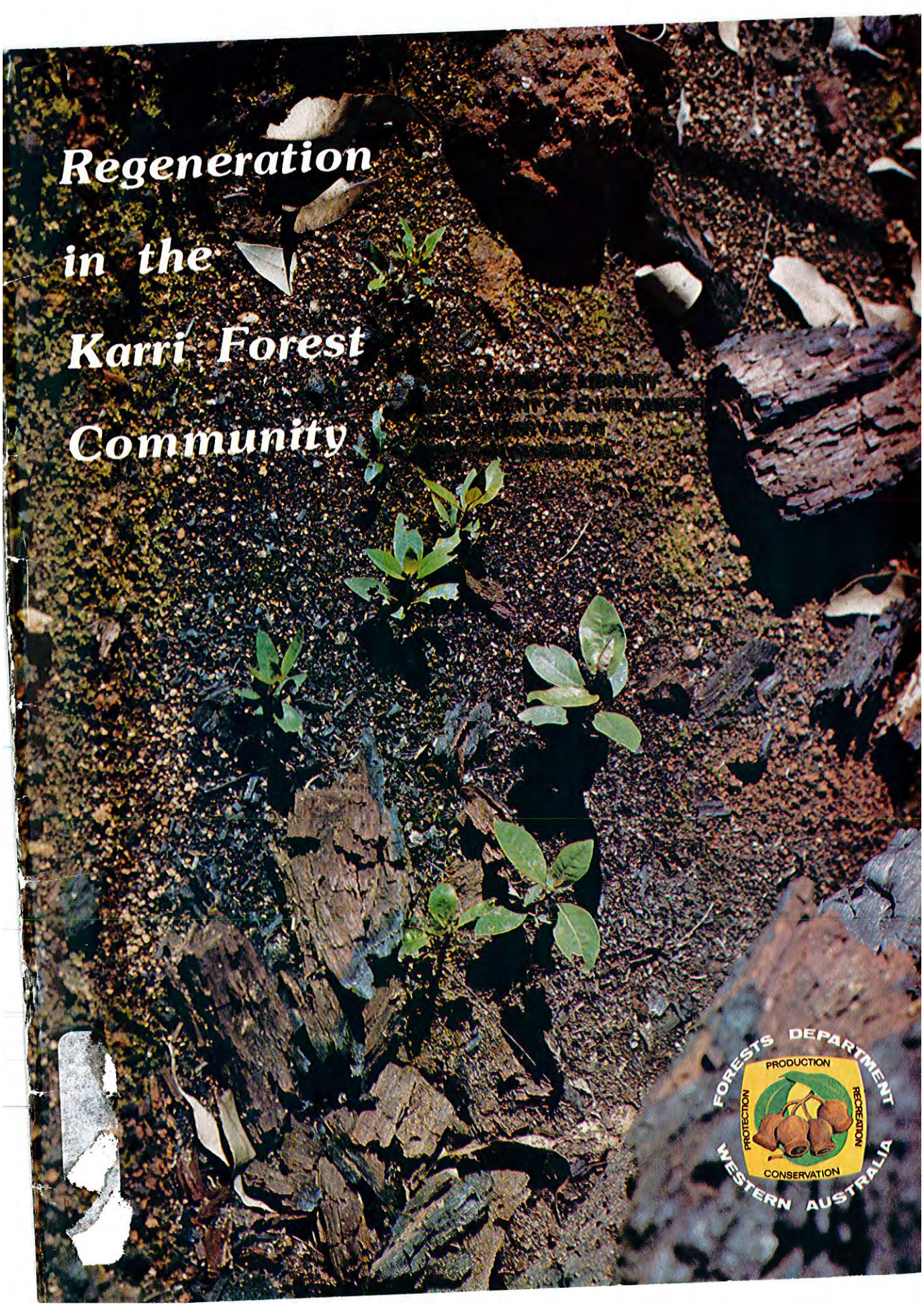
Regeneration in the Karri Forest Community



Regeneration in the Karri Forest Community

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Front cover
Newly germinated seedlings in
ash-bed conditions

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Contents

Introduction

Of all the natural resources occurring in Western Australia, the karri forest community must be listed among the most valuable. Few forests of the world combine elegance with utility in such a propitious manner. Included in this community are the pure stands, which in the virgin state show karri at its magnificent best, and the natural mixtures wherein the shorter, scaley barked marri contrasts with the smooth emergent karri.

Karri and karri-marri forests occur naturally only in the extreme south-west of Western Australia (see map, pages 12 and 13). Evidence from a number of sources suggests that in the past karri was more widespread in times of greater rainfall (1). Increased aridity and the advent of man's agricultural development have reduced the resource to its present 250 000 hectares. Although small in comparison to many other major forest formations of the world, this resource is of sufficient size to justify an industry based on its utilisation. The strong regenerative powers of karri and marri, their fast growth rate, versatile wood quality and resistance to natural enemies make them ideal trees for forest management on a permanently renewable basis. Equally important, the karri forest is one of the prime tourist attractions of the State. Magnificent stands of both virgin and regrowth karri occur throughout the Pemberton, Manjimup and Walpole districts and are enjoyed by tens of thousands of forest visitors each year.

