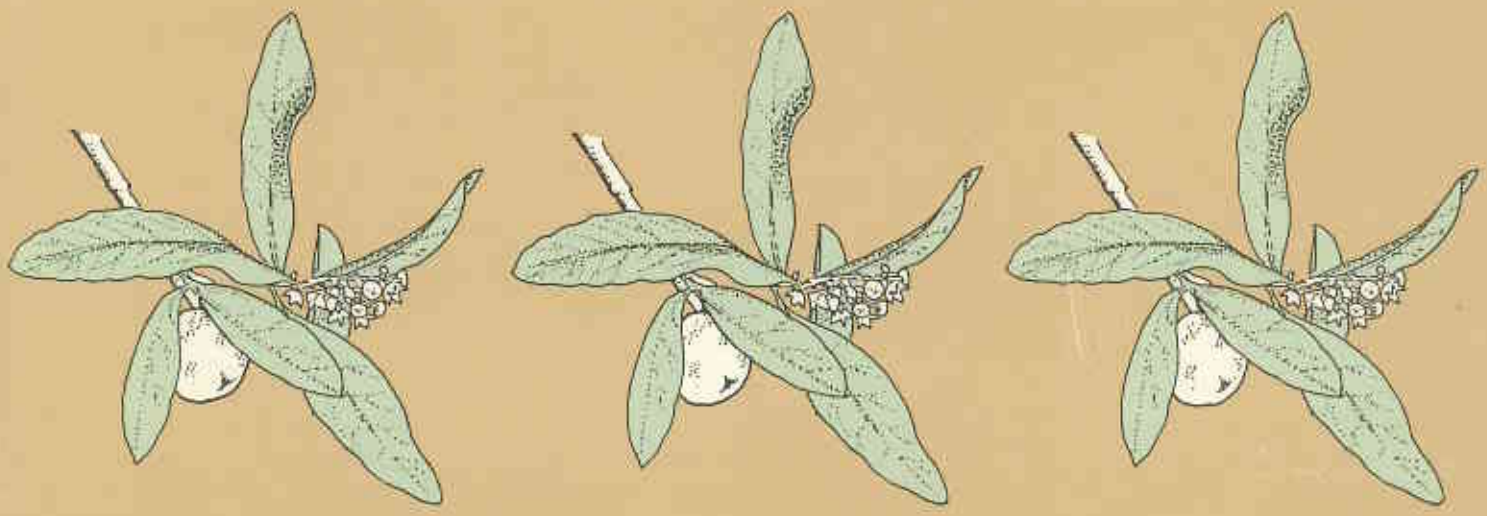
The Management of Sandalwood

by Ian G. Kealley



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MANAGEMENT OF SANDALWOOD

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Ian G. Kealley

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1. INTRODUCTION

This wildlife management program outlines the conservation and management of Sandalwood (*Santalum spicatum* (R.Br.) A. DC.) in Western Australia.

The program provides a summary of biological and ecological knowledge of sandalwood, the current industry and a statement of objectives and strategies for continued management. Extensive details of the species and the history of harvesting are documented in the references.

A wildlife management program for sandalwood is required because of:

- the long history of harvesting sandalwood in Western Australia with export from 1845;
- the ongoing industry which is dependent on a resource modified by the history of harvesting, the presence of exotic herbivores, other conflicting land uses and inherited historical management and harvesting impacts;
- the necessity to ensure both viability of sandalwood populations and sustainability of the industry.

Unless superseded earlier the term of this program shall be ten years (1991-2001).

2. RESOURCE INFORMATION

2.1 Distribution and Biology

2.1.1 Distribution

The natural distribution of sandalwood in Western Australia is from latitude 24°S (approximately 80 km north of Carnarvon), eastwards along the lake system around the Nullarbor Plain into South Australia, south to a latitude of 34°S and west as far as the drier fringe of the main forest area on the Darling Ranges: an area of around 90 million ha (Fig. 1). Additional plants have been recorded in localized areas outside of the main distribution (Hewson and George 1984; Kealley 1989; Loneragan 1990).

Clearing for agriculture and the history of harvesting in the Wheatbelt region of Western Australia has reduced sandalwood occurrence in this area to only occasional remnants.

Throughout the remaining area of its natural distribution sandalwood is widespread although locally patchy.

2.1.2 Taxonomy

A description of sandalwood has recently been summarized in *Flora of Australia* (Hewson and George 1984):

> Shrub to 4 m tall. Bark rough, grey. Branchlets stiff, spreading. Leaves lanceolate to narrowly elliptic, flat, obtuse; lamina 2-7 cm long, 3-15 mm wide, concolorous, grey-green; petiole 3-5 mm long. Flowers numerous in panicles, scented; peduncle 3-5 mm long; pedicels 1 mm long. Receptacle 1-1.5 mm long. Tepals triangular-ovate, 1.5-2 mm long, scurfy inside, red-green, persistent in fruit; hair tufts small. Disc shortly lobed. Style 0.5 mm long; stigma bilobed. Drupe 1.5-2 cm diam.; epicarp green or brown; mesocarp firm, usually adhering to endocarp when ripe; endocarp smooth. Sandalwood.

It is further described and illustrated with ecological information in *Forest Trees of Australia* (Boland *et al.* 1984).

Four named species of the genus *Santalum* occur in Western Australia. Sandalwood (*Santalum spicatum* (R.Br.) A. DC.), is found only in Western Australia and South Australia. The other three species - *S. lanceolatum* (R.Br.), or Plumbush, *S. acuminatum* (R.Br.) A. DC., Quandong or Candle Nut and *S. murrayanum* (Mitchell) C. Gardn., Bitter Quandong - are widely distributed throughout Australia. All three lack aromatic fragrance, but Plumbush contains oil. Plumbush has an ovoid, dark plum-like fruit, and is found mainly in the north-west of Western Australia, and northern Australia. Quandong fruit has a red outer covering, a deeply pitted stone and an oily, edible kernel; Bitter Quandong has a bitter brownish-red outer covering and a finely pitted stone. Both are widespread throughout the warmer parts of temperate Australia. There are possibly other unnamed taxa on the Southern Nullarbor and near Shark Bay.

2.1.3 Description

Sandalwood (*Santalum spicatum* (R.Br.) A. DC.) is a small tree or shrub, maturing to 3-8 m tall and 10-30 cm stem diameter with sparse irregular spreading branches and dull grey-green fleshy leaves. Sandalwood is an obligate root hemi-parasite (Herbert 1925; Barrett 1989a) associated with a wide range of hosts that it requires for growth to maturity.

Sandalwood is well adapted to drought and is slow growing, taking 50-90 years, depending on rainfall, to achieve commercial size of 127 mm stem diameter (Loneragan 1990). Sandalwood heartwood contains highly valued, quality aromatic oils. Sandalwood is distributed from the Western Australian coast and Wheatbelt agricultural areas through the drier areas of W.A. and S.A. to north of the Flinders Ranges. It grows on a wide range of soils with best stands occurring where vegetation types mix, giving the widest range of hosts.

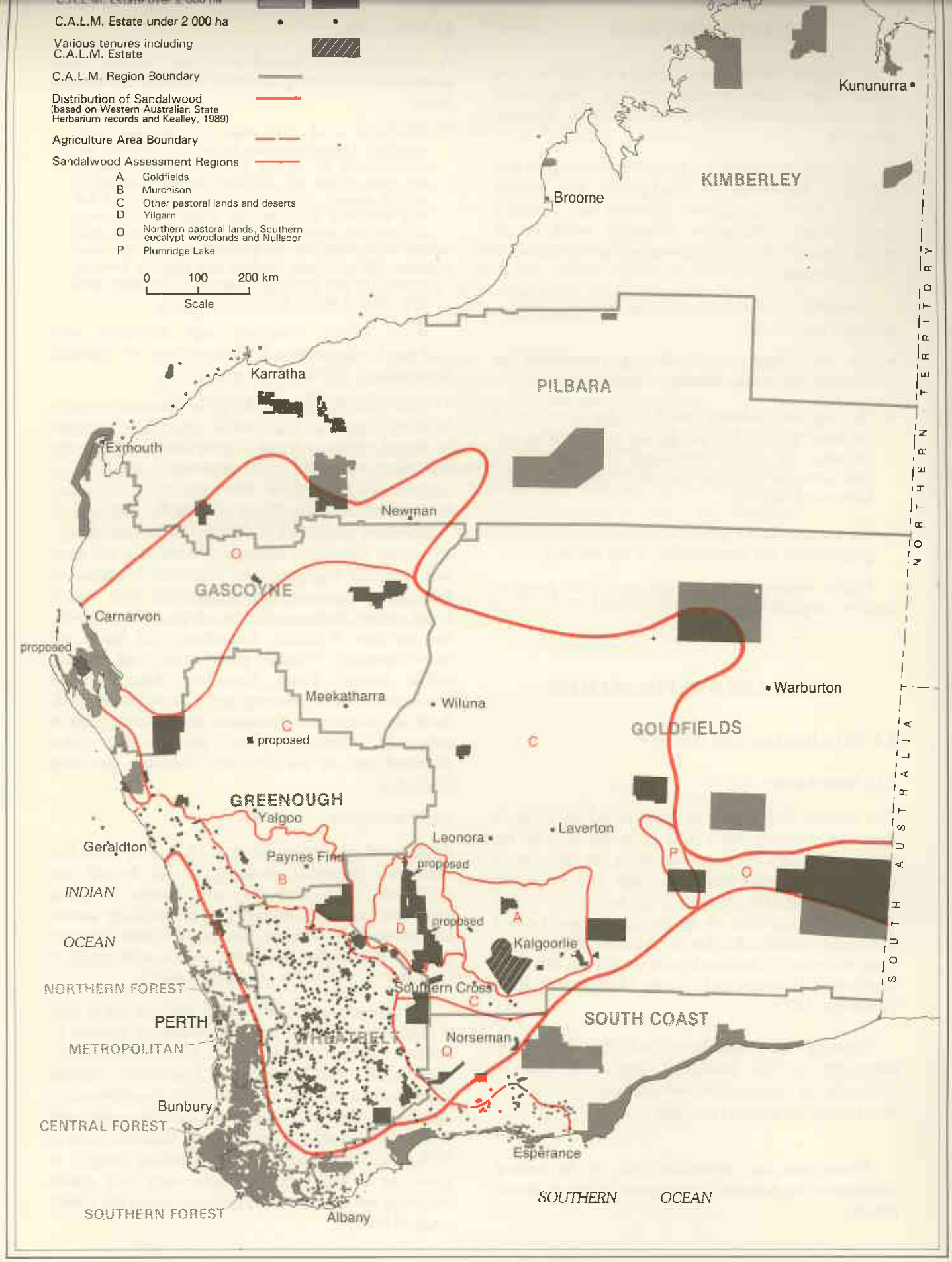

Figure 1
Distribution of Sandalwood in Western Australia. Conservation reserves and sandalwood assessment regions throughout the range of sandalwood outside the agriculture area

2.1.4 Phenology and Reproduction

Flowering is in response to rainfall and can occur in any season. The small primitive pungent flowers develop into fruits with a red brown leathery exocarp surrounding a smooth round hard endocarp (nut) up to 2 cm diameter.

Sandalwood nuts, produced in quantity in good seasons, are nutritious and palatable. They are similar to other nuts, high in fat (60 per cent) and rich in protein (18 per cent) yielding 2945 kJ per 100 g (Barrett 1989a). Sandalwood nuts are under investigation for human consumption, although not currently recommended until further research is conducted on the effects of santalbic acid present in the kernels.

Sandalwood nuts germinate following rain and subsequent cracking of the nut. In nature, under normal circumstances, germination rate is low with very low survival (1-5 per cent) of germinants (Loneragan 1990). Several years of above-average rainfall are required for good germination and survival.

The low germination and survival combined with susceptibility to fire, minimal coppicing, and grazing by domestic and feral herbivores has resulted in low levels of regeneration outside conservation reserves in the last 50-60 years (Section 2.3.3).

Research into phenology and reproduction has shown that:

- sandalwood flowers at 3-4 years old and sets seed at 6-7 years old (Barrett 1987a; Barrett *et al.* 1989; Loneragan 1990);
- sandalwood flowers regularly and consistently in natural stands with buds appearing from mid-summer to autumn. Flowering commences at differing times on different trees (Barrett 1987a);
- fruits take around 6 months to mature, ripening from October to December;
- at Curtin University of Technology, initial studies on stigma receptivity and anthesis indicate that pollen appears to be released over a short period soon after the bud begins to open. The stigma appears to be most receptive rather later with the onset of pink tepal and receptacle colouration. This study indicated that self pollination is unlikely;
- further bagging experiments were conducted in attempts to provide more definitive information on whether flowers are self or cross pollinated. Results strengthen the indication that outcrossing may occur (Fox and Barrett 1989);
- flowers are mildly, but distinctly carrion-scented and nectariferous. Flies, bees, wasps, ants, native cockroaches and moths have been observed on flowers (Barrett 1987b).

