowth, while the 'minor' taxa and flies may have been reduce due also to the decline in nutrient availability. However although the species richness was reduced at the autumn burnt sites, a number of taxa were captured that had not been captured from the unburnt sites. This indicates that the combined species richness of the burnt and unburnt sites had increased, which suggests that the prescribed fires had increased the diversity of available forest floor habitats and hence increased the regional diversity of the jarrah forest in this study area. The majority of these 'new' taxa were captured in the more intensely burnt autumn fire sites.

General this study suggests that the spring and autumn prescribed fires, although initially differing in impact, both caused an increase in productivity or abundance at an early post-fire successional stage of the litter invertebrate community which was composed of a different but more simplified taxonomic structure, probably due to the increased availability of litter nutrients. This changed taxonomic composition particularly of the autumn burnt litter communities increased the regional diversity of the study area. Also the burst of productivity following the prescribed fires was first apparent in the increased decomposition rate and the increase in abundance of small decomposers such as collembolans. This burst of productivity may continue to move up the food web from decomposers and herbivores, to small predators and parasitoids, then to larger predatory guilds and ultimately may increase the food supply of insectivorous vertebrates.

1) Impact of fire on selected Orders

Of the four orders (spiders, wasps, flies and beetles) selected as possible bio-indicators of seral change of invertebrate communities, we are initially concentrating on the beetles. The beetle morphospecies at Batalling seem to show far more predictable and analysable seral changes after fire. The beetle order is also much richer in species than the other 3 selected orders and the beetle species probably occupy a wider range of trophic niches in the litter community. Also the impact of fire on beetles at the morphospecies level has been studied in other Australian plant communities, therefore allowing ecological comparisons to be made on a continental scale (Neumann et al., 1995, Friend et al., 1993 unpublished).
To date the beetle morphospecies have been sorted for the following samples: November 1992, November 1993 and November 1994 with 165 morphospecies of beetles having been distinguished. These 165 morphospecies represent 32 families which is comparable with the 109 species and 30 families caught in the litter of dry sclerophyll mix eucalypt forest (905mm rainfall) in west-central Victoria (Neumann et al., 1995).

The body dimensions of all beetle morphospecies were measured as the size of a beetle species may be strongly correlated with its position in the food web and may have been determined by strong evolutionary pressures over a long period of time (Peters,1989).

Data summarised in report 6 of the frequency distribution of the number of beetle morphospecies occurring in 1 centimetre increments of body length indicated this may represent a stable structure of the jarrah forest beetle community that can be used to predict long term impacts of fire. This frequency distribution of morphospecies indicates that the litter beetles in the jarrah forest could possible be divided into three groups: Group 1 (1mm to 7.9 mm), a very species rich group containing some very abundant species eg staphylinids and pselaphids; Group 2 (8mm to 40mm), a group containing only a few very large beetle species possibly with low reproductive and dispersal powers eg amcyterine weevils and some large apterous carabid species; and Group 3 (less than 1 mm in length), very small beetle species which may have specialised microhabitats and be very vulnerable to moisture or other changes in their immediate environment eg. some minute species of Ptiliids and pselaphids.

Upon identification of the beetle morphospecies to at least family level, information on their life histories and general trophic guilds can be obtained from the current literature. Using this information and the data I have collected on the body dimensions, each morphospecies will be categorised in to a functional guild and multivariate analyses conducted to determine any patterns of response to the impacts of the different burning seasons.

Sorting of the beetle morphospecies indicates a change in beetle species composition which may be correlated to the intensity of the prescribed fires. For example a small species of hydrophilid beetle whose larvae are predatory and adults are saprophytic was extremely common in the deep leaf litter of the control sites in November 94 while a species of the predatory acanthocnemid beetle was quite uncommon at these sites. Following the spring 94 fires, this species composition was reversed at the burnt sites with the hydrophilid beetles become far less common , while the acanthocnemids became extremely common. This marked change in the composition of litter invertebrates following the prescribed fires probably led to an increased regional diversity of the study area.

g) To date 371 morphospecies have been distinguished, comprising 71 spiders, 30 flies, 16 ants, 29 wasps, 165 beetles, 12 bugs, 4 slaters, 6 orthopterans, 2 earwigs, 2 springtails, 14 mites, 3 caterpillars, 1 termite, 1 cockroach, 1 pseudoscorpion, 2 snails, 1 pauropod, 7 thrips, 2 harvestmen and 1 earthworm.

H. Preliminary Recommendations for Management

This project will provide process-based empirical data on the impact of prescribed burning on terrestrial invertebrate communities in the jarrah forest, and lead to the development of sound forest management prescriptions which take invertebrate conservation values into account. The work will also facilitate the development of predictive models of the response patterns of invertebrates to fire, thus allowing improved and broad-based decision-making regarding forest management.

I. Work to be Completed

a) Continue post-fire sampling particularly at the autumn 96 prescribed burnt areas.

b) On-going sorting and identification of invertebrates from trapping periods, with emphasis on late spring and autumn samples. The continued sorting of beetle morphospecies to determine the extent of changes to regional diversity, the rate of convergence with control site taxonomic composition and the identification of a predictable functional guilds.

c) Continue measurement of habitat parameters to monitor pre and post- fire environmental changes.

d) The final data will be analysed for fire season impacts on taxa abundance using the Before-After-Control-Impact analysis of variance method. Fire impacts on ordinal, sub-ordinal taxa, mean species richness and morphospecies of select taxa will be analysed using the appropriate diversity indices such as Shannon-Wiener, Margalef and Pielou and multi-variate analyses to determine patterns of impacts. Functional guilds responses to fire season will be analysed using the appropriate multi-variate analysis.

