FIRE CONSIDERATIONS IN DRYANDRA FOREST

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A SURVEY REPORT

MANJIMUP RESEARCH STATION.

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CONTENTS

SUMMARY

Effective fire management is a fundamental step in the management of nature reserves in the south west. Fire management must take account of the surrounding land owners and reserve visitors, but should also allow natural ecological processes to continue. This requires a sound understanding of the fuel and vegetation characteristics of the reserve, which will determine the behaviour and effects of fire, either planned or unplanned.

From a recent survey of Dryandra Forest, it is clear that the activities of adjacent landowners have posed the greatest wildfire threat to the forest. To date, no fires have burnt out of Dryandra Forest. We suggest that the best approach to wildfire control is prevention. this requires direct, regular and constructive liaison with farmers, forest users and the public at large and the maintenance of effecient detection, suppression and firebreak systems. We also advocate frequent edge burning in certain strategic areas.

Broadacre, cyclic and frequent (<20 yrs) burning for fuel reduction is costly, and an unnecessary wildfire control measure in the Dryandra Forest. Further, there is evidence that such a practice will cause the deterioration of important fire sensitive, thicket forming species such as

the poisons (*Gastrolobium* sp.). We suggest a monitoring system and the development of an "Ecology Index" to determine the need to burn an area and the intnesity and timing of the fire.

This concept and others are discussed at length in the following report.

PREFACE

This report contains information relevant to fire management in Dryandra forest. Data were mostly gathered during a field survey in August, 1984. This document is not a bibliography of the fire ecology of Dryandra forest nor is it a fire management plan. It is a compilation of some facts and ideas which I hope will assist planners in developing appropriate fire management.

This report was prepared jointly by all staff at the Manjimup Research Station and as such, is the first of its kind. Where data are needed for the formulation of management plans, field surveys of this kind can provide sufficient information for interim plans. I trust this document, together with other detailed studies and constructive dialogue, will contribute to the management of this remarkable forest.

Neil Burrows

(PROJECT LEADER)

1. INTRODUCTION

Fire plays an important role in maintaining natural ecosystems in the south west of Western Australia. The Mediterranean type climate of cool, moist winters and hot dry summers, together with accumulations of flammable scrub and litter predisposes this environment to fire. It is not surprising then, that appropriate fire management is fundamental to effective management of nature conservation forests in the south west. Fire management plans for individual forests are common as managers recognize the importance of tailoring fire management to local ecosystems and local social and human factors. Fire management must be based on research and information relevant to conservation objectives and on the need to reduce the risk and impact of unwanted wildfires. To use fire as a controllable management tool, the manager needs a good knowledge of fire behaviour and of its long and short term ecological and social effects. With very few exceptions, detailed knowledge of ecological processes and of the role of fire, does not exist for most nature conservation forests. While certain principals and processes are transferable from one ecosystem to another, it is best to examine individual forests. In most cases, managers can not "take no action" until researchers provide detailed ecological biological information, which may take many years to accrue. However we believe that a working knowledge of the role of fire in achieving conservation objectives in forest reserves can be obtained fairly cheaply and in a relatively short time. The hazard posed by unwanted wildfires and strategies for minimising their environmental and social impact can be defined.

We describe the methods used to determine the role of fire in Dryandra State Forest. The techniques provide short term answers to management questions about the role of fire, but concurrent, detailed research is needed to consolidate the process of fire management planning.

1.1 Dryandra State Forest - A Description

Dryandra forest is one of the few remnants of wheatbelt vegetation found in the Narrogin District of the South West of Western Australia. The forest lies to the east of the main jarrah (Eucalyptus marginata) forest belt and in the 500mm rainfall zone. Open woodlands of wandoo (E. wandoo) and powder bark wandoo (E. accedens) with occurrences of brown mallet (E. astringens), marri (E. calophylla) and jarrah are found on a countryside of plateaus, slopes and valley floors. Landform units and soils have been well described by McArthur et al (1977)

Dryandra forest is of major ecological significance. It represents the severely depleted original vegetation of this wheatbelt region and is one of the few remnants large enough to maintain viable population of rare animals.

The total area of Dryandra forest is about 28 000 hectares, consisting of a large central block and smaller outliers surrounded by cleared farmland. The Western Australian Department of Conservation and Land Management currently administers the forest as an area for the conservation of flora, fauna and landscape values. A comprehensive regional management plan is being prepared. Fire management is a vital component of this plan. A lack of fuels data and poor understanding of the role of fire in the area prompted researchers from the Department of Conservation and Land Management's Manjimup Station to carry out a three week study in June 1984 to provide base line data. This survey was not intended to be a detailed and long term biological study, but rather, the objective was to measure and observe field indicators of the past fire regime and to develop ideas about something of the role of fire in maintaining ecological processes. We also addressed the question of the threat posed by unwanted wildfires to both conservation and landscape values and to forest users and adjacent land owners.

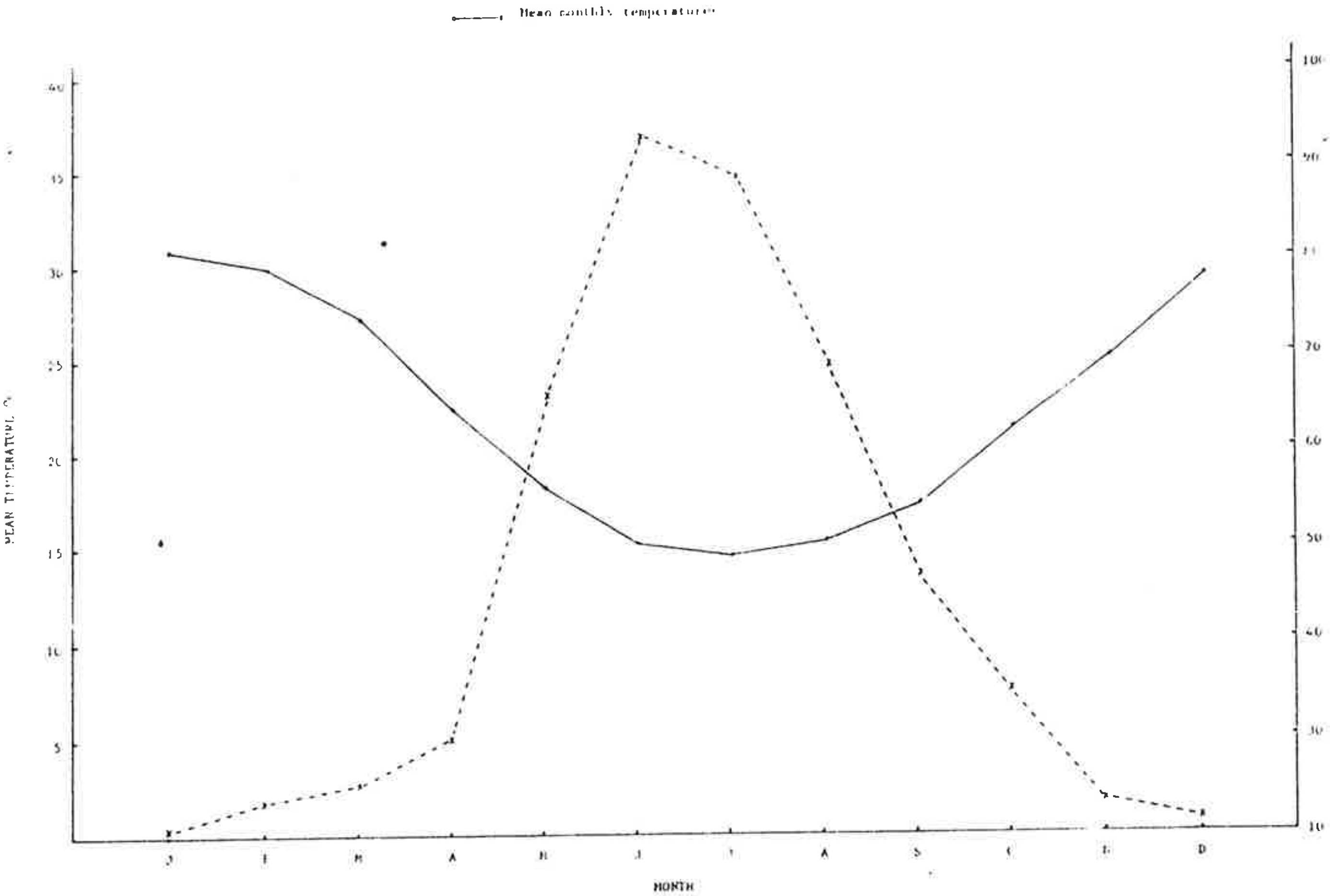
2. CLIMATE

Climate, vegetation and fire have a long association in the south west. Climate effects the fire proneness of an area by the quantity of fuel available for burning, the surface burning conditions (such as fuel dryness, wind speed, temperature, stability etc.), the length of time for which fuels are dry enough to burn and the likelihood of lightning caused ignitions.

Here, we have examined meteorological records for Narrogin (south of Dryandra), provided by the Bureau of Meteorology. Records have been kept since 1933 and are summarized below for temperature and rainfall. We were unable to obtain records of wind strength and direction for this period.

From the figures below, it can be seen that Narrogin experiences a strongly Mediterranean type climate with warm to hot, dry summers and cool, wet winters. The mean annual rainfall (for the last 50 years) is 508 mm, of which almost 80% falls between the months of May and September inclusive. In summer, rain can be expected to fall on only 2 or 3 days of each month. This leaves a considerable period over summer for fuels to become very dry, especially given the hot, dry easterly winds experienced here. Based on average conditions over the last 50 years and the graphs in figures 1, 2 and 3, we can expect that the Dryandra forest fire season, or the period during which fuels <u>may</u> burn, to be the months of November, December, January, February, March and April.

FIGURE 1: Mean monthly temperature and rainfall for Narrogin
(1933 - 1984)



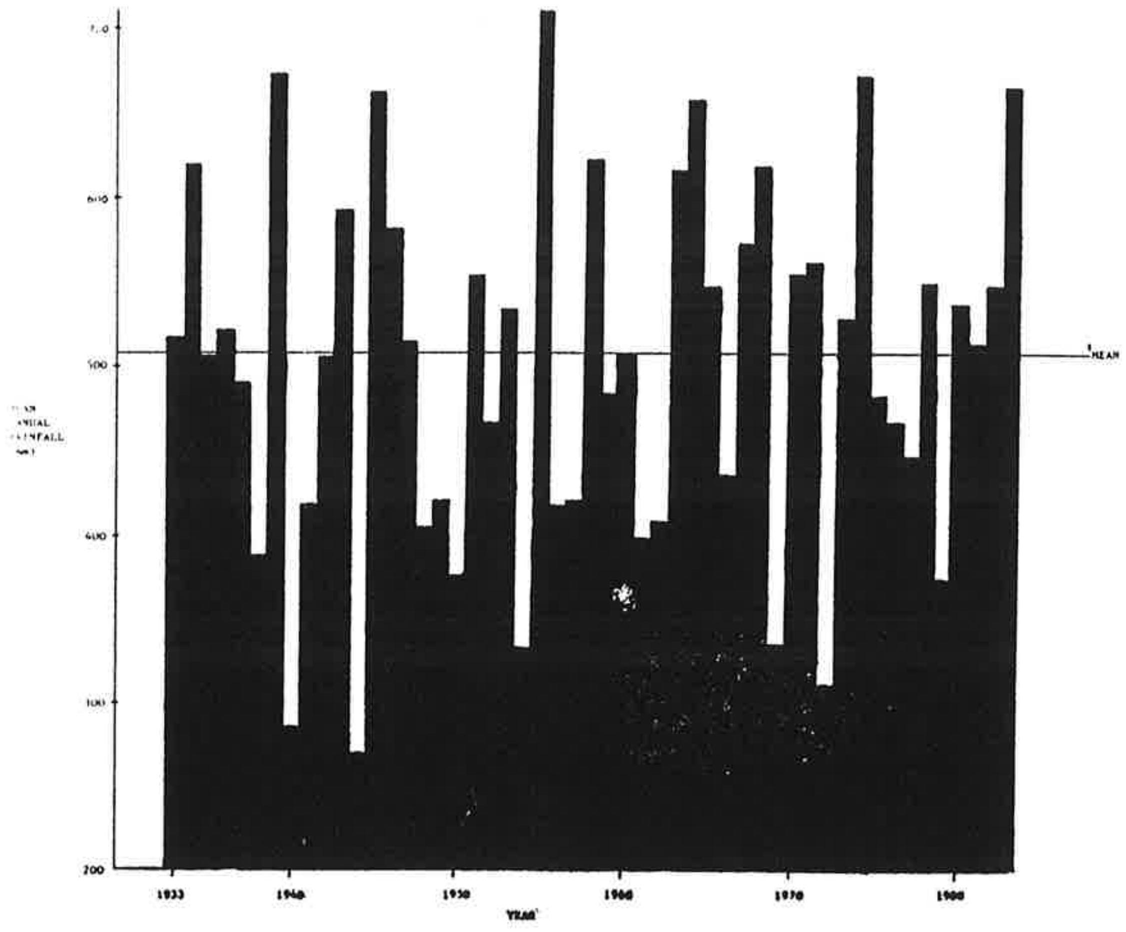
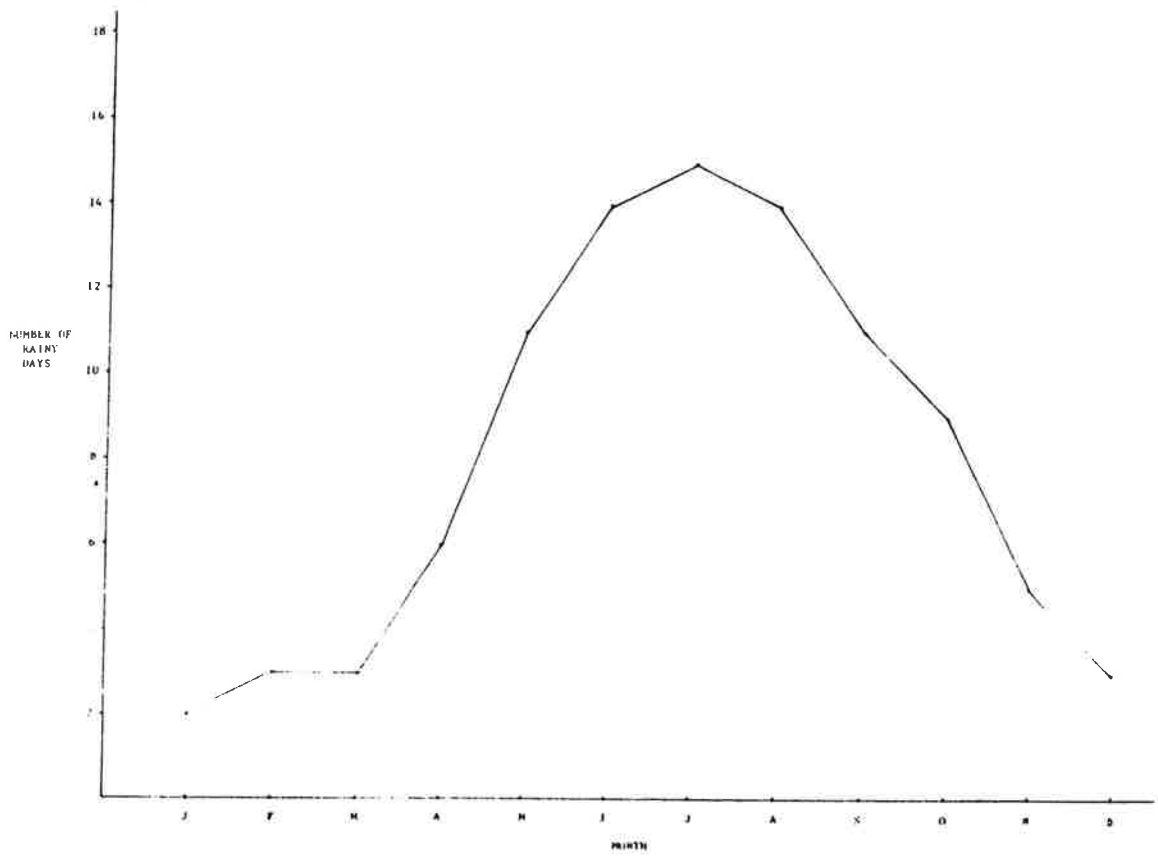


FIGURE 3: Mean number of rainy days per month for Narrogin



The most severe fire weather will be experienced in December, January, February, March and the early part of April. This is an average fire season and will obviously vary from year to year. Even so, it is a considerably long period during which fuels are likely to burn. This period will be extended and will be more severe, in terms of potential fire severity, in very dry years, (rainfall <400 mm) of which there have been 10 in the last 50 years. The period will be shortened and less severe in very wet years, (rainfall >600 mm/annum) of which there have been 12 in the last 50 years.

On the basis of the number of hot, dry days experienced in Dryandra forest, one would expect regular severe fire outbreaks. However, this has not been the case. The occurrence and size of past wildfires in the region does not relate well to weather conditions. Dry conditions were experienced in 1948, 49, 50 and there were major fire problems in those years. However, as discussed in the next section, this was largely due to human activities in this period, and was aggravated by the drought. The primary reason for the paucity (by comparison with western forests) of large and devastating wildfires is the limited availability of fuels, (or vegetation) associated with the low rainfall experienced in this region.

3. FIRE HISTORY

Methods

Fire history, including wildfires and prescribed fires, was obtained from records held by the Department of CALM and over the period 1938-1984. Prior to 1970, wildfire records were somewhat sketchy, but provided some information about fire occurrence, size, location and in most cases, cause. Prescribed fires were marked in on annual burning plans. These plans and any other documented information (such as annual reports,, fire reports etc.) were used to re-construct the recent fire history of Dryandra. Fire does not confine itself to land tenure boundaries,so we decided to examine all fires within a 20km radius of the Dryandra fire tower. This takes in all of Dryandra forest and a considerable area of adjacent farmland.

3.1 Wildfires

3.1.1. Results

Over the period 1938-1984, a total of 87 wildfires burnt within a 20km radius of the fire tower (see appendix 1). A summary of wildfires over this period is presented in Table 1 below.

TABLE 1: A summary of wildfires burning within a 20kms radius of the Dryandra forest fire tower and for the period 1938-1984.

FREQUENCY	No of wildfires which <u>started</u> in Dryandra forest	9
	" " " " " " private property	69
	" " " " " " other areas	9
	TOTAL WILDFIRES	87

SOURCE	No of wildfires which <u>started outside</u> Dryandra forest but which <u>burnt into</u> Dryandra forest	20
	No of wildfires which <u>burnt out of Dryandra into private property</u>	0

SIZE	Average size of wildfire which <u>started in</u> Dryandra forest	40ha
	Largest wildfire which <u>started in</u> Dryandra forest	260ha
	Largest fire which burnt on private property	2550+ha
	Average wildfire size on private property	503ha
	Cause of wildfires which started in Dryandra forest:	
	escape from control burning	5
	lightning	2
	other	2
	TOTAL	9
	Total number of wildfires in Dryandra	29

CAUSE	Causes of <u>all</u> wildfires within 20km radius of fire tower:	
	private property clearing burns	39
	harvesting operations	18
	locomotives	10
	lightning	4
	escapes from F.D. control burns	5
	other (billy fires, campers etc.)	4
	unknown	7

FIGURE 4: Total area burnt by wildfire between 1938 - 1984

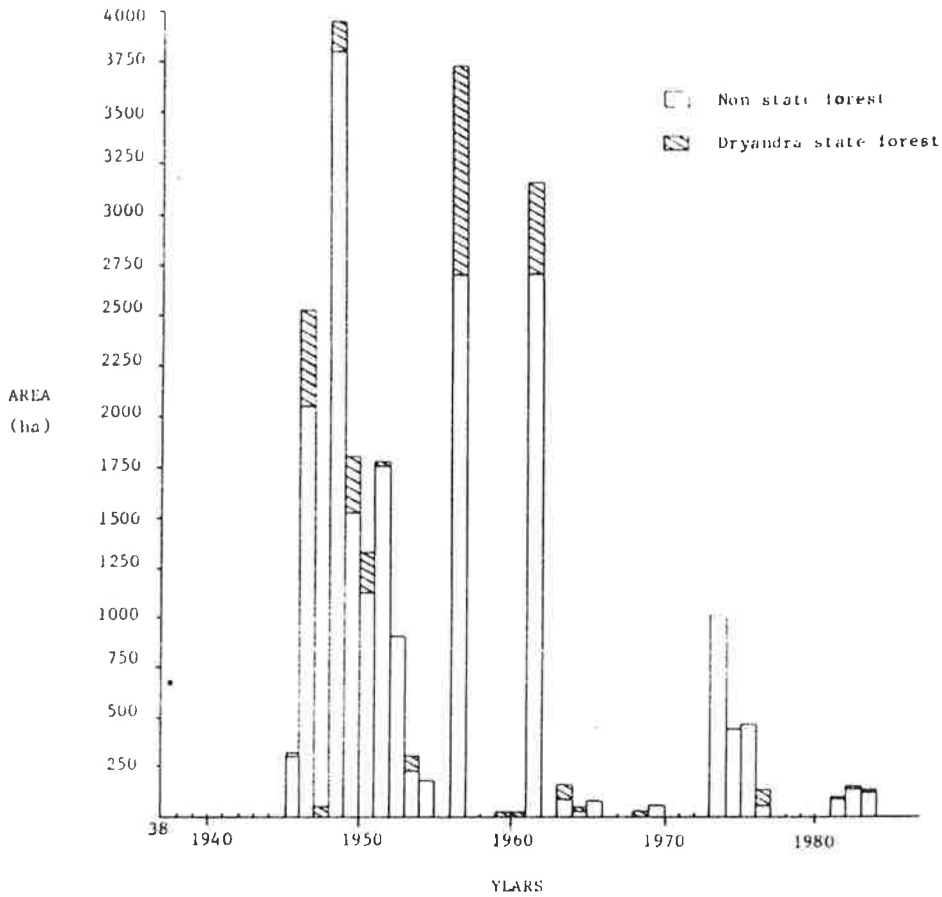
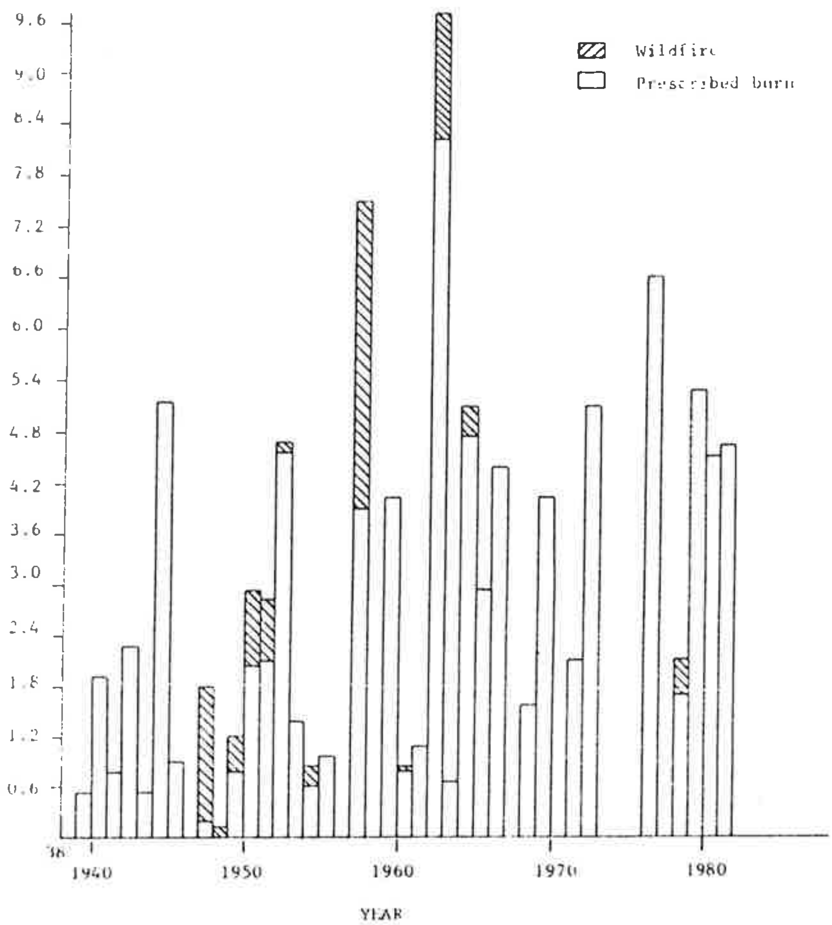


FIGURE 5: % area of Dryandra forest burnt annually 1938 - 1984



3.1.2. Discussion of Wildfire Results

The number of wildfires in and around Dryandra forest over the period studied, is very low in comparison with other forest districts in the higher rainfall, western zone. the level of wildfire proneness of Dryandra forest could be rated as low. It is not uncommon for western forest districts to experience 20-40 wildfires each year. Of the 87 wildfires, only 9 started in Dryandra. The remaining fires started in private property around Dryandra. The period 1946-1970 was the worst in terms of numbers of wildfires and total area burnt by wildfires (figure 4). This was due to the vast amount of clearing and associated burning off which took place after the war. Escapes from clearing burns accounted for most wildfires in this period. Wildfires since 1970 were caused mostly by harvesting operations on wheatlands. There have been considerably fewer wildfires and considerably less area burnt by wildfires since 1970 (figure 5). This is largely due to a reduction in clearing burns (figure 7), a greater awareness of wildfires, and better wildfire detection, and suppression techniques.

