

A COMPARISON BETWEEN REGENERATION PATTERNS OF
EUCALYPTUS REGNANS AND MIXED FOREST SPECIES, ON
LOGGED COUPES IN SOUTH WEST TASMANIA

A thesis submitted by

Rosye Hefmi Rechnelty Tanjung

to the

Department of Plant Science, University of Tasmania

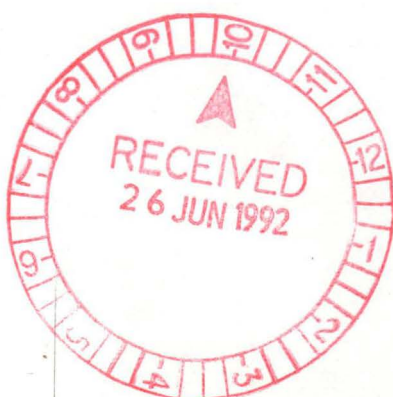
in partial fulfilment of the requirements for

the Degree of Master of Science

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge and belief contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text.


Rosye H.R. Tanjung



Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge and belief contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text.

Rosye H.R Tanjung

CONTENT

ACKNOWLEDGEMENTS

ABSTRACT

I. GENERAL INTRODUCTION	1
1.1 Aims	1
1.2 Terminologies and definitions	2
1.3 The relationship between fire and three forest types in Tasmania	2
1.4 Fire as management tool in Tasmania	5
1.5 Descriptions of study sites	12
1.5.1 Location	12
1.5.2 Vegetation	12
1.5.3 Climate	12
1.5.4 Topography	14
1.5.5 Geology and soil	15
II. REGENERATION PATTERNS OF TREE SEEDLINGS	24
2.1 Introduction	24
2.2 Materials and methods	26
2.3 Analysis data	28
2.4 Results	29
2.4.1 Regeneration of tree seedlings on mudstone sites	29
2.4.2 Regeneration of tree seedlings on quartzite	39
2.4.3 Regeneration on landing area and snig track	41
2.5 Discussion	42
III. THE EFFECT OF FIRE ON THE COMPOSITION AND DISTRIBUTION OF UNDERSTOREY SPECIES	61
3.1 Introduction	61
3.2 Materials and methods	63
3.3 Results	64
3.4 Discussion	71

IV. FROST RESISTANCE	76
4.1 Introduction	76
4.2 Materials and methods	79
4.3 Results	82
4.4 Discussion	93
V. PHOTOSYNTHETIC RESPONSES TO LIGHT	96
5.1 Introduction	96
5.2 Materials and methods	97
5.3 Results	100
5.4 Discussion	107
VI. CONCLUSION	110
VII. REFERENCES	116

ACKNOWLEDGEMENTS

There are many people to whom thanks are due for their encouragement, generous help and support during the year.

Firstly, I would like to express my sincere thanks to my supervisor, Assoc. prof. R.S. Hill of Departement of Plant Science, University of Tasmania for his continuos help and encouragement during all stages of this study. I am also grateful to those members and all students of the Department of Plant Science who gave me their assistance during the process of my study.

I acknowledge with thanks assistance given to me by Greg Jordan for his invaluable help both in the field and discussion throughtout the project. Also, I would like to thanks Fred Duncan of the Forestry Commission in Hobart for providing access and assistance in the information.

Special thanks are due to my friends Michael John Kay for his help in the field, making most of the photographs, helpful discussion throughout a year and his encouragement, also, thanks must go to Antonius Bambang Wijanarto, without whom the completion of this thesis would not have been possible and Eretta Anggerek for her encouragement, making this a memorable year.

I gratefully acknowledge DIKTI Jakarta and the AIDAB/ IDP Australian universities & colleges for financial support during my study.

Finally, very special thanks are due to my dearest parents " Bunda Rosmani" and "Papa R.J Husein ", also all my dear brothers & sisters, without whose moral supports, this study would not have been carried out.

Rosye H.R Tanjung

ABSTRACT

The effect of different stages of forestry practices on regeneration of *Eucalyptus regnans* and understorey and rainforest species was determined for logged coupes in South West Tasmania. Observations were made across six different logged sites which were mixed forests prior to logging. Results at different stages of logging activity were investigated with undisturbed mixed forests used as controls. Mudstone is the main rock type at the study sites, and on some sites was found to be combined with quartzite. Study sites were divided into two groups. The first group, unburnt sites, consisted of unlogged mixed forest sites, sites from which eucalypts had been selectively logged, and clearfelled sites. The second group consisted of sites which had been burnt. Sample quadrats on the burnt sites were classified according to fire intensity; unburnt (small patches within the generally burnt area), low medium and high fire intensities. Sites were classified as two, five, seven and nine years after burning.

Regeneration of rainforest species occurred on logged sites, with regeneration on unburnt sites and on unburnt quadrats of burnt sites significantly greater than the regeneration of *Eucalyptus regnans*. Stocking rates of rainforest species was found to decrease with increasing fire intensity.

A positive association occurs between the density of rainforest seedlings and mosses, and a negative association between density of rainforest seedlings and shrubs and ferns.

Nothofagus cunninghamii and *Eucryphia lucida* regenerate better than other rainforest species. No significant difference was found between the regeneration rates of *Nothofagus cunninghamii* and *Eucryphia lucida*.

Evidence was found which indicates that floristic composition changes with increasing time since fire and with different fire intensities.

Eucalyptus regnans was found to regenerate poorly. On burnt sites, stocking rates of *E. regnans* increased with increasing fire intensity and this increase varied according to both fire intensity and time since fire. However, no strong evidence was found which indicated that greater stocking rates existed in quadrats on unburnt or burnt parts of the burnt sites. In contrast, when results were expressed in terms of mean seedling number, there was found to be a significant difference in the regeneration of *Eucalyptus regnans* in quadrats where fire had occurred compared to quadrats in unburnt parts of burnt sites with increasing time since fire. Furthermore, fire intensity did not affect regeneration rates and there was no obvious interaction between fire intensity and the time since fire.

All species investigated were found to regenerate poorly on quartzite. *Eucalyptus regnans* stocking rates were not affected by fire intensity on quartzite sites.

Phebalium squameum tended to be the most frequent tree seedling associated with *Eucalyptus regnans* on logged sites following fire. *Acacia* species were uncommon on the study sites.

Photosynthetic responses to light and frost resistance of the main species were measured, in order to correlate field observations with the physiology of selected species. Based on photosynthetic responses to light, *Phebalium squameum* and *Eucalyptus regnans* are considered to be relatively light requiring (sun plants).

The ferns *Pteridium esculentum*, *Histiopteris incisa*, *Hypolepis muelleri* and the hepatic *Marchantia berteroana*, dominate the ground layer of burnt sites during the early stages of recolonisation. The dominant shrubs on all sites, burnt and unburnt, included *Anopterus glandulosus* and *Monotoca glauca*. Mosses dominate the ground layer on all sites, at all the intervals since fire that were examined. The greatest number of species were found in sites where five years had elapsed since burning. Compared to undisturbed forest sites, sites two years after fire have a low index of similarity (approximately 50%). All other sites have indices of similarity which exceed 50%.

GENERAL INTRODUCTION

1.1. Aims

The aim of this study is to present data relating to early stages of the regeneration of tree seedlings in mixed forest (*Eucalyptus* canopy over a rainforest understorey) which has been subjected to differing logging techniques and different post-logging treatments to stimulate regeneration. The forest occurs on two different rock types.

- (1) Examination of the regeneration of forest following logging to compare how several stages of different forestry practices influence regeneration. The objective of the field work was to assess seedling regeneration of mixed forest species, particularly *Eucalyptus regnans* on logged sites subjected to different fire intensities and various times after burning. In addition, the influences of rock and soil type were investigated. Differences in life form and species distribution were also studied.
- (2) Investigation of the physiology of seedlings, firstly by measuring photosynthetic rates of species that were collected in the study site, and secondly by measuring frost resistance of selected species grown in a glasshouse and from field collected plants. The physiological studies were designed to allow some ecological aspects, such as the distribution of plants, and plant associations, to be correlated with photosynthetic performance and frost resistance.

1.2. Terminologies and definitions

Mixed forest species are defined as the main tree species which are common in mixed forest, including dominant rainforest species and wet sclerophyll tree species as defined by Gilbert (1959); Jarman *et al.* (1984) and Jarman *et al.* (1991). Species nomenclature follows Curtis (1963, 1967); Curtis and Morris (1975) and Wakefield (1975).

1.3. The relationships between fire and three forest types in Tasmania

Due to its frequent occurrence in the past and the present, fire is no doubt an important factor influencing the dynamics of the forest types in Tasmania. A number of authors have discussed the relationship between fire and vegetation types. In this chapter, an overview of three forest types will be presented, and related then to research in South West Tasmania, where the vegetation of the study sites (as described in description of study sites) is dominated by wet sclerophyll forest to pure rainforest.

(1) Temperate rainforest

Tasmania's rainforest, known as cool temperate rainforest, has been defined by Jarman and Brown (1983) as forest taller than eight metres which is dominated by species of *Nothofagus*, *Eucryphia*, *Atherosperma*, *Arthrotaxis*, *Lagastrobos*, *Phyllocladus* and / or *Diselma*, and capable of regeneration in the absence of large-scale disturbance. Species depending on fire and high light intensity for their regeneration are not regarded as rainforest. Jackson (1968) believed that the low light intensity in rainforest prohibits the growth of *Eucalyptus*. Rainforest is classified into four basic types; callidendrous, thamnisc, implicate and open montane

rainforest (Jarman *et al.* (1984)) each of which type has a different structure and floristic composition, as described by Jarman *et al.* (1991).

Cool temperate rainforest is spread throughout Western Tasmania with some tracts in the north-eastern highlands (Kirkpatrick and Brown 1984a). It is characterised by wet humid environments and is found mostly in the area where the annual rainfall is greater than 1000 mm and the summer rainfall exceeds 50 mm per month (Jackson 1965), and it ranges from sea level to over 1000 metres. On low land fertile, well drained soils is a tall closed forest (Specht 1970), with a canopy up to 40 m, dominated by *Nothofagus cunninghamii* with *Atherosperma moschatum* sub-dominant. These forests have an open understorey, however sometimes they contain a sparse layer of ferns and mosses on the humid sites, and have a very low diversity of angiosperm species. This type of forest association is not only found in Tasmanian, but also occurs in Victoria where suitable climate and low fire frequency co-occur (Busby and Bridgewater 1977).

The dominance of *Nothofagus* decrease with decreased soil fertility. Forest structure becomes more complex, and *Eucryphia lucida* and *Phyllocladus aspleniifolius* appear as common components of the canopy, and shrubs become more common in the understorey (Jackson 1965, 1968; Kirkpatrick 1977).

(2) Mixed forest

Following Gilbert (1959) mixed forest is defined as: eucalypt forest which contains three layers of shade tolerant trees, a dense understorey of shrubs and ferns with grasses in more open situations. It is a disclimax vegetation type, maintained by low fire frequencies, with even aged eucalypt that germinated simultaneously. In this community, the rainforest understorey plays a major part. The *Eucalyptus* overstorey becomes sparse as the forest approaches maturity. *Acacia* species,

especially *Acacia melanoxylon*, also occur with rainforest species in localised stands, these species are regarded as seral within the rainforest, due to the regeneration which is influenced by disturbance (fire or flood) (Howard 1981; Jarman *et al.* 1984).

The relationship between rainforest and eucalypt forest in Tasmania has been discussed by many authors (for example, Casson 1952; Gilbert 1959; Cremer 1960, Jackson 1968; Mount 1979; Noble and Slatyer 1981; Brown and Podger 1982a; Jarman *et al.* 1982). Mixed forest represent intermediate vegetation between these two forest types and could arise from either an increased fire frequency in rainforest or decreased fire frequency in mixed forest (Jarman *et al.* 1984).

Mixed forest and wet forest represent different stages of the successional series from wet sclerophyll to rainforest (Gilbert 1959; Jackson 1968; Bowman and Jackson 1981). Furthermore Jackson (1968) showed that fire is a major factor controlling aspects of ecological distribution in sclerophyll communities, and fire interacts to produce an 'ecological drift' in vegetation types (Fig. 1.1). However, Mount (1979) believed that these communities are stable features and that the fire frequency required to maintain them is inevitable.

Lowland mixed forest is maintained by infrequent fire with an interval of 100 to 350 years, which allows the re-establishment of shade intolerant eucalypt and *Acacia* seedlings (Jackson 1968). Pure rainforest develops as the over mature eucalypts are eliminated when fire is less frequent than about 350 to 450 years (Gilbert 1959; Jackson 1968; Bowman and Jackson 1981). The ~~vegetation~~ between wet sclerophyll forest and rainforest which is occupied by eucalypt communities is considered to be mixed forest (Jackson 1981b).

(3) Wet sclerophyll forest

Wet sclerophyll communities in Australian forest are dominated by

Eucalyptus. Definitions have been presented for this community, such as Beadle and Costin (1952) who defined them as tall open forest which are dominated by eucalypts (over 40 metres in height; ^{Ashton 1981} and frequently contain multiple strata of mesomorphic notophyllous to microphyllous shrubs and trees, ground ferns, herbs and grasses. Gilbert (1959), in his works on forest succession in the Florentine Valley, differentiated this community into two based on soil conditions.

(1) Eucalypt forest on soils of moderate to high fertility.

(2) Eucalypt forest on soils of poor fertility.

In these forests, rainforest tree species were considered to play a minor part.

In Tasmania, wet sclerophyll forest dominate the area with annual rainfalls of approximately 100 cm, when annual rainfall exceeds 150 cm and where fire has not occurred frequently, the wet sclerophyll forest might be replaced by rainforest communities if a seed source is available (Jackson 1968).

The regeneration of *Eucalyptus* in wet sclerophyll forest depends on disturbance events, usually fire disturbance. The fire frequency in this community varies from 20 to 100 years, depending on sites conditions, the diversity of the vascular plants tends to decrease as the forest approaches maturity, whilst for non-vascular plants the opposite occurs (Duncan 1985). The dense shrub understorey hinders regeneration of *Eucalyptus*, whereas fire is a promotor for *Eucalyptus* seedling establishment (Jackson 1968).

1.4. Fire as a management tool in Tasmania

Many plants which occur in Australia are adapted to various fire intensities and frequencies. Fire is a factor of prime importance to the Australian vegetation. The important role fire plays on vegetation has long been recognised and discussed by many investigators. Because fire itself has a long-standing association with man,

attempts to control forest fires were limited at first to defence of improved property. The systematic development of forest fire control to protect forest values is a relatively young science which is still evolving. It is a natural environmental variable in many ecosystems. Its recent effects depend largely on fire intensity, however, longer-term effects depend on fire frequency and when it occurred (Gill 1975). In temperate regions, all forest types have been affected to some degree by fire (Brown and Davis 1973).

In Australia, it is generally accepted that the first fires preceded the arrival of white man 200 years ago, and even that of Aborigines about 40,000 years ago. Fire was the only major tool used in the Aboriginal culture which shaped the vegetation across the continent, often over large areas. Fire was the core of their technology (Gilbert 1959; King 1963; McArthur 1970 and Gill 1975). Heilers (1975) believed that fires were more frequent but of lower intensity during the aboriginal era than at present.

In ^{western} Tasmania, fires were frequent in old, even-aged stands of eucalypts before white settlement. The recent spread of fire-sensitive rainforest into areas which were once grasslands, attests to this. Fire has played a dynamic role in the evolution of the Tasmanian environment for a very long time. There is also some evidence that fire was used for manipulation of the environment in order to aid in the capturing of useful game, and perhaps even ^{to promote the growth of} certain plant species (Kirkpatrick 1976). Fire has markedly different effects on different species and vegetation types.

Fire acts as a selective process causing changes in plant communities regenerating from seed, light fires will rapidly select out sensitive species with poor vegetative recovery and will result in the spread of species with underground stems, lignotubers, thick resistant bark ^{or root suckers}. Vegetative recovery depends on the intensity of

the fire (Jackson 1978).

Fire frequency and fire intensity, coupled with other environmental factors, have brought about the existing natural vegetation pattern in South West Tasmania (Edwards 1978). Jackson (1968b) has explained the interactions between fire frequency and other environmental factors (Fig. 1.2). Many plant genera produce seeds which are protected within heat resistant woody fruits (i.e. *Eucalyptus*), or by hard seed coats (i.e. *Acacia*). Auld (1980) believe that successful seed germination and seedling emergence will depends on several factors:

- (1) The distribution of seed in the soil and the amount of insulating soil above a seed, influencing the degree of heating experienced during a fire and setting the upper limit below which successful emergence is impossible.
- (2) The intensity and duration of a fire.
- (3) The availability of adequate moisture.
- (4) Site location, where the seeds located in safe sites are more likely to survive.

Desiccation of woody fruits, during and after fire liberates the seeds and heat causes differential expansion ^{and cracking of} the seed coat and stimulates germination in greater quantities (Floyd 1966,1976; Purdie and Slatyer 1976; Farrel and Ashton 1978; Pedley 1978; Shea *et al* . 1979; Bell and Koch 1980; Monk *et al* . 1981).

Over the last few decades fire has become an increasingly important tool in Tasmanian forestry management practises concerning wood production. It is an important factor influencing the dynamics of the plant communities in Tasmania. In monetary terms, fire is probably the cheapest management tool used in the manipulation of native vegetation today. It is also highly controversial.

Many workers have presented arguments about the advantages and disadvantages of advocating fire as a management tool. Some of the perceived advantages of prescribed burning are:

- (1) a means of controlling woody weeds. Coaldrake (1961) has shown that fire can be used to maintain an understorey suitable for grazing in the forest and woodland.
- (2) a means of stimulating flowering. Immediate post-fire flowering is an adaptive trait in many native species (Attiwill and Leeper 1987).
- (3) triggering dehiscence of fruits, releasing stored seeds (Jackson 1978; Attiwill and Leeper 1987).

Therefore plants species which have massive blooms immediately after fire, dispersing seeds over a large area, are able to take advantage of the post fire conditions. Some known disadvantages of prescribed burning which ecologists believe are important include :

- (1) loss of nutrients. Possible disruption of the nitrogen balance with nitrogen compounds removed by smoke, and deposited elsewhere by precipitation.
- (2) death of mature and regenerating trees.
- (3) change in the composition and structure of communities.

Tasmanian foresters began an active research period concerning the effects of fire on vegetation processes in the early 1960's (e.g. Gilbert 1959; Cunningham 1960; Cremer 1962; and Mount 1964). The evidence so far available indicates that fire has had strong effects on the vegetation of Australia in the past, and is probably responsible for many of the vegetation patterns which now exist. The timing of fire has the greatest impact, has varied from place to place and has been greatest where an exotic flora has been available to take advantage of the conditions following fire. Although appropriate climates, and adequate fuel are essential pre-requisites for increasing the importance fire has on the landscape, human activity may prove to have been the deciding factor, significantly affecting a large proportion of Australia's vegetation .

The forest trees of Australia may be arranged conveniently into two broad categories, hardwoods and softwoods. Hardwoods, (angiosperms), include all the woody plants except conifers. The land suitable for intensive hardwood timber production is approximately 1.5 percent of area of the whole country (Eldridge 1974).

Eucalyptus is a hardwood genus which predominates in most Australian forests. *Eucalyptus* ranges from fully tropical environments to the alpine timber line (Sakai, Paton and Wardle 1981). It dominates 95% of the forest area, for example, in south east Australia, *Eucalyptus regnans* is noted for its excellent stem form, rapid growth, absence of pests and diseases and desirable wood qualities, although it is not a very frost tolerant species (Rook *et al.* 1980). There are more than 600 species of eucalypts, and most show regional endemism.

Because of economic reasons, most researchers have focussed on fire with respect to *Eucalyptus* regeneration. These works have been conducted as an integral part of silvicultural research by foresters and botanists and ecologists or for pure research purposes. Forestry research has focussed on the regeneration of eucalypts following logging, relating to wood production (Floyd 1976; Bowman and Jackson 1980 ; Lockett and Candy 1984) while ecological research has focussed on regeneration types and pattern following wild fires or other natural disturbances (Gilbert 1959; Mount 1975; Christensen and Kimber 1975 ; Read and Hill 1984). These are the most familiar features in the Australia scene, though mixed forest and rain-forest vegetation can eventually invade and replace eucalypts into the wettest regions, and acacias, some grasses and desert shrubs dominate the considerable areas unfavourable for colonization by eucalypts in the drier areas.

Most Tasmanian foresters believed that slash burns are a vital part of a more general prescribed burning programme (Mount 1968a, 1969). Duncan (1985) has

discussed the importance of fire, particularly as a tool for forest management. Fuel reduction burning is used in some vegetation types to protect the forest assets, and fire is also used to prepare a site for regeneration. The ecological consequences of fuel reduction burning will be determined primarily by the extent, frequency and intensity of the burn. Some evidence has been presented to suggest that recurrent fires have influenced the degree of importance eucalypts have in vegetation types which has changed during evolutionary time. This has resulted in a vegetation type which is both highly-inflammable and fire dependent (Mutch 1970).

Tree felling in Australia's hardwood forests began with the first settlement of Europeans, and continues on an extensive scale along the eastern coast of the main land, in Tasmania and in the south west of Western Australia. In 1979/1980, the hard wood logging industry supplied 75 percent of Australia's timber and pulpwood. This contribution is not expected to decrease by more than 15 percent over the next 35 years (Anon 1980a). Foresters in Tasmania have utilized clearfelling as a systematic regeneration operation since 1971, a date related to the introduction of pulp woodchip production (Lockett and Candy 1984). The coupes are generally regenerated by reseeding following burning of the logging slash, where seed are sown from commercial tree species native to the area.

Clear-felling is a widely used harvesting technique for woodchip production in Tasmania. A clear-felling system of harvesting provides full sunlight for regeneration from seed (Grose 1973). In this process, clear-felling is preferably followed by burning of the logging slash. This provides a burnt seed bed, which is also considered to be an ecological requirement for the establishment of fire climax forest types. Moreover Duncan (1985) believes that the effects of clearfelling and the regeneration practice is influenced by the forest type, the environmental scale of the operation and the logging method employed. In this case, Jackson (1979) and Hill

(1982) have concluded that the disruption caused by fire generally has a greater impact on plant species in Tasmania because they are not so well adapted to fire as species in mainland Australia.

Lockett and Rich (1977) mention that since 1976 the Forestry Commission in Tasmania has adopted a policy allowing up to 20 percent of the area logged in open forest, other than those at high altitude, to be excluded from slash burning. The arbitrary 20% limit has since been revised and current policy for this forest is that slash should be burnt to prevent future burns on all sites except where the disadvantages of such burns outweigh the advantages. Some of these disadvantages and advantages have been discussed by Felton (1976).

Studies on the effect of fire and / or logging on mixed forest are limited. Regeneration of mixed forest after fire or logging depend on the re-establishment of rainforest species. In the absence of the successful regeneration of mixed forest species, the forest is likely to become wet sclerophyll forest.

Hill and Read (1984) have examined regeneration of sclerophyll species in some western Tasmanian mixed forest after wild fire, which formed as a result of disturbance rather than the regeneration practise of the forestry industry. Regeneration practises in Tasmania differ significantly from wild fires, in that:

- (1) Wildfire leaves many more dead trees, logs on the ground and residue rootstocks, which may act as buffers against soil erosion and shelter sites for seedling regeneration.
- (2) Wildfires are generally more patchy, which results in sites being more likely to be close to fertile seed bearing adult trees, which are essential for the re-establishment of rainforest species with poor dispersal characteristics (Hickey *et al.*, 1982).

It is important to consider the effect forestry practises have (burning

following clearfelling) on eucalypt regeneration. Langford (1974) found that regeneration of *Eucalyptus regnans* overtopped other species in mixed forest usually after a crown fire which killed the mature trees which are thin-barked and fire sensitive. *Eucalyptus regnans* seedlings cannot establish under the influence of the dense canopy provided by the trees and understorey. Bowman and Kirkpatrick (1984) have shown that the establishment of eucalypt seedlings is better on bare ground which is produced by fire.

1.5. Description of the study area

1.5.1. Location

The study area occupies an area of logged forest at the Clear Hill - Ragged Range area in South West Tasmania approximately 110 km West North West of Hobart (Fig.1.4). Study sites are located at approximately 300 - 400 metres above sea level.

This part of Tasmania has been utilized for the production of newsprint (Fig.1.5) (Gilbert 1965). Prior to logging, this area consisted of a mixed forest (that is, eucalypt forest with rainforest understorey).

1.5.2. Vegetation

The vegetation surrounding the logged forest is dominated by wet forest, ranging from wet sclerophyll to pure rainforest (Fig.1.6 and Plate 1.1). Davies (1984) surveyed the vegetation in this area, and classified into 12 major vegetation types, 6 of which were mature rainforest and mixed forest types. The Florentine Valley, which was investigated by Gilbert (1959), is the closest area which is geographically and floristically similar to this study site.

1.5.3. Climate

Since no climatic data of the study sites were collected during this

investigation, general figures of climate have been taken from data available.

In general Tasmania has a maritime type of humid mesothermal climate (Trewartha 1954), with Southern Ocean depressions influencing the pattern of weather in Tasmania (Gilbert 1959).

The area studied is located in a climatic region between the perhumid cool area and perhumid cold climatic zone (Fig. 1.7)(Gentili 1972).

The rainfall is relatively high, with more than 1016 mm per annum recorded in the south west region (see Fig.1.8). Low temperature associated with the southern region and the mountainous topography creates orographic cloud and precipitation.

Strathgordon is the nearest weather station (about 5 km to the west of the study site). Nunez (1978), and Jarman *et al.* (1988) provide precipitation data. Approximately 2500 mm is reported at Strathgordon, and the number of rain days are 240 per annum. rainfall is highest in the winter, with 330 mm recorded in July and coincides with the highest frequency of frontal passages and the greatest differences in sea and air temperature (Fig. 1.9). July is the coldest month, with a mean daily maximum temperature of 9.2 °C. The ^{mean} minimum temperature in July is 2.9°C.

Frost incidence is a complex function of topography, elevation and distance from the coast. Total snow fall is highly variable from year to year. Accumulation of snow is not common before June and ^{occurs} only above 900 m.

As spring progresses into summer, a gradual drop in precipitation and an increase in temperature occurs. The study sites of the south west region are especially characterized by intense and rapidly changing weather systems.

1.5.4. Topography

The study site (latitude 42° 30' S, longitude 146° 20' E) consists of a gently sloping terrain with small hills interspersed with level plains. The Gordon river meanders along the eastern and southern side, to the west side lies lake Gordon and to the east lies the Florentine Valley. The sites are described in detail in Jordan et al. (1992).



Plate 1.1. Physiognomy of the mixed forest study sites in South West Tasmania.
Eucalyptus regnans seedlings grow along the road.

A group of mountains dominate in this area. From North to South the main mountains include Mt. Mueller and Mt. Bowes, Mt. Wedge and the steep slopes of the Tiger Range to the West side.

1.5.5. Geology and Soil

The geology of the study site, following Boulter (1978) and Jarman *et al.* (1991), comprises mainly Precambrian Quartzite Gordon Group sediments (an alternating sequence of limestone, sandstone and conglomerate), Cambrian mudstones including some volcanics, and alluvium of Quaternary to recent age (Fig. 1.10).

Edaphic characteristics are largely determined by the underlying parent rock. For example, dolerite weathers to produce a relatively fertile clay rich 'yellow podzol'; and quartzite gives rise to a relatively poor skeletal soil. Peat development in this area was observed to be minimal, owing to the recent firing.

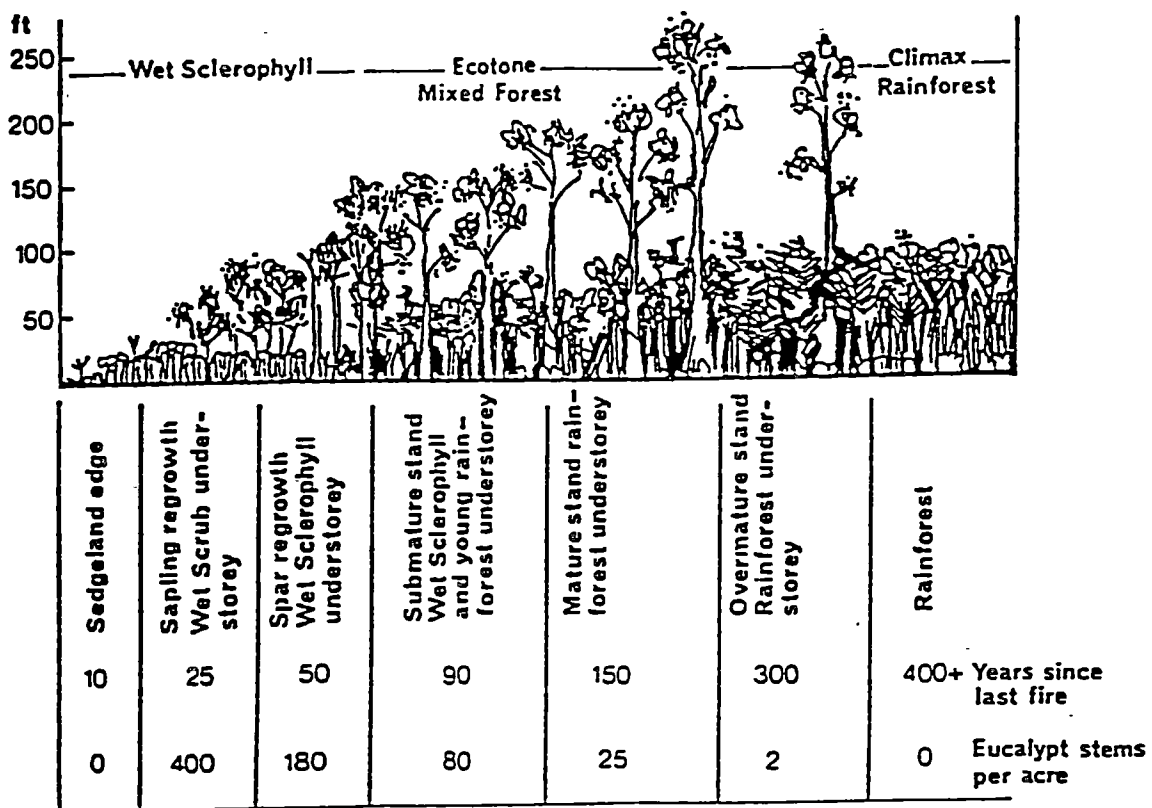


Fig. 1.1 Ecological Drift (Source: Jackson 1968)

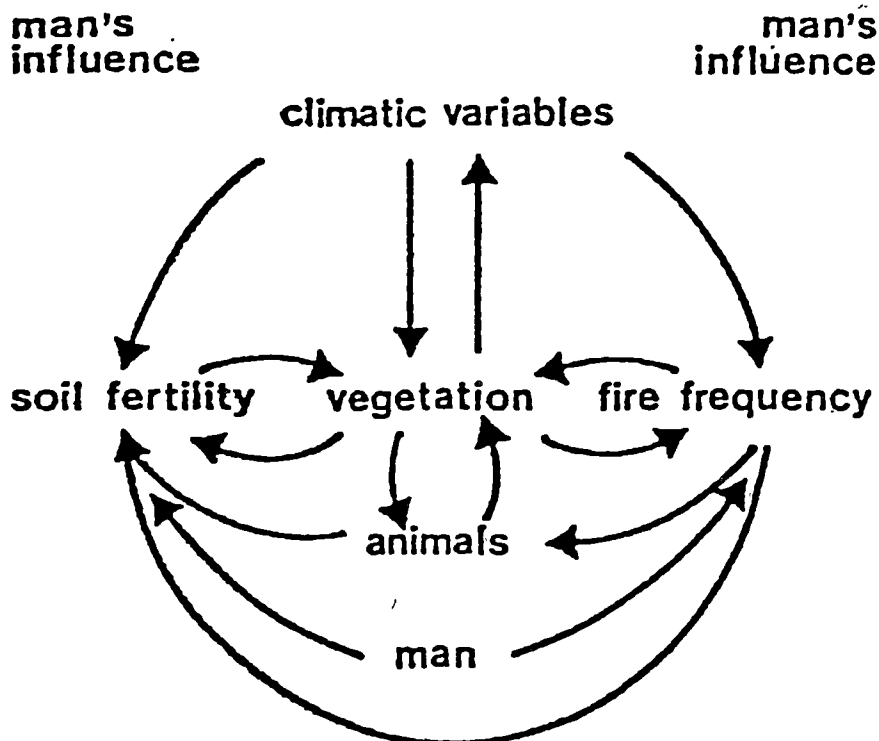


Fig. 1.2 Interactions determining vegetation type (after Jackson 1978)

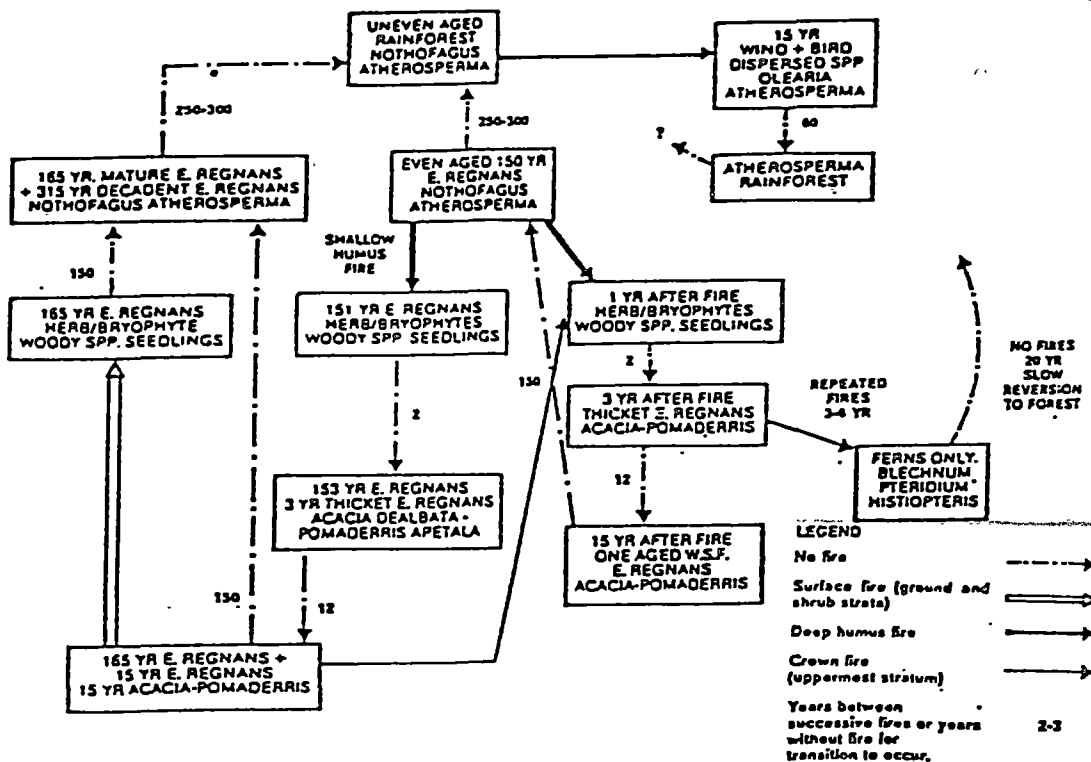


Fig. 1.3. A model impact of fire on tall forest in Tasmania (after Ashton 1981).

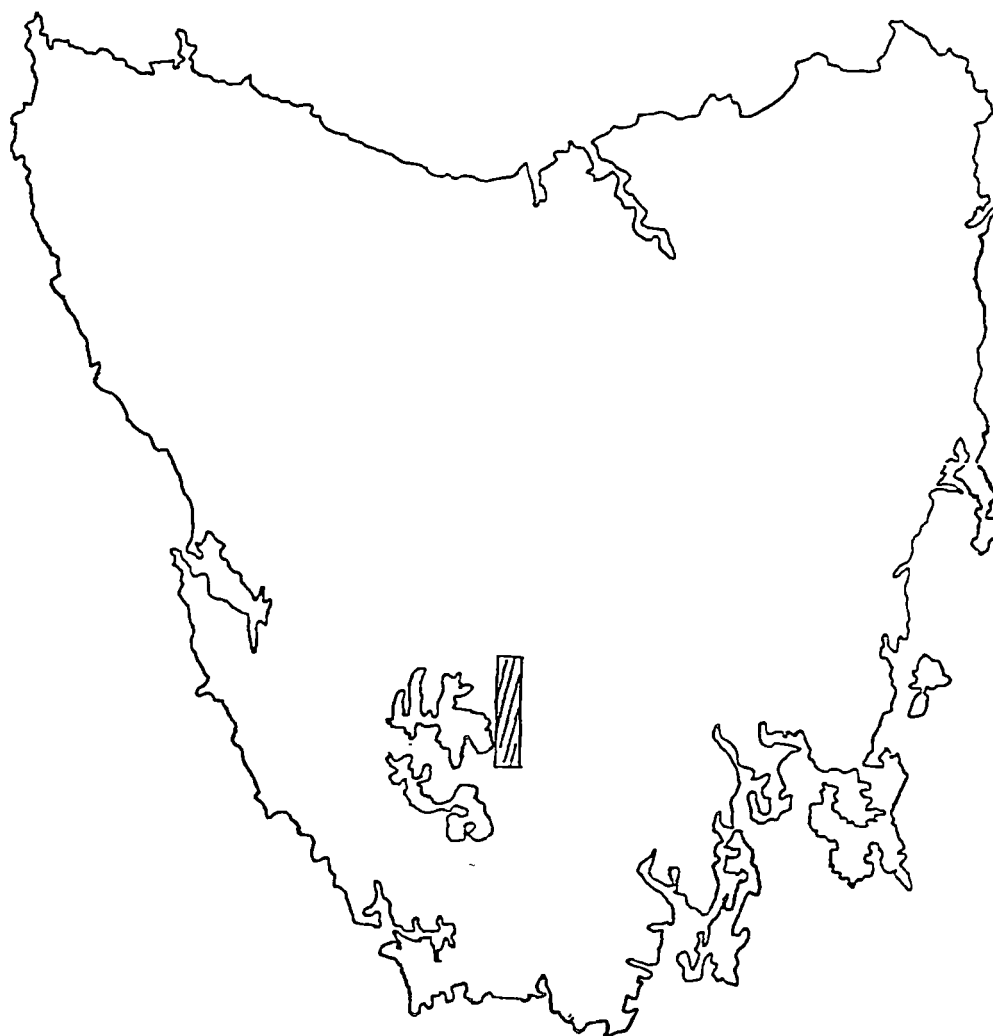


Fig. 1.4 Location of coupes surveyed, logged sites in South West Tasmania

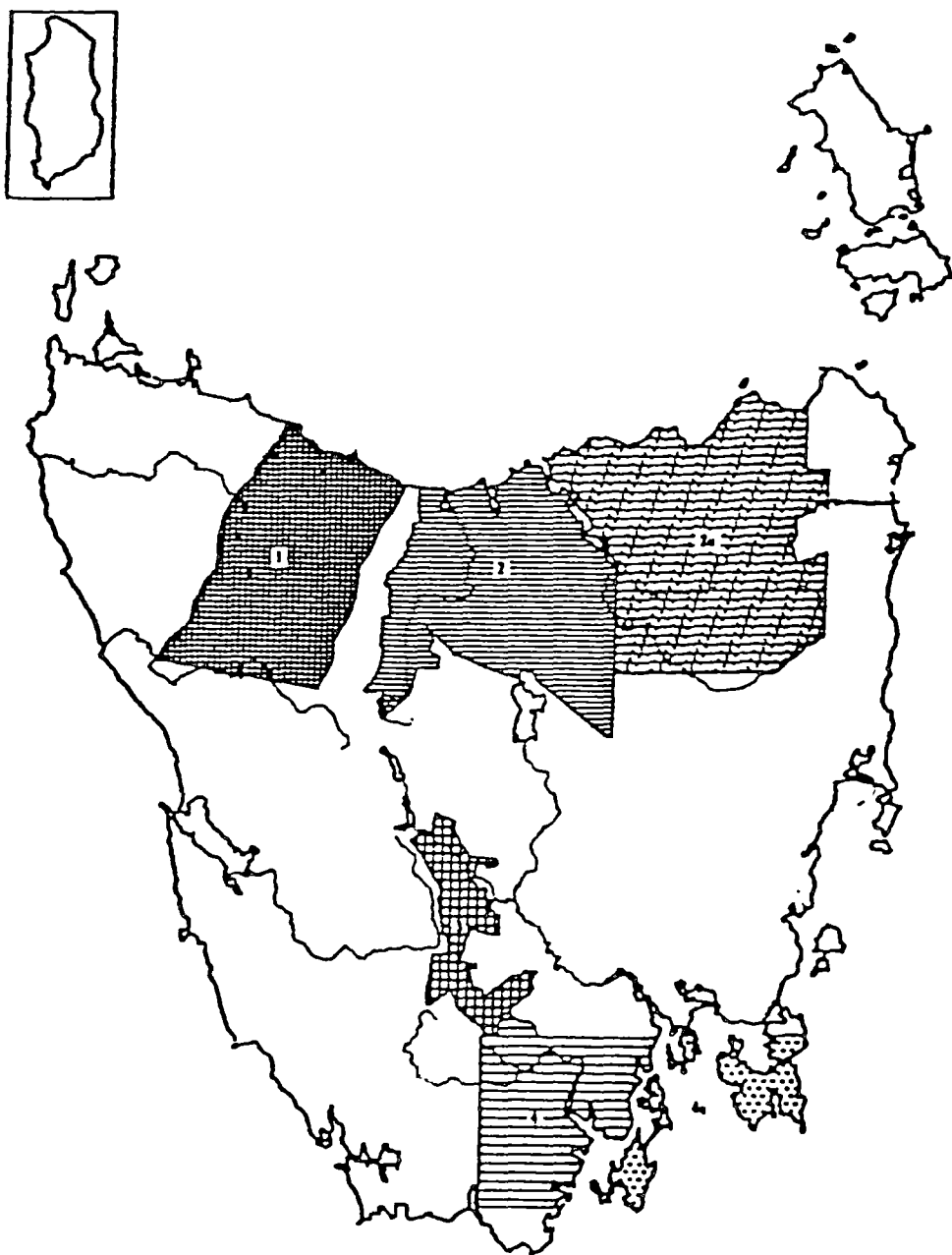


Fig. 1.5 Disposition of timber concession area (after Gilbert 1965)

- 1. Fine writings and printings
- 2 & 2a. Reserve area
- 3. Newsprint
- 4 & 4a. Pulpwood

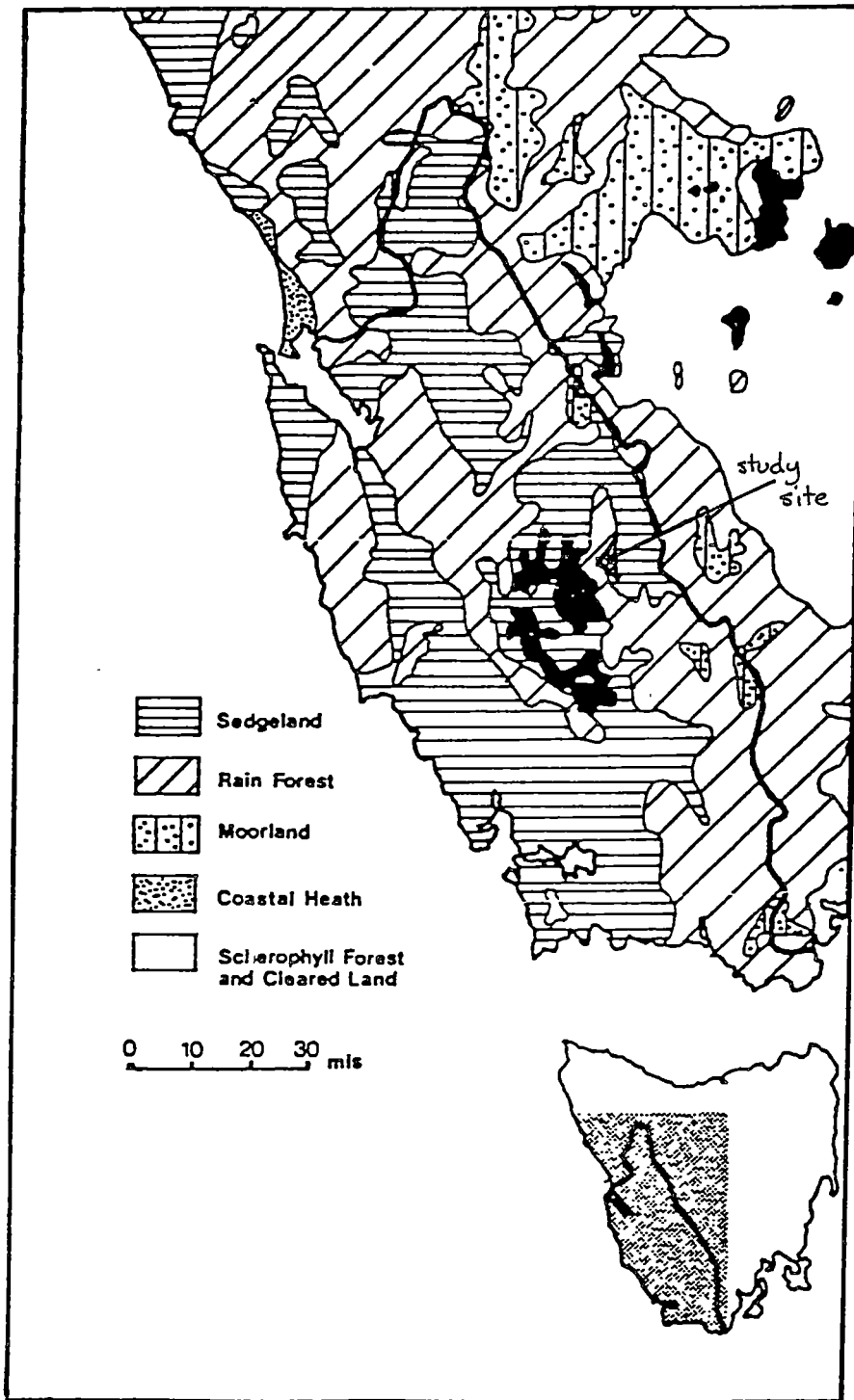


Fig.1. 6. Vegetation map of South West Tasmania.