Implications for final statistical analysis and diversity indices:
The implications on the final analysis of the seasonal oscillations and long term trends in the data summarised to date are as follows: 1) the large differences in structural parameters between seasons indicate it is essential to compare before and after impacts of fire only within like seasons; 2) that the seasonal effect in this data makes it inappropriate to use the magnitude of the difference between fire sites and control sites to even out this seasonality, as even pre-fire sites maybe more similar in the harsh autumn seasons and less similar during the spring peaks therefore causing insensitivity in the analysis and 3) due to the rapid temporal changes in structural parameters it is of greater importance to increase replication within each site at each sampling date than increasing the number of samples taken through time in lieu of within site replication.

J. Difficulties Encountered

a) The over spending in the World Wide Fund for Nature budget has been reduced to $548 and will be corrected to a balanced budget in future quarters. The Department of CALM in general is suffering a limitation of funds which is reducing the quantity of trapping materials that can be purchased and the amount of vehicle travel undertaken for field sample collections. I have, therefore, put up a proposal to CALM to allow me to use my own commercial vehicle for field work at a invoiced kilometre cost that is cheaper than the current private company's vehicle hire rate. This proposal would save CALM approximately $400 per year and hence would also reduce my budgeted vehicle expenditure by $400.

K. Budget Report

World Wide Fund for Nature funding for the 18 week period 26 April 1996 - 30 August 1996.

	Budget	**Expenditure**
Salaries	5980	5188
Materials	0	0
Travel	381	149
Other (admin 5%)	0	312
Publication	346	0
TOTAL	**6707**	**5649**
GRAND TOTAL TO DATE (13 June 94 - 30 August 96)	**36,964**	**37,512**

Expenditure receipts are included at the end of this report.

Department of Conservation and Land Management funding for the 18-week period 26 April 1996 - 30 August 1996.

	Budget	**Expenditure**
Salaries	6092	5547
Materials	104	637
Travel	381	393
Other (admin)	346	346
Publication	0	0
TOTAL	**6923**	**6923**

L. Reports or Publications Arising

None at present early stage.
A video tape may be prepared for the summary and presentation of the final results in addition to the final report.

M. References

Burrows, N.D.(1995). "A framework for assessing acute impacts of fire in jarrah forests for ecological studies." CALMScience 4: 59-66.

Friend G. and Williams, M.(1993). "Fire and Invertebrate Conservation in Mallee-Heath Remnants" World Wide Fund for Nature Australia, Project P144.

Main, B.Y. (1987). "Ecological disturbance and conservation of spiders: Implications for Biogeographic relics in Southwestern Australia." In Majer, J.D.(ed.), The Role Of Invertebrates In Conservation and Biological Survey.(1987). Western Australian Department of Conservation and Land Management Report.

Neumann,F.G., Collett, N.G. and Tolhurst, K.G. (1995). "Coleoptera in litter of dry sclerophyll forest and the effects of low intensity prescribed fire on their activity and composition in west-central Victoria." Aust. For. 58(3): 83-98.

Peters, H. R.(1989). "The ecological implications of body size." Cambridge University Press.

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For: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
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Mr Ray Nias
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Dear Ray

Sorry for over due progress report but CALM has employed me to study Relict Gondwanan invertebrates in the only existing patch of Tingle forest (*Eucalyptus guilfoylei*) on the extreme south coast and the initial experimental design has taken quite abit of organisation and field time. A very detailed Progress Report No. 7 (due 28th August 1996) for Project P199: "Conservation of Jarrah Forests in W.A.: the impact of Prescribed Burning" is almost complete and will be in the mail within the week. My apologies.

Yours sincerely

Paul Van Heurck
Eco-Insect Consultants

16 September 1996.

Eco-Insect Consultants

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Phillipa Walsh,
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Telephone: (02) 247 4126

Dear Phillipa

A very detailed 31 page Progress Report No. 7 (due 28th August 1996) for Project P199: "Conservation of Jarrah Forests in W.A.: the impact of Prescribed Burning" is complete other than the final edit. As my usual CALM supervisor Matthew Williams is away on study leave in North America I have sent this report to Dr. Ian Abbott and Dr. Tony Friend, two CALM entomologists, for final review. Therefore the final document will be posted to you no later than the 23/10/96. I apologise again for the long delay but as I mentioned in my previous letter I have had a very hectic few months establishing another study for CALM on Gondwanan invertebrates relics in the only patch of Tingle Forest in existence.

Yours sincerely

Paul Van Heurck
Eco-Insect Consultants

18 October 1996.

Eco-Insect Consultants

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For: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
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Dear Ray

Enclosed is a very detailed(but repetitious summary of "Results") Progress Report No. 7 (due 28th August 1996). My apologies, again. I hope this long delay has not caused you too many problems.

Yours sincerely

Paul Van Heurck
Eco-Insect Consultants

23 October 1996.