Cutting of karri forest has been in progress at varying rates for about a century. In recent years some 1600 ha of pure karri have been cut annually for utilisation. In the immediate future the cutting of pure stands will cease and operations will move into mixed forest of karri-marri for saw logs and for woodchip raw material at a level of 4000 ha per year. The replacement, or regeneration, of these cut-over stands is one of the most vital functions of the Forests Department.

As with most successful schemes used to regenerate forest, the system used by the Forests Department to regenerate karri and marri follows closely that found in nature. The aim of this booklet is to describe the process by which karri and marri regeneration is obtained.

Fig. 1. Karri regeneration, forty years old, on Rainbow Trail.

The karri forest community

In ecological terms, the karri forest community is described as a "wet sclerophyll" forest, the only such community to be found in this state. Permanent streams in shaded gullies abound and, although it enjoys a generous surplus of moisture for nine months, each year it must endure a period of three months moisture stress, in which rainfall does not meet the requirements of the plants (2).

Regular summer drought and frequent lightning strikes highlight the interdependence of fire and drought in the life cycle of the karri forest.

Karri (*Eucalyptus diversicolor* F. Muell.) has much in common with other very tall eucalypts such as the eastern states' species mountain ash (*E. regnans* F. Muell.), blackbutt (*E. pilularis* Sm.), shining gum (*E. nitens* Maiden) and kamarere (*E. deglupta* Blume). All regenerate from seed only, and do not develop lignotubers. Most have smooth "gum" type bark, which appears to render them more susceptible to bole damage from fires than the rough barked eucalypts such as jarrah (*E. marginata* Sm.) and messmate (*E. obliqua* l'Herit) (3). Marri (*E. calophylla* R. Br.), which is also known as red gum, is a member of the bloodwood group of eucalypts and in contrast regenerates freely and rapidly from "advanced" lignotuberous plants, coppice from stumps and from seed. Both karri and marri are tolerant to damage by the fungus *Phytophthora cinnamomi* Rands.

Regeneration in the Virgin Forest

In the virgin forest, trees such as karri and mountain ash tend to occur in even-aged patches which vary in size from several to many hectares in extent. Observation of behaviour on ash-beds after a hot fire suggests that this was the cause of even-aged stand development (4). Indeed many examples can be found where mature stands of pure karri have been replaced by fire-caused regrowth forming a typically dense even-aged community. Figure 2 shows such a stand. Karri is probably more fire resistant than many other very tall eucalypts and in the course of replacement some may survive and become grossly over-mature members of the next generation.

Forests Department records show that nearly every summer, days occur when all the factors contributing to a bad fire situation coincide. Catastrophic fires able to kill karri trees of 75 metres height are the inevitable result, with or without the help of man. Marri, in contrast, is rarely killed by these severe fires but will be damaged, and heavy deposits of gum or "Kino" will result in degrade of the ultimate log values. Natural regrowth crops such as shown in Figure 2 can usually be traced to certain years, well known and remembered for the severity of their bushfires. Such were the summers of 1939, 1950 and 1961.

The karri seed cycle

It takes about five years from the initiation of buds in the axils of leaves to the completion of seed shed from mature capsules. Most karri trees form buds, flower and fruit in unison and only one age of floral parts is present in the forest at any one time. New crops of buds may appear each year but the one dominant crop is able to suppress the development of the others.

Seed, therefore, is not present in the karri forest every year and great care must be taken to ensure that regeneration measures are undertaken only when seed is present. The availability of seed tends to be cyclic in nature, with two crops occurring each decade. The pattern for the past twenty years has been a light crop early in the decade (1961-62, 1971-72) followed by a heavy crop in the latter half (1956-57, 1967-68). Seed supplies can be available for two or three summers in each peak, but in between peaks there are similar periods in which little or no seed is to be found.

Buds first appear in the period of leaf flush (January); they develop slowly over the next year and flower at two to two and a quarter years old in the summer and early winter (February-April). Capsules ripen during the following year and contain mature seed by the fourth summer after bud formation.

During a cycle there is continual loss of floral parts from the tree. Of every 100 buds initiated, only 25 flower and 20 survive to become mature capsules. The pattern of loss is consistent over a number of cycles and is similar whether the crop is large or small. Such consistency is useful in allowing predictions to be made as to what proportion of a crop observed at any stage of the cycle will reach maturity and be useful for regeneration. Figure 3 shows the development of a seed crop in graphical form, a method which facilitates prediction.

When capsules are ripe, seeds begin to fall. If the forest is burnt at this time, all available seed is shed within a short period after the burn. When a karri tree is defoliated by fire, the capsules holding the seed are not consumed. Drying out is accelerated but the capsule valves do not start to open until two to three days after the burn, letting the seed fall into the cool ash beneath. The thin coated karri seed would not normally survive fire if shed beforehand into ignitable litter.

Without fire, seedfall is greatest in the hot, dry summer months. Capsules on side branchlets that have ceased to grow shed their seed in the fourth summer after initiation of the flower buds.