2.2 Silvicultural Characteristics

Past and ongoing research has investigated the biology, regeneration and management of sandalwood with a view to:

- re-establishing the species in areas where it once occurred naturally (e.g. agricultural areas);
- managing the existing industry, and sandalwood as a species;
- providing data for commercial plantations or crops on areas where this is an acceptable land use;
- conserving the species on reserves.

Extensive research into the reproductive biology, regeneration and management of sandalwood was conducted in the Wheatbelt and Goldfields in the 1970s and '80s by the Forests Department and Department of Conservation and Land Management.

The research provided detailed information on growth rates in different climatic zones, flowering and seeding cycles and the factors which influence the success of seed germination, survival, and growth to maturity (Loneragan 1990).

2.2.1 Seed Production and Viability

Observations and experiments to determine seed production and viability found:

- seed production is variable between trees and years and related to seasonal conditions, genetic variability, hosts and nutrition. In above-average rainfall years seed production is heavy (Barrett *et al.* 1989; Loneragan 1990);
- observations at Bullock Holes and Calooli Sandalwood reserves phenology plots, show regular flowering and a relationship between rainfall and successful seed production in an average mature stand. In 1984 following above-average rainfall (320 mm compared with 250 mm average), 26 trees at Bullock Holes yielded 3038 seeds (variation 6 to 860 nuts per tree). At Calooli 27 trees yielded 11 858 seeds (variation 2 to 1350 nuts per tree). Average nut mass was 3.3 g;
- seed viability can be high (85 per cent) at seed fall but decreases rapidly after two years at room temperture (Loneragan 1990);
- seed can be stored for long periods in a cool store at 4-5°C, with silica gel, retaining a viability of up to 50 per cent after eight years (Loneragan 1990).

2.2.2 Regeneration

Early observations revealed that natural regeneration of sandalwood was low and growth slow. With high levels of harvesting and agricultural clearing the need for research and management was recognized and led to initial research and experimental planting of

sandalwood. Early work was carried out by the Forests Department in the 1920s and '30s at sites in the Wheatbelt and Goldfields. Results revealed low germination rates, poor survival (around 1 per cent) and problems with grazing by stock and rabbits. Best results were achieved in water-gaining sites on good loam soils, where grazing could be prevented (Loneragan 1990).

Since 1973 a series of regeneration studies were undertaken, results are as follows.

GERMINATION AND PLANTING

Initial experiments (Loneragan 1990) on germination requirements, using various treatments and planting of seeds and seedlings found:

- no beneficial effects from any pre-treatment of seed, apart from endocarp removal;
- improved germination occurred when the hard seed coat (endocarp) was removed and that seeds readily germinated under moist warm conditions;
- that planting of germinated seed adjacent to suitable hosts achieved the best survival rates (up to 30 per cent);
- that planting of 1-year-old seedlings with hosts was generally unsuccessful (survival 2-5 per cent) owing to failure of the sandalwood to achieve adequate host connections.

COPPICE TRIALS

Studies in the Goldfields (Loneragan 1990), to determine whether sandalwood could be regenerated by coppice found:

- that 4.5 per cent of stems coppiced, however, none of the coppice survived;
- that regeneration cannot be reliably obtained from coppice, either following fire or cutting. More recently, it has been found that root and stem coppicing is often successful, with survival up to 80 per cent after 2 years, in the Shark Bay area, a climatically milder zone (Barrett 1989b).

Early attempts to grow sandalwood seedlings to maturity under both controlled field conditions and in many rural localities had limited success (Fox and Wijesuriya 1985). In an attempt to better define regeneration and establishment requirements for sandalwood, Curtin University of Technology has conducted research since 1979. Publications have described the following:

- optimum conditions and methods for germinating sandalwood seed (Crossland 1981; Sawyer 1981; Chilvers 1982; Crossland 1982a; Barrett 1987b);
- distribution and planting of seedlings by property owners as a means of establishing sandalwood (Fox and Wijesuriya 1985);
- regeneration techniques following harvesting including coppicing and direct sowing of seed at Shark Bay (Barrett 1989b);

From the research findings, a basic prescription and pamphlets for artificial regeneration, direct seeding and planting sandalwood in trays and pots have been developed and field tested (Underwood 1984; Barrett 1990a; Barrett 1990b). The prescription and pamphlets cover:

- seed - provenance, collection, cleaning and storage;
- nursery techniques for preparation of seed for sowing and raising seedlings for transplantation;
- selection of planting or sowing sites and sowing niches in the field;
- recommended timing of operations;
- subsequent management.

It is relatively easy to plant and regenerate sandalwood in the Wheatbelt (over 350 mm rainfall) where commercial-sized stems can be produced in 45-50 years. However, regeneration is not possible in areas grazed by sheep, cattle or goats, infested with rabbits, or subject to fire.

Planting and regeneration is far more difficult in the arid zone owing to variable seasons and difficulties of site selection. On pastoral leases planting is not considered worthwhile, unless grazing can be excluded.

2.2.3 Survival and Damaging Influences

Factors affecting survival of sandalwood regeneration and mature plants have been subject to considerable research as follows.

SANDALWOOD SURVIVAL

Studies (Loneragan 1990) on the effects of sowing seed, cultivation, fire and exclusion of grazing found:

- that fencing has a significant effect on seedling survival in grazed areas and a smaller effect on reserves, where grazing is restricted to native herbivores, rabbits and isolated introduced herbivores (stock);
- that cultivation improves germination of natural seed, however, survival is low owing to destruction of suitable host roots;
- to maintain a reasonable survival rate in the Goldfields, above-average rainfall is required for several consecutive years;
- that planting of 1-year-old seedlings with hosts was generally unsuccessful (survival 2-5 per cent) owing to failure of the sandalwood to achieve adequate host connections;

- mature and regenerating sandalwood is very susceptible to fire. Studies have shown all but light scorch will kill sandalwood. Coppicing after fire does occur, however, survival is low (10 per cent).

Additional research has been conducted at Curtin University of Technology; research has been published on the following:

- optimum age and conditions for planting sandalwood seedlings (Barrett 1987b);
- soil types best suited for young plants (Wijesuriya and Fox 1985);
- water and nutrient requirements - mineral nutrition of sandalwood in relation to host plants and mineral levels in healthy plants and seedlings of different ages (Barrett *et al.* 1985; Wijesuriya and Fox 1985; Struthers *et al.* 1986);
- host suitability and parasite/host dependence (Crossland 1981; Struthers *et al.* 1986);
- the growth of sandalwood in relation to shade (Fox and Barrett 1989).

Grazing is the critical external factor affecting the survival of sandalwood regeneration. Environmental factors (e.g. fire and drought) are the most important factors for survival of mature sandalwood.

2.2.4 Growth Rates and Recruitment

Comprehensive studies were undertaken in the 1970s to determine the range in size of sandalwood trees and growth rates (Loneragan 1990).

Growth rates are related to factors such as site conditions, climate and soils. A wide range of growth rates were discovered with sandalwood taking 32-59 years to reach commerical size (127 mm diameter at 150 mm above the ground) in the Wheatbelt and 59-115 years near Kalgoorlie (Loneragan 1990).

More specific research has since been completed and published as follows:

- development of individual plants, haustoria, and growth rates of leaves, stems, and whole trees (Crossland 1981; Barrett *et al.* 1985);
- the effect of various fertilizers on growth (Crossland 1981, 1982b).

2.3 Population and Resource For Harvesting

2.3.1 Introduction/Resource Assessment

Until the late 1970s, owing to the scattered nature of sandalwood occurrence, there was uncertainty about the extent and nature of the resource. To overcome this, a five-year assessment program was undertaken from 1980 to 1984, funded jointly by the Forests Department and the Australian Sandalwood Company.

Throughout its range, sandalwood is located in a variety of habitats with greatly varying density. The resource assessment quantified and located sandalwood stands allowing mapping and planning for management of the species, production, conservation and reservation.

METHOD

Sandalwood in better stands is widely distributed with few reliable indicators to define where it will occur. The only reliable guideline is that homogeneous vegetation types, whether pure mulga (*Acacia aneura*), pure eucalypt woodland, pure hummock grassland (spinifex) or pure bluebush (Maireana spp.), generally contain little or no sandalwood.

As the assessment was the first comprehensive and systematic survey of this type, methods of assessment had to be developed.

The irregular distribution of sandalwood in the field and the inability to accurately pre-determine sandalwood occurrence were the main factors that decided the assessment method. These factors led to adoption of an assessment method of road survey using experience, aerial photography, Landsat images and vegetation maps as a guide to assessing sandalwood within all vegetation and landform types within a particular area.

Each region to be assessed was divided into discrete areas, pastoral leases and geographical features (e.g. lakes) being the most common boundaries.

Before assessment, each discrete area was investigated, and if possible pre-stratified using 1:250 000 topographic maps, vegetation maps (Beard 1974, 1975, 1976, 1981), aerial photography and Landsat imagery.

Preliminary work and pre-stratification aimed to:

- define areas that had little chance of containing sandalwood such as homogeneous vegetation types;
- identify suitable tracks and access for road survey;
- identify areas of similarity for grouping of data when extrapolating assessment results.

SAMPLING

The method used was the 'Tally Plot Method'. It involved travelling all roads, tracks, fencelines and mineral exploration gridlines in a four-wheel drive vehicle. Cross country traverses by motorcycle and vehicle were made when needed to assess undeveloped areas.

The routes travelled were selected to sample as wide a range of vegetation and landform types as possible. The aim was to achieve a minimum 1 per cent sample of the area and to intersect all different

vegetation types interpreted from aerial photos and Landsat images.

All sandalwood, green and dead, within 20 m each side of the track was assessed as follows.

- The diameter at 150 mm above the ground of each green sandalwood in the 40 m strip was estimated and tallied into the following size classes:

  0-24 mm diameter - regeneration;
  25-74 mm diameter - undersized for harvesting;
  75-124 mm diameter - undersized for harvesting;
  125-174 mm diameter - merchantable size;
  greater than 175 mm diameter - merchantable size.

All stems over 127 mm diameter at 150 mm from the ground are of merchantable size.

- Dead sandalwood was tallied as either pieces (dead sandalwood externally weathered to a grey colour) or burnt wood.
- Tallies were kept for each 1-km unit along the track using a trip meter.
- Observations were made on the occurrence of sandalwood, especially regeneration, in relation to site and vegetation.
- Routes travelled, assessment traverses and observations were recorded on 1:250 000 topographic maps of the area.
- For some areas assessed, two measured plots were established where all stem diameters (at 150 mm) within a plot 1 km x 40 m (4 ha) were measured and the plot location recorded. Results of size class distribution from these measured plots are shown in Figure 3.

The assessment method resulted in 0.8 per cent - 2.5 per cent of the areas being assessed, depending on the extent of development and access.

RESOURCE CALCULATION

The assessment data and tally plots were analysed to calculate the total sandalwood population and resource.

Where sandalwood occurred in scattered isolated pockets and boundaries could not be defined, the assessment sample was assumed to be representative and applied to the total area assessed.

If a discrete area of sandalwood could be defined from aerial photography owing to landform or host vegetation associations, it was interpreted, mapped and the assessment sample for this area was calculated and applied separately to the remainder of the area.

Tallies and assessment data were converted into resource data for the area assessed by conversion into stems per hectare, then converting this to kilograms per hectare using air-dry stem weight data from previous research (Loneragan 1990) and data obtained from shipments to the Australian Sandalwood Company. Weight per stem for harvested green sandalwood is represented in Figure 2.

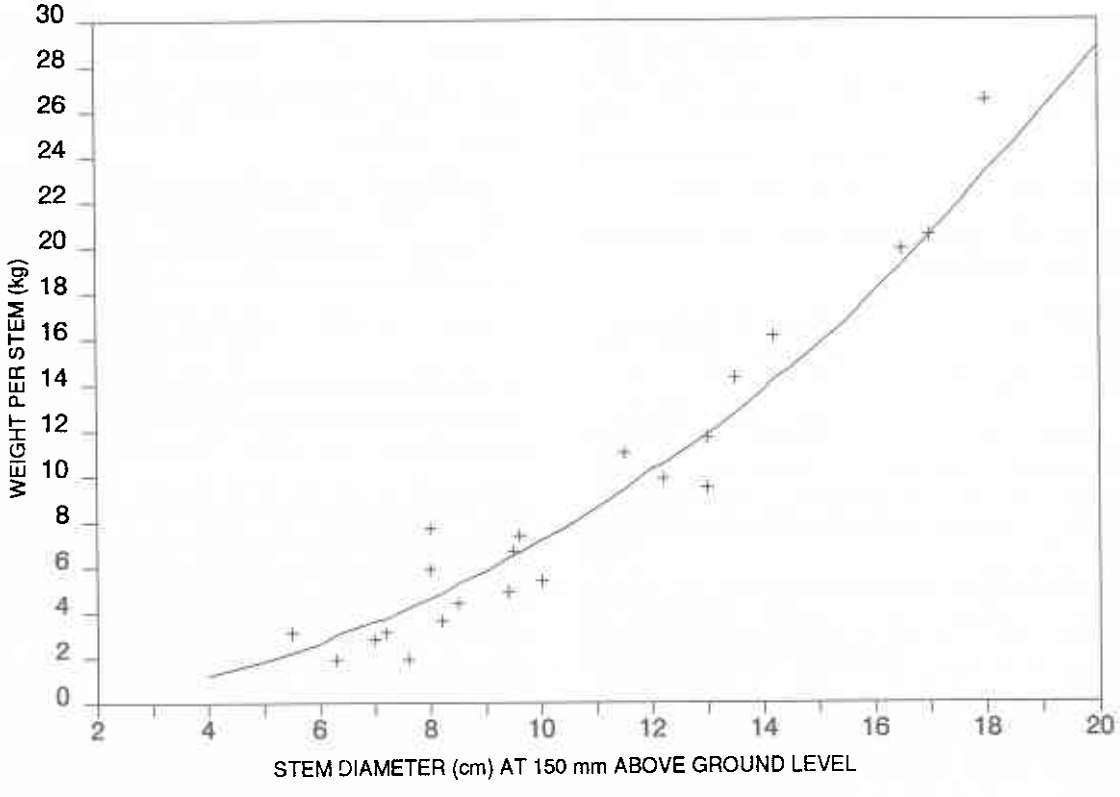

Figure 2
Weight per stem of green sandalwood when harvested

Dead sandalwood resource was calculated for the two categories, pieces and burnt. Burnt sandalwood weighed an average 6 kg per stem. Pieces (dead sandalwood weathered to a grey colour) weighed 3 kg per stem average.