Source: Vegetation map of Tasmania
Tasmanian Atlas, Davies (1965)

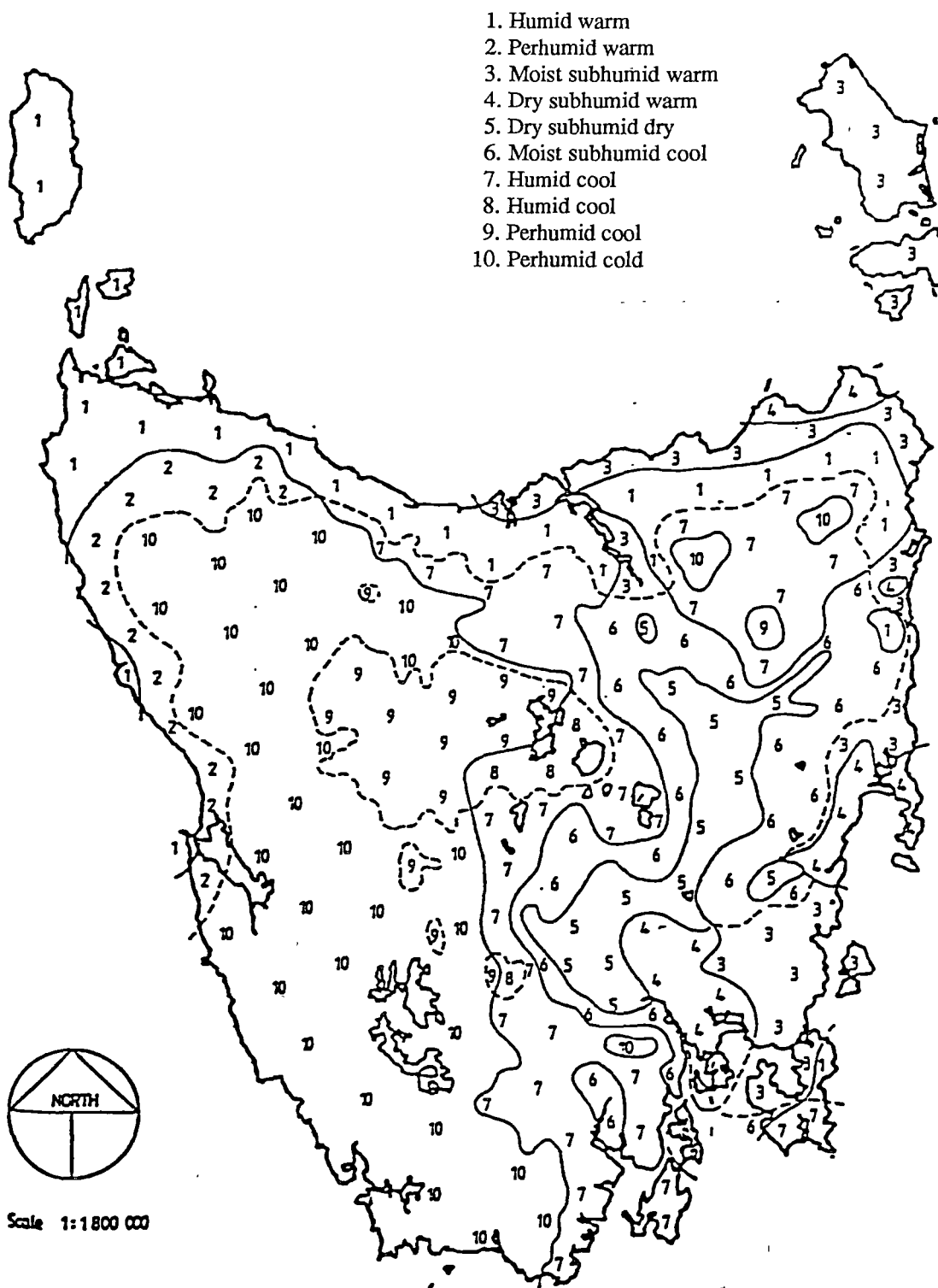


Fig. 1.7. Tasmanian climatic zones (after Gentili 1972)

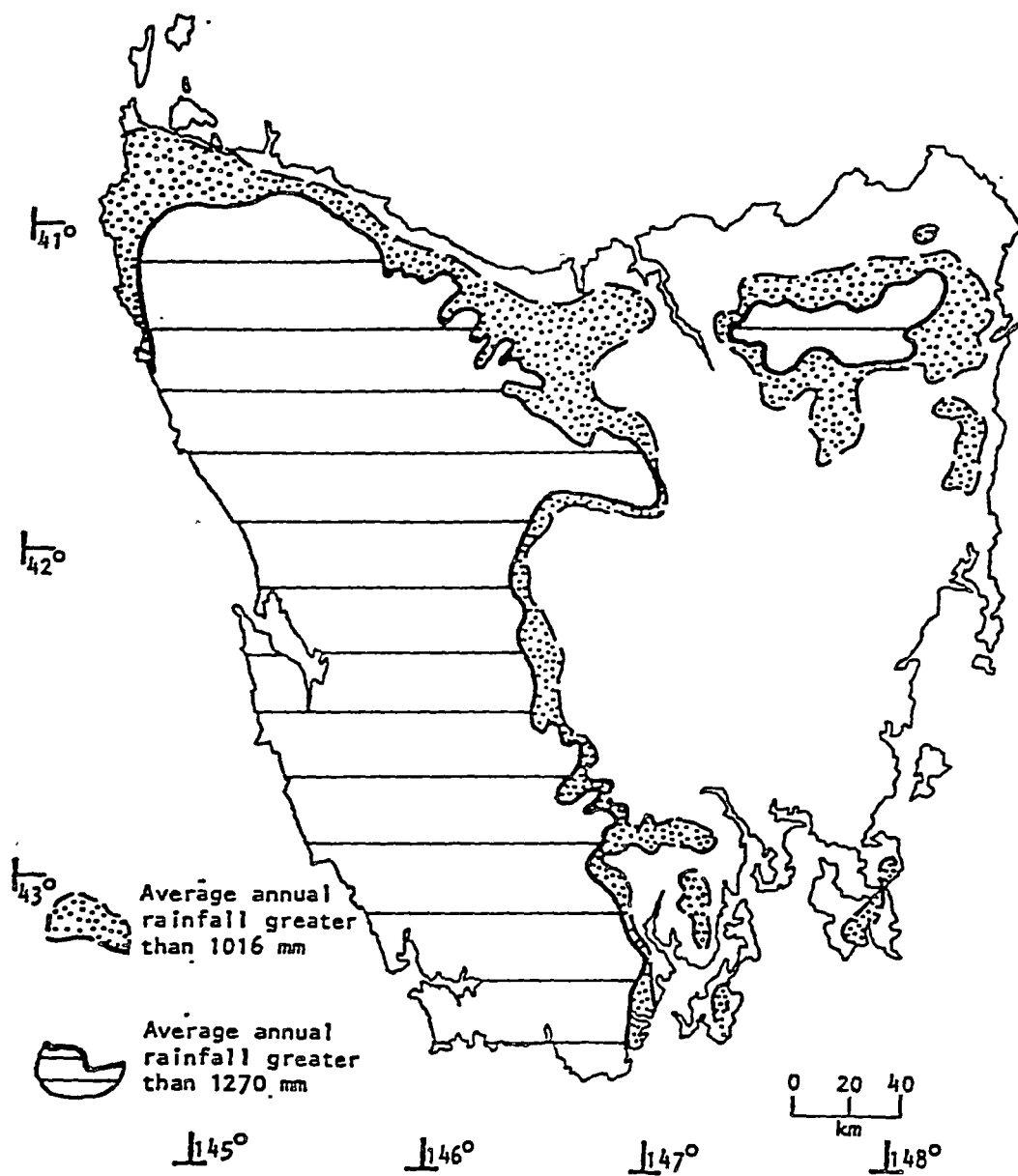


Fig. 1.8. Distribution of annual rainfall in Tasmania (after Gentili 1972)

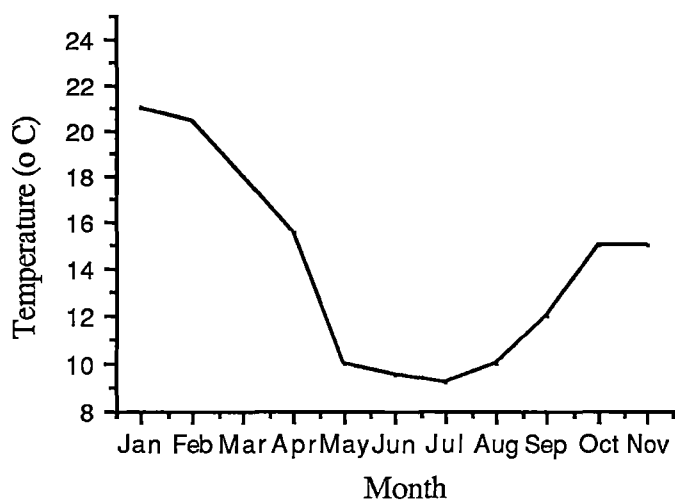


Fig. 1.9a Average daily maximum temperature, recorded at Strathgordon.
(Source: Boulter 1978).

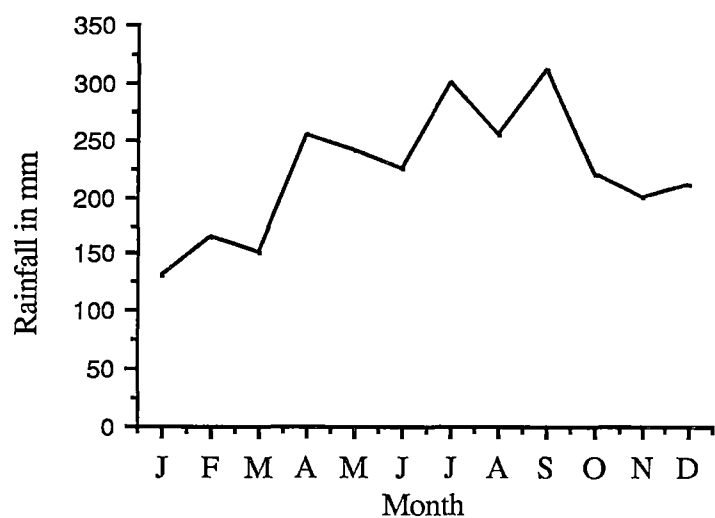


Fig. 1.9b Average monthly rainfall in mm, recorded at Strathgordon.
(Source: Boulter 1978)

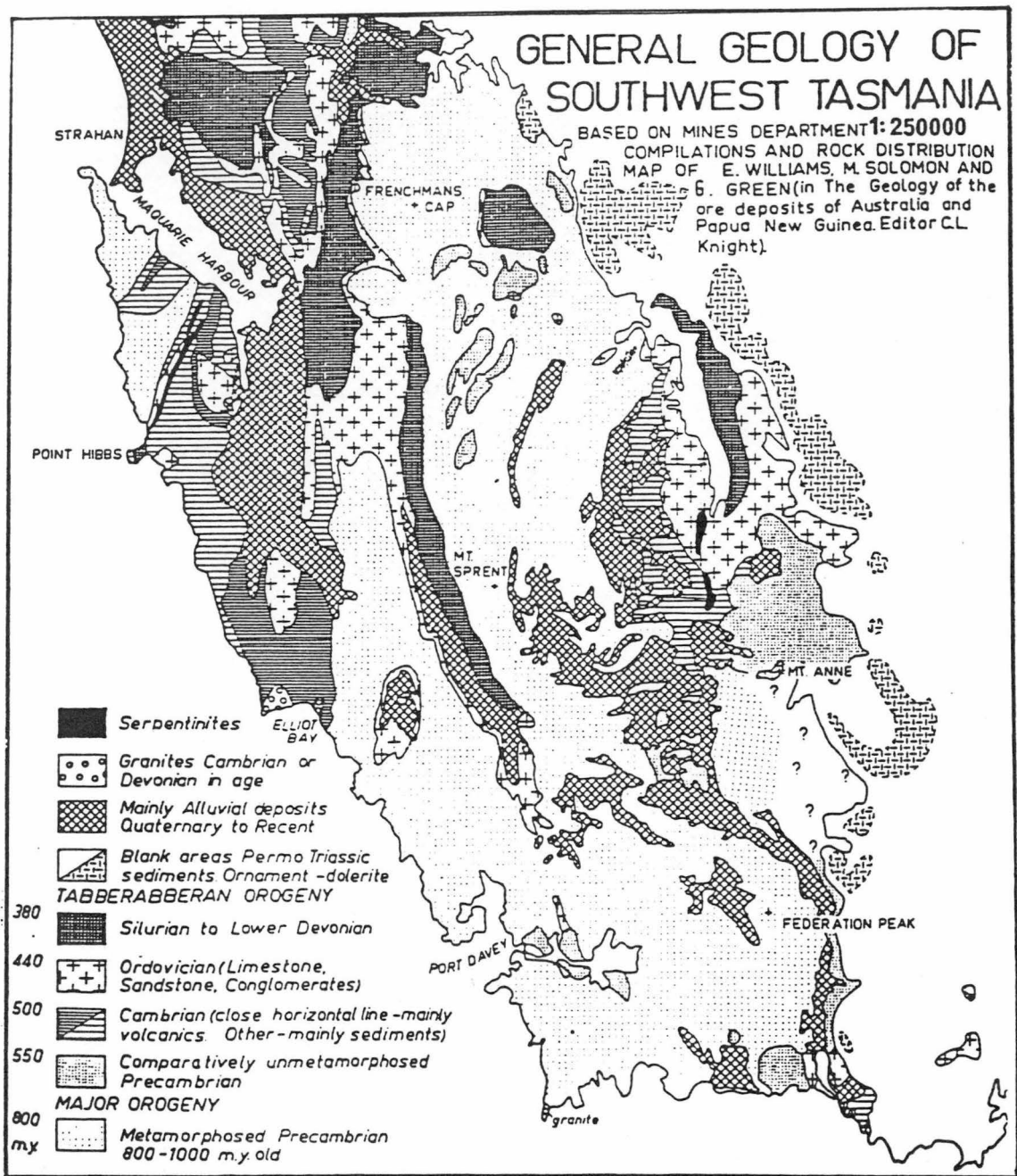


Fig. 1.10 Geology of South West Tasmania (after Jarman *et al.* 1991).

REGENERATION PATTERNS OF TREE SEEDLINGS

2.1. Introduction

The strong effect fire has on forest regeneration has been investigated by a number of workers (Maissurow 1941; Vannoorf 1960; Jacobs 1955; Wallace 1966 and Loneragan 1986). The regeneration of eucalypts has become an important research area for ecologists and foresters in Australia's forests particularly after fire (Purdie 1975; Morgan 1988 and Christensen and Abbot 1989). Fire is known to be a major factor controlling the distribution and type of forest (Jackson 1968). Fire changes the floristic structure and composition. As mentioned in chapter one, most research which has been conducted has focussed in the regeneration of *Eucalyptus* for economic reasons, because eucalypts are the main tree genus and represent a large portion of Australia's forests.

An increasing proportion of the forest land in Tasmania is being managed by clearfelling, slash burning and aerial seeding following logging activities. This aesthetically unpleasant procedure was devised for eucalypt forests with dense shrub, or tree understories, where it has some ecological justification (Gilbert 1959; Cunningham 1960; Jackson 1968). Very little research has been conducted on the impact that slash and burn systems have on native vegetation types. Few works exist where comparisons have been made between regeneration on unlogged and logged sites with and without fire.

A number of investigators have studied the regeneration pattern of South West Tasmanian forest, especially natural regeneration of rainforest after fire (Peter 1978; Barker 1990; Jarman *et al.* 1991). The vegetation of South West Tasmania is strongly influenced by fire. Without fire dominating the vegetation, plant communities would be expected to consist almost entirely of rainforest communities. Exceptions to this would be relatively few (Peter 1978).

The works of Gilbert (1959), Jackson (1965, 1968a, 1968b); Kirkpatrick (1977a, 1977b); Kirkpatrick *et al.* (1976); Harwood and Jackson (1975) discussed, both generally and specifically, the effect which fire has on the development of the structural formation and the floristic composition of South West Tasmanian vegetation, including the importance of the ash bed effect.

Following Jordan (unpub.) it is hypothesized that the forms of disturbance caused by logging and the regeneration practises of the forestry industry in Tasmania differ significantly from wildfire. Furthermore, Jordan (unpub.) noted that knowledge of regeneration of rainforest species after logging is valuable :

1. For conservation reasons. Mixed forest is an important vegetation type in Tasmania and one under pressure from forestry activities.

2. In understanding the regeneration of potentially valuable tree species. Myrtle (*Nothofagus cunninghamii*), Celery Top Pine (*Phyllocladus aspleniifolius*) and Sasassfras (*Atherosperma moschatum*) are valuable timbers and Leather Wood (*Eucryphia lucida*) is one of mainstays of the honey industry. They are major species in the understorey of mixed forest in this area. Black-wood (*Acacia melanoxylon*) and Silver Wattle (*Acacia dealbata*) both provide valuable timber and occur in both mixed forest and wet sclerophyll forest. However other wet sclerophyll forest species do not have economic or other values. Hence, excluding the eucalypt component, mixed forest is likely to be more valuable than wet sclerophyll forest.

3. For aesthetic reasons. Mixed forest is considered by many to be more attractive than wet sclerophyll forest.

2.2. Materials and Methods

The study commenced in March 1990. The sampling technique used was the transect method, where at each site transects were placed along gradients following the procedure outlined by Tansley (1946); Muller and Dombois (1974) and Moore and Chapman (1986). All data are presented in the appendices.

The study was carried out on a logged area, which lies on the Clear Hill-Ragged Range. Eight sites were selected: coupes W2, W2B2, W2B, W3A, W6, W8, W9A and the remaining old forest (undisturbed mixed forest) around this area was used as control. The area chosen occurred on two rock types ^{has} and different fire histories (age after fire). Data from old forest, unburnt logged areas, before and after clear-felling and selectively logging areas were collected.

Quadrats were located along transects at 25 m intervals along parallel lines, 100 m or 200 m apart in large sites and 50 m or 75 m in small sites.

Three types of quadrat were used: circles with areas of 4 m² and 16 m² were employed to study seedling regeneration at logged forest sites (Lockett unpub.) and 100 m² circles were used in the vegetation survey at old forest sites (after Oosting 1956). In each of the logged forest coupes, the species present were listed and regeneration status of *Eucalyptus regnans* F. Muell., *Nothofagus cunninghamii* (Hook.) Oerst., *Atherosperma moschatum* Labill., *Eucryphia lucida* (Labill.) Baill., *Phyllocladus aspleniifolius* (Labill.) Hook. f., *Acacia melanoxylon* R. Br. and *Acacia dealbata* Link were recorded for each species

as either: (1) present in a 4 m² circle ; (2) present in a 16 m² circle including the 4 m² circle; or (3) absent from the 16 m² circular quadrat. Regeneration refers to seedlings of any size, advanced growth or vegetative growth. Following Lockett (unpub.), "understocked" implies that there are not enough plots containing sufficient seedlings for even regeneration. Quantitative measurements of the vegetation present in each quadrat were made, including the largest ^{stem}/diameter/ ^{at the base} the tallest individual, density and percentage ^{canopy}/cover. The diameters of trees were measured at 1.3 m above ground level (Myer and Shelton 1980; Avery and Burkhat 1983).

Each quadrat was classified according to fire intensity, rock type and effects of machinery.

1. Fire intensity was classified as :

- a. unburnt
- b. low intensity
- c. moderate intensity
- d. high intensity

Fire intensity was recorded either at each quadrat from the amount of charring and litter size, or when this information was unavailable, descriptions were obtained from the Forestry Commission burn officer responsible. First hand observations have the potential to be biased by vegetation types, but correlated well with the records of the burn officer. Burn officer records are less specific than personal observations, and thus quadrats along fire boundaries described by this method have been excluded. Burn officer records do not allow for patchiness in burns, which is particularly apparent in low intensity fires.

2. Rock types were either

- a. Mudstone (M) or
- b. Quartzite (Q)

The basal rock types were used to give an idea of the soils on which regeneration was occurring. They were described for each quadrat, at the time of the survey, or by inspection of the coupes and comparison with coupe maps. Quadrats along rock type boundaries described by the fire officer records were excluded due to the potential for misinterpretation of results.

At the time of the survey it was noted whether quadrats were located on tracks, roads, landing areas, turning bays, quarries or if they were in unlogged areas or areas which had since been reburnt.

Estimates of percentage cover were obtained from records of all the species encountered in a downward, vertical projection at each point and these were expressed in terms of percentage cover for every species. Cover was then estimated by eye.

The height of trees was measured using a clinometer, first as a standard and then by visual estimates due to the time consuming nature of clinometer measurement. Density was defined as the average number of plants per unit area (Oosting 1956; Kershaw 1973; Muller and Dombois 1974; Myers and Shelton 1980).

A list of common plant names used in the text is given with their scientific names in Appendices 1 to 8. Scientific names follow Curtis and Morris (1963, 1967, 1975) and Wakefield (1975).

2.3. Analysis of Data

The data from this work was analyzed using quantitative and descriptive methods.

Results of the regeneration survey were tested^{using a correlation coefficient} at two levels of significance, 0.01 and 0.05 to show more or less high correlation. Frequencies of quadrats containing regeneration of each taxon within treatment classes were calculated (for

example, the frequency of unburnt 16 m² quadrats on mudstone containing eucalypts), when expressed as a percentage they are referred to as stocking rate. Statistical test using the Analysis of variance (ANOVA) following quantitative analysis were made between sites.

Selected subsets of data were analyzed, this included testing the groups of classes and paired comparisons of classes. Rainforest species were analyzed both as a group and separately, where appropriate contingency tests between factors were made. Distribution patterns of species on each transect were qualitatively presented. Community indices for six different logged sites were made between mixed forest sites (control) and each logged site. Community index was based on the methods of Sorensen (1948) (cited in Muller-Dombois and Ellenberg 1974), which compares the floristic similarity of two sites based on species presence or absence, to examine changes in floristic composition as a result of different logging activities. The formula follows as :

$CC = (2c/a+b) \times 100\%$, where :

a = total number of species in the mixed forest site.

b = total number of species in the logged site

c = number of species common to the two sites

CC is the index of similarity, where CC is less than 50% , this shows there are differences between two plant communities.

2.4. Results

2.4.1. *Regeneration of Tree Seedlings on Mudstone Sites*

Figs. 2.1- 2.7 show the stocking rate of each species in 16 m² quadrats for different sites, while Figs.2.8 - 2.14 show the mean seedling number of each species

in the same quadrat size. 4 m² stocking rates are recommended by the Tasmanian Forestry Commission to assess the quality of regeneration of eucalypts (Lockett unpub.), however, in this study the 16m² stocking rate was used instead of 4m². Using 4 m², the stocking rate was often too low for minor species to be used to separate treatment classes statistically (Jordan, unpub.). 4m² quadrats were used to record the presence or absence of species in the study sites. The results will be discussed in next chapter.

Regeneration of rainforest species was significantly lower in burnt sites compared to unburnt sites. In contrast, *Eucalyptus regnans* had significantly lower regeneration rates in unburnt sites compared to burnt sites. Unburnt logging sites support excellent regeneration of *Eucryphia lucida*. A similar result was found in work done previously (Blakesley 1978; Hickey 1981, 1982, 1983 and Neyland 1983).

Most seedlings of rainforest species were found in quadrats with less dense herb and shrub cover. The ground coverage consisted of more than 20% mosses (Plate 2.1). There is evidence that a positive association occurs between rainforest species and mosses. A negative association occurs between ferns and shrubs. Rainforest species are found clumped in the quadrats along the boundaries between logged sites and mixed forest sites.

Unlogged Mixed Forest

These sites were used as a control. From Figs. 2.1 and 2.8, it can be seen that the stocking rate of rainforest seedlings is much higher than for *Eucalyptus regnans*. Based on seedling number, *Eucryphia lucida* had the highest stocking rate, followed by *Atherosperma moschatum* and *Nothofagus cunninghamii*.

Rainforest species had ^{significantly ($p > 0.05$)} greater mean seedling number/quadrat/ ^{than *E. regnans*} *Nothofagus cunninghamii* has the highest seedling number per quadrat (14.3/16 m²) followed by *Eucryphia lucida* (5.8/16 m²) and *Atherosperma moschatum*. (5.3/16 m²) *Phyllocladus aspleniifolius* has a low mean seedling number (1/16m²) , which suggests that this species has lower regeneration rates than other rainforest species. The *Eucalyptus* species do not successfully regenerate under the canopy in these sites.

Nothofagus cunninghamii had the highest tree density (193/ha), followed by *Atherosperma moschatum* (143/ha), *Eucryphia lucida* (133/ha), *Phyllocladus aspleniifolius* (23 /ha) and *Eucalyptus regnans* (30/ha). The total number of trees on this sites is 523 / ha. (Table 2.1).

The density of adult trees in this site is 30/ha, with stocking rate as low as 15%/16m². Rainforest species reach 100% stocking rate with *Nothofagus cunninghamii* having the highest stocking rate (70%), followed by *Eucryphia lucida* and *Atherosperma moschatum* (50%). *Phyllocladus aspleniifolius* has the lowest stocking rate (15%).

Selected Logging Sites

^{Regeneration on} This site is similar to the mixed forest sites in that rainforest species have a higher proportion of regeneration than eucalypts, (100%), with *Eucryphia lucida* having the highest stocking rate (87%), followed by *Nothofagus cunninghamii* (50%) and *Atherosperma moschatum* (28%). *Phebalium squameum* was present on this site with higher mean seedling number than *Eucalyptus regnans* whilst other species in these site have a similar value.(Figs. 2.1 and 2.9)

Table 2.1 Characteristics indicating distribution and dominance of mixed forest species. Relative frequency (RF), relative dominant (RDo), density (RDe) and importance value (IV) is shown for *E. regnans* (diameter ≥ 10 cm). Data 100m² quadrats, at mixed forest sites.

Species	:	RF(%)	:	RDo(%)	:	RDe(%)	:	IV(%)
<i>N. cunninghamii</i>	:	29.70	:	45.33	:	36.94	:	111.97
<i>A. moschatum</i>	:	26.40	:	10.38	:	27.39	:	64.17
<i>E. lucida</i>	:	26.40	:	9.64	:	25.48	:	61.52
<i>E. regnans</i>	:	9.90	:	32.21	:	5.73	:	47.48
<i>P. aspleniifolius</i>	:	7.59	:	2.42	:	4.46	:	14.47

There is a significant difference ($p < 0.05$) in mean seedling number per quadrat between rainforest species and *Eucalyptus regnans*, however, *Eucalyptus regnans* regenerated better on selectively logged sites in the absence of the forest canopy. *Acacia* spp. were absent on selectively logged sites as they were on mixed forest sites.

Unburnt Site (1 Year After Clear-felling)

Data collected from unburnt sites is similar to those in the mixed forest and selectively logged sites, with the stocking rate of rainforest species being higher than *Eucalyptus regnans* (60%), *Acacia melanoxylon* (20%), and *Acacia dealbata* (17%). Rainforest species reach 100% stocking rate (Fig.2.3). Of the four rainforest species, *Eucryphia lucida* had the highest stocking rate (78%) followed by *Atherosperma moschatum* (74%) and *Nothofagus cunninghamii* (68%). *Phyllocladus aspleniifolius* had relatively a low stocking rate (20%).

Rainforest species had a relatively large seedling number per quadrat (30/16m²) with *Atherosperma moschatum* having the greatest mean seedling number

(13), follow by *Nothofagus cunninghamii* (11), *Eucryphia lucida* (10) and *Phyllocladus aspleniifolius* (3) (Fig. 2.10).



Plate 2.1. *Nothofagus cunninghamii* seedlings regenerate well in quadrats less densely covered by herbs and shrubs cover.



Plate 2.2. Sites one year after clear-felling. The community lost some species, *Eucalyptus regnans* seedlings grow together with rainforest species.

Most regeneration ^{in all species} occurred from seed (90% of stems less than 2 cm in diameter were seedlings).

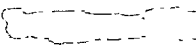
Eucalyptus regnans regenerated better than in the mixed forest sites and selectively logged sites which suggests that bare ground is required for the establishment of *Eucalyptus regnans* seedlings (Fig. 2.2).

Sites After Fire (2,5,7 and 9 Years After Fire)

Stocking rate and mean seedling number are shown in Figs. 2.4 - 2.7 and 2.11-2.14). These results indicate that a higher proportion of the 16 m² quadrats on the unburnt site supported regenerating rainforest species.

Eucalyptus regnans had higher stocking levels on burnt sites, and quadrats with medium or high fire intensity had a higher proportion than those quadrats subjected to low intensity burns. However, stocking rate of *Eucalyptus regnans* does not appear to be affected by the time after the fire (5,7 and 9 years after burning).

Nothofagus cunninghamii, *Eucryphia lucida* and *Atherosperma moschatum* had their highest regeneration rates on sites subjected to low fire intensities or on unburnt sites compared to sites subjected to medium or high fire intensity.

 *Phyllocladus aspleniifolius* had a lower stocking rate than other rainforest species in this area. However, the data from some sites are too small to statistically analyze differences in the regeneration of this species.

(1) Two years after fire

On these sites rainforest species have higher stocking rates (50%) in unburnt quadrats, stocking rates decrease to less than 20% in quadrats subjected to low fire intensity and the species are absent in quadrats with moderate to hot fire. Between the

rainforest species present on these sites, *Nothofagus cunninghamii* had the highest stocking rates in both unburnt quadrats and quadrats subjected to low fire intensities, *Eucryphia lucida* and *Atherosperma moschatum* had similar values for stocking rates, which indicates that *Nothofagus cunninghamii* was more common on this site.

Based on the mean seedling number per quadrat different patterns of seedling regeneration are apparent. *Eucryphia lucida* had a higher mean seedling number than *Nothofagus* in unburned quadrats, which indicates that *Eucryphia lucida* is clumped in its distribution patterns in some quadrats and as a consequence has a lower stocking rate. *Atherosperma moschatum* had low seedling numbers in both ^{the} unburnt quadrats and those subjected to low fire intensity.

The regeneration pattern of *Eucalyptus regnans* is relatively similar when results are expressed in terms of stocking rate and mean seedling number, but it is different to the pattern of the rainforest species. The stocking rate of *Eucalyptus regnans* increased with increase in the intensity of fire. Results from quadrats with low and medium fire intensities tended to support the hypothesis that they are the best fire intensity for regeneration (Fig.2.4). No significant difference was found in mean seedling number between different ^{intensities} of fire (Fig.2.11).

Although seeds of *Eucalyptus regnans* were artificially sown ^{on all sites}, there is evidence that rainforest species in general had highly significant differences ($p < 0.01$) in mean seedling number per quadrat in unburnt quadrats. In contrast, the mean seedling number of rainforest species in burnt quadrats was significantly lower than *Eucalyptus regnans*. This indicates that fire is inhibitory for regeneration of rainforest species and promotes regeneration of *Eucalyptus regnans*.

Phebalium squameum is the only wet sclerophyll species present on these sites. It exhibits a similar pattern to the regeneration of *Eucalyptus regnans*. *Phebalium squameum* was found in quadrats subjected to all levels of fire, which

suggests that this species possesses a wide tolerance range to fire (Fig.2.4).

(2) Five years after fire

The data collected on sites five years after burning indicate similar trends to that found on sites 2 years after fire. Rainforest species have the highest stocking rate in unburnt quadrats, significantly higher than *Eucalyptus regnans*. Rainforest species regeneration occurred in all levels of fire intensity, which suggests that rainforest species regenerated better on burnt sites with time since burning. There are five rainforest species and there are additional wet sclerophyll species, *Acacia dealbata* and *Acacia melanoxylon* on this site (Fig.2.5).

Eucryphia lucida, *Nothofagus cunninghamii* and *Atherosperma moschatum* have similar stocking rates and mean seedling numbers, which are higher on unburnt quadrats than burnt quadrats. However, no significant difference between the majority of rainforest species was apparent in mean seedling number mean seedling from low to medium fire intensity. This shows that after five years, seedlings had the same response to different fire intensities (Fig.2.12).

The stocking rates of *Eucalyptus regnans* indicate slight change with changes in the level of fire and time after burning, with low fire intensity sites having the highest stocking rate. In terms of mean seedling numbers, *Eucalyptus regnans* from low to hot fire intensity, had similar values (Figs. 2.5 and 2.12).

Phebalium squameum had a higher stocking rate and mean seedling number than the rainforest species in all levels of fire intensity, which suggests it is more competitive in burnt quadrats. Regeneration of this species occurred from seed (70%) and coppice (30%), while rainforest species were 80% from seed and 20% from coppice (except regeneration of *Phyllocladus aspleniifolius*, which was entirely from seed).

Regeneration data found on these sites is similar to that in site two years after fire, there is evidence that the seedling number of rainforest species is significantly greater than *Eucalyptus regnans* on unburnt quadrats ($p < 0.01$), but there is no significant difference from low to medium fire intensity. In quadrats with high fire intensity *Eucalyptus regnans* is significantly greater in mean seedling number than rainforest species.

(3) Seven years after fire

On these sites, stocking rate and mean seedling number per quadrat were found to be similar to those of sites subjected to fire five years ago. Rainforest species regenerate at all fire intensities on sites which have had a recovery period of five years, with unburnt quadrats having the greatest mean seedling number and a high stocking rate (Figs. 2.6 and 2.13). Only *Eucryphia lucida* and *Nothofagus cunninghamii* grow in quadrats subjected to moderate fire intensity, while *Atherosperma moschatum* is absent in quadrats subjected to moderate fire intensity and *Phyllocladus aspleniifolius* was only found in unburnt quadrats.

Regeneration of *Eucalyptus regnans*, based on stocking rate, shows that in quadrats subjected to low to high fire intensities, similar stocking rates occur, which reach the maximum regeneration rate (100%). Unburnt quadrats had a lower stocking rate (75%). Generally the stocking rate of *Eucalyptus regnans* in this site is higher than those in sites two years and five years after fire.

In terms of seedling number, the results were compared to results based on stocking rates. Mean seedling number of rainforest species is significantly greater in unburnt quadrats, and significantly lower in quadrats with high fire intensity (Fig. 2.13).

Phebalium squameum exhibits lower stocking rates and mean seedling

numbers per quadrat on sites seven years after fire, compared to sites five years after burning. This may be because the denser canopy on these sites would hinder the regeneration of *Phebalium squameum*. Other sclerophyllous species which are present on this site are *Acacia dealbata*, *Acacia melanoxylon*, and *Eucalyptus delegatensis*. *Acacia* species were found growing on quadrats near logged sites which had previously been wet ^{sclerophyll} forest with *Zieria arborescens* forming an understorey.

(4) Nine years after fire

In general, regeneration patterns of rainforest species were similar to those on sites burnt five and seven years ago. Rainforest species regenerated in all levels of fire intensity (with the exception of *Phyllocladus aspleniifolius*) and reached 100% stocking rate in unburnt quadrats. However, most of the rainforest species had decreased in mean seedling number, and were lower than mean seedling number on sites 5 and 7 years after fire. *Eucryphia lucida* and *Nothofagus cunninghamii* had similar stocking rates and mean seedling numbers, *Atherosperma moschatum* had a low stocking rate compared to those of *Eucryphia lucida* and *Nothofagus cunninghamii* (Figs. 2.7 and 2.16).

For *Phebalium squameum*, the regeneration pattern is also similar to those on sites five and seven years post-fire. Similar to the regeneration pattern of rainforest species, the stocking rate of *Phebalium squameum* increased on these sites but decreased in mean seedling number per quadrat. It seems the fast growth of *Eucalyptus regnans* influences the mean seedling number of tree species (Plate 2.3). Competition for space may become a limiting factor on this site, where with increasing duration after fire many seedlings established, especially *Eucalyptus regnans*, and consequently the capacity of the quadrats to carry a relatively large

number of seedlings has decreased.

Other species recorded on these sites are *Acacia dealbata*, *Acacia melanoxylon* and *Eucalyptus viminalis* which have relatively very low stocking rate and mean seedling numbers (Fig.2.7 and 2.16).

Acacia species

Three species of *Acacia* were found on the study sites, *Acacia dealbata*, *Acacia melanoxylon* and *Acacia mucronata*. These species were uncommon, as indicated by low stocking rates compared to other tree species. From observations on the remaining mixed forest sites, these species were absent, although from visual observations around the outside of the sample quadrats, some *Acacia dealbata* and *Acacia melanoxylon* trees were present, especially along the boundaries near the road and wet sclerophyll forest.

Acacia dealbata and *Acacia melanoxylon* were found on sites five, seven and nine years after fire, and also on clearfelled sites. *Acacia mucronata* was found only on sites 9 years after fire and with a relatively high stocking rate. *Acacia dealbata* and *Acacia melanoxylon* were found to regenerate well on quadrats which were either unburnt or subjected to low intensity fires.

2.4.2. Regeneration of Tree Seedlings on Quartzite Sites

Since too little data was collected from quartzite quadrats, no statistical tests were performed. However, from visual observations outside quadrat samples and according to some data collected from three sites (rainforest sites, sites five years and seven years old after burning), it was noted that unsuccessful regeneration of tree seedlings occurs on quartzite. This was indicated by the reduced number of species

and lower density of seedlings, compared to sites situated on mudstone rock type.

On quartzite at mixed forest sites, *Anodopetalum biglandulosum* was found to be an important species with its stocking rate reaching 100% and similarly mean seedling number per quadrat was high (Figs. 2.19-2.22).

No differences between stocking rates of *Eucalyptus regnans* on quartzite at different fire intensities were apparent. Stocking rate of rainforest species on quartzite burnt sites were higher than *Eucalyptus regnans*.

Nothofagus cunninghamii, *Eucryphia lucida* and *Atherosperma moschatum* had relatively similar stocking rates and mean seedling numbers.

Phebalium squameum regenerated well on quartzite five years after fire, in contrast this species was absent on mixed forest sites.



Plate 2.3. *Eucalyptus regnans* stand on burnt sites. *Eucalyptus regnans* grow faster than other tree species, and are dominant in burnt quadrats.

2.4.3. Regeneration on landing areas and snig tracks

Log - Landing areas were subjected to excessive disturbance due to soil disturbance caused by heavy machinery. This mixing of top soil has obvious consequences on the regeneration capacities of all the species were present. Further, the turnover of

soil would probably result in any young seedlings, vegetative root stocks able to support coppice, and seeds, being placed too deep in the soil stratum to successfully produce new growth.