Fig. 2. Virgin karri stand, thirty years old. Regenerated naturally by fire.

Capsules on growing green branchlets, persist unopened through the fourth summer and open the following, or fifth, summer. Approximately half the total seed falls each summer.

Seedling germination takes place following the first rains in autumn. Growth on ash-beds is dramatic and much faster than away from them. This phenomenon is common with most eucalypts and shows yet another adaptation to fire (Figures 4 and 5).

Knowledge of the seeding behaviour of karri is imperative for the successful regeneration of the forest using natural seedfall.

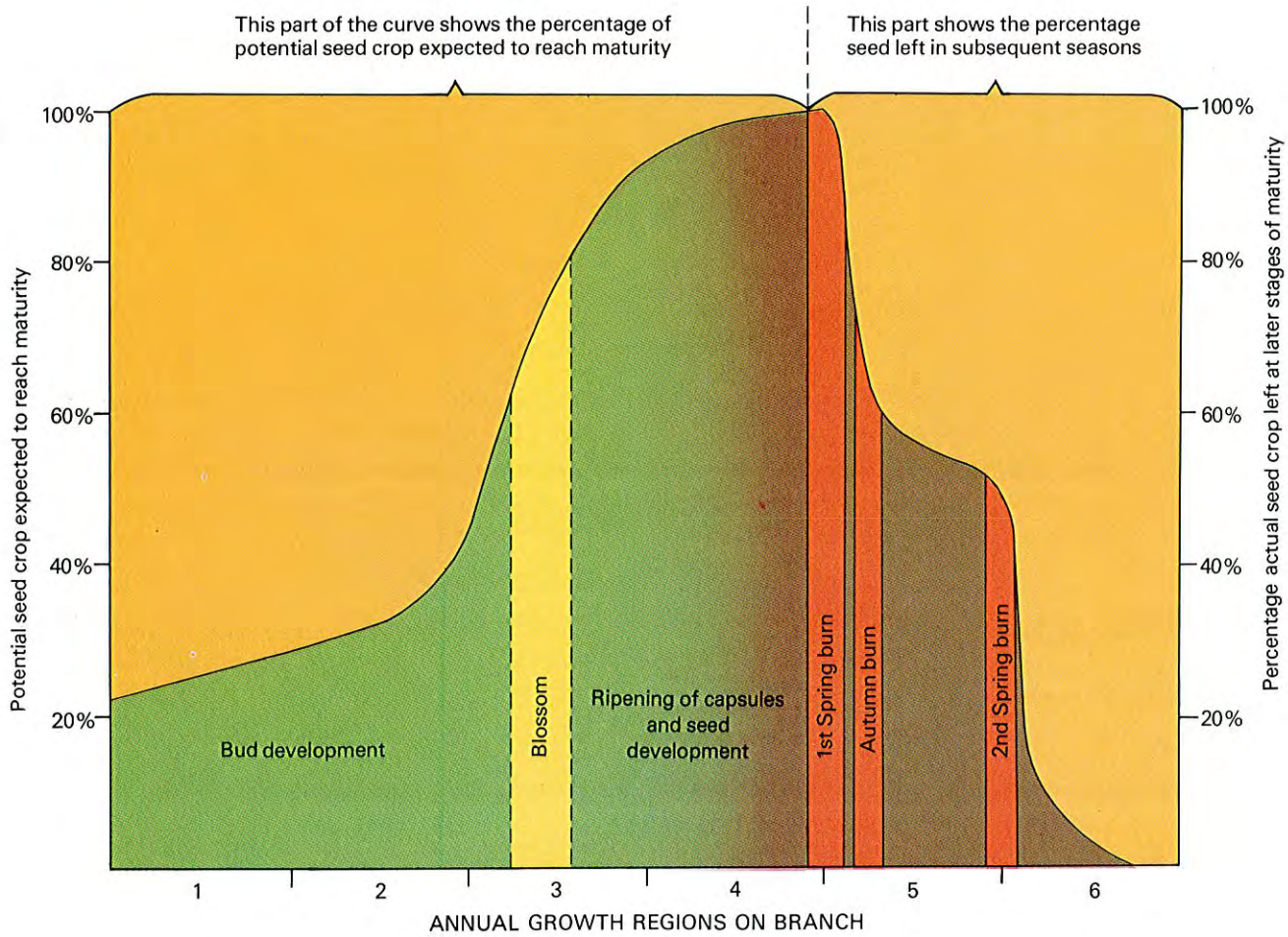
Fig. 3. Development of a seed crop.

Fig. 4. Vigorous karri regeneration around a charred stump.

The marri seed cycle

Unlike karri, there is a little marri flower every year, with a heavy flowering occurring each three to four years. During February and March, the white, showy blossom is a feature of the mixed stands. It provides a useful honey flow while at the same time ensuring an adequate supply of seed for regeneration. Marri capsules are nearly always present on the tree and will also release their seed after fire, for germination on the ash-bed.