Lightning caused wildfires in and around Dryandra were a rarity (at least over the period studied). In comparison with other forested areas, Narrogin district had the lowest incidence of lightning strikes (Table 2).

There has been only 2 recorded lightning caused fires in Dryandra forest since 1938. Steam locomotives also caused many early wildfires, but this ignition source has long since passed. Ironically, the watering points and dams constructed for these locos are now important for wildfire suppression. Clearly the wildfires in and around Dryandra forest have been land use related (Table 1). Close attention to the activities of adjacent landowners and co-operation between farmers and the Department of CALM is necessary to minimize wildfire outbreaks. Currently, most wildfires are caused by harvesting operation, so it would be in the Departments best interests to offer fire protection assistance by way of training, advice and/or resources to farmers who are carrying out any burning or harvesting operations. It would be mutually beneficial for Departmental staff based at Narrogin to maintain close contact with farmers adjacent to Dryandra so that the Department is informed as to when and where harvesting or burning operations are about to take place. Knowledge of which lands are under cropping will assist in planning spring burning adjacent to private property and any other fire protection operation (herbicide spraying, clearing up breaks, maintenance of water points, stag falling etc.). Regular "good will" visits to farmers and forest users, both adjacent to and within Dryandra, will contribute to wildfire prevention. Other points are discussed in the section - "Dryandra Forest Boundary Survey".

The higher proportion of autumn burning done during the 1950's and 1960's was probably in conjunction with clearing burns carried out at this time. More recently (1970's and 1980's) fuel reduction burning has mostly been carried out in spring, although not entirely (figure 7).

It is difficult to evaluate the effectiveness of past prescribed burning (both edging and broadacre burning) in terms of wildfire control, as there have been major changes in activity on adjacent land, hence wildfire causes. Most wildfires (prior to 1970) were caused by clearing burns on private property. Little or no clearing burns have been carried out since 1970 (as all arable land has been cleared!) and the incidence of wildfires has dropped markedly. Co-incidently, the area of broadacre fuel reduction burning has increased. It is most likely that the reduction in wildfires has been largely due to a cessation in clearing burns and to the establishment of high value wheat crops. The risk of high monetary losses resulting from wildfires has seen the development of well organized and well equipped bushfire brigades and a more cautious use of fire on the land.

4. Boundaries and Fire Breaks

Methods

In order to determine the condition of firebreaks around the perimeter of the main block, an extensive field survey was carried out by Narrogin Divisional staff.

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The survey was conducted by driving around the perimeter of the main block and assessing the condition of firebreaks and the private property - Dryandra forest interface. Observations were made from points spaced at 200m intervals along the perimeter and by completing a multiple choice questionnaire (see appendix 2). A distance of 50m either side of each sample point was assessed. Lengths of roads and fire breaks in and around the main central block were measured from 1:50,000 scale maps.

4.1 Results

The perimeter of the central block is about 100km. A total of 550 points around the perimeter were sampled according to the questionnaire in appendix 2.

Appendix 3 shows the breakdown of each 20 variables examined. From these tables (appendix 3), it can be seen that 42% of the perimeter is surrounded by land which is used for wheat cropping and 49% is surrounded by pasture or grazing land. Firebreaks are in place on both sides around the entire perimeter. On 72% of the perimeter, the farmers firebreak was within 2m of the fence and the Departments break was within 5m of the farmers fence. In 10% of cases, the Departments firebreak was up to 20m from the farmers fence. In 28% of the cases, the land between the breaks was wandoo forest with a grassy understorey and in 42% of cases, the understorey was thick scrub. In 80% of cases, grass grew on land between the breaks.

About 75% of the perimeter requires immediate attention to bring it up to an acceptable firebreak standard. Of the area of perimeter requiring immediate attention, 46% required spraying to reduce the grass cover. A further 25% of the perimeter required both spraying of grasses between the firebreaks and re-grading of firebreaks which had become overgrown with scrub.

4.2 Discussion

There were two readily identifiable types of firebreaks in Dryandra forest. The first of these were man made firebreaks, where fuels had been physically separated to form a bare mineral earth strip from 2m to 50m (in mallet plantation) wide. the second type of firebreaks were natural features, particularly rocky breakaways and areas of very low and patchy fuels.

4.2.1. Man-made fire breaks

These rely on fuel separation if they are to be effective in either stopping or slowing a fire or if they are to be used to control fires by backburning. They must also be trafficable as rapid attack is essential for quick fire suppression. In and around Dryandra forest there are about 600km of roads and tracks which also serve as firebreaks.

Of these, about 300km occur within and around the central block. This forest has a very high density of roading, with most compartments being only 100-200ha. The largest compartment is in the order of 350ha. the effectiveness of firebreaks and tracks in stopping fire will obviously depend on break width and fire behaviour. Most firebreaks (2-3m width) would probably stop low intensity fires (<300kW/m). Wide breaks (50m) may be more effective. Firebreaks are more effective in stopping grassland fires where intensities are usually lower than forest fires and spotting is less severe. In comparison with higher rainfall western forests, firebreaks in and around Dryandra, where properly maintained, are likely to be far more effective in stopping or slowing a fire run because:

i) fuels are generally light and patchy

ii) spotting is likely to be less intense and firebrands will not be thrown as far due to the lack of fibrous barked trees and the low tree canopy.

4.2.2. Natural firebreaks

Much of Dryandra is dissected by rocky outcrops up to 5-10m wide. During this survey, there was evidence where rock outcrops had stopped low intensity fires. In other instances, low intensity fires were stopped by areas of low and patchy fuel accumulation.

These natural firebreaks would not stop a major headfire run under severe weather conditions, but would break up the headfire and slow it down. Any moderation of fire behaviour is advantageous to fire fighters. Due to the high density of man made firebreaks, roads and tracks, it would not be necessary to use natural features in wildfire suppression but they could be useful in controlling prescribed burn patterns under mild conditions.

5. Fuel Quantity and Accumulation Rates

Methods

To adequately measure the existing fuel quantity and to define the rate of fuel accumulation in Dryandra forest, a technique of stratified, grid point sampling was used. The forest was stratified according to whether it was natural forest or mallet plantation. In the natural forest, six forest blocks were chosen for sampling. The choice of these blocks was guided by a number of criteria:

i) known fuel age

ii) a range of fuel ages between the blocks

iii) adequate representation of fuel and vegetation types.

The size and location of these blocks is shown on the map in appendix 4. Within each of these six blocks, a sample grid was constructed and was either 100m x 100m or 100m x 200m,depending on the size of the block (Table 3).

The location of sample points in mallet plantation aimed at covering the range of plantation ages (Table 3). Sample points were located along line transects, and at 50m intervals. Grid point sampling could not be used in mallet plantations as each year of planting was often a narrow tongue rather than a large block. The location of line transects in mallet plantations is shown on the map in appendix 4. Table 3 below summarises the sampling.

The age of fuels in natural forest was determined from records held by the Department of Conservation and Land Management. These records were verified in the field by using visual indicators of time since last burnt, including such things as charcoal weathering, extent of charcoal on stems and logs, the diameter and height of coppice regrowth, litter depth and scrub height.

Three fuel types were identified and measured. These were;

i) ground litter, which consisted of leaves and twigs (<10mm in diameter) and tree floral parts on the forest floor

ii) vegetation (live and dead) up to 2m above the ground

iii) large (>10mm diameter) dead and downed woody material (logs).

TABLE 3. Fuel sampling design - Dryandra forest.

NATIVE FOREST

BLOCK No.	BLOCK NAME	AREA SAMPLED ha	No. OF SAMPLE POINTS	FUEL AGES SAMPLED (YEARS) 1	3	4	5	8	9	15	20	44	46
1	Skelton	160	79	X		X	X						X
2	Smith	100	54					X	X		X		
3	Frank	160	80			X						X	
4	Peters	60	30		X								X
5	Bald Rock	200	91										X
6	Dryandra	100	45	X	X			X		X			
	TOTALS	800	379										

MALLET PLANTATIONS

Plantation age(yrs)	25	36	39	42	45	46	47	48	50	51	TOTAL
No. of sample points	10	16	16	16	14	24	24	8	8	16	224

Grass fuels often found on the forest boundary were not measured.

5.1.1. Measuring Ground Litter

Ten quadrats (each .04m^2) were randomly located within a 20m radius of each grid point. The litter depth within each quadrat was measured from three depth readings taken along a diagonal. All litter down to mineral earth was removed from the quadrats and placed into paper bags. Bagged samples were later oven dried, sorted into fractions and weighed. The litter was sorted as;

- i) fresh leaves
- ii) decomposing leaves
- iii) twigs (<10mm diameter)
- iv) bark and
- v) floral parts.

Tree basal area (m^2/ha) was measured from each grid point and using a wedge prism (2x). The fuel age for the point being sampled was also recorded.

5.2. Results of Ground Litter Survey

5.2.1. Fuel Age

A wide range of fuel ages existed within and between the studied blocks (Table 4).

Blocks 1, 2 & 5 were thought to have been areas which had not been burnt for at least 46 years (as long as records have been kept) but sampling revealed that 34% of Block 1 had been burnt in the last 6 years. This area (34%) had been recently burnt by edge burning to reduce litter fuel weights around the perimeter of the block. These fires were generally lit from a roadside and were allowed to burn back into the block for a distance of 50-100m before self extinguishing as fuels absorbed moisture towards evening. Our sampling revealed that edge burns, on occasions ran up to 200m into Block 1, but mostly burnt 20m-100m in, giving a discontinuous and patchy edge burn effect. Block 2 also contained a range of different fuel ages, each corresponding to edge burns. Generally, edge burning under drier conditions in autumn resulted in fires burning deeper into the forest than was anticipated. There was no evidence of Block 5 having been burnt since records were kept (Table 4).

Most of Block 3 (89%) was burnt under dry conditions 4 years prior to the study. The remainder of the block had not been burnt for 44 years. Likewise, most of block 4 (77%) was experimentally burnt 3 years prior to this study and under dry conditions. Fuel age in Block 6 was variable (Table 4), probably as a result of frequent edge burning. Of the 6 natural forest blocks studied, 34% of the area had not been burnt in the last 46 years.

This study also highlights the small grain mosaic of fuel ages which has resulted from edge burning in the past and the patchy results of more recent broadacre fuel reduction burning under cool, moist conditions. Where fires were lit under dry conditions in summer or autumn, burning was virtually complete.

TABLE 4: Fuel age by % area, in each block.

FUEL AGE YEARS	BLOCK NUMBER 1	2	3	4	5	6	ALL BLOCKS
1	2	0	0	0	0	20	4
3	0	0	0	77	0	20	17
4	16	0	89	0	0	0	19
5	16	0	0	0	0	8	4
8	0	42	0	0	0	12	10
9	0	34	0	0	0	0	6
15	0	0	0	0	0	40	0
20	0	24	0	0	0	0	4
44	0	0	11	0	0	0	2
46	66	0	0	23	100	0	34
TOTAL	100	100	100	100	100	100	100

5.2.2 Ground Litter Fuel Quantity

The quantity of ground litter fuels ranged from 0.2t/ha to 52t/ha (Table 5). The heaviest quantities were found in mallet plantations, which had not been burnt since their establishment. Heavy fuel quantities were also found in natural forest unburnt for 46 years. As to be expected, forest most recently burnt carried lightest fuels. From Table 5 it can be seen that fuel quantity varied considerably within blocks, even where fuel age remained constant.

Block 5, which has remained unburnt for 46 years, carries less than 8t/ha of ground litter fuel over about 40% of the total area. Frequency distribution of ground litter fuels are shown in figures 8 and 9 below.

Table 6 below contains the mean ground litter fuel quantities and variability for each age mallet plantation.

It is clear from these data that ground litter fuel quantity is variable and not well described for a forest block using an arithmetic mean. It is also clear that, generally, fuel quantities are low and are dependant not only on the time since the last fire, but on tree stocking. Ground litter quantity and the time since the last fire (or fuel age) were related by the equation;

Equation 1:

$$(\log_{10}\text{litter weight}[t/ha]) = .59(\log_{10}\text{litter age}[years]) -0.05$$

$$R^2 = 0.60$$

Considerably more variability in ground litter quantity was accounted for by including tree basal area in the equation:

Equation 2:

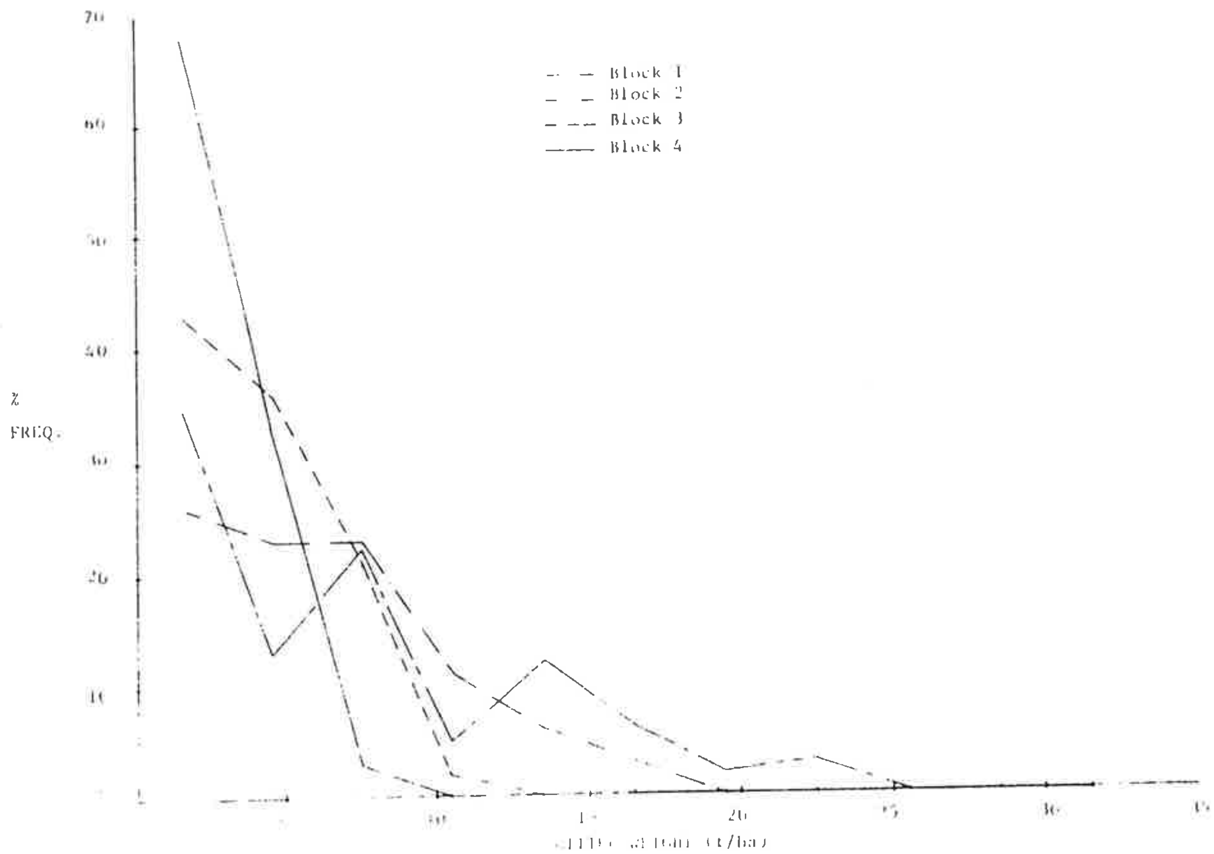
$$(\log_{10}\text{litter quantity}[t/ha]) = 0.53(\log_{10}\text{litter age}[yrs]) + 0.029(\text{basal area}[m^2/ha]) \; 0.15$$

$$R^2 = 0.66$$

Equation 2 is graphed in figure 10 below. These equations (1 & 2) hold equally well for both natural forest and for mallet plantation. Mallet plantations usually carry heavier fuels because of their higher and more uniform basal area. For a given basal area, the rate of litter fuel accumulation was similar, regardless of tree species. Accumulation rates presented here do not account for additional fuels resulting from thinning in plantations.

TABLE 5: Leaf litter fuel loadings for blocks studied. Blocks 20, 30 and 40 are mallet plantations (good quality).

