SOME EFFECTS OF KARRI FOREST MANAGEMENT ON PLANTS AND ANIMALS

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INTRODUCTORY NOTE

This paper is a preliminary report on research work into the ecological effects of karri forest management. It is incomplete in that there is no statistical treatment of those data which are suitable, and the section on insects has yet to be written due to difficulties in the identification of the insects collected. Nevertheless the report in its present form will be a valuable research contribution in the field of environmental effects of forest management practices.

The report will be issued in its complete form later in 1976.

Although two names appear on the title page, the study represents contributions from the entire staff of the Manjimup Research Station. Mr. P. Christensen designed the mammal studies. The work on insects was planned and supervised by Mr. S. Curry, Entomologist, Department of Agriculture. Soil fauna information was derived exclusively from the work of Dr. J.A. Springett.

1-7-76

1. INTRODUCTION

1.1 This study was initiated by the Research Station at Manjimup to gain basic information on indigenous fauna and flora populations of the karri forest, which could be used to predict the environmental impact of integrated harvesting of the forest for sawlog and chipwood.

The introduction of chipwood production into karri forest harvesting is expected to have little overall impact per se. However the chipwood project has coincided with the near exhaustion of merchantable material in pure stands of karri. Future cutting will be mainly in mixtures of karri and marri, and a larger area than before will be cut over annually to harvest a similar volume of karri logs. This increase in the area of forest cut each year has prompted the present investigation.

Past use of the uniform system of managing karri was conducted rather differently from present procedures in that there was no limit to coupe (= cutting unit) size, there was no direct attempt at dispersion of coupes, and cutting proceeded on a face throughout the coupe. Under present prescription coupe size is limited to a maximum of 200 hectares, coupes are dispersed as widely as possible, and strips of forest are left uncut bordering major roads and streams. Within a coupe an average of 20 percent of the area now remains uncut.

This study was done in areas operated without these constraints and the recorded changes, particularly in fauna populations, may be more radical than can be expected in the future.

The period of the study extended from April 1974 to October 1975.

1.2 The Karri Forest

Karri is confined to the extreme south of the State. Most stands occur in the 1000mm + rainfall region and the species is confined to areas where the mean rainfall of the driest months exceeds 16mm (Churchill 1968). The distribution of karri within its climatic limits is adaphically controlled. Pure karri stands are most frequently found on red earths, while mixtures with marri (E. calophylla) and to a lesser extent jarrah (E. marginata) are the norm on podsolic soils. A generalised catenary series follows the trend of karri/marri on the alluvial valley floors, pure karri on lower and mid slopes grading to karri/marri mixtures on upper podsolic slopes. Ridge tops are frequently lateritic carrying jarrah/marri mixtures and karri is absent.

The virgin forest is distinctly storeyed in structure, as the upper canopy of karri crowns is remote from the dense shrub layer. An understorey of karri oak (Casuarina decussata) on some sites extends the shrub canopy to a high level, but the tree crowns remain remote. The shrub layer is typically very dense and dominated by legumes where regular burning is practised.

The karri forest has been variously described as a wet sclerophyll type and as a temperate rain forest type. Sclerophyllic and mesophyllic characteristics are about evenly represented for the first few years of succession following fire. Exclusion of fire from the forest for a long period results in a distinctly mesophyllic shrub layer.

Regenerated stands are protected from fire for 15 years. Stands older than this are burnt under prescription on a 7 to 8 year rotation.

1.3 Forest management - history and practice

Clear felling, followed by uniform (even-aged) regeneration was practised in the karri (*Eucalyptus diversicolor*) forests 30 to 40 years ago. In the 1940's the management system was changed to one of selection cutting where generally more than 50 percent of the original crop was left and only the gaps created by felling were regenerated. In 1968 clear felling was reintroduced and this system has been followed in pure karri stands since. The areas of forest treated by clear felling and uniform regeneration over the years are shown in Figure 1.1.

FIGURE 1.1

Areas of karri forest clear-felled
(uniform regeneration)

Year	Area (hectares)	Present Age of regrowth (years)
1930-34	2752	40 - 45
1935-39	1896	35 - 40
1940-44	-	-
1945-49	-	-
1950-54	-	-
1955-59	-	-
1960-64	192	10 - 15
1965-69	2035	5 - 10
1970-74	2100	0 - 5

1.4 Management Practice

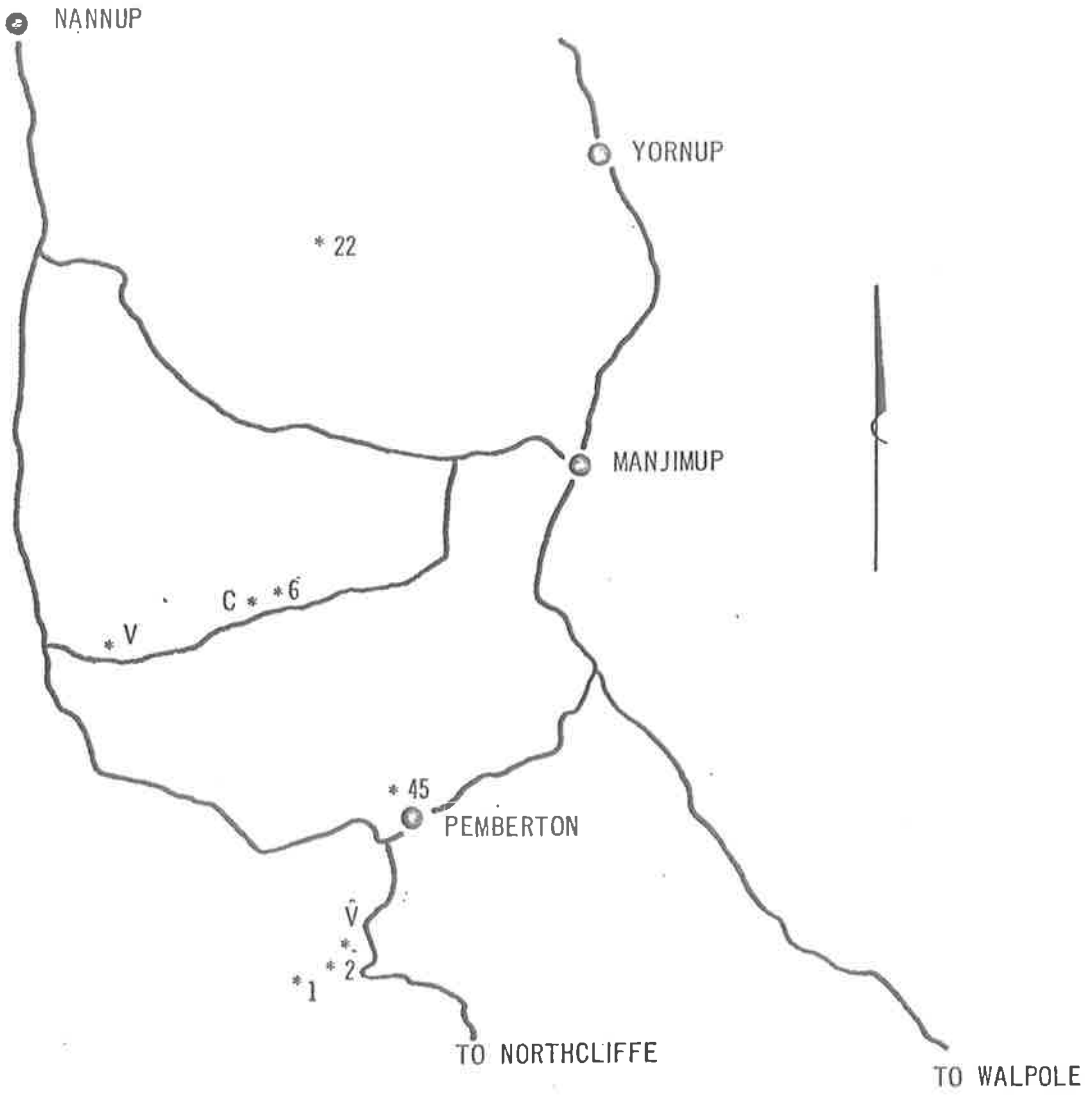
Four well spaced, mature trees are left standing on each hectare as a source of seed at felling. The felled area is left until the seed trees are bearing an adequate seed crop; this may be a period of up to four years. During this time the shrub layer may recover and grow vigorously. If it does it is flattened by bulldozer prior to the regeneration burn.

The regeneration burn is carried out in the autumn or spring of the year in which the seed trees are carrying ripe seed. The fire is intense, the heat opens the capsules and the seed falls onto the freshly burnt ground within a few days of burning. Germination takes place in April, May and June. The seed trees are cut and removed as soon as adequate regeneration is apparent, within two years of the burn.

1.5 Flora and Fauna

The karri forest is low in fauna species diversity compared with more open dry sclerophyll forest type of the South West. Sixty-six species of land birds have been recorded (compare 87 in the jarrah forest), and 11 species of native mammals excluding bats (19 in the jarrah forest). However, in terms of population levels, the karri forest is rich in numbers, particularly with regard to birds. A number of surveys done in both forest types have resulted in a mean number of bird sightings per kilometre of survey of 126 in karri forest and 46 in jarrah.

Fig. 2.1 EXPERIMENTAL AREAS



SCALE 1 : 500 000

10 0 10 20 30 Km

* LOCATION OF EXPERIMENTAL AREAS

V - VIRGIN FOREST
C - CUTOVER, NOT YET REGENERATED (SEED TREES REMAINING)
1 - ONE YEAR OLD REGENERATION
2 - TWO YEAR OLD REGENERATION
6 - SIX YEAR OLD REGENERATION
22 - TWENTY - TWO YEAR OLD REGENERATION
45 - FORTY FIVE YEAR OLD REGENERATION

2. STUDY AREAS

2.1 The study was contained in pure karri stands to the west and south-west of Manjimup, as shown in fig. 2.1. Areas were chosen to represent different stages in the development of the karri forest and ranged from cutover, unregenerated stands, through to virgin forest. All the experimental areas were governed by similar edaphic and climatic conditions, and most were dissected by a stream. Studies in the virgin and forty-five year old stand were duplicated to sample areas within and outside the prescribed burning programme to isolate the effect of a prescribed mild burn.

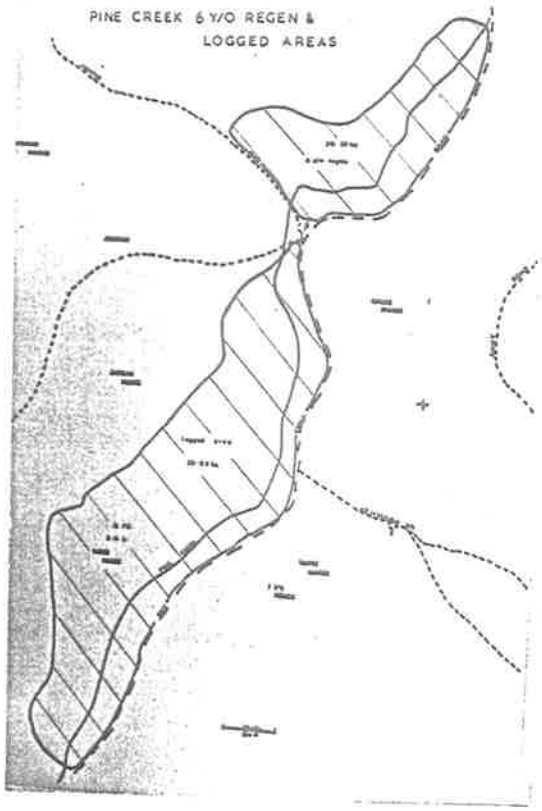
The size of each study area ranged from 6.9 to 190 hectares (fig. 2.2). The detailed location of study areas and the forest types adjoining them are shown in figure 2.3.

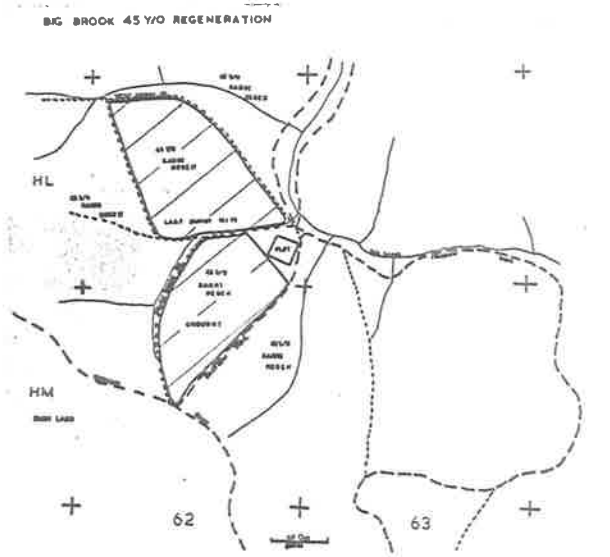
Figure 2.2

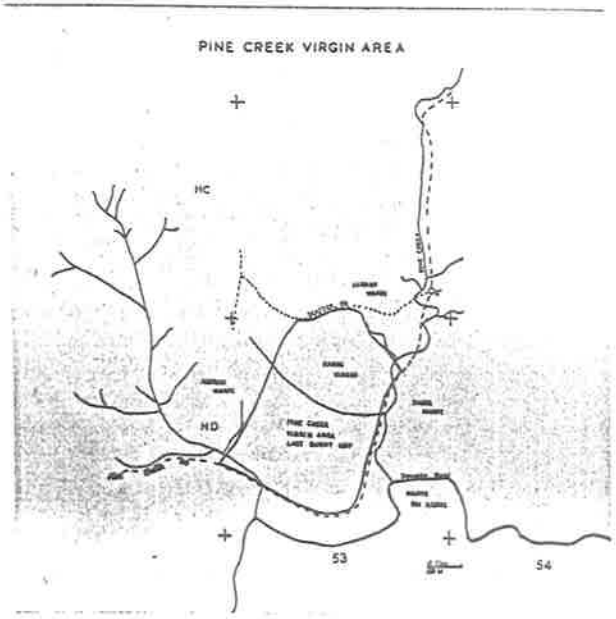
Summary of Study Areas

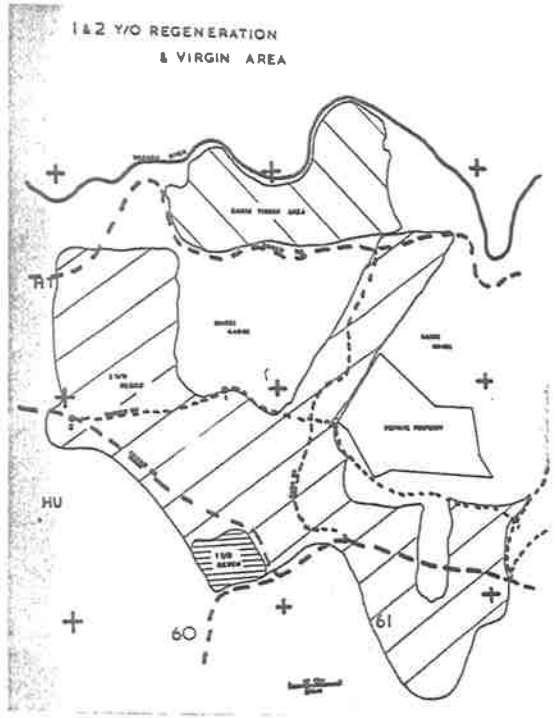
Site No.	Year logged or regenerated	Location (Forest Block)	Area (ha)	Date of last burn
1	Logged 1972	Beavis	53.1	1967
2	Regen. 1974	Warren	6.9	1974
3	Regen. 1972	Warren	190.0	1972
4	Regen. 1969	Beavis	20.8	1969
5A	Regen. 1930	Big Brook	20.6	1972
5B	Regen. 1930	Big Brook	56.8	1930
6A	Virgin	Strickland	50.5	1967
6B	Virgin	Warren	51.2	ca.1950