The very large marri seed is better adapted to germinate and survive under the canopy shade



of other trees. Following germination, swellings appear in the junction of the first pairs of leaves. As the seedling ages, these enlarge and form a bulbous mass called a lignotuber (Figure 7), the greater part of which is buried below the soil surface. Though the aerial shoots may be damaged by fire, animals or insects, the new buds and food reserves in the lignotuber enable it to shoot again when conditions become more favourable. When the overhead canopy is removed, the lignotuberous advance growth has the capacity to form a dynamic shoot (Figure 8), which continues to grow and provides for the replacement of the original crop.

Unlike marri, karri does not form lignotubers.

As well as regenerating from seed and from lignotubers, marri stumps sucker vigorously and this is yet another way of ensuring a replacement crop. In most stands, the availability of lignotuberous advance growth and the capacity to sucker will ensure that regeneration of marri will be adequate, if somewhat clumped in distribution.

Planned Regeneration

Past techniques

In 1878 M. C. Davis established the first karri mill of any consequence in the State at Karridale (5). This was followed by the construction of a mill at Denmark in 1884 by C. & E. Millar, the forebears of the present Millars (W.A.) Pty. Ltd.

All early cutting was on an unrestricted exploitation basis, with little or no thought given to the regeneration of the forest following logging. Severe wildfires occurred and seed from unfelled cull trees regenerated large areas, the results of which can be seen at Boranup near Karridale and as remnant stands among farms in the

Scotsdale district north of Denmark. The original sawmills at Karridale and Denmark ceased cutting in the early 1900s.

A karri sawmill was established at Pemberton by the State Sawmills in 1913 and the Eastbrook farming area developed in the wake of its unrestricted cutting.

The Forests Act in 1918 heralded the dedication of large areas as State Forest and led to a change in attitude from exploitation to conservation, with deliberate planning to ensure regeneration. By 1925, large areas were cut-over and ready for regeneration, and in that year a working plan for regeneration was drawn up (6) covering operations in the present Big Brook Forest. Detailed prescriptions described a "clear felling" system in which fire was used to promote regeneration, following complete utilisation cutting. Unsaleable or cull karri trees were retained as the seed source and were left untouched prior to the burn, but all other species of both understorey and overstorey were ring-barked. A mid-summer burn when seed was plentiful was programmed (and took place) in the summer of 1929-30.

Fig. 5. Growth on ash-beds is dramatic and much faster than away from them. The tallest centre trees in this four-year-old regeneration grew from the deepest and hottest ash-bed.

Fig 6. Marri regeneration, forty years old, west of Manjimup.

When successful regeneration was obtained, the cull seed trees were ring-barked. Other interesting features of this system were the saving of immature groups, ring-barking if necessary to promote seedfall, lopping tops flat to ensure complete burning and the use of broadcast seeding to regenerate failed patches artificially.

This regeneration system was retained until well into the 1930s. Good results, for example Big Brook and Treen Brook Forests, were obtained. From the mid-1930s onwards, however, the system began to change. Not only groups, but outstanding immature trees were retained by foresters. Stems were often blazed to signify retention and a system of tree marking for


INDIAN OCEAN
SOUTHERN OCEAN
SOUTH WESTERN HWAY
BUNBURY
COLLIE
HIGHWAY
BUSSELTON
SOUTH
VASSE
BUSSELL
BRIDGETOWN
HWAY
WESTERN
Blackwood
BROCKMAN
MANJIMUP
Perup
River
HIGHWAY
AUGUSTA
PEMBERTON
HWAY
Warren