PLOT NO.	MEAN	VARIANCE	RANGE	S.E.	MIN	MAX
1	7.78	57.0	42.0	1.03	0.9	42.9
2	6.24	20.54	21.4	0.61	0.2	21.6
3	3.95	5.4	9.3	0.3	0.4	9.7
4	3.11	3.31	8.3	0.3	0.6	8.9
5	12.05	75.5	37.7	0.89	0.2	37.9
20	13.25	56.7	32.0	0.86	3.1	35.0
30	15.28	47.1	20.3	2.17	4.0	24.3
40	20.43	94.4	46.6	1.56	5.9	52.5



[illegible] 8(a). [illegible] distribution v's ground litter weight

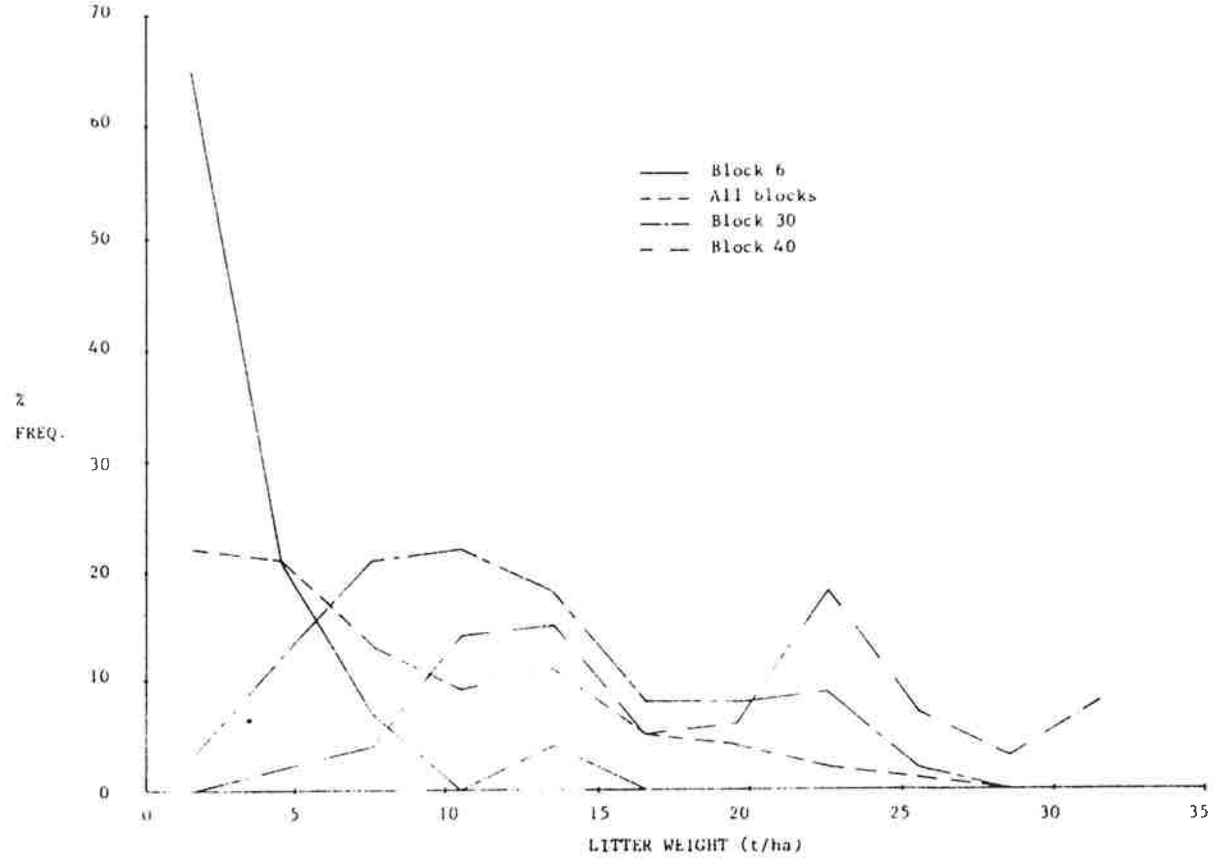


FIGURE 8(b): % frequency distribution v's ground litter weight

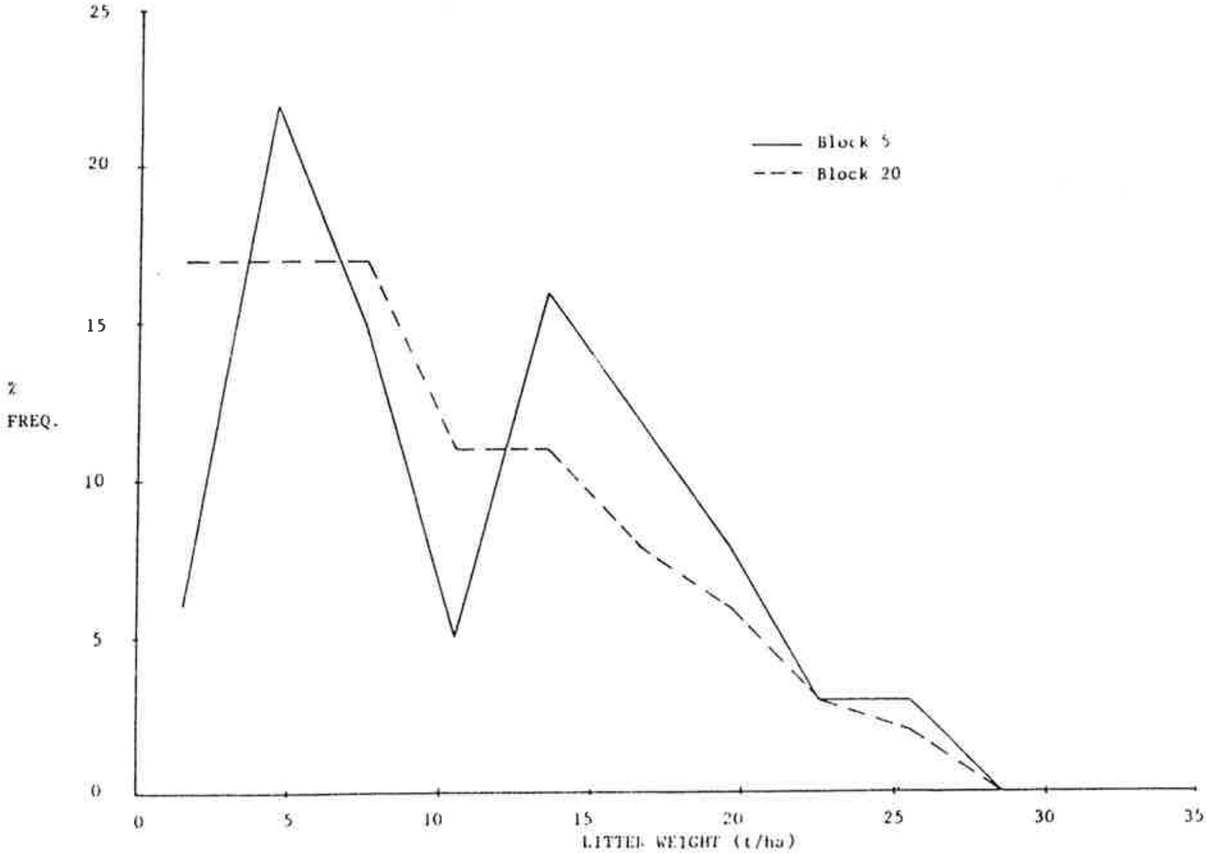


FIGURE 8 (c). % frequency distribution v's ground litter weight

FIGURE 9: Litter weights cumulative frequency

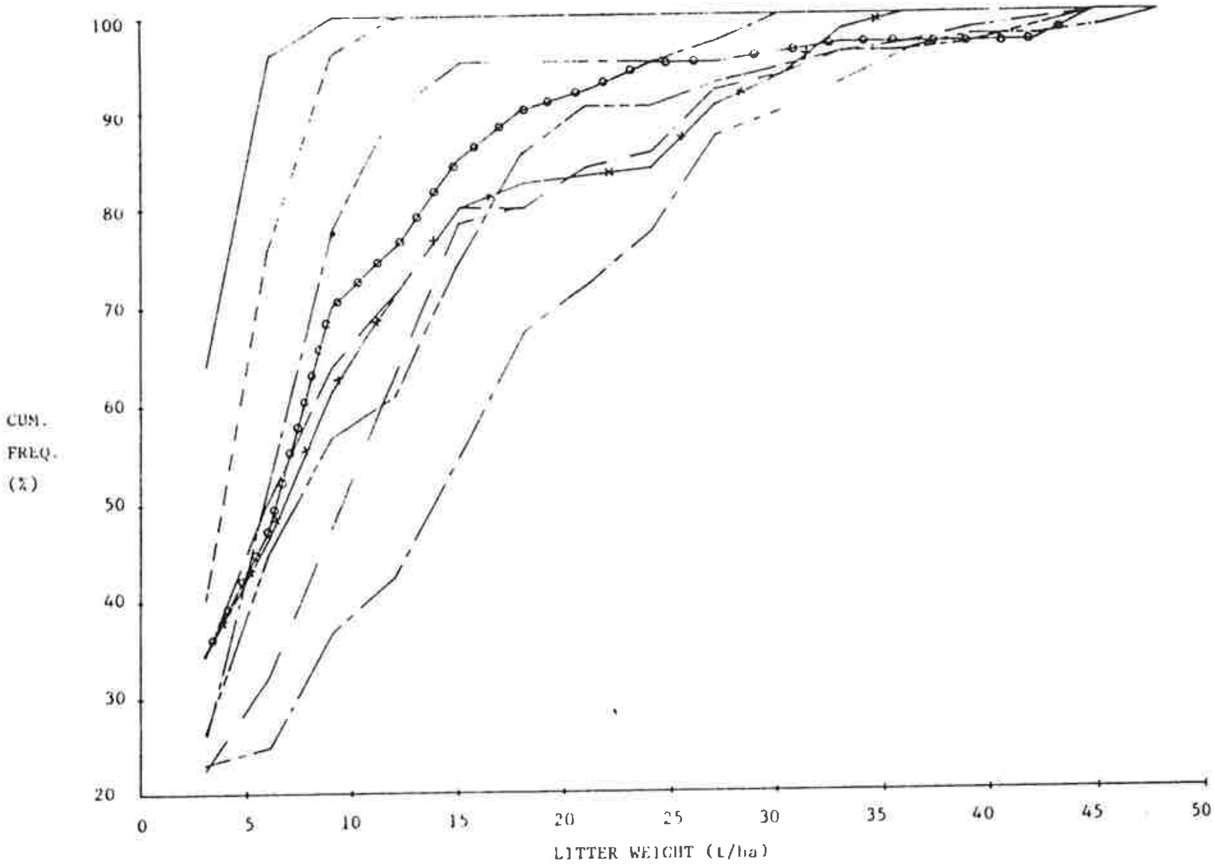
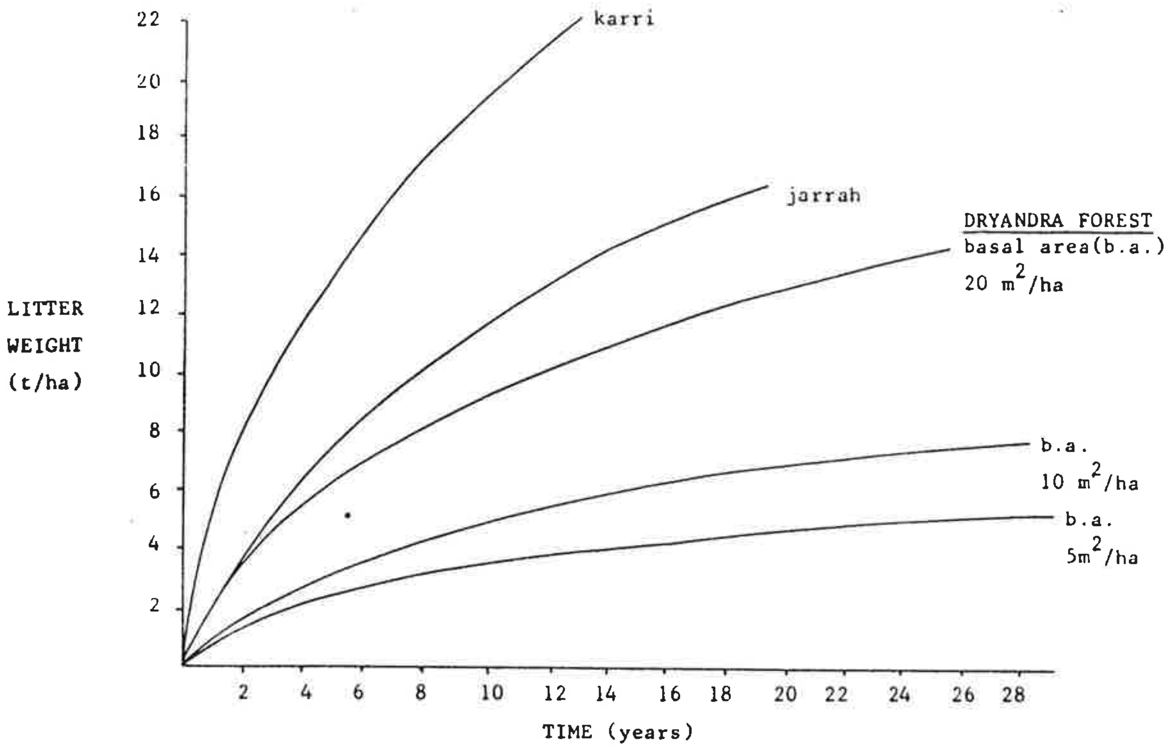


TABLE 6: Mallet (*E.astringens*) plantation ages and ground litter weight statistics.

PLANTATION AGE (YRS)	MEAN WT. (T/HA)	MAX WT. (T/HA)	VARIANCE	STANDARD ERROR
25	8.8	18.3	20.0	1.58
36	13.4	24.3	51.6	1.79
39	18.1	31.9	47.2	1.70
42	22.4	52.4	164.1	3.2
45	15.8	35.4	49.8	1.87
46	10.8	42.6	67.4	1.67
47	15.1	34.1	82.8	1.84
48	21.6	28.8	29.1	2.30
50	12.2	23.6	41.0	2.30
51	15.8	45.4	99.6	2.51

FIGURE 10: Leaf litter accumulation rate for various forest types



The mean tree basal area for natural forest blocks was found to be 8.2m²/ha. However, like ground litter quantity, tree basal area, hence tree canopy cover, varied considerably (Table 7 and Table 8).

TABLE 7: Tree basal areas (m^2/ha) for 6 of the study blocks. Blocks 20 and 30 are mallet plantations.

BLOCK No.	MEAN BASAL AREA (M^2/HA)	VARIANCE	MAXIMUM	MINIMUM
1	10.5	42.4	34.0	2.0
2	9.8	34.0	21.0	2.0
5	9.0	19.2	16.0	2.0
6	3.6	3.3	6.0	2.0
20	14.3	15.5	19.0	8.0
40	12.1	14.4	18.0	3.0

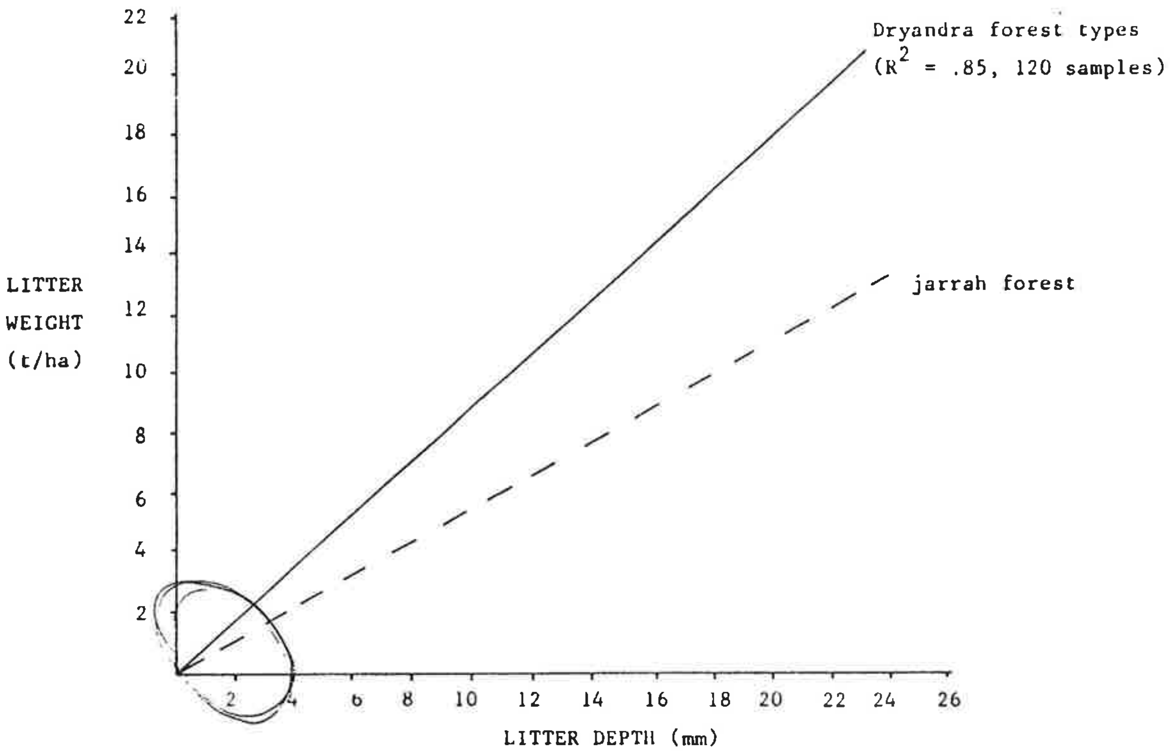
TABLE 8: % area of tree basal area for 6 blocks. Blocks 20 and 40 are mallet plantations.

BLOCK No.	BASAL AREA (m^2/ha) CLASS					
	0-5	5-10	10-15	15-20	20-25	25+
1	18.9	45.9	24.3	2.7	5.4	2.7
2	21.7	34.8	26.1	13.0	4.3	0
5	25.0	46.4	14.3	14.3	0	0
6	71.4	28.6	0	0	0	0
20	0	16.7	50.0	33.3	0	0
40	11.8	41.2	35.3	11.8	0	0

5.2.3 Ground Litter Fuel Structure

The ground litter beneath the smooth barked eucalypt forests which typify Dryandra, is of a much higher bulk density than ground litter in the higher rainfall jarrah forest (figure 11).

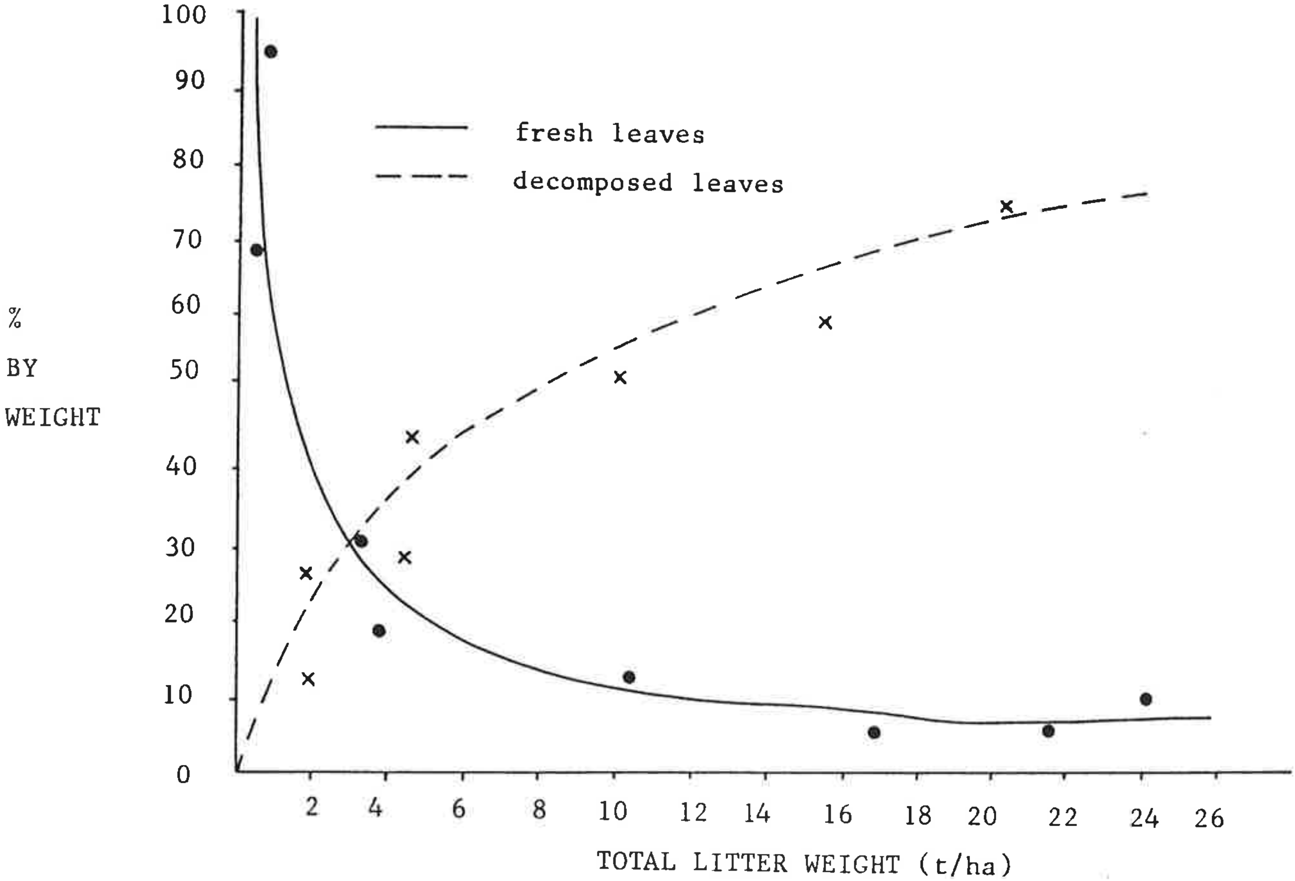
FIGURE 11: Litter weight/depth relationship for Dryandra forest types and for jarrah forest



The proportion of decomposing leaves (duff) increased with increasing total ground litter quantity and according to the relationship graphed in figure 12.

When the ground litter quantity exceeded about 10t/ha, fresh leaves comprised only about 12-15% by weight of the total. The remainder consisted of duff and woody material including bark, twigs and capsules.

FIGURE 12: Proportions of leaf litter with increasing litter weights



The high bulk density and the relatively high component of weathered and woody material in the ground litter would probably cause this fuel type to be less flammable than equivalent fuel types in the western jarrah forest. It is reasonable to assume that fires burning in this fuel type would not be as fast moving as fires in jarrah forest litter fuels under the same conditions. However, under dry conditions, the after burn time or smouldering combustion of woody material would be considerably longer even though less fuel would be consumed in the flaming zone. In effect this would mean that the available fuel factor, or fuel which burns in the flaming zone, would be considerably less than the total fuel quantity, even under dry conditions. A longer duration of smouldering combustion would probably cause a higher level of damage to tree boles and to vegetation under dry fuel conditions.

5.2.4 Forecasting Ground Litter Accumulation

Due to the highly variable rates of ground litter fuel accumulation, an average accumulation rate or an average quantity does not reveal much about the condition of ground litter fuels in a forest block in Dryandra forest. Table 9 below is an example of ground litter quantities to be expected over time for a natural forest block of some 150-200ha.

TABLE 9: Likely fuel loading with time for a typical Dryandra forest block of 150-200ha (natural forest)

FUEL AGE (YRS)	50% OF THE BLOCK WILL CARRY:	20% OF THE BLOCK WILL CARRY:	20% OF THE BLOCK WILL CARRY:	10% OF THE BLOCK WILL CARRY:	MEAN WT.
2	1.6	2.3	1.2	4.4	2.1
4	2.4	3.3	1.6	6.4	3.1
6	2.9	4.1	2.2	7.9	3.8
8	3.4	4.7	2.6	9.3	4.4
10	3.8	5.3	2.9	10.4	5.0
12	4.2	5.9	3.2	11.4	5.5
14	4.6	6.4	3.5	12.5	5.9
16	4.9	6.9	3.8	13.4	6.4
18	5.2	7.3	4.0	14.2	6.8
20	5.5	7.7	4.2	15.0	7.2
22	5.8	8.1	4.4	15.8	7.6
24	6.1	8.5	4.6	16.6	8.0

5.3.0 Measuring Dead and Downed Wood, Fuels (logs)

Method:

The quantity and size of logs and woody material >10mm in diameter was measured at each grid point position and over 20m using van Wagner's line intercept method. Logs intercepted by the line transects were tallied into one of 8 diameter classes (see Table 10).