FIGURE 2·3 Study Areas









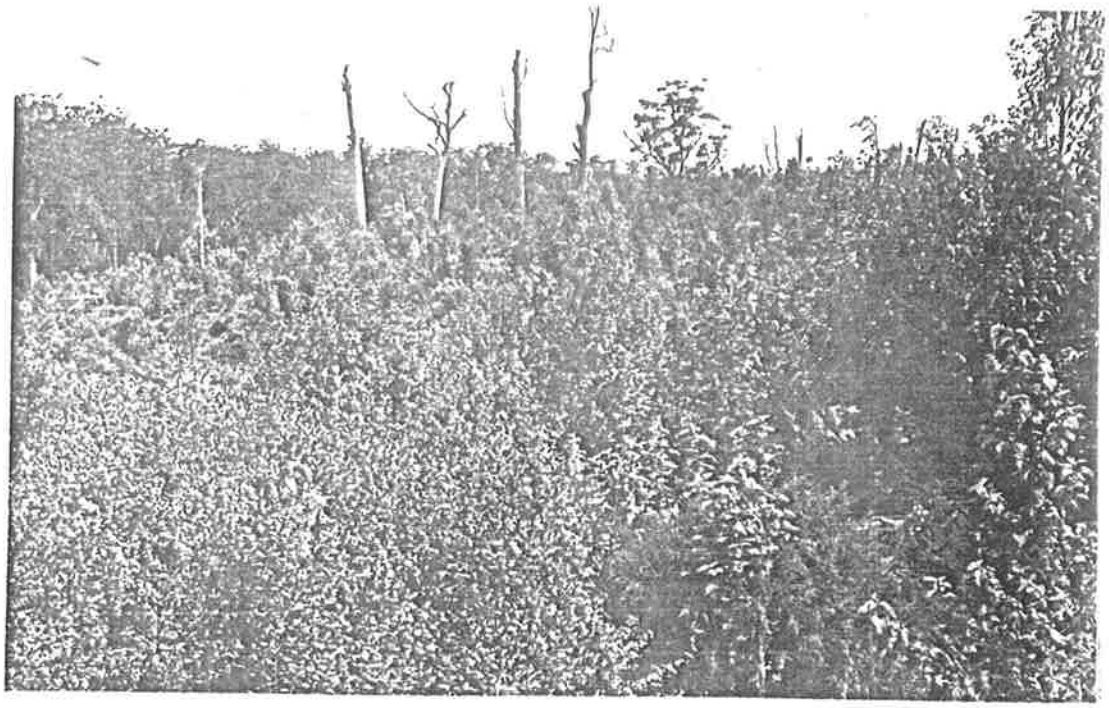
2.2 Site 1. Logged but not yet regenerated

Four seed trees per hectare had been left standing when the area was logged in 1972. Regeneration is scheduled to take place in Autumn 1976. The area was dissected by Pine Creek, a perennial stream. Heavy accumulations of logging debris were present on the ground.

2.3 Site 2. Regenerated in 1974 (one year old)

This was the smallest of all the study areas, 2.6 hectares in extent. The method of regeneration was not as normally practised in the karri forest. The area had been totally felled and the logging debris burnt in March 1974. The area was then seeded with karri by hand. Subsequent seedling counts showed the area to be fully stocked with karri.

2.4 Site 3. Regenerated in 1972 (3 years old)



This, the largest study area of 260 hectares, borders Site 2. Two seasonal streams dissect the area and the shrub vegetation bordering the streams was not burnt in the regeneration burn. All seed trees had been removed by 1974.

2.5 Site 4. Regenerated in 1969 (6 years old)

This area adjoins Site 1. It is 21 hectares in area and is dissected by the perennial Pine Creek. Vegetation bordering the creek was burnt as part of the regeneration burn.

2.6 Site 5. Regenerated in 1930 (45 years old)

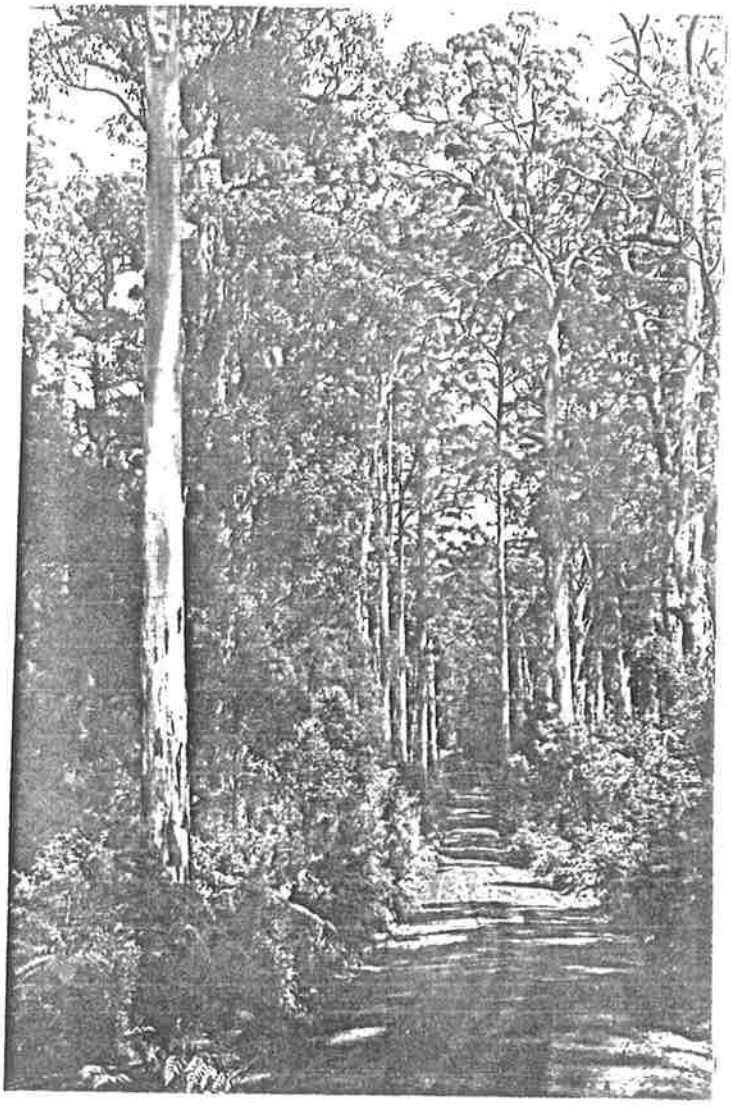
The site was divided into two parts and each formed a separate part of the study. Both sites formed part of an extensive block of forest of more than 1000 hectares which was regenerated in the same year.

2.6.1 Site 5A. An area subjected to prescribed burning and extending to 20.6 hectares. Only one prescribed hazard reduction burn had been made since the original regeneration burn, and that was in Spring 1973. The site

is bordered by House Brook, a perennial stream, and the vegetation bordering the brook was also burnt in 1973.

2.6.2 Site 5B. 57 hectares adjacent to the area described in section 2.5.1. The area had not been subjected to fire since the regeneration burn of 1930.

2.7 Site 6. Virgin forest



Two virgin areas were studied in separate locations.

2.7.1 Site 6A Virgin forest subjected to regular prescribed burning. The area was last burnt in 1967 so the shrub and ground vegetation were 7 to 8 years old. The site is located close to the Donnelly River and extends to 50.5 hectares.

2.7.2 Site 6B - is situated in the southern part of Warren National Park. The fire history of this area was unknown, but ring counts on understorey species suggested

that it had not experienced fire for at least 25 years.

The study area was dissected by a seasonally flowing stream.

2.8 An area of forest heavily cut on the selection system and regenerated 22 years ago was among the study areas. Although the majority of the area was 22 year old regeneration, it was decided to confine investigations in this area to the mammals, and to the gross vegetation structure only.

3. FLORA STUDIES

3.1 Method

Differences in the flora of different aged karri stands were assessed on the basis of gross structure and composition. Structure is particularly important as changes in fauna populations are likely to be associated with changes in the vegetation structure.

3.1.1 Structure

Data was collected in a form which allowed the construction of profile diagrams to demonstrate structure. A plot 100 metres x 20 metres was located in each experimental area crossing the contours. Within this plot tree measurements of top height, height to first branching, diameter at 1.3 metres and crown shape were taken and the positions of the trees were mapped as offsets from the hundred metre boundary.

Measurements of maximum shrub height were taken at 10 metre intervals along the one hundred metre boundary line. At each sample point three readings were taken at five metre spacing across the plot. The mean of these three readings was taken as maximum shrub height at that sample point.

3.1.2 Species presence

A list of all species present in each area was compiled during the course of the study period. At the end of this period a search was carried out in each area to complete and check the list.

3.1.3 Species dominance within the shrub layer

Dominance was measured as the percentage cover by

species in a metre square quadrat. Quadrats were located at ten metre intervals along four parallel lines, three hundred metres long and one hundred metres apart. These lines ran across the contour.

3.2 Results

3.2.1 Structure of the vegetation.

Profile diagrams for tree and shrub canopies in virgin, and 6, 22 and 45 year old forest are shown in figures 3.2 to 3.5

Reference to the diagram for 6 year old regeneration will show the general emergence of the crowns of the tree saplings above the shrub layer, although the live canopies of both strata form a continuous canopy. In the 22 year old stand (figure 3.4) separation has largely taken place between tree and live shrub canopies. The lower shrub layer at this stage consisted of mainly dead material. In both the virgin and 45 year old stands the live shrub layer extends to ground level because both stands had been burnt under prescription within the previous 7 years.

The number of trees per hectare (stocking) decreased rapidly with increasing age and height of the stand (figure 3.1). Mortality was high in the younger stands due to intense competition.

Figure 3.1 Stocking levels and heights of karri stands

Age of stand (years)	1	6	22	45	Virgin
Stems per hectare	44,870	13,170[1]	2,900	675	20
Upper canopy height (m)		7.5	16.4	36	60

Note 1 - measured outside the study areas.