The removal of timber ^{and soil compaction} along snig tracks, inhibits regeneration of most species, although observations made in the field, suggest that species of *Eucalyptus regnans*, *Nothofagus cunninghamii* and *Eucryphia lucida*, along with the understorey species ; *Histiopteris incisa* and herbaceous dicots, are able to regenerate to some extent. Since field data ^{are} too small from these quadrats, no statistical tests can be made. Presumably regeneration of these plants occurs ^{are} due to the close proximity of parental seed ^{or spore} stocks.

2.5. Discussion

a. Rainforest species

Rainforest species were found to regenerate on all sites, from mixed forest sites to burnt sites following logging. In mixed forest sites to clearfelled sites (unburnt sites), rainforest species regenerate successfully. However, different taxa form dominant species on sites subjected to different fire histories and logging practises. There is evidence that regeneration of rainforest tree species occurs immediately after logging, with their stocking rates and mean seedling numbers varying between sites. Environmental variation, especially habitat conditions resulting from fire intensity and recovery time after fire, seem to be essential factors determining the regeneration patterns since different species have different requirements for establishment. As a result, this influences the stocking rate and mean seedling number per quadrat. The ability of a species to regenerate is also ^{germination characteristics} related to other characteristics such as artificial seeding, seed dispersal ^{and growth} habit. Clearly species with wide tolerance ranges to environmental stresses will be

more successful at regenerating and re-establishing.

Positive associations between rainforest species and mosses are apparent, perhaps related to the ability of mosses to retain sufficient moisture for germination. Negative associations between rainforest species and ferns and shrubs exist, probably because of competition for light and soil nutrients.

In general, seedling regeneration clearly shows that rainforest species regenerate better on sites without fire (mixed forest, clearfelling and selectively logged sites). Rainforest species are more fire sensitive than *Eucalyptus regnans* and wet sclerophyll/^{understorey} species. However, there are some differences in requirements within this group, which account for the different stocking rates and/or number of seedlings found per sites. *Phyllocladus aspleniifolius* has the lowest stocking rate or mean seedling which suggests that this species regenerates poorly. *Nothofagus cunninghamii*, *Atherosperma moschatum* and *Eucryphia lucida* have better regeneration than *Phyllocladus aspleniifolius*. Several authors have noted the micro site preference for regeneration of rainforest species, for example *Atherosperma moschatum* requires shade for regeneration (Cremer and Mount 1965), but has reliable annual seed production, while *Eucryphia lucida* and *Nothofagus cunninghamii* are able to establish on a variety of substrata, including bare soil, and are commonly found in a forest after logging, even after low intensity burns. Previous researchers have found that *Phyllocladus aspleniifolius* and *Eucryphia lucida* are common on infertile soil. On this soil *Nothofagus* is less competitive than other rainforest species (Jackson 1965).

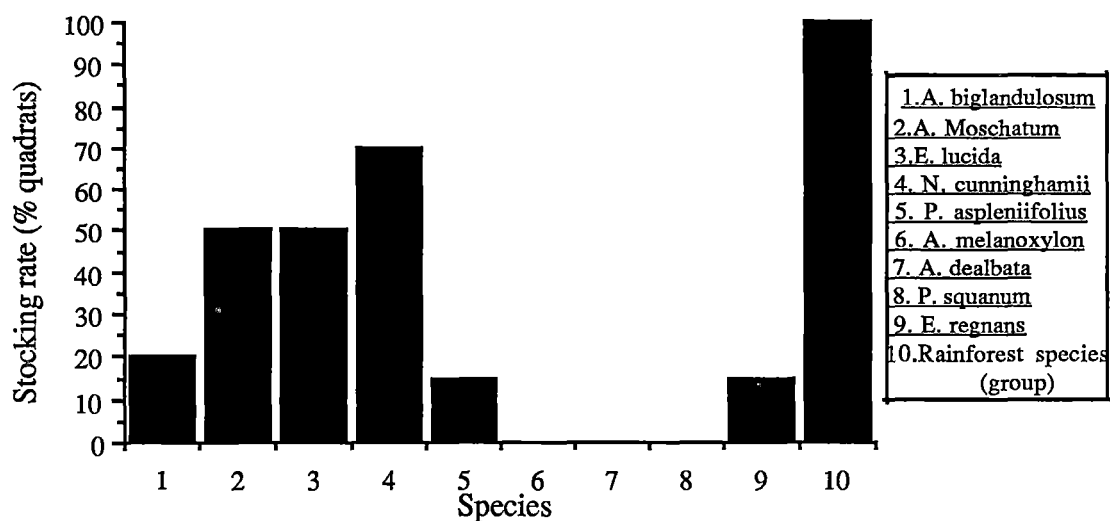


Fig. 2.1 Stocking rate for different species in 16m² quadrats in mixed forest sites, Clear Hill-Ragged Range South West Tasmania

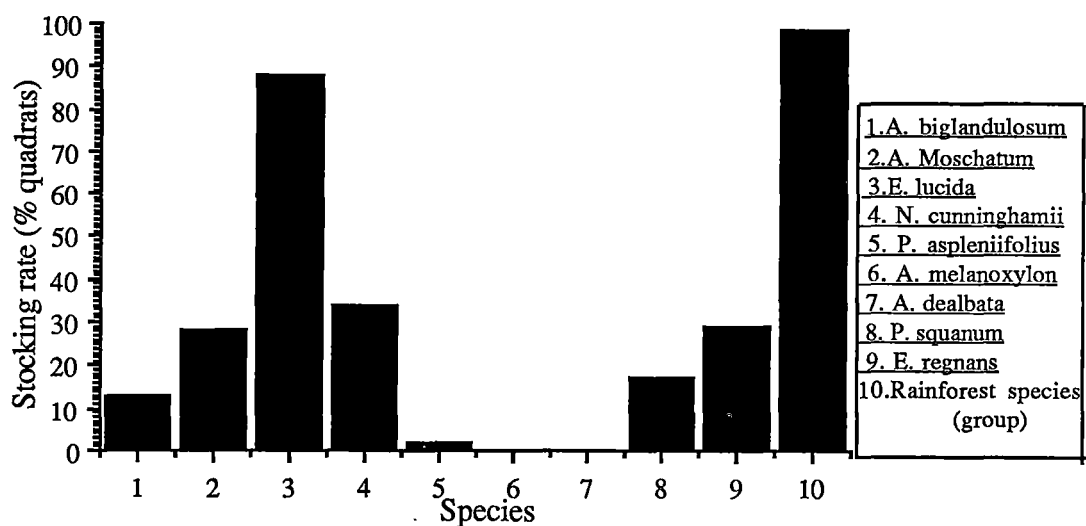


Fig. 2.2 Stocking rate for different species in 16m² quadrats at selectively logged sites.

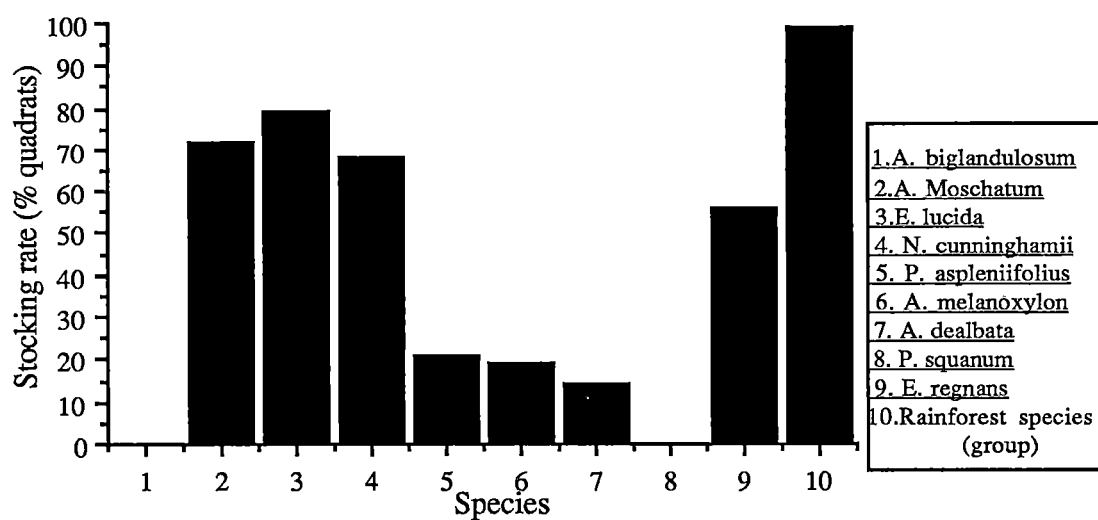


Fig. 2.3 Stocking rate for different species in 16m² quadrats at clear-felling sites.

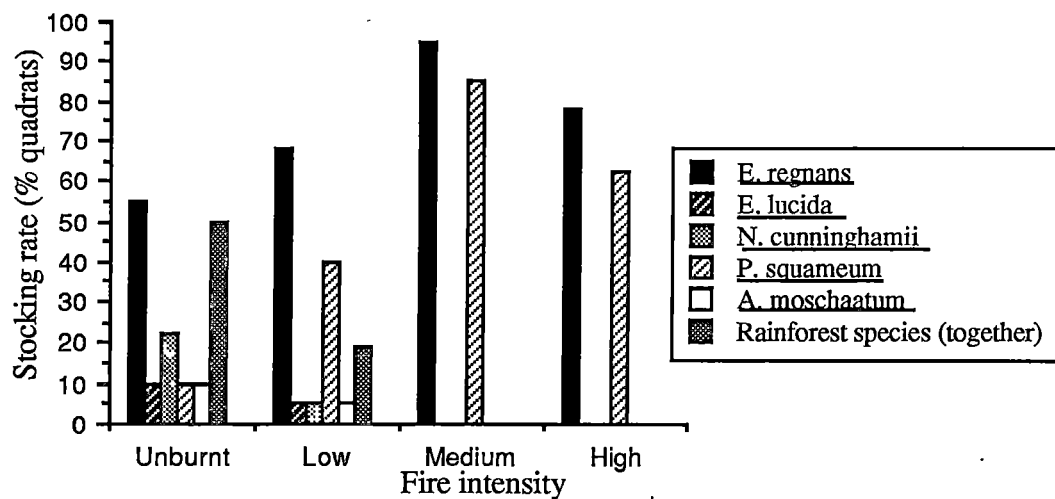


Fig. 2.4 Stocking rate for different species in 16 m², quadrats at different fire intensities on 2 years post fire sites.

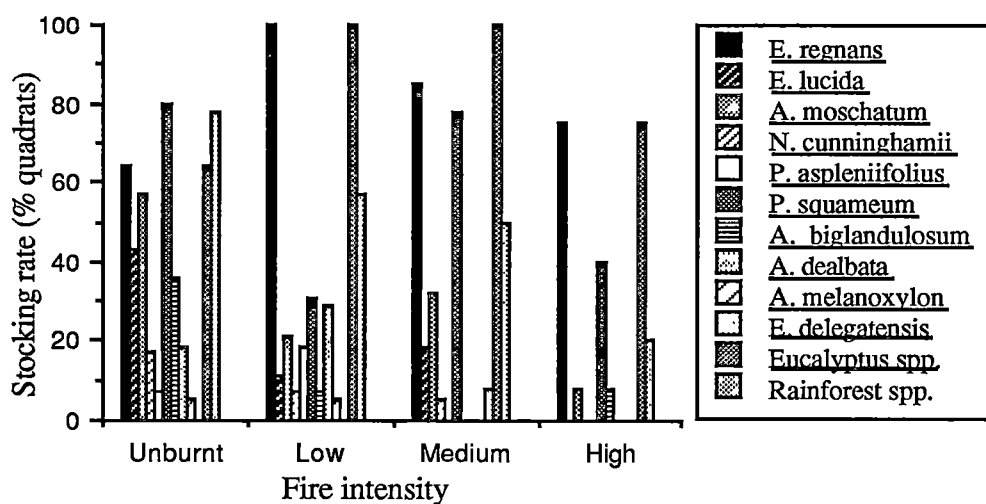


Fig. 2.5 Stocking rate for different species in 16 m², quadrats at different fire intensities on 5 years post fire sites.

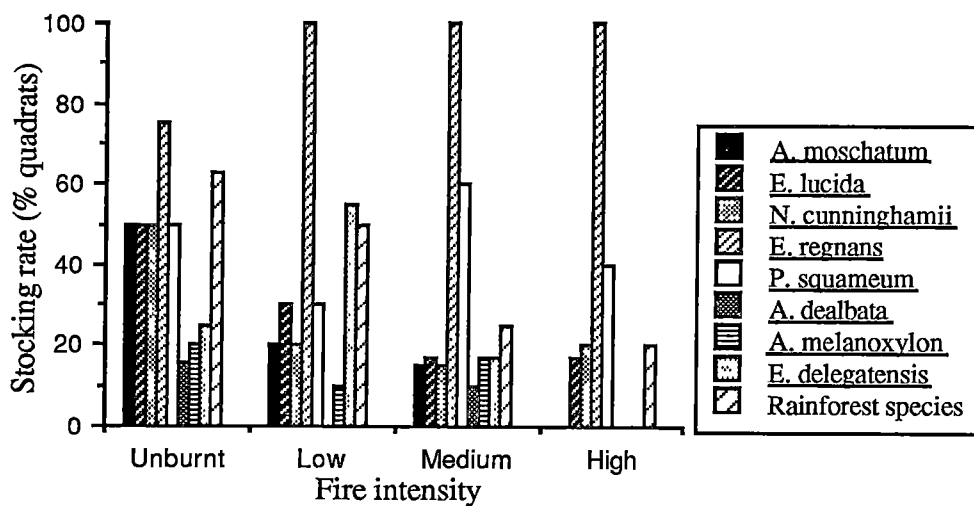


Fig. 2.6 Stocking rate for different species in 16 m², quadrats at different fire intensities on 7 years post fire sites.

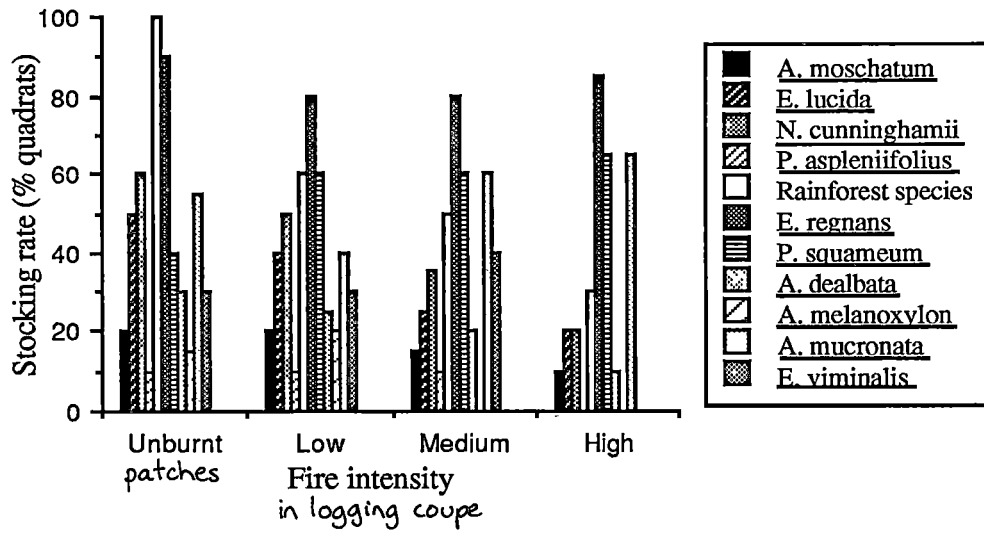


Fig. 2.7 Stocking rate for different species in 16 m², quadrats at different fire intensities on 7 years post fire sites.

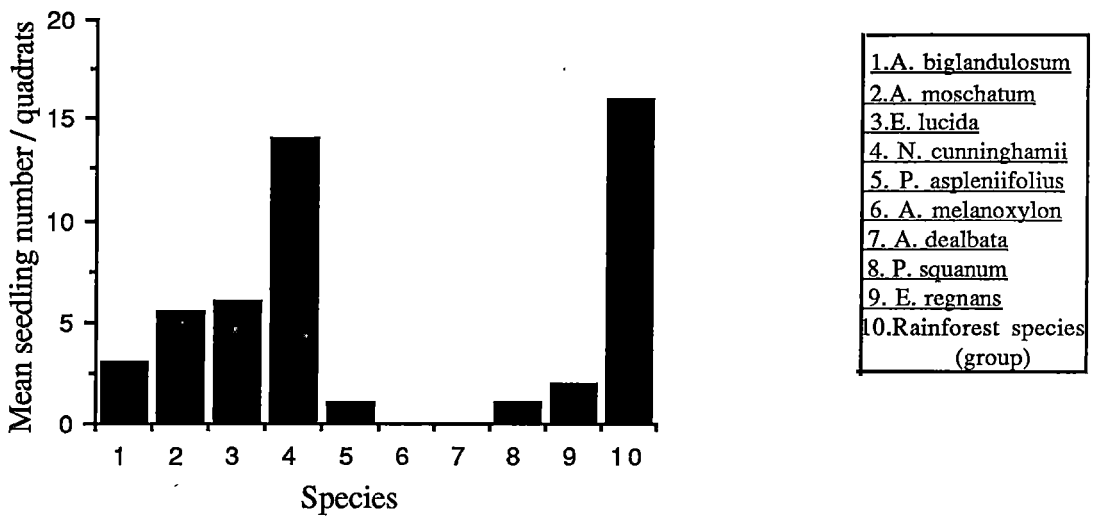


Fig.2.8 Mean seedling number per 16 m² quadrat on mixed forest site.

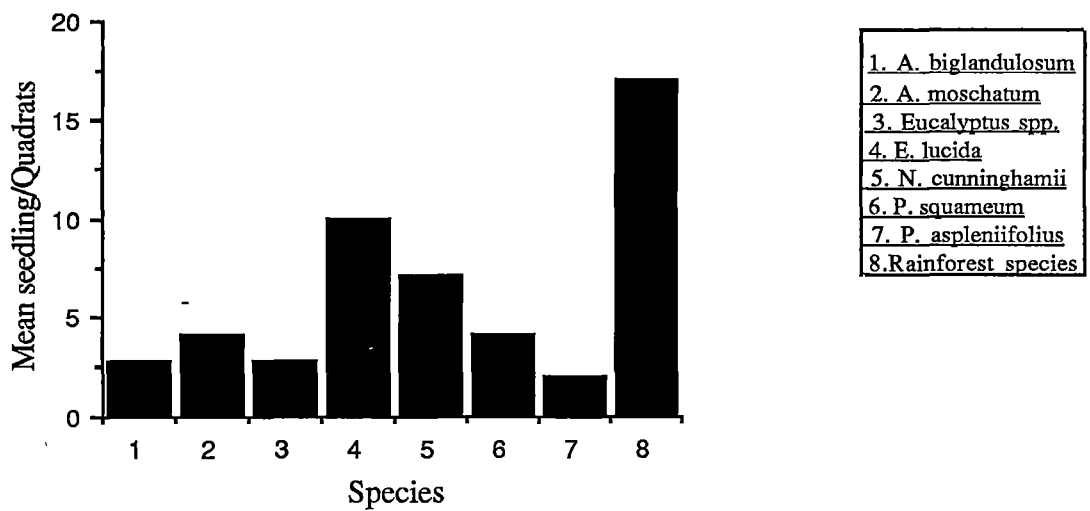


Fig.2.9 Mean seedling number per 16 m² quadrat on selectively logged sites.

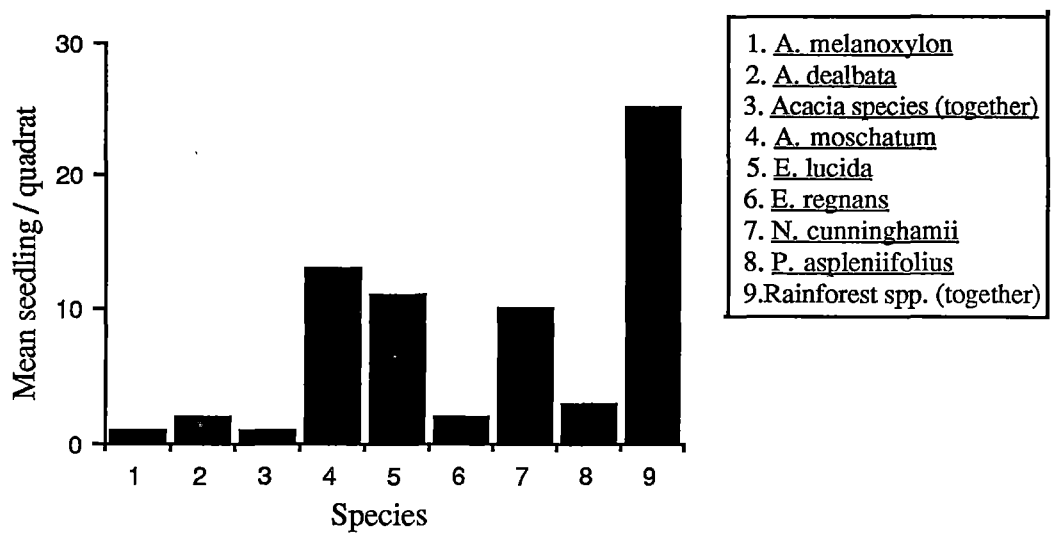


Fig.2.10 Mean seedling number per 16 m² quadrat on clearing on clearing-felling sites.

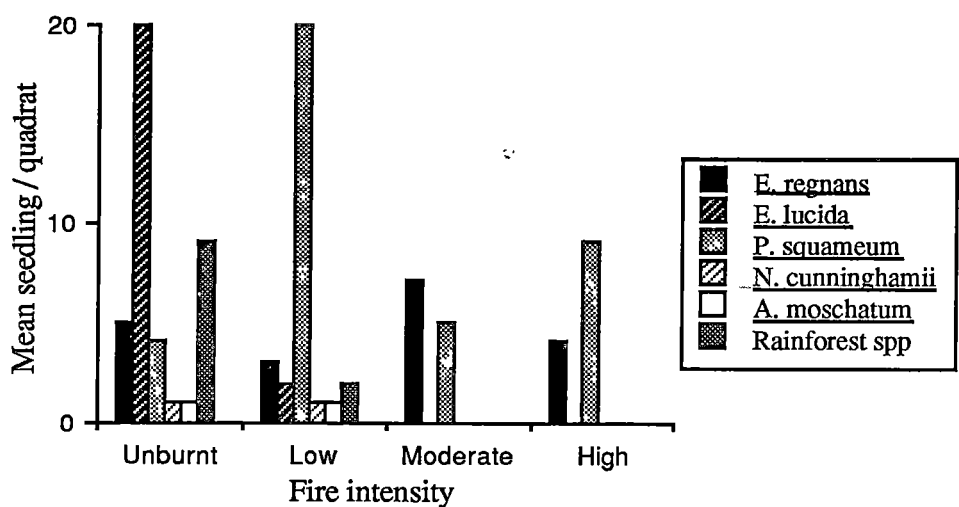


Fig.2.11 Mean seedling number per 16 m² quadrat at different fire intensities on 2 years post fire sites.

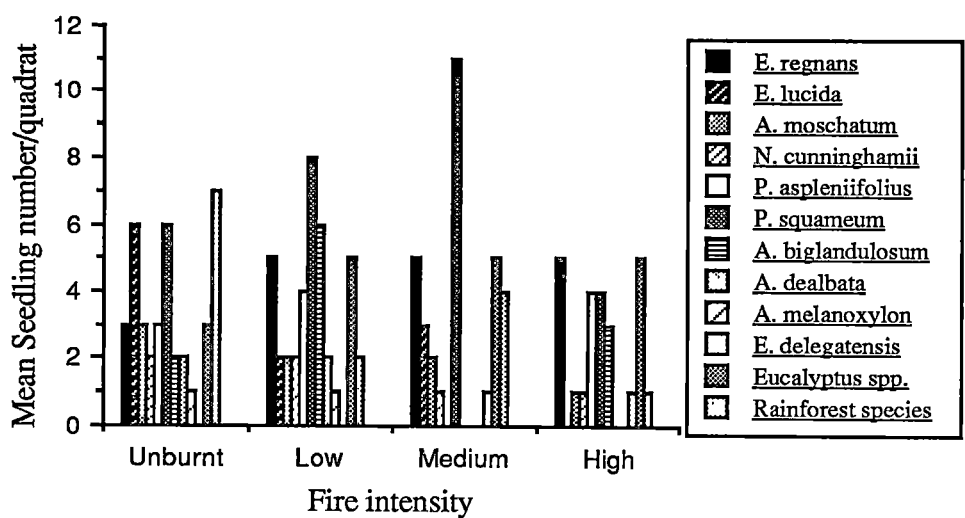


Fig. 2.12 Mean seedling number per 16 m² quadrat at different fire intensities on 5 years post fire sites.

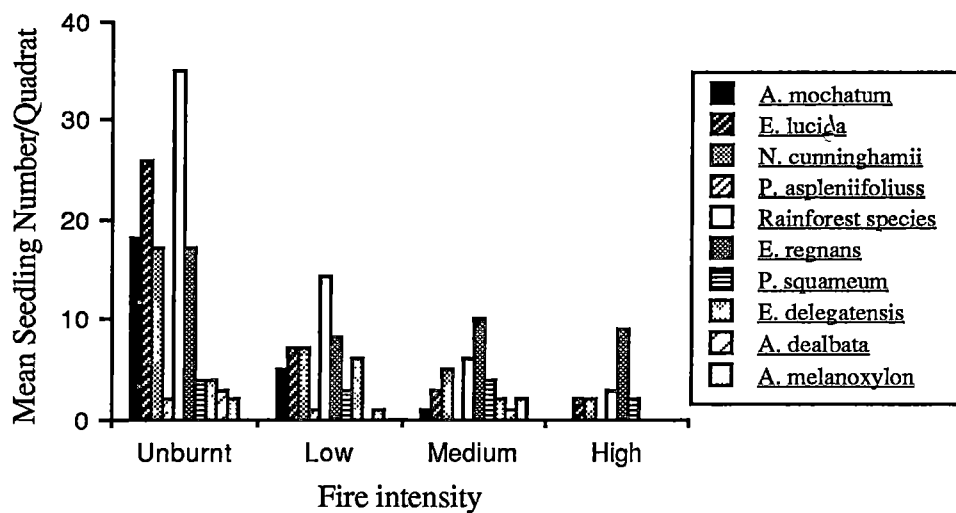


Fig. 2.13 Mean seedling number per 16 m² quadrat at different fire intensities on 7 years post fire sites.

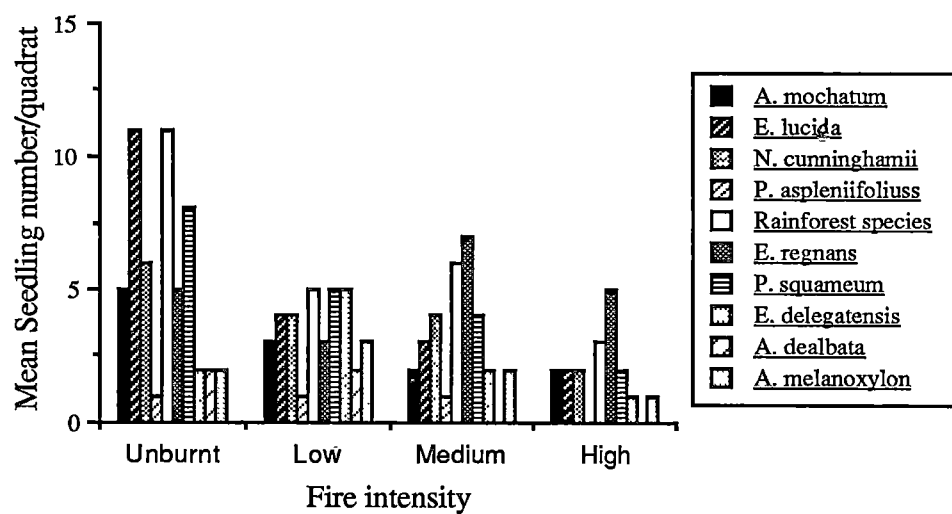


Fig.2.14 Mean seedling number per 16 m² quadrat at different fire intensities on 9 years post fire sites.

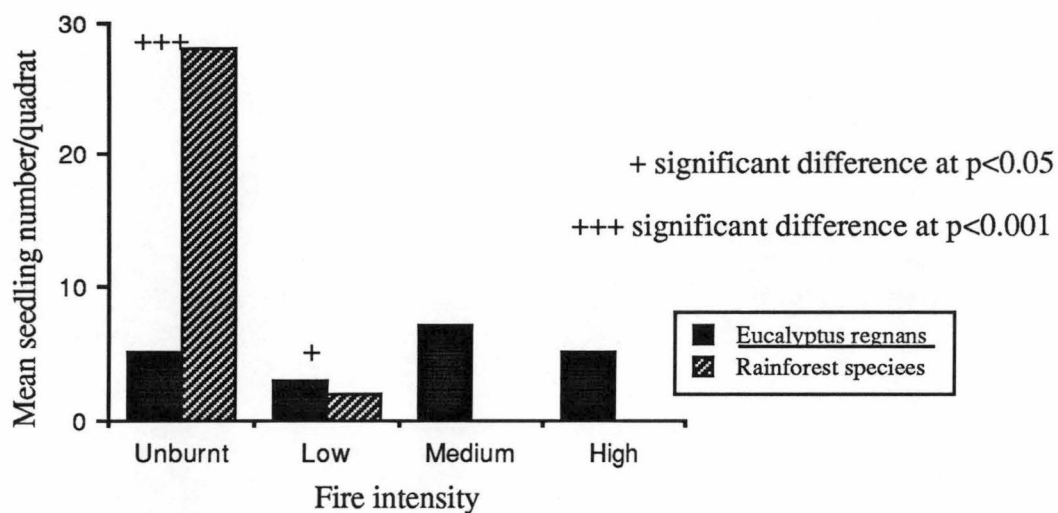


Fig.2.15 Relationship between mean seedling number of *Eucalyptus regnans* and rainforest species on 2 years post fire sites.

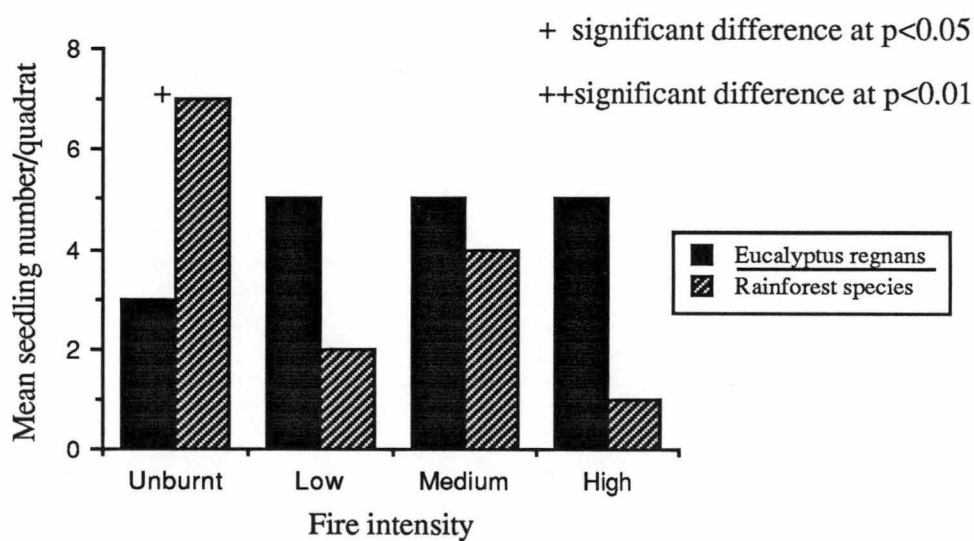


Fig. 2.16 Relationship between mean seedling number of *Eucalyptus regnans* and rainforest species on 5 years post fire sites.

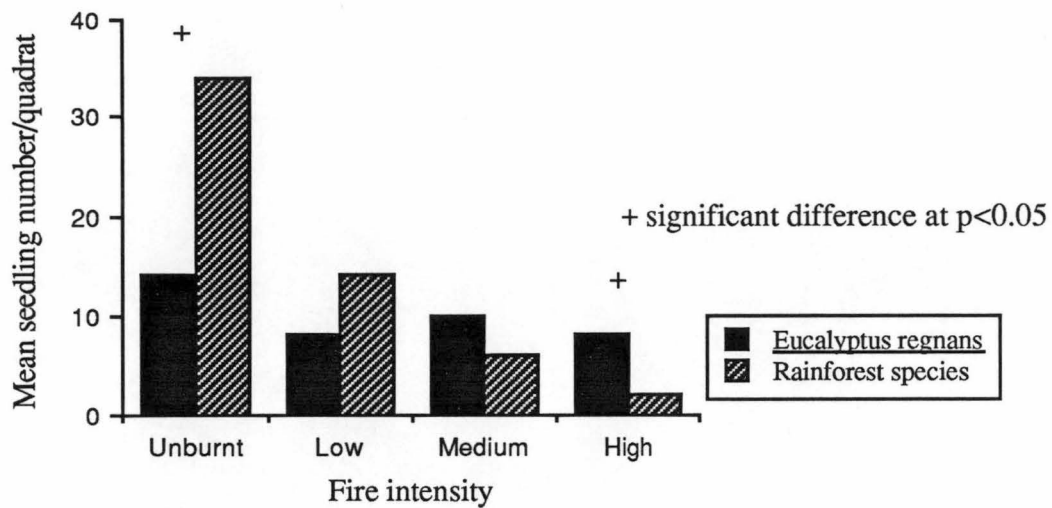


Fig. 2.17 Relationship between mean seedling number of *Eucalyptus regnans* and rainforest species on 7 years post fire sites.

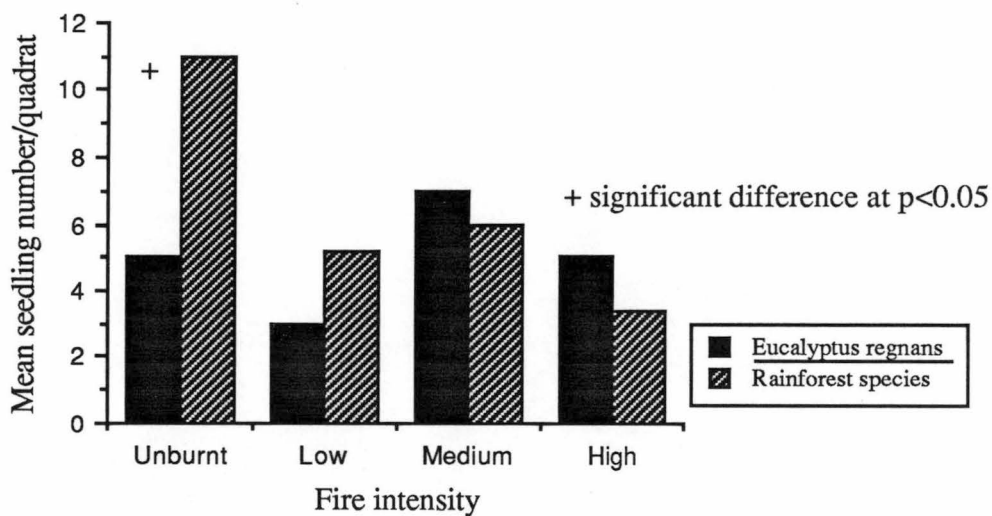


Fig. 2.18 Relationship between mean seedling number of *Eucalyptus regnans* and rainforest species on 9 years post fire sites.

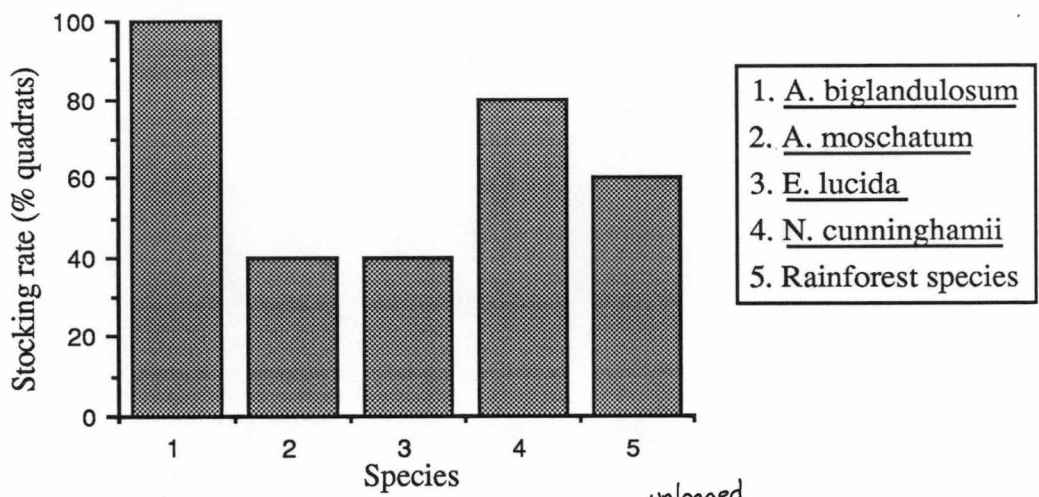


Fig.2.19 Stocking rate for different species on quartzite/^{unlogged}mixed forest sites.

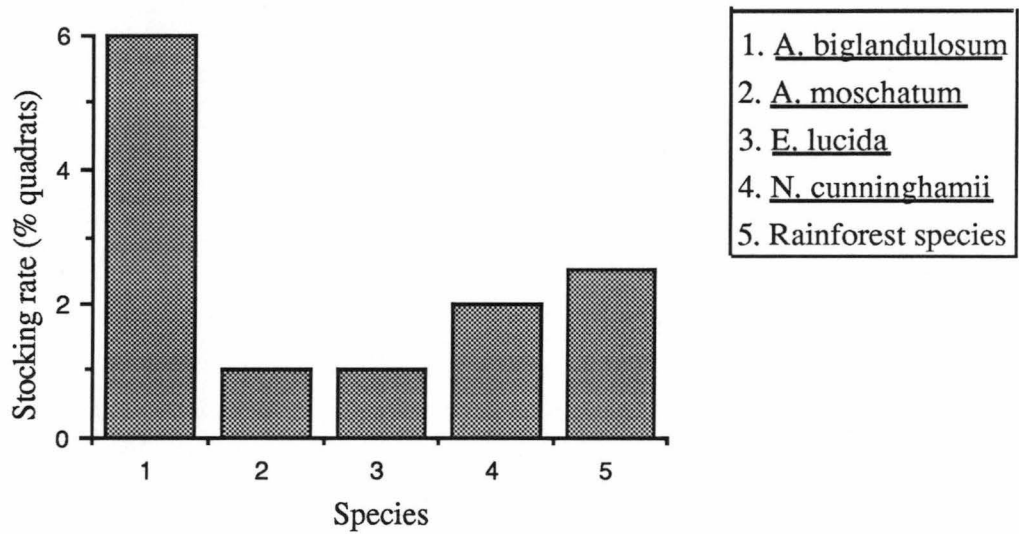


Fig.2.20 Mean seedling number per 16 m² quadrat on quartzite/^{unlogged}mixed forest sites.

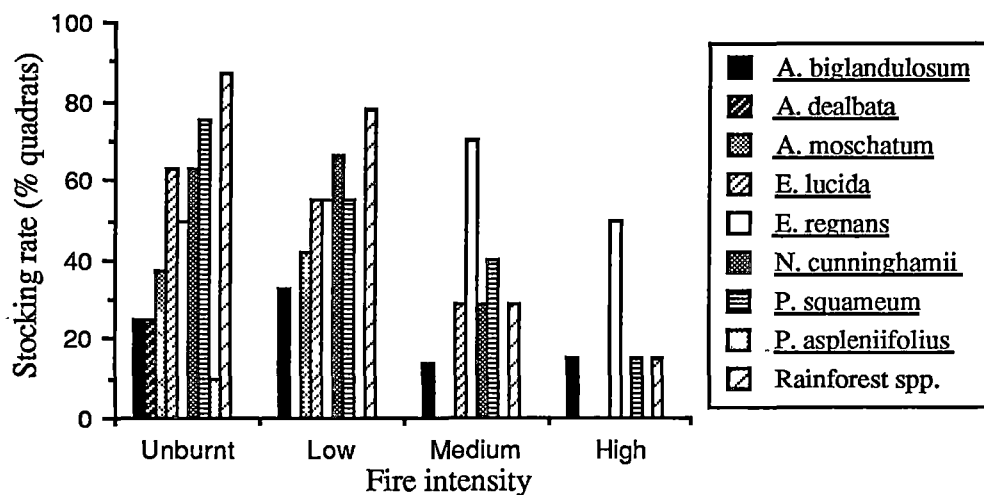


Fig.2.21 Stocking rate for different species at different fire intensities on quartzite, 5 years post fire sites.

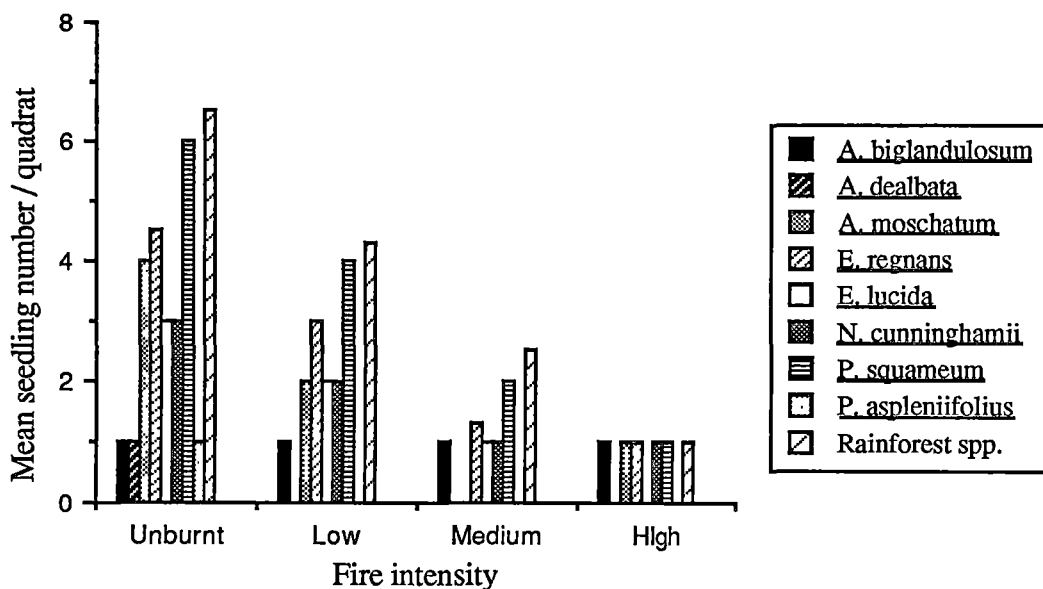


Fig.2.22 Mean seedling number per 16 m² quadrat on quartzite, 5 years post fire sites.