Results

The quantity (t/ha) and occurrence of logs was generally very patchy and generally low by comparison with the higher rainfall western forest (Table 10). Plateaus which carried a heavier stocking of jarrah trees (such as was the case in much of Block 1) carried higher log loadings. This was largely due to debris remaining after logging. Forest overstorey, fire history and land use were all factors instrumental in dictating the frequency, loading and size of logs on the forest floor. Recently burnt blocks (3 &4) showed a marked reduction in the weight and frequency of small diameter wood (10-75mm). This material was probably consumed in the recent fires and has not yet re-accumulated. The quantity of woody material in mallet plantations was not significantly different to that in natural forest which had not been logged or burnt for 20 years or more.

Where the clearing burns on mallet plantation sites were incomplete, then greater quantities of log material were encountered.

The quantity and frequency of smaller diameter woody material in blocks which had not been burnt for many years (>20 years) was similar to western jarrah forest which had not been burnt for about 6 years. The rate of accumulation of woody material in Dryandra (in the absence of logging or other man-caused disturbances) is commonly slower than in the western jarrah forest. It is also possible that the rate of breakdown by xylophagous invertebrates is much greater in Dryandra.

The quantity and frequency of woody material is sufficiently low not to be considered as a fuel likely to influence fire behaviour. The low occurrence of large logs is probably advantageous in that mop-up costs following a fire would be minimal. A negative aspect of the low occurrence of logs is in the importance of logs for shelter for animals such as the numbat. From observations during this survey, all logs with a sufficiently large diameter hollow, had or were being used by animals, probably by numbats. While infrequent moderate intensity fires can add to the log supply by burning down trees, frequent firing (6-12 years) under autumn conditions could seriously deplete the supply of suitable habitat logs over several rotations.

TABLE 10: The weight (t/ha) of downed woody material, by diameter size class, for each study block. % frequency is the % of points at which this size class occurred (Blocks 20,30 and 40 are mallet plantations).

PLOT	DIAMETER	10-25	25-50	50-75	75-100	100-150	150-200	200-300	300+
1	Mean wt.	1.4	1.8	2.8	2.6	2.7	2.8	2.8	6.2
	Max wt.	5.2	9.0	19.2	23.5	28.8	56.4	77.0	186.0
	% Freq.	98	77	44	27	20	11	5	5
2	Mean wt.	1.4	1.4	1.3	1.6	2.3	1.0	1.4	5.7
	Max wt.	6.4	11.7	9.6	14.1	28.8	18.8	38.0	197.0
	% freq.	96	65	33	54	19	5	4	5
3	Mean wt.	0.9	1.4	1.1	1.0	0.9	0.4	0.9	-
	Max wt.	3.6	9.0	12.0	18.8	19.2	18.8	38.0	-
	% freq.	90	63	25	9	7	2	2	0
4	Mean wt.	0.5	0.9	0.9	0.99	2.9	2.5	3.8	-
	Max wt.	1.8	7.2	7.2	14.1	19.2	18.8.	38.0	-
	% freq.	85	45	26	13	20	13	10	0
5	Mean wt.	2.1	1.9	1.6	1.1	1.1	0.8	2.0	-
	Max wt.	11.6	9.0	7.2	14.1	19.2	18.8	38.0	-
	% freq.	98	73	44	19	10	4	6	0
20	Mean wt.	2.7	2.4	2.1	1.0	1.4	1.5	6.5	5.3
	Max. wt.	9.6	11.7	21.6	4.7	28.8	18.8	77.0	154.0
	% freq.	97	61	42	21	7	8	15	4
30	Mean wt.	0.9	0.9	0.4	0.5	0.5	-	3.2	7.4
	Max wt.	4.0	7.2	4.8	9.4	9.6	-	77.0	98.0
	% freq.	95	45	12	10	5	0	6	10
40	Mean wt.	2.0	1.2	1.2	0.6	0.5	-	2.0	-
	Max wt.	5.8	6.3	7.2	4.7	9.6	-	38.0	-
	% freq.	94	55	39	13	5	0	5	0
ALL	Mean wt.	1.6	1.5	1.4	1.1	1.4	1.0	2.8	3.1
PLOTS	Max.wt.	11.6	11.7	21.6	23.5	28.8	56.4	77.0	197.0
	% freq.	91	60	32	17	10	5	6	3
WEST.	Mean wt.	0.8	1.7	3.5	5.8	9.0	15.3	4.2	8.0
JARRAH	Max wt.	3.0	6.3	24.0	23.5	76.8	75.2	36.8	73.8
	% freq.	97	75	59	63	39	46	44	35

5.4.0 Vegetation as Fuel

Vegetation maps were produced by the Forests Department in 1937. Mapping was based largely on overstorey species. In this study we have re-surveyed vegetation with equal emphasis on understorey species.

Methods

At each of the grid sample points described earlier, all woody plants within a 20m radius (including trees) were recorded and given an abundance rating (after Havel, 1976). A computer program was used to identify links between species, or to identify which species most often occurred together or in association. Vegetation clusters, or types were then sampled for fuel characteristics. Four grid points were sampled in each vegetation type. Each sample consisted of:

i) visually assessing the average height of vegetation in a 10m radius around the sample point

ii) visually assessing the projected per cent ground cover of vegetation

iii) cutting out and bagging all vegetation within a 3m x 1m plot

iv) oven drying each bagged sample to determine biomass

Results

The final clustering analysis produced 10 vegetation types. These types can be divided into 4 main categories, based on landform (after Burbidge). The 4 readily identifiable landform units and most common vegetation found on these units were:

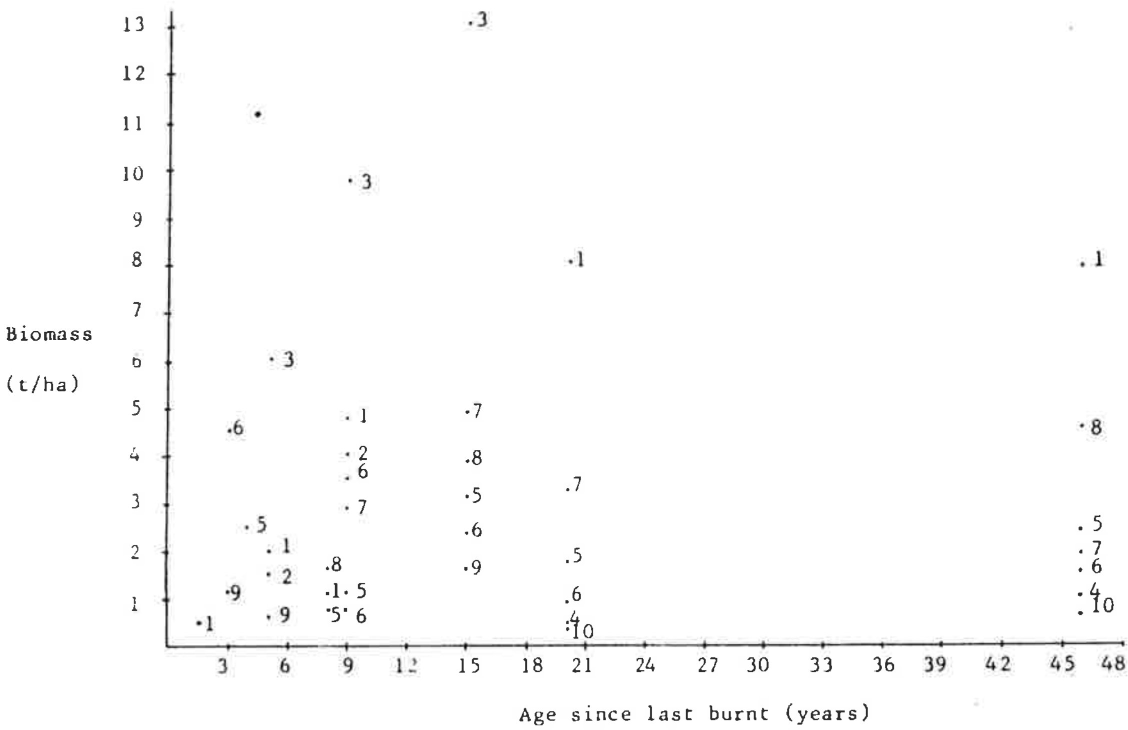
1. Lateritic landforms (Plateaus)

These are uplands found at the back of the breakaways. Often the soils are yellow sandy gravels on gently undulating plateau remnants. Vegetation is variable, but for our purposes, three types were recognized. Often, these types formed ecotones and were not easily separated.

Lateritic vegetation type 1: This type consisted of associations of *Dryandra nobilis*, *D.armata*, *Petrophile hetrophylla*, *P. diversifolia*, *Styphelia tenuiflora*, *Davesia rombifolia*, *Hakea trifuricata*, *Casuarina humilis* and with a sparse overstorey of marri, jarrah and powder bark wandoo. Biomass sampling intensity over the range of this vegetaiton type was too low to enable biomass production with time to be determined. Table 11 summarizes the weights, ground cover and height from the limited number of samples taken for all vegetation types. Biomass versus age since burnt is shown in figure 13.

Lateritic vegetation type 2: This type is usually associated with less gravelly uplands, consisted of species such as *D.carduacea*, *Adenanthos cygnorum*, *Bossiaea eriocarpa*, *Hakea ruscifolia*, *Acacia pulchella*, *Grevillea tenuiloba*, *Petrophile serruriae*, *Melaleuca polygaloides* with a sparse

FIGURE 13: Biomass v's age since last burnt for 10 vegetation types



overstorey of jarrah, some marri and/or powder bark wandoo.

Lateritic vegetation type 3: Usually found on the poorer soils. This type is often described as the mallee type as there are few or no single stemmed overstorey trees. Species include *Eucalyptus drummondii*, *Leptospermum erubescens*, *Petrophile ericifolia*, *P.serruriae*, *M. polygaloides*, *P.biloba*, *Dryandra nivea* and *Grevillea armigeia*.

Slopes below breakaways (pediments)

Breakaways give way to slopes of varying degrees of steepness. Soils on steep slopes below breakaways are often very gravelly, whereas the gently sloping pediments contain variable quantities of gravel in grey/brown sandy loams. Vegetation most commonly associated with these slopes are;

Slope vegetation type 4: Brown mallet (*E. astringen*) often occurs in pure, even aged stands with little or no understorey and immediately below the breakaway. On the more gentle slopes and less gravelly soils, brown mallet may occur with a smattering of wandoo or powder bark wandoo. When this is the case, then a sparse understorey of sandplain poison (*Gastrolobium microcarpum*) or *Bossiaea eriocarpa* may be present.

Slope vegetation type 5: Usually occurs further downslope of slope vegetation type 4 and on yellow sandy soils. Most common species include G. microcarpum or (G.triloba, G. spinosum, G. parvifolium), Astroloma ciliatum, Dianella revoluta, with occurrences of Acacia alata, G.platypoda, and B.penduncularis. Powder bark wandoo is the most common overstorey, but occurrences of wandoo and/or brown mallet are not uncommon.

Slope vegetation type 6: This type occurs further down slope on deep yellow duplex soils flanking valley floors. Mostly, this type consists of an overstorey of sandplain poison and short grasses.

Alluvial Soils

Two vegetation types were identified on the white alluvial sands.

Alluvial vegetation type 7: Species include Leptospermum erubescens, Hypocalymma angustifolium, Melaleuca uncinata, Mesmoleana uncinata, Petrophile media, Santalum sp., Conospermum sp., G.reticulatum, G.microcarpum with sparse occurrences of marri and wandoo.

Alluvial vegetation type 8: Associations of Calothamnus quadrifidis, D.fraseri, Hakea undulatu, G.microcarpum. There is usually little of no overstorey, but there may be occurrences of marri, wandoo or Eucalyptus falcata.

Valley Floors

Valley floor vegetation type 9: Sand underlain by clay-loam. Mostly wandoo woodlands with a grassy understorey. Jam (*Acacia acuminata*) is often found on these soils.

Granite Soils

Granite soil vegetation type 10: Rock oak (*Casuarina huegliana*) occurs on granitic soils near granite outcrops. These pure stands often had a sparse understorey of sedges.

Discussion

From figure 13, it is obvious that sampling intensity was inadequate to cover the range of vegetation types and ages since last burnt, combinations. The only reasonable pattern to emerge was for the biomass increase with time, for vegetation type 1. Here, biomass levelled off after about 20 years. Overall, scrub weights and increments were very low. There were only 1-3t/ha of scrub on most sites. Vegetation type 1, after 20 years, carried about 6-7t/ha. These weights include both living and dead vegetation. *D.nobilis* retains dead leaves on the plant and in old thickets (>20 years) dead leaf material could comprise up to 30% of the total fine fuel (<6mm diameter) component. Vegetation type 3, the mallee scrub type, was the heaviest and most dense (figure 13).

Scrub as a fuel is probably only significant on the lateritic landform vegetation types (types 1,2 & 3). Moderate to high intensity experimental fires in these types, particularly types 2 & 3, promoted a rapid regeneration of dense scrub which reached a weight of almost 6t/ha, 5 years after the fire. Generally, scrub regrowth following fire was very slow, being somewhere between 0.1 - 0.3 tonnes/ha/annum. Vegetation types 1 & 3 could carry fire even under cool conditions, providing winds were strong. Under warm, dry conditions, these scrub fuels generate severe fire behaviour (see figure 14 below). The grassy understorey on slope and alluvial types could readily carry low intensity, but often fast spreading fires.

6. Fire Behaviour

While the behaviour of fire in Dryandra forest fuel types was not studied here, we present a general discussion of the likely fire behaviour based on our knowledge of the physical fuel characteristics, the climate and weather of the region, the lie of the land. We also include limited research carried out by McCormick on the behaviour of fire in *D.nobilis* thickets.

6.1 Fuels

Four basic fuel types were recognized. These were:

i) simple ground litter fuels, as found beneath mallet stands (natural and planted), casuarina groves and wandoo and powder bark wandoo slope vegetation types (as discussed earlier). Here, ground litter is the dominant fuel type and will regulate fire behaviour.

ii) scrub fuels, such as are found on the lateritic landforms vegetation types. These include vegetation types 1,2, & 3. Generally, these types carry only light and patchy ground fuels and fires will burn predominantly in the aerated scrub component.

iii) duplex fuels, consisting of both a layer of ground litter fuel and a second tier of aerated, scrub fuel.

iv) grass fuels, mostly found beneath wandoo woodlands and adjacent to farmland.

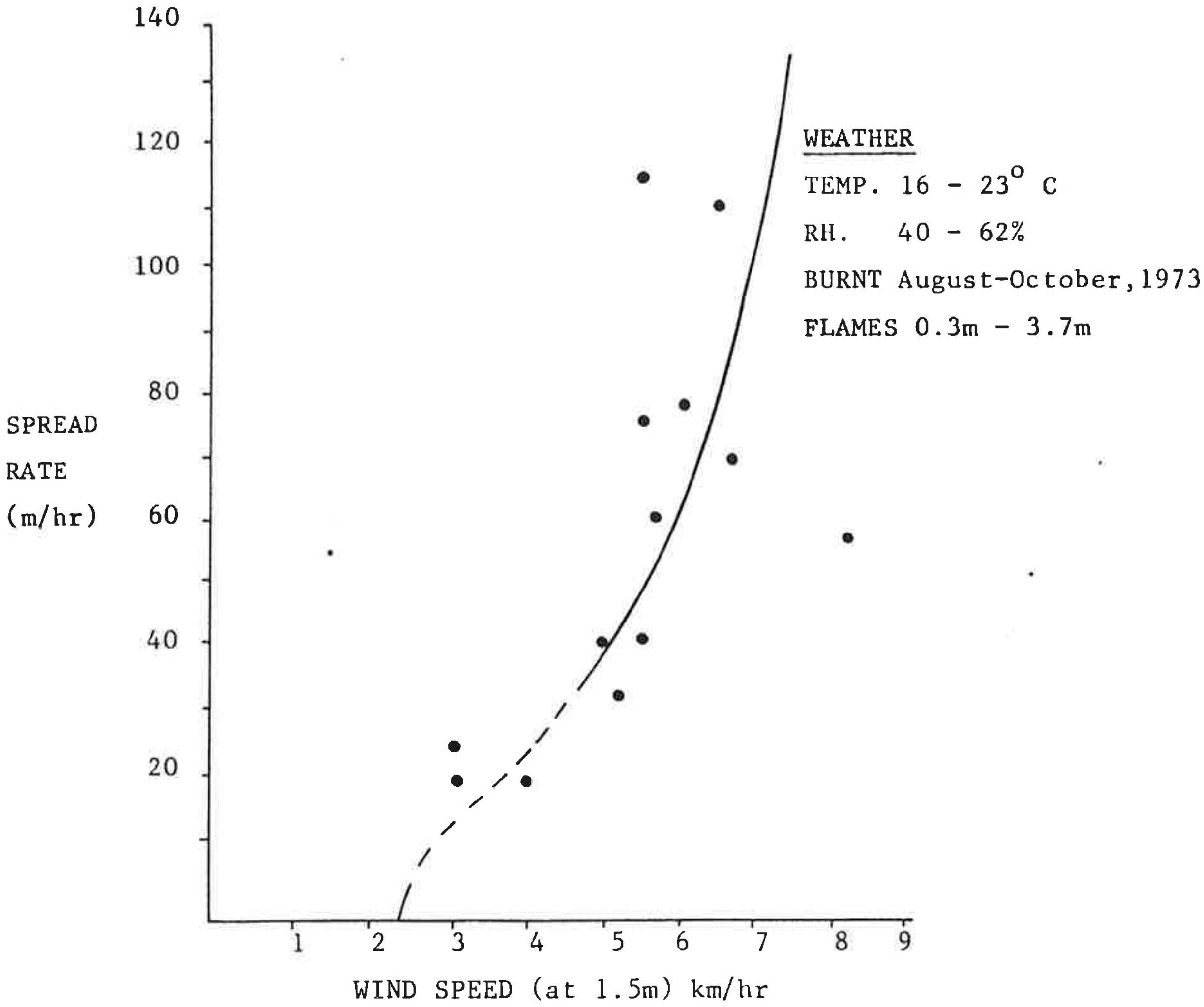
These four fuel types form a patchwork over the total forest area and generally follow the landform units as mapped by McArthur. Together with the patchiness of fuel ages (hence fuel weights), fire behaviour is likely to be highly variable and fires would probably burn in tongues, following the most flammable fuel types and heavier fuels. This effect would tend to be less obvious as surface burning conditions (fuel moisture, wind and RH) became more severe and as fires became large.

Fires burning in fuel type 1, ground litter fuels, are likely to behave primarily as predicted in the "Forest Fire Behaviour Tables for Western Australia". The higher bulk density, generally low fuel weight and patchiness of the fuels here, would cause fires to travel slower and with lower intensity than equivalent age fuels in western jarrah forests burning under similar conditions. Further research is necessary to confirm this and to improve our knowledge of fire behaviour in Dryandra forest. Scrub fuels (fuel type 2) present the most flammable fuel type in Dryandra. The following description is taken from McCormick (1977)

"It is characteristic of this scrub species (D.nobilis) that it retains its dead leaves on its branches for a number of years, thus providing a "fuel bed" at about 1-2m above the ground. It is this aerial fuel that carries fire. There is little or no ground fuel. Fire can progress through the scrub crowns only when fanned by strong winds. A brief drop in wind causes the fire to go out. Dryandra scrub does not lend itself to ignition by spot fires. Line fire is a superior technique. Winds must be strong (>6 kph near ground or >25 kph tower). Because the dead leaves are well aerated, Dryandra scrub will burn throughout most of the year.

Figure 14 (after McCormick,1973) illustrates the rate of spread/wind relationship for D.nobilis thickets. While these thickets can exhibit severe fire behaviour, they are localised and rarely extend for more than several hectares. Fire run would be short and sharp.

FIGURE 14: Rate of spread v's wind speed - fires burning in 26 year old *Dryandra nobilis* thicket (after McCormick)



7. Vegetation as a Descriptor of the Fire Environment

Methods

Simple measurements and observations of the various ways in which different plants regenerate and grow, can provide information about past fire regimes.

In this study, we were not able to examine all species and communities. Instead, we selected a number of species which we deemed to be important in terms of their uniqueness, abundance, distribution role as food and shelter for animals, and their fire sensitivity.

Initially, all species recorded were simply rated as;

i) rootstock species
ii) non rootstock species with hard seeds
iii) non rootstock species without hard seeds

This covered most of the range of woody shrubs and trees dealt with here.

We made observations and took some measurements of fire sensitive (non-rootstock) species which form pure stands. These included poison thickets (G. microcarpum), natural mallet stands (E. astringens), Dryandra thickets (D. nobilis) and rock oak stands (Allocasuarina huegliana).

Some 16 poison "thickets" covering a range of burning ages, were destructively sampled. All plants within a 5 metre radius of a known grid point were cut off at or near ground level and the diameter of each stem measured. Growth rings (assumed to be annual) were counted after preparing stem cross sections.

The objective was to determine the age/size class structure of thickets and relate this to fire history. Many people have observed that poison bush is readily killed by even mild fires, but "hot" fires have promoted the regeneration of dense thickets from hard seeds buried in the soil. It has been reported that thickets cannot develop in the absence of "hot" fires and that mild spring fires kill mature plants but do not encourage any regeneration. If this was the case, then we would expect poison thickets to be pretty much even-aged.