FIGURE 3·2—3·5

VEGETATION STRUCTURE IN DIFFERENT AGED KARRI FOREST

SCALE : 1 c.m. = 7 metres

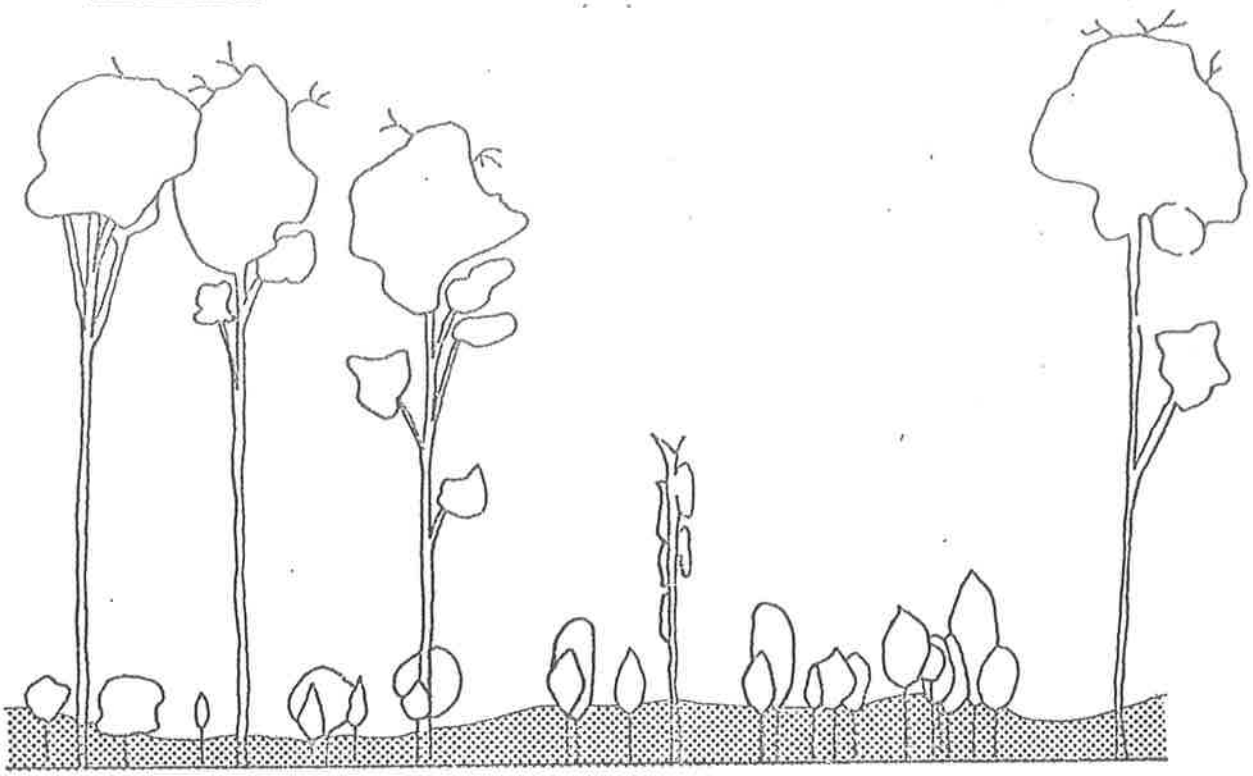
LEGEND

LIVE SHRUB LAYER (FOLIAGE)

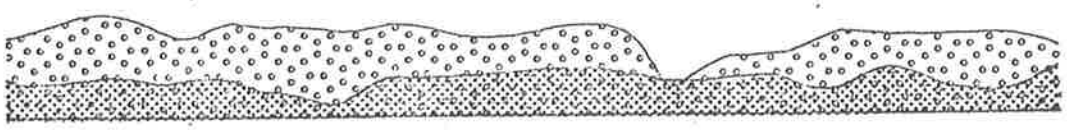
TREE REGENERATION (FOLIAGE)

VEGETATION STRUCTURE IN DIFFERENT AGED KARRI FOREST

·2 VIRGIN FOREST

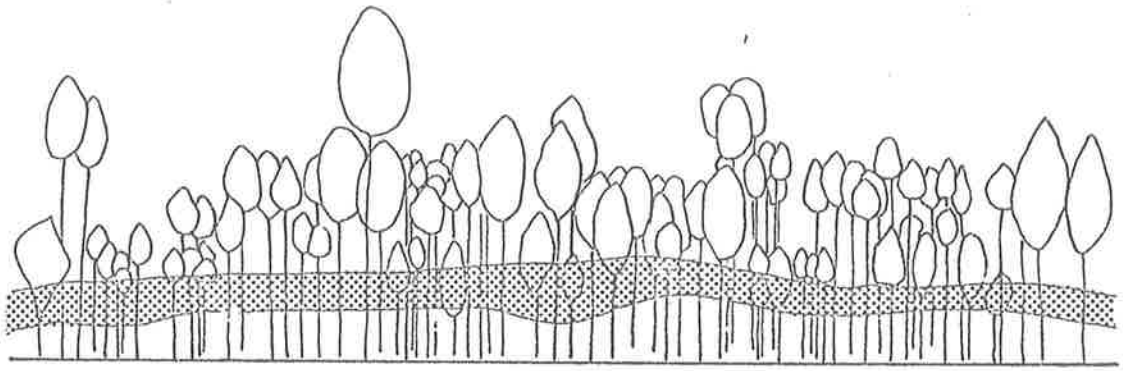


3·3 6 YEAR OLD

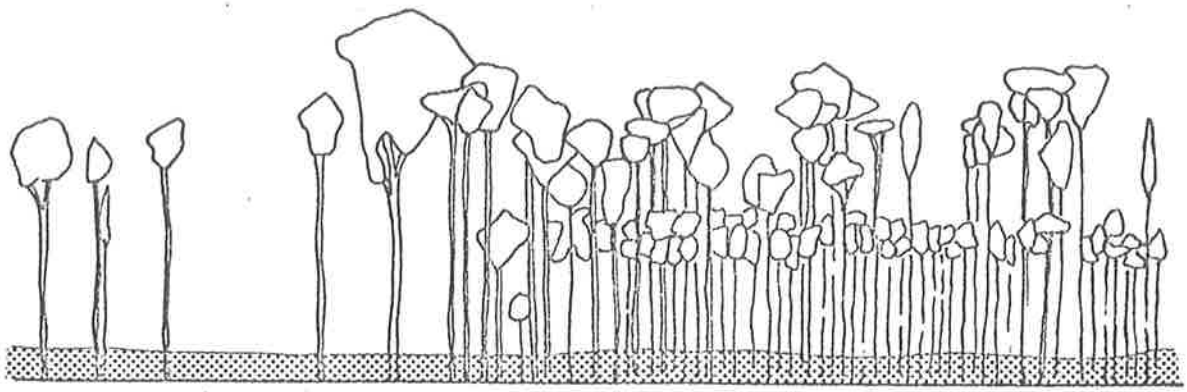


VEGETATION STRUCTURE IN DIFFERENT AGED KARRI FOREST

3·4 22 YEAR OLD



3·5 45 YEAR OLD



A true forest structure, with stratification of the shrub and tree canopies, was evident in the 22 year old stand and had probably developed earlier, but no stands of intermediate age were available to confirm this.

Although no measures of the density of the tree canopy were made as such, the profile diagrams illustrate a much denser tree canopy of the stand in the pole stage (22 and 45 years) than in virgin forest.

The ground cover is shown in figure 3.6

Figure 3.6 Percentage cover of the shrub layer

Regeneration stage	Ground cover present	Remarks
Logged, not burnt	27.8	
1 year old	34.5	
2 year old	91.7	
6 year old	51.0	
45 year old burnt	66.7	Burnt 2 years previously
45 " " unburnt	40.6	
Virgin burnt	34.9	Burnt 7 years previously
Virgin unburnt	60.5	

The logged area had been cut 2 years prior to the study and some recovery of the ground vegetation had taken place. Hence the figure of 27.8 percent ground cover is not necessarily representative of the site immediately after logging.

Recovery following the regeneration burn was apparently rapid and the vegetation cover peaked at 91 percent after two years. The decline in cover percent in older stands can be accounted for by two factors. Firstly competition from the tree stratum would influence the shrub layer.

Secondly, and applying particularly to the long unburnt, older stands, the live canopy exceeded the height of measurement and had started to form an understorey.

3.2.2 Composition of the vegetation

3.2.2.1 All species

The number of plant species increased markedly after felling and within 2 years of the regeneration burn (figure 3.7) 50 species were found in the logged area prior to burning, 60 in one year old regeneration, and 60 in the two year old. Part of this increase was attributable to the appearance of exotic species.

In 6 year old regeneration the number of plant species declined to 44 but rose to 53 in the recently burnt (2 years previously) forty-five year old stand. A decline in numbers was found in the forty-five year old and virgin stands which had not been burned for many years.

These results are echoed in the diversity index which takes into account both species number and cover (Shannon and Weaver 1949, Pielou 1966). The diversity index is highest in the one and two year old regeneration and lowest in the forty-five year old unburnt.

Figure 3.7 Characteristics of the shrub species in karri forest at various stages of regeneration

Age of regeneration (years)	Logged not burnt	1	2	6	45 (a)	45 (b)	Virgin (a)	Virgin (b)
Number of species	50	60	60	44	19	53	34	46
Diversity index	2.7	3.7	3.4	2.6	2.2	2.5	2.7	2.4

Note (a) Not burnt for 25 to 45 years
(b) Burnt 2 years prior to study
(c) Burnt 7 years prior to the study

Figure 3.8 Shrub species recorded in karri forest of various ages

((1) - denotes exotic species)

Forest Age / Species	Logged	1	2	6	45 burnt	45 unburnt	Virgin burnt	Virgin unburnt
CASUARINACEAE								
Casuarina decussata	*	*	*	*	*	*	*	*
COMPOSITAE								
(1) Erigeron bonariensis	*	*	*					
Gnaphalium sp.		*						
Helichrysum ramosum		*	*				*	
Hypocheris radiata			*					
Senecio ramosissimus	*	*	*		*		*	*
CYCADACEAE								
Macrozamia reidlei	*	*	*	*	*	*	*	*
CYPERACEAE								
Lepidosperma augustatum	*	*	*	*	*	*	*	*
Lepidosperma effusum	*	*	*	*	*		*	*
Lepidosperma leptostachyum	*	*	*	*	*	*	*	*
Lepidosperma tetraquestrum	*		*	*	*		*	*
DILLENIACEAE								
Hibbertia amplexicaulis		*	*		*			
Hibbertia cuneiformis	*	*	*		*	*		*
Hibbertia inconspicua	*				*		*	
Hibbertia montana	*	*	*		*		*	*
DROSERACEAE								
Drosera pallida					*			*
EPACRIDACEAE								
Andersonia caerulea				*				
Leucopogon concinnus	*							
Leucopogon propinquus			*					*
Leucopogon revolutus	*	*	*	*	*	*	*	
Leucopogon verticillatus			*	*				
Leucopogon sp.		*			*			
EUPHORBIACEAE								
Ricinocarpus glaucus	*			*				
GENTIANACEAE								
Centaurium minus		*	*	*	*			
Villarsia sp.	*							

Species \ Forest Age	Logged	1	2	6	45 burnt	45 unburnt	Virgin burnt	Virgin unburnt
GERANIACEAE								
Pelargonium sp.		*						
GOODENIACEAE								
Dampiera sp.		*		*	*		*	
Scaevola sp.	*	*	*	*	*		*	*
GRAMINEAE								
Grasses	*	*	*	*	*	*	*	*
HALORRHAGACEAE								
Halorrhagis rotundifolia	*	*	*	*	*			
IRIDACEAE								
Orthrosanthus laxus		*	*		*		*	
Patersonia occidentalis	*	*	*	*	*		*	
Patersonia xanthina	*							
JUNACEAE								
Juncus sp.	*							
LEGUMINOSAE								
Acacia cyanophylla					*			
Acacia decipiens	*	*	*	*	*		*	
Acacia hastulata	*		*					
Acacia pulchella	*	*	*		*		*	*
Acacia myrtifolia		*						
Acacia scapelliformis			*					
Acacia strigosa	*		*	*			*	
Acacia urophylla		*	*	*	*		*	*
Albizzia distachya		*	*		*		*	
Bossiaea laidlawiana	*			*	*	*	*	
Bossiaea linophylla			*					
Chorizema ilicifolium		*	*				*	*
Hardenbergia comptoniana	*	*	*			*	*	
Hovea elliptica		*	*		*		*	*
Kennedya coccinea		*	*	*	*		*	
Oxylobium lanceolatum	*	*	*		*		*	*
(1) Trifolium subterraneum		*	*					
Viminaria denudata			*					
LILIACEAE								
Liliaceae sp.	*	*						
Lomandra sp.			*					
Thysanotus sp.				*				
Xanthorrhoea nana		*						
LOGONIACEAE								
Logania serpyllifolia		*	*	*	*	*		*
Logania vaginalis		*	*				*	

Species \ Forest age	Logged	1	2	6	45 burnt	45 unburnt	Virgin burnt	Virgin unburnt
MYRTACEAE								
Agonis flexuosa	*		*	*			*	*
Agonis linearifolia	*			*	*			
Agonis parviceps	*			*	*			*
Astartea fasicularis			*					
Eucalyptus calophylla	*				*		*	
Eucalyptus diversicolor	*	*	*	*	*		*	*
ORCHIDACEAE								
Corybas dilatatus						*		*
OXALIDACEAE								
(1) Oxalis corniculata		*	*				*	
PITTOSPORACEAE								
Billardiera floribunda					*		*	*
Marianthus sp.		*						
PLANTAGINACEAE								
(1) Plantago lanceolata		*						
PODOCARPACEAE								
Podocarpus drouyniana			*	*				
POLYPODIACEAE								
Pteridium esculentum	*	*	*	*	*	*	*	*
PROTEACEAE								
Banksia grandis		*	*				*	
Persoonia longifolia	*		*	*	*		*	
RANUNCULACEAE								
Clematis aristata	*	*	*	*	*	*	*	*
Ranunculus lappaceus		*			*		*	*
RHAMNACEAE								
Trymalium spathulatum	*	*	*	*	*	*	*	*
ROSACEAE								
(1) Rubus fruticosus		*	*					
RUBIACEAE								
Opercularis hispidula	*	*	*	*	*	*	*	*
RUTACEAE								
Boronia fastigata	*			*				
Chorilaena quercifolia	*	*	*	*	*	*	*	*

Species \ Forest Age	Logged	1	2	6	45 burnt	45 unburnt	Virgin burnt	Virgin unburnt
RUTACEAE cntnd								
Crowea dentata	*	*	*	*	*			
Hypocalyma cordifolium	*			*				
SAPINDACEAE								
Dodonaea caespitosa				*	*			
SOLANACEAE								
(i) Physalis peruviana		*						
(i) Solanum nigrum		*	*					
STACKHOUSIACEAE								
Stackhousiaceae					*			
STERCULIACEAE								
Lasiopetalum floribundum	*	*	*	*	*	*	*	*
Thomasia pauciflora		*		*	*			*
Thomasia quercifolia	*		*	*	*			
STYLIDIACEAE								
Stylidium sp.	*	*	*	*	*		*	*
TREMANDRACEAE								
Tremandra stelligra	*	*	*	*	*	*	*	*
THYMELAEACEAE								
Pimelia elevata	*	*	*		*		*	
UMBELLIFERAE								
Daucus glochidiatus		*						
Xanthosia huegelii	*							
VIOLACEAE								
Hybanthus floribunda	*	*		*	*	*	*	*
Number of Species	50	60	60	44	53	19	46	34
Number of Families	28	34	26	26	29	17	25	22
Years since last fire	8	1	2	6	2	45	8	ca25

The trend in the number of plant species appeared to follow more closely the fire history of the area than the stage of regeneration of the karri stand. That is, the greater the period since the last fire, the fewer the plant species that were found.