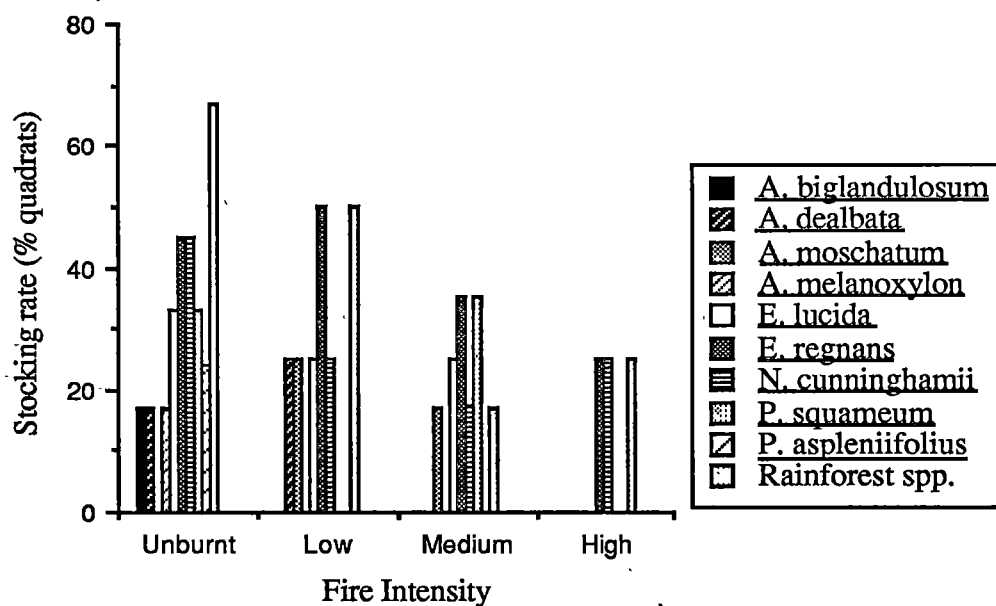


Fig.2.23 Stocking rate for different species at different fire intensities on quartzite, 7 years post fire sites.

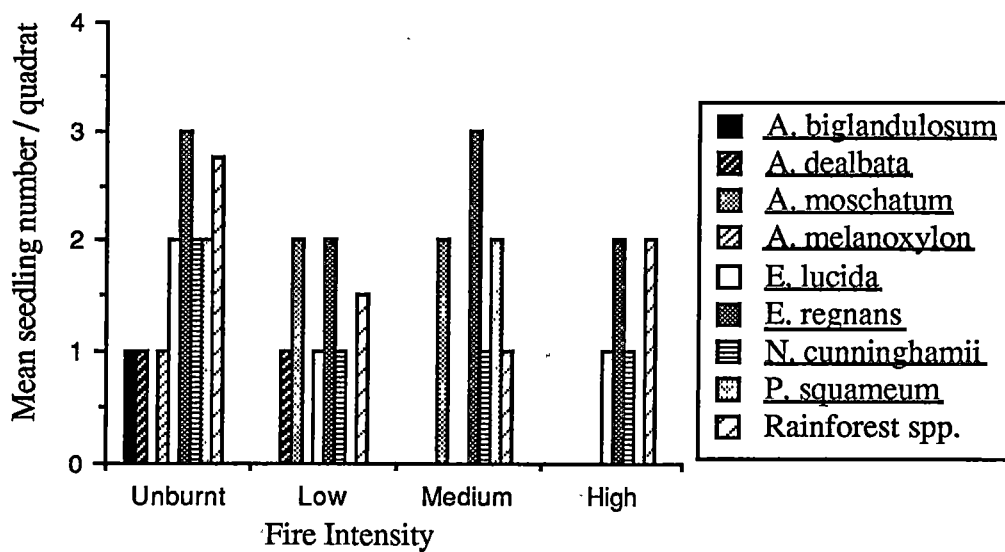


Fig.2.24 Mean seedling number per 16 m² quadrat on quartzite, 7 years post fire sites.

However, there was no evidence in this study that *Nothofagus cunninghamii* was less competitive in infertile soil quadrats. The results from this study indicates that *Phyllocladus aspleniifolius* has the lowest stocking rate and seedling number in all sites. *Nothofagus cunninghamii* regenerated successfully in all the quadrats not subjected to fire or low intensity burns. Results from this study suggest that although soil fertility may play a role in controlling the distribution of *Nothofagus cunninghamii*, other factors, such as fire history of the site, seed availability and dispersal capability may be important, as are the number of parent trees present before fire, and seed dispersal. *Phyllocladus aspleniifolius* is bird dispersed (Preest 1963), *Eucryphia lucida* poorly wind-dispersed (Read and Hill, 1983), *Nothofagus cunninghamii* is also poorly wind dispersed (Preest 1963; Cranwell 1963; Howard 1970) and *Atherosperma moschatum* is wind-dispersed (Preest 1963).

Atherosperma moschatum, *Nothofagus cunninghamii* and *Eucryphia lucida* have similar regeneration capabilities. This shows that the micro-climates in these sites are suitable for successful seed germination and survival. In relation to seed availability, adult trees of *Nothofagus cunninghamii*, *Eucryphia lucida* and *Atherosperma moschatum* have higher importance values (IV) in mixed forest before logging which suggests that these species have a greater seed source than *Phyllocladus aspleniifolius* (Table 2.2). *Nothofagus cunninghamii* has the highest importance value, which means that this is the most important species in the study site. The high relative frequency (RF) for *Nothofagus cunninghamii* suggests that this species is common in most quadrats, covering approximately half of the study area. As a consequence, *Nothofagus cunninghamii* has a high relative dominance based on basal area (RDo) which is indicated by the high relative density (RDe). These characteristics show the structure and composition of mixed forest prior to

logging. Thus, *Nothofagus cunninghamii* was found to be dominant and associated with *Eucryphia lucida* and *Atherosperma moschatum* as understorey, with *Eucalyptus regnans* forming the overstorey.

Physiological characteristics also play an important role in seedling establishment. In logged areas followed by burning perhaps this prevents the germination of *Phyllocladus aspleniifolius*. The establishment curve of *Phyllocladus aspleniifolius*^{in New Zealand} shows a definite optimum at low light intensity of 42% full day light (Bieleski 1959). Read (1983) has shown that *Phyllocladus aspleniifolius* is more shade tolerant than *Nothofagus cunninghamii* and has very short seed viability (Wardle 1969). In this study, *Phyllocladus aspleniifolius* was found not only to have a low stocking rate and number of seedlings per site, but also relatively small seedlings. The higher light intensity in the study area may limit photosynthesis, hence the low seedling growth rates. Soil organic content may not allow *Phyllocladus aspleniifolius* to regenerate successfully. This is purely speculative, since soil fertility was not investigated, except by investigating two different rock types, where it was assumed that quartzite rock has less fertility than mudstone rock.

Atherosperma moschatum, *Nothofagus cunninghamii* and *Eucryphia lucida* have a similar ability to regenerate on all sites. In contrast, on sites after fire rainforest species have high stocking rates and ^{high} seedling densities in unburnt quadrats (i.e. where the fire was patchy). Stocking rate and number of seedlings decrease significantly with increasing fire intensity. As previously discussed, that rainforest species are more fire sensitive than *Eucalyptus regnans* which is adapted to fire, and is not only fire resistant but promotes fire (Jackson 1979). Rainforest species are poorly adapted to fire and do not regenerate well after being burnt.

It has been noted by Mount (1964a, 1964b) that seeds of *Nothofagus cunninghamii* are relatively heavy and have no apparent adaptation for long range

dispersal. However, in this study *Nothofagus cunninghamii* was found over a wide area. The wide distribution may be due to a large amount of seed in the soil resulting from the high density of adult trees, where from observation in remaining mixed forest sites, *Nothofagus cunninghamii* has the largest number of adult trees per ha. Hickey (1990) also found that regeneration on logged sites which were artificially sown, using eucalypt seeds, resulted in excellent regeneration of *Nothofagus cunninghamii* with *Eucryphia lucida* appearing as the second most important species followed by *Atherosperma moschatum*, while *Phyllocladus aspleniifolius* was uncommon.

b. *Eucalyptus regnans*

On ^{unlogged} mixed forest sites, *Eucalyptus regnans* regenerates poorly. Clearly this species has no ability to be competitive with rainforest species under closed canopy conditions. Micro-sites may not allow *Eucalyptus regnans* to regenerate (low intensity and low source seed, due to low number of adult trees per ha). Results from the investigations of photosynthetic rates (chapter 5) indicate that *Eucalyptus regnans* seedlings are less tolerant of shade than rainforest species, although *Nothofagus cunninghamii* was the only rainforest species used to represent the rainforest species. There is a significant difference in stocking rate and number of seedlings between *Eucalyptus regnans* and rainforest species.

On logged and burnt sites, with artificial sowing of seed, *Eucalyptus regnans* exhibits very high regeneration rates. Stocking rate increases with increasing intensity of fires. The time after fire results in changes of stocking rate. On sites five years after fire *Eucalyptus regnans* has the highest stocking rate at all levels of fire intensity compared to stocking rates in other sites. This may be because of different microclimate, nutrient availability in the soil between these sites, or competition after a

few years. In relation to the effect of fire intensity on regeneration of *Eucalyptus regnans*, stocking rate increase in the sequence unburnt < low < hot < medium. Quadrats subjected to low to hot fire intensities result in stocking rates higher than 65%, which are regarded as successful regeneration. 65% stocking rate is the acceptable standard for stocking rate (in 16 m² quadrats) (McKinnel *et al.* 1991).

c. *Phebalium squameum*

The success of *Phebalium squameum* to regenerate on logged sites, seems to be due to its ability to establish very quickly after fire. This could be because of the seed source in soil and dispersal advantages. Bazzaz (1968); Raynal and Bazzaz (1973) and Drury and Nisbet (1973) noted that colonization by woody plants may be limited by some inhibitory life forms, such as herbs, which may become established quickly. *Phebalium squameum* has good regeneration either from seedling or regrowth, and also is a good competitor. *Phebalium squameum* is found as an associate with *Eucalyptus regnans* in all sites.

Regeneration of *Phebalium squameum* does not show any special pattern with changing ^{of} intensity fire and age after burning. *Phebalium squameum* regenerates relatively well overall in logging sites associated with *Eucalyptus regnans*.

d. *Acacia* species

The rarity of *Acacia* spp. on the sample quadrats may be because of lack of seed on the quadrat sample, and because they are less competitive than other species. From visual observation around the study sites, *Acacia* spp. grow in mixed forest with more open canopy than the study sites and become more common on wet sclerophyll forest, also along the road in the logging area. This indicates that the denser canopy hinders establishment of *Acacia* spp, which is supported by results of

photosynthetic response to light (chapter 5), where *Acacia* species have a higher P_{max} on a leaf area basis than *Nothofagus cunninghamii*, which suggests they are sun plants.

The poor regeneration on quartzite rock suggests that low soil nutrient tend to be a limiting factor for germination of seed and subsequent establishment. In quartzite quadrats covered by *Anodopetalum biglandulosum* (on mixed forest sites), light becomes another limiting factor. *Anodopetalum biglandulosum* is able to regenerate by coppice^{and layering} on quartzite mixed forest sites, as discussed above, vegetative growth has some advantages because the roots are already developed and hence are more competitive and earlier to reach maturity than regeneration from seed.

THE EFFECT OF FIRE ON THE COMPOSITION AND DISTRIBUTION OF UNDERSTOREY SPECIES

3.1. Introduction

Vegetation disturbance, which is followed by the successional process, has been widely discussed by research workers in Australia and overseas. Fire is one environmental aspect which plant communities must cope with. The subsequent successional changes during re-establishment have been widely documented.

Much of the classical theory of secondary succession is based on the sequence of floristic change observed after the abandonment of previously cultivated areas (Odum 1969), even though it refers strictly to redevelopment of sites previously occupied by biotic communities.

The model normally used to describe such old field succession has been referred to by Egler (1954) as a relay floristic model, in which successive suites of species are assumed to progressively occupy the site under consideration. It is implied and sometimes explicitly stated, that each suite of species tends to make the environment less suitable to the persistence of the following suite and that this process continues until a community develops which can regenerate in its own environment. This is the climax community.

The generality of this model was questioned by some authors. Egler (1954) proposed that in many cases the initial floristic composition of a site directly after a major perturbation to a community dominated the subsequent pattern of succession,

with the longest-lived species among those present in the initial ensemble finally becoming dominant. This view has been reinforced by Niering & Egler (1955); Drury & Nisbet (1973) ; Niering & Goodwin (1974) and Connell and Slatyer (1977).

The distribution of forest species is determined by physical gradients within the stand, by the pattern of disturbance imposed on these gradients, and by the contrasting biologies of sympatric forest species. Most examples in the literature involve tree species, and patterns have often been related to opportunities from recruitment and growth provided by canopy gaps (Hara 1987; Armesto and Fuentes 1988). Factors structuring the distributions of ground vegetation such as shrubs and herbs appear to be more diverse and less well understood.

Distribution of ground vegetation in a forest may be used to explain the degrees of disturbance, or to predict the compositions of vegetation in the future. Previous studies have presented the distribution of ground vegetation according to different form of disturbance. Examples include works by Gibson and Good (1987) who looked at the presence of moss beds providing protection from ground fires. It has been noted that disturbances, in the form of canopy gaps may offer opportunities for colonization by herbs species, or may exclude certain species by altering the local light or temperature regimes (Odum 1969). Collins and Pickett (1987) have examined the vegetation in ^{relatively small} canopy gaps where they found little change in the composition of herb and shrub layers.

A number of previous studies have described secondary succession following clearcut logging. Broad successional stages were described from reconnaissance data, for example Isaac (1940), who studied succession following clearcut logging in the Douglas-fir region of North America. They believe that only broad successional stages may be discerned by this approach, as vegetation on

disturbed sites is influenced not only by time after disturbances, but also by many uncontrolled factors such as soil, elevation, climate.

Cremer and Mount (1965) found that successional stages may be divided into three main categories

- (1) The moss liverwort stages
- (2) The short-lived perennials/herbs stages
- (3) The shrubs/tree seedlings stages

Generally, they found on burnt sites, in early succesional stages, that during the first 5 to 7 years shrub cover was more abundant in unburnt areas than on adjacent burned sites, while herbaceous cover was approximately the same on burnt and unbunt site, although species composition was often appreciably different .

The objective of this study was to describe the change of composition and distribution patterns of ground layer species in logged sites which are disturbed by logging and fires. This chapter is concerned with the distribution and composition of ground vegetation excluding tree seedlings. Distribution patterns and regeneration patterns of tree seedlings was discussed in chapter 2.

3.2. Material and Methods

The methods used were similar to those described to examine regeneration of tree seedlings (chapter 2). Six different types of sites were selected to represent the logged sites in South West Tasmania and mixed-forest was used as a control. Presence- absence of understorey species were recorded in 4 m² quadrats. Percentage cover, height of plant and number were recorded in 16 m² quadrats. Fire intensity and time since fire occurred were recorded for each site.

Relative frequency (RF) and Relative dominant (RDo) were calculated for each species on each site. These value were used to calculate an importance value

(IV). The maximum importance value is 200%, and it only occurs in uniform vegetation (dominated by one species). Relative dominance was calculated from the percentage cover. The relative frequency value it used to consider the distribution of species on the area according to the frequency of appearance in the quadrat samples. From the importance value, it was assumed that species with high values tend to be important species in a community (Muller - Dombois and Engler 1974), which may be used to predict characteristics and composition of vegetation in the future and the effect of disturbance.

An Index of similarity (IS) was calculated from each logged site and compared to mixed forest sites to examine the change in the vegetation composition as a result of the disturbances (logging and burning). If the IS is less than 50%, it could be assumed that the two sites differ dramatically in their composition.

3.3. Results

Seventy two species of vascular plants and bryophytes were recorded in the study sites (Appendix 8). It was found that species richness was higher in burnt sites with less percentage cover than in mixed forest and selectively logged sites. Herbaceous plants and ferns which are adapted to high light intensities were markedly reduced in terms of percentage cover on unburnt sites, while shrubs and more shade tolerant ferns were poorly represented on recently disturbed sites.

Most species found occurred in both burnt and unburnt sites, however, there are differences in their dominance and pattern of distribution from site to site due to different fire intensities and rock soil types. *Marchantia berteroana*, *Senecio velleioides* and *Pteridium esculentum* were absent in mixed forest sites (Table 3.1)

The same number of rainforest species occurred in all sites, while non-rainforest species were better represented in logged sites compared to the mixed

forest undisturbed sites. The six different logged sites (four burnt site and two unburnt sites) are different, with less species in burnt sites (2,5,7,9 years after fire) than selectively logged site and clear-felling site (Appendices.3.2-3-7).

The importance values (IV) of each species which are greater than 10% are shown in table 3.1. They show the change in important species from site to site. The composition and distribution in each site is described below.

(1) Unburnt sites in mixed forest

a. Unlogged control

Thirty five species were recorded on mixed forest sites and, twenty five of them are under storey species. Mixed forest sites supported fewer understorey species than sites five and nine years after fire, but more than sites two years after fires. On such sites, mosses, the fern *Microsorium billardieri* , Cutting grass (*Gahnia grandis*) and the shrub *Anopterus glandulosus* dominated the ground layer. Mosses were found spread widely on these sites with high percentage cover in most quadrats (at least 30%). *Microsorium billardieri* tended to be the second most common species, based on frequency of the appearance of individual which is indicated by the relative frequency value, followed by cutting grass (*Gahnia grandis*) and the shrub *Anopterus glandulosus* (Table 3.1).

b. Selectively logged sites

Mosses were also common in selectively logged sites. However, for the ferns species, *Microsorium billardieri* was replaced as dominant by the soft fern *Histiopteris incisa* . Thirty species were recorded on selectively logged sites, which

were divided into two major groups: ten tree species and twenty understorey species (Appendix 2). Communities on these sites were similar to the mixed forest sites, as indicated by a high index of similarity (70.77%). Mosses tended to be the most common ground layer vegetation on these sites followed by three species of ferns (*Histiopteris incisa*, *Hypolepis muelleri*), *Dicksonia antarctica*) and the epacridaceous shrub *Monotoca glauca* (Table 3.2). Species typical of burnt quadrats are also found on these sites, especially in quadrats which lay on transects near a burnt area.

c. Sites one year after clear-felling

Only twenty four species were recorded on clearfelled sites (Appendix 3), indicating that some species are lost after disturbance. These sites have the smallest number of species present among the seven study sites. Five understorey species had importance value greater than 10% (Table 3.3), with *Histiopteris incisa* having the highest frequency of appearance, as well as percentage cover and hence the highest importance value. Two of five main species which are present on these sites are also found as dominant species in mixed forest sites, and three of those five species also dominated selectively logged sites. Less shrubs and woody plants were recorded on these sites, which indicates that one year after disturbance is not sufficient duration to support the re-establishment of shrubs. The index of similarity of these sites compared to mixed forest sites is 54.24%, which is lower than the index of similarity of selectively logged sites compared to mixed forest sites.

(2) Burnt sites

a. Sites two years after burning

Thirty one species were recorded on these sites, consist of twenty five

understorey species and six tree species (Appendix 4). Three species of ferns, the liverwort *Marchantia berteroana*, the fire-weed *Senecio velleioides* and mosses dominate these sites. The bracken *Pteridium esculentum* tended to be the most important species, with an importance value of 28.33% followed by *Senecio velleioides* (22.47%), Mosses (21.01%), *Marchantia berteroana* (15.06%), and *Dicksonia antarctica* (10.26%) (Table 3.4). *Senecio velleioides* was found widely spread in quadrats subjected to fire, which was indicated by its having the highest relative frequency value among the species present. The index of similarity of this vegetation compared to mixed forest sites is similar to the index similarity between clearfelled sites, which is the lowest index similarity between all study sites (54.24%). This indicates that composition of the vegetation on these sites is different to that of mixed forest sites.

b. Sites five years after burning

Sites five years after burning had the greatest number of species (forty six), consisting of ten tree species and thirty six understorey species (appendix 5). Three fern species and mosses tended to be the main species on these sites. The soft fern *Histiopteris incisa* had the highest relative frequency and relative dominance, and hence had the highest importance value, followed by mosses, the other soft fern *Hypolepis muelleri*, and the bracken *Pteridium esculentum* (Table 3.5). All of the four main species appeared as main species on sites two years after fire. *Senecio velleioides* and *Marchantia berteroana* reduced their percentage cover on these sites.

The index of similarity of these sites compared to mixed forest sites is high (64.2%), which indicates that re-establishment of plant communities takes about five years after fire has occurred. On these sites more woody shrubs were found compared to sites two years after burning, and herbs were reduced in percentage

cover.

c. Sites seven years after burning

Thirty seven species were recorded on these sites, consisting of nine tree species and twenty seven understorey species (Appendix 6). The index of similarity of these sites compared to mixed forest sites is high (62%). On these sites, four understorey species had an importance value greater than ten percent, all of these species were dominant on sites two and five years after burning. *Histiopteris incisa* had the highest importance value, followed by mosses.

In general, species composition on these sites is similar to the species composition on sites five years after burning. The dominance of *Pteridium esculentum* on sites five years after fire was reduced with increasing time after burning and was replaced by the shrub *Monotoca glauca*. This indicates the successional stages with time after disturbance.

d. Sites nine years after burning

Forty one species were recorded on these sites, consisting of ten tree species and thirty one understorey species (Appendix 7). The composition of the vegetation is largely unchanged from sites five and seven years after burning. Three of the four main species on these sites were similar to the main species on sites seven years after burning, also three were similar to those main species on sites five years after burning. Mosses had the highest relative frequency and relative dominance, hence the highest importance value, followed by *Pteridium esculentum*, *Histiopteris incisa* and *Monotoca glauca* (Table 3.7). The index of similarity of vegetation on these sites compared to vegetation on mixed forest sites is 55%.

Table 3.1 Understorey species found on mixed forest sites with relative frequency (RF), Relative dominant (RDo) and importance value (IV) greater than 10%.

Species	: RF(%)	: RDo(%)	: IV(%)
Mosses	: 12.78	: 26.23	: 30.67
<i>Microsorium billardieri</i>	: 12.70	: 8.05	: 13.28
<i>Anopteris glandulosus</i>	: 5.00	: 6.65	: 11.65
<i>Gahnia grandis</i>	: 6.70	: 3.78	: 10.48

Table 3.2 Understorey species found on Selectively logged sites with relative frequency (RF), Relative dominant (RDo) and importance value(IV) greater than 10%.

Species	: RF(%)	: RDo(%)	: IV(%)
Mosses	: 11.62	: 19.92	: 31.54
<i>Histiopteris incisa</i>	: 8.50	: 19.47	: 27.97
<i>Hypolepis muelleri</i>	: 3.87	: 10.62	: 14.07
<i>Dicksonia antarctica</i>	: 3.87	: 8.19	: 12.06
<i>Monotoca glauca</i>	: 2.30	: 8.19	: 11.09

Table 3.3 Understorey species found on clearfelling sites with relative frequency (RF), Relative dominant (RDo) and importance value (IV) greater than 10%.

Species	: RF(%)	: RDo(%)	: IV(%)
<i>Histiopteris incisa</i>	: 11.87	: 24.35	: 36.22
Mosses	: 10.77	: 13.06	: 23.83
<i>Hypolepis muelleri</i>	: 7.20	: 8.09	: 15.29
<i>Gahnia grandis</i>	: 5.20	: 9.61	: 14.81
<i>Dicksonia antarctica</i>	: 3.60	: 8.09	: 11.6

Table 3.4 Understorey species found on sites two years after burning with relative frequency (RF), Relative dominant (RDo) and importance value (IV) greater than 10%.

Species	: RF(%)	: RDo(%)	: IV(%)
<i>Pteridium esculentum</i>	: 2.39	: 25.94	: 28.33
<i>Senecio velleioides</i>	: 16.95	: 5.52	: 22.47
Mosses	: 11.08	: 9.93	: 21.01
<i>Marchantia berteroana</i>	: 4.56	: 11.04	: 15.06
<i>Hypolepis muelleri</i>	: 4.93	: 5.52	: 10.45
<i>Dicksonia antarctica</i>	: 1.98	: 8.28	: 10.26

Table 3.5 Understorey species found on sites five years after burning with relative frequency (RF), Relative dominant (RDo) and importance value (IV) greater than 10%.

Species	: RF(%)	: RDo(%)	: IV(%)
<i>Histiopteris incisa</i>	: 14.76	: 16.26	: 31.02
Mosses	: 7.90	: 8.70	: 16.60
<i>Hypolepis muelleri</i>	: 11.25	: 4.53	: 15.78
<i>Pteridium esculentum</i>	: 2.77	: 9.41	: 12.18

Table 3.6 Understorey species found on sites seven years after burning with relative frequency (RF), Relative dominant (RDo) and importance value (IV) greater than 10%.

Species	: RF(%)	: RDo(%)	: IV(%)
<i>Histiopteris incisa</i>	: 11.93	: 18.55	: 30.48
Mosses	: 8.80	: 11.13	: 19.93
<i>Monotoca glauca</i>	: 9.70	: 5.30	: 15.00
<i>Hypolepis muelleri</i>	: 7.07	: 5.04	: 12.11

Table 3.7 Understorey species found on sites nine years after burning with relative frequency (RF), Relative dominant (RDo) and importance value (IV) greater than 10%.

Species	: RF(%)	: RDo(%)	: IV(%)
Mosses	: 10.19	: 12.44	: 22.63
<i>Pteridium esculentum</i>	: 6.25	: 13.51	: 19.75
<i>Histiopteris incisa</i>	: 6.25	: 5.33	: 11.58
<i>Monotoca glauca</i>	: 7.48	: 3.20	: 10.68

3.4. Discussion

A species distribution pattern and composition changes with time following disturbance. However, the dominant life-forms do not clearly reflect the successional sequence expected, where mosses are replaced by herbaceous plants, then shrubs and finally woody plants. This may be because fire in the sites of the same age was not uniform, since it seems that fire intensity plays an important role in determining floristics and community structure as well as the duration after disturbance. Purdie (1977a, 1977b) believed that the patterns of regeneration following fire, and the next species dominance, depends on intensity and timing of the fire, and also depends on weather. In this study data collection occurred over several months between 2 different ages of sites, and this can also influence the data collected, especially for annual herbs and mosses which have fast growth. Hence the difference in species composition between different ages after disturbance is not necessarily due to the successional process based on time since disturbance.

The dominance of *Pteridium esculentum* in the study areas is due to the

conditions of the environment of the study sites, which are favourable for the growth of this species. It has been noted that *Pteridium esculentum* colonizes well in disturbed areas after burning (Plate 3.1). Fire seems to stimulate its growth. *Pteridium esculentum* produces large numbers of spores and the wind enables the spores to be distributed well, although the significance of regeneration from spores is uncertain.



Plate 3.1. The bracken, *Pteridium esculentum* dominates burnt quadrats on sites two years after fire.



Plate 3.2. Soft ferns *Histiopteris incisa* and *Hypolepis muelleri* grow well over all quadrats under open canopy on selectively logged sites.

Regrowth also can establish from sprouting rhizomes following fire. Even if there are no spores in the soil, establishment can occur if immigrant spores fall in an area with favourable conditions. *Pteridium esculentum* seems to establish more often by growth from rhizomes than from spores (Neyland 1986).

Others common species on burnt quadrats were *Marchantia berteriana* and *Senecio velleioides*. The abundance of these species may influence the seedling germination and initial growth of woody plants. Dense 'mats' of either species may prevent germination and can grow over seedlings. Coverage of *Marchantia berteriana* was common on burnt sites as found in works conducted by some previous researchers (Cremer and Mount 1965, Watson 1971, Southorn 1976). *Marchantia berteriana* characteristically occurs on burnt sites, and this species has been found to germinate only on burnt sites (Duncan and Dalton 1982).

Understorey rainforest species (with the exception of some ferns such as *Grammitis billardieri* and *Hymenophyllum marginatum*) regenerated in burnt sites, especially with increasing duration after fire. As discussed in chapter 2 for regeneration of tree seedlings, many factors are assumed to influence the ability of understorey rainforest species to regenerate on burnt sites: e.g. seed-dispersal, micro-habitat and physiological characteristics. Species with a wide tolerance range will be able to compete and re-establish in an unfavourable habitat. Also, with increasing duration after fire, changes occur in the microclimate of the habitat, and possibly the formation of some patchy areas allow rainforest understorey to become established.

Histiopteris incisa and *Hypolepis muelleri* were found to have very wide habitat ranges, from mixed forest sites to burnt sites, but it was noticed that these species did not grow well in quadrats subjected to high fire intensity and were not associated with *Pteridium esculentum*. These species were common in the areas with open canopy in mixed forest sites, unburnt quadrats and burnt quadrats subjected to

low fire intensity (Plate 3.2). This indicates that *Histiopteris incisa* and *Hypolepis muelleri* are more shade tolerant than *Pteridium esculentum*. The fern which was absent from burnt sites was *Grammitis billardieri*, which was found only in damp micro-habitats, and is an epiphyte, associated with mosses and some shade tolerant herbs.

Neyland (1986) noted that *Dicksonia antarctica* in lowland sites is restricted to moist shady gullies, and, grows well in forests where the tree canopy is disturbed. However, because fire on the burnt sites was not uniform, the distribution of *Dicksonia antarctica* in this study area was not restricted to mixed forest and undisturbed sites, but it also occurred on burnt sites

Another species which was found to have a high importance value was *Anopteris glandulosus*, which established from vegetative sprouts. Sprouting has some advantages in that a species exhibiting sprouts can effectively compete for water, light and nutrients, where sprouts already have a well developed root system (Barker 1990). Further, such plants are able to reach sexual maturity earlier than plants which regenerate from seed, and may be faster in establishment and develop to become important species in one area.

In this study, besides important under storey species (based on importance value) described above, it was noted that *Polystichum proliferum* was found on most sites even though it was found to have low percentage coverages. It seems *Polystichum proliferum* is adapted to a variety of environments in these study sites, and it occurred in both sun and shade conditions.

FROST RESISTANCE

4.1. Introduction

It has long been known that the freezing stress caused by sub-zero temperatures is one of the main problems experienced by plants that grow in areas of higher altitude and / or latitude. Frost resistance is closely related to the early termination of autumn growth. Susceptibility to injury by frost is probably the single most important factor limiting plant distribution (Parker 1963; Sutcliff 1977), and it is also a major cause of damage. However, plant death at low temperature is not always caused by frost.

When frost injury occurs, the temperature drops so low that ice crystals may form in the intercellular spaces and cellular water then diffuses out and condenses on these ice crystals, which prevents ice formation within the cell. In frost resistant plants, water from melting ice crystals returns to the undamaged cells and hence metabolism returns to normal.

Ways of avoiding damage caused by frost which are adopted by plants, include :

1. Increasing the cell solute concentration in order to depress the freezing point.
2. Producing heat, which is achieved by an increased metabolic rate.
3. The heat (of crystallization) released during the freezing of water adhering

to leaf bases.

4. Heat created by a suitable microclimate.

5. Adopting a glaucous leaf layer to reduce the incidence of water (and freezing) on a leaf surface.

All of these combine to enhance the survival prospects of a plant in different conditions.

Plants vary greatly in their sensitivity to low temperature. The resistance to freezing injury alters markedly throughout the life of a plant. It also varies amongst leaves on the same plant, between plants of the same species and across altitudinal gradients. Some tropical and sub-tropical plants are killed by chilling to low temperatures still well above 0°C, whereas others, notably arctic alpine plants (high latitude) can survive prolonged exposure to sub-zero temperature (Lyons and Raison 1990). Some plants will even tolerate extremely low temperatures, for example some plants can tolerate -196°C in mid winter (Sakai 1960). It is also believed that the survival of a plant species is generally determined by the limits to which their metabolic processes continue to function under low temperature stress and their cold resistance (Larcher and Bauer 1981). However, the freezing resistance of plants changes seasonally and through different developmental stages.

Frost occurs over many parts of Australia generally with increasing severity and frequency at more southerly latitudes and higher altitudes (Turnbull and Eldridge 1983). Although fire might play a greater role in the distribution of Australian vegetation, freezing remains an extremely influential factor. It has been noted that New South Wales, Victoria and Tasmania are the states most subject to extreme cold, with temperatures recorded below -13 °C (Hall *et al.* 1981) and an absolute minimum of -22 °C has been recorded in New South Wales and Tasmania

(Davidson and Reid 1985).

In a closed forest, frost is rarely a selective force which influences seedling survival. However with the opening up of the forest, under the open canopy the ground lies exposed, and frost and low temperature may become important factors determining survival of seedlings. For a rainforest species to invade large exposed areas, it either must tolerate conditions of frost or avoid them. The latter is achieved by the extension of the canopy from the forest edge which affects microclimate conditions on the forest floor, and by establishment in safe-sites which are protected from temperature extremes and fluctuations.

The temperature of a plant usually comes to equilibrium with that of the environment immediately following convection of low temperature air. The lowest temperature in a stand of plants is immediately above the ground in the undisturbed air (Sakai and Larcher 1987).

The effects of low temperature can also be studied at the cellular and molecular levels to give an insight into the basis of the biological mechanism (Grout and Morris 1987). Differential responses to temperature, in terms of growth rate and the rate of net photosynthesis, have been recorded among species native^{to} areas with contrasting temperature regimes; among species with overlapping ranges; and among populations of a species (for example, Slatyer 1977; Berry and Raison 1981; Hill *et al.* 1988). Frost resistance has been investigated in a similar manner (for example Sakai *et al.* 1981; Alberdi and Rios 1983; Steubing *et al.* 1983; Alberdi *et al.* 1985; Tibbits and Reid 1987b; Read and Hill 1988; Read and Hope 1989).

In this investigation, plants of selected species were collected from the study area and their frost resistances were determined. The objective of this study is to investigate how significant a role frost resistance plays in determining the distribution of major species in nature, or in regeneration following artificial disturbance.

4.2. Materials and Methods

The majority of researchers have looked at frost resistance of plant either caused by natural frost or artificial ^{frost} (Dexter 1930,1932; Ashton 1958; Eldrige 1968; Raymond *et al* . 1986; Hallam 1986; Sakai and Larcher 1987; Read and Hill 1988). Frost hardiness may be measured in whole plants or on samples of plant tissue, such as a leaf. Research on cold resistance is concerned, on the one hand, with elucidating the factors responsible for death due to cold, i.e. determining the plants resistance to cold; and on the other hand concerned with determining the specific resistance limits of different plant species.

In this experiment electrolyte leakage was used as a measure of how much cellular damage occurs at low temperature. The conductivity of a leaf tissue suspension provides an index of frost resistance. The reliability, and advantages of this technique have been noted in many studies (Dexter *et al* .1930, 1932; Hallam 1986; Raymond *et al* . 1986; Tibbits and Reid 1987a, Read and Hill 1988).

Most research which has been conducted on frost resistance, including in Australia, has focussed on frost resistance in alpine vegetation and species of *Eucalyptus* . Little attention has been paid to frost resistance of mixed forest species. Following the observation on regeneration (chapter 2 and 3), frost resistance of the leaves of common species found in the mixed forest/wet forest was measured.

Ten discs were punched from freshly collected, fully expanded ^{adult} leaves or phyllodes of selected species from the study sites. Glasshouse grown plants were used as controls. The selected species from the field are listed below:

1. *Acacia melanoxylon* R. Br
2. *Atherosperma moschatum* Labill.
3. *Eucalyptus delegatensis* R.T Baker
4. *Eucalyptus obliqua* L Herit.

5. *Eucalyptus regnans* F. Muell
6. *Eucryphia lucida* (Labill.) Baill.
7. *Nothofagus cunninghamii* (Hook.) Oerst.
8. *Olearia argophylla* F. Muell.
9. *Phebalium squameum* (Labill.) Engler.
10. *Phyllocladus aspleniifolius* (Labill.) Hook. f.
11. *Pomaderris apetala* Labill.

Each sample of ten discs was placed in a small glass vial with one drop of distilled water, added to ensure freezing and avoid supercooling. Vials were then placed on a reflective aluminium tray, 5 cm above the floor of the frost chamber, cooled by a coil located at the top with the controlling temperature sensor positioned 1 cm above the tray. The chamber was cooled to the set temperature, which, once reached, was maintained for at least 1 hour. The vials were then removed from the chamber and 8 ml of distilled water was added to each. The vials were then capped and put on a shaker at room temperature for 24 hours, a period long enough to allow steady solution conductivity. The conductivity of each vial was then measured after samples were boiled completely, killing the leaf tissue. The vials were shaken again for 24 hours and the solution conductivity was then measured again. Control tissues were obtained by using the same technique, but they were not exposed to the low temperature, although they received the boiling treatment.

Frost Resistance of foliar organs of plants grown in the glass house.

Six seedlings of each of *Acacia dealbata*, *Nothofagus cunninghamii*, *Phebalium squameum* and *Pomaderis apetala* were collected in the field and seed of *Acacia melanoxylon* and *Eucalyptus regnans* were grown in the glass house from September 1990 to July 1991. Plants were grown in sandy loam and watered daily.

During this period no measurement of the temperature was made since it was assumed that all plants were exposed to the same temperature. Plants were hardened by placing pots outside the glasshouse for 14 days. Using the methods described above, freezing damage of foliar organs was then measured..

The leaf tissue conductivity after freezing is usually expressed as a percentage of the conductivity of heat killed tissue weighted by the conductivity of an unfrozen control. However , Flint *et al.* (1967) found that conductivity of unfrozen tissue varies among and within species. They suggested an index of injury (I_t) which ranges from zero, in unfrozen tissue, to 100 in fully damaged tissue. The formula used in this method is as follows:

$$I_t = 100 (R_t - R_o) / (1 - R_o) , \text{ where}$$

$$R_t = L_t / L_k \text{ and } R_o = L_o / L_d$$

I_t is the index of injury resulting from exposure to temperature t

R_t is the fractional release of total electrolytes from the sample exposed to temperature t .

R_o is the fractional release of the electrolytes from an unfrozen sample.

L_o is the specific conductance of leachate from an unfrozen sample.

L_k is the specific conductance of leachate from a sample frozen at temperature t and then heat-killed.

L_d is the specific conductance from an unfrozen sample which has been heat killed.

The index of injury was evaluated from each sample, and the temperature producing T_{50} (50% leaf damage) were calculated. Frost resistance was measured in July 1991.

FROST RESISTANCE OF FIELD COLLECTED PLANTS

A number of previous investigators noted change of freezing resistance with season, altitude and some different conditions of habitat. Many factors influence the frost resistance of plants. Using the method described above, frost resistance of the foliage of plants collected from the field was also measured. Leaves were collected in the field, put in plastic bags and kept in an ice box to avoid desiccation prior to measurements. During the experiment, leaves were kept in a cool room for a maximum of 48 hours after collection.

4.3. Results

a. Frost resistance of plants grown in the glass house

Plants responses to low temperature are shown in Fig.4.3 and Appendix 20, and Table 4.3 shows the T₅₀ value of plants examined. *Eucalyptus regnans* and *Phebalium squameum* show leaf tissue damage exceeding 50% at -6°C, while the remaining show T₅₀ value at -8°C for *Acacia melanoxylon*, -10°C for *Pomaderris apetala* and at -12°C for *Nothofagus cunninghamii*. Clearly *Nothofagus cunninghamii* is more tolerant to frost than other species tested.

b. Frost resistance of seedling collected from the field

Fig.4.1-4.2 and Appendices 18, 19 show the value of the frost resistance for field collected plants which were measured in September 1990 (spring) and in July 1991 (winter).

Some of the samples show that the response to temperature begins at -6°C where, at this point, leaf tissue has reached 50% damage whilst some species begin

this response at -8 °C and -10 °C. All species have reach more than 10% damage by - 6° C (Appendices 23 and 24).

The temperature at which 50% damage occurred which corresponds to mean leaf damage scores of 50%, were evaluated and are presented in Tables 4.1 - 4.2.

Frost resistance of *Eucalyptus* has been widely investigated, since these species range from tropical to alpine environments (Sakai *et al.*, 1981). The frost resistance within this genus varies according to the ability to adapt to habitat conditions. The three species tested(measurement in September 1990), showed different T₅₀ values with the hardest being *Eucalyptus delegatensis* greater than *Eucalyptus regnans* and *Eucalyptus regnans* greater than *Eucalyptus obliqua* (Table 4.1). This result agrees with that of Rock. (1980) who found that *Eucalyptus delegatensis* was more frost resistant than *Eucalyptus regnans*. *Eucalyptus delegatensis* extends to subalpine areas

The rainforest species, *Nothofagus cunninghamii*, shows more tolerance to frost than the other rainforest species. From Tables 4.1 and 4.2 it can be seen that *Nothofagus cunninghamii* has the lowest T₅₀ value followed by *Eucryphia lucida*, *Phyllocladus aspleniifolius* and *Atherosperma moschatum*. This means that *Nothofagus cunninghamii* is the rainforest species least susceptible to frost, which supports the results of Read and Hill (1985).

Of the three understorey species, *Olearia argophylla* is the most resistant species, followedby *Pomaderris apetala*, *Acacia melanoxylon* and *Phebalium squameum*.. These results were consistent between measurements made in September 1990 and July 1991.

The maximum and minimum freezing resistance temperatures are shown in Table 4.4. *Nothofagus cunninghamii* appears to be highly frost resistant with a

maximum temperature at which 50% leaf tissue damage occurred at -9.6°C and minimum at -11°C. The maximum temperature at which damage was recorded was lower than data recorded by Read & Hill (1988). This may be because of different climatic conditions during hardening.