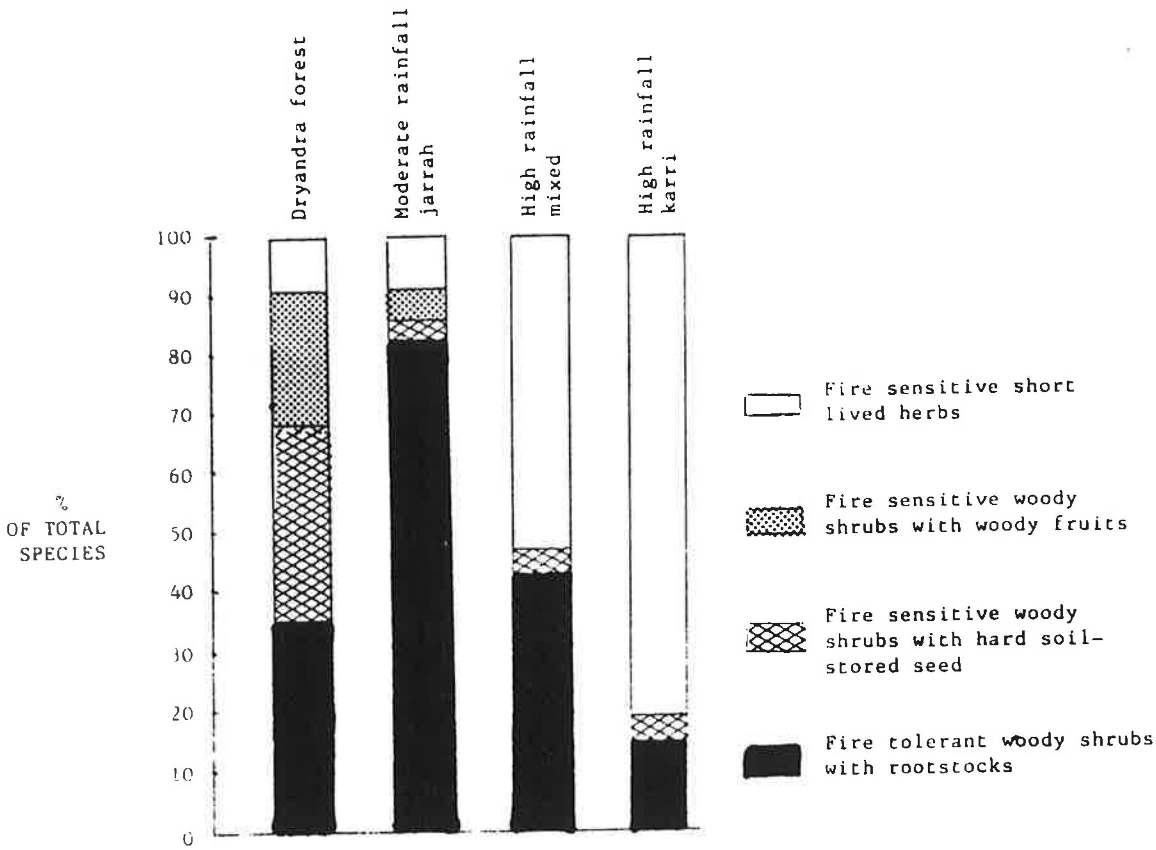
Other species pure stands examined were mallet, rock oak and dryandra. Here, we simply observed the responses to fire of these species (from experimental and operational fires) and again, destructively sampled to make annual ring counts to describe population age class structure.

Results and Discussion.

Contribution of Life Forms.

Figure 15 contains a comparison of life forms for various forests. The data for Dryandra forest are 100 or so of the more obvious plant species, so are certainly not comprehensive. However, it does reveal differences in life form structures, probably largely due to climatic variation. Fire, climate and vegetation are undoubtably linked.

FIGURE 15: Contribution to vegetation by various life forms.

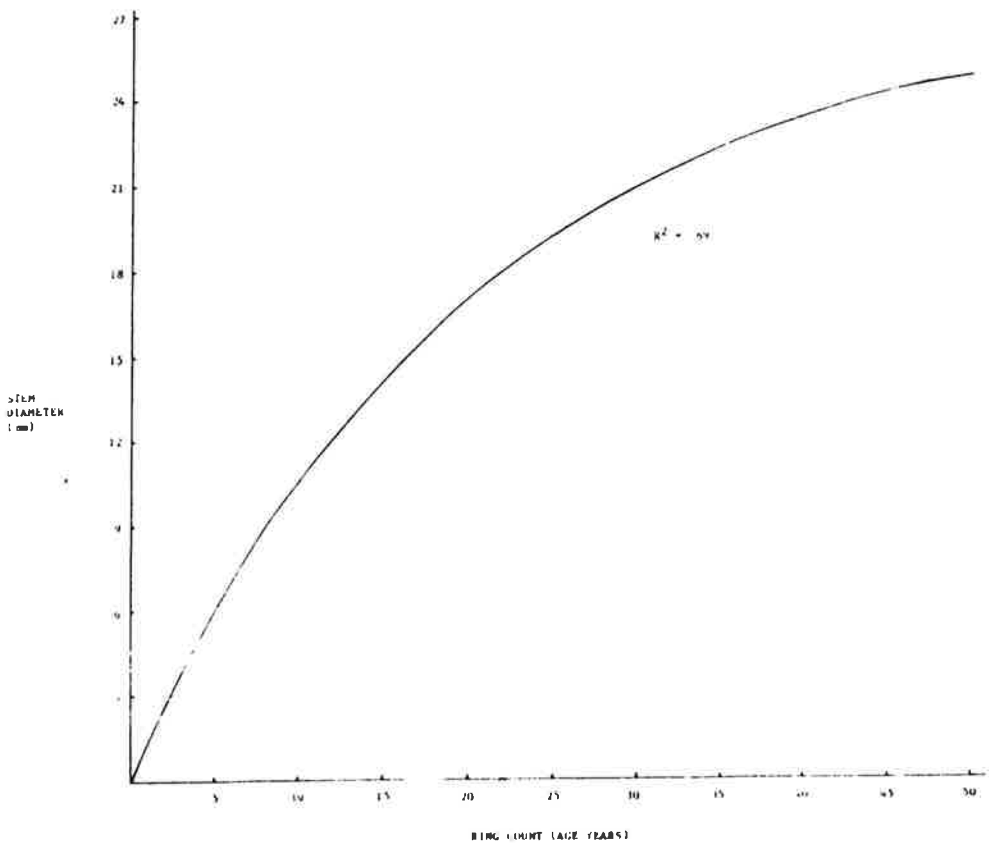


The lower representation of fire tolerant woody rootstock species and equal high representations of both fire sensitive classes of species, indicates again, that fire is infrequent to this forest. It also suggests that successful regeneration of fire sensitive species is most likely following summer or autumn fires of moderate intensity.

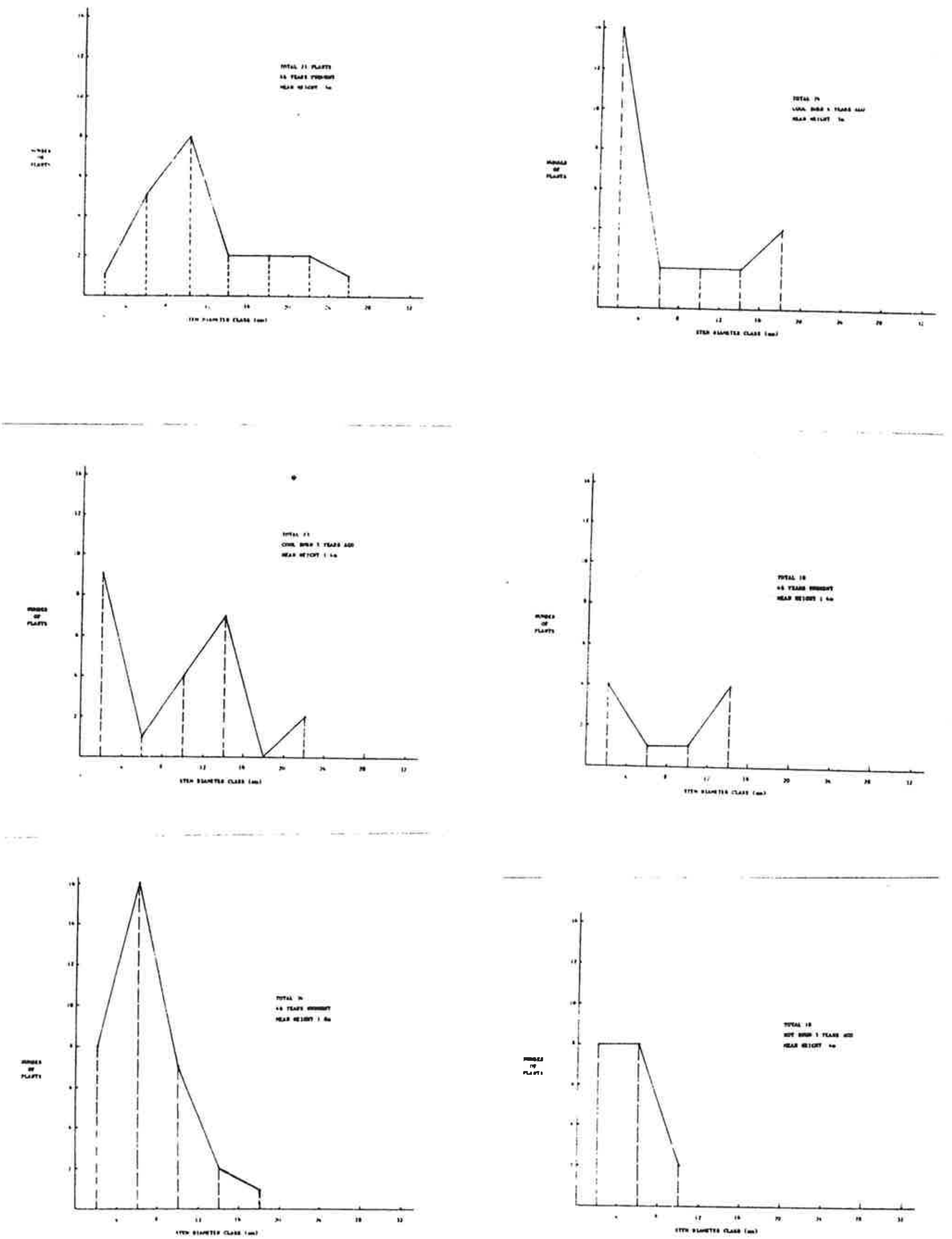
Frequent, mild fires in spring may kill the parent plants (of fire sensitive species) but may not produce conditions suitable for viable regeneration (such as adequate soil soil heating, removal of litter layer, "ashbed" effects etc). If the frequency of <u>any</u> burning is less than the time taken for species to reach flowering age and to build viable seed stores, then again, these species will be disadvantaged. Rootstock species will be favoured by frequent (say <15 years) firing. Very frequent burning (2 - 5 years) will encourage the development of grasses.

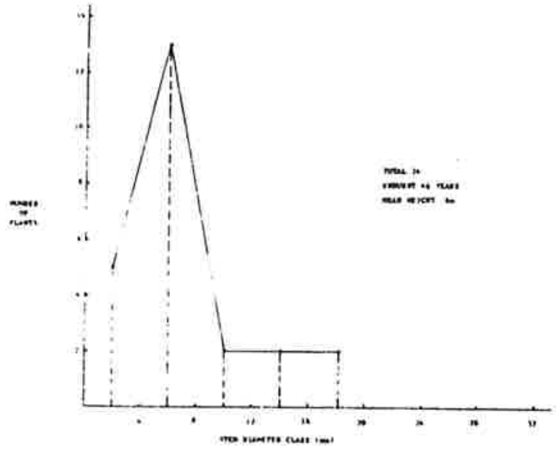
7.1 Age/Size Class Structure of Poison Thickets.

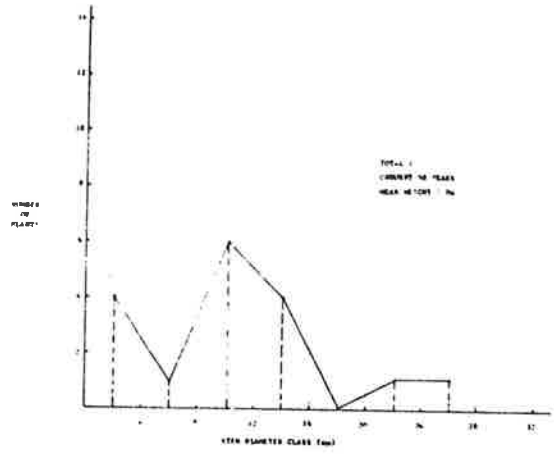
FIGURE 16a: Relationship Between Stem Diameter Measured Near Ground Level and Annual Ring Count (Age?) for *C. microcarpum*

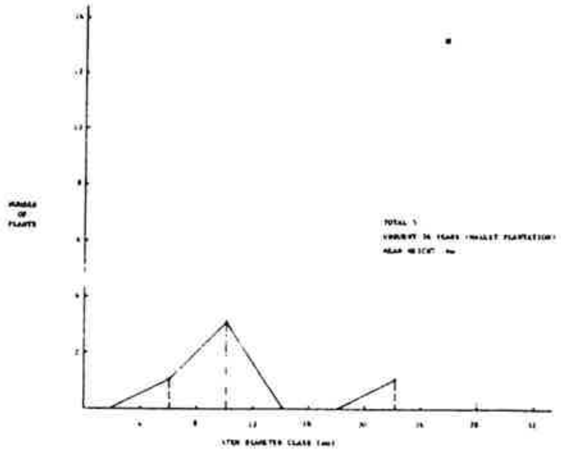


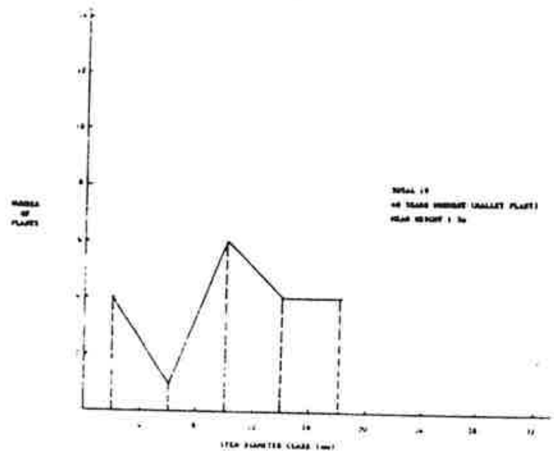
FIGURES 16 : Stem diameter structures for some of the Poison Bush (Gastrolobium species) studied.

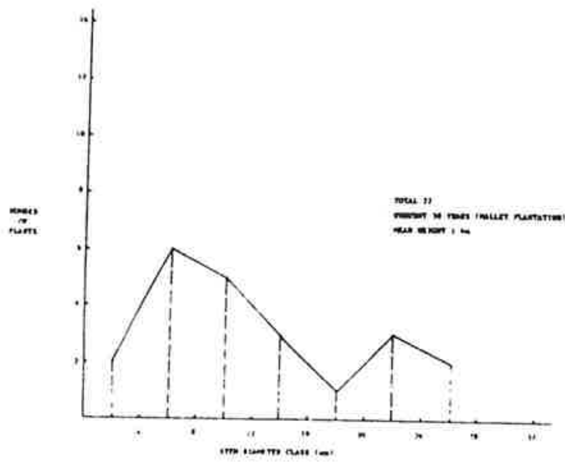












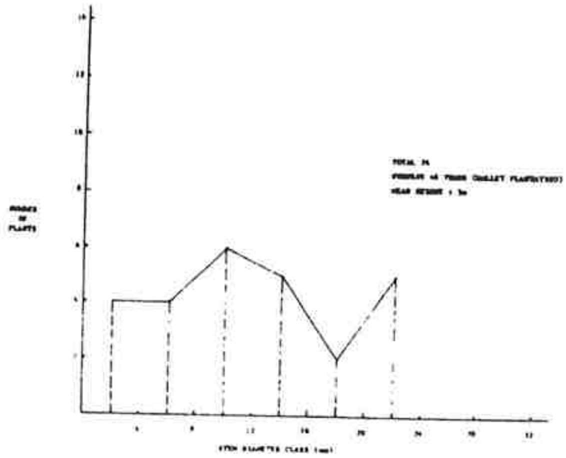


TABLE 11: Summary of the Structure of some Thickets of Poison bush (Gastrolobium species) in Dryandra Forest.

Burn Age (yrs)	No. of Sample Plots	Alive Plants			Dead Plants Per Sample Plot			% Ground Cover Per Sample Plot			Height of Thicket Per Sample Plot		
		Mean	Max	S.E.	Mean	Max	S.E.	Mean	Max	S.E.	Mean	Max	S.E.
3	10	4.0	14	1.4	2.0	7	.73	7	30	2.1	.6	1.2	0.09
4	49	20	55	5.2	1	6	-	18	60	3.3	.6	1.4	0.06
5	2	17	27	9.5	1	1	-	36	80	22.4	1.2	1.4	0.115
8	5	3	6	.8	8	18	2.4	10	20	3.0	.6	.8	0.1
9	6	5	12	1.6	8	23	4.9	16	30	3.9	.7	.8	0.09
18	9	8	15	1.4	4	6	1.2	18	40	3.6	1.2	1.6	0.07
20	3	5	6	1.0	4	9	2.5	47	60	13.3	1.3	1.8	0.29
44	5	5	9	1.5	8	8	.5	12	25	4.3	.6	.8	0.1
46	80	5	57	.8	3	11	.5	12	85	1.4	.9	3.0	0.05
Combined	146	8	57	1.1	4	23	.5	14	85	1.1	.8	3.0	0.04

We were able to determine a reasonably good relationship between the diameter of poison bush stems (near ground) and growth ring count, which we assumed to be annual rings (Fig 16a) (R^2 = .69). On the basis of this relationship, some plants were aged at 55 years. Ring counting to determine age was cross checked against known thicket ages (from known fire events) and was found to be within 10% on most counts.

Poison bush does not necessarily form even-aged thickets (figure 16) and there is no clearly definable single explanation for the development of poison bush "thickets" or occurrence. Most of the 16 thickets studied were different in age/size class structure, density and spacial continuity. There was no clear relationship between time since fire and thicket characteristics. In some instances, experimental "hot" fires promoted the development of "even-aged" thickets, but not in all instances. Often, even after a "hot" fire which killed the plants, regeneration was poor or non-existent.

"Cool" edge burns trickled around amongst thickets and killed a proportion of the mature plants. In some instances, these fires promoted regeneration, but mostly, regeneration was poor or not at all. The high incidence of "dead" plants appearing in burn ages 8 & 9 (Table 11) is an example of this.

Poison plants on sites which have not been burnt for 44 - 46 years contain senescing individuals, young regeneration and a range of ages in between. Fire is not essential to regenerate these thickets, but we believe summer or early autumn, moderate intensity fires can create a dense, vigorous even-aged thicket, providing there is adequate seed stored in the soil and providing regenerates are not browsed. Results of past research indicate that "hot" fires are "hit and miss" in terms of regenerating dense poison thickets.

Examination of thickets and the growth of poison plants in mallet plantation (see figure 16) reveals that thickets do regenerate in the absence of fire, but the amount of regeneration is low and its growth rate is slow. Given the longevity of these plants (about 40 - 55 years) and their prolific seeding habit, this is not a problem, providing losses due to seed eaters, fire, grazers, or whatever, are not higher than the rate of recruitment. Thickets which regenerated following the establishment of mallet plantations have collapsed and died out completely where the stocking of mallet is high (basal area >12 m^2/ha). Where mallet has failed, then generally the thickets have succeeded. Poison bush prefers to grow in an open, woodland forest, unimpeded by eucalypt leaf litter, overstorey canopy or root systems.

An overriding feature of the regeneration and development of poison bush is soil type. Most species of poison bush have a strong preference for the slopes below breakaways and on sandy soils near valley floors. Individuals can be found further up slope near the breakaways and even behind breakaways on the lateritic soils, but thickets develop best beneath the open wandoo and powder-bark wandoo flats.

7.2 <u>Observation of D. nobilis</u>.

This thicket forming species occurs on laterite soils behind breakaways. The species is relatively long-lived (50 - 60 years), is non-lignotuberous and fire sensitive. For regeneration, it relies on seeds which fall from papery capsules. During a fire, the seed in the capsules is usually burnt, and seedlings regenerate from seeds on the ground and in the soil. Dryandra thickets carry aerial fires, there is little or no ground fuel to support a ground fire. Generally, seeds on the soil surface are able to survive the fire. Most of the fires heat is directed upwards in convection. As with poison bush, dryandra commonly occurs in even-aged thickets, but not entirely. The age structure of the population is a function of a number of environmental factors, including fire. We observed that dryandra was generally very slow to regenerate in the absence of fire. In some instances, there were no visual signs of regeneration following fire, but in other cases, we observed prolific post fire regeneration.

As with poison thickets, there are many possible causes for variability in post burn regeneration, including quantity of viable seed, seed bed and climatic conditions, grazing and browsing, pressure etc.

7.3 Observations of Mature Mallet Stands.

Mallet is an extremely fire sensitive tree which grows in pure, even-aged stands. The smooth bark is very thin (maximum measured = 5 mm) and is shed annually. Shed bark accumulates at the base of the tree which assures that the tree will be girdled and killed by even the mildest of fires. It has no rootstock. A continuous and often deep ground litter fuel guarantees that any fire will kill most of the trees. This litter also suppresses any regeneration between fire periods.

There is a massive and synchronized seed release from woody capsules following fire. Seeds fall onto a receptive seed bed and usually results in "wheatfield" regeneration. Many plants are suppressed and die as the stand develops. Mallet flowers sometime around age 12 - 14 years. By taking stem cross section from one particular stand, we were able to piece together the fire history over the last 80 years or so. Ring counts were made on a veteran tree, a dead stag and several young regrowth trees. The veteran tree, one of only 3 surviving on this site, was aged at somewhere between 75 - 80 years. Its d.b.h.o.b. was 25 cm and bark thickness only 5 mm.

This tree was fire scarred at age 50 years. The same fire killed almost all other trees in the stand (as evidenced by stags) and caused the regeneration of the existing stand, now aged about 25 years. The fire history for this site then is; a fire somewhere around 1905 - 1910 and the most recent fire, 1955 - 1960.

7.4 Observations of Rock Oak.

Like mallet, this species is extremely fire sensitive and forms pure stands. It will regenerate from capsule-stored seed following a fire which consumes all ground fuels but, as with other species mentioned, there are many factors determining whether post fire regeneration will succeed or fail. The species (as with most) will regenerate in the absence of fire providing there has been some form of soil disturbance and opening up of the canopy.

8. Poison Thicket Seed Bank Study

Thickets of poison plant species (*Gastrolobium* and *Oxylobium* species) are considered important habitat for some fauna species, including Tammar wallabies and Woylies. In the woodland associations of Dryandra forest, these low, dense thickets provide a food source for seed eating birds and cover for animals. The often leguminous thicket forming species are also important in their own right.

While the plants are fire sensitive, "hot" fires in summer and autumn (under dry conditions) have been observed to trigger massive germination of soil stored seed, producing a dense thicket structure.

A possible management option is to regenerate decadent thickets using fires set under dry conditions. However, this has sometimes failed to produce the desired result in experimental burns. The timing of the burn could be critical in terms of producing the right type of fire and in stimulating successful thicket regeneration. During this survey, we observed and measured a considerable amount of Quail and Bronzewing pigeon digging activity beneath poison thickets. We suspected that regeneration failures following fires may have been partially due to a lack of seed beneath the thickets due to harvesting by birds and insects.