Mean green stem weights for the merchantable size classes tallied were:

125-175 mm diameter (mid point 150 mm) - 16.18 kg;
greater than 175 mm diameter (mid point 200 mm) - 28.76 kg.

Once the resource for the sample area was calculated in tonnes per hectare, the total resource could be calculated for the area to which the sample applied.

2.3.2. Population Levels

The total population of living sandalwood, outside the agriculture areas where no assessment was done, was calculated from the 1980-1984 assessment data.

The original distribution of sandalwood in W.A. was about 90 million ha with agricultural clearing reducing the distribution by around 13 million ha.

Within the remaining 77 million ha assessment revealed considerable variation in the location and density of sandalwood. Table 1 indicates the sandalwood population within discrete regions as shown in Figure 1.

The total population of living sandalwood is around 23 million with the most dense populations in the Goldfields, Yilgarn, Lower Murchison and Plumridge Lakes regions.

2.3.3 Age/Size Class Distribution

An indication of the size class distribution for sandalwood was obtained from data compiled during the 1980-1984 assessment of sandalwood resource.

Size class data, from 15 measured 4-ha plots on 12 pastoral stations, in representative stands of sandalwood from the Goldfields and lower Murchison areas is shown in Figure 3.

A similar trend was observed throughout the entire area (8.96 million ha) assessed.

The existing size class distribution, when analysed against research results for growth rates, survival and damaging influences, is related to the introduction of grazing by domestic herbivores (sheep, goats and cattle) and feral herbivores (rabbits). The reduced number of plants below 90 mm diameter (approx 70-90 years old in pastoral areas) correlates well with the developing pastoral industry and introduction of rabbits.

In the lower Murchison where pastoral activity commenced earlier and is more developed than in the Goldfields, the impact on regeneration and smaller size classes is more severe.

2.3.4 The Potential Resource for Harvesting

Sandalwood resource available for harvesting (merchantable) consists of live sandalwood over 400 mm circumference (127 mm diameter) measured over bark at 150 mm above ground level and dead sandalwood trees of any size, in areas where harvesting is permitted.

Restrictions on harvesting areas include:

- no sandalwood harvesting whatsoever on Nature Reserves or National Parks;
- no green sandalwood harvesting on Lands Act Sandalwood Reserves;
- no green sandalwood harvesting within areas defined by CALM Act regulations (forests) 95(b) or the 20-km radius green belt around the City of Kalgoorlie-Boulder (Appendix I);
- no green sandalwood harvesting within restricted areas defined on the sandalwood licence (CLM 695) and order (CLM 265) (Appendices II and III) including;

  within a radius of 500 m from any watering point,
  within a radius of 2 km from any homestead or shearing shed,
  within 100 m of the edge (table drain) of any major road,
  within 20 m of the edge of any pastoral station service road.

The number of merchantable stems on land outside reserved and restricted areas and the sandalwood resource level calculated from the assessment is outlined in Table 2.

The 1980-1984 assessment revealed that within the distribution of sandalwood the area available for harvesting is around 52 million ha. An estimated merchantable resource of 137 100 t exists including 110 000 t of green wood and 27 100 t of dead wood.[1]

The proportion of the total merchantable resource that could be harvested economically varies between regions and is influenced by:

[1] Details of the 1980-1984 sandalwood resource assessment are being prepared for publication by Caporn, N.C., Kealley, I.G., and Williamson, A.J.
Improved utilization standards introduced since 1984, mainly affecting dead wood harvesting, have increased the amount of dead wood considered merchantable.
The total merchantable resource of dead wood was calculated using 1980-1984 standards and a mean weight per utilized stem. Since completing the survey a comparison between resource assessed and actual quantities harvested was made to further refine the data. Results to date show an under-estimate (still to be quantified) of total merchantable dead wood resource in the 1980-1984 assessment, mainly owing to the changed utilization standards.

Table 1
TOTAL NUMBER OF LIVING SANDALWOOD OUTSIDE AGRICULTURAL AREAS FROM 1980-1984 ASSESSMENT

Region (see Fig. 1)	*Total Area (ha x 10³)*	*Area covered by assessment (ha x 10³)*	*Number of individual sandalwood (x 10³)*	*Sample size*	
				For area assessed (%)	*For total area (%)*
Goldfields 'A'	4 900	3 190	6 670	1.05	0.68
Murchison 'B'	2 800	1 140	2 020	1.07	0.44
Other pastoral lands& deserts 'C'	50 990	3 125	11 420	0.80	0.05
Yilgarn 'D'	2 760	1 140	2 580	0.58	0.24
Plumridge Lake 'P'	367	367	500	0.70	0.70
Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'	16 000	-	160	-	-
TOTAL	77 817	8 962	23 350	0.89	0.10

Table 2
ESTIMATED NUMBER OF MERCHANTABLE SANDALWOOD STEMS AND RESOURCE AVAILABLE OUTSIDE RESERVES FROM 1980-1984 ASSESSMENT

Region	*Total area (ha x 10³)*	*Area available for harvesting (ha x 10³)*	*Number of merchantable stems (x 10³)*		*Weight of merchantable stems (t)*		
			Green	*Dead*	*Green*	*Dead*	Total
Goldfields 'A'	4 900	4 160	1 330	3 000	23 400	10 800	34 200
Murchison 'B'	2 800	2 400	740	550	11 800	1 000	12 800
Other pastoral lands & deserts 'C'	50 990	29 000	3 570	2 500	59 500	12 500	72 000
Yilgarn 'D'	2 760	910	800	410	13 100	1 200	14 300
Plumridge Lake 'P'	367	260	65	210	1 000	1 100	2 100
Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'	16 000	15 200	75	110	1 200	500	1 700
TOTAL	77 817	51 930	6 580	6 780	110 000	27 100	137 100(a)

(a) Crown land resource harvested since assessment (1984-1989) includes 4 813 tonnes of green wood and 5 935 tonnes of deadwood (Table 6).

- density of stands;
- price and market conditions;
- the scale and method of field operations;
- access and management.

Current operations are located in Murchison, Goldfields, Yilgarn, other pastoral land and desert regions.

2.3.5 Regeneration and Recruitment

The sandalwood resource assessment indicated that outside conservation reserves, regeneration of sandalwood and recruitment into larger size classes, as shown in Table 3, is poor.

The lowest recorded levels of regeneration were in the developed pastoral lands of the Murchison, Gascoyne and Goldfields.

Lack of sandalwood regeneration is related to grazing by feral and domestic herbivores, mainly sheep, goats and rabbits (Mitchell and Wilcox 1988; Loneragan 1990).

Research has also shown that sandalwood has specific requirements for sucessful seed set, germination and survival (Barrett 1987b; Loneragan 1990). As these specific requirements are met only irregularly, successful regeneration is possibly cyclical. These cyclical regeneration events, combined with environmental changes and grazing, have led to the current poor levels of regeneration and recruitment.

Regeneration and recruitment on reserves is superior to that on vacant Crown land and pastoral leases, although still affected by feral animals (rabbits and goats).

The size class used for regeneration in Table 3 (0-24 mm diameter), represents seedlings from 1 to 20 years old assuming diameter growth rate of 1 mm per annum. Regeneration numbers as shown in Table 3 and Figure 3 indicate annual levels of recruitment around 12 500 outside reserves.

Sandalwood is declining throughout its range, outside of conservation reserves, owing to this lack of regeneration. In the short to medium term the sandalwood industry is no threat to the survival of the species. In the long term, harvesting will impact if

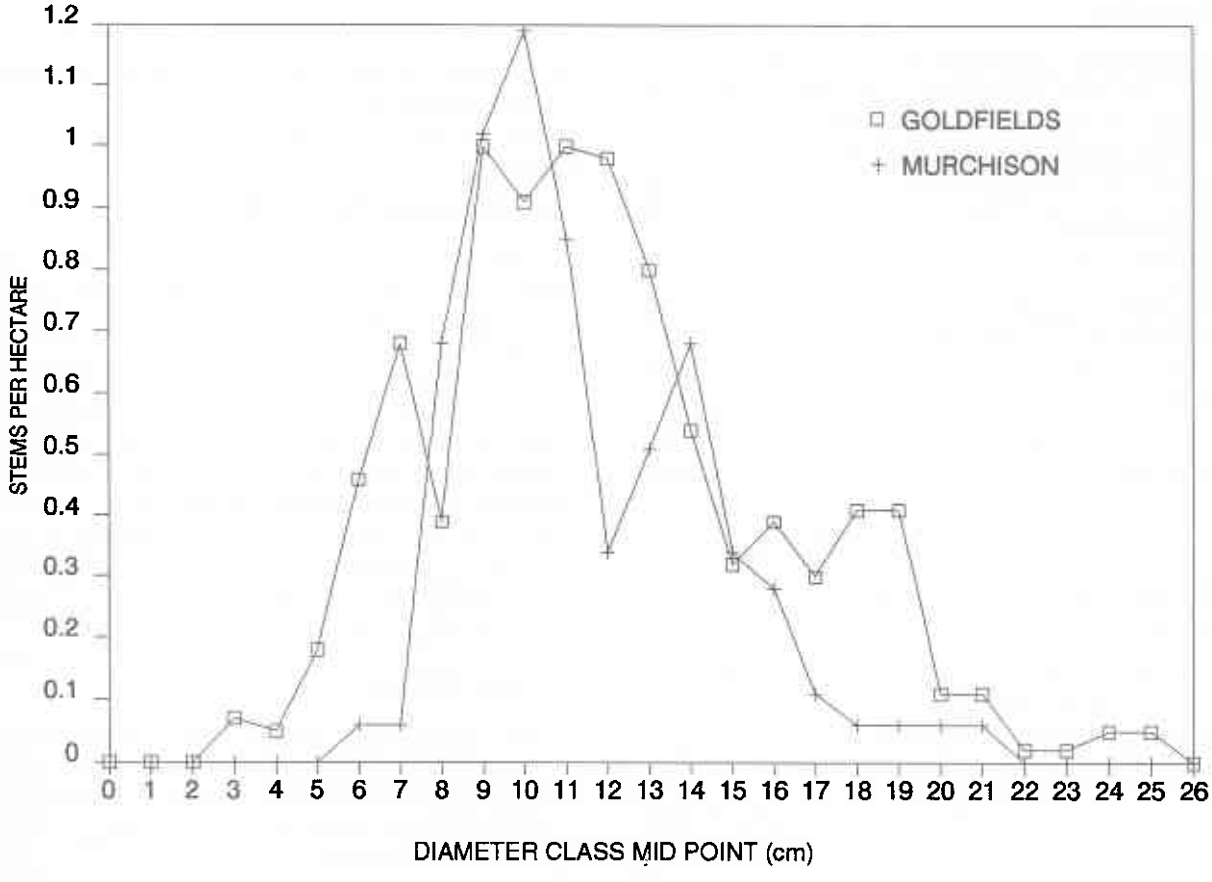

Figure 3
Sandalwood size class distribution for merchantable areas

failure of regeneration is not reversed, or alternative sources of supply not developed.

2.4 Conservation

Conservation of sandalwood can be achieved through adequate reservation and careful management of the sandalwood industry, efficient use of the timber resource, by minimizing conflicts between sandalwood conservation and other land uses and by promoting the regeneration and planting of sandalwood.

2.4.1 Conservation Through Reservation

Throughout the range of sandalwood there is a large area of statutory reserves that contain sandalwood to varying degrees (Table 4, Appendix IV). Reserves created under the CALM Act and Regulations and Land Act are defined in terms of vesting, tenure and purpose as follows:

National Parks - Vested in the National Parks and Nature Conservation Authority (NPNCA) as A or C Class reserves (agreement of both houses of parliament is required before the purpose of National Parks can be changed) for flora and fauna and landscape conservation, scientific study and preservation of features of archaeological, historic or scientific interest, together with recreational enjoyment by the public.