Table 4.1. T50 of Species evaluated in September 1990. The values are the means of five replicates with standard errors shown.

Species	:	T50 (°C) : From Read & Hill (1988)	
		Mt.Field, 700 m a.s.l	
<hr/> 2 years old <hr/>			
<i>Acacia melanoxylon</i> (phyllodes)	:	-9.00 ± 0.09	
<i>Atherosperma moschatum</i>	:	-5.90 ± 0.12	: -6.50
<i>Eucalyptus delegatensis</i>	:	-6.49 ± 0.03	
<i>Eucalyptus obliqua</i>	:	-4.79 ± 0.04	
<i>Eucalyptus regnans</i>	:	-5.14 ± 0.04	
<i>Eucryphia lucida</i>	:	-8.46 ± 0.12	: -9.20
<i>Nothofagus cunninghamii</i>	:	-8.75 ± 0.08	: -10.50
<i>Olearia argophylla</i>	:	-9.92 ± 0.31	
<i>Phebalium squameum</i>	:	-5.75±0.02	
<i>Phyllocladus aspleniifolius</i>	:	-6.44±0.02	: -9.1
<i>Pomadouris apetala</i>	:	-9.51±0.11	

Table 4.2 T50 of species evaluated in July 1991. The values are the mean of five replicates with standard errors shown. Adult plants were used.

Species	:	T50(°C)
<i>Acacia melanoxylon</i> (phyllodes)	:	-10.30 ± 0.80
<i>Acacia melanoxylon</i> (leaves)	:	- 7.60 ± 0.40
<i>Acacia dealbata</i>	:	-10.70 ± 0.09
<i>Atherosperma moschatum</i>	:	- 6.14 ± 0.11
<i>Eucalyptus delegatensis</i>	:	- 7.06 ± 0.23
<i>Eucalyptus obliqua</i>	:	- 4.85 ± 0.04
<i>Eucalyptus regnans</i>	:	- 5.23 ± 0.02
<i>Eucryphia lucida</i>	:	-10.80 ± 0.04
<i>Nothofagus cunninghamii</i>	:	-10.90 ± 0.04
<i>Olearia argophylla</i>	:	- 9.40 ± 0.24
<i>Phebalium squameum</i>	:	- 5.71 ± 0.10
<i>Phyllocladus aspleniifolius</i>	:	- 8.71 ± 0.20

two year old plants with adult leaves

Table 4.3. T50 of species which were grown in a glass house. The values are the mean of five replicates with standard errors shown.

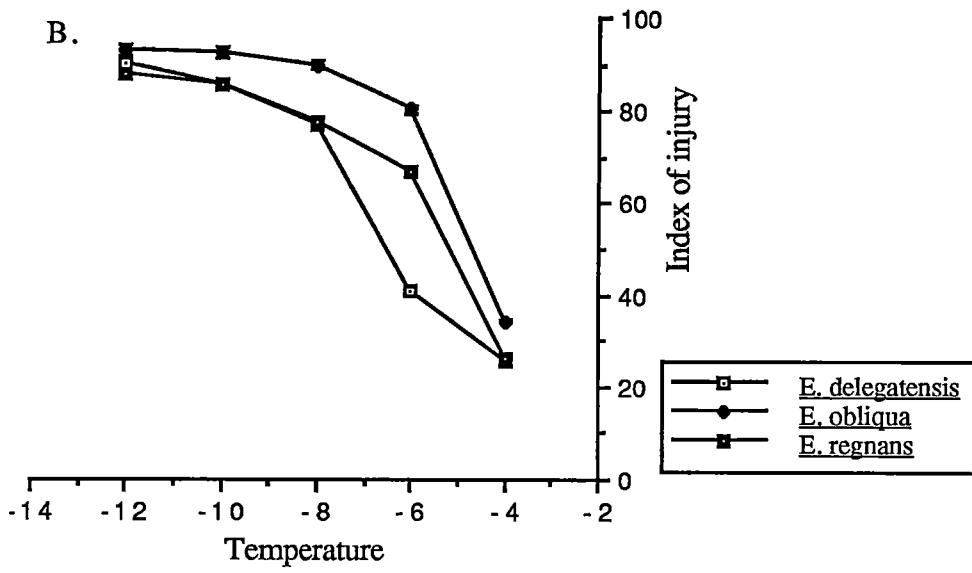
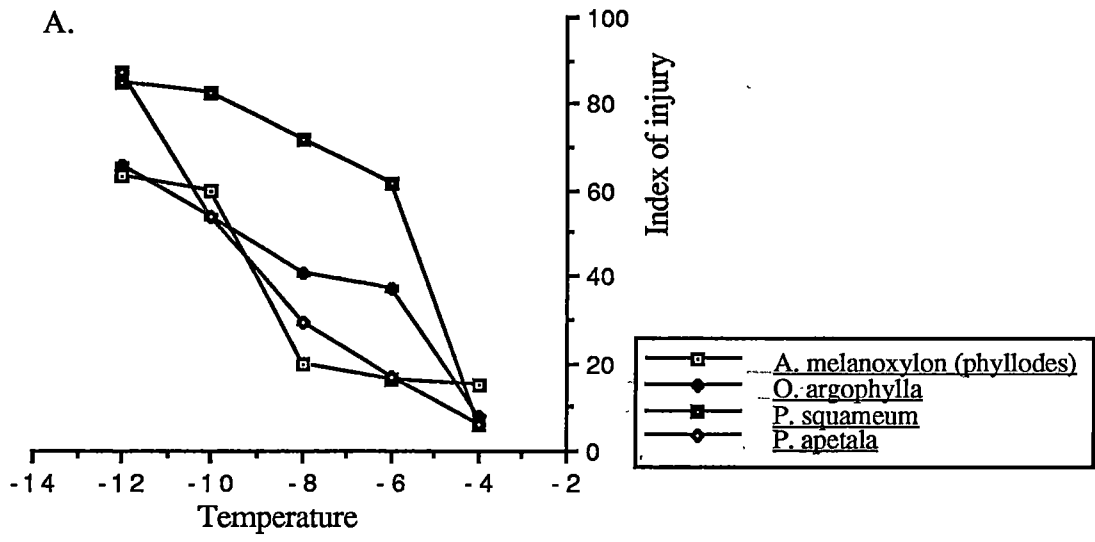
Species	:	T50 (°C)
<i>Acacia dealbata</i>	:	-9.87 ± 0.41
<i>Acacia melanoxylon</i> (leaves)	:	-7.90 ± 0.04
<i>Eucalyptus regnans</i>	:	-5.57 ± 0.09
<i>Nothofagus cunninghamii</i>	:	-9.80 ± 0.14
<i>Phebalium squameum</i>	:	-5.50 ± 0.23
<i>Pomaderris apetala</i>	:	-9.46 ± 0.41

Table 4.4 . Maximum and minimum T50 values of foliage from plants grown in the glasshouse and hardened, and plants collected in the field.

Species	Month T50 (°C) measurements were made:						: Data recorded Read&Hill			
	Sept. 1990		: July 1991		: July 1991 (glasshouse)		: (1988)			
	: Max.	Min.	Max.	Min.	Max.	Min.	: Glasshouse: Mt.Field			
							: Max. Min : Max. Min.			
<i>A. melanoxylon</i> (phyllodes)	: -8.80	-9.20	-8.00	-10.95	_____	_____				
<i>A. melanoxylon</i> (leaves)	: _____	_____	-7.45	-8.10	-7.70	-8.50				
<i>A. dealbata</i>	: _____	_____	-10.60	-11.00	_____	_____				
<i>A. moschatum</i>	: -5.70	-6.20	-5.90	-6.40	_____	_____	: -3.80	-6.00	: -3.70	-7.80
<i>E. delegatensis</i>	: -6.25	-6.60	-6.50	-7.25	_____	_____				
<i>E. obliqua</i>	: _____	_____	-4.55	-4.70	_____	_____				
<i>E. regnans</i>	: -4.95	-5.25	-5.10	-5.50	-5.30	-5.75				
<i>E. lucida</i>	: -8.00	-8.65	-10.80	-11.00	_____	_____	: -4.30	-7.30	: -6.00	-12.80
<i>N. cunninghamii</i>	: -8.50	8.95	-10.90	-12.00	-9.60	-11.00	: -4.30	-9.50	: -6.90	-15.90
<i>O. argophylla</i>	: -8.90	-10.40	-8.75	-10.10	_____	_____				
<i>P. squameum</i>	: -5.50	-5.75	-5.50	-6.10	-5.20	-6.10				
<i>P. aspleniifolius</i>	: -6.20	-6.45	-8.20	-10.00	_____	_____	: -4.00	-6.80	: -3.80	-11.10
<i>P. apetala</i>	: -9.40	-10.00	-8.05	-10.00	8.15	-10.20				

Fig. 4.1. Index injury for eleven species tested collected from study sites (approximately 300 a.s.l.), logged ^ocupes South West Tasmania. Measurement was made in September 1990.

- A. *Acacia melanoxylon* (phyllodes and leaves)
Pomaderris apetala, *Olearia argophylla*, *Acacia dealbata* and *Phebalium squameum*
- B. *Eucalyptus delegatensis*, *Eucalyptus regnans*
and *Eucalyptus obliqua*
- C. *Nothofagus cunninghamii*, *Atherosperma moschatum*, *Eucryphia lucida* and
Phyllocladus aspleniifolius



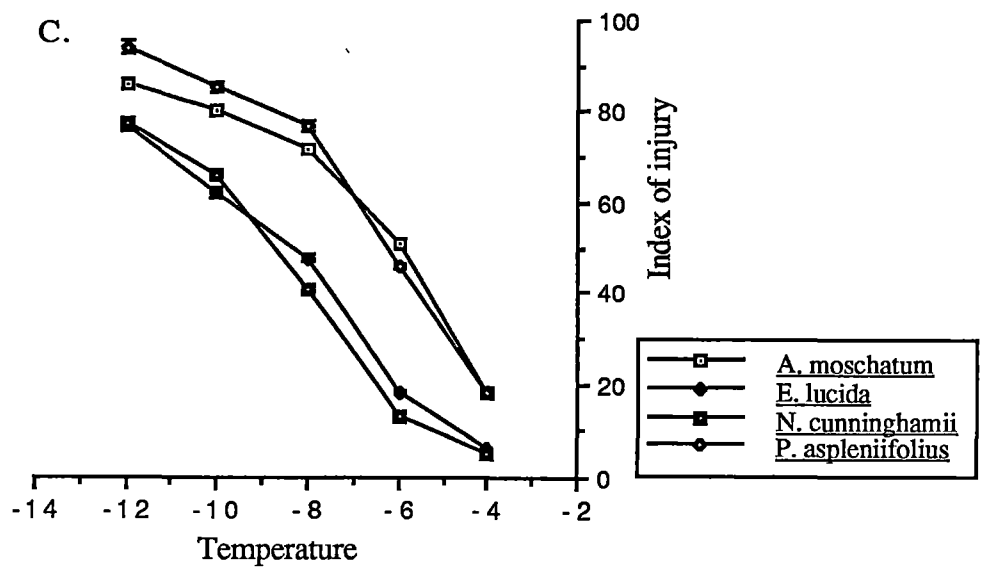
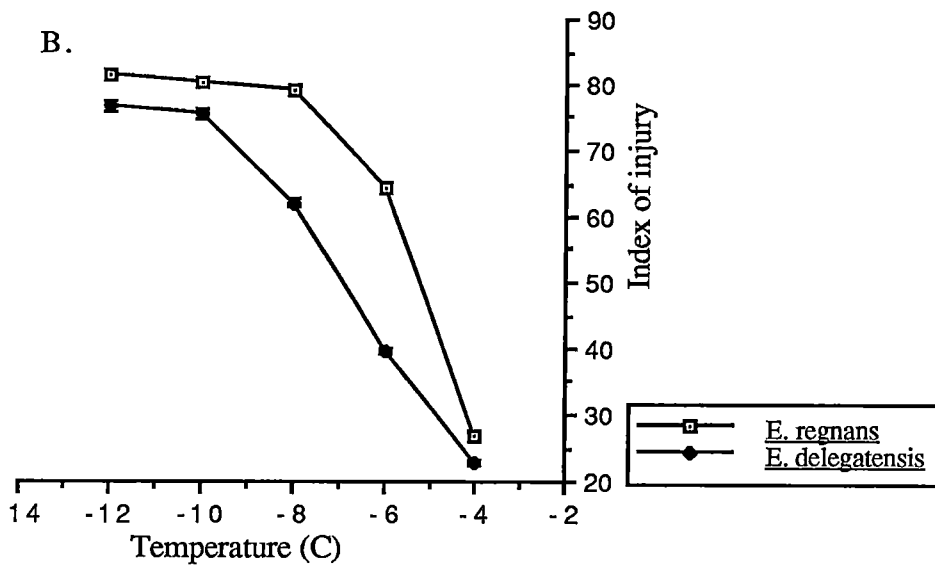
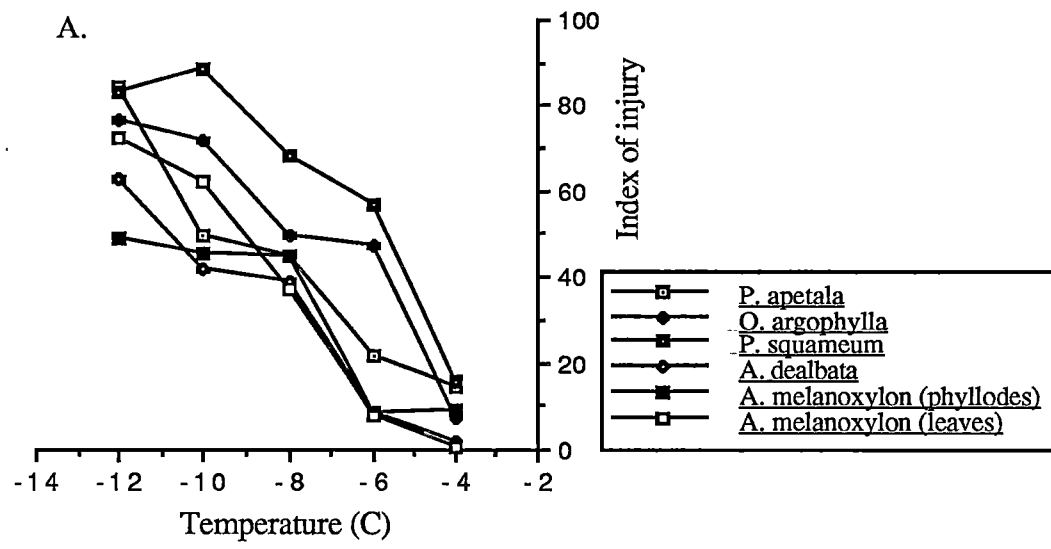


Fig. 4.2 Index injury for eleven species tested collected from study sites (approximately 300 a.s.l.), logged coupes South West Tasmania. Measurement was made in July 1991.

- A. *Acacia melanoxylon* (phyllodes & leaves),
 Pomaderris apetala, *Olearia argophylla* and
 Acacia dealbata
- B. *Eucalyptus delegatensis* and *Eucalyptus regnans*
- C. *Nothofagus cunninghamii*, *Atherosperma*
 moschatum, *Eucryphia lucida* and
 Phyllocladus aspleniifolius



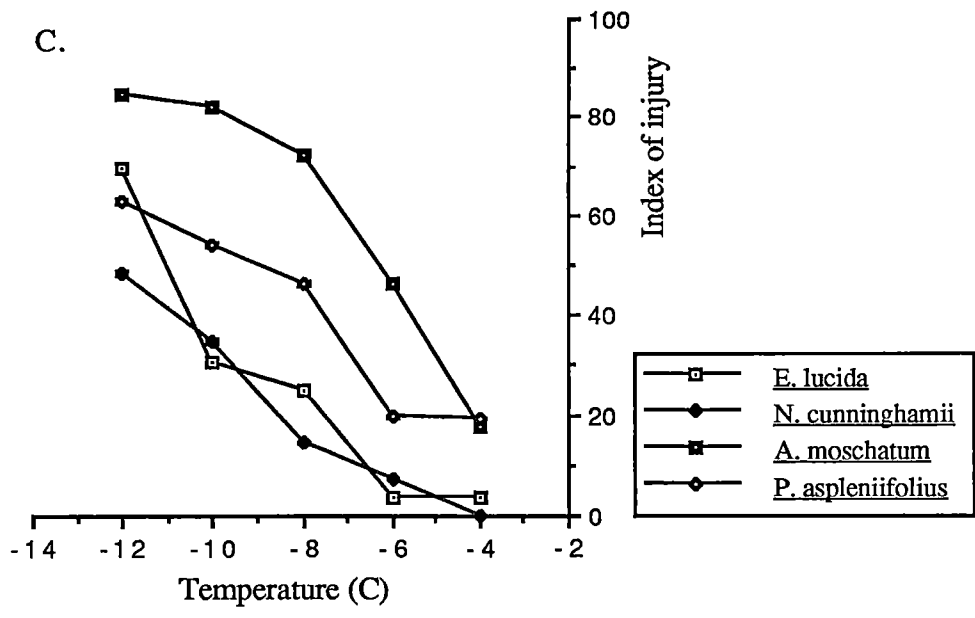


Fig. 4.3 Index of injury for six species glasshouse-grown and hardened
Measurement was made in July 1991.

A. *Acacia dealbata* (leaves), *Acacia melanoxylon* (leaves),
Phebalium squameum and *Pomaderris apetala*

B. *Nothofagus cunninghamii* and *Eucalyptus regnans*

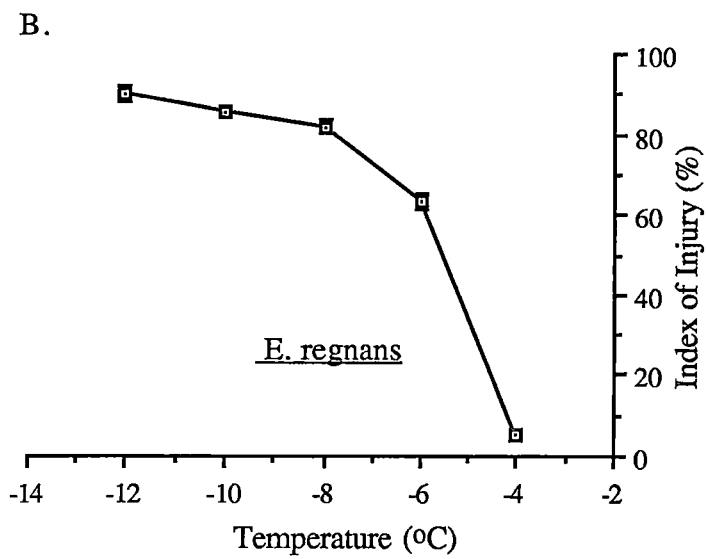
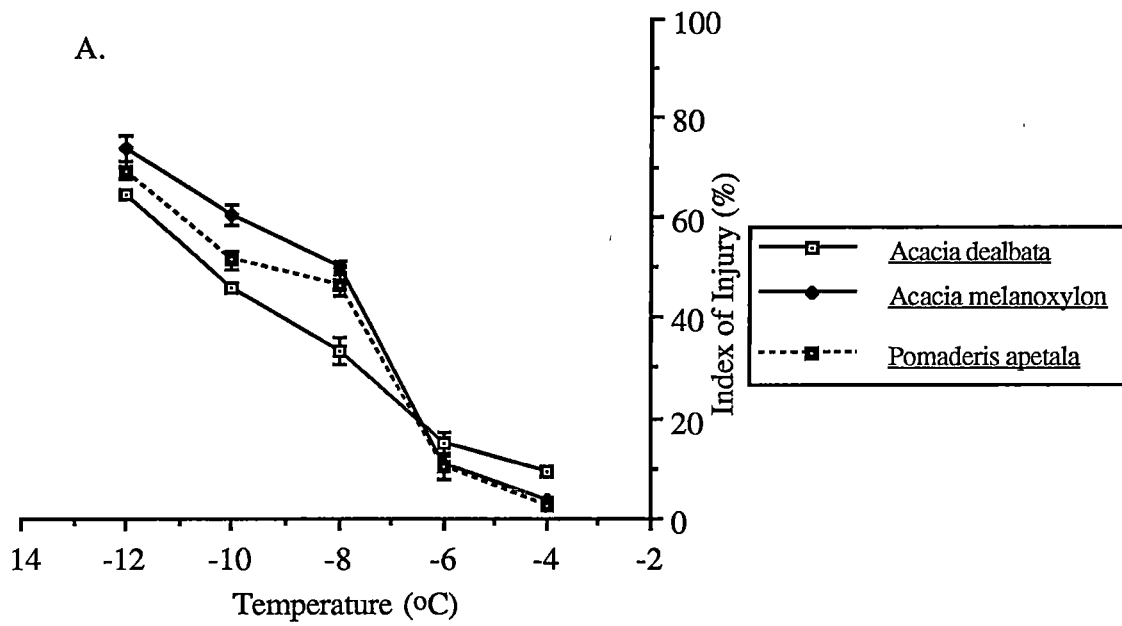


Table 4.5. Frost reistance (T50) of foliage collected from seedlings at the logged area in South West tasmania.

* T50 of measurement in July and September differ significantly ($p < 0.01$)

Species	: Month T50(°C) measurements were made:			
	September 1990 July 1991			
<i>Acacia melanoxylon</i> (phyllodes)	:	-9.00	:	-10.3 *
<i>Atherosperma moschatum</i>	:	-5.92	:	-6.12
<i>Eucalyptus delegatensis</i>	:	-6.42	:	-7.00 *
<i>Eucalyptus regnans</i>	:	-5.08	:	-5.29 *
<i>Eucryphia lucida</i>	:	-8.32	:	-10.90 *
<i>Nothofagus cunninghamii</i>	:	-8.75	:	-11.45 *
<i>Olearia argophylla</i>	:	-9.90	:	-9.40
<i>Phebalium squameum</i>	:	-5.61	:	-5.70
<i>Pomaderris apetala</i>	:	-9.68	:	-9.53
<i>Phyllocladus aspleniifolius</i>	:	-6.33	:	-8.71 *

Table 4.5 shows the seasonal change of T50 value, where measurements made in the winter season have lower T50 values than measurements made in the spring season. There is a significant difference ($p < 0.05$) for *Acacia melanoxylon*, *Eucalyptus regnans*, *Eucalyptus delegatensis*, *Eucryphia lucida*, *Nothofagus cunninghamii* and *Phyllocladus aspleniifolius*, and no significant difference for the remaning species.

4.3. Discussion

Most plants will die when the index of injury reaches 50%. So, T₅₀ is approximately the temperature minimum which causes the damage of leaf tissue where most plants can not survive.

The order of foliar resistance among rainforest species is similar to that recorded by Read and Hill (1988) and Read and Hope (1989), with *Nothofagus cunninghamii* having the lowest freezing temperature based on the T₅₀ value followed by *Eucryphia lucida*, *Phyllocladus aspleniifolius* and *Atherosperma moschatum*. (Figs. 4.1 and 4.2). However, considering the regeneration and distribution pattern in the field, it seems that the importance of frost resistance is uncertain in these species. This may be because the lowest temperature recorded is still above the temperature at which 50% damage occurs, or lower than T₅₀ but the duration is not long enough to damage plant tissue.

Phyllocladus aspleniifolius has a lower frost resistance than *Atherosperma moschatum*. However, *Atherosperma moschatum* was found to regenerate better ^{in the study area} than *Phyllocladus aspleniifolius*. The frost resistance of a plant is determined by various characteristics of form, structure and physiological attributes. The low foliar frost resistance of *Atherosperma moschatum* is consistent with its greater frequency at low altitude and infrequency at high altitude relative to *Nothofagus cunninghamii* (Read & Hill, 1988). This suggests that some other factors such as light intensity, soil fertility and water availability, as well as seed source are playing a more important role in determining the pattern and distribution of seedlings. This condition is common in lowland disturbed forest especially after logging with low fire intensity, dominated by *Eucryphia lucida*, *Nothofagus cunninghamii* and *Atherosperma moschatum*.

Eleven of the species tested in September show increases in their frost

resistance. *Olearia argophylla* is the most frost resistant, followed by *Pomaderris apetala*, *Acacia melanoxylon*, *Phebalium squameum*, *Eucalyptus regnans* and *Eucalyptus obliqua*.

Measurements made in July 1991 show changes in the order of frost resistance, in that *Nothofagus cunninghamii* had the highest frost resistance. This result shows that *Nothofagus cunninghamii* acclimated to low temperature better than the other species, with its T50 value becoming more negative (by 2.7°C) followed by *Eucryphia lucida* (2.58°C), *Phyllocladus aspleniifolius* (2.38°C), *Acacia melanoxylon* (1.3°C), while other species improved by less than 1°C. Different species have different abilities to acclimatize to low temperature. Some plants can acclimatize in a short time thereby increasing their frost resistances, while other species need a longer duration.

The higher degree of exposure required to achieve the same level of tolerance of the understorey species *Pomaderris apetala* and *Olearia argophylla* may be because these species are more drought tolerant and their leaf morphology, may play an important role in frost resistance. The tomentose leaves of *Pomaderris apetala* and waxy layer on *Olearia argophylla* leaves may reduce the water content in the leaf cell. These species tend to grow in drier and more open areas, and tend to be more sun tolerant being plants in early successional sequences which are usually more tolerant to drought. It has been noted that dry leaf surfaces are more tolerance to frost than wet leaves (Thomas and Barber 1974).

These species have been noted as understorey species in wet sclerophyll forest, and are absent at high altitude. In this study, *Pomaderris apetala*, *Olearia argophylla*, *Acacia dealbata* and *Acacia melanoxylon* were uncommon, while other species, which have less frost tolerance, were found to regenerate successfully. This indicates that no correlation between frost resistance and distribution patterns were

found for these species.

Juvenile leaves of *Acacia melanoxylon* show lower frost resistance than phyllodes, and this is evidence that young leaves lack protected tissue and are thus less tolerant to frost than mature leaves (Levitt 1956).

The results of frost resistance experiments compared to observation in the field, show that frost resistance is more important in determining the regeneration pattern and distribution at high altitude or in colder areas. Frost resistance does not appear to play an important role in determining regeneration pattern and distribution in low land sites. In the low land site the temperature is usually above the freezing temperature of plants. Photosynthetic performance may be more important than frost resistance.

The seasonal change between two different time measurement was shown in this study. July measurements have slightly lower T_{50} values, although for some species it is not significantly different (Table 4.5). The results show the seasonal change of frost resistance, which increases in winter (Levitt 1956; Sakai and Otsuka 1970; Burke *et al.* 1976; Larcher 1981; Horiuchi and Sakai 1978)

In comparison with field collected plants, seedlings grown in the glasshouse and hardened show a decrease in their frost resistance. Seedlings grown in the field, which are exposed to low temperature, better acclimate to low temperature than glass house grown plants (Levitt 1956; Larcher 1981; Larcher 1982).

PHOTOSYNTHETIC RESPONSE TO LIGHT

5.1. Introduction

No doubt growth of plants is influenced by the intensity of light which is the driving force of photosynthesis. Light intensity is probably one of the most important environmental variables which the plant must adapt to. The relationship between photosynthetic performance and light intensity has long been recognised. The phenomenon of light saturation has been known for more than a century. However the response of plant to light has been studied intensively only for about 50 years, for example by Rabinowict (1951); Blackman (1956, 1968); Bjorkman & Holmgren (1963; Bjorkman 1968, 1973); Boardman (1977); Bazzaz & Calson (1982) and (Turton 1990). The photosynthetic response of plants to light, like frost resistance, is one of the ecophysiological aspects that affect the distribution and abundance of species in the forest.

Plants have different abilities to adapt to factors such as light intensity. It is known that leaves of plants grown under, or ecologically restricted to, high irradiance levels generally have higher photosynthetic rates per unit leaf area at those levels than plants restricted or acclimated to low irradiance (Bjorkman *et al.* 1972a, 1972b; Bjorkman 1973; Boardman 1977). Sun plants have the ability to increase light saturation with increased photon flux density during growth (Bjorkman and Holmgren 1963). Furthermore Boardman (1977) noted the leaves of shade plants are thinner and their chloroplasts larger and richer in chlorophyll than leaves of sun

plants.

Most experiments which have been conducted reflect the characteristics of herbaceous plants. The potential of woody plant to acclimate to light intensity is not well known. It was found, in work done by Wallace and Dunn (1980), that in leaves of temperate forest tree seedlings the potential was similar, irrespective of whether the tree ultimately occupied low (shaded) or high light intensity. However, according to Bjorkman *et al.* (1972), plants which obligately occupy the deeply shaded areas show very limited potential for acclimation to high light.

This work examines the net photosynthetic rate of some plant seedlings collected from wet/forest/ mixed forest and grown in contrasting shade and sun conditions in a glass house. By doing this, it was possible to investigate how significant a role light intensity plays in determining the distribution of these species in nature. Leaves of seedlings were used to investigate whether factors which contribute some species which dominate from an early stage of regeneration could be discovered.

5.2. Materials and Methods

Six species were collected^{as seedlings} from the study sites and were grown in a glasshouse. Seedlings of each species were grown in contrasting light regimes in the glasshouse from December 1990 to February 1991. All plants were grown in sandy loam and watered daily.

The methods used in this experiment were similar to those used by Read (1985) and Read and Hill (1985), where an IRGA (Infra Red Gas Analyser) was used to measure the net rate of CO₂ assimilation at selected incident photon flux densities. A flow diagram (Fig. 5.1) shows the gas circuit and apparatus used.

Infra Red Gas Analysers are now the most commonly used type of CO₂ analyser. They are popular because of their accuracy and reliability of performance, as well as the simplicity of their operation. Their undeniable advantages are that they continuously and directly measure the CO₂ density (Sestak *et al.* 1971).

The light source consisted of a 400 watt multimetal lamp. Photosynthetically active radiation was measured by a LiCor LI-1185 meter with quantum sensor. A variety of neutral density filters were used to vary the amount of light directed onto the leaf. Humidified air (317 - 340 ppm CO₂) was pumped through the leaf chamber of cross sectional area 10 cm² at a flow rate of between 400 - 530 ml min⁻¹. The leaf chamber was made of perspex and consisted of two halves which fitted together above and below the attached horizontal leaf. The petiole lay in a groove which was sealed on the out side of the chamber by blu-tack. Moisture was condensed from the gas lines prior to analysis. The CO₂ differential was recorded by a chart recorder after a steady assimilation rate had been reached. Leaf temperature was measured by a thermocouple on the lower leaf surface and temperature was kept within the range of 20 ± 2° C. This was considered to be within the optimal temperature range for all species investigated (Larcher 1973, Read 1985).

Five plants of each species were grown in shade outside the glass house (approximately 80% of the PAR of natural sunlight), and the same number received direct sunlight. The total number of replicates were four, where one plant was damaged, to five in each treatment, and one leaf per plant was used. Leaf area was measured using a leaf scanner, and leaf dry weight was taken to measure the specific leaf area (SLA). Carbon dioxide exchange was measured at light intensity ranging from total darkness to 1300 $\mu\text{E m}^{-2} \text{s}^{-1}$, starting at the highest light intensity. Measurements were recorded after readings had stabilised for about 5 to 10 minutes.

The results obtained from the recorder in ppm of CO₂ were converted to the net uptake of CO₂. To calculate the rate of CO₂ fixation, the following formula was used (after Read 1985a):

$$P = 44000/22.4 \times f \times d/106 \times 1/a; \quad \text{where :}$$

44000 = the mgm molecular weight of CO

P = The net uptake of CO₂ (mg CO₂ cm⁻² hr⁻¹)

f = flow rate (l/hr)

d = CO₂ differential (ppm)

a = leaf area (cm²)

22.4 = the volume of 1 mole of CO₂

During the experiment the photosynthetic response of six species of leaf tissue samples was measured. The species were:

1. *Acacia dealbata* Link.
2. *Acacia melanoxylon* R.Br
3. *Eucalyptus regnans* F. Muell
4. *Nothofagus cunninghamii* (Hook f.) Oerst
5. *Phebalium squameum* (Labill.) Engler
6. *Pomaderris apetala* Labill.

The resulting photosynthetic data were graphed to compare the light - dependence of plants grown in sun and shade.

5.3. Results

Details of the light-dependence curves (Figs.5.2A-5.2E) and leaf characteristics are summarised in Table 3 and 4. Only data for five of the six species above was obtained, since the *Pomaderris apetala* sun treatment plants lost their leaves, perhaps due to high winds, droughting or high light intensities during treatment.

All species acclimated to shade conditions by decreasing the dark respiration rate (DRR), instantaneous light compensation point (LCP) and increasing the specific leaf area (SLA). From tables 5.1 and 5.2, it can be seen that all species grown in full sunlight have higher dark respiration rates (DRR), instantaneous light compensation points (LCP) and maximum rates of net photosynthesis (Pmax.) on a leaf area basis compared to seedlings grown in the shade.

Nothofagus cunninghamii, *Phebalium squameum* and *Pomaderris apetala* show no significant difference ($p < 0.05$) in DRR, between leaves subjected to different light regimes (sun and shade). The maximum rate of photosynthesis (Pmax) on a dry weight basis of all species are not significantly different in different growth light conditions (sun and shade) except that the Pmax of *Acacia dealbata* is significantly different ($p < 0.005$). Also the dark respiration rates (DRR) on a dry weight basis of all species was unaffected by the light regime during growth. This does not clearly show the typical response of shade plants as described by Bordman (1977), where a plant grown under shade conditions is supposed to have a lower dark respiration rate than plant when grown in full sun light. Read (1985) believed that this is because seedlings grown in a glass house which were collected from sites receiving full light on low land sites, had thickened leaves which is not a typical characteristic of plants growing in full sunlight on low land sites such as the logged forest sites after fire.

Of the six species tested, *Eucalyptus regnans* showed the highest dark

respiration rate (DRR), light compensation point (LCP) and maximum photosynthesis (P_{max}) on a leaf area basis (Fig.5.2 & Table 5.1). In both shade and sun-raised seedlings, *Acacia melanoxylon* has the highest specific leaf (phyllode) area consequently has the highest P_{max} on dry weight basis. Specific leaf area is altered by growth light conditions. Specific leaf area increased in shade conditions with *Eucalyptus regnans* having the highest proportion of increasing specific leaf area from sun to shade (51%) followed by *Acacia dealbata* (31.5%), *Phebalium squameum* (28.6%), *Nothofagus cunninghamii* (2.4%) and *Acacia melanoxylon* (2.05%). This indicates that response of photosynthesis to the light intensity was influenced by different light condition during growth (Bjorkman & Holmgren 1963).

From Table 5.2, it can be seen that all shade plants are slightly higher in quantum efficiency than sun plants although there is no significant difference between sun and shade plants of *Phebalium squameum*, *Pomaderris apetala* or *Acacia dealbata*. *Nothofagus cunninghamii* had the highest quantum efficiency value, which suggest that is more shade tolerant than the other species.

Acacia melanoxylon and *Eucalyptus regnans* have a higher quantum efficiency than *Acacia dealbata* and *Phebalium squameum*. This does not reflect the adult characteristics for these plants, since juvenile leaves were used for *Acacia melanoxylon* and *Eucalyptus regnans*. Ashton & Turner (1979) believed that juvenile leaves of *Eucalyptus regnans* are more shade tolerant than adult leaves. In this study, this was shown to be true for *Acacia melanoxylon* and was assumed to happen in *Eucalyptus regnans*.

Nothofagus cunninghamii had the lowest light saturation at approximately 300 $\mu\text{mol quanta m}^{-2}\text{s}^{-1}$ for shade plants and 500 $\mu\text{mol quanta m}^{-2}\text{s}^{-1}$ for sun plants. *Acacia melanoxylon*, *Acacia dealbata* and *Phebalium squameum* have

relatively similar light saturation intensities. The low light saturation intensity of *Nothofagus cunninghamii* suggest that this species should be considered to be a late successional plant and shade tolerant. It has been noted that early successional plants have a higher light saturation level than plants which occur in later successional sequences (Loach 1967).

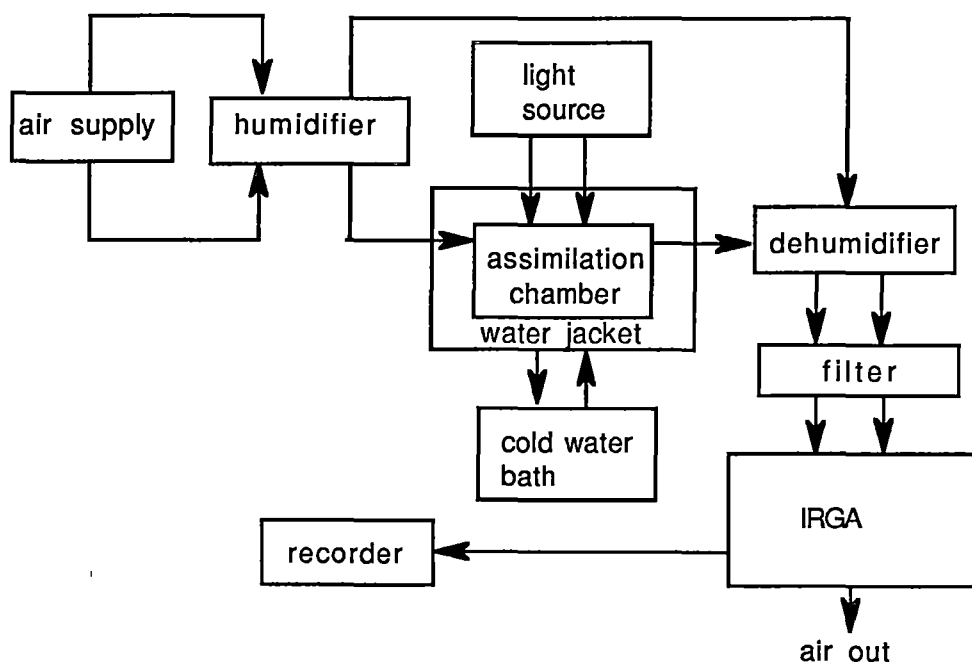


Fig. 5.1. Diagram open-flow IRGA

Figure 5.1. Light dependence curves of photosynthesis of plants grown in sun (____) and shade (-----) conditions in a glasshouse. Each point is the mean of four to five replicates. Standard error is shown on each curve.