During the survey, we collected litter and soil samples from beneath a number of healthy thickets to determine the quantity of stored seed. We found no viable seed. This prompted us to initiate a program of sampling over time to monitor the seed bank beneath thickets.

8.1 Methods

During the general surveys mentioned earlier, we described the condition (in terms of % cover, number of dead and alive plants) of thickets.

We also recorded the level of digging and scratching (by birds) activity beneath the thickets. Of the thickets surveyed, we selected 5 for a seed bank study.

About 40 sample points were located in the 5 thickets. At each sample point, we placed 10 quadrats (each $0.04m^2$) and from these quadrats, we collected litter and topsoil separately. We then tediously sorted through the soil and litter to extract seed. We commenced the study immediately after seed fall in February 1985 and repeated the procedure in August and July, 1985. Table 12 below describes the location of sample sites. All thickets selected were "mature" and had not been burnt for at least 20 years.

TABLE 12: Location of Poison Thicket sample sites (Dryandra 1:50 000 plan).

	MAP REF.	DIST. FROM FARMLAND	POISON SPECIES	%COVER
Site 1	CW 12238	0.5 km	G. parvifolium	65
Site 2	CW 11742	0.0 (adjacent)	G. microcarpum	80
Site 3	CW 11413	3.0 km	G. microcarpum	35
Site 4	CX 11366	2.0 km	G. microcarpum	45
Site 5	C2 11431	0 (adjacent)	G. microcarpum	40

Some 250 sample grid points from the general survey described earlier, contained occurrences of poison species on thickets. We compared the population of these which had been visited by Quails or Bronzewings, against the thicket density, expressed as a % of ground cover.

8.2 Results

The amount of seed beneath the thickets, dwindled rapidly with time after seedfall (Table 13 below).

TABLE 12: Total number of seeds at various time of year in 1985.

	TOTAL NUMBER OF SEEDS IN LITTER			TOTAL NUMBER OF SEEDS IN SOIL		
	FEB.	JUNE	AUG.	FEB.	JUNE	AUG.
SITE 1	772	337	156	779	274	207
SITE 2	246	2	0	85	34	0
SITE 3	1769	772	65	678	400	68
SITE 4	343	346	20	339	170	225
SITE 5	74	43	6	299	59	65

The figures above, expressing seed found in the soil, are misleading. The seed was actually resting on the soil surface, and little or no seed was found in the soil. The surface seeds were gathered up when the soil samples were taken.

Figures 17, 18 and 19 below illustrate the decline in the seed bank with time after seed fall.

Figure 17: TOTAL NUMBER OF POISON SPP. COLLECTED FROM EACH SITE

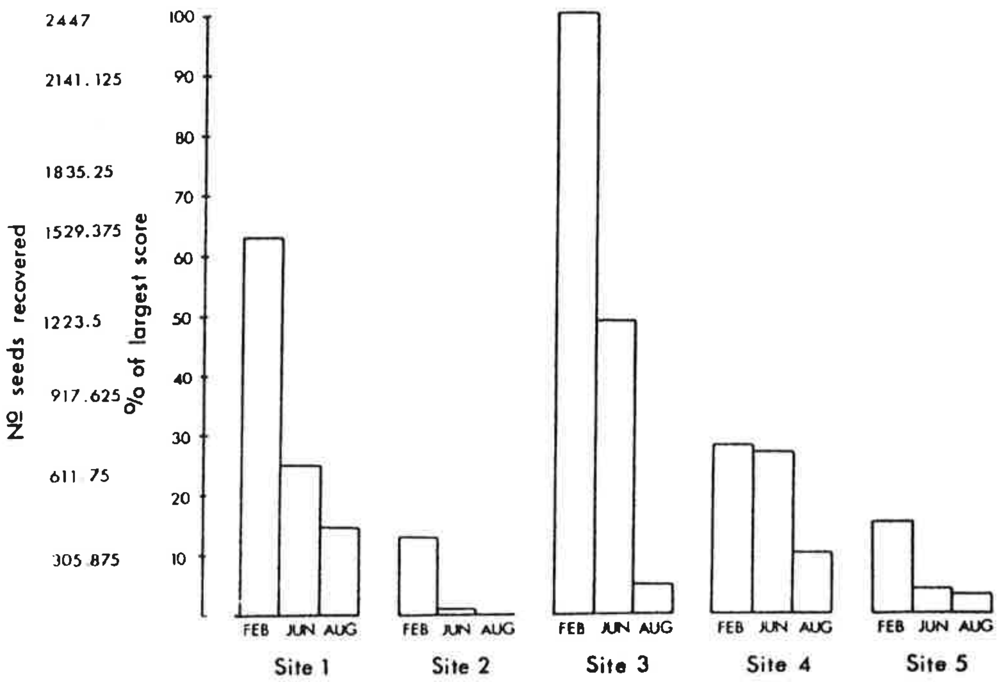


Figure 18: SEEDS FOUND IN LITTER SAMPLES (% SCALED OF LARGEST SCORE)

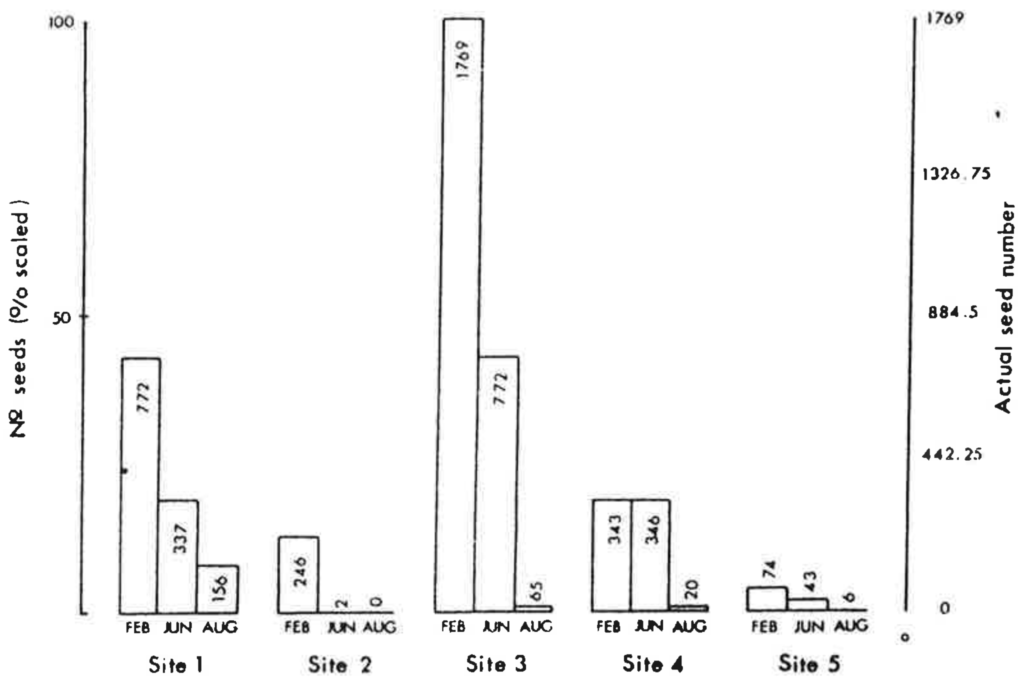
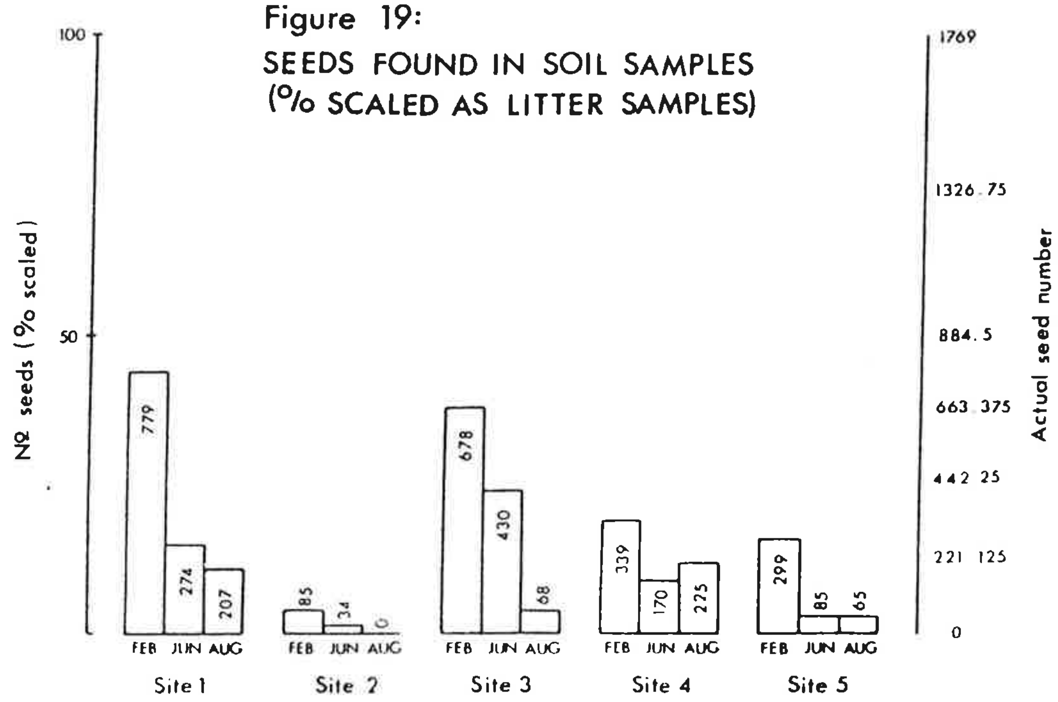
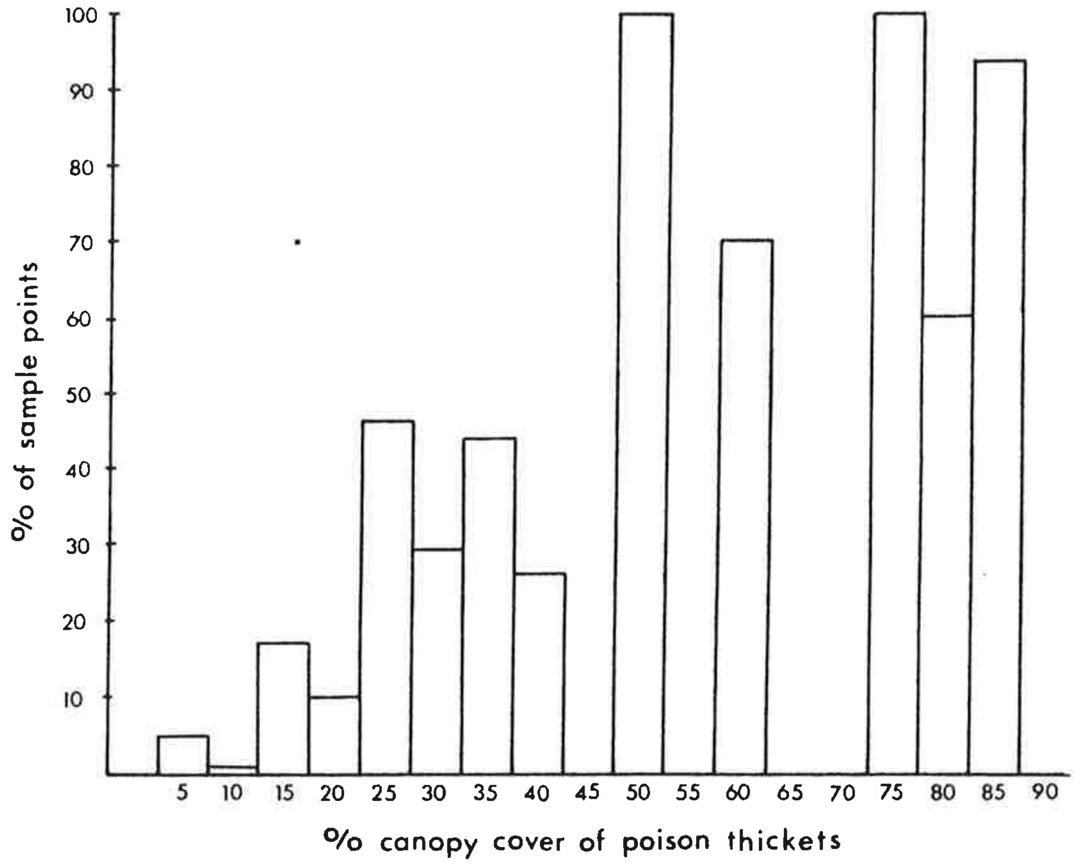


Figure 19:
SEEDS FOUND IN SOIL SAMPLES
(% SCALED AS LITTER SAMPLES)



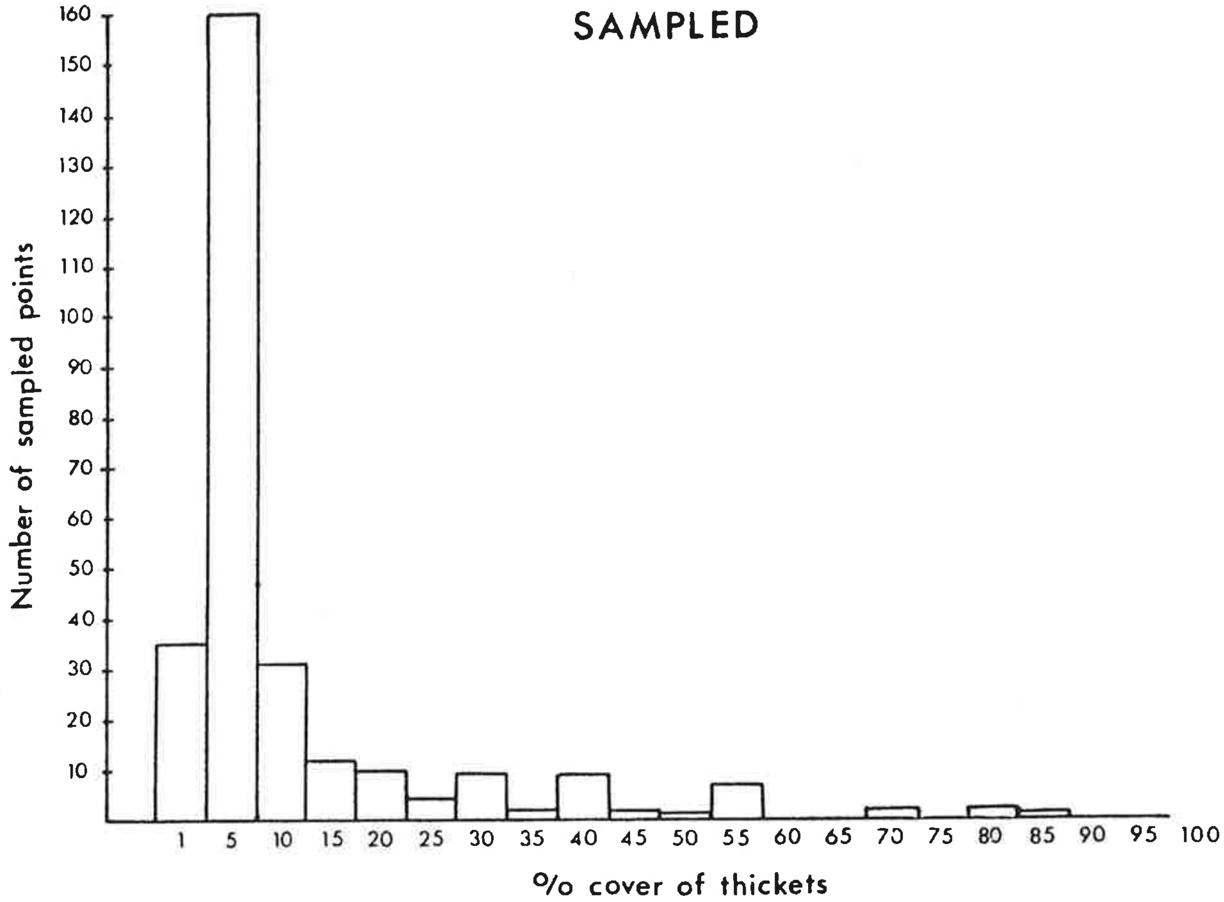
Quail and Bronzewing pigeons favoured those thickets which were dense, or which had greatest canopy cover. This is well illustrated in figure 20 below.

Figure 20:
% OF SAMPLE POINTS IN % COVER CLASSES WHERE PIDGEON/QUAIL DIGGINGS WERE RECORDED



The frequency distribution of thickets by % cover is shown in figure 21.

Figure 21:
DISTRIBUTION OF % COVER OF THICKETS SAMPLED



8.3 Discussion

The quantity of seed recovered from the litter and soil, decreased with each visit after seedfall. Maximum quantity of seed was available immediately after seedfall in mid-summer and early autumn. We believe that little or no seed would be found had we sampled again in September, 1985.

We suggest that poison thickets are raided for their seed by birds and insects. The region can probably sustain a high population of seed eaters because of the vast amount of seed available on adjacent wheatlands, especially in late spring and summer. However, towards the end of winter when the grain seed has all germinated, the birds and insects probably concentrate their feeding on the thickets in Dryandra forest, resulting in an almost total removal of seed.

The seed eaters concentrated on those thickets nearest farmland and on the denser (in terms of cover) thickets. Obviously, dense thickets provide cover and greater source of seed.

Lack of seed partially explains the often poor germination response following fire, especially when the fires are set late in autumn. Another important factor effecting thicket development is site. Poison thickets grow best on the lightly timbered lower slopes, on sandy loams and alluvial soils flanking valley floors. Poorest development was found on the upland, lateritic soils.

To have any chance of regenerating thickets using fire, fires must be set in summer when fuels and soils are dry and before seed is harvested. Only those sites (sandy soils - S5 & S6 landforms) where thickets develop best, should be treated. These sites can be easily identified and mapped.

Poor or decadent thickets on these sites should be targetted for regeneration burns. If regeneration fails, then these areas should be artificially seeded in mid winter using seed collected from the bush. We believe that a successful thicket, in terms of food and shelter for animals, is one which reaches greater than 60% cover at maturity. While more research is needed, we suggest that regeneration should produce no less than 1 - 2 plants per square metre. Thickets which are old, senescing or which will not reach 60% plus canopy cover, which are growing on ideal sites (S5 & S6 soil types) should be rehabilitated.

The size (area) and continuity of thickets will be important management consideration as grazing pressure and seed removal may retard or prevent thicket development where areas are small and isolated. Large scale aerial photographs could be used to map the structure and distribution of thickets, especially those growing on sandy soils. These maps could then be used to pin point those thickets requiring rehabilitation and to improve the overall pattern of thicket distribution. Natural distribution and site will dictate this to a large degree.

Figure 21 indicates the general poor condition of most thickets with only about 8 - 10% of thickets being in excess of 60% canopy cover.

9. Fauna, Fire and Vegetation

An extensive fauna survey was carried out, but data have not yet been analysed. From a cursory look at these data, it would appear that they generally support findings by Burbidge (1971). The discussion section of Burbidges report is in Appendix 5.

From our work and of Burbidge, most animals feed and move through various vegetation types, regardless of the age of the vegetation (or time since last burnt), except where the vegetation was recently burnt. However, most animals, including the woylie, require a dense shrub layer in which to build nests. Burbidge stated that dense thickets of poison species are not only useful for shelter and food for certain fauna, but introduce the poison 1080 into the food chain. This is important in controling the numbers of feral animals (cats and foxes) which prey on native animals.

Burbidge also suggests infrequent burning - 30-40 years or longer, which is supported by our data. He also states that cool, frequent burns do not produce the habitat necessary for diurnal refuge sites (thick vegetation cover).

10. General Discussion.

We consider that managers must take an active role in determining the fire regime of the Dryandra forest. A policy of "let burn" is neither practical nor appropriate in this valuable reserve.

Managers require information in order to plan and implement fire regimes which are in accordance with the long term conservation objectives of the reserve and which meet the constraints of time, money, fire protection and legislation. We propose that a survey, such as the one described here, can provide a sound basis for developing an interim fire management plan. As more information about the ecology of the reserve becomes available, then fire management can be modified accordingly.

Knowledge of the fire history of a forest is of key importance in determining its "fire climate". The fire proneness of the forest will help determine the importance placed on fire management for wildfire protection alone, as opposed to overall fire management. In this context, fire management is defined as;

"The integrating of fire related biological, ecological, physical and technical information into land management to meet clear objectives and to maximize benefits to society".

The results from this study clearly indicate that fires escaping from Dryandra forest have not posed a major threat to the surrounding wheatlands during the past 46 years. However, it is also very evident that fires entering Dryandra forest from surrounding wheatlands have and continue to pose a threat to the forest. This is not to say that fires will not leave Dryandra and burn adjacent lands in the future, but it does place the wildfire hazard in perspective. Together with the fact that almost all wildfires within a 20 km radius of the Dryandra fire tower are caused by human activities on adjacent lands and that the average number and size of these wildfires is small in comparison with western forests, money and resources spent on fire control should be rationalized. Fire protection measures should, therefore concentrate on excluding unwanted fires from entering the reserve.

We do not see broadacre, cyclic fuel reduction burning as the cornerstone to wildfire protection in Dryandra forest. Given the generally low fuel accumulation rates, the low "fire proneness", the extensive network of roads and firebreaks, the high level of suppression and detection capability, we believe the main thrust must be on fire prevention, pre-suppression and suppression.

Dryandra forest and surrounds has a low incidence of lightning caused fires so fire prevention must receive a high priority. The fact that most recent fires have started from harvesting operations highlights the importance of positive liaison with surrounding landowners. This could take the form of regular goodwill visits, co-operative works with local brigades and good house keeping along and within the forest boundary itself. Fire prevention should be stressed to forest visitors and users. Perhaps the banning of open fires and the construction of gas fires around regularly frequented recreation sites would promote fire prevention.

Dryandra forest and surrounds are well suited to pre-suppression work. Fuels are light and patchy for the most part, spotting potential is low and the country is gently undulating. Fire breaks are in place on "both sides of the fence" around the entire perimeter of the central block. There is a high density of roading and a number of wide firebreaks within the forest itself. However, a considerable distance of firebreak has fallen behind in maintenance and a substantial program of work is required to raise these areas to an acceptable standard for fire control. Spraying with herbicides may be a better alternative to regular burning, which will favour the development and spread of annual grasses. Grading fire breaks to clear them of scrub and other fuels and to improve vehicular access must be done.