Nature Reserves - Vested in the NPNCA as A, B or C Class reserves (agreement of both houses of parliament is required before purpose can be changed on A Class reserves) for flora and fauna and landscape conservation, scientific study and preservation of features of archaeological, historic or scientific interest.

State Forest - Vested in the Lands and Forests Commission (LFC) with security of tenure identical to that of A Class reserves, but with a multiple use purpose.

Timber Reserve - Vested in the LFC, change of tenure is at the discretion of the Minister, purpose is multiple use.

Sandalwood Reserve - Not vested, no security, created under the Land Act with the purpose of timber and sandalwood conservation.

CALM Act Regulations (forests) Reserves - Reserves created under the Regulations, e.g. Reg. 95(b), cannot be changed without ministerial approval. The purpose is for sandalwood conservation.

Green Belt - The green belt around Kalgoorlie-Boulder (20 km radius) is not vested and has no security. Forest produce licences are not issued for green wood, including sandalwood harvesting, on precedent.

Pastoral Lease - CALM is purchasing pastoral leases (Lands Act) for sandalwood conservation. They remain temporarily pastoral leases in the name of the Executive Director until converted to more appropriate tenure (e.g. State Forest).

Reserves within the CALM Goldfields Region boundary are currently being reviewed during the preparation of a Regional Management Plan. Recommendations are included to improve the security of tenure of reserves, include upgrading Timber Reserves and Sandalwood Reserves to State Forests, and conversion of purchased pastoral leases to State Forest.

There are 4.6 million ha of statutory reserves distributed throughout the range of sandalwood (Table 4, Appendix IV and Fig. 1). Within reserves there is an estimated population of 3.2 million living sandalwood or around 13.7 per cent of the total sandalwood population. The area of reserves and proportion of the regional population in reserves is outlined in Table 4.

The distribution and area of conservation reserves and representative sandalwood populations in reserves is considered adequate in the Goldfields, Central deserts and Nullarbor. In the Yilgarn and Plumridge Lake areas reservation is excellent.

Additional reserves are required in the north-eastern Goldfields pastoral areas to complete reservation of representative sandalwood areas.

In the Murchison and Gascoyne districts and northern part of the range of sandalwood, reservation is inadequate. Very few areas outside of pastoral leases remain available for reservation and all areas are grazed.

2.4.2 Conservation Outside Reserves

Of the estimated sandalwood population of 23.35 million the majority (20.15 million) are outside conservation reserves.

Conservation and management of sandalwood outside reserves faces many practical problems. The most important problem is the lack of sandalwood regeneration (Table 3) in areas where grazing by domestic and feral animals, mainly sheep, goats and rabbits, occurs. Sandalwood, like a number of other long-living, palatable woody shrubs with specific regeneration requirements, is declining in the pastoral areas. Grazing impacts severely on these species.

Other issues are:

- the availability of suitable land for conversion to conservation reserves is restricted owing to existing tenure, the availability of funds for purchase and difficulties in achieving secure tenure owing to conflicting land uses;
- the impact of harvesting before the current controls were introduced;
- increases in the size and frequency of fires in the pastoral/arid zone since European settlement,

Table 3

AVERAGE STOCKING AND NUMBER OF SANDALWOOD REGENERATION (0-24 MM DIAMETER SIZE CLASS) OUTSIDE STATUTORY RESERVES FROM 1980-1984 ASSESSMENT

Region	*Area outside reserves (ha x 10³)*	*Average stocking of regeneration (0-24 mm size class) (s.p.h.)*	*Total number of sandalwood regeneration*
Goldfields 'A'	4 377	0.009	39 400
Murchison 'B'	2 465	0.00008	200
Other pastoral lands & deserts 'C'	49 365	0.0005	24 700
Yilgarn 'D'	2 085	0.065	179 400
Plumridge Lake 'P'	260	0.004	1 000
Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'	14 660	0.0005	7 300
TOTAL	73 212	0.0035	258 000

Table 4

THE NUMBER OF LIVING SANDALWOOD WITHIN STATUTORY CONSERVATION RESERVES (AT DECEMBER 1990) FROM 1980-1984 ASSESSMENT

Region	*Total area (ha x 10³)*	*Reserves (a) area (ha x 10³)*	*Reserves as a percentage of the total area*	*Individuals in reserves*	
				No. x 10³	*as percentage of regional population*
Goldfields 'A'	4 900	523	10.7	1 010	15.1
Murchison 'B'	2 800	335	12.0	340	16.8
Other pastoral lands & deserts 'C'	50 990	1 625	3.2	340	3.0
Yilgarn 'D'	2 760	675	24.4	1 320	51.2
Plumridge Lake 'P'	367	107	29.1	180	36.0
Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'	16 000	1 340	8.4	10	6.2
TOTAL	77 817	4 605	5.9	3 200	13.7

(a) Individual reserves and vesting are listed in Appendix IV.

which have a severe effect on the survival, distribution and regeneration of fire-sensitive sandalwood.

The current sandalwood industry is based on merchantable sandalwood that occurs outside nature conservation reserves and areas where harvesting is restricted by licence conditions (Section 2.3.4).

Within the 51.93 million ha available for harvesting (Table 2) there is an estimated (at 1985) merchantable resource of 137 000 t includng 6.58 million green sandalwood trees. In addition, ingrowth of 1930 t per annum is occurring (Appendix V) which involves about 177 000 trees. The amount of this estimated resource that could be harvested economically is very subjective.

Harvesting since assessment and future harvesting, as outlined in this management program (Section 3.9), will remove around 54 000 t of green wood over 50 years (1985-2030), an estimated 3.24 million stems which is 13.7 per cent of the total existing green stems. Beyond 50 years harvest of green sandalwood will continue to reduce to a sustainable level, including salvage and normal operations in areas that can sustain harvesting. It is proposed that green wood harvest will be reduced as plantation-grown Indian Sandalwood (*Santalum album*) becomes available in the long term.

The impact of harvesting will vary between regions as outlined in Table 5.

2.4.3 Industry Management

Up until 1950 sandalwood harvesting was carried out with little regard for conservation of the resource or the species.

From 1950 the current industry has operated under licence conditions with strict management guidelines that assist with conservation including:

- a minimum size restriction for harvesting of live trees (127 mm diameter at 150 mm above ground level);
- excluding areas from green wood harvesting such as

  500 m radius from water points,
  2 km radius from homesteads and outbuildings,
  100 m from any main road,
  20 m from any pastoral access track;

- complete utilization of every tree harvested;
- incentives to harvest a greater amount of deadwood and salvage dead trees;
- a requirement to plant seeds when harvesting green stems;
- restricted or no harvesting in areas designated as having high conservation value (e.g. regeneration zones and fire effected areas);
- harvesting only if it causes no damage to young plants, or alteration to the distribution or conservation status of the species.

These measures have increased the proportion of Crown land dead wood harvested to the 1989 level of 60 per cent of the quota.

Quantifying of regeneration and recruitment and better resource data have resulted in a number of further recent changes. These include: removing some areas from green harvesting (e.g. Gindalbie Station owing to impacts of fires), area specific harvesting conditions (e.g. Shark Bay), and a program for acquiring further reserves.

2.5 Sandalwood Research

Research on sandalwood biology and regeneration problems commenced around 1900 and continued spasmodically to the present. Research was supported and conducted by the Forests Department, CALM, Curtin and Murdoch Universities and since 1980 with co-ordination and support from the Sandalwood Research Institute.

2.5.1 The Sandalwood Research Institute

The Sandalwood Research Institute (SRI) exists to fund and promote research on sandalwood in Australia. It was established in 1980 by the Australian Sandalwood Company as a non-profit industry research institute. It is recognised by the Australian Taxation Office as an 'approved research institute'.

The basic philosophy of the SRI is to support research and development activities which appear to have good potential to contribute to the maintenance and expansion of the sandalwood industry in W.A., in line with the State's overall plan for the future of the industry. This means that SRI will support projects concerned with either the endemic *Santalum spicatum* or any introduced *Santalum* species. Priority will generally be given to those activities which show promise of economic benefit to the industry and the State.

The basic objectives of the SRI are to promote scientific research, investigation and experimentation of:

- the incidence and habitat of sandalwood in Australia;
- reforestation of the species in Australia;
- the biotic strains of sandalwood and the union with host plants;
- the species of sandalwood in other countries and methods employed to regenerate, propagate and improve stocks of sandalwood;
- the introduction of foreign species of oil-bearing sandalwood into Australia.

Table 5
IMPACTS ON SANDALWOOD NUMBERS (AS ASSESSED 1980-1984) OF PLANNED 50 YEARS OF GREEN SANDALWOOD HARVESTING 1985-2035

Region	*Total no. sandalwood (x 10^3)*	*No. merchantable stems at 1985 (x 10^3)*	*No. of stems ingrowing to merchantable size* (a)		*Estimated no. merchantable removed by harvesting 1985-2035 (x 10^3)*	*Percentage of total stems harvested*
			Annually (x 10^3)	*Total 1985-2035*		
Goldfields 'A'	6 670	1 330	61	3 040	990	14.8
Murchison 'B'	2 020	740	16	790	800	39.6
Other pastoral lands & deserts 'C'	11 420	3 570	73	3 650	550	4.8
Yilgarn 'D'	2 580	800	22	1 090	800	31.0
Plumridge Lake 'P'	500	65	4	220	50	10.0
Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'	160	75	1	50	50	31.2
TOTAL	23 350	6 580	177	8 840	3 240	13.7

(a) Calculation outlined in Appendix V.

Its activities so far have been to disburse funds for research projects, mainly at tertiary institutions in W.A., which were deemed to provide information useful for the continuation of the sandalwood industry. These projects have covered research on both *S. spicatum* and *S. album*. The SRI has also supported an annual seminar on current sandalwood research in order to improve communication among those interested in this field.

The SRI receives administrative support from the Australian Sandalwood Company, is governed by a Board of Trustees and operates under a 5-year research and development plan (Anon. 1989b).

Support for the SRI in the past has been from funds made available by the Australian Sandalwood Company arising from Commonwealth export incentive awards. Future funds will come from the Sandalwood Conservation and Regeneration Project (SCARP), as determined in this management program and other external funds and grants. The SCARP project will contribute $100 000 annually to the SRI.

2.5.2 Research Priorities

Research results and inventory data permitted the development of this management program and prescriptions for artificial regeneration, direct seeding and planting.

As a generalisation, it can be said that it is possible to regenerate sandalwood fairly reliably in the Wheatbelt, provided it is protected from fire and grazing, but regeneration in the more arid areas is much more uncertain.

Research success in establishing sandalwood has not resulted in extensive regeneration programs owing to economic constraints. In neither the Wheatbelt nor Goldfields areas does plantation culture of sandalwood for wood production alone meet normal economic criteria for return on investment.

For these reasons, attention from about 1984 was increasingly directed towards the possibility of replacing *S. spicatum* with the tropical *S. album*, which grows in India and parts of eastern Indonesia, as a plantation crop for timber production grown in tropical areas of the State.

With research on W.A. sandalwood having progressed to the stage that provides basic silvicultural knowledge, and increasing interest in Indian Sandalwood, the principal areas of research priority identified at this stage are as follows.

TISSUE CULTURE OF *S. ALBUM*

It is necessary to develop reliable techniques for the field establishment of sandalwood clonal material. This holds great potential for mass propagation of genotypes with superior tree characteristics and oil quality and quantity. The possibility that physiologically mature clonal material might produce oil-containing heartwood earlier than seedling plants also needs investigation.

RESEARCH ON HEARTWOOD FORMATION IN *S. ALBUM*

Research is required to determine how soon heartwood is formed on various soil types and what degree of genetic variation in oil content exists. An iso-enzyme technique for non-destructive assessment of oil content appears promising and needs to be further developed and refined.

ESTABLISHMENT OF *S. ALBUM*

There is still no reliable technique for the production of vigorous and healthy seedlings of this species. The optimum primary (nursery stage) host for W.A., or whether a host is needed, has not yet been determined. Once adequate local seed supplies are available, it is very desirable to develop a reliable method of establishing this species by direct seeding.

USE OF *S. SPICATUM* AS A FOOD NUT

There are promising indications that sandalwood nuts may have commercial potential but a number of aspects need further research.

SILVICULTURE OF *S. ALBUM*

Research into selection of optimum secondary host species, adaptability of the species to different soil types in the Kimberley area, determination of optimum stocking patterns of sandalwood and hosts, and collection of growth data are required.

2.5.3 Ongoing Research and Development

Research into aspects of *Santalum spicatum* and *Santalum album* is being conducted by CALM, Curtin and Murdoch Universities and through involvement with the Australian Centre for International Agricultural Research (ACIAR), and includes:

SANDALWOOD (*SANTALUM SPICATUM*)

- Sandalwood woodlots and conservation in the Wheatbelt - a project to describe and identify:

  variation in the morphology of sandalwood in the Wheatbelt;

  sandalwood habitats in the Wheatbelt;

  relationships between growth, morphology and habitat;

  sandalwood populations which are phenotypic variants, and of these, those which have the best characteristics for woodlots.