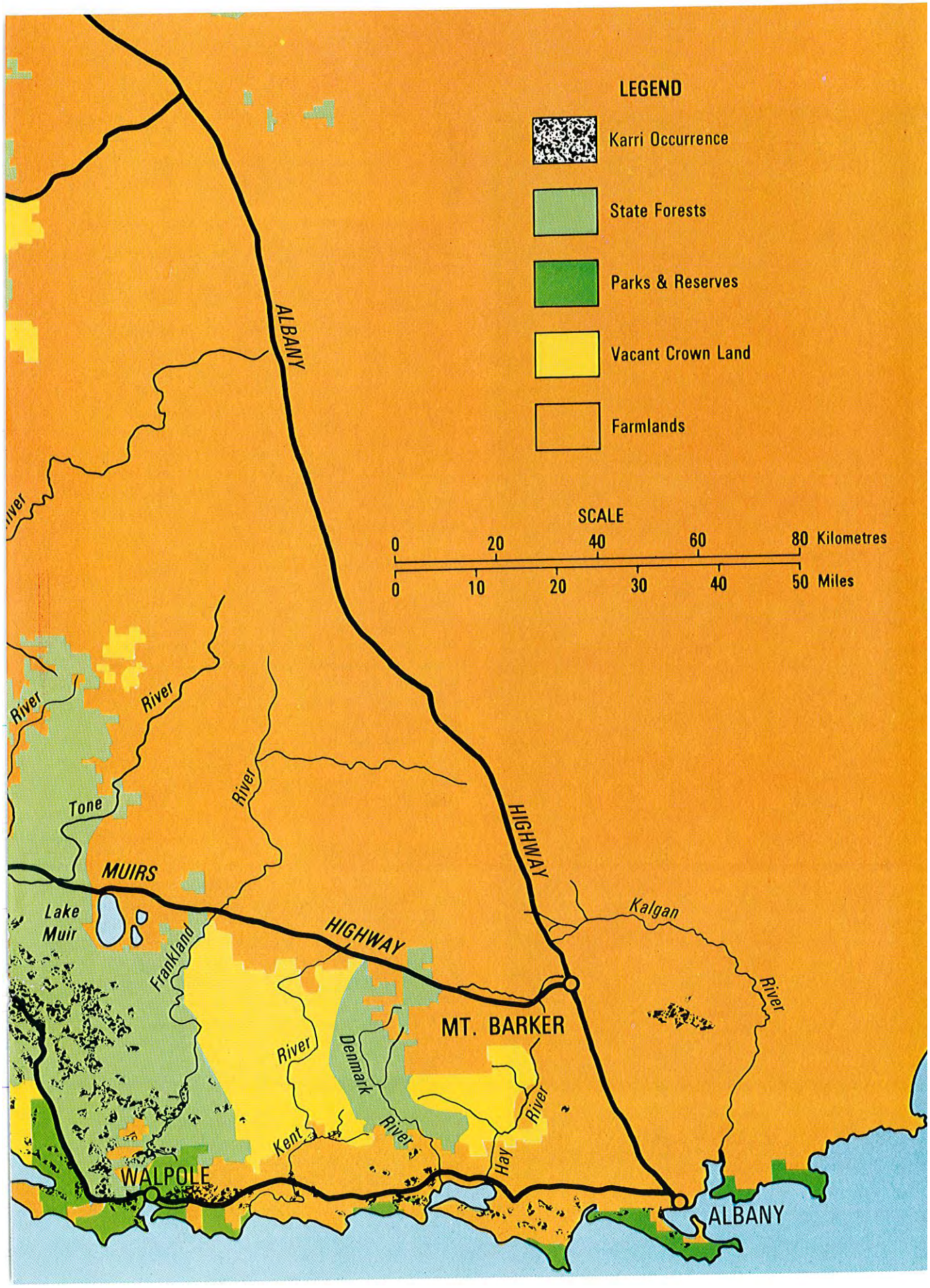

LEGEND
Karri Occurrence
State Forests
Parks & Reserves
Vacant Crown Land
Farmlands
SCALE
0 20 40 60 80 Kilometres
0 10 20 30 40 50 Miles
ALBANY
HIGHWAY
HIGHWAY
River
River
River
Tone
MUIRS
Lake Muir
Frankland
River
Denmark
River
Kent
River
Hay
River
Kalgan
River
MT. BARKER
WALPOLE
ALBANY

Fig. 7. Lignotuberous root of a young marri seedling.

retention began to emerge. The number of trees retained gradually increased, while the ring-barking of marri and karri was less zealously pursued.

The change was made for good reasons, foremost among which was the waste of smaller sized stems. The traditional market for karri demanded high quality, large section and long length for export. Hence trees that would not yield large sections were not wanted, even though the same size in another species would have been considered prime market trees. Under the clear falling system followed in the 1920s, these stems were destroyed. As time progressed the hand-falling of understorey and ring-barking of unwanted stems became progressively more expensive and was discontinued.

By the late 1940s, the system had changed into a recognisable selection falling system in which the static volume was removed for sale and the dynamic volume (trees still vigorous, sound and healthy) was retained for continued growth. Regeneration of gaps caused by removals was obtained by burning the slash therein at a time when seed was present in the crowns of the retained growing stock. By the 1960s, more than half of the volume standing in the virgin forest was being retained as growing stock (7).

Current techniques

Since 1968, by concentrating on cutting in pure karri forest, it has been possible to revert to a clear felling with seed trees system without wasting the marri resource in the mixed marri-karri forest. The marri woodchip industry now allows application of the system to mixed karri-marri forest types. The aim is to produce an even-aged regrowth forest with the assistance of an integrated marketing operation. As with the early Big Brook working plan, fire and natural seedfall are the basic tools used.

When logging and regeneration procedures are planned, many problems arise. Other values, such as the quality and quantity of streamflow, landscape, amenity and the conservation of flora and fauna, must be considered,

Fig. 8. The strong dynamic shoot from this two-year-old marri advance growth will form the tree stem.

given due weight and provision made for them. Current procedure requires that uncut strips of forest be left on either side of streams and major roads.

Some areas of particular value, for example an essential component of a striking landscape, an area containing an exceptional diversity of faunal habitats or an area containing rare plants, may be excluded from cutting altogether. At least 20 per cent of each forest block, which is an administrative area of 4000 to 5000 ha with natural boundaries, must remain uncut and in certain places whole blocks have been withdrawn from cutting.

Roading must be located to best effect and constructed well in advance; winter and summer cutting must be found and balanced; areas ready for regeneration burning must be protected from unwanted fire; areas to be cut must be equated with the capacity of the sawmill. All planning is done in detail in units of five years and part of each five year plan states where the subsequent five year plan will be. Agreement is reached between the forest and sawmilling authorities before any plan is adopted.