Reference to figure 3.8 shows that all species present in the virgin forest were also found in one or more of the regenerated areas.

3.2.2.2. Exotic species

Exotic species were evident in the early stages of the succession following the regeneration burn, but were not found in the 6 year old and 45 year old regeneration (figure 3.9)

Figure 3.9 Characteristics of exotic plant species in karri forest in various stages of regeneration

Age of regeneration (years)	Logged, not burnt	1	2	6	45 (a)	45 (b)	Virgin (a)	Virgin (c)
Number of species	1	7	5	0	0	0	1	1
Percentage of total plant cover	0.72	4.00	0.88	0	0	0	0.14	0.43

Exotic species were largely confined to disturbed and compacted areas such as roadsides, tracks, and log landings. Their contribution to the total plant cover was generally small except when their population levels peaked one year after the regeneration burn. At this stage they contributed 4 percent of the cover.

Some exotics, such as Oxalis cornuta were found along road verges throughout the forest and were recorded in one of the virgin karri stands studied. The occasional indigenous species was found to have been carried to an 'off-site'

location during forest operations. Thus Andersonia caerula normally confined to jarrah forest, was recorded on a roadside sand dump in the six year old karri regeneration.

3.2.3 Dominance

Plant species have been grouped by life-forms and regeneration mechanism in order to promote clarity in describing the changes in dominance that were found to take place. The plants contributing to each group are listed in Appendix 1 and their characteristics are summarised below.

a) Annuals and biennials - live from one to two years. Are killed by fire and regenerate either from seed stored in the ground or by windblown seed.

b) Long-lived soft herbs - small plants which do not develop into a woody form but live considerably more than two years. Most are not killed by fire but regenerate from some form of bulb or root structure (e.g. Drosera spp. and orchids)

c) Fire weeds - woody plants whose degree of develo-ment depends on the age to which a particular species lives. Acacia pulchella with a life-span of 8 to 10 years reaches 2 metres in height, while Trymalium spathulatum, a species living 40 years or more, will develop into a small tree exceeding 10 metres in height.

The majority of species in this group are legumes, and produce seed prolifically. The seed is hard coated and survives in the soil for long periods. It requires heat to promote germination, hence strong germination generally follows fire. The group has been sub-divided into short, medium, and long lived species.

All fireweeds are killed by fire.

d) Rootstock species - All are long-lived and none are killed by fire. Shoots burnt off during a fire are regenerated from a woody rootstock (e.g. Hibbertia spp.) a rhizome (e.g. bracken and Dryandra nivea) or a subterranean meristem (e.g. many monocotyledons) Most rootstock species grow to one metre or less in height. A few develop into large bushes up to 5 metres high in the absence of fire (e.g. Podocarpus drouyniana)

e) Tree seedlings

The changes in dominance are recorded in figure 3.10 as the percentage contribution of life form groups to the total vegetation cover. Absolute values for cover are shown in figure 3.11

a) Annuals and biennials.

This group achieved a high level of dominance 1 year after the regeneration burn. (20 percent of the vegetation cover). Its contribution to the vegetation cover had declined to 8.5 percent in 2 year old regeneration. In 7 year old regeneration the level of dominance had declined to that of older stands. In older forests the contribution was particularly low in the absence of burning, but was higher in both the 45 year old and virgin stands which had been subjected to prescribed burning a few years prior to the study. The highest contribution in the older forests was 3.4 percent of the cover in the burnt virgin stand.

b) Long-lived herbs

Long-lived herbs followed a similar pattern of change to annuals and biennials. However, they contributed considerably more to the vegetation cover in all the study areas. The highest level of contribution was

ure 3.10 Dominance in the shrub layer of Karri forest in various stages of regeneration

(Dominance is expressed as the percentage contribution to the total plant cover area)

of regeneration s) Life-form	Logged not burnt	1	2	6	45 (a)	45 (b)	Virgin (c)	Virgin (d)
uals and biennials	1.4	20.0	8.5	0.9	0	1.1	1.8	3.4
g-lived herbs	6.3	19.6	15.2	7.4	5.1	14.6	4.0	13.4
rt-lived fireweeds	0.1	0.5	17.9	4.4	0	4.5	0.1	20.7
lium-lived fireweeds	10.0	0	1.4	34.8	9.3	26.6	4.0	0.3
g-lived fireweeds	19.8	0.8	4.7	15.0	27.1(d)	14.6	18.6	16.4
tstock species	56.6	56.1	28.0	31.5	57.2	36.4	70.9	43.5
e seedlings	5.8	3.0	24.3	6.0	1.3	2.2	0.6	2.3

Notes (a) Not burnt for 45 years
(b) Burnt 2 years prior to the study
(c) Not burnt for ca. 25 years
(d) Burnt 8 years prior to the study

Figure 3·11

Shrub Cover Percent (0–2 meters) by Life-forms in Karri Forest at Various Stages of Regeneration

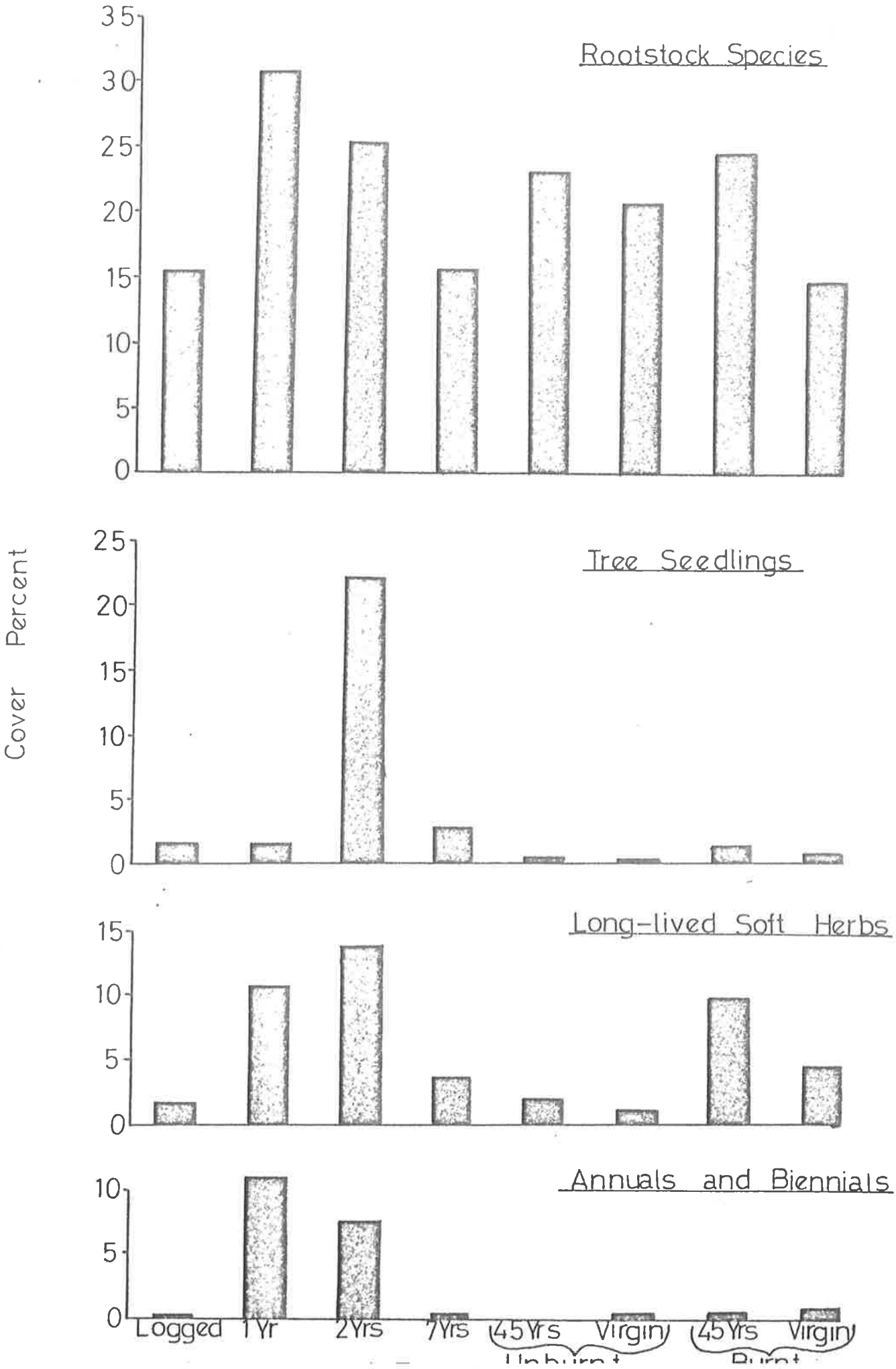
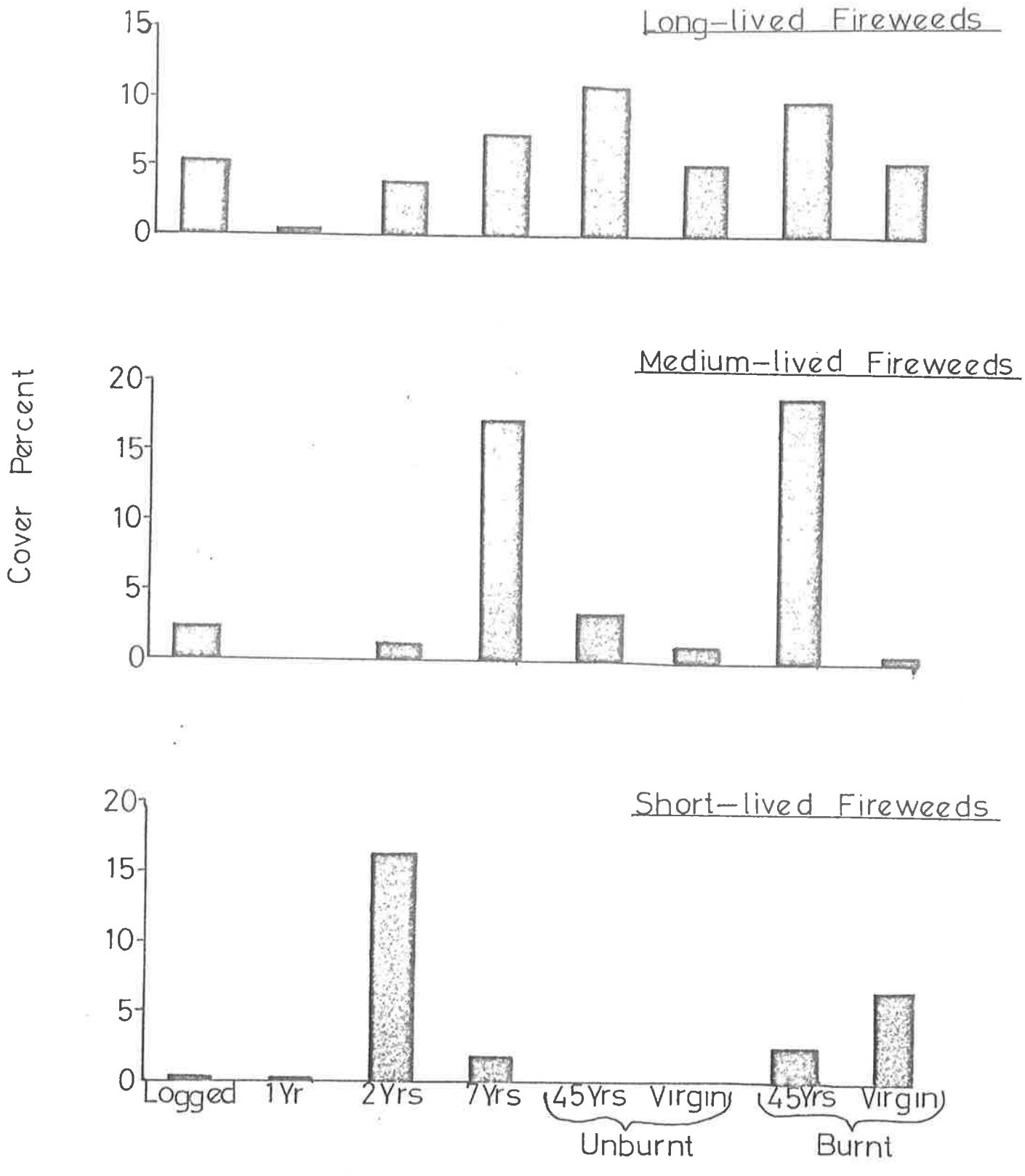


Figure 3·11 continued



again reached one year after the regeneration burn at 19.6 percent, and the lowest in long unburnt virgin forest at 4.0 percent.

c) Fireweeds

All three groups of fireweeds contributed to the vegetation cover to a large degree at all stages of development in the forest stand with the exception of 1 year old regeneration. The period of peak contribution varied with age in the younger, developing stands where short-lived fireweeds reached a maximum contribution of 17.9 percent of the vegetation cover in 2 year old regeneration. Medium-lived members of the group peaked in the 7 year old regeneration at 34.8 percent, and the long-lived fireweeds reached their maximum contribution in the unburnt 45 year old stand at 27.1 percent.

The figures for fireweeds in those stands where fire had been excluded for long periods are artificially low (figure 3.10) due to plants frequently having exceeded the 2 metre height limit of assessment. In long unburnt stands fireweeds form a dense, continuous low understorey canopy (see figure 3.4) below which the fireweed foliage is mostly dead.