  The project is funded by SCARP funds with results to be used in establishing trial 20-ha woodlots at Narrogin and Katanning. It is conducted by a consultant supervised by CALM (Kealley 1990).

- Identifying remnant sandalwood stands, fencing and regenerating sandalwood demonstration plots on farms in the Greenough district.

  A project involving fencing plots of 3-4 ha on farms containing remnant sandalwood, to include regeneration work, vermin control and assessment of regeneration. Funded by SCARP funds, conducted by CALM (Kealley 1990).

- Coppicing and direct seeding of sandalwood at Nanga Station, Shark Bay.

  A 3-year (1988-1990) project to assess the impacts of harvesting and regeneration from coppice and direct seeding. Early observations confirm that *S. spicatum* will produce coppice from cut stump and root suckers and direct seeding has had some success (Anon. 1989a; Barrett 1989b).

  Funded by the Australian Sandalwood Company conducted by Curtin University and CALM staff.

- The use of sandalwood as a food nut: preliminary research (Fox and Barrett 1989; Barrett 1989a; Anon 1989a) indicated research into sandalwood nut production as an alternative crop was merited.

  A project funded by the SRI conducted by Curtin University has commenced.

- Ongoing studies on flower and fruit production documenting yearly crop development. Curtin University project.

- Tissue culture (vegetative propagation) of *Santalum spicatum*: attempts to vegetatively propagate sandalwood by both cuttings and tissue culture were unsuccessful. In tissue culture it was found to be possible to develop plantlets with shoots but after much work no way could be found to promote root formation (Chilvers 1982). Work was conducted at Murdoch University with SRI funding.

- Trial planting with farmers in the Avon Valley with 5 ha planted on seven properties. A Curtin University/National Afforestation Project.

- Assessment of genetic variation within sandalwood and its reservation status.

  Apart from these ongoing projects and identified priority areas no further *S. spicatum* research is envisaged.

INDIAN SANDALWOOD (*SANTALUM ALBUM*)

- Vegetative propagation and tissue culture

Research into vegetative propagation of *S. album* was conducted at Murdoch University in an attempt to identify and reproduce high yielding strains of sandalwood. This field of research is finally, after some years, meeting with success and has reached the stage of having seedlings growing in pots for planting out in the field. These trials will give invaluable experience in handling clonal material and the vegetative propagation technique will be a very useful research tool.

Research will be ongoing funded by the SRI.

- Field Trials

Interest in *S. album* as an alternative species to *S. spicatum* and as a commercial plantation species led to field trials commencing in the tropical Kimberley region of W.A..

CALM established several small trial plots in the Kimberley from 1986 onwards, leading towards a trial 20-ha plantation being prepared for initial planting in 1990/91, within irrigated land at Kununurra (Kealley 1990).

A summary of field research as outlined by McKinnell (1990) is;

'Early results (from *S. album* plantings) are very promising: mean heights of 3 m being achieved in 2 years under irrigation at Kununurra. The survival has been generally good and no real difficulties are foreseen in establishing the species routinely if a suitable nursery procedure can be developed. Early plantings used several Kimberley *Acacia* species as host. There were distinct differences in growth of the sandalwood with different Acacias, e.g. there was markedly better growth in the first two years with *A. trachycarpa* than with *A. ampliceps*. In the early trials, the sandalwood was grown under supplementary irrigation, as there is ample water available at Kununurra and the annual rainfall is only 500 mm.

All the seedlings in the initial trials were raised in the same pot as the hosts and some difficulty was encountered in finding a host which did not overcrowd the rather slow growing sandalwood seedling. Pruning the host was the answer, but that could clearly not be used in anything more than a research trial. A further problem appeared two or three years after planting out when it was found that the host was too close to the sandalwood and was pushing the sandalwood over. This prompted a move to a two stage host system: the primary host being a small, low-growing species such as *A. transluscens* and the long term host being a variety of large Acacias and other species of tree.

The only real problem so far with sandalwood in the Kimberley has been some damage from a stem girdling moth. Damage is erratic and is only noticeable in some seasons. It will have to be watched but is not seen as a real threat at this stage.

There is also a research program on *S. album* in progress at Murdoch University in Perth. Funded both by the SRI and a Commonwealth Government research grant, and with field support from CALM, it has field trials in the Kimberley to determine the best secondary host species. Secondary host species being tested are:

Khaya senegalensis, Cordia sebastina, Acacia gracillima, Adenanthera pavonina, Azaderachta indica, Allocasuarina equisetifolia, Melaleuca leucodendra, Terminalia petiolaris, T. platyphylla, Dalbergia sissoo, assia siamea and *Pterocarpus indicus*.'

Research will be ongoing in conjunction with plantation development, SRI projects, and external project research and provenance trials.

The ACIAR Project

At about the same time as interest in *S. album* developed in W.A., CALM became involved in the management of a research project in West Timor funded by the Australian Centre for International Agricultural Research (ACIAR), which was partly concerned with the development of reliable techniques for regeneration of *S. album*. This has accelerated the pace of sandalwood research in W.A. and widened its scope to a considerable degree.

The ACIAR project has several distinct parts:

Effect of tree age and rate of growth on sandalwood oil content;

Identification of high quality stands of S. album for reservation as seed production areas;

Development of reliable nursery techniques;

Seed viability studies;

Silvicultural requirements of S. album;

Direct seeding studies.

Most of this research has been carried out by Dr John Fox at Curtin University in Perth. Results are directly applicable to plantation establishment and trials at Kununurra.

After preparation of a literature review relevant to the project objectives (Barrett 1988), most of the research has been devoted to the development of a

reliable nursery technique for the establishment of the species. Although planting seedlings may not be the technique used by a large-scale regeneration program, it is an essential research tool and at the very least, a fall back operational establishment procedure, especially if seed resources are limiting.

Initial results of this and earlier research have been outlined by Fox and Barrett (1989).

It is also important to keep in touch with current research on sandalwood in Indonesia and New Caledonia, to ensure that duplication of work does not occur and that any useful developments can be followed up here. At this stage, this contact is maintained through CALM's involvement in the ACIAR project. Should this terminate, other avenues of maintaining contact will be developed.

It is also of great interest to compare the growth of different species of sandalwood and their adaptation to a range of sites. Some additional funds were obtained from ACIAR in 1988 to support the establishment of an international species/provenance trial to follow up this aspect. It was originally intended to include Australia, Indonesia, New Caledonia, Fiji and Vanuatu, but could be extended to include other countries if desired. Progress has been slow owing to seed losses caused by cyclones and by the withdrawal of Indonesia, but the first plantings should take place in 1990 and hopefully some of the Hawaiian species may now be included. A provenance trial will be established at Kununurra as part of this project.

Research into *S. album* in the Kimberley including ACIAR, SRI and CALM (SCARP) will be co-ordinated and implemented by a full-time research officer funded jointly for 3 years (1991-1993) to be stationed at Kununurra.

Research in all these areas will be ongoing.

3. SANDALWOOD INDUSTRY

3.1 Introduction

Sandalwood is highly valued for the aromatic qualities of the oils contained in the heartwood. Sandalwood has been harvested and exported from Western Australia since 1845. Although varying over the years, the industry, under present market conditions, is now stable and profitable.

Sandalwood is exported by the Australian Sandalwood Company, Fremantle, as various products to Taiwan, Hong Kong, Singapore, Thailand and Malaysia where it is used, mainly in powdered form, for the manufacture of joss sticks used in religious ceremonies.

The history of the Western Australian sandalwood industry is well documented (Underwood 1954; Robertson 1958; Ware 1975; Richmond 1983; Talbot 1983; Statham 1988).

3.2 History

In the late 1920s and early '30s, four companies were exporting sandalwood and competing for markets in China. Sandalwood was being gathered (known as pulling) from the agricultural and pastoral areas of W.A. by contract pullers with no restriction on prices or quantities. Mostly these pullers were paid low rates and the industry provided only a subsistence wage to them.

By 1929 China was torn by civil war, the market collapsed and huge stocks of sandalwood accumulated at Fremantle and country rail sidings. Pullers were not being paid for wood supplied and the industry was in a state of chaos.

In order to rationalize the industry and to provide funds to pay the pullers, who were in desperate financial trouble, the Government of the day agreed to underwrite the sandalwood stocks provided the four companies merged. In 1929 the Sandalwood Act was passed and in 1930 the companies were amalgamated to form the Australian Sandalwood Company Ltd, and the Sandalwood Export Committee was established.

3.3 The Sandalwood Export Committee

The Sandalwood Export Committee was established on 22 July 1932 by agreement between the Governments of Western Australia and South Australia, the Australian Sandalwood Company Ltd, and the Co-operative Sandalwood Company (South Australia) Ltd. This agreement was renegotiated and ratified in 1952 when the parties agreed that it remain in force indefinitely until terminated by any party.

As South Australia no longer produces sandalwood for export, there has been no recent South Australia participation in the activities of the Committee and South Australia formally withdrew from the agreement from 1 January 1987.

The Sandalwood Export Committee is now composed of:

- a representative of the W.A. Minister for Conservation and Land Management who is the nominated Chairman;
- an Australian Sandalwood Company representative as a member;
- a Secretary supplied by CALM;
- also attending by invitation are advisors from CALM including The Director, Forest Resources Division, the State Sandalwood Control Officer and the Chairman of the Australian Sandalwood Company board.

The Committee meets approximately every two months. Subjects such as export prices and policy, payments to pullers, conservation practices in the industry and quotas to be applied to pullers are discussed and decided upon by the Committee. The Committee also sets the annual export quota based upon the availability of sandalwood, quantities required to meet market needs, conservation of the species and the long-term viability of the industry. Decisions reached are binding on the Company by virtue of the terms of the Sandalwood Export Agreement.

3.4 Responsible Organization and Statutory Basis

Sandalwood harvesting in W.A. is administered by the Department of Conservation and Land Management, according to the provisions of the Sandalwood Act (1929 as amended), CALM Act (1984 as amended) and CALM Act regulations (Forests) (Appendix I).[2]

3.5 Demand and Supply

Demand for selected grade sandalwood from the various markets is known to be substantially greater than the current maximum harvesting level of 2000 t.

The target harvest will be 2000 t per annum, subject to minor seasonal variations, for conservation and management reasons, to maximise returns and maintain a stable market.

Demand is tempered by the Export Committee by requiring the market to accept a substantial proportion of lower grade material which in past years was regarded as non-marketable residue.

3.6 Harvesting Level and Employment

The Sandalwood Export Committee and CALM have determined a present harvesting level (quota) of 2000 t per annum. This consists of:

- 200 t from private property, the maximum 10 per cent of the quota as allowed under the Sandalwood Act;
- 1800 t from Crown land: to satisfy conservation and management strategies this will include a minimum 45 t reserved for pastoralists under provisions of the environmental hardship policy and maximising the harvest of dead wood including salvage.

Sandalwood production from 1970-1989 is outlined in Table 6. Recent private property production is mainly from the Hampton Areas in the Goldfields, between Kambalda, Coolgardie and Kalgoorlie.

Commercial sandalwood is harvested from various regions - 1989 Crown land operation areas included:

- Plumridge Lakes area - 18.4 per cent of production;
- North Eastern Goldfields and Central Desert areas - 3.2 per cent of production;
- Goldfields - 29.8 per cent of production;
- Yilgarn - 22.8 per cent of production;
- Paynes Find Area - 20.5 per cent of production;
- Gascoyne District - 4.4 per cent of production;
- Shark Bay Area - 0.9 per cent of production.

In 1989 employment in the sandalwood industry harvesting operations included:

- 11 full-time contractors - 81.9 per cent of production;
- 7 part-time contractors - 6.6 per cent of production;
- 3 pastoralist contractors - 1.4 per cent of production;
- 5 private property licences - 10.0 per cent of production.

A further 56 sandalwood timber workers' registrations were issued to contractor's employees.

With the current stability in the industry, most of the existing contractors have been harvesting sandalwood for many years. The industry depends on small independent contractors and provides employment and income to groups, including Aboriginal communities in remote areas.

At times, sandalwood harvesting is used as supplementary income for pastoralists suffering difficulties caused by environmental hardship (e.g. fire or drought). Quotas of up to 20 t are available under these hardship provisions.

3.7 Prices and Returns

The 1990 prices received by sandalwood contractors were:

- $970 per tonne for green wood;
- $970 per tonne for dead wood (known in the industry as pieces);
- $24 per tonne as a pallet loading allowance;
- $60 per tonne isolation allowance paid to contractors operating in remote areas

Prices are adjusted each year by the Sandalwood Export Committee after taking into consideration a number of factors, including variations in the Consumer Price Index (C.P.I.) for the year plus any special circumstances such as marked changes in operating costs owing to changed utilization standards or variation in licence conditions. Previously these prices had been set generally to operate for a financial

[2] At the time of publication of this management program, revised Forest Management Regulations under the CALM Act are being prepared. These regulations are expected to be gazetted later in 1991.