Before falling commences, the stand is tree-marked. Unless a tree is marked by a Forest Officer, no authority exists for its removal and its falling constitutes a serious offence under the Forests Act.

Varying somewhat with size and health of stand, four trees per hectare are left unmarked as seed trees. As these will be the parents of the future crop, only the best members of the original stand are selected. (This contrasts with the earlier, clear felling system when cull trees were retained as seed trees.) Logging then begins.

When all saleable timber has been removed, seed trees, cull trees and understorey trees remain standing. As any living trees left on the area will occupy space to the exclusion of the young regeneration sought, removal of all unwanted stems is desirable.

Seed falling into green scrub or ground vegetation germinates but does not survive in the intense competition. To produce the optimum conditions to favour germination survival, "scrub

Fig. 9. Superior seed trees left standing ready for regeneration burn.

rolling" is carried out. A large bulldozer rolls all scrub and understorey stems flat to the ground. Any cull trees too big to push down are fallen as part of the same operation. Upon its completion, only the seed trees remain standing. The copious slash so produced provides the best possible conditions for creation of the ash-bed needed for germination of karri and marri seeds.

For optimum results favouring karri, the regeneration burn must coincide with seed being available in the crowns of seed trees left standing. To ensure correct timing, all cutting coupes are checked twice yearly. Using samples of branchlets shot down by rifle fire and the graph shown in Figure 3, predictions are made of the expected time and amount of seedfall. As

Figs. 10 and 11. Seed sampling by rifle shot.

the optimum expected time for burning draws near, check samples are taken. Planning in the meantime will have ensured that the regeneration area has been safe-guarded by prescribed fuel reduction burns in the surrounding forest.

Most regeneration burns take place in early January, late March and early April. The aim is to obtain as high an intensity fire as possible, commensurate with safety. High fire intensity helps the regeneration process by providing a maximum coverage of receptive ash-bed, a minimum of living plant competition, and by bringing down all available seed in a short period of time. Defoliation and stem damage to seed trees, short of actual burning down, is of no consequence because they have only one opportunity to function as a seed source.

Should planned regeneration of karri fail, prompt artificial means of regeneration are employed. In any case the availability of advance growth of marri ensures formation of a new forest.

The value of the seed trees as high quality logs is unimpaired by fire damage, provided they are utilised within two years of the burn, before sun-cracks, insect infestation or fungal attack have had time to develop.

The final operation, that of seed tree removal, need not await germination, but sufficient time must elapse after the burn for all seed to be shed and dispersed. A hot burn brings down all seed within several weeks; a cool burn takes longer. Logging of seed trees after germination has taken place makes no significant difference to stocking, provided that the seedlings are young (less than two years old) and that existing snig-trails are re-used.

In good seed years stockings of 100000 seedlings per hectare are common—patches of 240000 per hectare have been measured. Nevertheless even in good seed years it is unusual to obtain good stocking over 100 per cent of the area. Local lack of seed, uneven

Fig. 13. Karri forest immediately after regeneration burn, showing the ash-bed conditions ideal for karri seedlings.

Fig. 12. Regeneration burn under karri forest.

dispersion, variable seed-bed, flooding, frost and other causes lead to unstocked patches. For these reasons, natural regeneration is typically clumped in distribution. Germination takes place after the first rains, usually in mid-April. By May the germinants are visible, whereupon regeneration surveys are carried out to determine stocking levels and define failed areas.

Unstocked patches in highly productive sites represent wasted potential and are therefore not allowed to remain, even though in mixed forest, regeneration with marri is assured. Since regeneration with karri is preferred, unstocked areas, as indicated by surveys, are planted immediately they are known, all operations being completed during the first winter after the burn. Planting left for later years loses the benefit of the fresh ash-bed and has to compete with naturally regenerated scrub.

The vigorous, hardy and drought resistant properties of seedling karri allow it to be raised in beds and planted out open-rooted, which is the most economic technique of planting forest crops. Broadcast and spot seeding have been tried but the technique is not yet operational.

Selective or clear felling?

The group selection system promised many advantages:

1. No waste of immature size classes.
2. Flexibility in application—intensity of cut could vary with condition of virgin stand. Over-mature or fire-damaged stands could be virtually clear fallen.
3. Size class distribution of the forest as a whole could be progressively adjusted to favour sustained yield.
4. The marri resource need not be squandered.
5. A faster rate of cut through the forest meant the faster establishment of high class access, with consequent benefit to fire protection, management, inventory, etc.
6. Decadent stands could be utilised sooner.

Time has shown, however, that the group selection system is not ideal. The case for the change to a clear felling with seed trees system is strengthened by the following benefits that are gained:

1. The better and more natural use of fire.
2. Ease of management.
3. The better matching of silvicultural characteristics to operations.
4. The better matching of operations to the current market conditions.

These are discussed separately.

Use of fire. Fire is used to regenerate cut-over karri or karri-marri and to afford protection by prescribed burning to all but the younger sapling stands.