A. *Acacia dealbata*

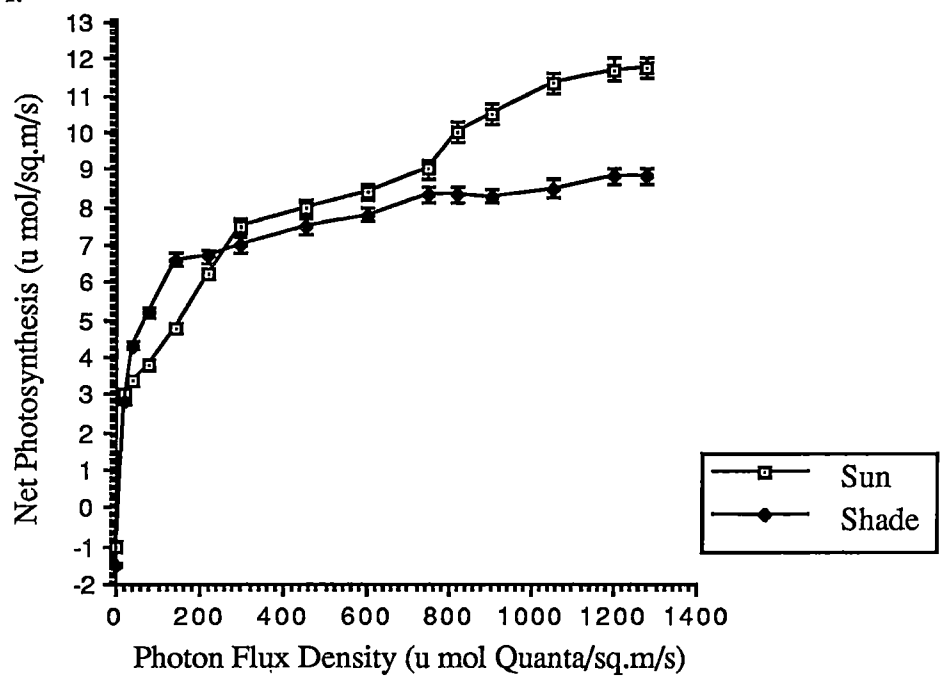
B. *Acacia melanoxylon*

C. *Eucalyptus regnans*

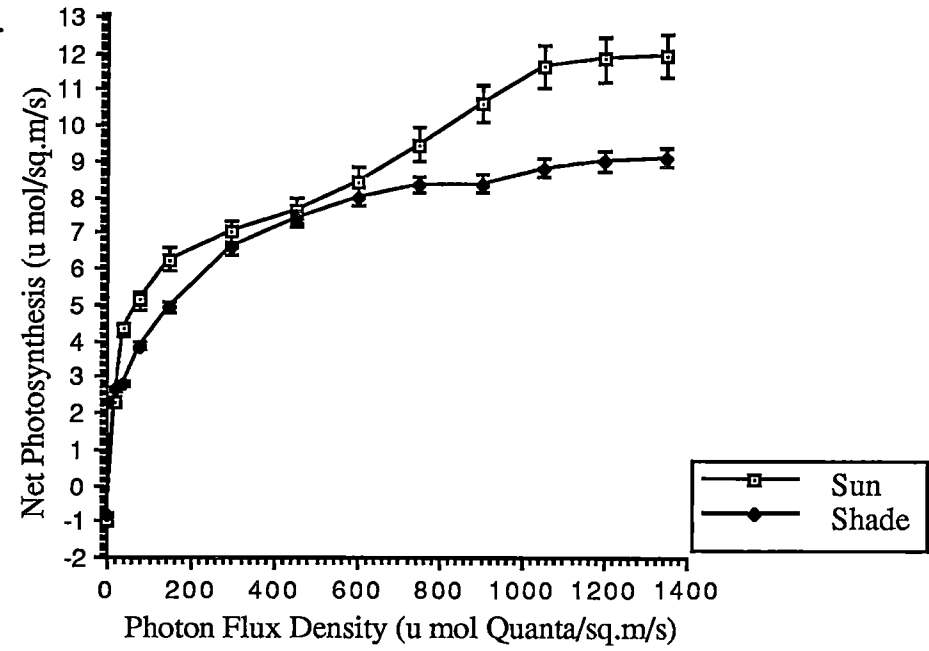
D. *Nothofagus cunninghamii*

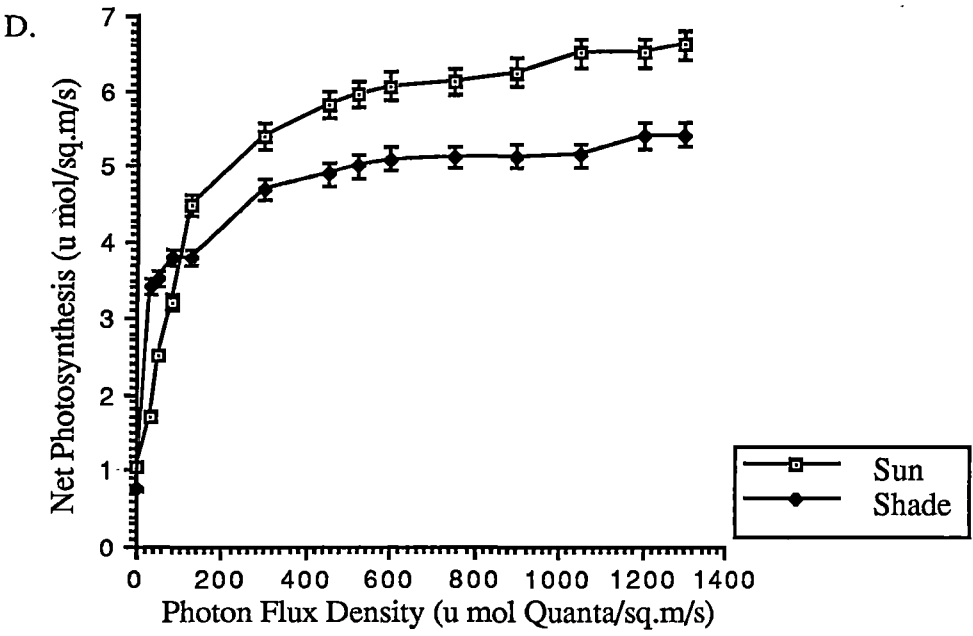
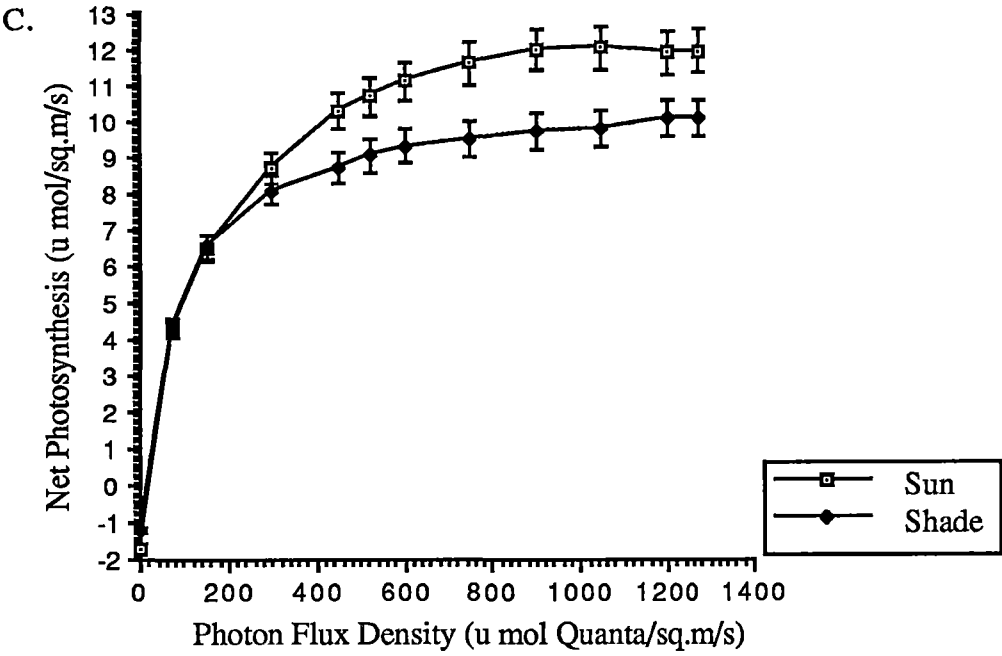
E. *Phebalium squameum*

A.



B.





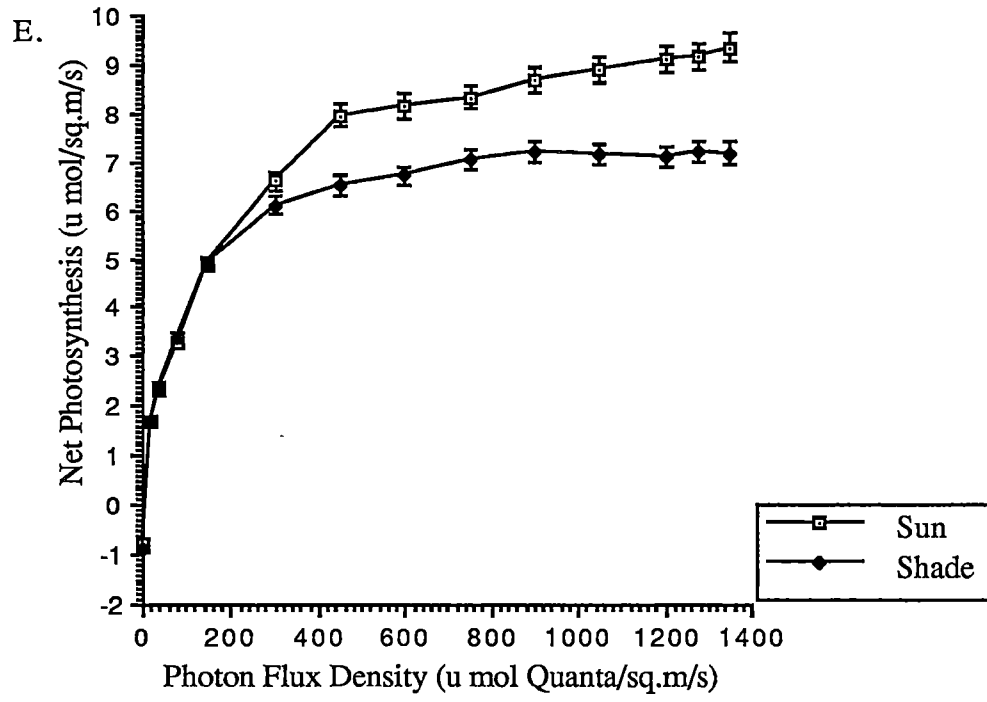


Table 5.1. Leaf characteristics and details from the light -dependence curves for plants raised in shade and sun conditions outside the glass house.

Species	Light regime	Specific leaf area (cm ² g ⁻¹)	DRR (μmol m ⁻² s ⁻¹)	DRR (μmol g ⁻¹ s ⁻¹)	LCP (μmol g ⁻¹ s ⁻¹) (quanta m ⁻² s ⁻¹)	Pmax (μmol g ⁻¹ s ⁻¹)
<i>Acacia dealbata</i>	SUN	53.3±5.2*	1.1±0.4*	0.0013±0.0003	14.1±3*	0.108±0.008*
	SHADE	79.1±1.2	0.5±0.06	0.0034±0.0009	9.7±1	0.082±0.002
<i>Acacia melanoxylon</i> #	SUN	83.2±3.9*	0.9±0.2*	0.0160±0.0040	15.8±3*	0.241±0.004
	SHADE	83.9±5.8	0.6±0.1	0.0160±0.0030	10.8±1	0.220±0.009
<i>Eucalyptus regnans</i> #	SUN	39.4±3.2*	1.6±0.8*	0.0130±0.0040	20.0±4*	0.117±0.009
	SHADE	59.5±3.6	0.8±0.2	0.0100±0.0020	11.5±1	0.140±0.003
<i>Nothofagus cunninghamii</i>	SUN	61.8±2.9*	1.1±0.4	0.0210±0.0080	14.8±3*	0.121±0.013
	SHADE	63.3±2.2	0.8±0.2	0.0100±0.0040	7.3±1	0.091±0.008
<i>Phebalium squameum</i>	SUN	38.6±0.9*	1.2±0.1	0.0150±0.0020	17.6±2*	0.121±0.024
	SHADE	47.8±4.8	0.8±0.06	0.0160±0.0020	12.0±1	0.162±0.040

Each value is the mean of four to five replicates, with standard error.

* Sun and shade treatments of the same species differ at the 95% significance level.

Juvenile leaves

Table 5.2 Quantum efficiencies (plants grown in sun and shade conditions outside the glasshouse).

Species	Light regime	Quantum efficiency
<i>Acacia dealbata</i>	Sun	2.10 ± 0.20
	Shade	2.40 ± 0.30
<i>Acacia melanoxylon</i> #	Sun	2.40 ± 0.20*
	Shade	3.20 ± 0.20
<i>Eucalyptus regnans</i> #	Sun	2.40 ± 0.20*
	Shade	3.00 ± 0.10
<i>Nothofagus cunninghamii</i>	Sun	2.20 ± 0.20*
	Shade	3.50 ± 0.10
<i>Phebalium squameum</i>	Sun	1.85 ± 0.10
	Shade	2.70 ± 0.20

Juvenile leaf

Each value represents the mean from 4 to 5 replicates with standard error.

* Sun and shade treatments of the same species differ at the 95% significance level.

5.4. Discussion

Nothofagus cunninghamii has a low light compensation point in shade-raised plants. Low light compensation points are typical of shade plants. The greater shade-tolerance of *Nothofagus cunninghamii* suggests that this species would regenerate under denser canopies. However, regeneration patterns of *Nothofagus cunninghamii* based on results of this study do not clearly support this assumption. *Nothofagus cunninghamii* was found to regenerate well in open areas of the study site. This may be influenced by some environmental factors during establishment and growth. It seems, besides photosynthetic character, some other factors in the study site such as seed availability or soil condition allow this species to regenerate under open area. It has been found in some previous studies that *Nothofagus*

cunninghamii has the ability to regenerate under low to moderate light intensity. In rainforest this species has its greatest importance near the forest edge (Read 1983) and is very competitive under favourable conditions (Read 1985).

Nothofagus cunninghamii does not possess a low dark respiration rate as commonly expected for typical shade tolerant plants. The dark respiration rates on both a leaf area and dry weight basis are lower for *Acacia dealbata* and *Acacia melanoxylon* when plants are grown in the shade, while *Eucalyptus regnans* has a dark respiration rate which is most similar to *Nothofagus cunninghamii* in terms of leaf area and dry weight. This does not reflect the characteristics for these species, but suggests that juvenile leaves of *Eucalyptus regnans* are more shade tolerant than adult leaves. In other words, results from this study (Table 5.3) do not clearly show the typical features of sun or shade adaptation as described by Boardman (1977) and Bjorkman (1981). This may be because in this study juvenile leaves were used for some species. The leaf thickness of plants grown in the glasshouse is not typical of plants growing in the low land site. It has been noted from previous results that non herbaceous plants do not all clearly show typical sun or shade responses like herbs (Langerhem *et al.* 1984). Results of the photosynthetic response of *Nothofagus cunninghamii* to light intensity in this study reflect that this species is not an obligately shade plant. However, *Nothofagus cunninghamii* has the highest quantum efficiency value, which suggests that this species is the most tolerant of the species tested and can probably regenerate under denser canopies.

The quantum efficiency of *Acacia melanoxylon* and *Eucalyptus regnans* (juvenile leaves) is higher than *Acacia dealbata* and *Phebalium squameum* (Table 5.2). Considering that in their natural distribution these species commonly occur together as understorey species in wet forest, the results do not reflect all characteristics of these species. This is further evidence which suggests that juvenile leaves are more shade tolerant than adult leaves.

Nothofagus cunninghamii, *Acacia dealbata*, *Acacia melanoxylon*, *Eucalyptus regnans* and *Phebalium squameum* do not exhibit photosynthetic characteristics which allow them to be clearly separated from each other. However, *Eucalyptus regnans* is still more efficient than the other species when grown in full sunlight and *Eucalyptus regnans* has higher maximum photosynthetic rates on a leaf area basis compared to the other species under high photon flux densities.

On a dry weight basis, *Acacia melanoxylon* has a higher maximum photosynthetic rate in both sun and shade raised plants. The high specific leaf area for this species in sun and shade conditions increased the P_{max} on dry weight basis (Table 5.1), however on a leaf area basis *Eucalyptus regnans* had the highest P_{max} (Fig.5.1-5.5). This results shows that it is difficult to determine whether plants tend to be sun or shade adapted, based on maximum photosynthesis alone.

CONCLUSION

The data presented in this study indicate that *Eucalyptus regnans* is dominant on sites after fire, and is often associated with *Phebalium squameum* which is faster growing than rainforest species. The rapid establishment of *Phebalium squameum* often from fast growing coppice, and its greater height, may inhibit the reestablishment of rainforest species after burning.

On unburnt sites which are either logged, undisturbed, ^{or} surrounded by burnt areas, rainforest species were found to regenerate significantly better than *Eucalyptus regnans* in terms of the frequency of seedlings. Despite aerial seeding of *Eucalyptus regnans*, rainforest species were still found to regenerate more successfully than *Eucalyptus regnans* on unburnt quadrats. The decrease in stocking rates (seedling frequency) ^{for a given quadrat size} for rainforest species with increasing fire intensity is, in general due to, species sensitivities to fire. However, species exhibit different abilities to adapt to habitats which have been subjected to fire. For example *Nothofagus cunninghamii* and *Eucryphia lucida* regenerate better than other rainforest species because they are able to adapt to a variety of habitats and have greater capacity for regeneration, as indicated by the high densities of adult trees. These species were found to be able to establish on bare soil and quadrats subjected to low fire intensity.

It was found in this study that all the important tree species regenerate soon after disturbance. It has been noted that in favourable sites, seedlings of rainforest

species can establish soon after seed fall. For example *Nothofagus cunninghamii* and *Eucryphia lucida* can establish in one to two months after seed fall (Read 1989). On the study sites, only *Phyllocladus aspleniifolius* seems to need shade to be able to become established. The reasons for sparse distribution in undisturbed mixed forest sites and the low seedling regeneration of this species are unknown. There is an obvious need for more detailed data of soil condition, soil seed availability, as well as eco-physiological and seed characteristics of this species.

It appears that secondary succession^{is} not only influenced by duration after disturbance, but also by the type of disturbance. Regeneration after fire does not proceed according to the classical 'succession' concept, where one successional sere prepares the site for the next. Even though 'opportunists', such as liverworts and mosses rapidly colonized the burnt sites, most important woody species were observed soon after the firing event, but not to the exclusion of their predecessors. However, in general the succession in the study sites following cutting and burning was found to be similar to other lowland temperate forests. Previous workers have obtained similar results, in that bryophytes, ferns, herbs and woody shoots from trees most commonly dominate communities in early succession (McMinn 1951; Cremer and Mount 1965; Brown and Podger 1982; Biondini *et al* . 1989). The further development of the regeneration process seems to be determined by the relative competitive ability, canopy forming ability, and life span of the available species.

Clearfelled sites one year after disturbance, and sites two years after burning tended to contain the fewest species. Species richness reach^{ed} a maximum at five to seven years after fire.

Species were found to regenerate poorly on quartzite . It seems that the low soil fertility resulting from quartzite rock types does not support strong establishment of seedlings. *Eucalyptus regnans* stocking rates were not affected by fire intensity

on burnt quartzite sites.


There is about a 50% floristic similarity (as indicated by index of similarity) between logged sites which were burnt two years ago and one year after clearfelling, compared to undisturbed mixed forest sites. At least half of the species to be common between selectively logged, burnt sites of ages five, seven and nine years after burning and undisturbed mixed forest sites. This indicates that sites two years after fire and one year after clearfelling are significantly different in species composition compared to undisturbed mixed forest sites. It was concluded that fire intensities have very different effects on the species composition.

Eucalyptus regnans, on mixed forest sites, was found to regenerate poorly. On burnt sites, stocking rates of *Eucalyptus regnans* increased with increasing fire intensity and this increase varied according to both fire intensity and the duration after burning. However, no strong evidence was found to indicate that *Eucalyptus regnans* has greater stocking rates on either unburnt or burnt quadrats. In contrast, when results were expressed in terms of mean seedling number, there was found to be a significant difference in the regeneration rates of *Eucalyptus regnans* in burnt quadrats compared to unburnt quadrats on burnt sites, with increasing duration after burning. It has been noted that many factors influence the regeneration of *Eucalyptus regnans* where seed were sown, including the nature of the seed bed, the amount of seed sown, the weather following sowing, and the prevailing conditions for seed survival (Felton 1976). Although, there is evidence that *Eucalyptus regnans* seedlings cannot establish under dense canopy in mixed forest sites, in this study fire intensity was also not found to strongly affect regeneration rates and there was no obvious interaction between fire intensity and the period after burning.

Mosses were found to have a positive association with the establishment of tree seedlings⁹, however, the influence of bryophytes on the establishment of seedlings are perhaps not as important as the negative association between seedlings with ferns

and woody shrubs. The poor regeneration of seedlings in quadrats covered by ferns and woody shrubs indicates that ferns and woody shrubs inhibit the establishment of tree seedlings. It seems the development ^{of} seedlings ~~is~~ determined largely by the relative competitive ability which is also influenced by seed characteristics.

On logged sites following fire *Phebalium squameum* tends to be the most frequent tree seedling associated with *Eucalyptus regnans*. Although physiological experiments (frost resistance and photosynthetic responses to light) did not confirm that *Phebalium squameum* possesses attributes which indicate that this species ^{is} able to regenerate successfully. *Phebalium squameum* was found to have the ability to establish very quickly, soon after disturbance. This could be because of seed availability in the soil, dispersal advantages, or the ability to establish by coppicing. Bazzaz (1968) and Raynal and Bazzaz (1983) noted that colonization of woody plants may be limited by inhibitory life forms such as herbs, some of which become established quickly.

The ferns *Pteridium esculentum*, *Histiopteris incisa*, *Hypolepis muelleri*, the hepatic, *Marchantia berteroana*, and the herb  *Senecio velleioides* were found to dominate the ground layers of burnt sites. *Histiopteris incisa* and *Hypolepis muelleri* are also common on unburnt sites (selectively logged and clearfelled sites), and were present in undisturbed mixed forest. The dominant shrubs on all sites, burnt and unburnt, included *Anopterus glandulosus* and *Monotoca glauca*. The greatest number of species were found in sites five years after burning.

The frost resistance of species investigated was found to be higher in July than September. This suggests that plants acclimatize to low temperature in winter (Sakai 1970; Tranguinlini 1979; Steubing *et al.* 1983). Result of the frost resistance measurements do not correlate with distribution and regeneration patterns. It was found that species which are less frost resistance regenerate better than species which are more frost resistance, for example *Eucalyptus regnans* and *Phebalium squameum*

which were found to dominate the logged area, have less frost resistance than rainforest species, however, they regenerate better than rainforest species. Further, it was found in the experiment that *Olearia argophylla* and *Pomaderris apetala* have high frost resistance, but these species were uncommon on the study sites. This suggests frost resistance does not play an important role in regeneration^{of} seedlings. It has been noted by some previous workers that frost resistance does not play an important role in regeneration on low land sites (Read 1985).

It has been noted that the difference in photosynthetic rates and light compensation point with varying light regimes is higher for sun grown plants than plants grown in shade, and under the same light regime is higher for species tolerant to sun than species tolerant to shade conditions (Loach 1967; Bazzaz 1979). Results of photosynthesis measurement show that plants investigated acclimatize to the light regime during growth. In this study *Eucalyptus regnans* was found to reflect attributes associated with sun adaptation, which is indicated by the high photosynthetic rates of seedlings grown in full sun light. This species was found to regenerate very successfully in open areas of the study sites.

Nothofagus cunninghamii has a low light compensation point in shade-raised plants. Low light compensation points are typical of shade plants. The greater shade-tolerance of *Nothofagus cunninghamii* suggests that this species would regenerate under denser canopies. However, regeneration patterns of *Nothofagus cunninghamii* based on results of this study do not clearly support this assumption. This is probably influenced by other factors. *Nothofagus cunninghamii* was found to regenerate well in open areas of the study site. It has been foundⁱⁿ in some previous studies that *Nothofagus cunninghamii* has the ability to regenerate under low to moderate light intensity. In rainforest, this species has its greatest importance near the forest edge (Read 1983) and is very competitive under favourable conditions (Read 1985).

Further study is needed to investigate some other physiological characters

such as chlorophyll content, water relations, nutrient availability in the soil, as well as physiological study of the major species by growing them in the glasshouse.

REFERENCES

- Alberdi, M., and Rios, D. 1983. Frost resistance of *Embothrium coccineum* and *Gevuina avellana* Mol. during development and aging. *Oecologia Plantarum* 4, pp. 3-9.
- Alberdi, M., Romero, M., Rios, D., and Wenzel, H. 1985. Altitudinal gradients of frost resistance in *Nothofagus* communities of Southern Chile. *Oecologia Plantarum* 6, pp. 21-30.
- Anon. 1980. Australian forest resources. Forest Branch, Department of Primary Industry, Canberra.
- Armesto, J. J., and Fuentes, E. R. 1988. Tree species regeneration in a mid-elevation, temperate rainforest in Isla de Chiloe, Chile. *Vegetatio* 74, pp. 151-159.
- Ashton, D. H. 1958. The ecology of *Eucalyptus regnans* F. Muell. The species and its frost resistance. *Australian Journal of Botany* 6, pp. 154-17.
- Ashton, D. H. 1981. Fire in tall open forests (wet sclerophyll forest). In: *Fire and the Australian Biota* (Eds. A. M. Gill, R. H. Goves and I. R. Noble), pp. 339-366. Australian Academic Science, Canberra.
- Ashton, D. H., and Turner, J. S. 1979. Studies on the light compensation point of *Eucalyptus regnans*. *Australian Journal of Botany* 27, pp. 589-607.
- Attiwill, P. M., and Leeper, G. W. 1987. Forest soil and nutrient cycles. Melbourne, University Press.
- Auld, J. D. 1980. Population dynamics of the shrub *Acacia suaveolens* (Sm.) Willd. *Australian Journal of Ecology* 11, pp. 373-385.
- Avery, T. E., and Burkhat, H. E. 1983. Forest measurement. Third edition, McGraw-Hill Book Company. Toronto.

- Barker, M. 1990. The effect of fire on rainforest. In: *Tasmanian rainforest research* . Proceedings of a seminar on rainforest research carried out under the Tasmanian component of the national rainforest conservation program. (Eds. J. E. Hickey, M. J. Brown, D. E. Rounsevell and S. J. Jarman). Tasmanian NRCP Report No.1.
- Bazzaz, F. A. 1968. Succession on abandoned fields in the Shawnes Hills, Southern Illinois. *Ecology* **49** (5), pp. 924-936.
- Bazzaz, F. A. 1979. The physiological ecology of plant succession. *Annual Review of Ecology and Systematics* **10**, pp. 351-371.
- Bazzaz, F. A., and Carlson. 1982. Photosynthetic acclimation to variability in the light Environment of early and late succession plants. *Oecologia* **54**.
- Beadle, N. C. W., and Costin, A. B. 1952. Ecological classification and nomenclature. *Proceeding of the Linnaean Society New South Wales* **77**, pp. 61-82.
- Bell, D. T ., and Koch, J. M. 1980. Post-fire succession in the nothern jarrah forest of Western Australia. *Australian Journal of Ecology* **5**, pp. 9-14.
- Berry, J. A., and Raison, J. K. 1981. Response to macrophytes to temperature. In: *Physiological plant ecology I. Response to physical environment*. (Eds. O. L. Lange, P. S. Nobel , C. B. Osmond and H. Ziegler), pp. 277-338, Spinger - Verlag. Berlin.
- Bieleski, R. L. 1959. The effect of light on the establishment of *Kauri* and *Phyllocladus Trichomanoides*. *Australian Journal of Botany* **7**, pp. 252-267.
- Biondini, M. E., Steuter, A. A., and Grygiel, C. E. 1989. Seasonal fire effects on the diversity patterns, spatial distribution and community structure of forbs in the Northern Mixed Praire, USA. *Vegetatio* **85**, pp. 21-31.
- Bjorkman, O.1968. Further studies on differentiation of photosynthesis in sun and shade ecotypes of *Salidago virgaurea* . *Physiologia Plantarum* **21**, pp. 84-99.

- Bjorkman, O. 1973. Comparative studies on photosynthesis in higher plants. In: *Current topics in photobiology, photochemistry and photophysiology* . (Ed. A. Giese), Vol. 8, pp. 1-63, Academic Press, New York.
- Bjorkman, O. 1981. Response to different quantum flux densities. *Encyclopedia of plant physiology*. New series. Vol. 112 A, pp. 57-107.
- Bjorkman, O., and Holmgren, P. 1963. Adaptability of the photosynthetic apparatus to light intensity in ecotypes from exposed and shaded habitats. *Physiologia Plantarum* 16, pp. 889-914.
- Bjorkman, O., Ludlow, M. M., and Morrow, P. A. 1972a. Photosynthetic performance of two rainforest species in their native habitat and analysis of their gas exchange. *Carnegie Ins. Wash. Year Book* 71, pp. 94-102.
- Bjorkman, O., Boadman, N. K., Anderson, J. M., Thorne, S. W., Goodchild, D.J., and Pyliotis, N. A. 1972b. Effect of light intensity during growth of *Atriplex patula* on the capacity of photosynthetic reactions, chloroplast components and structure. *Carnegie Inst. Wash. Year Book* 71, pp. 115-135.
- Blackman, G. E. 1968. The application of concept of growth analysis to the assessments of productivity. In: *Functioning of terrestrial ecosystems at the primary productivity level*. (Ed. Eckardt. F), pp. 243-260. UNESCO, Paris.
- Blackman, G. E. 1956. Influence of light and temperature on leaf growth. In: *The growth of leaves* . (Ed. Milthorpe, F.L), pp. 151-169. Butterworth, London.
- Blakesley, A. 1978. Rainforest regeneration survey in eucalypt treatment areas of Smithon district. (Unpub.), Forestry Commission, Tasmania.
- Bordman, N. K. (1977). Comparative photosynthesis sun and shade . *Annual Review of Plant Physiology* 28, pp. 355-377.
- Boulter, C. 1978. Geology. In: *The South-West Book*. (Ed. H. Gee and J. Fenton), pp. 71-76, Australian Conservation Foundation, Melbourne.

- Bowman, D. M. J. S., and Jackson, W. D. 1980. Slash-burning in the regeneration of dry eucalypt forest. *Australian Forestry* **44**, 118-124.
- Bowman, D. M. J. S., and Jackson, W. D. 1981. Vegetation succession in South West Tasmania. *Search* **12**, 358-362.
- Bowman, D. M. J. S., and Kirkpatrick, J. B. 1984. Geographic variation in the demographic structure of stands of *Eucalyptus delegatensis* R. T. Baker on dolerite in Tasmania. *Journal of Biogeography* **11**, pp. 427-437.
- Brown, A. A., and Davis, K. P. 1973. Forest fire control and use. Second edition. McGraw-Hill Book Company, Sydney.
- Brown, M. J. , and Poddger, F. D. 1982. Floristics and fire regimes of a vegetation sequence from sedgeland-heath to rainforest at Bathurst Harbour, Tasmania. *Australian Journal of Botany* **30**, pp. 659-676.
- Busby, J. R., and Bridgewater, P. B. 1977. Vegetation associated with *Nothofagus cunninghamii*. *Proceedings of the Royal Society of Victoria* **89**, pp. 173-182.
- Burke, M. J., Gusta, L. V., Quamme, H. A., Weiser, C. J., and Li, P. H. 1976. Freezing and injury in plants. *Annual Review of Plant Physiology* **27**, pp. 507-528.
- Casson, P. B. 1952. The forest of Western Tasmania. *Australian Forestry* **16**, 71-86.
- Christensen, P. E., Abbot. 1989. Impact of fire in the eucalypt forest ecosystem of southern western Australia.: a critical review. *Australian forestry* **52** (2), pp. 103-121.
- Christensen, P. E., and Kimber, P. C. 1975. Effect of prescribed burning of the flora and fauna of South-west Australian forest. Managing Terrestrial Ecosystems. *Preceedings of the Ecological Society of Australia.* **9**, pp. 85-106.
- Coaldrake, J. E. 1961. Ecosystem of the Coastal Lowlands. Southern Queensland Bulletin No.283. C.S.I.R.O, Australia.

- Collins, B. S., and Pickett, S. T. A. 1987. Influence of canopy opening on the environment and herb layer in a northern hardwood forest. *Vegetatio* **70**, pp. 3-10.
- Connell, J. H., and Slatyer, R. O. 1977. Mechanisms of succession in natural communities and their role in community stability. *American Naturalist* **111**, pp. 1119-1144.
- Cranwell, L. M. 1963. *Nothofagus* : living and fossil. In: *Pacific Basin Biogeography* (Ed. J. L. Gresser), pp. 387-400. Bishop Mus. Press, Honolulu.
- Cremer, K. W 1960. Eucalypts in rainforest. *Australian Forestry* **24**, pp. 120-126.
- Cremer, K. W. 1962. The effect of fire on eucalypts reserved for seeding. *Australian Forestry* **26**, pp. 129-154.
- Cremer, K. W., Mount, A.B. 1965. Early stages of plant succession following complete felling and burning of *Eucalyptus regnans* forest in the Florentine Valley, Tasmania. *Australian Journal of Botany* **13**, 303-322.
- Cunningham, T. M. 1960. The natural regeneration of *Eucalyptus regnans*. Bulletin of the school of forestry, University of Melbourne, **1**, 1960.
- Curtis, W. M. 1963. The student's flora of Tasmania. Part 2. Government Printer, Tasmania.
- Curtis, W. M. 1967. The student's flora of Tasmania. Part 3. Government Printer, Tasmania.
- Curtis, M. W. and Morris, D. I. 1975. The student's flora of Tasmania. Part 1. Government Printer, Tasmania.
- Davidson, N. J., and Reid, J. B. 1985. Frost as a factor influencing the growth and distribution of subalpine eucalypts. *Australian Journal of Botany* **33**, pp. 657-667.

- Davies, J. C. 1965. Atlas of Tasmania. Lands and Surveys Department, Hobart.
- Davies, J. B. 1984. A survey of the vegetation in the Clear Hill-Ragged Range Region of Tasmania (Wedge forest block). Tasmanian Forestry Commission.
- Dexter, S. T. W. E., Tottingham, W. E., and Graber, L. F. 1930. Preliminary results in measuring the hardness of plants. *Plant Physiology* 5, pp. 215-223.
- Dexter, S. T. W. E., Tottingham, and Graber, L. F. 1932. Investigations of the hardness of plants by measurement of electrical conductivity. *Plant Physiology* 7, pp. 63-78
- Duncan, F. 1981. Regeneration and species diversity in a Tasmanian dry sclerophyll forest. In: *Fire and Forest Management in Tasmania* (Ed. J. B. Kirkpatrick), pp. 33-44. (Tasmanian Conservation Trust: Hobart).
- Duncan, F. 1985. Tasmania's vegetation and its response to forest operations. Working Paper 6. Background to the environmental impact statement on Tasmanian woodchip export beyond 1988. Forestry Commission Hobart.
- Duncan, D., and Dalton, P. J. 1982. Recolonisation by bryophytes following fire. *Journal of Bryology* 12, pp. 53-63.
- Drury, W. H., and Nisbet, I. C. T. 1973. Succession. *Journal Arnold Arboretum* 54, pp. 331-368.
- Edwards, I. J. 1978. Vegetation. In: *The South-West Book*. (Eds. H. Gee and J. Fenton), pp. 85-91 Australian Conservation Foundation, Melbourne.
- Eldridge, K. G. 1968. Physiological studies of altitudinal variation in *Eucalyptus regnans*. *Proceedings of the Ecology Society of Australia* 3, pp. 70-76.
- Eldridge, K. G. 1974. Forest tree improvement in Australia. In: *Forest tree breeding in the world*. (Ed. R. Toda), pp. 170-180, Meguro, Tokyo Japan.

- Engler, F. E. 1954. Vegetation science concepts. I. Initial floristic composition, a factor in old field vegetation development. *Vegetatio* 4, pp. 412-417.
- Farrel, T. P., and Ashton, D. H. 1978. Population studies on *Acacia melanoxylon* R. Br. I. Variation in seed and vegetative characteristics. *Australian Journal of Botany* 26, pp. 365-380.
- Felton, K. C. 1976. Regeneration of cut-over areas of Tasmanian eucalypt forest. In: Woodchip Symposium Papers. 47th ANZAAS Congress Hobart. Publication of the Forestry Commission, Tasmania.
- Flint, H. L., Boyce, B. R., and Beatti, D. J. 1967. Index of injury - a useful expression of freezing injury to plant tissues as determined by the electrolytic method. *Canadian Journal of Plant Science* 47, pp. 229-230.
- Floyd, A. G. 1966. Effect of fire upon weed seeds in the wet sclerophyll forest of northern N.S.W. *Australian Journal of Botany* 14, pp. 243-256.
- Floyd, A. G. 1976. Effect of burning on regeneration from seeds in wet sclerophyll forest. *Australian Forestry* 39, pp. 210-220.
- Gentilli, J. 1972. Australian climatic patterns. Nelson. Melbourne.
- Gilbert, J. M. 1959. Forest Succession in the Florentine Valley, Tasmania. *Papers and Proceedings of the Royal Society Tasmania*. 93, pp. 1129-151.
- Gilbert, J. M. 1965. Forestry. In: *Atlas of Tasmania*. (Ed. J.C Davies), pp. 66-67 Lands and Surveys Department, Hobart.
- Gill, A. M. 1975. Fire and the Australian flora: A review. *Australian Forestry* 38, pp. 4-25.
- Grose, R. J. 1973. Environmental consideration in harvesting and regeneration of forest. *Australian Forestry* 36, pp. 73-79.

- Grout, B. W., and Morriss, B. J. 1987. *The Effect of Low Temperatures on Biological Systems*. Edward Arnold Pty-Ltd, Australia.
- Hall, N., Johnston, R.D., and Chippendale, G.M. 1981. Long Reach Tas.: Forest Resources. *Forest Trees of Tasmania*.
- Hallam, P. M. and Tibbits, W. N. 1986. Determining frost hardness of *Eucalyptus* using the electrical conductivity of diffusate. *Canadian Journal of Forest Research*.
- Hara, M. 1987. Analysis of seedling banks of a climax beech forest: ecological importance of seedling sprouts. *Vegetatio* **71**, pp. 67-74.
- Harwood, C. E., and Jackson, W. D. 1975. Atmospheric losses of four plant nutrients during a forest fire. *Australian Forestry* **38**, pp. 92-99.
- Heilers, A. 1975. The effect of fire on fauna. A review. Eucalypt forests resources or refuge symposium. 46th. A.N.Z.A.A.S. Congress, Canberra.
- Hickey, J. E. 1981. Julius dolomite rainforest logging and regeneration trial establishment report. (Unpublished), Forestry Commission, Tasmania.
- Hickey, J. E. 1982. Natural and artificial regeneration of some Tasmania rainforest trees, In: *Tasmanian rainforest: Recent Research Result*. Forest Ecology Research Fund, Forestry Commission, Hobart.
- Hickey, J. E. 1983. Natural and artificial regeneration of some Tasmanian rainforests trees. In: *Tasmanian Rainforests*. Recent Research Fund, Tasmanian Forestry Commission, Hobart.
- Hickey, J. E., Blakesley, A. J., and Turner, B. 1982. Seedfall and germination of *Nothofagus cunninghamii* (Hook.) Oerst., *Eucryphia lucida* (Labill.) Baill. and *Atherosperma moschatum* Labill. Implications for regeneration practice. *Australian Forestry Research* **13**, 21-28.

- Hill, R. S. 1982. Rainforest in Western Australia. *Australian Journal of Botany* **30**, pp. 583 -589.
- Hill, R. S., and Read, J. 1984. Post-fire regeneration of rainforest and mixed forest in western Tasmania. *Australian Journal of Botany* **21**, pp. 79-92.
- Hill, R. S., Read, J., and Busby, J. R. 1988. The temperature - dependence of photosynthesis of some Australian temperate rainforest trees and its biogeographical significance. *Journal of Biogeography* **15**, pp. 431-439.
- Howard, T. M. 1981. Southern closed-forests. In: *Australian vegetation* (Ed. R. H. Groves), pp. 102-120. Cambridge University Press, London.
- Horiuchi, T., and Sakai, A. 1978. Effect of solar radiation on frost damage to young cryptomerias. In: *Plant cold hardiness and freezing stress*. Vol.I. (Eds. P. H. Li, A. Sakai), pp. 281-295. Academic Press, London, New York.
- Isaac, L. A. 1940. Vegetative succession following logging in the Douglas-fir region with special reference to fire. *Journal Forestry* **38**, pp. 716-721.
- Jackson, W. D. 1965. Vegetation. In: *Atlas of Tasmania..* (Ed.J. L.Davies), pp. 30-35, Mercury Press, Hobart.
- Jackson,W. D. 1968a. Fire, air, water and earth: an elemental ecology of Tasmania. *Proceedings of the Ecological Society of Australia* **3**, 9-16.
- Jackson,W. D. 1968b. Fire and the Tasmanian flora. In: *Tasmania Vegetation Year Book* No.2, 1968. Department of Science, Melbourne.
- Jackson,W. D. 1978. Ecological drift - an argument against the continued practice of hazard reduction burning. In: *The South-West Book*. (Eds. H. Gee and J. Fenton), pp. 98-102, Australian Conservation Foundation, Melbourne.
- Jackson, W. D. 1981a. Vegetation. In: *The vegetation of Tasmania*. (Ed. W. D. Jackson), pp. 11-16, Australian Academic Science , Canberra.

- Jackson, W. D 1981b. Fire patterned vegetation. In: *The vegetation of Tasmania* (Ed.W. D. Jackson), pp. 17-35, Australian Academic Science, Canberra.
- Jacobs, M. R. 1955. Growth habit of the Eucalypts. Commonwealth Government Printer, Canberra.
- Jarman, S. J., Crowden, R. K., and Brown, M. J. 1982. Descriptive ecology of the vegetation of the Lower Gordon River basin, Tasmania. *Papers and Proceeding of the Royal Society of Tasmania* **116**, 165-177.
- Jarman, S. J., Brown, M. J., and Kantvilas, G.1984. Rainforest in Tasmania. Tasmanian National Parks and Wildlife Service, Hobart.
- Jarman, S. J., Kantvilas, G., and Brown, M. J. 1991. Floristic and ecological studies in Tasmanian rainforest. Tasmanian NRCP report No. 3.
- Jarman, S. J., Kantvilas, G., and Brown, M. J. 1988. Buttongrass moorland in Tasmania. Research Report No.2. Tasmanian Forest Research Council INC. Hobart.
- Jordan, G.J., Patmore, C., Duncan, F. & Luttrell, S. 1992. The effects of fire intensity on the regeneration of mixed forest tree species in the Clear Hill/Mount Wedge area. *Tasforests* 4, 25-38.
- Kershaw, K. A. 1973. Quantitative and dynamic plant ecology . Second edition. Edward Arnold Publishing Co. Ltd. London.
- King, A. R. 1963. The influence of colonosation on the forest and prevalence of bushfire in Australia. C.S.I.R.O. Division of Physics Chemistry Melbourne.
- Kirkpatrick, J. B .1977a. Impact of man on land. In: *Landscape and man. Royal Society of Tasmania*. Symposium, published June.
- Kirkpatrick, J. B .1977b. Vegetation in the West Coast. In: *Landscape and man. Royal Society of Tasmania*. Symposium, published June.

- Kirkpatrick, J. B . 1980. The ecology of Tasmanian forests. Unpublished manuscript, Geography Department, University of Tasmania.
- Kirkpatrick, J. B ., and Brown, M. J. 1984a. A numerical analysis of Tasmanian higher endemism. *Botany Journal Linneaeus Society* London **88**, 165-182.
- Langenheim, J.H., Osmond, C.B., Brooks, A., Ferrar, P.J., 1984. Photosynthetic responses to light in seedlings of selected Amazonian and Australian rainforest tree species. *Oecologia* **63**, No. 2, pp. 215-224.
- Langford, K. J. 1974. Change in yield of water following a bushfire in a forest of *Eucalyptus regnans*. Melbourne and Metropolitan Board of Works. Departmental Report N0.31.
- Larcher, W. 1973. Gradual progress of damage due to temperature resistance and survival. In: *Temperature and life*. (Eds. H. Precht , J. Christophersen, H. Hensel and W. Larcher), pp. 195-203 Springer, Berlin, Heidelberg, New York.
- Larcher, W. 1981. Effects of low temperature stress and frost injury on plant product. In: *Physiological process limiting plant productivity*. (Ed. C. D. Johnson), pp. 253-269, Butterly, London.
- Larcher, W. 1982. Typology of freezing phenomena among vascular plants and evolutionary trends in forest acclimation. In: *Plant cold hardiness and freezing stress*, vol II. (Eds. P.H. Li and A. Sakai), pp. 417-426. Academic Press. London, New York.
- Lacher, W., and Baeuer, H. 1981. Ecological significance of resistance to low temperature. In: *Physiological plant ecology*. I. Response to the physical environment. Encyclopedia of plant Physiology, volume 12A. (Eds. O. L. Lange, P. S. Nobel, C. B. Osmond and H. Ziegler), pp. 403-437, Springer, Berlin Heidelberg New York.
- Levitt, J. 1956. The hardiness of plant. Academic Press. London New York.