Table 6
SANDALWOOD PRODUCTION (TONNES) 1970-1989
(Source, CALM Kalgoorlie Records)

YEAR	CROWN LAND						PRIVATE PROPERTY		TOTAL
	Contractors		Pastoralists		Salvage Dead Wood (Chips)	Sub-Total			
	Green Wood	Dead Wood	Green Wood	Dead Wood			Green Wood	Dead Wood	
1970	660.00	101.00	-	-	-	761.00	-	-	761.00
1971	1027.00	153.00	-	5.00	-	1180.00	-	-	1180.00
1972	708.00	250.00	-	4.00	-	962.00	-	-	962.00
1973	1243.00	136.00	3.00	-	-	1382.00	-	-	1382.00
1974	838.00	294.00	-	-	-	1132.00	-	-	1132.00
1975	888.00	424.00	3.00	-	-	1315.00	-	-	1315.00
1976	807.00	444.00	-	-	-	1251.00	28.32	-	1279.32
1977	741.00	722.00	11.00	15.00	-	1489.00	11.38	4.96	1505.33
1978	694.00	536.00	60.00	50.00	-	1342.00	14.15	21.39	1377.54
1979	822.00	610.00	43.00	50.00	-	1525.00	62.28	6.41	1593.69
1980	937.00	739.00	43.00	36.00	-	1755.00	15.97	6.92	1777.89
1981	1001.00	626.00	58.00	45.00	2.00	1732.00	1.13	0.40	1733.53
1982	964.00	616.00	52.00	20.00	-	1652.00	15.12	3.61	1670.73
1983	982.00	651.00	42.00	21.00	-	1696.00	1.25	1.41	1698.66
1984	869.19	841.39	52.08	6.32	6.15	1775.13	3.81	2.64	1781.58
1985	853.36	802.07	30.94	7.28	21.41	1715.06	-	9.40	1724.46
1986	785.99	913.39	50.05	12.75	105.72	1867.90	2.65	2.42	1872.97
1987	727.67	881.81	11.90	22.74	154.49	1798.61	170.49	16.69	1985.79
1988	702.46	926.19	7.39	8.29	166.59	1810.92	174.09	39.63	2024.64
1989	707.28	927.68	15.09	13.96	116.72	1780.73	155.49	57.27	1993.49

year, but from 1 January 1985 the Committee decided to set these prices for each calendar year, as this is also the negotiated period for the export prices.

The Australian Sandalwood Company arranges and pays for contract carriers to transport the sandalwood by road and rail to the processing shed at Spearwood.

Royalty charges are paid by the Australian Sandalwood Company at a rate based on 10 per cent of the monthly FOB value. This rate applied from 1 January 1987. In 1989/90 royalty yielded $985 928 to the Government.

In addition, the Australian Sandalwood Company pays the annual recoupable costs to the Department of Conservation and Land Management to cover expenses incurred on behalf of the Company and in supervising the industry. These comprise field inspections and control by Goldfields Region staff, plus secretarial and management functions at Head Office. In 1989/90 an amount of $76 830 was received.

In 1990 CALM appointed a full-time forester to supervise field operations associated with the sandalwood industry. All costs associated with the position are fully recouped from the Australian Sandalwood Company including salary, vehicle expenses, administration and overheads. The position will be ongoing, costing around $85 000 per annum.

Sandalwood is sold in various grades to Asian buyers, the 1990 FOB ($Aust) value per tonne at Fremantle was:

PRODUCTS	*24/02/90*
Sandalwood Logs (cleaned)	*$9 363*
Sandalwood Logs (uncleaned)	*$5 318*
Pieces (dead wood)	*$6 926*
Chips	*$4 788*
Butts	*$7 573*
Powder	*$5 000*
Shavings	*$2 952*
No. 2 Chips	*$2 500*

The maximum amount of sandalwood received at the Company's Spearwood shed is exported, including sawdust, which is sold at reduced prices by negotiation when sufficient has accumulated to warrant marketing.

The W.A. Government shares in the profits of this commercial operation in a manner laid down in the agreement. On profits of $300 per tonne, the proportion is $221 to the Government and $79 to the Company. Any amount in excess of $300 returns 90 per cent to the Government and 10 per cent to the Company.

For the financial year 1989/90 the W.A. Government received $985 928 in royalty, $76 830 as overheads and administration and $5 086 818 as share of profits. This is a total of $6 149 576 for the year from an operation that produced a gross export income in excess of $11.15 million.

3.8 Ingrowth

Since assessment of the merchantable resource of green sandalwood, there will be an annual addition to the merchantable resource as smaller sizes grow above 127 mm diameter.

Appendix V calculates ingrowth into greater than 125 mm size class (merchantable), on the area available for harvesting, as 1 930 t per annum. Only a proportion of this would be commercial in regions where quality sandalwood and ongoing harvesting occurs.

3.9 Future Harvesting

An ongoing sandalwood industry is proposed utilizing existing merchantable green and dead resources and ingrowth. Harvesting levels will be managed to achieve conservation objectives while maintaining the industry until alternative plantation grown resources can reduce green wood harvesting of natural stands.

The assessed Crown land merchantable resource (at 1985) of 137 000 t, including 110 000 t of green and 27 000 t of dead, would permit 76 years of harvesting at the current level of 1800 t per anuum. Ingrowth, calculated at 1930 t per annum, will further extend the available merchantable resource.

Many factors can have an impact on resource availability and alter future harvesting plans, such as:

- price and market conditions;
- the scale and economics of harvesting;
- changes to the tenure of areas where sandalwood grows;
- changes in land use and impacts, especially grazing;
- access and changing utilization standards;
- growth and regeneration;
- creation of new resource by plantation;
- changes in demand;
- bushfires.

These factors make long-term prediction of harvesting and resource, especially the proportion of dead and green, very difficult.

The amount of the total merchantable resource that can be considered economic for harvesting is very subjective (Section 2.3.4). A proportion occurs in scattered stands in remote regions (Table 2) and is less likely to be harvested. Initially harvesting would be concentrated in better sandalwood areas, for economic reasons, and will have differing impacts (Table 5). Management through adjustment of returns and profitability can ensure it remains economic to harvest remote and scattered resource, especially dead wood, therefore maximising dead wood resource utilization.

Future harvesting plans are outlined in Figure 4.

Harvesting since assessment (1985-1990) and planned 45 years of future harvesting (1991-2035, Fig. 4) will utilize around 30 000 t of merchantable dead wood resource and 54 000 t of merchantable green wood resource and ingrowth.

The impact on green sandalwood numbers of harvesting since assessment and planned future green wood harvesting in various regions is outlined in Table 5. Harvesting will remove 3.24 million green stems or 13.7 per cent of the total existing Crown land green stems.

Features of future Crown land harvesting are:

- Minimal changes to the current industry from 1990-2000, maintaining a harvesting level of around 800 t green and 1000 t dead wood. This permits restructuring of quotas to minimise impacts on existing contractors and gives time to refine resource data.
- A phased 20-year (2001-2020) reduction in dead wood harvest to accommodate reducing dead wood resource and allow quota reductions, industry restructuring and changes to harvesting areas. Beyond 2020, dead wood production will remain at

the level produced by concurrent green and dead wood operations, expected to be around 200 t per annum.

- The merchantable dead wood and total dead wood resource from the 1980-1984 assessment is under review. Improved utilization and changing standards may increase the resource (Section 2.3.4 Footnote). Once the resource is refined (during the life of this program) the effect on timing and quantity of the required reduction in dead wood harvest will be confirmed.

- Maintaining harvest of merchantable green wood and ingrowth at the level required to keep total production at around 1800 t per annum. In the longer term (2020 onwards), as plantation resource availability permits, there will be a phased reduction to a level of production generated from salvage operations and ongoing sustainable harvesting.

- From 2020 onwards, plantation resource, from Indian Sandalwood plantations in the Kimberley, will be phased in. It is recognized that utilizing Indian Sandalwood plantations differs significantly from harvesting W.A. Sandalwood. It is intended to utilize the opportunities created by the new plantation resource to reduce harvest of green W.A. Sandalwood, while maintaining an export industry and returns.

To meet planned future harvesting from plantations the following plantation development is required.

Planting Years	Area Planted (ha per annum)	Volume Harvested (tonnes per annum)	Harvesting Years
1991-1995	10	100	2021-2025
1996-2000	40	400	2026-2030
2001-2005	70	700	2031-2035
Total area of plantation 1990-2005	600		

This assumes a yield of 10 t/ha of heartwood with a rotation length of 30 years (Kealley 1990).

Within the life of this program (10 years) research on Indian Sandalwood silviculture will determine the optimum techniques for plantation silviculture. Based on these results, planned harvesting can be adjusted in future plans to achieve sustainable green wood harvest.

4. THE SANDALWOOD MANAGEMENT PROGRAM

4.1 Broad Objective

To conserve sandalwood as a species in W.A., and at the same time maintain the sandalwood industry by reducing harvest of the natural green wood resource

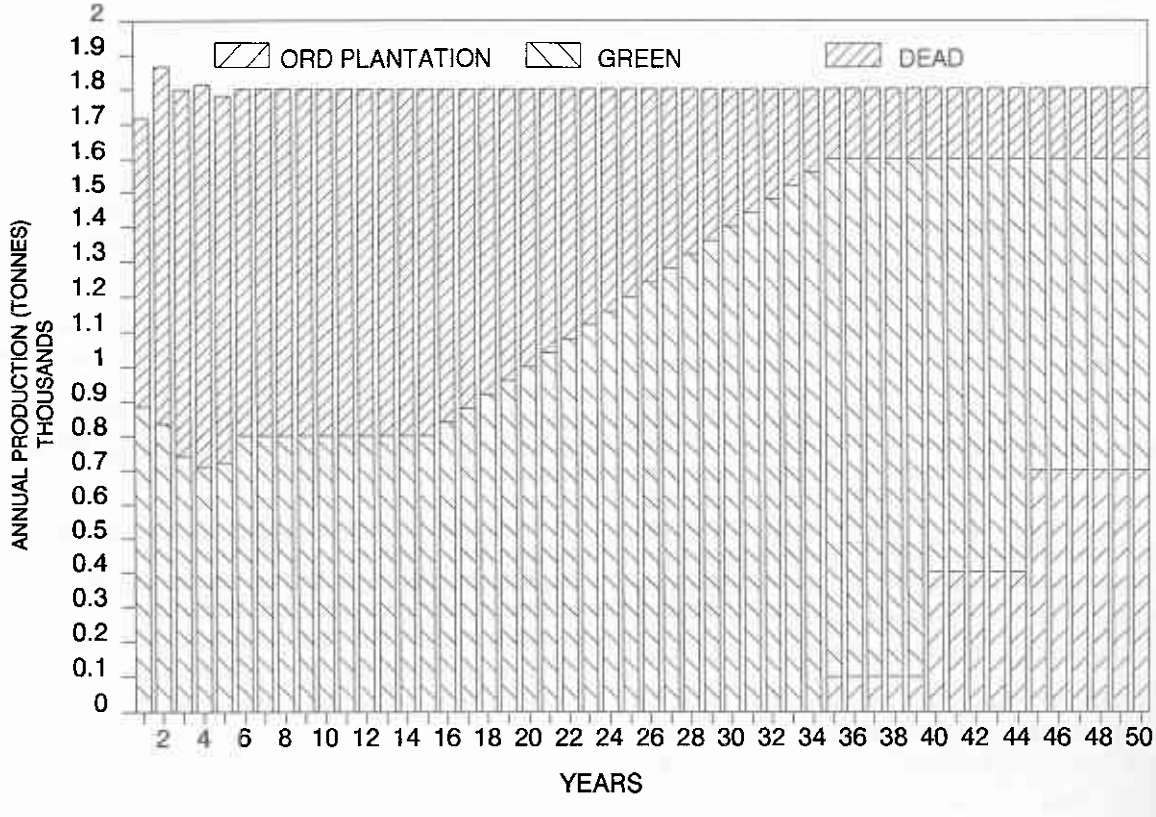

Figure 4
Planned 50 years of Crown land sandalwood harvesting 1985-2035

and supplementing the natural resource by the increasing use of plantations.

4.2 Specific Objectives

Specific objectives are to:

4.2.1 Conservation Reserves

Develop and manage an effective conservation reserve system to conserve and protect representative areas of sandalwood containing viable populations of plants throughout its range.

4.2.2 Research

Carry out research and inventory to ensure the best silvicultural, protection, conservation and utilization techniques are used in management and reservation.

4.2.3 Harvesting

Adjust the level of harvest from natural stands to a level consistent with growth, with due regard to employment and economic stability. Replace harvest of natural stands with increasing use of plantations, to meet demand and achieve conservation, land use and economic aims.

4.2.4 Marketing

Ensure that sandalwood products are marketed to favour the highest value products with the maximum level of local processing.

4.2.5 Management

Maintain sandalwood harvesting operations as planned with control by the present system of licences, quotas and conditions, and continue the emphasis on efficient utilization of the resource. Update protection and regeneration prescriptions in the light of research.

4.2.6 Education

Educate and promote public awareness of sandalwood management, conservation and reservation.

4.2.7 Regeneration

Improve the establishment and survival of regeneration, throughout the range of sandalwood, by control of introduced herbivores.