A regeneration burn, whether in selectively cut or clear cut stands, involves the consumption of considerable quantities of slash; fire intensity is usually high. In selection stands, experience has shown that it is difficult to restrict fire intensity so that damage to growing stock is kept within acceptable limits—yet for regeneration purposes a clean, and therefore intense, burn is desirable. In seeking the balance, too many stands were burnt either too hot, producing good regeneration but poor growing stock, or too cool, giving good growing stock but poor regeneration. Fire-caused stem damage often occurred high on the boles and remained unnoticed for some time after the burn (Figure 16).

In the selection system, the yield is sustained by returning to each hectare at regular intervals of time (thirty years) and removing a calculated volume of wood. After each cycle, the gaps created by cutting must be regenerated to ensure future growth. The use of fire to regenerate gaps after the first cut in virgin forest is difficult, but burning for regeneration in subsequent cycles, when immature trees from previous cycles are present, is even more difficult.

Fig. 15. Six-month-old karri seedling.

Fig. 14. The massed, "wheatfield" appearance of good karri regeneration.

Prescribed burning in mixed-aged stands must be governed by the youngest age class present. In general, therefore, only the lower fire danger ratings can be used. Prescribed burning is much easier in even-aged stands with more uniform litter and scrub. The older the stand, the greater the range of fire danger ratings which can be used.

Ease of management. A clear felling regime requires smaller, more compact areas than a selection regime and also has management advantages. Less roading is needed, supervision is more efficient and fire protection and regeneration burning is simplified. Confined bush operations also lessen the chance of spreading the root rot fungus *Phytophthora cinnamomi.*

Silvicultural characteristics. Karri and marri regrowth develop best with a complete absence of overhead canopy. With very tall eucalypts, a gap in the canopy has to be fairly large before the corresponding patch on the ground beneath can be said to be free from the influence of overhead canopy. Small gaps can lead to understocking by leaving insufficient room for the regeneration to develop.

These large trees require powerful equipment for their logging. Use of such equipment in mixed-aged stands can be expected to damage the younger age classes.

Both species have the ability to establish dominance quickly and permanently in overcrowded regrowth stands. If left unthinned, dominants can average 25 mm per annum girth growth over a period of 100 years. A mean

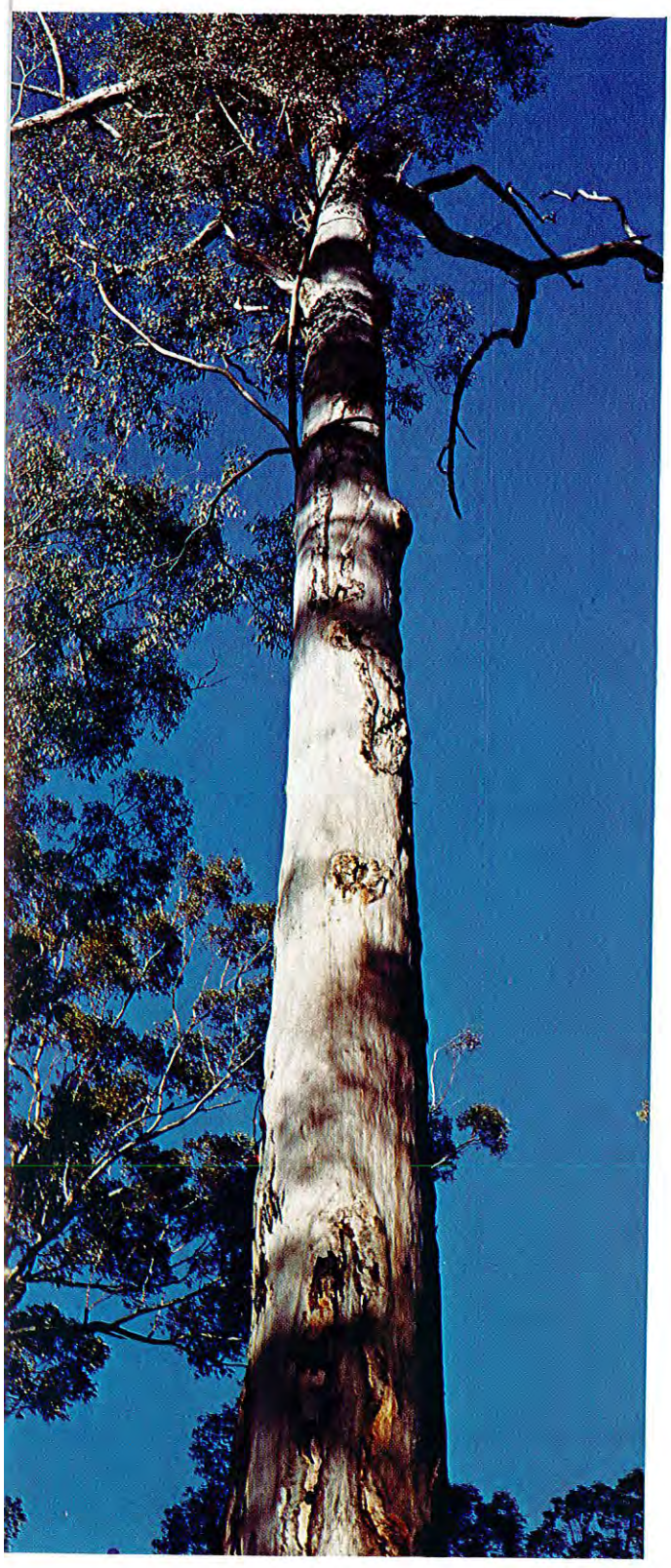


Fig. 16. Stem damage to growing stock caused by regeneration burns in selection-cut karri stands.

annual increment of 2·8 m^3 per hectare of saleable karri for ninety-two years has been measured. Unthinned even-aged stands remain productive.