Other forms of pre-suppression work should be considered. These include stag falling along firebreaks, moving logs off edges, burning or physically removing debris caused by road maintenance, maintenance of water points, etc.

While some of these activities may impinge on strict conservation values, we consider that such compromises are necessary in order to protect the reserve and adjacent land owners from fire. Deleterious effects of these activities can be minimized or offset by such actions as erosion control banks on firebreaks, the provision of artificial nest boxes to replace felled stags, etc.

Natural features can and should be used to the fullest in fire operations. For example, fuel moisture differentials, fuel quantity and structural diversity and natural firebreaks can play an important, effective role in both prescribed fire and fire suppression operations.

Fuel types are strongly linked to landform and vegetation. By examining wildfire scenarios before the event, we should be able to make advances in suppression strategy planning compatible with conservation objectives. For example, we may choose to allow a fire to burn into a Dryandra thicket and concentrate suppression efforts when the fire enters less flammable fuel types beneath powder-bark wandoo woodlands. With the extent of roading, firebreaks and low fuels, back-burning has enormous potential in wildfire control.

Accurate vegetation and fuel maps will assist with this type of planning but valuable information can be obtained cheaply from air photos.

Fuel loadings, accumulation rates, distribution and structure are vastly different and more variable in Dryandra than in the western forests. Fire control criteria and modes of operation established in the western jarrah and karri forests need to be reviewed and tailored to suit conditions at Dryandra.

Biological indicators provide a useful guide to the likely range of past fire regimes experienced in this area. We suggest that fire was an infrequent visitor to this forest and was more patchy than in the heavy, continuous fuels of higher rainfall forests. The occurrence of thickets, stands of natural mallet and general fuel characteristics indicate that the most frequent interval between fires was probably somewhere between 20 - 60 years. Such fires would most likely have burnt in summer or early autumn. Fire size is crucial. In the past, before European settlement, fires burning under extreme weather conditions and at 20 - 60 year intervals, may have burnt large areas before being extinguished by rain or before running into low fuel areas and other natural barriers. Ecologically, this would not have spelt disaster, as there were vast areas of surrounding unburnt forest from which re-colonization could occur.

Weeds and feral animals were non-existent then. Today, however, large fires, whether planned or unplanned, can have irreversibly deleterious effects on these small forest remnants.

The very slow post fire response of rootstock species, the poor ability for crown recovery of trees, the high proportion of fire sensitive species and the slow rates of ground litter accumulation are further indicators of the infrequency of fire. We believe that infrequent fires play an important role in maintaining desirable ecological processes but frequent fires (<15 year intervals) will cause the demise of important vegetation associations. The many fire sensitive species which develop into pure stands, or thickets, will eventually give way to rootstock species and grasses under a frequent fire regime.

Poison thickets provide food and shelter for fauna, as well as being important in their own right. The absence of seed beneath these thickets explains why "hot" experimental burns have often failed to regenerate these thickets. Ultimately, with or without fire, these thickets will deteriorate if current levels of seed harvesting are maintained. To offset this we suggest that seed be collected from the bush. Where thickets are declining and there are no signs of regeneration and where fire fails to regenerate thickets, then it will be necessary to artificially regenerate them using the collected seed.

A number of field trials will need to be conducted to determine the best technique. Artificially regenerating senescing thickets could be done by burning the thickets under dry conditions in summer-early autumn and broadcast sowing treated seed the following winter. The burnt thickets are unlikely to attract seed eating birds. Over-grazing of seedlings may be a problem. Field trials will provide useful information.

Given that infrequent fire does play a role in maintaining natural processes in Dryandra, the obvious question is "what is the appropriate fire regime?". This is difficult to define when the objective is poorly defined, the objective being to preserve and maintain the natural environment. One way of getting around the problem of the esoteric objective in this case is to monitor selected environmental components in the hope that this will reflect the "health" or condition of the ecosystem. An "ecology index", determined from measurements made on selected components can be used as a guide to ecosystem health.

Obvious measures to calculate the "ecology index" include;

- animal populations - both native and feral (numbers, population structure).
- vegetation assessments (floristics, structure).

There are standard techniques for obtaining measures of animal populations, including visual surveys, assessment of animal activities such as diggings, scratchings and scats, and by trapping.

There are also standard techniques for carrying out vegetation surveys to describe the floristics and structure of vegetation.

Monitoring is an integral part of every management operation and the maintenance of an "ecology index" using the methods described should become part and parcel of every-day operations. Specialist branches would assist with establishing the operation and with interpreting the data. Monitoring, done regularly and given a historical perspective, will provide a valuable insight to the state of "environmental health". It will provide early warnings of an impending "ecological disaster ", in a similar fashion to the way in which drought indices can give warnings of the severity of the impending fire season. Monitoring of this type also improves the managers knowledge and understanding of the ecology of his forest. Data and understanding can be used to make decisions about management actions. For example;

Monitoring reveals that animal numbers (of a single species or in total) are dwindling and the age class structure of populations is changing. At the same time, fox numbers are steadily increasing and vegetation, especially poison thickets, is degenerating. Immediately, the manager can guess that perhaps the increase in fox numbers is responsible for the decrease in, say, numbats. He may also decide that the degeneration of thickets is further depriving native animals of food and shelter.

With these facts and understanding, the manager is better placed to make decisions about remedial action - He may choose to undertake a poisoning program, or to attempt hot burning to regenerate the vegetation, and then to artificially seed if this fails. When animal numbers are critically low, he may decide to hold off burning. Such a disturbance could be very damaging at this stage of the population cycle. Conversely, when animal numbers are high and predator numbers are low, he may decide to attempt to regenerate selected areas using fire, or to do nothing.

This approach to management has a number of other advantages over committing a forest to a definite management plan (including fire regime) of action.

i) It ensures that the management dollar is spent most effectively and that something is not done without reason. It is also a measure of management performance.

ii) it keeps pace with ever changing ecosystem processes, is not outdated. The techniques will improve as researchers discover more.

iii) it encourages the manager into the biological aspects of his reserve.

The various and intricate ecological processes which have been going on in Dryandra for millenia, do not need to be actively encouraged or "managed" for their continuance.

However, managers must participate when these processes are breaking down through "unnatural" causes - such as feral animals, weeds, frequent fire, reduced habitat etc. The system briefly described above, can aid in identifying "ecosystem collapses".

11. Conclusions and Recommendations.

Fire Prevention.

1. All boundary firebreaks be upgraded to acceptable fire control standards and a program of regular checking and maintenance be activated. The central block should receive high priority.

2. Wide firebreaks around mallet plantations be upgraded, especially in the central block.

3. Grasses growing between boundary firebreaks must be sprayed, especially when adjacent land is under crop. Burning off boundary firebreaks should be only carried out when there or when there is no other option or when there is no likelihood of grass invasion due to frequent burning.

4. Fire suppression scenarios should be prepared which take into account all existing fire fighting resources (including brigades), detection capabilities, roads, firebreaks, natural firebreaks, water points, visitor and amenities protection, conservation values etc.

5. Prior to each fire season, plans showing activity on adjacent land should be prepared. These can be prepared from aerial surveillance and should include condition of adjacent paddocks e.g.; wheat crop, pasture, etc, and a survey of fire break condition on both sides of the fence.

6. Regular goodwill visits should be made to adjacent land owners and to forest users. Assistance and advice should be offered on any matters of fire control or burning off on wheatlands etc.

7. Through goodwill, stay informed as to when adjacent farmers are about to commence harvesting paddocks near Dryandra forest, or when they are about to carry out any fire hazard activity. Appropriate stages of "fire readiness" can be activated.

8. Examine the adequacy of existing fire detection and suppression capabilities in relation to 4 above.

9. Limit fuel reduction burning to small, strategic strips and areas of high fire risk, such as highways and recreation sites. Edge burning off major access roads may assist with wildfire prevention and control. Prominent roads are; Tomingley, Guru, York-Williams and Patonga.

Edge burning should aim to reduce the flammability of fuels for a distance of 50 metres either side of such roads. This depth must be strictly adhered too. Edging should be on a 6 - 8 year cycle and be carried out in such a manner that; logs and stags do not catch alight, flames are kept low (~ <50 cm), intensities are kept low (<100 kW/m) and edges do not re-ignite later. Perhaps in late autumn after the S.D.I. has fallen by 400 units may be the best time?

10. The use of open fires around picnic sites should be discouraged and gas B.B.Q.'s installed.

11. A well designed public education and awareness program focussing on fire prevention and fire management should be developed.

12. Develop hazard plans showing;

- litter fuel accumulations.
- location of highly flammable fuels, especially scrub and grasses.
- location of low flammability areas such as breakaways, gullies, wandoo flats, etc.

- location of wheat crops.
- mallet plantations.
- public utilities.
- this can be obtained largely from aerial photographs.

13. Map and document all fire hazard amelioration including burning, spraying, break maintenance etc.

14. Map and document all wildfire outbreaks within a 20 km radius of Dryandra fire tower.

15. Exclude from the central block, any activity or operation which will add to the fire hazard of the block e.g. logging slash, various machine operations in summer etc.

Fire Management.

1. Implement a monitoring system or an "ecology index" to monitor fuel accumulations, animal populations and the condition of vegetation, especially thickets and other types important to animals. Specialist branches to assist with the setting up of this system, to train field staff in various monitoring techniques and to assist with the interpretation of results and recommended action. Monitoring is also a useful performance guide.

2. With the exception of that described above no fuel reduction or prescribed burning to take place until the need is clearly identified from 1 above.

3. Collect seed of various species, especially;

Acacia acuminata

A. alata

A. celastrifolia

Casuarina huegeliana

Dryandra nobilis

D. carduacea

Gastrolobium calycinum

G. microcarpum

G. oxylobioides

G. parviflorum

G. reticulatum

G. spinosum

G. trilobum

Oxylobium parviflorum

Specialist branches to advise on methods of seed extraction, collection and artificial regeneration.

4. "Thicket Rehabilitation".

- map the distribution and structure of poison thickets in the Central block. This may be done from low level air photos.

- Use landform maps prepared by McArthur to identify S5 & S6 sites where thickets mostly occur.
- Identify degraded thickets (canopy cover less than 60%) on S5 & S6 soil units.
- Construct a program of rehabilitation for these thickets. Aim at forming large, continuous areas, where thickets once existed. Fires should not be allowed to spread from targetted areas.
- Carry out burns in these "thickets" in February or March and under stable conditions.
- Assess the success of these burns by seedling counts in June-July. Artificially seed where counts are less than 1 seedling/m².
- Monitor subsequent thicket development.

Research.

To continually refine any management plan, there must be an ongoing program of research. Main broad areas requiring considerably more research include;

- Fire behaviour in flammable scrub fuels.
- Fire behaviour in litter fuels.
- Relationship between fauna, flora and fire.
- Social research - neighbours and users perceptions of forest fire.
- Regeneration of poison thickets.

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APPENDIX 2

BOUNDARY SURVEY-DRYANDRA

CODE SHEET

VAR1 A LAND USE OUTSIDE STATE FOREST

1=cereal crop	4=ungrazed "dirty" bush
2=fallow	5=grazed "tidy" bush
3=pasture	6=recently chained bush and slash

VAR2 B DESCRIPTION OF FIRE BREAK ON P.O. OR LAND OUTSIDE S.F.

1=farmer, no break
2=farmer, break near fence <2m
3=farmer, break near fence 2m-5m
4=farmer, break near fence 5m-10m
5=farmer, break near fence 10m-20m
6=farmer, break near fence 20+m
7=F.D.break track or road to fence 0-5m
8=F.D.break track or road to fence 5-20m
9=F.D.break track or road to fence 20+m

VAR3 C TOPOGRAPHY

1=flat
2=gentle slope(5-10°) from S.F.downhill into P.P.
3=steep slope(10°+)from S.F.downhill into P.P.
4=gentle slope from S.F.uphill into P.P.
5=steep slope from S.F.uphill into P.P.
6=break running up or down hill gentle slope
7=break running up or down hill steep slope

VAR4 D FOREST TYPE IN S.F.

1=wandoo	5=casuarina
2=powder bark wandoo	6=jarrah/marri
3=mallet plantation	7=jam
4=mallet natural	8=non forest cover

VAR5 +D1 as for D but on strip between breaks

VAR6 E SCRUB COVER S.F.

1=low, open scrub (<1m, <30%)
2=low, dense scrub (<1m, >30%)
3=tall, open (>1m, <30%)
4=tall, dense scrub (>1m, >30%)
5=poison thicket

VAR7 +E1 as for E but on strip between breaks

VAR17 L DESCRIBE THE CONDITION OF THIS BOUNDARY IN TERMS OF STOPPING A WILDFIRE GOING <u>INTO</u> S.F. <u>FROM</u> P.P. (<u>NO</u> SUPPRESSION CREWS PRESENT)

1=yes, high intensity fire
2=could stop a moderate intensity wildfire
3=could stop a low intensity wildfire
4=could not stop any fire

VAR18 M COULD A SUPPRESSION CREW HOLD A FIRE ON THIS BREAK?

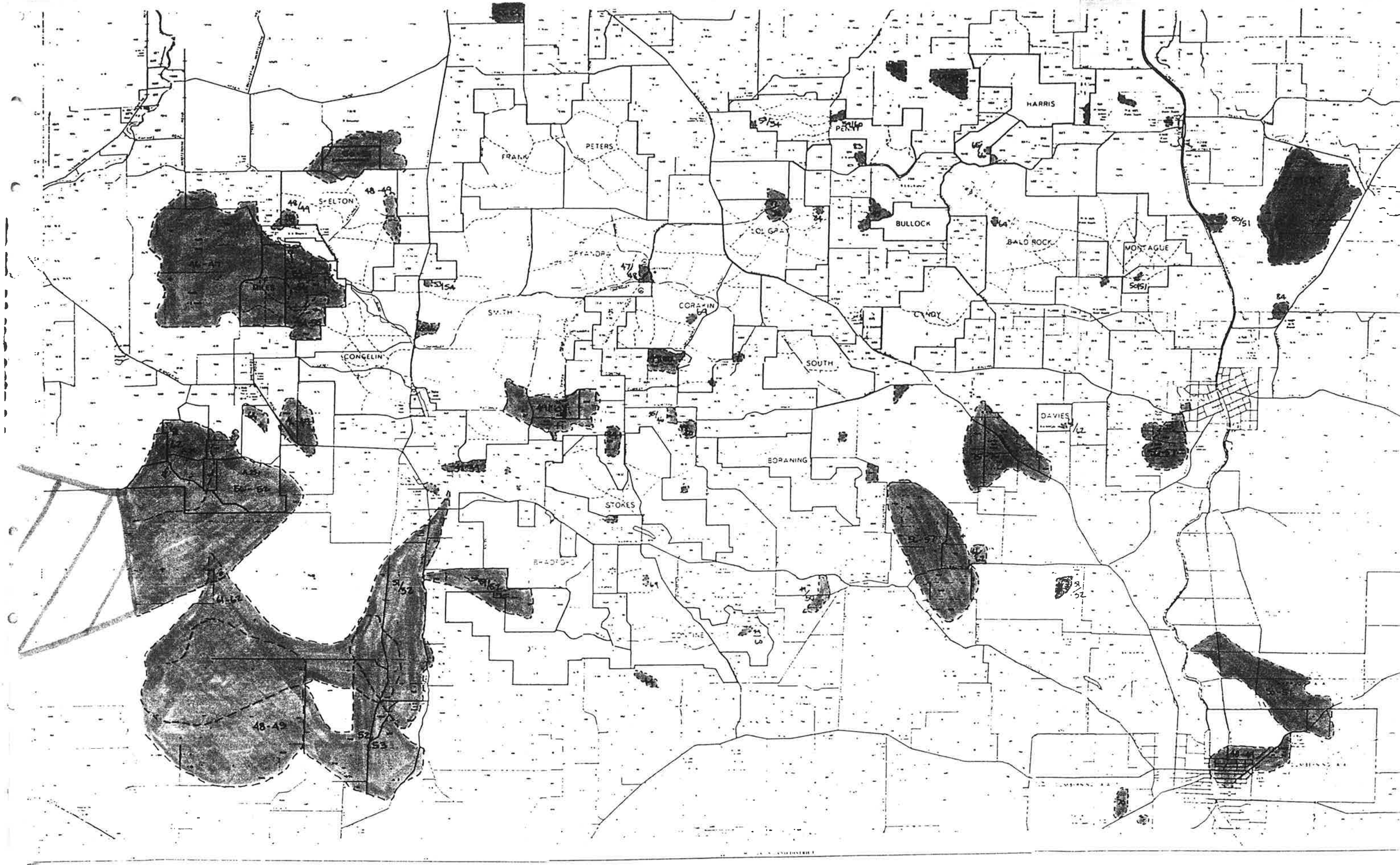
1=yes, high intensity fire
2=yes, moderate intensity fire
3=yes, low intensity fire
4=no, never

VAR19 N HOW DO YOU RATE THE PRIORITY FOR WORK TO BE DONE ON THIS SECTION?

1=high, needs immediate attention
2=moderate, can wait, but needs attention in 2 - 3 years
3=low - no action needed for 5 - 6 years

VAR20 O HOW DO YOU RECOMMEND THIS SECTION BE PREPARED?

1=break needs grading
2=bush needs burning
3=grass needs spraying with herbicide
4=break needs widening
5=trees need felling
6=need to liaise with adjacent land owner
7=no maintenance at present



APPENDIX 1: Wildfires since 1938 (to 1984)

DRYANDRA

APPENDIX 3: Results of boundary fire break survey

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VAR LABELS      VAR1,LAND USES OUTSIDE STATE FOREST/
                VAR2,FIRE BREAK/
                VAR3,TOPOGRAPHY/
                VAR4,FOREST TYPE IN S.F./
                VAR5,FOREST TYPE BETWEEN BREAKS/
                VAR6,SCRUB COVER S.F./
                VAR7,SCRUB COVER BETWEEN BREAKS/
                VAR8,GRASS COVER S.F./
                VAR9,GRASS COVER BETWEEN BREAKS/
                VAR10.GROUND COVER S.F./
                VAR11.GROUND COVER BETWEEN BREAKS/
                VAR12.MOP-UP DIFFICULTY S.F./
                VAR13,MOP-UP DIFFICULTY BETWEEN BREAKS/
                VAR14,ESTIMATE OF FUEL AGE IN S.F./
                VAR15.CONDITION OF BREAK IN S.F./
                VAR16,BOUNDARY CONDITION - STOP FIRE FROM P.P?/
               .VAR17.BOUNDARY CONDITIN - STOP FIRE TO P.P.?/
                VAR18.COULD BREAK HOLD FIRE?/
                VAR19.PRIRITY FOR WORK NEEDED ON BREAK?/
                VAR20,RECOMMENDATIONS FOR SECTION/
VALUE LABELS    VAR1,(1)CEREAL CROP
                     (2)FALLOW
                     (3)PASTURE
                     (4)UNGRAZED DIRTY BUSH
                     (5)GRAZED TIDY BUSH
                     (6)RECENTLY CHAINED BUSH AND SLASH/
                VAR2,(1)FARMER-NO BREAK
                     (2)FARMER-BREAK NEAR FENCE <2M
                     (3)FARMER-BREAK NEAR FENCE 2-5M
                     (4)FARMER-BREAK NEAR FENCE 5-10M
                     (5)FARMER-BREAK NEAR FENCE 10-20M
                     (6)FARMER-BREAK NEAR FENCE 20+M
                     (7)F.D. BREAK TO FENCE 0-5M
                     (8)F.D. BREAK TO FENCE 5-20M
                     (9)F.D. BREAK TO FENCE 20+M/
                VAR3,(1)FLAT <3 DEG.
                     (2)GENTLE SLOPE 5-10 DEG. S.F. DOWN TO P.P.
                     (3)STEEP SLOPE 10- DEG. S.F. DOWN TO P.P.
                     (4)GENTLE SLOPE S.F. UP TO P.P.
                     (5)STEEP SLOPE S.F. UP TO P.P.
                     (6)BREAK UP OR DOWN HILL - GENTLE SLOPE
                     (7)BREAK UP OR DOWN HILL - STEEP SLOPE/
                VAR4,VAR5,(1)WANDOO
                          (2)POWDER BARK WANDOO
                      (3)MALLET PLANTATION
                          (4)MALLET NATURAL
                          (5)CASUARINA
                          (6)JARRAH-MARRI
                          (7)JAM
                          (8)NON FOREST COVER/
                VAR6,VAR7,(1)LOW OPEN SCRUB <1M,<30 PERCENT
                          (2)LIW DENSE SCRUB <1M,>30 PERCENT
                          (3)TALL OPEN >1M,<30 PERCENT
                          (4)TALL DENSE >1M,>30 PERCENT
                          (5)POISON THICKET/
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27/09/

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VAR8,VAR9, (1)NONE
          (2)LOW  SPARSE <15CM, <30 PERCENT
          (3)LOW DENSE <15CM, >30 PERCENT
          (4)TALL SPARSE >15CM, <30 PERCENT
          (5)TALL DENSE >15CM, >30 PERCENT/
VAR10,VAR11, (1)LIGHT PATCHY
             (2)MODERATE COVER 10-20MM.
             (3)DEEP LITTER 20+MM./
VAR12,VAR13, (1)NO LOGS,NO STAGS WITHIN 50M OF P.P.
             (2)SOME LOGS,NO STAGS
             (3)NO LOGS,SOME STAGS
             (4)SOME LOGS AND STAGS/
VAR14, (1)0-2 YRS (2)2-5 YRS (3)5-10 YRS (4)10 YRS/
VAR15, (1)GOOD CLEAN EASILY ACCESSSIBLE BREAK
       (2)PARTIALLY OVERGROWN COVERED IN LITTER
       (3)OVERGROWN WITH SCRUB COVERED IN LITTER
       (4)PARTIALLY OVERGROWN GRASS/
VAR16,VAR17, (1)COULD STOP A HIGH INTENSITY FIRE
             (2)COULD STOP A MOD. INTENSITY FIRE
             (3)COULD STOP A LOW INTENSITY FIRE
             (4)COULD NOT STOP ANY FIRE/
VAR18, (1)YES,HIGH INTENSITY FIRE
       (2)YES,MOD. INTENSITY FIRE
       (3)YES,LOW INTENSITY FIRE
       (4)NO,NEVER/
VAR19, (1)HIGH, NEEDS IMMEDIATE ATTENTION
       (2)MODERATE.CAN WAIT BUT NEEDS ATTENTION 2-3 YRS
       (3)LOW,NO ACTION NEEDED FOR 5-6 YRS/
VAR20, (1)BREAK NEEDS GRADING
       (2)BUSH NEEDS BURNING
       (3)GRASS NEEDS SPRAYING WITH HERBICIDE
       (4)BREAKS NEED WIDENING
       (5)TREES NEED FELLING
       (6)NEED TO LIAISE WITH ADJACENT LAND OWNER
       (7)NO MAINTENANCE AT PRESENT
       (8)3+4+5 - SPRAY.WIDEN BREAKS,FALL TREES
       (9)3+5+6 - SPRAY.FALL TREES. LIAISE WITH P.P.
       (10)1+3+5 - GRADE,SPRAY,FALL TREES/
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VAR1 LAND USES OUTSIDE STATE FOREST

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
CEREAL CROP	1.	229	41.6	41.6	41.6
FALLOW	2.	1	0.2	0.2	41.8
PASTURE	3.	271	49.3	49.3	91.1
UNGRAZED DIRTY BUSH	4.	19	3.5	3.5	94.5
GRAZED TIDY BUSH	5.	11	2.0	2.0	96.5
RECENTLY CHAINED BUS	6.	6	1.1	1.1	97.6
	14.	8	1.5	1.5	99.1
	15.	1	0.2	0.2	99.3
	35.	4	0.7	0.7	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR2 FIRE BREAK

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CU.. FREQ (PC
FARMER-BREAK NEAR FE	2.	19	3.5	3.5	3.5
FARMER-BREAK NEAR FE	5.	1	0.2	0.2	3.
FARMER-BREAK NEAR FE	6.	2	0.4	0.4	4.0
	17.	7	1.3	1.3	5.[illegible]
	19.	7	1.3	1.3	6.
	25.	1	0.2	0.2	6.7
	27.	397	72.2	72.2	78.
	28.	58	10.5	10.5	89.5
	29.	26	4.7	4.7	94.
	37.	6	1.1	1.1	95.[illegible]
	47.	2	0.4	0.4	95.6
	57.	8	1.5	1.5	97.
	58.	3	0.5	0.5	97.6
	67.	10	1.8	1.8	99.
	69.	3	0.5	0.5	100.[illegible]
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR3 TOPOGRAPHY

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
FLAT <3 DEG.	1.	176	32.0	32.0	32.0
GENTLE SLOPE 5-10 DE	2.	97	17.6	17.6	49.6
STEEP SLOPE 10+ DEG.	3.	36	6.5	6.5	56.2
GENTLE SLOPE S.F. UP	4.	19	3.5	3.5	59.6
STEEP SLOPE S.F. UP	5.	3	0.5	0.5	60.2
BREAK UP OR DOWN HIL	6.	145	26.4	26.4	86.5
BREAK UP OR DOWN HIL	7.	67	12.2	12.2	98.7
	37.	6	1.1	1.1	99.8
	57.	1	0.2	0.2	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR4 FOREST TYPE IN S.F.