4.3 Strategies

Strategies to achieve objectives are:

4.3.1 Conservation Reserves

- Investigate and review current conservation reserves with a view to establishing an effective reserve system, with secure tenure and purpose, free of encumbrances, to conserve representative stands of sandalwood throughout its range.
- Review conservation through reservation of sandalwood throughout its range using inventory and distribution data. Improve conservation status by acquiring areas for sandalwood reserves.
- Manage conservation reserves to ensure maximum protection of existing sandalwood by removing and controlling grazing by introduced herbivores and by protecting from wildfire.
- Use developed techniques for enrichment and re-establishment of sandalwood in reserves where it occurred naturally.

4.3.2 Research

- Initiate a major study of alloenzyme variation in sandalwood to document the genetic resource and integrate sandalwood conservation with reservation strategies.
- Continue research on sandalwood management in accordance with defined priorities to achieve research objectives.
- Review existing research projects, remeasure established trials and publish existing research data.
- Contribute to ongoing research co-ordination by involvement with the Sandalwood Research Institute and maintaining an overview and input to research programs.
- Conduct research into sandalwood regeneration and enrichment techniques, and silvicultural techniques for plantations of both *S. spicatum* and *S. album*.

4.3.3 Harvesting

- Restructure licences and quotas, adjust the level of green wood harvesting to achieve management objectives without disadvantaging those engaged in the industry.
- Ensure harvesting of dead wood receives priority over harvesting living trees.
- Modify licence conditions to achieve objectives.

4.3.4 Plantations

- Investigate and establish trial commercial plantations of sandalwood (*Santalum spicatum* and *Santalum album*) where this is a practical, economic and an acceptable land use.
- If it is shown that viable plantations of *Santalum album* are possible, promote the economic returns, feasability and techniques to commence a program of plantation establishment with the long-term objective of transferring the majority of green wood harvesting to that species.
- Establish trial plots of W.A. sandalwood in the higher rainfall areas of its range and manage remnant stands throughout its former range.

4.3.5 Marketing

- Investigate and review harvesting, transport, and processing methods to achieve the most economic methods.
- Use returns from the sale of sandalwood for management, conservation and reservation.

4.3.6 Management

- Supply of sandalwood should not exceed 2000 t per annum: 1800 t maximum from Crown land, 200 t maximum from private property.
- Continue to provide advice to the Sandalwood Export Committee.
- Ensure operating areas are allocated to defined boundaries and directed to those areas where land use and conservation objectives are achieved.
- Use licence conditions to achieve management and conservation objectives and to minimise conflict with other land use objectives. Review conditions regularly.
- Provide infrastructure for management of the sandalwood industry and new initiatives associated with the management program.

4.3.7 Education

- Develop and disseminate information on sandalwood.
- Encourage landholders to regenerate and plant sandalwood and to manage remnant stands on private property.
- Use promotion, education and publicity to increase community understanding of sandalwood management.

4.3.8 Regeneration

- In conjunction with the Agricultural Protection Board and other land users, develop and implement control measures for introduced herbivores throughout the range of sandalwood.

4.4 Resources for Management

Resources for management of the sandalwood industry include finance, staff, infrastructure and the industry-funded SCARP project.

4.4.1 Finance, Staff and Infrastructure

Financial arrangements for CALM recovering industry management costs are outlined in Section 3.7. All costs incurred are recovered and these arrangements are ongoing.

Staff resources include one full-time CALM field officer funded by the industry on a recoup basis. Goldfields Region staff provide administration, infrastructure, management and support on a cost recovery basis.

Finance, staff and infrastructure are well resourced for the ongoing management of the sandalwood industry.

4.4.2 Sandalwood Conservation and Regeneration Project (SCARP)

In September 1988 the $1.5 million SCARP project co-ordinated by the Sandalwood Export Committee and supervised by CALM was commenced with funding allocated from the sandalwood industry.

The objective of this project is to improve the conservation status of sandalwood in W.A.

This will be achieved by:

- developing and managing an effective reserve system to conserve representative areas of sandalwood, containing viable populations of plants, throughout the range of the species, specifically:

  purchasing areas for sandalwood reserves (pastoral leases),
  purchasing grazing rights and removing grazing from reserves where sandalwood occurs,
  fencing reserves and other management measures to control grazing by feral animals;

- co-ordinating existing research, carrying out new research and reviewing and publishing completed research to ensure the best silvicultural, protection and utilization techniques are used in management of sandalwood;
- developing plantations of sandalwood to supplement harvesting of natural stands, specifically:

  establishing a trial 20-ha plantation of Indian Sandalwood (Santalum album) in the Ord irrigation area,
  establishing a 20-ha trial plantation of W.A. sandalwood in the Wheatbelt (Narrogin),
  encouraging plantings in remnant woodland on Wheatbelt farms in the Merredin, Katanning and Greenough districts;

- providing infrastructure to improve utilization and the efficiency of management of the current sandalwood industry;
- educating and promoting general awareness of sandalwood conservation and regeneration through publicity, information and interaction with landholders and the public;
- establish an extensive introduced herbivore control program to be implemented with the aim of improving the success of sandalwood regeneration.

The project is ongoing with initial objectives and timing (Kealley 1990) based on the original $1.5 million approved funds. Once projects involving the initial objectives have been implemented, ongoing funding

will be committed for maintenance and development (e.g. plantations, reserve management and research).

Achievements of the SCARP project, including projects commenced to December 1990, involving expenditure of $810 000, include the following.

RESEARCH

- A review and rewrite of unpublished past research has been completed and published (Loneragan 1990) ($37 000);
- A consultant is working on documenting remnant sandalwood in the Wheatbelt ($31 000);
- $170 000 has been directed to research projects through the Sandalwood Research Institute including research into Indian sandalwood (*S. album*) and W.A. sandalwood (*S. spicatum*).

CONSERVATION RESERVES AND MANAGEMENT

- In 1989 CALM purchased Jaurdi pastoral lease (320 000 ha) for sandalwood and nature conservation under the project ($65 000). In 1990 Mt. Elvire pastoral lease (154 000 ha) was also purchased ($85 000);
- Fencing has been completed, to control stock grazing, on Coonana and Wallaby Rocks Sandalwood Reserves in the Goldfields ($40 000);
- Conservation reserves containing sandalwood have been signposted to improve management ($10 000);
- The project has provided infrastructure for management of the existing industry including accommodation ($140 000) and equipment;
- Management work has been undertaken on purchased pastoral leases including building maintenance, fence repairs, cleanup and survey ($30 000);
- Kambalda Timber Reserve has been fenced and alternative water points provided to exclude stock grazing ($15 000);
- A 16 000-ha reserve has been created on Boolardy Station in the Murchison area in conjunction with the pastoral lessee, Land Conservation District and CALM. Fencing and survey have been completed ($25 000).

PLANTATIONS AND PLOTS

- A 20-ha plantation for Indian Sandalwood (*S. album*) is being established within the Ord irrigation area at Kununurra. The site has been prepared for irrigation. Planting has commenced using sandalwood and host seedlings raised at CALM's Broome nursery and by direct seeding ($45 000);
- Remnant stands of sandalwood in the Greenough area are being fenced in conjunction with landholders, regenerated and enrichment planted ($6 000);
- A field trial of Indian Sandalwood and various hosts has been established within the Ord Irrigation area, in conjunction with research being conducted by Murdoch University ($10 500);
- A 20-ha block has been purchased near Narrogin to establish a *S. spicatum* trial plantation and woodlot. Initial work for plantation development including site preparation for direct seeding and trials has commenced ($67 000).

EDUCATION

- A permanent display on sandalwood has been established at the Museum of the Goldfields ($25 000);
- Several publications and pamphlets on sandalwood have been produced ($6 000).

4.5 Implementation and Monitoring

Implementation of the management program will be achieved through an operational plan and the SCARP project.

A five-year operational plan reviewed annually will implement management, harvesting and marketing objectives and strategies. The SCARP project will implement objectives and strategies for reserves, research, plantations, regeneration and education.

Monitoring will be carried out by the Department of Conservation and Land Management regional staff, State sandalwood control officer, Sandalwood Field Forester with assistance from CALM's Research Division and the Sandalwood Research Institute.

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Approved for Reprint, 14th July, 1971.

WESTERN AUSTRALIA.

SANDALWOOD.

No. 27 of 1929.

(Affected by Act No. 113 of 1965.)

[As amended by Acts:
No. 43 of 1930, assented to 22nd December, 1930;
No. 13 of 1934, assented to 26th November, 1934;
and reprinted pursuant to the Amendments Incorporation Act, 1938.]

AN ACT to regulate the quantity of Sandalwood to be pulled or removed from Crown and other land.

[*Assented to 5th December, 1929.*]

BE it enacted—

Short title.

1. This Act may be cited as the *Sandalwood Act, 1929-1934*, and shall be read as one with the Forests Act, 1918, hereinafter referred to as the principal Act.

Power to limit quantity.

2. The Governor may from time to time, by Order in Council, limit and restrict the quantity of sandalwood that may be pulled or removed from Crown land and alienated land during a period therein stated.

Licenses. Amended by No. 113 of 1965, s. 8.

3. (1) No person shall pull or remove sandalwood—

(a) from Crown land, except under a license granted pursuant to regulations under the principal Act; or

90244/7/71—2750

(b) from alienated land, unless such person (being the grantee or lessee thereof, or a person lawfully claiming under him) is authorised to do so by a license in the prescribed form granted to him by the Conservator of Forests under this Act.

Penalty: Two hundred dollars.

(2) Licenses shall not be granted under paragraph (b) of subsection (1) of this section to authorise the pulling or removal of sandalwood in any quantity exceeding in the aggregate ten per centum of the total quantity as determined for the time being by Order in Council under section two.

(3) The granting of licenses under paragraph (b) of subsection (1) of this section shall be in the order of priority of application, and the allocation to each licensee of the quantity of sandalwood to be pulled or removed under license shall be determined by the Minister.

(4) In this section the words "alienated land" mean and include any land granted by the Crown for an estate in fee simple and any land held on conditional purchase or other lease or tenure under the provisions of the Land Act, 1898,[1] or the Mining Act, 1904, but shall not include any land granted or demised subject to the reservation to the Crown of sandalwood thereon.

Regulations.

4. The Governor may make regulations under the principal Act for the purposes of this Act, and by such regulations may (subject to such conditions as are prescribed) exempt from this Act any land in process of clearing for agricultural purposes.

Meaning of "Sandalwood".

Repealed and re-enacted by No. 13 of 1934, s. 2.

5. For the purposes of this Act the word "Sandalwood" means and includes the wood of any tree of the genera *Santalum* or *Fusanus*, and any other species of aromatic wood which is or may be used as a substitute for sandalwood.

[1]See now Land Act, 1933.

By Authority WILLIAM C BROWN, Government Printer

CONSERVATION AND LAND MANAGEMENT ACT
REGULATIONS (FORESTS) AS AMENDED[1]

SANDALWOOD

95. No license shall be granted for the cutting, pulling, or removal of living sandalwood trees on and from the following reserves and the area of Crown land defined hereunder:-

(a) Sandalwood Reserve No. 19211, Calooli.
Sandalwood Reserve No. 19212, Yellari.
Sandalwood Reserve No. 19214, Lakeside.
Sandalwood Reserve No. 19825, Bullock Holes.
State Forest No. 8, Karramindie.

(b) The Crown lands, or any portion of the Crown lands, within the area bounded by a line commencing from Kalgoorlie and extending along the Government railway line to Coolgardie, and thence along the Government railway line from Coolgardie to Widgiemooltha, thence across Lake Lefroy in a northeasterly direction to the Thirty-seven Mile peg on the Trans-Australian railway line, thence along the Trans-Australian railway line to Kalgoorlie.

96. No licensee, registered sandalwooder, or other person shall cut or pull or remove on or from Crown land any living sandalwood tree, or clean any sandalwood tree, so cut, pulled, or removed, of smaller dimension than as defined hereunder, that is to say, any sandalwood tree-

(a) of less than 330 millimetres in circumference measured over the bark at 150 millimetres from the ground level; or

(b) the log of which, when cleaned of sapwood, is less than 250 millimetres in circumference, measured at a point equivalent to 150 millimetres above ground level.

97. No person shall supply to any licensee or other person, in fulfilment of any order from such licensee or other person-

(a) any sandalwood tree of less than 330 millimetres in circumference measured over the bark at 150 millimetres from the ground level; or

(b) any sandalwood log which, when cleaned of sapwood, is less than 250 millimetres in circumference measured at a point equivalent to 150 millimetres above ground level.

being the product of any living sandalwood tree cut or pulled on Crown land.

98. The Executive Director may require any sandalwood to be inspected by an officer of the Department of Conservation and Land Management.

99. Application for a license to pull or remove sandalwood on and from land alienated from the Crown shall be made to the Executive Director in writing, and shall be accompanied by such particulars as the Executive Director may require.

100. Any person applying for a license other than the grantee or lessee of alienated land from which it is desired to pull or remove sandalwood may be required to produce to the Executive Director authority in writing from the grantee or lessee to pull sandalwood from the land therein specified.

101. A license to pull or remove sandalwood from alienated land may be in the Form No. 6 in the First Schedule to these regulations, and shall authorise the licensee to pull and remove the quantity of sandalwood therein specified on and from the alienated land therein defined.