Within the 45 year old and virgin stands the contribution of fireweeds as a group was related to the time that had elapsed since the last prescribed burn.

d) Rootstock species

This group tended to dominate the vegetation cover below 2 metres at all stages except within 2 to 7 years of a fire (either a regeneration burn or a fuel hazard reduction burn). Species within this group are

persistent and the maintained a high dominance level following logging and for one year after the regeneration burn. Their decline between 2 and 7 years coincided with the ascendancy of fireweeds. The re-assertion of dominance by rootstock species in the lower shrub layers (up to 2 metres) in the later stages of stand development was due to the fireweed canopy rising to above 2 metres with increasing age. The maximum development of rootstock species was found in long unburnt 45 year old and virgin stands where their contribution to cover below 2 metres was 57.2 and 70.9 percent respectively. The long lived fireweeds at this stage had reached the dimensions of small trees.

e) Tree seedlings

The contribution of tree seedlings to the shrub cover peaked in the two year old regeneration area. By seven years the majority of seedlings had developed a low canopy above the level of measurement and the 6.0 percent contribution in the 7 year old stand represented suppressed and dying individuals.

The low contribution of tree seedlings in the 45 year old and virgin stands characterizes the inability of karri to regenerate to any degree beneath a forest and shrub canopy. Slight increases in the dominance of karri seedlings were evident in those older stands that had been burnt within the past 2 to 7 years.

3.3 Discussion.

3.3.1 General

The forest system is in a dynamic state where growth senescence, death, and regeneration are continually taking place. Forest management merely systematises this chain

of events, and timber harvesting truncates the process by removing mature trees before senescence begins to set in. The changes in vegetation structure and composition associated with the life processes have been observed in the past and are predictable. The present study has served to record these changes on a quantitative basis.

Forest regeneration by clear felling is undoubtedly traumatic to the ecosystem. However the relationship between successful regeneration of karri and fire, and the inability of karri seedlings to establish within the undisturbed ecosystem leaves open the possibility of catastrophic fire as the natural agent of karri regeneration. In this respect the present system of clear felling, intense regeneration burn and uniform regeneration probably simulates the natural regeneration processes of past centuries. Further evidence for this hypothesis can be found from the present study where the recovery and vegetation succession following clear felling and regeneration parallels that following prescribed burning in the forest (see Christensen and Kimber, 1975).

3.3.2 Structure

The structure of the karri forest is made up of two basic strata, the upper stratum, or tree canopy and the lower stratum or shrub vegetation.

It is necessary to examine the development of the two strata separately as the factors which influence the characteristics of each strata are quite different.

Until the stand reaches fifteen years old the influences on both the canopy and shrub vegetation are similar. After this the stand is subjected to mild prescribed burns which remove the shrub vegetation and litter layers but have

little effect on the canopy. Thus after the age of fifteen the characteristics of the canopy strata are determined by the amount and type of trees regenerated, the age of the stand, the site and climatic factors, whilst the characteristics of the shrub vegetation are dependent largely on time since the last fire

In the first six years following regeneration both tree saplings and shrub form a single canopy. After about six years the tree sapling crowns begin to emerge above the shrubs, and separation of tree and shrub canopies is completed by 22 years or earlier. By age 45 the tree canopy is separated from the shrub canopy by an interval of around 20 metres in height.

The recovery of a shrub canopy following the regeneration burn is rapid, and is complete in the second year. Thereafter the depth of the shrub canopy increases with increasing height of the shrubs. A single canopy stratum then remains until the tree saplings emerge above the shrubs.

3.3.3 Species composition.

All the species found in the virgin areas were also found in one or more of the regenerated areas. This would imply that no species was lost in the logging and regeneration processes.

The appearance of exotic species in young regeneration appeared to be a transitory phenomenon. The numbers dwindled rapidly once a canopy of indigenous shrubs had developed, when they became largely restricted to sites where soil compaction was greatest on roads and log landings.

3.3.4 Dominance

The pattern and succession of dominance by the various life-form groups was found to be so nearly identical with

that following prescribed burning in uncut forest that logging and regeneration could not have significantly affected this parameter.

APPENDIX I

Shrub species classified by life-form and regeneration mechanism

A. ANNUALS AND BIANNUALS

Erigeron bonariensis
Compositae
Helichrysum sp.
Hybanthus floribundus
Ranunculaceae sp.
Stylidium sp.

B. LONG LIVED HERBS

Corybas dilatatus
Drosera pallida
Grasses
Halorrhagis rotundifolia
Logania serpyllifolia
Orchidaceae
Scaevola sp.
Xanthosia huegelii

C. SHORT LIVED FIREWEEDS

Acacia decipiens
Acacia myrtifolia
Acacia pulchella
Acacia scapelliformis
Acacia strigosa
Acacia urophylla
Kennedya coccinea

D. MEDIUM LIVED FIREWEEDS

Agonis parviceps
Boronia fastigiata
Bossiaea laidlawiana
Crowea dentata
Dodonaea caespitosa
Ricinocarpus glaucus
Thomasia pauciflora
Thomasia quercifolia

E. LONG LIVED FIREWEEDS

Albizzia distachya
Chorilaena quercifolia
Oxylobium lanceolatum
Trymalium spathulatum

F. LONG LIVED LIGNOTUBEROUS

Agonis flexuosa
A. parviceps
Billardiera floribunda
Chorizema ilicifolium
Clematis aristata
Dampiera sp.
Hardenbergia comptoniana
Hibbertia amplexicaulis
Hibbertia cuneiformis
Hibbertia inconspicua
Hibbertia montana
Hovea elliptica
Hypocalymma cordifolium
Lepidosperma angustatum
Lepidosperma leptostachyum
Lepidosperma tetraquetrum
Leucopogon propinquus
Leucopogon revolutus
Leucopogon verticillatus
Lilium
Macrozamia reidlei
Opercularia hispidula
Oxalis sp.
Patersonia xanthina
Pimelea clavata
Podocarpus drouyniana
Pteridium esculentum
Tremandra stelligera
Xanthorrhoea nana

4. MAMMALS

Mammal studies were based on a survey technique which allowed comparison between the species present in the various study areas.

4.1 Methods

Four techniques were used to locate animals. Two of them, trapping and counting faecal scats, allowed some estimates of relative population densities to be made. Observation and searching, including using spotlights at night, gave information on the presence of a particular species in an area.

4.1.1 Trapping

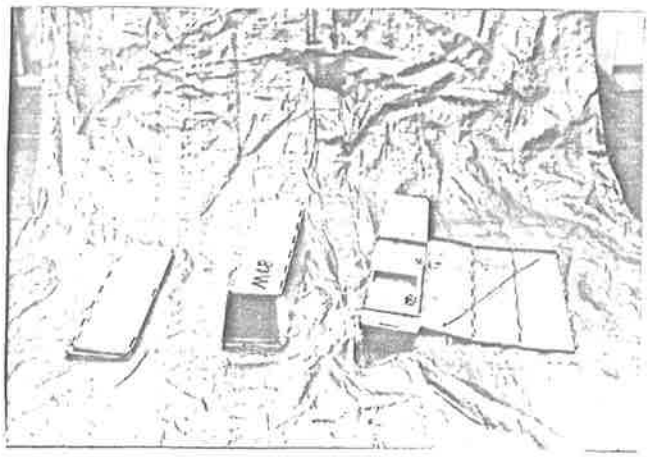
Traps suitable for catching small mammals were used in all the study areas. They were laid on an L-shaped transect one arm of which was close to a stream, and the other run up a slope away from the stream. Three types of trap were used. Breakback rat traps provided the majority supplemented by Elliot and possum traps. Elliot traps are small collapsible aluminium traps with spring loaded doors and are suitable for animals up to the size of a rat. Possum traps are wire cages with a spring loaded door and are suitable for catching animals up to the size of a quokka. Both trap types are illustrated in fig. 4.1. The distribution of traps and the trapping effort in each area are listed in fig. 4.2.

Each animal trapped was identified and sexed. Those caught in Elliot and possum traps were set free.

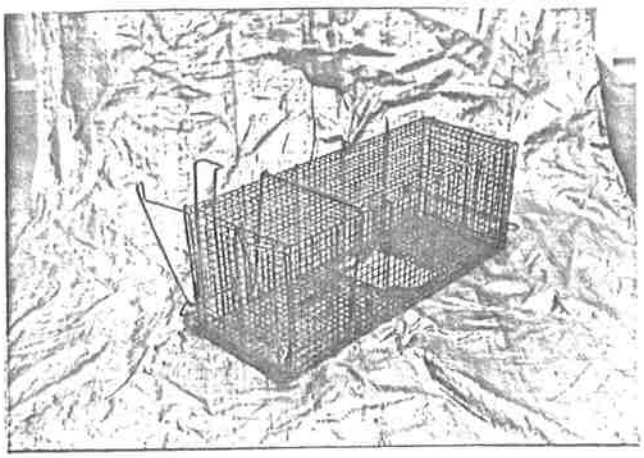
4.1.2 Scat counts and analysis

Scat counts of the grey kangaroo (Macropus fuliginosus), fox (Vulpes vulpes), and rabbit (Oryctolagus cuniculus) were

Figure 4.1 Trap types



Elliot Trap



Possum Trap

Figure 4.2 Trapping effort in the study areas

Trap type / udy area		Number of trap nights					
		Hill			Creek		
		Breakback	Possum	Elliot	Breakback	Poesum	Elliot
rgin	Burnt	96	12	24	168	28	56
	Unburnt	144	0	48	168	0	56
year d	Burnt	168	0	52	168	0	52
	Unburnt	156	0	52			
year d		144	24	48	168	24	56
year d		144	24	48	168	28	56
year d		168	0	9	196	0	49
year d		156	0	52	0	0	0
gged Area		126	15	42	144	24	48

A 'trapnight' is one trap set for one night

Figure 4.3 . Mammal species recorded in different ages of karri forest

Species \ Study Area	Logged	1 year	2 years	6 years	22 years	45 years (burnt)	45 years (unburnt)	Virgin (burnt)	Virgin (unburnt)
(1) House mouse (Mus musculus)		*	*			*			
Bush rat (Rattus fuscipes)	*	*	*	*	*	*	*	*	*
(1) Ship rat (Rattus rattus)				*		*		*	
Mardo (Antechinus flavipes)	*			*		*	*	*	*
Water rat (Hydromys chrysogaster)			*						
Wambenger (Phascogale tapoatafa)					*				
Pygmy possum (Cercartetus concinnus)						*			
Quokka (Setonix brachyurus)			*						
Grey Kangaroo (Macropus fuliginosus)	*	*	*	*	*	*	*	*	*
(1) Rabbit (Oryctolagus cuniculus)	*		*	*	*				
(1) Fox (Vulpes vulpes)	*	*	*	*				*	*
Number of species	5	4	7	6	4	6	3	5	4

(1) - non native species

carried out in some of the study areas. The counts were made on traverses following old tracks within the areas. Both kangaroo and rabbit scats occurred as groups of pellets. They were counted by groups for the rabbit, and by individual pellets for the kangaroo.

Fox scats were analysed in the laboratory for the identification of hair and bones so that the diet of the foxes could be assessed.

4.1.3 Spotlight surveys

Spotlighting runs were made in all study areas except the one year old regeneration. Two spotlights were used from a vehicle travelling at 10 kph. Sightings of animals were mapped.

4.1.4 Observation and searching.

Animal sightings which resulted from casual observation and from deliberate searching were recorded.

4.2 Results

Eleven species of mammals were located by all methods within the study areas. The records for each of the areas are shown in fig. 4.3

The technique of spotlighting proved very unproductive in this study probably due to the dense lower vegetation in nearly all the study areas. However, it did provide some negative result in demonstrating the scarcity of the ring-tailed possum (Pseudocheirus peregrinus) and the brush-tailed possum (Trichosurus vulpecula) in the Karri forest. Where two species are frequent they are very easily detected by spotlight. Two hours of spotlighting failed to reveal an individual of either species.

Figure 4.4 Trapping results from different ages of karri forest (Trapped from 6 to 24th May 1974)

Forest Age (years)	Last fire (yrs)	Trap Nights	Catch rate percent (1)					
			Rattus fuscipes	*Antechinus flavipes*	*Mus musculus*	*Rattus rattus*	*Phascogale*	All species
Virgin	7	384	9.9	0.2	0	0.2	0	10.3
Virgin	ca 25	416	4.3	1.2	0	0.2	0	5.7
45	2	440	3.6	0.5	0.2	0.5	0	4.8
45	45	208	1.4	8.6	0	0	0	10.0
22	22	464	4.2	0.4	0	0	0.5	5.1
6	6	468	6.0	0.2	0	0.4	0	6.8
2	2	422	6.9	0	0.5	0	0	7.4
1	1	208	2.4	0	9.6	0	0	12.0
Logged	13	399	5.2	2.3	0	0	0	7.5

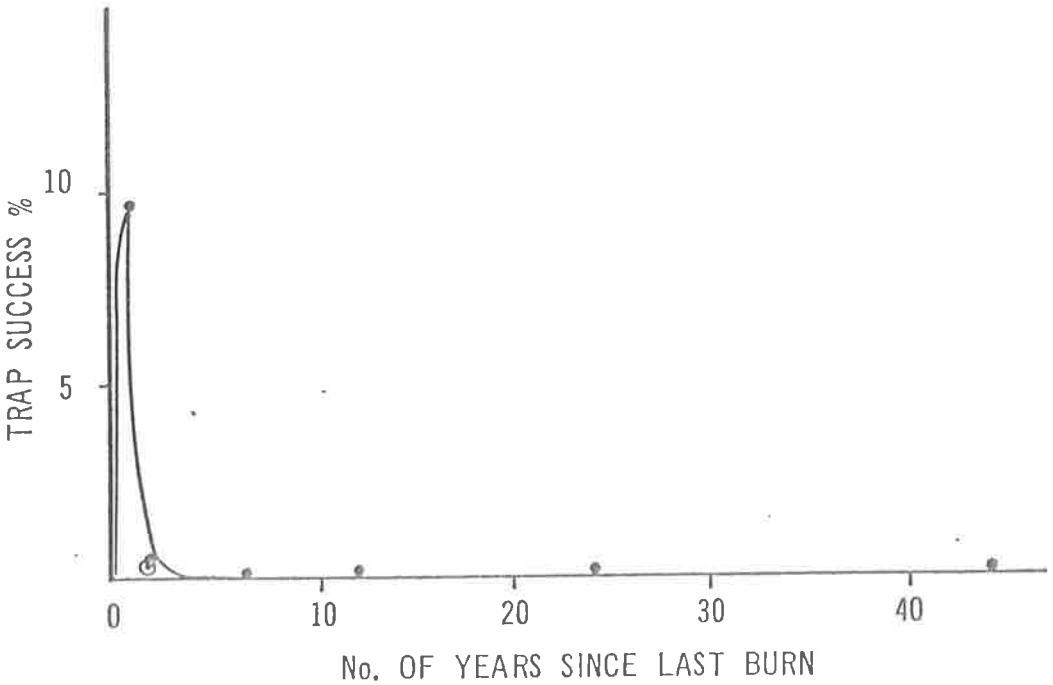


Fig. 4·5 TRAP SUCCESS OF MUS MUSCULUS RELATED TO FIRE HISTORY

Mammal data collected from trapping suggested that animal numbers (using the catch rate percent as an index of numbers) were more closely related to the period since the last fire than they were to the age of the forest (fig. 4.4). The relative abundance of the various mammal species were likewise apparently related primarily to the fire history of the area and followed a distinct successional pattern. This phenomenon will be described further under individual species headings.