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	0.	1	0.2	0.2	0.2
WANDOO	1.	175	31.8	31.8	32.0
POWDER BARK WANDOO	2.	24	4.4	4.4	36.4
MALLET PLANTATION	3.	172	31.3	31.3	67.6
MALLET NATURAL	4.	3	0.5	0.5	68.2
CASUARINA	5.	10	1.8	1.8	70.0
JARRAH-MARRI	6.	5	0.9	0.9	70.9
JAM	7.	9	1.6	1.6	72.5
NON FOREST COVER	8.	6	1.1	1.1	73.6
	12.	13	2.4	2.4	76.0
	13.	3	0.5	0.5	76.5
	14.	14	2.5	2.5	79.1
	15.	44	8.0	8.0	87.1
	16.	23	4.2	4.2	91.3
	17.	22	4.0	4.0	95.3
	18.	1	0.2	0.2	95.5
	23.	2	0.4	0.4	95.8
	24.	3	0.5	0.5	96.4
	25.	2	0.4	0.4	96.7
	26.	9	1.6	1.6	98.4
	35.	2	0.4	0.4	98.7
	37.	1	0.2	0.2	98.9
	45.	1	0.2	0.2	99.1
	57.	4	0.7	0.7	99.8
	67.	1	0.2	0.2	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR5 FOREST TYPE BETWEEN BREAKS

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	0.	1	0.2	0.2	0.2
WANDOO	1.	154	28.0	28.0	28.2
POWDER BARK WANDOO	2.	17	3.1	3.1	31.3
MALLET PLANTATION	3.	4	0.7	0.7	32.0
MALLET NATURAL	4.	11	2.0	2.0	34.0
CASUARINA	5.	17	3.1	3.1	37.1
JARRAH-MARRI	6.	21	3.8	3.8	40.9
JAM	7.	21	3.8	3.8	44.7
NON FOREST COVER	8.	228	41.5	41.5	86.2
	12.	4	0.7	0.7	86.9
	14.	9	1.6	1.6	88.5
	15.	20	3.6	3.6	92.2
	16.	12	2.2	2.2	94.4
	17.	21	3.8	3.8	98.2
	24.	1	0.2	0.2	98.4
	25.	2	0.4	0.4	98.7
	26.	5	0.9	0.9	99.6
	45.	1	0.2	0.2	99.8
	57.	1	0.2	0.2	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR6 SCRUB COVER S.F.

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
LOW OPEN SCRUB <1M, <	1.	237	43.1	43.1	43.1
LOW DENSE SCRUB <1M,	2.	30	5.5	5.5	48.5
TALL OPEN >1M,<30 PE	3.	83	15.1	15.1	63.6
TALL DENSE >1M,>30 P	4.	64	11.6	11.6	75.3
POISON THICKET	5.	136	24.7	24.7	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR7 SCRUB COVER BETWEEN BREAKS

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
LOW OPEN SCRUB <1M, <	1.	450	81.8	81.8	81.8
LOW DENSE SCRUB <1M,	2.	15	2.7	2.7	84.5
TALL OPEN >1M,<30 PE	3.	34	6.2	6.2	90.7
TALL DENSE >1M,>30 P	4.	33	6.0	6.0	96.7
POISON THICKET	5.	18	3.3	3.3	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR8 GRASS COVER S.F.

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
NONE	1.	223	40.5	40.5	40.5
LOW SPARSE <15CM, <	2.	127	23.1	23.1	63.6
LOW DENSE <15CM, >30	3.	60	10.9	10.9	74.5
TALL SPARSE >15CM, <	4.	46	8.4	8.4	82.9
TALL DENSE >15CM, >3	5.	94	17.1	17.1	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR9 GRASS COVER BETWEEN BREAKS

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
NONE	1.	105	19.1	19.1	19.1
LOW SPARSE <15CM, <	2.	174	31.6	31.6	50.7
LOW DENSE <15CM, >30	3.	142	25.8	25.8	76.5
TALL SPARSE >15CM, <	4.	15	2.7	2.7	79.3
TALL DENSE >15CM, >3	5.	114	20.7	20.7	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR10 GROUND COVER S.F.

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
LIGHT PATCHY	1.	190	34.5	34.5	34.5
MODERATE COVER 10-20	2.	182	33.1	33.1	67.6
DEEP LITTER 20+MM.	3.	178	32.4	32.4	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR11 GROUND COVER BETWEEN BREAKS

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
LIGHT PATCHY	1.	435	79.1	79.1	79.1
MODERATE COVER 10-20	2.	72	13.1	13.1	92.2
DEEP LITTER 20+MM.	3.	43	7.8	7.8	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR12 MOP-UP DIFFICULTY S.F.

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
NO LOGS, NO STAGS WIT	1.	118	21.5	21.5	21.5
SOME LOGS, NO STAGS	2.	57	10.4	10.4	31.8
NO LOGS, SOME STAGS	3.	31	5.6	5.6	37.5
SOME LOGS AND STAGS	4.	344	62.5	62.5	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR13 MOP-UP DIFFICULTY BETWEEN BREAKS

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
NO LOGS, NO STAGS WIT	1.	432	78.5	78.5	78.5
SOME LOGS, NO STAGS	2.	30	5.5	5.5	84.0
NO LOGS, SOME STAGS	3.	15	2.7	2.7	86.7
SOME LOGS AND STAGS	4.	73	13.3	13.3	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR14 ESTIMATE OF FUEL AGE IN S.F.

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
0-2 YRS	1.	31	5.6	5.6	5.6
2-5 YRS	2.	82	14.9	14.9	20.5
5-10 YRS	3.	40	7.3	7.3	27.8
10 YRS	4.	397	72.2	72.2	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR15 CONDITION OF BREAK IN S.F.

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
GOOD CLEAN EASILY AC	1.	357	64.9	64.9	64.9
PARTIALLY OVERGROWN	2.	58	10.5	10.5	75.5
OVERGROWN WITH SCRUB	3.	17	3.1	3.1	78.5
PARTIALLY OVERGROWN	4.	112	20.4	20.4	98.9
	24.	6	1.1	1.1	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR16 BOUNDARY CONDITION - STOP FIRE FROM P.P?

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
COULD STOP A HIGH IN	1.	3	0.5	0.5	0.5
COULD STOP A MOD. IN	2.	113	20.5	20.5	21.1
COULD STOP A LOW INT	3.	344	62.5	62.5	83.6
COULD NOT STOP ANY F	4.	90	16.4	16.4	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR17 BOUNDARY CONDITIN - STOP FIRE TO P.P.?

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
COULD STOP A HIGH IN	1.	3	0.5	0.5	0.5
COULD STOP A MOD. IN	2.	97	17.6	17.6	18.2
COULD STOP A LOW INT	3.	355	64.5	64.5	82.7
COULD NOT STOP ANY F	4.	95	17.3	17.3	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR18 COULD BREAK HOLD FIRE?

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
YES, HIGH INTENSITY F	1.	6	1.1	1.1	1.1
YES, MOD. INTENSITY F	2.	446	81.1	81.1	82.2
YES, LOW INTENSITY FI	3.	92	16.7	16.7	98.9
NO, NEVER	4.	6	1.1	1.1	100.0
	TOTAL	550	100.0	100.0	

VALID CASES 550 MISSING CASES 0

VAR19 PRIRITY FOR WORK NEEDED ON BREAK?

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
HIGH, NEEDS IMMEDIAT	1.	412	74.9	74.9	74.9
MODERATE, CAN WAIT BU	2.	112	20.4	20.4	95.3
LOW, NO ACTION NEEDED	3.	26	4.7	4.7	100.0
	TOTAL	550	100.0	100.0	

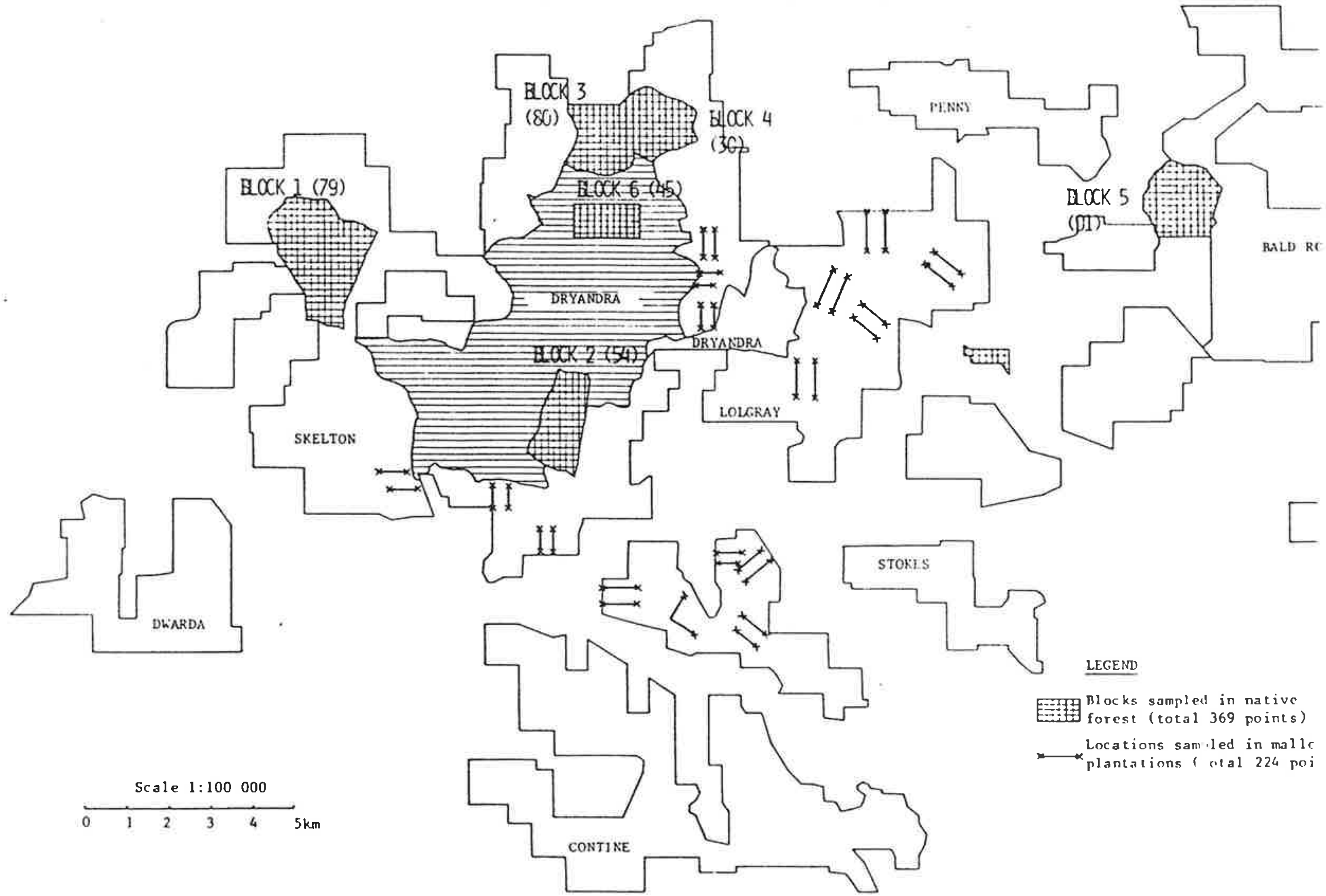
VALID CASES 550 MISSING CASES 0

FILE DRYBOUND (CREATION DATE = 27/09/85)

VAR20 RECOMMENDATIONS FOR SECTION

CATEGORY LABEL	CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
	0.	6	1.1	1.1	1.1
BREAK NEEDS GRADING	1.	15	2.7	2.7	3.8
BUSH NEEDS BURNING	2.	2	0.4	0.4	4.2
GRASS NEEDS SPRAYING	3.	248	45.1	45.1	49.3
BREAKS NEED WIDENING	4.	29	5.3	5.3	54.5
TREES NEED FELLING	5.	7	1.3	1.3	55.8
NEED TO LIAISE WITH	6.	6	1.1	1.1	56.9
NO MAINTENANCE AT PR	7.	12	2.2	2.2	59.1
3+4+5 - SPRAY, WIDEN	8.	12	2.2	2.2	61.3
3+5+6 - SPRAY, FALL T	9.	10	1.8	1.8	63.1
1+3+5 - GRADE, SPRAY,	10.	1	0.2	0.2	63.3
	13.	38	6.9	6.9	70.2
	14.	5	0.9	0.9	71.1
	23.	6	1.1	1.1	72.2
	34.	105	19.1	19.1	91.3
	35.	25	4.5	4.5	95.8
	36.	2	0.4	0.4	96.2
	37.	4	0.7	0.7	96.9
	45.	3	0.5	0.5	97.5
	46.	14	2.5	2.5	100.0
	TOTAL	550	100.0	100.0	

APPENDIX 4: Dryandra forest - showing location of fuel and ecological survey dample points



APPENDIX 5

Discussion from Burbidges 1971 report

The results of trapping indicate that woylies feed in all vegetation types except plateau. When time since fire is taken into account it seems that this has no effect. No animals were captured in recently burned Wandoo Slope or Wandoo Flat but some were taken in recently burnt Powder Bark Slope. Since the traps are presumably capturing animals which are either moving from their diurnal refuge to feed, feeding, or returning to the refuge, this suggests that woylies feed in all vegetation types, independent of fire-age, except plateau. Thus the data indicated that fire history has no effect on feeding or general movements within the home range.

On the other hand the radio-tracking data suggest that woylies only construct their diurnal refuges in areas with a well established, dense shrub layer. Sampson (1971) located nine nests at Tutanning Nature Reserve. Of these 6 were in plateau vegetation, 2 in heath and 1 in woodland. Sampson did not describe the density of vegetation nor give its age. Department of Fisheries and Wildlife records indicate that the area Sampson had worked in had not been burned since the 1940's or earlier.

The purpose of the nest seems to be principally the avoidance of temperature extremes. Sampson (1971) measured the temperature in nests built from hay by captive *B.pencillata* and found that when the air temperature was below 28°C, the unoccupied nest temperature was higher. On the other hand when the air temperature was above 32°C the nest temperature was lower. Even with air temperatures as high as 36.4°C the nest temperature did not rise above 33°C. Data reported here from recently occupied nests support Sampson's conclusions; in fact the highest temperature recorded in a Dryandra nest was 31.5°C even though air temperatures were as high as 37°C.

Brush Possums were captured in all vegetation types with the poorest results in Harri and heath. When the fire history of the trapping area is taken into account it can be seen that capture rates were extremely variable and independent of fire age. Subjectively trapping success in different areas related to the availability of trees and logs with suitable hollows rather than to any other factor.

The extremely low capture rates for the Quenda make it difficult to interpret the available data. However, it appears that this species avoids open country and plateaux and occurs only where there is fairly dense shrub layer. Sampson (1971) found that, at Tutanning, Quendas also avoid areas with little understorey. However, he did capture this species on laterite plateaux but in his study area these are not as extensive as at Dryandra. Sampson (*loc.cit*) discussed the type of nests constructed by this species and describes one nest he found in wandoo slope vegetation. No nests were found during this study.

The trapping data for House Mice suggest a population "explosion" during early 1972 rather than a preference for particular vegetation types or vegetations of particular fire-age.

The data obtained from spotlight traverses is of little value for three of the four small species - Tammar, Woylie and Quenda. Data on Brush Possums is of more value. This is directly related to visibility. No Quendas were trapped in Wandoo Flat indicating their preference for areas with a dense shrub layer where visibility is poor. Although both woylies and tammar feed in open country at least some of the time, and were observed in this country during spotlight traverses, the data are heavily biased toward this type of country because of poor visibility in other vegetation formations.

Brush Possums are much more visible than the above three species for two reasons - their arboreal habits and very bright eye-shine in a spotlight beam. The spotlight data for this species confirm the trapping data to the extent that the species was observed in all vegetation types. The high number of sightings in Wandoo Flat compared with other formations is probably also due to better visibility rather than a real preference for this vegetation.

Spotlighting counts for the two larger species - Western Grey Kangaroo and Western Brush Wallaby - can be expected to be more reliable, particularly for kangaroos which stand above much of the shrub layer. On the assumption that the effective search strip for kangaroos was 100m wide the spotlight counts show an average density of 1 animal per 17.2ha. Sightings were highest in Wandoo Flat (1 animal per 11.4ha) and lowest in Powder Bark Slope (1 animal per 41.7ha). Using the same assumed effective search strip the average density of Brush Wallabies is 1 animal per 62.5ha, with very little variation between the various vegetation formations.

Dryandra Forest is a particularly important area for the woylie - only two other populations of this once widespread species known to-day. It is of interest to note that the three areas from which woylies are known - Tutanning Nature Reserve, Dryandra Forest and the Perup-Tone Rivers area east of Manjimup have shown important similarities. They are all comparatively large areas of predominantly woodland vegetation typical of much of the woodlands of the south-west before clearing. They all also have extensive stands of shrubs of the genus Gastrolobium. These plants contain the toxic chemical monofluoro-acetic acid. Its sodium salt is the widely used vertebrate pesticide "Compound 1080". Oliver et al (1977) have shown that some native mammals in the south-west of Australia have evolved a high degree of resistance to this chemical. On the other hand the two species of exotic carnivores which are now widely established in Australia - the European Fox (vulpes vulpes) and the Domestic Cat (Felis catus) - are very susceptible. It is noteworthy that our spotlight traverses recorded these two species very infrequently. The inference is that these carnivores are unable to inhabit dense poison country because the chemical is passed to them through the food chain.

It is clear from the work reported here that the woylie requires a dense shrub layer in which to build the nests which serve as diurnal refuge from temperature stress. The above theory makes it clear that management strategies should not only provide a dense shrub layer in the woodlands but also that it is vital that this layer be composed largely of Gastrolobium species.

A management plan for Dryandra Forest therefore needs to make a provision for areas of slope vegetation with an old, dense layer of Gastrolobium microcarpum. Areas of dense Dryandra spp. near slopes are also valuable. More long term research and monitoring work are needed before fire prescriptions and intervals can be given precisely. In the short term, say over the next decade, the best policy would be:

1. Leave extensive areas of dense Gastrolobium unburnt. While there is evidence to suggest that Gastrolobium requires a hot fire before good regeneration will take place it is my belief that this only needs to occur every 30 to 40 years or perhaps even longer. On the

other hand it seems that the cool prescribed burns used a Dryandra over the past decade to not produce the habitat necessary for diurnal refuge sites.

2. Conduct research arrived at finding the necessary prescription for regenerating Gastrolobium to the required density.

3. Should summer wildfires occur at Dryandra then follow a "let burn" policy to some extent so that a substantial area of vegetation is burnt under hot conditions. This would approximate the type of fire which occurred naturally, following ignition from lighting, than would cool prescribed fires lit in Spring and Autumn.

4 Use cool prescribed burns for the purpose of fuel reduction only in those parts of the forest where it is necessary to protect property and plantations; as well as some areas throughout the forest in order to provide places from which wildfires can be controlled.