The faster growth of young marri and karri on an ash-bed can be used to best effect in clear falling, where intense burns can be obtained without compromise.

When a mature karri stand is logged and individuals, which previously grew in a community, become isolated single stems, the crowns react by dying back from the top. This crown regression continues for many years and is accompanied by the formation of permanent epicormic shoots on the boles. What once were vigorous, clean-boled, healthy-crowned dominants take on the appearance of over-mature trees. A mixed-age condition does not suit the karri forest.

Change in market conditions. Over the years, a market for small scantling sizes in karri has developed alongside the traditional demand for long lengths and large sections. Impregnated karri crossarms are now saleable, as are very small cross-sections for tile battens. Thus smaller sized karri logs, equivalent in size to other species such as jarrah, are saleable. The selection system therefore becomes less appropriate. Although a small market for marri timber has persisted for some years it is anticipated that availability of a wider selection of marri sawlogs will achieve an improvement in sawmill recovery, an upgrading of timber specifications and a consequent rise in demand.

Management of regrowth crop

High density of young seedlings is a common occurrence in natural situations. Though severe mutual competition must restrict the growth of dominants to some extent, marri and karri have the ability to establish their dominants early and to continue growing at the expense of their neighbours. Other overcrowded plant communities tend to stagnate and require a longer period before dominance is established.

When left unthinned, the dominants continue to grow steadily for an indefinite period.

Thinning, though not essential for the reasons discussed, if carried out early in the life of the stand, improves its growth markedly; it would also shorten the rotation, or the time required for a predetermined marketable size to be reached. As yet little operational thinning is carried out because markets do not exist for the thinned material. In the foreseeable future, demand for pulpwood, poles and small sawlogs is expected to allow thinning to proceed in existing regrowth stands.

Of perhaps more immediate importance is the protection of the new crop from fire and other damaging agencies. Little combustible material remains after an intense regeneration burn and all growth in the ensuing few years is fresh and lush. As it takes about five years for sufficient litter to accumulate to carry a fire, the most fire-prone period extends from age five until the trees become tall enough, and their bark thick enough, to withstand a low intensity burn; depending on site, this could be at ten to fifteen years of age. At this stage, protection can be given by prescribed burning to reduce fuel accumulations. From then on, regular burning can keep fuel accumulation low and thus reduce the risk of damaging fires.

Thinning and burning must go hand in hand. A prescribed burn is needed to improve access prior to thinning operations and a further burn is required to remove the resulting slash build-up. There is some evidence to suggest that thinning by fire is a natural process.

Research

Observations and experiments over many years have disclosed the growth habits of karri and the understanding thus obtained has enabled natural processes to be applied to the karri-marri type. Research is a continuing process and, as each problem is clarified, other possibilities present themselves.

Research suggests that the seed tree system could be superseded by a karri planting system, with advance growth providing the requisite marri regrowth. Important benefits would follow: the annual planting of cut-over areas would avoid an extended wait for suitable seed years, along with the dangerous accumulations of heavy slash; loss of growth due to early overcrowding could be bypassed by wider planting, particularly if improved seed from select trees was used; better access would benefit all activities, including prescription burning, thinning, harvesting and public recreation. Benefits gained would have to outweigh the greater costs incurred. Only sustained research effort can give the answers required.

Although attention in this text is concentrated on regeneration for the continued production of wood material, other values are recognised. Indeed the ability of the karri forest community to produce pure water may well be its greatest single value to man in the long run. The fauna, the spectacular ground flora and the visual magnificence of the virgin forests are values which cannot be ignored.

Increasing research effort into the ecology of these forests takes into account all aspects. Many values can undoubtedly be accommodated in a "multiple use" approach to forest management. Other values, in particular the preservation of virgin stands, cannot and such features can only be preserved in separate areas such as national parks and certain state forest areas. Besides providing visual satisfaction, such areas also provide ecological reference points of great potential value. Within state forest a number of such management control areas have been declared and are withheld from cutting.

Though it is impossible not to mourn the harvest of the virgin stands, the vigorous disciplined order of the new stands has its own beauty. This beauty has been recognised by many people in their sustained use of the Rainbow Trail, a scenic drive through the karri regrowth stands of Big Brook Forest.

Fig. 17. Dead-topped trees with permanent epicormics in selection-cut karri stands.

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Back cover

Karri regeneration, 100 years old, in the early morning summer sun. Older karri and marri trees in foreground.