4.2.1 House mouse (*Mus musculus*)

The house mouse appeared as a colonising species shortly after fire. It was present in an area three to four months after a regeneration burn but population levels dropped fairly soon after the return of thick vegetation cover and this species was not captured in the two year old regeneration. It appeared again in the forty-five year old stand two years after a prescribed mild burn. Fig. 4.5 shows the relationship between the house mouse and the burning history for an area.

These results closely followed that of Christensen and Kimber (1975) in the karri, and Newsome et al (1975) in the forests of south eastern Australia.

4.2.2 Southern Bush Rat (*Rattus fuscipes*)

This species is confined to areas of dense ground vegetation, south of a line joining Bunbury and Katanning. It is commonly found in the karri forest and was represented in all study areas.

Trapping results (see Fig. 4.6) show that the bush rat was present in the one year old area four months after burning, but the population was restricted to a band of

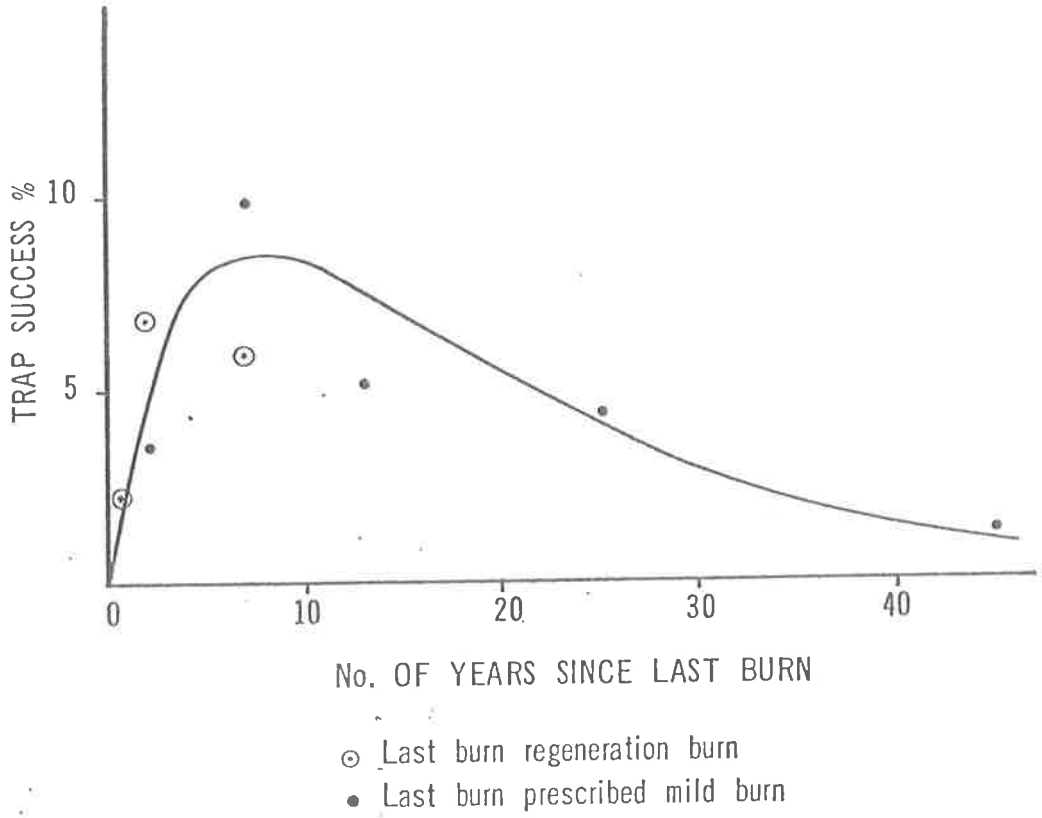


Fig. 4·6 TRAP SUCCESS OF RATTUS FUSCIPES RELATED TO FIRE HISTORY

undisturbed vegetation twenty metres wide and bordering a stream. No bush rats were caught within the burnt area.

In the two year old regeneration trap success was at 6.9 percent and by the seventh year after a prescribed burn the population appears at a maximum (trap success 9.9 percent).

As the dense shrub layer attains a height of fifteen to twenty feet, light is prevented from reaching the forest floor and ground cover becomes sparse. In these areas there was a resultant drop in captures. Trap success in the twenty year old unburnt, the forty year old unburnt and the virgin unburnt were all very low if compared to that of the more recently burnt areas (fig. 4.6)

Because very few bushrats survive more than one season in the wild, the maintenance of a local population is dependent on the recruitment of young. This in turn is dependent on the sex ratios of the resident population.

Previous studies (Christensen and Kimber, 1975) have shown that recolonization following fire was initiated by transient males. As the population stabilised the proportion of females in the population grew until they eventually outnumbered males.

Results from this study (figure 4.7) show a preponderance of females as early as 2 years after the regeneration burn and suggest a very early stabilisation of the population.

Figure 4.7 Population characteristics of the bush rat in karri forest of various ages

Forest age	Last fire (years)	Sex ratio F : M	Number captured	Mean Wt (gm) F	Mean Wt (gm) M
Logged	13	1.9 : 1	26	65.0	85.0
2	2	1.1 : 1	21	87.0	93.5
7	7	1.2 : 1	28	94.5	111.0
22	22	3.5 : 1	9	84.0	82.0
45 (burnt)	2	1.7 : 1	16	87.0	86.0
45 (unburnt)	45	3 : 0	3	85.5	-
Virgin (burnt)	7	1.5 : 1	38	93.5	96.0
" (unburnt)	ca 25	0.6 : 1	17	96.0	92.0

The logged area typifies a habitat subject to disturbance in the absence of fire. Here population level was relatively high and largely restricted to the stream margins, where vegetation density was greatest. The sex ratio favoured females and was similar to the one obtained in virgin forest. However mean weight of animals trapped in this area was low.

4.2.3 The Mardo (Antechinus flavipes)

The details of mardos trapped in the study areas are shown in figure 4.8. The largest numbers were taken in recently logged forest and in the unburnt forty year old stand, and the least in the young regeneration and the virgin forest which was subjected to regular prescribed burning. The data suggests that the mardo is insensitive to changes in the forest structure occasioned by felling or due to different stand ages. Little relationship was found between the age of the forest and the mardo population. Its relationship with fire history however, followed the distinct trends shown in figure 4.8. This species was found to reach its highest population levels in the study areas which had

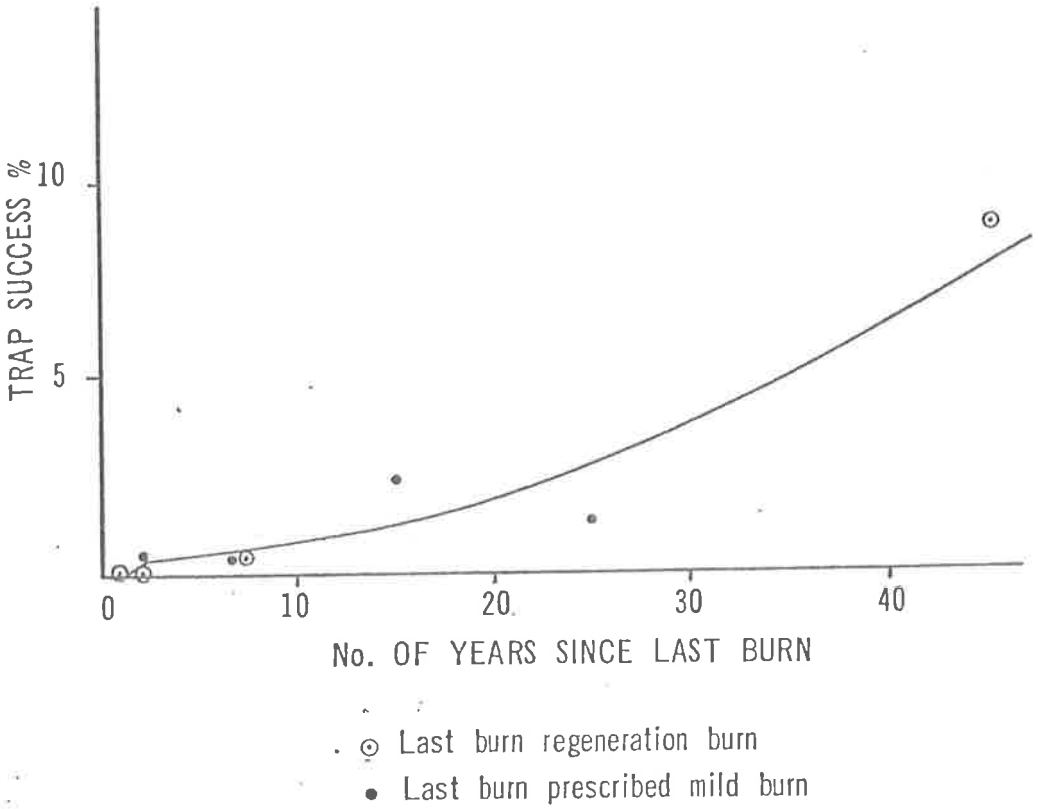


Fig. 4·8 TRAP SUCCESS OF ANTECHINUS FLAVIPES RELATED TO FIRE HISTORY

been protected from fire for the longest periods. It appeared to favour a dense overhead cover, with at least the lower few centimetres consisting of dead material. In the forty year old unburnt stand almost the entire lower cover consisted of dead material, and a similar situation existed in the logged area where the dead crowns of the cut trees provided most of the cover.

Evidence of repopulation following forest regeneration first appeared in the seven year old stand. However, as the species is difficult to trap when population levels are very low, it may be present in younger stands than this.

4.2.4 Phascogale tapoatafa (Wambenger)

This species occurs in much of the forest area south of Perth. During the course of the study only one individual was captured in a twenty-two year old karri regrowth stand. The failure to trap individuals in other areas was likely to be due to difficulty in trapping this species and would not indicate its absence.

Forests Department records for the species in the Manjimup Shire are tabled in figure 4.9.

Figure 4.9 Records of Phascogale tapoatafa in Manjimup Shire.

Location type	Jarrah forest	Karri forest	Farms	Residential areas
No. of individuals recorded	6	6	3	3

These records indicate that the species is adapted to a wide range of environmental conditions.

Records from the northern jarrah forest have shown the species is present in dense small stands of trees bordering streams, a vegetation type structurally akin to the twenty-two year old karri regrowth stand. If it has a preference for

this type of environment, then it is possible that the advent of greater areas of karri regrowth areas may result in an increase in its population size in the karri forest. A method to trap this animal is now being researched so that population studies can be made.

4.2.5 Cercartetus concinnus (Pygmy possum)

The pygmy possum is found in the coastal flats and the forest areas south of Perth. Gould notes that "they become very active at night in the flowering branches of shrubby low trees in search of insects and sweets".

Only one individual was captured in a forty-five year old karri stand. The karri was flowering at the time of capture.

4.2.6 Macropus fuliginosus (Grey Kangaroo)

The grey kangaroo is widely distributed throughout the southwest forest, but it occurs at relatively low population densities in the karri forest (Christensen 1970).

It was recorded in all study areas, either by sightings or by scats. Scat counts were made on this species and are shown in fig. 4.10. They indicated the existence of high population levels in 6 and 8 year old regeneration when compared with 22 year old and virgin forest.

Figure 4.10 Scat counts of Macropus fuliginosus

Forest age (yrs)	Logged	1	2	6	8(a)	22	Virgin
Scats (pellets per 100 metres)	22.4	11.5	15.0	68.4	42.0	2.9	16.5

(a) An additional area was used for this part of the study

(b) 45 year old forest was not assessed because there were no tracks in the study areas.

The scat counts in logged, and one year old forest

areas were lower than expected. The low counts may be an artifact due to the relatively open nature of the forest at this stage of regeneration, and the porbability that the kangaroo ranged widely under these conditions. In the older, denser stands kangaroo movements were likely to have been more restricted to the tracks. The scat survey was confined to these tracks.

4.2.7 Oryctolagus cuniculus (Rabbit)

Rabbits appeared to be present in very low numbers in the karri forest. Scat counts indicated a build-up in rabbit populations following regeneration of karri, reaching a peak at age 6. By the age of 22 the population had declined to a level comparable with that of virgin forest (fig. 4.11)

Figure 4.11 Scat counts of O. cuniculus taken along roads and tracks in different aged karri forest.

Age of forest (years)	1	2	6	22	45	Virgin
Scats/100 metres	0	6.3	4.2	0.2	0	0

4.2.8 Vulpes vulpes (Fox)

Foxes appeared to occur in uncut forest in very low numbers. Once these areas were logged and regenerated there appeared to be an increase in numbers as estimated from scat counts. The population then returned to a very low level in the older regeneration stands, and no fox scats were found in forty-five year old regeneration. Results of scat counts are shown in fig. 4.12 and the results of scat analysis are tabled in fig. 4.13.