- Loach, K. 1967. Shade tolerance in tree seedlings. I. Leaf photosynthesis and respiration in plants raised under artificial shade. *New Phytology* **66**, pp. 607-621.
- Lockett, E. J., and Candy, S. G. 1984 . Growth of eucalypt regeneration established with and without slash burns in Tasmania. *Australian Forestry* **47** (2), pp. 119-125.
- Lockett, E. J., Rich, R. P. 1977. The early years at Tribuana. (A look at management and silvicultural practices developed for Tasmania's first woodchip export scheme). Paper pres. 8th I.F.A. Conference, Adelaide.
- Lockett, E. J.(unpub). The interpretation of regeneration survey data. Tasmanian Forestry Commission.
- Loneragan, O. 1986. Ecology of jarrah (*Eucalyptus Marginata*) in the northern jarrah forest of Western Australia. *Conservation and Land Management*.
- Lyons, J. M., and Raison, J. K. 1970. Oxidative activity of mitochondria isolated from plant tissue sensitive and resistant to chilling injury. *Plant Physiology* **45**, pp. 386-389.
- Massurow, D. K. 1941. The role of fire in the perpetuation of virgin forest of Northern Wisconsin. *Journal Forestry* **339**, pp. 201-207.
- McArthur, A. G. 1970. Historical aspects of fire. In Fire ecology symposium. Monash University, Forestry Commission and Zoology Department, Melbourne.
- McMinn, R. G. 1951. The vegetation of a burn near Blaney Lake, B. C. *Ecology* **32**, pp. 125-140.
- Monk, D., Pate, J. S., and Loneragan, W. A. 1981. Biology of *Acacia pulchella* R. Br. with special referece to symbiotic nitrogen fixation. *Australian Journal of Bot.any* **29**, pp. 579-592.
- Moore, P. D., and Chapman, S. B. 1986 Methods in plant ecology. Second edition Blackwell Scientific Publishers. Melbourne.

- Mount, A . B. 1964. Eucalypt ecology as related to fire. Proceeding Tall Timbers Fire. Ecology Conference 9, pp. 75-108.
- Mount, A. B. 1964a. Three studies in forest ecology. M.Sc. Thesis. University of Tasmania.
- Mount, A. B. 1964b. The interdependence of the eucalypts and forest fires. *Australian Forestry* 28, pp. 166-172.
- Mount, A . B. 1968a. The vegetation as a guide to prescribed burnings in Tasmania. Revised paper presented at 1965 IFA Conference. Hobart (unpub.).
- Mount, A . B. 1969. Eucalypt ecology as related to fire. Proceeding of the annual Tall Timber Fire Ecology Conference. No. 9, pp. 10-11. April 1969.
- Mount, A. B. 1979. Natural regeneration processes in Tasmanian forests. *Search*.110, pp. 180-186.
- Muller-Dombois, D., and Ellenberg, H. 1974 . Aims and methods of vegetation ecology. Willey. New York.
- Mutch, R. W. 1970. Wildland fires and ecosystems- a hypothesis. *Ecology*. 51, pp. 1046-1051.
- Myer , W. L., and Shelton, R. L. 1980. Survey methods for ecosystem management. A Wiley Interscience Publication, John Wiley & Sons, Brisbane.
- Neyland, M. G. 1983. Regeneration survey result on mixed forest regeneration trial, Holder 9. (Unpub.) Forestry Commission, Tasmania.
- Neyland, M. G. 1986a. Conservation and management of tree ferns in Tasmania. Wildlife Division Technical Report 86 / 1. National Parks and wildlife service. Hobart.
- Niering, W. A., and Egler, F. E. 1955. A shrub community of *Viburnum lentago* stable for twenty-five years. *Ecology* 36, pp. 356-360.

- Niering, W. A., and Goodwin, R. H. 1974. Creation of relatively stable shrublands, on rights-of way and pasture land. *Ecology* **55**, pp. 784-795.
- Noble, I. R., and Slatyer, R. O. 1981. Concepts and models of succession in vascular plant communities subject to recurrent fire. In: *Fire and Australian Biota*. (Eds. A. M. Gill, R. M. Groves., I.R. Noble), pp. 331-335. Australian Academic Science, Canberra.
- Nunez, M. 1978. Climate. In: *The South-West Book..* (Eds. H. Gee and J. Fenton), pp. 67-70, Australian Conservation Foundation, Melbourne.
- Odum, E. P. 1969. The strategy of ecosystem development. *Science*, NY **164**, pp. 262-270.
- Oosting, H. J. 1956. The study of plant communities: An Introduction to plant ecology. 2nd (Ed. W. H. Freeman and Co.), San Fransisco and London.
- Parker, J. 1963. Cold resistant in woody plants. *Botanical Review* **29**, pp. 123-201.
- Pedley, L. 1978. A revision of *Acacia* Mill. in Queensland. *Austrobaileya* **1**, pp.75-337.
- Preest. 1963. A note on the dispersal characteristics of the seed of New Zealand podocarps and beeches and their biological significance. In: *Pacific Basin Biogeography*. (Ed. J. L. Gressit), pp. 415-424. Bishop Mns. Press, Honolulu.
- Purdie, R. W. 1975. Ecological succession after burning in dry sclerophyll vegetation. Ph.D. thesis The Australian National University.
- Purdie, R. W., and Slatyer, R. O. 1976. Vegetation succession after fire in sclerophyll woodland communities in south-eastern Australia. *Australian Journal of Ecololgy* **1**, pp. 223-236.
- Purdie, R. W. 1977a. Early stages of regeneration after burning in dry sclerophyll vegetation. I. Regeneration of the understorey by vegetative means. *Australian Journal of Botany* **25**, pp. 21-34.

- Purdie, R. W. 1977b. Early stages of regeneration after burning in dry sclerophyll vegetation. II. Regeneration by seed germination. *Australian Journal of Botany* **25**, pp. 35-46.
- Rabinowitch, E. I. 1951. Photosynthesis and related processes. Vol.2.pt. I. Interscience Publication, New York.
- Raymond, C. A., Harwood, C. E., and Owen, J. V. 1986. A conductivity method for screening population of eucalypts for frost damage and frost tolerance. *Australian Journal of Botany* **34**, pp. 377-393.
- Raynal, D. J., and Bazzaz, A. F. 1973. Establishment of early successional plant population on forest and prairie soil. *Ecology* **54**, pp. 1335-1341.
- Read, J. 1985. The dynamics of *Nothofagus cunninghamii* rainforest associations in Tasmania- an ecophysiological approach. Ph. D. Thesis, Tasmania University.
- Read, J. 1985a. Photosynthetic and growth response to different light regimes of the major canopy species of Tasmanian cool temperature rainforest. *Australian Journal of Ecology* **110**, pp. 327-334.
- Read, J. 1989. Phenology and germination in some canopy species at Mount Field National Park Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **123**, pp. 211-221.
- Read, J., and Hill, R. S. 1983. Rainforest invasion onto Tasmanian old-fields. *Australian Journal of Ecology* **8**, pp. 149-161.
- Read, J., and Hill, R. S. 1985. Photosynthetic response to light of Australian and Chilean species of *Nothofagus* and their relevance to the rainforest dynamics. *New Phytology* **101**, pp. 731-742.
- Read, J., and Hill, R. S. 1988. Comparative responses to temperature of the major canopy of Tasmanian cool temperate rainforest and their ecological significance. I. Foliar frost resistance. *Australian Journal of Botany* **36**, pp. 131-143.

- Read, J., and Hope, G. S. 1989. Foliar frost resistance of some evergreen tropical and extratropical Australasian *Nothofagus* species. *Australian Journal of Botany* **37**, pp. 361-373.
- Rook, D. A., Wilcox, M. D., Holden, D. G. and Warrington, I. J. 1980. Provenance variation in frost tolerance of *Eucalyptus regnans* F. Muell. *Australian Forest Research* **110**, pp. 213-238.
- Sakai, A. 1960. Survival of the twigs of woody plants at -196°C. *Nature* (London) **185**, pp. 393-394.
- Sakai, A. 1970. Freezing resistance in willows from different climates. *Ecology* **51**, pp. 485-491.
- Sakai, A., and Larcher, W. 1987. Frost survival of plant. Responses and adaptation to freezing stress. Ecological Studies Vol. 62, Springer-verlag. Berlin.
- Sakai, A., and Otsuka, K. 1970. Freezing resistance of alpine plants. *Ecology* **51** No. 4, pp. 665-671.
- Sakai, A., Paton, D. M., and Wardle, P. 1981. Freezing resistance of trees of the South temperate zone, especially subalpine species of Australasia. *Ecology* **62**, pp. 563-570.
- Sakai, A., Paton, D. M., and Wardle, P. 1981. Freezing resistance of trees of south temperate zone, especially subalpine species of Australasia. *Ecology* **62**, pp. 563-570.
- Sestak, Z., Catsky, J., Jarvis, P. G. 1971. Plant photosynthetic production. Manual of methods. Dr. W. Junk N. V. Publishers. (Eds. The Hague).
- Shea, S. R., Mc Cormick, J., and Portlock, C. C. 1979. The effect of fires on regeneration of leguminous species in the northern Jarrah (*Eucalyptus marginata* Sm.) forest of Western Australia. *Australian Journal Ecology* **4**, pp. 195-206.

- Slatyer, R. O. 1977. Altitudinal variation in the photosynthetic characteristics of snow gum, *Eucalyptus pauciflora* Sieb. ex Spreng. W. Temperature response of four populations grown at different temperatures. *Australian Plant Physiology* 4, pp. 583-593.
- Southorn, A. L. D. 1976. Bryophyte recolonisation of burn ground with particular reference to *Funaria hygrometrica*. I. Factors affecting the pattern of recolonisation. *Journal of Bryology* 9, pp. 63 - 80.
- Specht, R. L. 1970. Vegetation. In' The Australian environment. (Ed. G. W. Leeper), 4th ed. (rev.), pp. 44-67. CSIRO. Australia and Melbourne University Press, Melbourne.
- Squire, R. O., Campbell, R. G., Wareing, K. J., and Featherston, G. R. 1991. The mountain ash forests of Victoria: Ecology, silviculture and management for wood production. In: *Forest management in Australia*. (Eds. F. H. McKinnell, E. R. Hopkins and J. E. D. Fox). Surrey Beatty & Sons, Pty Limited. New South Wales.
- Steubing, L., Alberdi, M., and Wenzel, H. 1983. Seasonal changes of cold resistance of Proteaceae of South Chilean Lawrel forest. *Vegetatio*. 52, pp. 35-44.
- Sutcliffe, J. 1977. Plants and temperature. Edward Arnold Ltd. London.
- Tansley, A. G. 1946. Introduction to plant ecology. George Allen & Unwin Ltd, London.
- Thomas, D. H., and Barber, H. H. 1974. Studies in leaf characteristics of a line of *Eucalyptus urnigera* from Mount Wellington, Tasmania: 1. water repellency and freezing leaves . *Australian Journal of Botany* 22, pp. 501-512.
- Tibbits, W. N., and Reid, J. B. 1987. Frost resistance in *Eucalyptus nitens* (Diane & Maiden). Physiological aspect of hardiness. *Australian Journal of Botany* 35, pp. 235-250.

- Tibbits, W. N., and Reid, J. B. 1987b. Frost resistance in *Eucalyptus nitens* (Deane & Maiden) Maiden. Genetic and seasonal aspect of variation. *Australian Forest Research* 17, pp. 29-47.
- Tranguilini, W. 1979. Physiological ecology of the alpine timberline. Ecological studies 31. Springer Verlag, Berlin.
- Trewartha, G. T. 1954. An introduction to climate. Third edition. McGraw-Hill, New York.
- Turton, S. M. 1990. Light environments within montane tropical rainforest, Mount Bellenden Ker, North Queensland. *Australian Journal of Ecology* 15, pp. 35-42.
- Van Noort, A. C. 1960. The development of jarrah regeneration. Forestry Department Wildlife Australian Bulletin 65.
- Wallace, W. R. 1966. Fire in the jarrah forest environment. *Journal of the Royal Society of West Australia* 49, pp. 33-44.
- Wakefield, N. A. 1975. Ferns of Victoria and Tasmania, Revised edition. Field Naturalist Club of Victoria, Melbourne.
- Wardle, P. 1969. Biological flora of New Zealand. IV. *Phyllocladus alpinus*. *New Zealand Journal of Botany* 7, pp. 77-89.
- Watson, E. V. 1971. The structure and life of Bryophytes. Third edition. Hutchinson, London.

Appendix 1. Species found on mixed forest sites in alphabetical order.

	Species	Family	Life-form	RF(%)	RDc(%)	IV(%)
1	<i>Anodopetalum biglandulosum</i>	Cunoniaceae	Tree	2.60	3.28	5.88
2	<i>Anopterus glandulosus</i>	Escalloniaceae	Shrub	5.00	6.65	11.65
3	<i>Aristotelia peduncularis.</i>	Elaeocarpaceae	Shrub	2.66	0.50	3.16
4	<i>Asplenium bulbiferum</i>	Aspleniaceae	Fern	3.70	0.71	4.41
5	<i>Atherosperma moschatum</i>	Monimiaceae	Tree	6.70	4.41	11.11
6	<i>Blechnum nudum</i>	Blechnaceae	Fern	1.00	0.50	1.50
7	<i>Blechnum wattsii</i>	Blechnaceae	Fern	5.37	0.50	5.87
8	<i>Cennarhenes nitida</i>	Proteaceae	Shrub	0.34	2.62	2.96
9	<i>Coprosma quadrifida</i>	Rubiaceae	Shrub	0.67	0.50	1.17
10	<i>Dianella tasmanica</i>	Liliaceae	Herb	1.00	0.50	1.50
11	<i>Dicksonia antarctica</i>	Dicksoniaceae	Fern	6.70	5.60	12.30
12	<i>Drymophila cyanocarpa</i>	Liliaceae	Herb	2.00	3.15	5.15
13	<i>Eucalyptus obliqua</i>	Myrtaceae	Tree	0.66	2.62	3.28
14	<i>Eucalyptus regnans</i>	Myrtaceae	Tree	0.66	3.15	3.81
15	<i>Eucryphia lucida</i>	Eucryphiaceae	Tree	2.00	9.34	11.34
16	<i>Gahnia grandis</i>	Cyperaceae	Grass	6.70	3.78	10.48
17	<i>Gaultheria hispida</i>	Ericaceae	Herb	1.68	0.50	2.18
18	<i>Grammitis billardierii</i>	Grammitidaceae	Fern	6.37	0.50	6.87
19	<i>Histiopteris incisa</i>	Dennstaedtiaceae	Fern	1.34	1.57	2.91
20	<i>Hydrocotyle javanica</i>	Umbelliferae	Herb	1.00	0.50	1.50
21	<i>Hymenophyllum marginatum</i>	Hymenophyllaceae	Fern	6.70	0.50	7.20
22	<i>Hypolepis muelkii</i>	Dennstaedtiaceae	Fern	0.33	2.62	2.95
23	<i>Microsorium diversifolium</i>	Polypodiaceae	Fern	12.78	0.50	13.28
24	<i>Monotoca glauca</i>	Epacridaceae	Shrub	1.00	0.50	1.50
25	Mosses		Mosses	4.37	26.30	30.67
26	<i>Nothofagus cunninghamii</i>	Fagaceae	Tree	9.41	9.76	19.17
27	<i>Olearia argophylla</i>	Compositae	Shrub	0.66	1.57	2.23
28	<i>Phyllocladus aspleniifolius</i>	Podocarpaceae	Tree	2.00	1.92	3.92
29	<i>Polysticum proliferum</i>	Aspidiaceae	Fern	4.37	1.10	5.47
30	<i>Pteris sp.</i>	Pteridaceae	Fern	1.00	0.50	1.50
31	<i>Rumohra adiantiformis</i>	Davalliaceae	Fern	0.66	0.50	1.16
32	<i>Sticherus tenax</i>	Gleicheniaceae	Fern	0.66	1.47	2.13
33	<i>Tasmannia lanceolata</i>	Winteraceae	Herb	0.66	0.50	1.16
34	<i>Trochocarpa gunnii</i>	Epacridaceae	Shrub	1.68	1.47	3.15
35	<i>Uncinia tenella</i>	Cyperaceae	Grass	0.34	0.50	0.84

Appendix 2. Species found on selectively logged sites in alphabetical order.

	Species	Family	Life-form	RF(%)	RDo(%)	IV(%)
1	<i>Anodopetalum biglandulosum</i>	Cunoniaceae	Tree	2.50	0.44	2.94
2	<i>Anopterus glandulosus</i>	Escalloniaceae	Shrub	4.65	4.87	9.52
3	<i>Asplenium bulbiferum</i>	Aspleniaceae	Fern	2.50	0.53	3.03
4	<i>Atherosperma moschatum</i>	Monimiaceae	Tree	7.75	0.44	8.19
5	<i>Blechnum wattsi</i>	Blechnaceae	Fern	3.87	0.44	4.31
6	<i>Cyathodes juniperina</i>	Epacridaceae	Shrub	0.85	0.44	1.29
7	<i>Dicksonia antarctica</i>	Dicksoniaceae	Fern	3.87	8.19	12.06
8	<i>Dryophila sp.</i>	Liliaceae	Herb	2.50	0.44	2.94
9	<i>Eucalyptus delegatensis</i>	Myrtaceae	Tree	0.85	2.21	3.06
10	<i>Eucalyptus obliqua</i>	Myrtaceae	Tree	0.43	2.21	2.64
11	<i>Eucalyptus regnans</i>	Myrtaceae	Tree	5.60	3.19	8.79
12	<i>Eucalyptus viminalis</i>	Myrtaceae	Tree	0.43	1.33	1.76
13	<i>Eucryphia lucida</i>	Eucryphiaceae	Tree	8.50	0.60	9.10
14	<i>Gahnia grandis</i>	Cyperaceae	Grass	3.45	0.58	4.03
15	<i>Gaultheria hispida</i>	Ericaceae	Shrub	1.30	4.40	5.70
16	<i>Gleichenia sp.</i>	Gleicheniaceae	Fern	0.43	0.44	0.87
17	<i>Histiopteris incisa</i>	Dennstaedtiaceae	Fern	8.50	19.47	27.97
18	<i>Hypolepis mulleri</i>	Dennstaedtiaceae	Fern	3.45	10.62	14.07
19	<i>Microsorium diversifolium</i>	Polypodiaceae	Fern	1.30	0.44	1.74
20	<i>Monotoca glauca</i>	Epacridaceae	Shrub	2.13	8.19	10.32
21	<i>Mosses</i>		Moss	1.70	19.92	21.62
22	<i>Nothofagus cunninghamii</i>	Fagaceae	Tree	11.62	0.78	12.40
23	<i>Olearia argophylla</i>	Compositae	Shrub	9.49	1.33	10.82
24	<i>Phebalium squameum</i>	Rutaceae	Tree	1.30	0.80	2.10
25	<i>Phyllcladus aspleniifolius</i>	Podocarpaceae	Tree	3.45	0.44	3.89
26	<i>Polystichum proliferum</i>	Aspidiaceae	Fern	2.50	0.44	2.94
27	<i>Pteridium esculentum</i>	Dennstaedtiaceae	Fern	0.43	1.77	2.20
28	<i>Richea scoparia</i>	Epacridaceae	Shrub	0.43	1.24	1.67
29	<i>Rumohra adiantiformis</i>	Davalliaceae	Fern	0.85	0.44	1.29
30	<i>Senecio velleioides</i>	Compositae	Shrub	1.70	1.99	3.69
31	<i>Trochocarpa gunii</i>	Urticaceae	Shrub	0.85	2.21	3.06

Appendix 3. Species found on clearfelled sites in alphabetical order.

	Species	Family	Life-form	RF(%)	RDo(%)	IV(%)
1	<i>Acacia dealbata</i>	Leguminosae	Tree	2.21	2.22	4.43
2	<i>Acacia melanoxylon</i>	Leguminosae	Tree	2.24	1.13	3.37
3	<i>Anodopetalum biglandulosum</i>	Cunoniaceae	Tree	0.27	8.09	8.36
4	<i>Asplenium bulbiferum</i>	Aspleniaceae	Fern	1.37	0.81	2.18
5	<i>Atherosperma moschatum</i>	Monimiaceae	Tree	9.07	1.41	10.48
6	<i>Blechnum wattsii</i>	Blechnaceae	Fern	2.98	0.81	3.79
7	<i>Coprosma quadrifida</i>	Rubiaceae	Shrub	1.37	0.81	2.18
8	<i>Cyathodes juniperina</i>	Epacridaceae	Shrub	2.98	1.10	4.08
9	<i>Dicksonia antarctica</i>	Dicksoniaceae	Fern	3.60	8.09	11.69
10	<i>Eucalyptus regnans</i>	Myrtaceae	Tree	6.34	4.18	10.52
11	<i>Eucryphia lucida</i>	Eucryphiaceae	Tree	7.95	1.21	9.16
12	<i>Gahnia grandis</i>	Cyperaceae	Grass	5.20	9.61	14.81
13	<i>Histiopteris incisa</i>	Dennstaedtiaceae	Fern	11.87	24.35	36.22
14	<i>Hypolepis muelleri</i>	Dennstaedtiaceae	Fern	7.20	8.09	15.29
15	<i>Microsorium diversifolium</i>	Polypodiaceae	Fern	1.37	0.81	2.18
16	<i>Monotoca glauca</i>	Epacridaceae	Shrub	1.61	0.81	2.42
17	Mosses		Mosses	10.77	13.06	23.83
18	<i>Nothofagus cunnighamii</i>	Fagaceae	Tree	9.39	1.47	10.86
19	<i>Pimelia drupacea</i>	Thymelaeaceae	Shrub	1.12	0.81	1.93
20	<i>Phebalium squameum</i>	Rutaceae	Tree	2.49	1.62	4.11
21	<i>Phyllocladus aspleniifolius</i>	Podocarpaceae	Tree	1.93	1.00	2.93
22	<i>Pteridium esculentum</i>	Dennstaedtiaceae	Fern	2.21	2.22	4.43
23	<i>Senecio velleioides</i>	Compositae	Herb	3.60	5.47	9.07
24	<i>Ulex europaeus</i>	Papilionaceae	Herb	0.83	0.81	1.64

**Appendix 4. Species found on sites two years after burning
in alphabetical order.**

	Species	Family	Life-form	RF(%)	RD(%)	IV(%)
1	<i>Anopterus biglandulosus</i>	Escalloniaceae	Shrub	0.64	2.76	3.4
2	<i>Atherosperma moschatum</i>	Monimiaceae	Tree	0.98	0.55	1.53
3	<i>Blechnum wattsii</i>	Blechnaceae	Fern	0.64	0.55	1.19
4	<i>Cennarrhenes nitida</i>	Proteaceae	Shrub	0.64	0.55	1.19
5	<i>Cirsium sp.</i>	Compositae	Herb	0.96	0.55	1.51
6	<i>Clematis aristata</i>	Ranunculaceae	Climber	1.28	0.55	1.83
7	<i>Cyathodes juniperina</i>	Epacridaceae	Shrub	1.94	0.55	2.49
8	<i>Dicksonia antarctica</i>	Dicksoniaceae	Fern	1.94	8.28	10.22
9	<i>Eucalyptus regnans</i>	Myrtaceae	Tree	13.02	4.69	17.71
10	<i>Eucalyptus viminalis</i>	Myrtaceae	Tree	0.32	0.55	0.87
11	<i>Eucryphia lucida</i>	Eucryphiaceae	Tree	1.3	0.55	1.85
12	Unknown sp.	?		0.32	0.55	0.87
13	<i>Gahnia grandis</i>	Cyperaceae	Grass	3.2	0.55	3.75
14	<i>Gaultheria hispida</i>	Ericaceae	Shrub	0.32	0.55	0.87
15	Herbaceous(unidentified)		Herb	2.92	2.76	5.68
16	<i>Histiopteris incisa</i>	Dennstaedtiaceae	Fern	7.45	3.3	10.75
17	<i>Hydrocotyle pterocarpa</i>	Umbelliferae	Herb	1.62	0.55	2.17
18	<i>Hypolepis muelleri</i>	Dennstaedtiaceae	Fern	6.49	5.52	12.01
19	<i>Leptospermum scoparium</i>	Myrtaceae	Shrub	0.32	0.55	0.87
20	<i>Marchantia berterona</i>	Marchantiaceae	Thalloid	11.34	11	22.38
21	<i>Microseris sp.</i>	Compositae	Herb	1.56	6.9	8.46
22	<i>Monotoca glauca</i>	Epacridaceae	Shrub	2.59	0.55	3.14
23	Mosses		Mosses	7.85	9.93	17.78
24	<i>Nothofagus cunninghamii</i>	Fagaceae	Tree	1.3	0.55	1.85
25	<i>Olearia argophylla</i>	Compositae	Shrub	1.62	0.55	2.17
26	<i>Phebalium squameum</i>	Rutaceae	Tree	9.45	0.66	10.11
27	<i>Pimelia drupacea</i>	Thymelaeaceae	Shrub	0.32	2.21	2.53
28	<i>Pomaderris apetala</i>	Rhamnaceae	Shrub	0.64	1.1	1.74
29	<i>Pteridium esculentum</i>	Dennstaedtiaceae	Fern	3.25	25.9	29.19
30	<i>Senecio velleioides</i>	Compositae	Shrub	13.28	5.52	18.8
31	<i>Urtica incisa</i>	Urticaceae	Shrub	0.64	0.55	1.19
32	<i>Zieria arborescens</i>	Rutaceae	Shrub	0.64	0.55	1.19

**Appendix 5. Species found on sites five years after burning
in alphabetical order.**

	Species	Family	Life-form	RF(%)	RDo(%)	IV(%)
1	<i>Acaena sp.</i>	Rosaceae	Shrub	0.28	0.4	0.68
2	<i>Anopterus glandulosus</i>	Escalloniaceae	Shrub	1.38	1.07	2.45
3	<i>Aristotelia peduncularis</i>	Elaeocarpaceae	Shrub	0.55	0.4	0.95
4	<i>Asplenium bulbiferum</i>	Aspleniaceae	Fern	0.83	2.14	2.97
5	<i>Acacia dealbata</i>	Leguminosae	Tree	1.85	0.4	2.25
6	<i>Acacia melanoxylon</i>	Leguminosae	Tree	0.55	2.52	3.07
7	<i>Anodopetalum biglandulosum</i>	Cunoniaceae	Tree	2.2	2.52	4.72
8	<i>Atherosperma moschatum</i>	Monimiaceae	Tree	5.17	2.52	7.69
9	<i>Blechnum wattsi</i>	Blechnaceae	Fern	1.38	0.53	1.91
10	<i>Cenarrhene nitida</i>	Proteaceae	Shrub	0.28	0.4	0.68
11	<i>Clematis aristata</i>	Ranunculaceae	Climber	0.55	0.4	0.95
12	<i>Coprosma quadrifida</i>	Rubiaceae	Shrub	0.55	0.4	0.95
13	<i>Cyathodes juniperina</i>	Epacridaceae	Shrub	1.66	0.68	2.34
14	<i>Dicksonia antarctica</i>	Dicksoniaceae	Fern	2.77	2.99	5.76
15	<i>Dipsacus sylvestris</i>	Dipsacaceae	Herb	0.28	0.4	0.68
16	<i>Eucalyptus delegatensis</i>	Myrtaceae	Tree	0.28	1.71	1.99
17	<i>Eucalyptus regnans</i>	Myrtaceae	Tree	16.24	8.56	24.8
18	<i>Eucryphia lucida</i>	Eucryphiaceae	Tree	2.95	2.72	5.67
19	<i>Gahnia grandis</i>	Cyperaceae	Grass	6.09	2.54	8.63
20	<i>Gaultheria hispida</i>	Ericaceae	Herb	0.55	0.4	0.95
21	<i>Histiopteris incisa</i>	Dennstaedtiaceae	Fern	14.76	16.26	31.02
22	<i>Hydrocotyle pterocarpa</i>	Umbelliferae	Herb	0.55	0.4	0.95
23	<i>Hypolepis muelleri</i>	Dennstaedtiaceae	Fern	11.25	4.53	15.78
24	<i>Leptospermum glaucosum</i>	Myrtaceae	Shrub	0.28	2.14	2.42
25	<i>Leptospermum scoparium</i>	Myrtaceae	Shrub	0.28	2.14	2.42
26	<i>Marchantia bethiana</i>	Marchantiaceae	Thalloid	1.38	2.14	3.52
27	<i>Microsorium diversifolium</i>	Polypodiaceae	Fern	0.55	0.4	0.95
28	<i>Monotoca glauca</i>	Epacridaceae	Shrub	3.33	1.03	4.36
29	Mosses		Mosses	7.9	8.7	16.6
30	<i>Nothofagus cunninghamii</i>	Fagaceae	Tree	1.11	1.71	2.82
31	<i>Olearia argophylla</i>	Compositae	Shrub	0.55	1.28	1.83
32	<i>Phebalium squameum</i>	Rutaceae	Tree	10.7	3.55	14.25
33	<i>Phyllocladus aspleniifolius</i>	Podocarpaceae	Tree	1.11	0.4	1.51
34	<i>Pittosporum bicolor</i>	Pittosporaceae	Shrub	1.38	1.28	2.66
35	<i>Poa sp.</i>	Gramineae	Grass	0.83	0.4	1.23
36	<i>Pomaderris apetala</i>	Rhamnaceae	Shrub	0.55	1.28	1.83
37	<i>Polystichum proliferum</i>	Aspidiaceae	Fern	0.83	0.4	1.23
38	<i>Pteridium esculentum</i>	Dennstaedtiaceae	Fern	2.77	9.41	12.18
39	<i>Ranunculus sp.</i>	Ranunculaceae	Herb	1.11	1.28	2.39
40	<i>Richea scoparia</i>	Epacridaceae	Shrub	0.55	1.28	1.83
41	<i>Richea springleioides</i>	Epacridaceae	Shrub	0.28	1.03	1.31
42	<i>Rumohra adiantiformis</i>	Davalliaceae	Fern	0.55	0.4	0.95
43	<i>Senecio velleioides</i>	Compositae	Shrub	8.85	1.07	9.92
44	<i>Trochocarpa gunnii</i>	Epacridaceae	Shrub	1.66	1.28	2.94
45	<i>Urtica incisa</i>	Urticaceae	Shrub	0.55	0.6	1.15
46	<i>Zieria arborescens</i>	Rutaceae	Shrub	0.55	1.28	1.83

Appendix 6. Species found on sites seven years after fire in alphabetical order.

	Species	Family	Life-form	RF(%)	RDo(%)	IV(%)
1	<i>Acacia dealbata</i>	Leguminosae	Tree	1.10	10.26	11.36
2	<i>Acacia melanoxylon</i>	Leguminosae	Tree	1.77	1.59	3.36
3	<i>Acaena sp.</i>	Rosaceae	Shrub	0.44	0.53	0.97
4	<i>Anopterus glandulosus</i>	Escalloniaceae	Shrub	1.99	1.59	3.58
5	<i>Aristotelia peduncularis</i>	Elaeocarpaceae	Shrub	0.65	0.53	1.18
6	<i>Asplenium bulbiferum</i>	Aspleniaceae	Fern	1.77	0.66	2.43
7	<i>Atherosperma moschatum</i>	Monimiaceae	Tree	3.30	0.53	3.83
8	<i>Billiardiera longiflora</i>	Pittosporaceae	Shrub	0.65	0.53	1.18
9	<i>Blechnum nudum</i>	Blechnaceae	Fern	0.44	0.53	0.97
10	<i>Blechnum wattsi</i>	Blechnaceae	Fern	0.65	0.53	1.18
11	<i>Cyathodes glauca</i>	Epacridaceae	Shrub	0.88	0.53	1.41
12	<i>Cyathodes juniperina</i>	Epacridaceae	Shrub	1.10	0.53	1.63
13	<i>Cennarhenes nitida</i>	Proteaceae	Shrub	0.66	0.53	1.19
14	<i>Centaurea sp.</i>	Compositae	Shrub	0.44	0.53	0.97
15	<i>Clematis aristata</i>	Ranunculaceae	Climber	1.10	0.53	1.63
16	<i>Dicksonia antarctica</i>	Dicksoniaceae	Fern	2.87	5.30	8.17
17	<i>Tasmannia lanceolata</i>	Winteraceae	Shrub	1.99	0.53	2.52
18	<i>Eucalyptus delegatensis</i>	Myrtaceae	Tree	3.98	2.65	6.63
19	<i>Eucalyptus regnans</i>	Myrtaceae	Tree	11.05	12.72	23.77
20	<i>Eucryphia lucida</i>	Eucryphiaceae	Tree	3.76	0.77	4.53
21	<i>Gahnia grandis</i>	Cyperaceae	Grass	3.30	2.65	5.95
22	<i>Gaultheria hispida</i>	Ericaceae	Shrub	0.88	0.53	1.41
23	<i>Histiopteris incisa</i>	Dennstaedtiaceae	Fern	11.93	18.55	30.48
24	<i>Hydrocolyle pterocarpa</i>	Umbelliferae	Herb	0.88	0.53	1.41
25	<i>Hypolepis muelleri</i>	Dennstaedtiaceae	Fern	7.07	5.04	12.11
26	<i>Monotoca glauca</i>	Epacridaceae	Shrub	9.70	5.30	15.00
27	Mosses			8.80	11.13	19.93
28	<i>Nothofagus cunninghamii</i>	Fagaceae	Tree	3.30	2.12	5.42
29	<i>Olearia argophylla</i>	Asteraceae	Shrub	0.65	1.06	1.71
30	<i>Phebalium squameum</i>	Rutaceae	Tree	5.50	2.65	8.15
31	<i>Phyllocladus aspleniifolius</i>	Podocarpaceae	Tree	1.10	0.53	1.63
32	<i>Polystichum proliferum</i>	Aspidiaceae	Fern	1.99	0.53	2.52
33	<i>Pteridium esculentum</i>	Dennstaedtiaceae	Fern	2.65	5.30	7.95
34	<i>Senecio velleioides</i>	Compositae	Shrub	1.55	0.53	2.08
35	<i>Trochocarpa cunninghamii</i>	Epacridaceae	Shrub	0.65	0.53	1.18
36	<i>Zieria arborescens</i>	Rutaceae	Shrub	0.88	0.74	1.62

Appendix 7. Species found on sites nine years after burning in alphabetical order.

	Species	Family	Life-form	RF(%)	RDo(%)	IV(%)
1	<i>Acacia dealbata</i>	Mimosaceae	Tree	2.44	7.00	9.44
2	<i>Acacia mucronata</i>	Mimosaceae	Tree	6.25	7.00	13.25
3	<i>Acacia melanoxylon</i>	Mimosaceae	Tree	1.05	0.89	1.94
4	<i>Amperea xiphioides</i>	Euphorbiaceae	Shrub	2.85	0.35	3.20
5	<i>Anopterus glandulosus</i>	Escalloniaceae	Shrub	1.22	1.42	2.64
6	<i>Atherosperma moschatum</i>	Monimiaceae	Tree	1.90	0.43	2.33
7	<i>Billiardiera longifolia</i>	Pittosporaceae	Shrub	0.81	0.35	1.16
8	<i>Blechnum wattsii</i>	Blechnaceae	Fern	1.22	0.35	1.57
9	<i>Coprosma quadrifida</i>	Rubiaceae	Shrub	0.40	0.35	0.75
10	<i>Cyathodes juniperina</i>	Epacridaceae	Shrub	6.25	1.42	7.67
11	<i>Dianella tasmanica</i>	Liliaceae	Herb	2.04	0.70	2.74
12	<i>Dicksonia antarctica</i>	Dicksoniaceae	Fern	1.63	4.00	5.63
13	<i>Dryophylla cyanocarpa</i>	Liliaceae	Herb	1.05	0.35	1.40
14	<i>Epacris impressa</i>	Epacridaceae	Shrub	1.05	0.50	1.55
15	<i>Eucalyptus regnans</i>	Myrtaceae	Tree	9.65	12.44	22.09
16	<i>Eucalyptus viminalis</i>	Myrtaceae	Tree	3.12	1.78	4.90
17	<i>Eucryphia lucida</i>	Eucryphiaceae	Tree	3.40	0.50	3.90
18	<i>Gahnia grandis</i>	Cyperaceae	Grass	3.12	5.45	8.57
19	<i>Gaultheria hispidula</i>	Ericaceae	Shrub	0.62	0.35	0.97
20	<i>Histiopteris incisa</i>	Dennstaedtiaceae	Fern	0.62	5.33	5.95
21	<i>Hypolepis muelleri</i>	Dennstaedtiaceae	Fern	2.85	2.49	5.34
22	<i>Lepidosperma elatius</i>	Cyperaceae	Grass	0.62	0.50	1.12
23	<i>Leptospermum glaucosum</i>	Myrtaceae	Shrub	1.65	6.22	7.87
24	<i>Marchantia berteroana</i>	Marchantiaceae	Thalloid	0.40	1.95	2.35
25	<i>Monotoca glauca</i>	Epacridaceae	Shrub	7.48	3.20	10.68
26	Mosses		Mosses	10.19	12.44	22.63
27	<i>Nothofagus cunninghamii</i>	Fagaceae	Tree	4.21	1.29	5.50
28	<i>Olearia argophylla</i>	Compositae	Tall shrub	0.62	0.89	1.51
29	<i>Oxylobium ellipticum</i>	Papilionaceae	Shrub	1.65	1.42	3.07
30	<i>Phebalium squameum</i>	Rutaceae	Tree	6.52	1.78	8.30
31	<i>Phyllocladus aspleniifolius</i>	Podocarpaceae	Tree	0.81	0.89	1.70
33	<i>Pomaderris apetala</i>	Rhamnaceae	Tall shrub	0.81	1.15	1.96
34	<i>Pteridium esculentum</i>	Dennstaedtiaceae	Fern	6.25	13.51	19.76
35	<i>Pultanea juniperina</i>	Papilionatae	Shrub	0.20	8.89	9.09
36	<i>Richea scoparia</i>	Epacridaceae	Shrub	1.05	0.50	1.55
37	<i>Senecio velleioides</i>	Compositae	Herb	0.40	0.35	0.75
38	<i>Sticherus tenax</i>	Gleicheniaceae	Fern	0.60	0.35	0.95
39	<i>Trochocarpa guihii</i>	Epacridaceae	Shrub	1.22	0.35	1.57
40	<i>Zieria arborescens</i>	Rutaceae	Shrub	3.76	0.35	4.11

Appendix 8. Vascular plants found on the study sites.

1. Aspleniaceae
Asplenium bulbiferum
2. Aspidiaceae
Polystichum proliferum
3. Blechnaceae
Bechnum nudum
Blechnum wattsii
4. Compositae
Olearia argophylla
Senecio sp.
Cirsium sp.
Centaurea sp.
5. Cunoniaceae
Anodopetalum biglandulosum
6. Cyperaceae
Gahnia grandis
Lepidosperma sp.
Uncinia tenella
7. Dicksoniaceae
Dicksonia antarctica
8. Davalliaceae
Ruhmora adiantiformis
9. Dennstaedtiaceae
Histiopteris incisa
Hypolepis muellerii
Pteridium esculentum
10. Dipsacaceae
Dipsacus sylvestris
11. Escalloniaceae
Anopteryx glandulosus
12. Elaeocarpaceae
Aristotelia pedicularis
13. Epacridaceae
Cyathodes juniperina
Epacris impressa
Monotoca glauca
Prionotes cerinthoides
Richea springelioides
Richea scoparia
Trochocarpa gunii
14. Ericaceae
Gaultheria hispida
15. Eucryphiaceae
Eucryphia lucida
16. Euphorbiaceae
Amperea xipoclada
17. Fagaceae
Nothofagus cunninghamii
18. Gleicheniaceae
Glichenia sp.
Sticherus tenner
19. Gramineae
Poa sp.
20. Grammitidaceae
Grammitis billardieri
21. Hymenophyllaceae
Hymenophyllum marginatum
22. Leguminosae
Acacia dealbata
Acacia melanoxylon
Acacia mucronata
Acacia verticillata
23. Liliaceae
Astelia sp.
Dianella tasmanica
Drymophyla cyanocarpa
24. Monimiaceae
Atherosperma moschatum
25. Myrtaceae
Eucalyptus delegatensis
E. obliqua
E. regnans
E. viminalis
Leptospermum glaucosum
L. scoparia
26. Oxalidaceae
Oxalis sp.
27. Papilionaceae
Oxylobium ellipticum
Pultanea juniperina
Ulex europaeus

28. Pittosporaceae
Pittosporum bicolor
Billardiera longifolia
29. Podocarpaceae
Phyllocladus aspleniifolius
30. Pittosporaceae
Pittosporum bicolor
Billardiera longifolia
31. Podocarpaceae
Phyllocladus aspleniifolius
32. Polypodiaceae
Microsorium diversifolium
33. Proteaceae
Cennarhens nitida
34. Pteridaceae
Pteris sp.
35. Ranunculaceae
Clematis aristata
Ranunculus sp.