Figure 4.12 Scat counts for V. vulpes taken along roads and tracks in different aged karri forest

Age of forest (years)	1	2	6	22	45	Virgin
Scats/100 metres	0.25	0.3	0.5	0.1	0	0

Figure 4.13 Mammals identified in fox scats from different ages of karri forest

Forest age (years)	1	2	6	10(1)	Virgin
Species					
Mus musculus	*				
Rattus fsucipes	*	*		*	
R. rattus	*				
Isodon obesulus	*	*	*		*
Oryctolagus cuniculus	*	*		*	
Macropus fuliginosus					*

(1) Scats were collected from an additional study area.

It is of interest to note that analysis of fox scats from a particular area reflected the expected animal populations in those areas. A good example of this would be seen in the one year old regeneration where the hair of the house mouse, the ship rat, and the southern bush rat were identified in fox scats. These animals would be expected to occur within the one year old regeneration and its adjacent undisturbed streamside vegetation.

4.2.9 Other species

Species which would be expected in karri forest but which were not in the study, or which were caught or observed in very low numvers are discussed in this section.

Hydromys chrysogaster (Water rat)

One individual was captured and a second one seen on the stream passing through the two year old regeneration.

Rattus rattus (Ship rat)

Individuals were captured in the moister sites adjacent to streams in 6 year old, 45 year old and virgin forest.

Isoodon obesulus (Short-nosed bandicoot)

None were captured and experience has shown the species to be shy of the types of trap used in this study. Evidence of their presence was found from the analysis of fox scats, but this avenue of identification did not define the precise locality of capture by the fox.

The distinctive diggings of the bandicoot were observed in regeneration areas of all ages.

Setonix brachyurus (Quokka)

This small wallaby was located at two points in the area of two year old regeneration, but no sign of it could be found in the other study areas. The species is of very localised distribution within the karri forest.

Sminthopsis murina (Mouse dunnart)

No specimens were located in this study. As it is normally easily found by searching it was assumed to be absent or present in very low numbers.

Trichosurus vulpeculus and Pseudocheirus peregrinus

Brush-tailed possum and Ring-tailed possum.

Neither species is known to be directly associated with karri trees, but both occur in adjacent forest types. None were located in this study.

Discussion

The study was conducted on a survey basis and thus lacked depth of detail for most species. The results however, can be taken as indicative of the broad effects of clear felling and regenerating karri on the mammals of the forest. Reference to figure 4.3 suggests that little change occurs in the number of species represented in forest of different ages. Slight increases in the number of species in young regeneration (two and six year old) are mainly due to the appearance of the fox and the rabbit.

A slightly larger number of species were found in the burnt samples of 45 year old and virgin forest, than in the unburnt samples.

The relative abundance of various species was found to change following regeneration, but the pattern of change was identical to that following fire in uncut forest.

It is concluded that the severe disturbance the animal population must suffer during the cutting of the forest and during the regeneration burn is transient. Repopulation of treated areas was found to occur very rapidly.

5. BIRDS

5.1 Study Areas

Studies of bird populations were carried out in four of the areas selected for vegetation study (see section 3). The areas with descriptions of some of their vegetation characteristics which were likely to affect bird populations are described below.

Area 1. Virgin karri forest. Had been subjected to regular prescribed burning for a number of years and was last burnt eight years prior to the study. The shrub layer was very dense and dominated by legumes.

Area 2. Mature karri logged 3 years prior to the study leaving four large trees per hectare. The area included a stream. Structural characteristics were a sparse overstorey, no understorey, and a shrub layer which was dense but very patchy. There were heavy accumulations of logging debris (dead tree crowns) on the ground.

Area 3. Two year old karri regeneration. The study area incorporated a stream. Fifty percent of the study area was dense swamp type vegetation and was structurally typical of five to six year old regeneration rather than two year old.

Area 4. Forty-five year old karri regrowth. The study area had not been subject to prescribed burning since forest regeneration 45 years previously. Consequently the shrub layer was sparse and the accumulation of ground litter was very thick.

5.2 Method.

As this study was largely exploratory and time was limited, no attempt was made to determine absolute population levels. The aim of data collection was rather to obtain

a comparative index of the abundance of each species (Lack and Venables, 1939) in each of the four study areas. The method of strip assessment that was used would be adequate for estimating total populations provided some index of conspicuousness (Colquhoun, 1940) could be determined for each species. This was not possible in the time available for the study.

The method used was one of successive surveys, recording all visual and auditory observations of birds along permanently marked lines. There were three such lines in each of the four areas. Each line was 300 metres long and lines were sited 100 metres apart.

Four surveys were done in each area between 1 October and 4 December 1974. During the survey the observers stopped for up to 10 minutes at points 50 metres apart along the lines. An Audubon bird call was used to attract the passerines of the shrub layer to within sight of the observers.

Surveys were conducted during the breeding season when the territorial bond was strongest and there was therefore the minimum likelihood of encountering wandering feeding associations of birds. According to Kendeigh (1944), four surveys of this type would establish 90% of the population levels of each species within the observation range of the survey line. However, it was realized that the relative conspicuousness, and hence the distance of observation would vary greatly between species. Thus the data could not be used for a total population estimate per unit area. The figures must be regarded as comparative index only. We did not consider that this approach in any way invalidated

the calculation of a diversity index, provided the index was used for comparative purposes.

5.3 Results

Total censuses by species are shown in figure 5.1 and a summary of observations by niche occupancy in figure 5.2

The nominal 2 year old regenerated area was probably the most disturbed habitat and this was reflected by the most marked changes in the composition of bird populations considered on the basis of niche occupancy. Species occupying the upper canopy, lower canopy and understorey were much reduced as also were the two eucalypt flower feeders, the Red wattle bird and the Purple-crowned lorikeet. Species occupying the shrub layer however, were greatly increased yielding twice as many observations as in the virgin forest.

The number of hole-nesting species in the 2 year old regeneration was high, indicating that some of the species involved probably feed at a low level (e.g. the Western rosella is frequently seen on the ground). Other species normally expected in the upper canopy adapted to some degree to a different habitat level. Thus the Red-tipped pardalote was frequently observed. The presence of relatively high numbers of hole-nesters in the young regeneration, where holes were virtually unavailable, is attributed to an edge effect. These species were presumed to have been nesting in adjacent uncut forest. The low number of hole-nesters found in 40 year old forest was presumed to be due to a lack of nesting sites. The 45 year old study area formed part of a large block which was originally cleared for

Figure 5.1 Numbers of birds observed in four surveys

Species	Niche (1)	Forest age (years) (number of observations)			
		Logged	2	45	Virgin
Whistling kite	6	0	0	1	0
Purple-crowned lorikeet	5.H	50	5	46	17
White-tailed black cockatoo	3.H	12	1	3	14
Western rosella	1.H	5	18	16	13
Red-capped parrot	3.H	3	0	0	0
Twentyeight parrot	3.H	13	5	0	18
Fan-tailed cuckoo	6	12	14	17	33
Golden bronze cuckoo	6	1	1	0	0
Kookaburra	6.H	11	0	2	0
Sacred Kingfisher	6.H	0	1	0	0
Tree martin	4.H	67	54	8	70
Black-faced cuckoo-shrike	6	11	1	0	0
White-browed babbler	1	0	8	3	0
Splendid wren	1	9	0	0	2
Red-winged wren	1	0	4	6	18
Western warbler	2	13	18	24	25
Broad-tailed thornbill	1	23	25	11	14
Spotted scrub-wren	1	25	41	26	24
White-breasted robin	1	2	3	3	5
Grey fantail	2	42	18	19	50
Golden whistler	2	30	27	35	58
Western shrike-thrush	2	1	1	4	3
Rufous tree-creeper	6	1	0	0	2
Spotted pardalote	3	0	1	19	14
Striated pardalote	3.H	36	25	47	46
Silvereye	1	3	1	0	0
White-naped honeyeater	3	5	16	34	24
White-eyed honeyeater	1	53	74	49	12
Red wattle-bird	5	16	11	33	9
Red-eared firetail	1	0	2	0	0
Dusky wood-swallow	4	24	11	0	27
Raven	6	0	3	0	1
Total observations		468	389	406	499
Total number of species		25	27	21	23
Diversity index		2.76	2.79	2.56	2.72

Note (1) - The niche is the vegetation level at which the bird was most frequently observed. The levels were

1. Low - Shrub layer
2. Understorey and lower tree canopy
3. Upper tree canopy
4. Hawking insects within or above upper canopy
5. Feeding on eucalypt flowers

6. Others - level of activity very wide or indefinable

H. Species nesting in holes in trees.

Figure 5.2 Bird survey results summarized by niche occupation (Some species appear in more than one category)

Forest age / Niche	Total number of observations in four surveys (number of species in parenthesis)			
	Logged	2 y.o	45 y.o	Virgin
1. Shrub layer	120 (7)	176 (9)	114 (7)	88 (7)
2. Understorey and lower tree canopy	86 (4)	64 (4)	82 (4)	136 (4)
3. Upper canopy	69 (5)	48 (5)	103 (4)	116 (5)
4. Hawking near upper canopy	91 (2)	65 (2)	8 (1)	97 (2)
5. Feeding on eucalypt flowers	66 (2)	16 (2)	79 (2)	26 (2)
6. Others	36 (5)	20 (5)	20 (3)	36 (3)
7. Tree-hole nesters (1)	147 (7)	104 (6)	76 (5)	161 (5)

Note (1) - The purple-crowned lorikeet is excluded because of its strong association with karri flowers. The virgin forest was not flowering, hence lorikeet numbers were low.

farming; very few large trees with holes remained. As such the area is not comparable with present day and projected forest practice where strips of large timber are left bordering major roads and water-courses.

Species normally seen hawking insects in the region of the tree canopy were in low numbers in the 45 year old stnad. The absence of the Dusky wood swallow could be attributed to the dense nature of the canopy. However, the presence of Tree martins in such low numbers we attributed to the lack of nesting hollows. However, the effect of the dense canopy of this forest in reducing visibility may account for at least part of the reduced sightings.

Understorey and lower tree canopy species were observed in fifty percent greater numbers in virgin forest than in the other three forest types. Their reduction in the looged and the two year old regeneration areas could be accounted for by the reduction and complete removal respectively of their habitat levels. The 45 year old stand was apparently suitable but in fact we suspect that the dense upper canopy made the habitat untenable.

The species diversity index was remarkably similar for all the study areas excepting the 45 year old stand where a small but significant reduction occurred in diversity. Species representation was greatest in the logged and two year old study areas, perhaps reflecting the development of a wider habitat diversity than occurs in uncut forest.

5.4 Discussion.

5.4.1 Species representation

No species was found in the virgin forest that was not represented in one of the three other study areas. We

believe the conclusion that no species is eliminated by the practice of clear-felling and regenerating karri to be a valid one from this study. It is also apparent from the study that the earlier stages in the life-cycle of an even aged karri stand support a slightly larger number of species than does mature forest. The period of least number of bird species appears to be in the pole stage when the tree canopy reaches its densest stage. That this study was done in an atypical 45 year old stand in that it had not been burnt for 40 years, and hence the shrub layer was sparse, did not affect populations of species normally inhabiting the shrub layer. The populations most affected were the understorey flower canopy inhabitants and the hole nesters.

Species representation at any particular stage in the forest succession was, in broad terms, related to the existence of a range of habitat levels. However, not all species showed sensitivity to habitat disturbance. Some adapted to a different level when their usual habitat was destroyed (e.g. the Red-tipped pardalote), while others may have a wider habitat acceptance than was recognized by us.

5.4.2 Numbers of Individuals

The greatest number of individuals of all species combined was observed in the virgin forest, and the least in two year old regeneration where numbers were 80 percent of those in the virgin forest. Differences of this order in numbers of individuals and in numbers of species are less than the fluctuations that occur following prescribed burning (Christensen and Kimber, 1975).

5.4.3 Edge effects

Both the logged and two year old study areas were bordered in part by lightly cut or uncut forest, thus some edge effect was introduced. The 45 year old study area was part of a large enough block to virtually eliminate edge effects.

The most pronounced effect was likely in the logged area which was only 53 hectares in extent. The two year old block was part of a larger unit than the clear felling units currently in use (maximum size 200 hectares), hence any edge effect that may have occurred in the study area will be repeated on units clear felled and regenerated in the future. The study can be regarded as a representative sample of bird populations for regeneration of this age and type.

5.4.4 Species showing large differences in numbers.

1. Purple-crowned lorikeet numbers were very low in two year old regeneration and low in the virgin forest. This species is closely associated with eucalypt flowers as a food source (Christensen 1971) and their low numbers are indicative of a paucity of karri flower. The high numbers in the logged and 45 year old areas was due to heavy flowering.

2. White-tailed black cockatoo, Twenty eight parrot, and Tree martin numbers were all lower in two and forty year old stands than in cutover and virgin stands. The lack of nesting hollows is assumed to be partly the reason. However, as the Western rosella, another hole nesting species, was seen frequently in the two year old regeneration, other factors could have affected the species under discussion.

3. The Kookburra was frequently seen in the cutover stand, but rare or absent in the others. The open nature, including significant areas of exposed ground, of the logged stand was presumed to favour the hunting habits of this species.

4. The Spotted pardalote was infrequently recorded in the logged and two year old areas, and was therefore assumed to be sensitive to the height and density of the tree canopy.

5. White-naped honeyeater numbers were very low in the logged stand due, presumably, to the severe reduction in tree canopy. Numbers increased markedly in the two year old regeneration indicating that this species is not sensitive to the height of the canopy.

6. The Dusky wood-swallow was absent in the forty five year old stand due, presumably, to its inability to hawk insects in the dense canopy development of this age of forest.

5.4.5 The choice of study areas.

The question of the representativeness of the study areas should be considered in an investigation of this nature. Bird surveys are time consuming, hence the number of different stages of forest development that could be included in the project was limited by this factor. We would like to have included certain other forest development stages, but suitable study areas were not available. Of particular interest would be stands of around 10 years of age when a forest structure begins to develop, and stands of between 40 and 80 years old where the dense canopy development of pole stands declines and approaches the condition of the virgin forest.

The areas chosen for this investigation were those where maximum changes in forest structure, when compared with the virgin forest, have taken place following timber harvesting. We can assume, therefore, that the changes in bird numbers and species which we have recorded are the greatest that can be expected to occur.

6. CONCLUSIONS

The greatest number of birds was found in virgin or mature karri forest. However, the number of species was higher in forest logged to seed trees and in two year old regeneration than in the virgin forest, and slightly less in a dense forty five year old pole stand.

The study showed that changes in bird populations were transient and that once a particular habitat level or niche developed following forest regeneration, it was occupied by the species normally found in that niche. Some species were able to apparently adapt to a change in habitat level.

No bird species was eliminated by the forest operations of harvesting and regeneration, although some species were apparently absent from a fortyfive year old pole stand, presumably due to its dense canopy.

6. SOIL FAUNA

6.1 Introduction

The knowledge of forest soil fauna in Western Australia is sparse and until recently no work had been done relating their populations to forest operations. Dr. J.A. Springett was commissioned to work on soil fauna by the Forests Department for a period of three years, and some of her studies were conducted in karri forest of various ages and various burning histories. (See Springett, 1973). The account that follows draws exclusively from her data and from her comments on the distribution of species. However, the present authors are responsible for the conclusions drawn from these data with regard to forest operations.

6.2 Some characteristics of Karri soil fauna

Karri soil fauna were found to be similar in structure (with regard to family or sub-family and where identification was possible to genus and species) to rich forest sites throughout the high rainfall area of the southwest. The similar sites included jarrah forest near Dwellingup, and further north a bullich (Eucalyptus megacarpa) swamp, blackbutt (E. patens) forest on a rich alluvial soil, and marri in a fairly moist habitat.

Animals typically present in this wide group of sites were Amphipoda, Onychophora, land planariums, and the limpit-shaped cockroach Laxta. Animals limited to karri country were Cubaris milsmorei, Styloniscus spp., Siphonotus sp. Rhinotus sp., Austrosuccinea sp., Luinodiscus spp., and Anoselix sp.

The wetter forests tended to have a less diverse ant fauna than was observed in the poorer and drier forest sites,

and they were also typically lacking in the genera Antichiropus, Hiturga, Otostigmus and Scolopendra. These four genera are typical of the wandoo (Eucalyptus wandoo) savannah country, although a species of Antichiropus was also found in the north east of the karri forest, and Hiturga in the karri outlier in the Porongorups.

6.3 Limitations of the data

Many of the animals collected by Springett were new species and have yet to be named. The level of taxonomic discrimination is therefore not fine enough for precise estimates of diversity. Also within the species list shown in figure 6.3 there is the possibility that more than one species occurs within a generic or family name purporting to represent one species.

6.4 Results

The numbers of animals per square metre in karri forest under various management conditions is shown in figure 6.1.

There were large differences in the numbers of animals in the three virgin forest sites sampled (compare sites 19, 27 and 29). All had a comparable fire history, and the differences could perhaps be ascribed to undetected differences in site, or to the level of sampling. The highest numbers were found in 40 year old regeneration which had not been subjected to fire since its inception, however a similar number was found in one of the virgin sites (No. 27) which had been burnt 6 or 11 years prior to being sampled.

The lowest numbers of animals were found in the most recently burnt sites, Nos. 18 and 25. Site No. 18 was 4 year old regeneration and the last fire on this site had been the very intense regeneration burn.

Figure 6.1

Numbers of Animals per m^2 in Karri forest. Results of Hand Sorting Turves
Sample size 4 x 0.1 m^2 (After Springett 1973)

Springett's Site Number	State of the forest	Period since last burn (years)	Worms	Land Planarians	Centipedes	Spiders	Woodlice	Insect larvae	Mature insects	Snails and slugs	Millipedes	Amphipods	Phalangids	Total Numbers of Animals
18	Regeneration, 4 years old	4	10	-	8	5	8	20	18	8	10	-	-	87
19	Virgin	9	20	5	13	10	-	(50)		3	20	-	-	121
21	Selectively cut	7	13	-	18	25	13	18	20	-	18	20	3	148
24	Regeneration 40 years old	40	90	10	90	25	80	25	15	-	145	20	15	515
25	Regeneration 40 years old	1	3	-	15	8	10	5	5	5	13	3	-	67
27	Virgin	6 or 11	30	-	33	30	180	(60)		20	38	103	13	507
29	Virgin	6 or 11	15	3	23	20	63	(28)		15	28	73	8	276

Figure 6.2

Site: Species Matrix for all Species Collected

(after Springett, 1973)

Sites are those described in figure 6.1

Species	Site Number						
	18	19	21	24	25	27	29
SCORPIONIDAE							
2. Cercaphonius			x			x	
DIPLOPODA							
1. Podykipus sp & Atelomastex sp.		x	x	x	x		x
3. Sphaerotrichopus sp. A	x	x	x	x			
4. Rhinotus sp.	x						
5. Siphonotus sp. A			x				
7. Siphonotus sp. B			x				
CHILOPODA							
1. Cormacephalus sp.		x	x		x	x	x
2. Cryptos sp.	x	x	x	x	x	x	
3. Dichelobius sp.		x		x	x	x	
4. Geophilidae - var 1	x	x	x			x	
5. Geophilidae - var 2	x	x	x	x	x	x	x
6. Geophilidae - var 3				x			
ISOPODA							
1. Laevaphiloscia & Eurygastor sp.	x	x	x	x	x	x	
8. Styloniscus australensis		x	x	x		x	
9. Laureola milsmorei			x	x	x		
20. Styloniscus sp.		x	x				
AMPHIPODA							
1. Parorchestia sp.	x	x	x	x	x	x	x
OLIGOCHAETA							
2. Oligochaeta, adults 40mm	x	x	x	x	x		x
ARANAEIDA							
1. Lycosa sp.		x					
2. Lycosidae	x	x	x	x	x	x	x
3. Oxyopidae		x		x	x		
4. Salticidae		x					
5. Dipneumonomorpha		x					
6. Chenistoria sp.	x		x	x	x	x	
7. Stanwellia sp.					x		
9. Clubiinidae	x	x	x	x		x	
11. Dipneumonomorpha			x			x	
12. Dipneumonomorpha			x				
17. Drassidae						x	
18. Dipneumonomorpha						x	

Species	Site Number						
	18	19	21	24	25	27	29
ARANAEDIA cntnd							
20. Dipneumonomorpha							
FORMICINAE							
1. Formicinae			x				
5. Formicinae		x					
9. Formicinae			x				
12. Dolichoderminae		x					
16. Ponerinae						x	
20. Formicinae			x		x	x	
21. Myrmicinae				x	x		
GASTEROPODA							
1. Limacidae					x		
2. Austrosuccinea sp.	x	x		x			
3. Pernagera sp.	x	x		x			x
4. Luinodiscus sp.	x				x		
6. Annoselix dolosa				x	x	x	
8. Bothriembryon sp.			x			x	
INSECTA							
1. Blattodea		x		x		x	x
2. Blattodea		x	x	x			
3. Blattodea	x	x	x				
6. Blattodea		x	x		x		x
7. Laxta sp.			x			x	x
10. Blattodea	x	x			x	x	
11. Blattodea	x	x			x	x	
13. Blattodea						x	
14. Curculionidae		x		x			x
15. Dermaptera	x	x	x	x	x	x	x
16. Scarabaeidae						x	
ONYCHOPHORA							
1.				x			
TURBELLARIA							
1. Geoplana sp. (brown)	x						
2. Geoplana sp. (striped)				x		x	
3. Geoplana sp. (yellow)	x	x		x		x	
4. Geoplana (brown & blue)						x	
PHALANGIDAE							
1. Laniatores			x	x		x	x
2. Palpatores							x
NUMBER OF SPECIES	19	31	31	27	21	29	16

Certain groups of soil animals appeared from the data to be more sensitive to fire, and slower to recover after it. Thus land planarians and Phalangids were undetected on sites burnt 1 and 4 years prior to sampling, however both were found in site 29 burnt 6 or 11 years before. Amphipods showed a similar sensitivity but their apparent recovery was faster (see fig. 6.1).

Burning, whether a mild prescribed burn or an intense regeneration burn, generally resulted in greatly reduced numbers of all animal groups in the short term.

The species found on each site, as far as taxonomic separation was possible, are listed in figure 6.2.

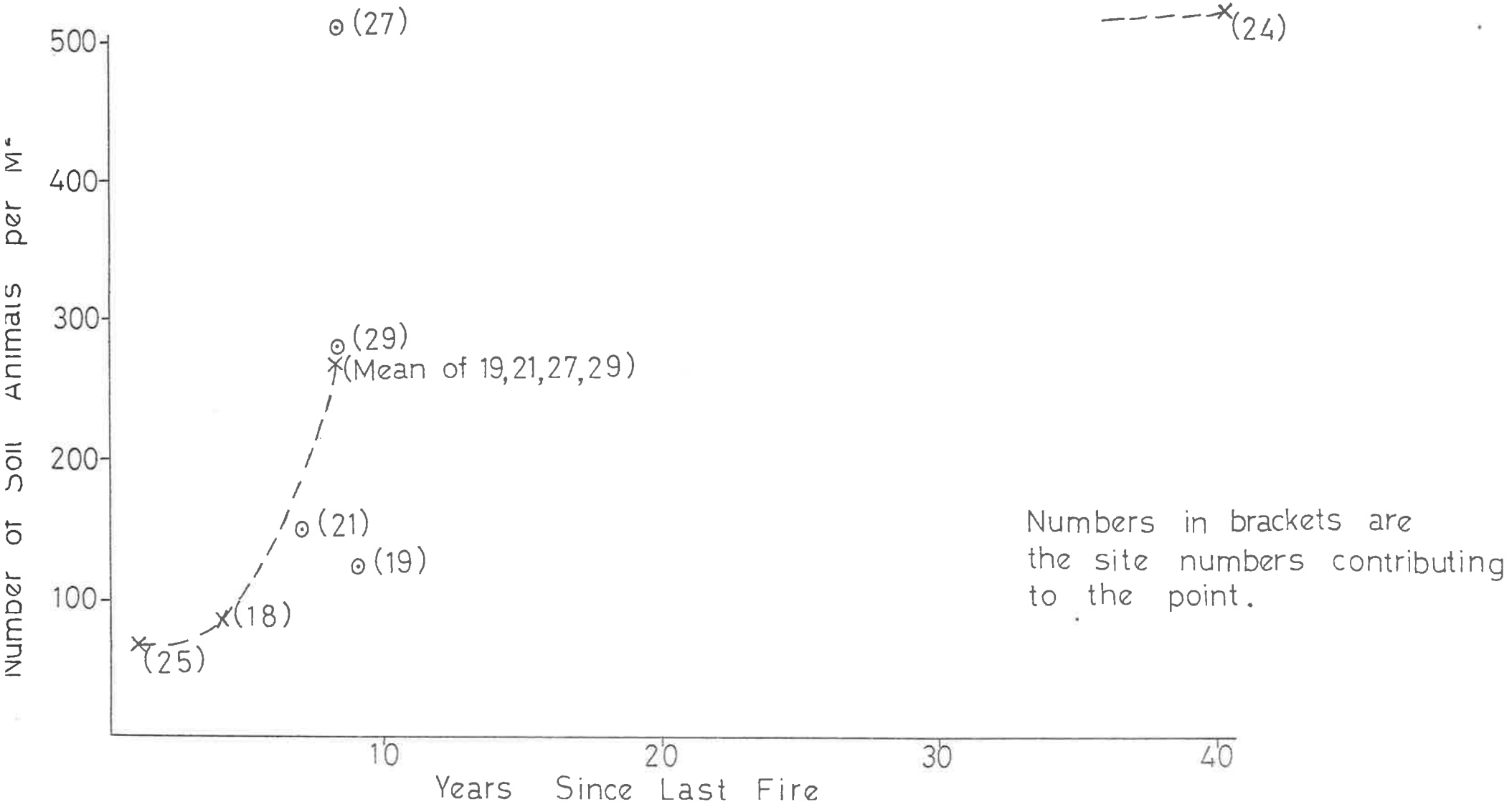
6.5 Discussion.

The effects of fire and the effects of the regeneration process are confounded to some degree in the presentation of data in figure 6.1. However the regeneration process involves fire, and, as soil animal numbers were higher in a regenerated site (24) than in any of the three virgin sites it can be assumed that the regeneration process itself was of minor importance in its long term effect on soil fauna. If the variations in animal numbers are thus ascribed to fire, then the recovery trend of soil animals following fire can be represented graphically by pooling the data from virgin, selectively cut, and regenerated stands. This trend is illustrated in figure 6.3 and shows a very rapid recovery in the first few years following fire.

Treatment of the numbers of species found on each site in a similar manner suggests that the impact of fire is likely to be less in reducing the number of species than it is in reducing the absolute numbers of animals (figure 6.4).

FIGURE 6·3

Recovery Trend of Soil Animals in Karri Forest Following Fire (and Regeneration)



The reappearance of species which could not be detected shortly after burning is also rapid and from evidence from sites 19 and 21 complete recovery of species representation appears possible between 7 and 9 years after fire.

Figure 6.4

Site No.	Period since last fire (years)	Number of species
25	1	21
18	4	19
19, 21, 27 29 (mean)	8 (6-11)	27 (16-31)
24	40	27

The 19 species recorded in 4 year old regeneration is rather lower than would be expected at this age when site 25, burnt 1 year previously, had 21 species. This fact casts an element of doubt on the assumption that the regeneration process involving clear felling has only a minor impact on soil fauna. Further work will be necessary to elucidate this point. However, the high number of animals and the high species count on site 24, which was a cut and regenerated forest, demonstrated a lack of long term effect of clear felling on the soil fauna.

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