36. Rhamnaceae
Pomaderris apetala
32. Rosaceae
Acaena sp.
37. Rubiaceae
Coprosma quadrifida
38. Rutaceae
Phebalium squameum
Zieria arborescens
39. Thymelaeaceae
Pimelia drupacea
40. Urticaceae
Urtica incisa
41. Umbelliferae
Hydrocotyle pterocarpa
Hydrocotyle javanica
42. Winteraceae
Tasmannia lanceolata

Appendix 9a.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275
Species												
Mosses	*	*	*	*	*	q*	q*	*			*	*
<i>Nothofagus cunninghamii</i>	*	*	*	*	*	q*	q*	*	*	*		
<i>Atherosperma moschatum</i>	*		*	*	*	q	q*	*				
<i>Anodopetalum biglandulosum</i>		*				q*	q*	*	*			*
<i>Eucryphia lucida</i>			*	*	*	q	q	*	*			
<i>Blechnum watsii</i>	*	*	*			q	q		*	*		
<i>Dicksonia antartica</i>		*	*			q	q		*			*
<i>Phyllocladus aspleniifolius</i>						q	q	*				
<i>Microsorium diversifolius</i>		*	*			q	q	*	*			
<i>Anopteris glandulosus</i>			*		*	q	q	*				*
<i>Trococarpa guhnii</i>						q	q		*	*		
<i>Polystichum juniperinum</i>		*				q	q				*	
<i>Asplenium bulbiferum</i>	*		*			q	q		*			
<i>Grammitis billardieri</i>		*			*	q	q	*		*		
<i>Dryophylla cyanocarpa</i>	*				*	q	q		*			
<i>Hypolepis muelleri</i>					*	q	q					
<i>Histiopteris incisa</i>					*	q	q					
<i>Cennarhenes nitida</i>						q	q	*				
<i>Eucalyptus regnans</i>						q	q	*				
<i>Gahnia grandis</i>						q	q			*	*	*

Appendix 9b.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300
Species													
Mosses	*	*	*	.	*	*	*	*	*	*	*	q*	q*
<i>Nothofagus cunninghamii</i>	*	.	.	q*		*	*	*				q*	q*
<i>Atherosperma moschatum</i>		.		q		.	.		.	.		q*	q
<i>Anodopetalum biglandulosum</i>			.	q*								q*	q*
<i>Eucryphia lucida</i>	*	*		q*	*					.	.	q*	q
<i>Blechnum watsii</i>		.	.	q*	.					.	.	q	q
<i>Dicksonia antarctica</i>	.			q	*	.	.	.	.	.	.	q	q
<i>Phyllocladus aspleniifolius</i>			.	q					.			q	q
<i>Microsorium diversifolius</i>	.			q							.	q	q
<i>Anopteris glandulosus</i>	.			q	*			.				q	q
<i>Polystichum juniperinum</i>	.	.		q						.		q	q
<i>Asplenium bulbiferum</i>	.		.	q				.			.	q	q
<i>Grammitis billardieri</i>		.		q	.		.	.			.	q	q
<i>Uncinia tenella</i>				q		*						q	q
<i>Histiopteris incisa</i>			.	q				.		.		q	q
<i>Eucalyptus regnans</i>	.		.	q		.		.				q	q
<i>Gahnia grandis</i>				q	.						.	q	q

Appendix 9c.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550
Species																							
Mosses	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
<i>Nothofagus cunninghamii</i>	*	*	*	*			*	*	*	*	q	q	q	q	q	*	*				*	*	*
<i>Eucryphia lucida</i>	*	*	*		*			*		*	q	q	q	q	q	*	*	*	*		*	*	*
<i>Atherosperma moschatum</i>					*	*	*				q	q	q	q	q*	*			*	*	*	*	*
<i>Anodopetalum biglandulosum</i>							*				q*	q*	q*	q*	q*						*		*
<i>Anopteryx glandulosus</i>	*	*	*								q	q	q	q	q	*	*	*	*				
<i>Grammitis billardieri</i>	*	*	*	*	*	*					q	q	q	q	q			*			*		
<i>Polystichum juniperinum</i>	*				*	*	*				q	q	q	q	q	*	*	*					
<i>Dicksonia antarctica</i>				*	*	*	*	*			q	q	q	q	q					*	*	*	*
<i>Microsorium diversifolium</i>	*	*									q	q	q	q	q	*	*	*					*
<i>Blechnum watsii</i>	*										q	q	q	q	q	*	*	*					
<i>Hymenophyllum australe</i>	*	*	*								q*	q	q	q	q			*	*				
<i>Drymophylla cyanocarpa</i>	*	*									q	q	q	q	q				*	*			
<i>Phyllocladus aspleniifolius</i>											q	q	q	q	q	*					*	*	*
<i>Eucalyptus regnans</i>					*						q	q	q	q	q							*	*
<i>Pteris</i> sp	*										q	q	q	q	q								*
<i>Trochocarpa gunii</i>											q	q	q	q	q							*	*
<i>Aristotelia</i> sp.											q	q	q	q	q		*						*
<i>Tasmania lanceolata</i>				*	*						q	q	q	q	q							*	*
<i>Coprosma quadrifida</i>											q	q	q	q	q						*	*	*
<i>Gahnia grandis</i>											q	q	q	q	q							*	*
<i>Gaultheria hispida</i>		*									q	q	q	q	q					*	*		*
<i>Dianella tasmanica</i>											q	q	q	q	q	*	*		*			*	*
<i>Hydrocotyle javanica</i>	*	*									q	q	q	q	q					*			*
<i>Monotoca glauca</i>											q	q	q	q	q								*
<i>Olearia argophylla</i>											q	q	q	q	q								*
<i>Blechnum nudum</i>				*	*						q	q	q	q	q						*	*	
<i>Rumohra adiantiformis</i>											q	q	q	q	q						*	*	
<i>Uncinia tenella</i>											q	q	q	q	q		*						
<i>Sticherus tenax</i>											q	q	q	q	q			*					

Appendix 10a.

[illegible]

Appendix 10.b

Distance (metre)	0	25	50	75	100	125	150	175	200	225
Species										
Mosses	*		*	q	q	q	q	*	*	*
<i>Histiopteris incisa</i>	*	*	*	q	q	q*	q*	*	*	*
<i>Eucryphia lucida</i>	*		*	q*	q*	q	q			
<i>Nothofagus cunninghamii</i>	*		*	q	q	q	q	*	*	
<i>Anopterus glandulosus</i>	*		*	q	q*	q	q			*
<i>Eucalyptus regnans</i>			*	q	q*	q	q			
<i>Anodopetalum biglandulosum</i>				q*	q*	q	q			
<i>Phebalium squameum</i>	*			q	q	q	q		*	*
<i>Asplenium bulbiferum</i>	*			q	q	q	q			*
<i>Dicksonia antarctica</i>		*		q	q	q	q		*	
<i>Polystichum proliferum</i>		*		q	q*	q	q			
<i>Blechnum watsii</i>				q*						*
<i>Atherosperma moschatum</i>				q	q	q	q		*	
<i>Gahnia grandis</i>				q	q	q	q		*	*
<i>Olearia argophylla</i>		*		q	q	q	q			
<i>Eucalyptus obliqua</i>				q	q*	q	q			
<i>Hypolepis muelleri</i>				q	q*	q	q			
<i>Rumohra</i> sp.	*			q	q	q	q	*		
Herb (unidentified)	*	*		q	q					

Appendix 10c.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250
Species											
<i>Nothofagus cunninghamii</i>	*		*		*	*		*			
<i>Anodopetalum biglandulosum</i>			*		*						
<i>Eucryphia lucida</i>	*		*	*	*	*	*		*	*	
Mosses	*				*	*		*	*		
<i>Anopteris glandulosus</i>	*			*	*	*	*				
<i>Histiopteris incisa</i>							*		*		
<i>Phebalium squameum</i>			*				*				
<i>Asplenium bulbiferum</i>	*					*					
<i>Monotoca glauca</i>			*	*				*	*		
<i>Richea scoparia</i>	*				*						
<i>Drymophylla cyanocarpa</i>	*										
<i>Trochocarpa guinii</i>				*	*						
<i>Eucalyptus viminalis</i>				*							
<i>Microsorium diversifolium</i>					*	*					
<i>Hypolepis muelleri</i>						*	*				
<i>Senecio velleioides</i>									*	*	*
<i>Cyathodes juniperina</i>											*
<i>Pteridium esculentum</i>				*							
<i>Dicksonia antarctica</i>						*	*				
<i>Eucalyptus regnans</i>	*				*	*					
<i>Atherosperma moschatum</i>	*	*	*		*			*		*	*
<i>Phyllocladus aspleniifolius</i>	*				*						
<i>Eucalyptus obliqua</i>		*	*	*	*				*		
<i>Blechnum watsii</i>						*					

Appendix. 11 a

Distance (metre)	0	25	50	75	100	125	150	175	200	225
Species										
Mosses	*	*	*	*	*	*	*	*	*	*
<i>Histiopteris incisa</i>	*	*	*	*	*	*	*	*	*	*
<i>Eucalyptus regnans</i>	*	*	*	*		*	*		*	*
<i>Nothofagus cunninghamii</i>	*	*	*	*	*	*	*	*	*	*
<i>Atherosperma moschatum</i>	*			*	*	*	*	*		*
<i>Hypolepis muelleri</i>	*	*	*	*				*	*	
<i>Eucryphia lucida</i>	*		*	*	*	*			*	
<i>Gahnia grandis</i>	*	*	*		*					*
<i>Acacia melanoxylon</i>		*			*	*				*
<i>Cyathodes juniperina</i>			*	*			*			
<i>Blechnum watsii</i>	*		*				*			
<i>Dicksonia antartica</i>			*				*			
<i>Senecio velleioides</i>			*	*						*
<i>Coprosma quadrifida</i>		*				*				
<i>Microsorium diversifolium</i>			*				*			
<i>Monotoca glauca</i>			*							
<i>Asplenium bulbiferum</i>		*			*					

Appendix 11b.

Distance (metre)	0	25	50	75	100	125	150	175
Species								
<i>Histiopteris incisa</i>	*	*		*	*	*	*	*
<i>Eucalyptus regnans</i>	*	*	*	*	*	*	*	*
<i>Atherosperma moschatum</i>	*	*		*	*	*	*	*
<i>Dicksonia antarctica</i>	*	*	*	*	*	*	*	
<i>Eucryphia lucida</i>		*	*	*	*	*	*	*
<i>Nothofagus cunninghamii</i>	*	*	*	*			*	*
<i>Hypolepis muelleri</i>			*		*	*	*	*
Mosses	*	*	*	*			*	
<i>Gahnia grandis</i>	*		*		*	*		
<i>Cyathodes juniperina</i>			*	*			*	
<i>Acacia melanoxylon</i>					*	*	*	
<i>Senecio velleioides</i>	*				*	*		
<i>Phyllocladus aspleniifolius</i>		*		*		*		
<i>Pteridium esculentum</i>							*	*
<i>Pimelia drupacea</i>	*				*			
<i>Acacia dealbata</i>	*			*				
<i>Asplenium bulbiferum</i>				*				
<i>Microsorium diversifolium</i>				*				

Appendix 11c.

Distance (metre)	0	25	50	75	100	125	150	175
Species								
<i>Hisopteris incisa</i>	*	*	*	*	*	*	*	*
Mosses	*	*	*	*	*	*	*	*
<i>Atherosperma moschatum</i>	*	*	*	*	*	*	*	*
<i>Nothofagus cunninghamii</i>	*	*	*	*		*		*
<i>Eucryphia lucida</i>			*		*		*	*
<i>Hypolepis muelleri</i>	*			*		*	*	*
<i>Senecio velleioides</i>		*	*	*		*		
<i>Blechnum watsii</i>	*		*		*			*
<i>Gahnia grandis</i> c	*			*	*			
<i>Dicksonia antaxifca</i>			*	*		*		
<i>Pteridium esculentum</i>	*			*				*
<i>Monotoca glauca</i>	*				*			*
<i>Phyllocladus aspleniifolius</i>	*					*		
<i>Eucalyptus regnans</i>			*				*	
<i>Coprosma quadrifida</i>		*	*					
<i>Asplenium bulbiferum</i>				*		*		
<i>Ulex</i> sp.					*	*		
<i>Acacia dealbata</i>			*	*				
<i>Phebalium squameum</i>		*		*				
<i>Cyathodes juniperina</i>		*						
<i>Pimelia drupacea</i>		*						
<i>Microsorium diversifolium</i>					*			
<i>Anodopetalum biglandulosus</i>		*						

Appendix 11 d.

Distance (metre)	0	25	50	75	100	125	150	175	200
Species									
<i>Histiopteris incisa</i>	*	*	*	*	*	*	*	*	
Mosses	*	*	*	*	*	*	*	*	*
<i>Atherosperma moschatum</i>	*	*	*	*	*	*	*		
<i>Hypolepis muelleri</i>		*	*	*	*	*	*		
<i>Gahnia grandis</i>	*	*	*	*			*		*
<i>Nothofagus cunninghamii</i>	*	*	*	*		*			
<i>Eucryphia lucida</i>	*			*	*	*			
<i>Senecio velleioides</i>	*		*	*					
<i>Dicksonia antarctica</i>	*				*	*			
<i>Acacia dealbata</i>				*	*				
<i>Phyllocladus aspleniifolius</i>		*		*					
<i>Cyathodes juniperina</i>		*	*						
<i>Blechnum nudum</i>	*		*						
<i>Phebalium squameum</i>	*		*						
<i>Microsorium diversifolium</i>				*					
<i>Eucalyptus regnans</i>				*					
<i>Pteridium esculentum</i>			*						
<i>Coprosma quadrifida</i>	*								
<i>Pimelia drupacea</i>		*							
<i>Monotoca glauca</i>			*						

Appendix 11 e.

Distance (metre)	0	25	50	75	100	125	150	175	200
Species									
<i>Histiopteris incisa</i>	*	*	*	*	*	*	*	*	*
Mosses	*	*	*	*	*	*	*	*	.
<i>Eucryphia lucida</i>
<i>Nothofagus cunninghamii</i>		
<i>Hypolepis incisa</i>
<i>Atherosperma moschatum</i>		
<i>Senecio velleioides</i>			
<i>Eucalyptus regnans</i>					
<i>Phebalium squameum</i>		.	.						.
<i>Acacia dealbata</i>		.						.	.
<i>Dicksonia antarctica</i>	*				.	.			
<i>Pteridium esculentum</i>	.				.	.			
<i>Gahnia grandis</i>	.		.	.					
<i>Blechnum watsii</i>	.	.	.						
<i>Cyathodes juniperina</i>				.	.				
<i>Monotoca glauca</i>				.	.				
<i>Pimelia drupacea</i>				.	.				

2

1

Appendix 12 b.

[illegible]

Appendix 12 c.

[illegible]

Appendix 13b.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525
Species																						
<i>Eucalyptus regnans</i>		*	*			*			.	q*	q	q*	q*	q	q	q*
<i>Histiopteris incisa</i>	q*	q*	q*	q*	q*	q*	q*
<i>Hypolepis muelleri</i>	q	q*	q*	q	q	q	q*
<i>Gahnia grandis</i>										q	q	q	q*	q	q	q
<i>Eucryphia lucida</i>						.	.			.						q*	q	q	q	q	q	q
<i>Atherosperma moschatum</i>			q	q*	q*	q	q*	q	q
<i>Senecio velleioides</i>	q*	q*	q*	q	q	q*	q*
<i>Dicksonia antarctica</i>	.			.		.										q	q*	q	q	q	q	q
<i>Anodopetalum biglandulosus</i>		.														q	q	q	q	q	q	q
<i>Phyllocladus aspleniifolius</i>	.					.										q	q	q	q	q	q	q
<i>Cyathodes juniperina</i>		.	.	.												q	q	q	q	q	q	q
<i>Monotoca glauca</i>								q	q	q	q	q	q	q
<i>Phebalium squameum</i>																q	q	q	q	q	q	q
<i>Mosses</i>	*	*	q	q*	q*	q*	q*	q*	q
<i>Acacia melanoxylom</i>		.		.												q	q	q	q	q	q	q
<i>Acacia dealbata</i>			.	.												q	q	q	q	q	q	q
<i>Nothofagus cunninghamii</i>	.				.	.										q	q	q	q	q	q	q
<i>Pomaderris apetala</i>								.								q	q	q	q	q	q	q
<i>Acaena</i> sp.		.														q*	q	q	q	q	q	q
<i>Pteridium esculentum</i>		.														q	q	q	q	q	q	q
<i>Clematis</i> sp.												.				q	q	q	q	q	q	q

Appendix 13c.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500
Species																					
<i>Eucalyptus regnans</i>	*	*	*	*	*	*	*	*	*	*	*	q	q	q*	q	q*	q		*		*
<i>Histiopteris incisa</i>	*	*	*	*	*	*	*		*	*		q*	q*	q*	q*	q	q	*		*	*
<i>Hypolepis muelleri</i>			*					*				q	q	q	q	q	q				
<i>Gahnia grandis</i>	*						*	*			*	q	q	q	q	q	q				
<i>Eucryphia lucida</i>	*							*				q*	q*	q	q	q	q				
<i>Atherosperma moschatum</i>	*		*				*					q*	q	q	q*	q	q				
<i>Senecio velleioides</i>		*	*			*	*					q	q	q	q	q	q				
<i>Dicksonia antarctica</i>	*		*									q	q	q	q	q	q				
<i>Anodopetalum biglandulosus</i>		*		*								q*	q	q	q	q	q*				
<i>Phyllocladus aspleniifolius</i>								*				q	q	q	q	q	q				
<i>Cyathodes juniperina</i>							*	*				q	q	q	q	q	q				
<i>Monotoca glauca</i>			*							*	*	q	q	q	q	q	q				
<i>Phebalium squameum</i>	*	*	*	*		*	*					q*	q*	q*	q	q*	q	*			*
<i>Mosses</i>	*	*	*					*	*			q	q	q	q	q	q		*		
<i>Acacia melanoxylom</i>												q	q	q*	q*	q	q	*	*		
<i>Acacia dealbata</i>												q*	q*	q*	q	q	q*				
<i>Nothofagus cunninghamii</i>												q	q	q	q	q	q				
<i>Pomaderris apetala</i>												q	q	q	q	q	q				
<i>Pteridium esculentum</i>											*	q	q	q	q	q	q				
<i>Blechnum watsii</i>											*	q	q	q	q	q	q				
<i>Eucalyptus delegatensis</i>												q	q	q	q	q	q	*			

Appendix 13d.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350
Species															
<i>Eucalyptus regnans</i>	*	q*	q*	q	q	q	*	*	*	*	*	*	*	*	*
<i>Histiopteris incisa</i>	*	q*	q*	q*	q*	q	*	*	*		*	*	*	*	*
<i>Hypolepis muelleri</i>		q	q	q	q	q									
<i>Gahnia grandis</i>		q*	q	q	q	q				*	*		*	*	*
<i>Eucryphia lucida</i>		q	q	q*	q	q		*	*			*			
<i>Atherosperma moschatum</i>		q	q	q	q	q	*			*		*			
<i>Senecio velleioides</i>		q	q	q	q	q	*	*	*						*
<i>Dicksonia antarctica</i>		q	q	q	q	q	*				*				
<i>Anodopetalum biglandulosus</i>		q	q	q*	q	q		*	*						*
<i>Phyllocladus aspleniifolius</i>		q	q	q	q	q	*		*						
<i>Monotoca glauca</i>		q	q	q	q	q				*	*		*		
<i>Phebalium squameum</i>	*	q*	q*	q	q	q	*	*	*	*	*	*	*	*	*
Mosses		q	q	q	q	q									
<i>Acacia dealbata</i>		q	q	q	q	q							*	*	*
<i>Nothofagus cunninghamii</i>		q	q	q	q*	q*					*				
<i>Pteridium esculentum</i>		q	q	q	q	q		*	*						
<i>Blechnum wattsii</i>		q	q	q	q	q		*							
<i>Eucalyptus delegatensis</i>		q	q	q	q	q									
<i>Trochocarpa guihii</i>	*	q	q	q	q	q		*			*	*			
<i>Clematis</i> sp		q	q	q	q	q							*		
<i>Asplenium bulbiferum</i>		q	q	q	q	q					*			*	
<i>Anopteris glandulosus</i>		q	q	q	q	q		*					*		
<i>Acacia melanoxylon</i>		q	q	q	q	q				*					
<i>Cennarhenes nitida</i>		q	q	q	q	q				*					
<i>Coprosma quadrifida</i>		q	q	q	q	q		*							
<i>Gaultheria hispida</i>	*	q	q	q	q	q									
<i>Leptospermum galucosum</i>	*	q	q	q	q	q									
<i>Leptospermum scoparia</i>	*	q	q	q	q	q									
<i>Marchantia beteroana</i>		q	q	q	q	q	*	*				*			
<i>Olearia argophylla</i>		q	q	q	q	q	*								
<i>Polystichum proliferum</i>		q	q	q	q	q			*	*					
<i>Richea scoparia</i>	*	q	q	q	q	q									
<i>Urtica</i> sp.	*	q	q	q	q	q									
<i>Zieria arborescens</i>	*	q	q	q	q	q									
<i>Ranunculus</i> sp.								*		*				*	*

Appendix 13e

[illegible]

Appendix 14 a.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500
Species																					
<i>Eucalyptus regnans</i>	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	q	q*	q*	q	q	q
<i>Histiopteris incisa</i>		*	*	*	*	*	*	*	*	*	*	*	*	*	*	q*	q*	q*	q*	q	q*
<i>Monotoca glauca</i>	*		*	*	*	*	*	*	*		*	*	*	*	*	q*	q	q	q	q*	q
Mosses	*		↑	*	*	*	*	*	*		*		*	*	*	q*	q*	q*	q	q	q*
<i>Hypolepis muelleri</i>)			*	*			↑	↑			*	*		*	*	q	q*	q	q	q	q
<i>Eucryphia lucida</i>	*		*	*	*	*			*		*	*	*			q*	q	q	q	q	q
<i>Phebalium squameum</i>	*	*	*						*		*	*	*	*	*	q	q*	q*	q	q	q
<i>Nothofagus cunninghamii</i>	*	*		*					*				*		*	q	q	q*	q*	q	q
<i>Atherosperma moschatum</i>		*		*	*	*								*	*	q	q*	q	q	q	q
<i>Anopteryx glandulosus</i>		*		*							*	*			*	q	q	q	q	q*	q
<i>Gahnia grandis</i>			*				*	*								q	q	q	q*	q	q
<i>Hydrocotyle</i> sp.											*	*				q	q	q	q	q	q
<i>Gaultheria hispida</i>												*	*			q	q	q	q	q	q
<i>Acacia melanoxylon</i>									*				*			q	q	q	q	q	q
<i>Aristotelia</i> sp.									*	*						q	q	q	q	q	q
<i>Billardiera</i> sp.										*	*					q	q	q	q	q	q
<i>Blechnum nudum</i>											*		*			q	q	q	q	q	q
<i>Cennarrhenes nitida</i>										*			*			q	q	q	q	q	q
<i>Cyathodes juniperina</i>										*	*					q	q	q	q	q	q
<i>Blechnum wattsii</i>			*													q	q	q	q	q	q
<i>Lasmaria lanceolata</i>	*				*	*							*	*		q	q	q	q	q	q
<i>Pteridium esculentum</i>					*	*	*			*						q	q*	q*	q	q	q
<i>Dicksonia antarctica</i>		*						*			*	*				q	q	q	q	q	q
<i>Asplenium bulbiferum</i>	*				*	*					*	*				q	q	q	q	q	q
<i>Eucalyptus delegatensis</i>		*							*					*	*	q	q	q	q	q	q
<i>Cyathodes glauca</i>				*							*	*				q	q	q	q	q	q
<i>Phyllocladus aspleniifolius</i>					*	*							*			q	q	q	q	q	q
<i>Acacia dealbata</i>		*												*		q	q	q	q	q	q
<i>Senecio velleioides</i>								*	*	*		*	*		*	q	q	q*	q*	q	q

Appendix 14 b.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	
Species																									
<i>Eucalyptus regnans</i>	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	q	q*	q*	q
<i>Histiopteris incisa</i>	*			*	*	*	*	*		*	*	*				*		*	*			q	q	q	q*
<i>Monotoca glauca</i>	*			*	*	*	*	*		*	*		*	*			*		*	*		q	q	q	q
Mosses	*	*	*	*	*	*	*		*			*	*	*		*	*	*	*			q*	q	q*	q
<i>Hypolepis muelleri</i>		*		*	*		*			*								*	*			q*	q	q	q
<i>Eucryphia lucida</i>			*						*		*				*	*						q	q	q*	q
<i>Phebalium squameum</i>	*			*	*	*	*				*											q	q	q	q
<i>Nothofagus cunninghamii</i>			*	*		*	*														*	q	q	q	q
<i>Atherosperma moschatum</i>		*	*		*																	q	q	q	q
<i>Tasmanialanceolata</i>			*	*																		q	q	q	q
<i>Dicksonia antarctica</i>				*	*		*															q	q	q	q
<i>Asplenium bulbiferum</i>				*		*																q	q	q	q
<i>Eucalyptus delegatensis</i>			*	*			*				*	*		*								q	q	q	q
<i>Cyathodes glauca</i>		*	*	*																		q	q	q	q
<i>Phyllocladus aspleniifolius</i>					*		*															q	q	q	q
<i>Acacia dealbata</i>		*	*																			q	q	q	q
<i>Hydrocotyle</i> sp.		*				*																q	q	q	q
<i>Acacia melanoxylon</i>		*	*								*											q	q	q	q
<i>Blechnum nudum</i>				*																		q	q	q	q
<i>Senecio velleiodes</i>																		*	*			q	q*	q	q*
<i>Blechnum wattsii</i>			*																			q	q	q	q
<i>Gaultheria hispida</i>				*								*	*									q	q	q	q
<i>Pteridium esculentum</i>							*							*	*		*	*	*	*		q	q	q	q
<i>Anopterus glandulosus</i>				*	*							*	*	*	*							q	q	q	q
<i>Gahnia grandis</i>																	*	*	*	*		q*	q	q*	q

Appendix 14 c.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	
Species																											
<i>Eucalyptus regnans</i>	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	q	q	q	q	q	q
<i>Histiopteris incisa</i>	*	*	*	*	*	*	*	*	*	*		*		*		*	*	*	*	*	*	q*	q	q*	q	q*	q
<i>Monotoca glauca</i>	*		*			*		*			*	*	*	*	*			*	*	*	*	q	q*	q*	q*	q	q*
Mosses	*	*	*	*	*	*	*		*			*	*		*	*	*	*	*	*		q	q*	q*	q	q	q
<i>Hypolepis muelleri</i>		*		*	*			*		*			*			*						q*	q*	q	q	q	q
<i>Eucryphia lucida</i>					*	*						*	*									q	q*	q	q	q	q
<i>Phebalium squameum</i>	*	*					*		*		*				*	*	*			*	*	q	q	q	q	q	q*
<i>Nothofagus cunninghamii</i>		*				*	*								*	*	*					q	q	q*	q	q	q*
<i>Atherosperma moschatum</i>		*					*						*		*							q	q*	q	q	q*	q
<i>Gahnia grandis</i>			*	*													*	*	*			q	q	q*	q	q	q
<i>Tasmannia lanceolata</i>					*				*	*							*	*				q*	q	q	q	q	q
<i>Dicksonia antarctica</i>					*	*																q	q	q	q	q	q
<i>Eucalyptus delegatensis</i>			*				*		*	*		*		*								q	q	q	q	q	q
<i>Cyathodes glauca</i>	*								*	*												q	q	q	q	q	q
<i>Phyllocladus aspleniifolius</i>		*	*				*															q	q	q	q	q	q
<i>Acacia melanoxylon</i>					*	*																q	q	q	q	q	q
<i>Cennarrhenes nitida</i>							*	*														q	q	q	q	q	q
<i>Blechnum wattsii</i>					*																	q	q	q	q	q	q
<i>Senecio velleioides</i>								*	*													q	q	q*	q*	q	q
<i>Cyathodes glauca</i>								*														q	q	q*	q*	q	q
<i>Anodopetalum biglandulosum</i>																						q*	q	q	q	q	q
<i>Polysticum</i> sp.	*		*												*	*						q	q	q	q	q	q
<i>Pteridium esculentum</i>												*	*						*			q	q	q	q	q	q
<i>Aristotelia</i> sp.																		*				q	q	q	q	q	q

Appendix 15a.

Distance (metre)	0	25	50	75	100	125	150	175	200	225
Species										
<i>Eucalyptus regnans</i>	*	*	*	*	*	*	*	*	*	
Mosses	*	*	*	*	*	*	*	*	*	*
<i>Histiopteris incisa</i>	*		*		*	*		*	*	*
<i>Monotoca glauca</i>	*	*		*	*	*		*	*	*
<i>Pteridium esculentum</i>	*		*	*	*	*	*	*		*
<i>Acacia mucronata</i>	*	*	*	*	*	*	*	*	*	*
<i>Phebalium squameum</i>	*	*	*	*	*	*	*	*	*	
<i>Amperea xipoclada</i>	*	*	*	*	*	*		*	*	
<i>Histiopteris incisa</i>	*		*		*	*		*	*	*
<i>Cyathodes juniperina</i>	*	*	*		*			*	*	
<i>Zieria arborescens</i>		*	*				*	*	*	
<i>Oxylobium</i> sp.		*	*		*			*		*
<i>Eucalyptus viminalis</i>	*		*		*				*	*
<i>Eucryphia lucida</i>	*		*				*		*	
<i>Dianella tasmanica</i>					*	*	*		*	
<i>Nothofagus cunninghamii</i>	*	*		*			*			
<i>Billardiera longifolia</i>	*	*					*			
<i>Epacris impressa</i>			*				*		*	
<i>Drymophylla cyanocarpa</i>		*				*			*	
<i>Acacia melanoxylon</i>	*					*				
<i>Atherosperma moschatum</i>	*			*						
<i>Hypolepis muelleri</i>	*		*							

Appendix 15b.

Distance (metre)	275	300	325	350	375	400	425	450	475
Species									
<i>Eucalyptus regnans</i>	*	*	*	*	*	*	*	*	*
Mosses	*	*	*	*	*	*	*	*	*
<i>Histiopteris incisa</i>									
<i>Monotoca glauca</i>	*	*	*	*	*	*			*
<i>Pteridium esculentum</i>	*	*	*	*			*		*
<i>Acacia mucronata</i>	*			*	*	*		*	*
<i>Phebalium squameum</i>	*		*		*	*	*	*	*
<i>Histiopteris incisa</i>		*	*	*	*	*	*		*
<i>Gahnia grandis</i>	*		*		*	*	*		
<i>Cyathodes juniperina</i>	*		*		*	*	*	*	
<i>Zieria arborescens</i>	*								*
<i>Eucryphia lucida</i>					*	*			
<i>Hypolepis muelleri</i>				*					*
<i>Oxylobium</i> sp.									
<i>Eucalyptus viminalis</i>				*					
<i>Dianella tasmanica</i>			*		*			*	
<i>Nothofagus cunninghamii</i>		*							
<i>Epacris impressa</i>									
<i>Acacia melanoxylon</i>		*		*					*
<i>Richea scoparia</i>									
<i>Dicksonia antarctica</i>					*				
<i>Leptospermum glaucosum</i>							*	*	
<i>Lepidosperma</i>		*	*						
<i>Polystichum proliferum</i>						*			
<i>Anopteris glandulosus</i>								*	
<i>Trochocarpa guinii</i>					*				
<i>Blechnum watsii</i>		*		*					
<i>Pultanea juniperina</i>	*								
<i>Gaultheria hispida</i>					*				
<i>Marchantia beteroana</i>			*						
<i>Amperea xipoclada</i>		*						*	
<i>Epacris impressa</i>									
<i>Pomadouris apetala</i>									
<i>Drymophylla cyanocarpa</i>			*		*			*	

Appendix 15c.

Distance (metre)	0	25	50	75	100	125	150	175	200	225	250	275	300
Species													
<i>Eucalyptus regnans</i>	*	*	*	*	*	.		*
<i>Histiopteris incisa</i>	*	.	*	*	*	.		*	.	.	*		.
<i>Cyathodes juniperina</i>			
Mosses	*	.	*	*	.		*	*					
<i>Phebalium squameum</i>				
<i>Nothofagus cunninghamii</i>						
<i>Monotoca glauca</i>						
<i>Hypolepis muelleri</i>					
<i>Atherosperma moschatum</i>				
<i>Eucryphia lucida</i>	.	.	.										
<i>Acacia mucronata</i>			.						.	*			
<i>Pteridium esculentum</i>	.					.			*				
<i>Phyllocladus aspleniifolius</i>						.				.			
<i>Gahnia grandis</i>
<i>Polystichum proliferum</i>				.		.							
<i>Olearia argophylla</i>							.						.
<i>Senecio velleioides</i>	.		.										
<i>Pomaderris apetala</i>											.		
<i>Coprosma quadrifida</i>									.				
<i>Drymophylla cyanocarpa</i>									.				
<i>Amperea xipoclada</i>									.				
<i>Dicksonia antarctica</i>					.								

Appendix 15d.

[illegible]

Appendix 16.

The ANOVA Table 1.

Effect of different fire intensities and time after burning on regeneration of *Eucalyptus regnans* based on seedling numbers.

Source	df	SS	MS	F
Time (T)	3	1406.77	468.92	199.54***
Fire intensity (F)	3	326.02	108.67	46.26 ***
F x T	9	2184.08	242.67	103.26 ***
Error	192	451.29	2.35	
Total	207	3685.08		

The ANOVA Table 2.

Effect of different fire intensities and time after burning on regeneration of rainforest species based on seedling numbers

Source	df	SS	MS	F
Time (T)	3	8921.76	2973.92	116.89 ***
Fire intensity (F)	3	1994.35	664.78	26.13 ***
T x F	9	4355.89	483.99	19.02 ***
Error	182	46.31	25.44	
Total	197	19903		

* Significant at $p < 0.05$ **Significant at $p < 0.01$ *** Significant at $p < 0.001$

The ANOVA Table 3.

Effect of different fire intensities and time after burning on regeneration of *Eucalyptus regnans* based on stocking rate.

Source	df	SS	MS	F
Time (T)	3	4.78	1.59	21.20 * * *
Fire intensity (F)	3	-0.31	-0.1	1.33
T x F	9	4.37	0.48	-0.64
Error	46	-3.44	-0.075	
Total	99	5.44		

The ANOVA Table 4.

Effect of different fire intensities and time after burning on regeneration of rainforest species based on stocking rate.

Source	df	SS	MS	F
Time (T)	3	2.40	0.80	13.35 ***
Fire intensity (F)	3	2.14	0.71	11.83 ***
T x F	9	0.78	0.087	1.45
Error	48	3.09	0.06	
Total	63	8.41		

* Significant at $p < 0.05$ **Significant at $p < 0.01$ *** Significant at $p < 0.001$

Appendix 17.

Summary of data regeneration.

1. Seedling number of *Eucalyptus regnans* in different time after burning and different fire intensity.

Fire intensity	Duration after burning								Total
	2	5	7	9	2	5	7	9	
	Total of seedlings				Total	No. of quadrat			
Unburnt (U)	25	27	204	45	301	5	9	12	9
35									
Low (L)	30	90	160	48	328	10	18	20	16
64									
Medium (M)	119	80	180	77	456	17	16	18	11
62									
High (H)	32	70	135	50	287	8	14	15	10
47									
Total	206 267 679 220				1372				

2. Seedling number of rainforest species in different time after burning and different fire intensity.

Fire intensity	Duration after burning									
	2	5	7	9	2	5	7	9		
	Total of seedlings					Total	No. of quadrat			Total
Unburnt (U)	180	77	266	110	633	6	11	7	10	34
Low (L)	6	20	140	60	226	3	10	10	12	35
Medium (M)	0	36	30	42	108	0	9	5	7	21
High (H)	0	3	9	9	21	0	3	3	3	9
Total	186	136	445	221	988					

3. Stocking rate of *Eucalyptus regnans* in different time after burning and different fire intensity.

Fire intensity	Duration after burning									
	2	5	7	9			2	5	7	9
	Stocking rate/transect					Total	No. of transect			Total
Unburnt (U)	0.27	3.4	3.15	3	9.82		3	5	4	3
Low (L)	0.6	5	4	3.33	12.93		3	5	4	4
Medium (M)	0.98	4.8	4	3.5	13.31		3	5	4	4
High (H)	0.43	3.8	4	4	10.59		3	5	4	3
Total	2.28	17.06	15.15	12.16	46.65		12	20	16	14

3.Stocking rate of rainforest species in different time after burning and different fire intensity.

Fire intensity	Duration after burning										
	2	5		7		9		2	5	7	9
	Stocking rate/transect					Total		No.of transect				Total
Unburnt (U)	0.26	4.1	1.5	4	9.76	3	5	4	4	4	16
Low (L)	0.15	2.75	1.92	2.32	7.14	3	4	4	4	4	16
Medium (M)	0	0.63	1.3	2.08	4.0	4	3	4	4	4	17
High (H)	0	0.97	0.75	0.58	2.3	3	2	3	2	2	15
Total	0.41	8.45	5.07	8.98	23.21	13	20	16	15	64	

Appendix 18. The Index of Injury value (It) of plants at -4°C, -6°C, -8°C, -10°C and -12°C. The value are mean of five replicates with standard error. Plants were collected from logged West Tasmania (approx. 300 m a.s.l). Measurement made in September 1990.

	Index of injury (It) at temperature (°C):				
	-4	-6	-8	-10	-12
<i>Acacia melanoxylon</i> (phyllodes)	14.90±0.70	15.90±0.60	19.90±0.50	60.12±1.70	63.30±2.10
<i>Atherosperma moschatum</i>	18.08±0.60	50.70±1.49	71.64±2.18	80.26±1.19	85.90±1.96
<i>Eucalyptus delegatensis</i>	25.50±1.90	40.90±0.98	77.00±0.40	85.70±0.80	90.40±2.00
<i>Eucalyptus obliqua</i>	34.20±1.10	80.40±0.40	90.00±1.70	92.60±0.70	93.20±0.70
<i>Eucalyptus regnans</i>	26.22±1.00	66.80±1.40	77.80±1.00	85.80±1.30	88.10±1.70
<i>Eucryphia lucida</i>	6.20±0.20	18.10±0.60	47.70±1.10	62.10±1.10	76.60±0.90
<i>Nothofagus cunninghamii</i>	4.90±0.40	12.90±0.60	40.70±1.10	66.10±2.10	77.60±1.30
<i>Olearia argophylla</i>	6.96±0.41	47.14±1.96	49.54±1.95	71.87±0.96	76.54±1.98
<i>Phoradendron squameum</i>	5.76±0.53	61.58±1.08	71.90±0.92	82.86±1.97	85.00±1.72
<i>Phyllocladus aspleniifolius</i>	17.80±0.60	45.90±0.40	76.80±0.70	85.40±2.00	93.90±1.20
<i>Pomadouris apetala</i>	6.20±0.60	16.84±0.97	29.22±1.16	54.14±1.37	87.46±1.44

Appendix 19. The Index of Injury value (It) of plants at -4°C, -6°C, -8°C, -10°C and -12°C. Values are the means of five replicates with standard errors shown. Plants collected from logged areas in South West Tasmania (approx.300 m a.s.l). Measurement made in July 1991.

Species	Index of Injury (It) at temperature (°C):				
	-4	-6	-8	-10	-12
<i>E. lucida</i>	3.71 ±1.4	3.76 ±1.1	24.9±1.76	30.88±1.22	69.79±0.53
<i>N. cunninghamii</i>	0.13 ±0.13	7.12 ±0.52	14.59±0.8	34.93±1.97	48.44±3
<i>A. moschatum</i>	17.63±3.3	46.43±1.2	72.16±0.6	82.54±1.6	85.04±1.9
<i>P. aspleniifolius</i>	19.3 ±0.6	19.62±1.3	46.44±0.8	54.01±20	63.17±1.4
<i>P. squameum</i>	15.44±2.02	56.93±2.33	68.32±1.86	88.9±0.43	83.43±0.42
<i>P. apetala</i>	14.42±0.76	21.31±1.58	44.92±2.4	49.68±06	84.69±1.7
<i>O. argophylla</i>	7.62±0.63	37.1±0.6	40.5±1.1	53.74±1.6	65.74±1.6
<i>E. regnans</i>	26.79±2.01	64.23±0.6	79.04±0.47	80.56±0.77	81.7±0.96
<i>E. delegatensis</i>	22.8 ±2.09	39.46±1.13	62.1±2.15	75.73±2.14	76.96±1.42
<i>A. dealbata</i>	2.04 ±0.26	8.32 ±0.71	38.93±0.61	41.73±0.84	62.78±1.27
<i>A. melanoxylon</i> (phyllodes)	8.9 ±0.96	8.42 ±1	44.79±1.79	45.68±1.75	48.82±1.28
<i>A. melanoxylon</i> (leaves)	0.56 ±0.24	7.67 ±0.5	36.98±1.85	62.48±0.98	72.32±1.29

Appendix 20. The Index of Injury value (It) of plants grown in a glass house at -4°C, -6°C, -8°C, -10°C and -12°C.

Values are mean of five replicates with standard error. Measurement made in July 1991.

Species	Index of injury (It) at temperature (°C):				
	-4	-6	-8	-10	-12
<i>A. melanoxyton</i> (leaves)	3.61 ±0.47	11.19±1.17	50.02±0.85	60.47±2.10	74.15±2.60
<i>E. regnans</i>	5.30 ±0.95	63.22±2.02	81.94±1.70	86.85±1.12	90.13±2.08
<i>P. apetala</i>	2.59 ±0.50	10.30±2.39	46.33±2.29	51.35±2.00	69.36±1.84
<i>A. dealbata</i>	9.32 ±0.57	15.06±2.23	33.22±2.50	49.29±0.84	64.47±0.90
<i>P. squameum</i>	26.99±2.95	56.16±2.90	89.45±1.58	89.33±1.16	93.61±2.50
<i>N. cunninghamii</i>	1.78 ±0.85	24.06±1.69	40.51±2.10	49.90±0.55	56.05±1.90

Table . T50 of Species evaluated in September 1990. The value are the mean of five replicates with standard error.

Species	:	T50 (°C)
<i>Acacia melanoxylon (phyllodes)</i>	:	-9.00±0.09
<i>Atherosperma moschatum</i>	:	-5.90±0.12
<i>Eucalyptus delegatensis</i>	:	-6.49±0.03
<i>Eucalyptus obliqua</i>	:	-4.79±0.04
<i>Eucalyptus regnans</i>	:	-5.14±0.04
<i>Eucryphia lucida</i>	:	-8.46±0.12
<i>Nothofagus cunninghamii</i>	:	-8.75±0.08
<i>Olearia argophylla</i>	:	-9.92±0.31
<i>Phebalium squameum</i>	:	
<i>Phyllocladus aspleniifolius</i>	:	-6.44±0.02
<i>Pomaderris apetala</i>	:	

Table . T50 of species evaluated in July 1991. The value are the mean of five replicates with standard error.

Species	:	T50(°C)
<i>Acacia melanoxylon</i> (phyllodes)	:	-10.30±0.80
<i>Acacia melanoxylon</i> (leaves)	:	-7.60±0.40
<i>Acacia dealbata</i>	:	-10.70±0.09
<i>Atherosperma moschatum</i>	:	-6.14±0.11
<i>Eucalyptus delegatensis</i>	:	-7.06±0.23
<i>Eucalyptus obliqua</i>	:	-4.85±0.04
<i>Eucalyptus regnans</i>	:	-5.23±0.02
<i>Eucryphia lucida</i>	:	-10.80± 0.04
<i>Nothofagus cunninghamii</i>	:	-10.90± 0.04
<i>Olearia argophylla</i>	:	-9.40± 0.24
<i>Phebalium squameum</i>	:	-5.71± 0.10
<i>Phyllocladus aspleniifolius</i>	:	

Table . T50 of species were grown in a glass house. The value are the mean of five replicates with standard error.

Species	:	T50 (°C)
<i>Acacia dealbata</i>	:	-9.87±0.41
<i>Acacia melanoxylon</i> (leaves)	:	-7.90±0.04
<i>Eucalyptus regnans</i>	:	-5.57±0.09
<i>Nothofagus cunninghamii</i>	:	-9.80±0.14
<i>Phebalium squameum</i>	:	-5.50±0.23
<i>Pomaderris apetala</i>	:	-9.46±0.41