102. (1) A license under regulation 101 of these regulations may be issued for any period not exceeding six months from the date thereof.

(2) No extension of any license shall be granted in the event of a licensee failing to fully exercise his rights by pulling and removing the quantity of sandalwood therein specified within the term of the license. But a licensee may make application for a further license in respect of sandalwood not pulled or removed under a previous license, and such an application shall be dealt with in order of its priority.

103. Repealed Government Gazette 27/2/87.

104. It is an offence for any person to furnish any false, incorrect, or misleading statements, particularly with reference to the ownership of alienated land, or the ownership of sandalwood on alienated land, with a view to obtaining a license under these regulations.

[1]At the time of publication of this management program, draft Forest Management Regulations under the CALM Act are being prepared. These regulations are expected to be gazetted later in 1991.

Form CLM 695

Appendix II

WESTERN AUSTRALIA

FOREST PRODUCE (SANDALWOOD) LICENCE NO:_____

District.....

THIS IS TO CERTIFY that.....

of.....is hereby

licensed to obtain sandalwood as follows.....tonnes Barked.....tonnes Pieces

From.....

(Description of Crown Land from where sandalwood is to be obtained)

This licence is current from..... to .....
(Date) (Date)

and is **NOT VALID UNTIL THE HOLDER OBTAINS AN ORDER** for this amount of sandalwood from the Australian Sandalwood Company Limited.

This licence is issued subject to the following special conditions.....

.....

.....

and to the General Conditions printed below.

Dated at .....this .....day of .....19.....

.....
Executive Director

per.....
Issuing Officer

GENERAL CONDITIONS APPLYING TO THIS LICENCE

1. "EXECUTIVE DIRECTOR" means the Executive Director of the Department of Conservation and Land Management.
2. This licence is not transferable to another person and must be produced upon request to any Officer of the Executive Director.
3. This licence is issued under and subject to the provisions of the Sandalwood Act, the Conservation and Land Management Act and the Regulations in force under these Acts.
4. The licensee must comply with the provisions of the Bush Fires Act.
5. The licensee is hereby authorised to obtain and remove only that forest produce for which this licence is issued from pastoral or other leases or holdings within the said licence area on which the rights to forest produce are reserved to the Crown.
6. The licensee is to be permitted free access both with or without vehicles at all reasonable times to enter upon, depart from and pass over such pastoral ot other leases or holdings for the purpose for which this licence is issued, but this licence does not authorise the licence holder to cut through, break down or otherwise interfere with any fencing or other improvements erected upon or adjacent to the licence area.
7. This licence does not release the licensee from liability to legal action in respect of any damage caused by the licensee, his workmen, agents or any other persons acting for or on behalf of the licence holder.
8. The licensee shall keep closed all gates used by him and shall take all necessary action to prevent the movement of stock into or from any area within the licence area enclosed by fences which may have been damaged as a result of his operations.
9. The licensee shall at his own expense diligently and without delay:
   (a) remove from all roads and tracks through or adjacent to the licence area or from any land the property of an adjoining owner, all logs or other debris of any description; and
   (b) make good any damage to roads, tracks, fences or other improvements;
   resulting directly or indirectly from his operations.
10. The licensee shall comply with all conditions printed on the back of his Order Form (CLM 265) and with any special conditions notified in writing either on the Order Form or to him by an Officer of the Executive Director.
11. This licence shall be produced on demand to the lessees of any pastoral or other leases or holdings (or their representatives) on which the licensee may be operating.

A BREACH OF ANY OF THE ABOVE CONDITIONS CAN RESULT IN THE LICENCE BEING CANCELLED FORTHWITH BY THE EXECUTIVE DIRECTOR

E73208/12/89—500 SETS—AS/952

CLM 265

ORDER FOR SANDALWOOD FROM CROWN LANDS

(NOT TRANSFERABLE)

Order No.....

To: .....

.....

.....

To be obtained from Crown Lands (other than areas reserved for the protection of sandalwood) in the vicinity of .....an amount of.....tonnes of sandalwood .....to be consigned to the Australian Sandalwood Co. Ltd., Lot 17 Mell Road, Spearwood. The above sandalwood must be delivered before .....19..... after which date this order will no longer be valid.

PAYMENT

Subject to the conditions relating to sandalwood production on the back of this order and any other condition or specification stipulated below the price paid will be $..... per tonne.

In addition:

(a) A transport subsidy at the rate of $..... per tonne will be paid; or

(b) the transport of sandalwood obtained under this order will be arranged by the Australian Sandalwood Co. Ltd.

(c) where the sandalwood obtained under this order is stacked in approved pallets for transport an allowance of $..... per tonne will be paid.

Payment will be made on the quantity of sandalwood delivered, based on Spearwood or other official weighbridge weights.

PENALTIES

This order is issued under the authority and is subject to the Conservation and Land Management Act and the Department referred to is the Department of Conservation and Land Management and the Executive Director is the Permanent Head of that Department.

Should it be shown that this order has been obtained as the result of misrepresentation or incorrect statement, or that any of the conditions are not being or have not been complied with, this order may be cancelled and the whole or any portion of the sandalwood pulled or the pieces collected under this order are liable to confiscation by Departmental officers or, in the event of delivery having already been accepted by the company, the Executive Director may direct that the whole, or any portion of the proceeds of such sandalwood shall be paid to the Department.

All sandalwood supplied must have the bark completely removed and where there is brittle, shelly, charred or worm-eaten wood this must also be removed until only sound wood remains. All pieces supplied must be free of earth.

In the event of any sandalwood being delivered to the company which is not considered to be of fair average quality or is not of the specifications as set out in this order, the Executive Director will be asked to assess its value and this decision will fix the price to be paid for such wood and will be final and binding upon the parties to this order.

The holder of this order must be fully aware of the conditions printed overleaf.

The Executive Director may direct that such additional conditions be complied with as he considers necessary for the protection of the environment in the particular circumstances at the time, and such conditions are notified in writing hereunder.

ADDITIONAL CONDITIONS (IF ANY).....

.....

.....

This order is issued on behalf of the
Australian Sandalwood Co. Ltd.,
9/6 Suffolk Street, Fremantle, 6160 by.....on.....

E73207/12/89—500 SETS—AS/3524

CONDITIONS

1. A current Certificate of Registration as a Timber Worker issued by the Department must be held by all persons engaged in the pulling or gathering of sandalwood.
2. Any quantity of sandalwood pulled or gathered in excess of the current order held is liable to confiscation by Departmental officers.
3. The holder of this order is personally responsible for any damage which results from his operations. This applies particularly to fences, mills, tanks and other improvements on pastoral leases.
4. "Before any camp is established on a pastoral lease the pastoralist or the manager must be notified by the holder of the order and its location discussed.
   The holder of the order must notify the pastoralist or the manager when commencing operations and when entering or leaving the lease. Reasonable liaison must be maintained with regard to sandalwood operations on the lease."
5. Camps are to be maintained in a clean and tidy condition with all refuse properly and regularly disposed of. When camps are removed the sites must be cleaned to the satisfaction of the Departmental officer.
6. No dogs will be permitted on a pastoral lease without written permission from the pastoral lessee or his manager.
7. No person shall cut down, pull out, injure or destroy any living sandalwood tree of less than 400 millimetres in circumference measured over the bark at 150 millimetres from the ground level, or any sandalwood tree growing:
   (a) Within a radius of 500 metres from any watering point.
   (b) Within a radius of 2 kilometres from any homestead or shearing shed.
   (c) Within 100 metres of the edge (table drain) of any major road.
   (d) Within 20 metres of the edge of any pastoral station service road.
8. The girth limit in condition 7 does not apply to fire killed sandalwood but where fire killed sandalwood shows any sign of coppice or root sucker growth the dead tree must be cut at ground level and such new growth left undisturbed.
9. "All other sandalwood trees removed to fulfill orders must be pulled from the ground. All green limbs containing heartwood down to 25 millimetres in diameter, all living roots down to 25 millimetres in diameter and all dead wood containing heartwood must be included in the consignment."
10. Pieces are dead sandalwood stems which have weathered externally to a grey colour.
11. Pieces must be pulled from the ground and under no circumstances are they to be cut off at the base.
12. The holder of an order must work systematically through the bush removing all green and dead sandalwood within the specifications listed above so as not to waste any sandalwood which is within the specifications as laid down and which legally can be pulled or gathered.
13. The Executive Director may direct that such special conditions be complied with as he considers necessary for the protection of the environment in the particular circumstances at the time and such conditions, if any, will be notified in writing on this order in the space provided.

Appendix IV

STATUTORY RESERVES THROUGHOUT THE RANGE OF SANDALWOOD WITHIN 1980-84 ASSESSMENT REGIONS, OUTSIDE THE AGRICULTURAL AREAS, AT DECEMBER 1990

Region/Type/ Name	*Number*	*Vesting*	*Area (ha)*	*Purpose*	*Sandalwood Occurrence*
'A' GOLDFIELDS REGION					
National Parks					
Goongarrie	A35637	NPNCA[a]	60 335	Mulga woodland near the Eucalypt-Mulga Transition	Good sandalwood in east, some burnt.
State Forests and Timber Reserves					
Majestic	195/25	LFC[b]	2 226	Flora, Fauna and Landscape Conservation. Habitat, dimensions of Salmon Gums woodland. Virgin.	Good patches only.
Randell	194/25	LFC	16 350	Flora, Fauna and Landscape Conservation. A variety of inland forest and scrub types, mainly virgin in an extensive area of regrowth forest.	Good patches only.
Kambalda	199/25	LFC	3 342	Flora, Fauna and Landscape. Conservation. Undisturbed forest, ecological diversity, multiple use potential.	Good sandalwood.
Kangaroo Hills	198/25	LFC	6 657	Flora, Fauna and Landscape Conservation. Preservation of E. campaspe and E. clelandii. Historical and tourist interest.	Good sandalwood.
Karramindie	SF No. 8	LFC	781	Flora, Fauna and Landscape Conservation. Sandalwood State forest for long-term study of growth of sandawood.	Excellent sandalwood. Good regeneration.
Sandalwood Reserves					
Emu Rock	C19645	L ACT (NV)[c]	8 186	Sandalwood conservation.	Excellent sandalwood with reasonable regeneration.
Wallaby Rock	C19764	"	4 556	"	"
Coonana	C19640	"	37 061	"	"
Bullock Holes	C19825	"	13 313	"	"
Lakeside	C19214	COF[d]	3 787	"	"
Calooli	C19211	"	3 121	"	"
Yallari	C19212	"	6 102	"	"
Scahill	C19621	"	6 916	"	"
Other Reserves					
Kalgoorlie Green Belt (20 km radius)		Various (NV)	83 000	Green timber conservation.	Good sandalwood
Reserve Land Kalgoorlie - Coolgardie-Widgiemooltha [Regulation 95 b] Excluding Hampton areas and other reserves.		Various (NV)	260 240	Sandalwod conservation.	Excellent sandalwood.

Appendix IV (Continued)

Region/Type/ Name	*Number*	*Vesting*	*Area (ha)*	*Purpose*	*Sandalwood Occurrence*
Sandalwood Occurrence					
Nature Reserves					
Rowles Lagoon	A4274	NPNCA	404	Water & Fauna	Isolated stems only.
Clear & Muddy Lakes	C7634	NPNCA	1 926	Flora & Fauna	Isolated stems only.
Kurrawang	C35453	NPNCA	621	Flora & Fauna	Good sandalwood.
Kambalda	C33300	NPNCA	3 650	Flora & Fauna	Good sandalwood.
Binaronca Rock	C32552	NPNCA	185	Flora & Fauna	Isolated sandalwood stems only.
Victoria Rock	A8480	NPNCA	258	Flora & Fauna	"
Dordie Rock	C3211	MWR	121	Water, Flora & Fauna	"
Cave Hill	C17804	MWR(e)	202	Water, Flora & Fauna	"
Burra Rock	C7038	MW(f)	809	Water, Flora & Fauna	"
Cardunia Rock	A39148	NPNCA	38	Flora & Fauna	"
'B' MURCHISON DISTRICT					
Karroun Hill Nature Reserve	A36936	NPNCA	309 000	Conservation of Flora & Fauna.	Good scattered sandalwood.
Kadji Kadji	1/10	LFC	6 355	Conservation of Timber	Scattered sandalwood.
Timber Reserves	2/10	LFC	19 983	"	"
'C' PASTORAL LANDS & DESERTS					
National Parks					
Collier Range	A35104	NPNCA	277 841	Representative Upper Gascoyne River Range, country ungrazed.	Scattered sandalwood in creeks only.
Boorabbin	A35004	NPNCA	26 000	Typical heathland of the sandplains east of the Wheatbelt.	Isolated stems only.
Kalbarri	A27004	NPNCA	186 071	Coastal cliffs, Murchison River gorges and sandplain.	Scattered in east only (10 000 ha)
Nature Reserves					
Wanjarri Nature Reserve	A30897	NPNCA	53 248	Flora & Fauna	Scattered sandalwood stems only.
Queen Victoria Spring	A30491	"	272 607	Flora & Fauna	Scattered sandalwood in the west.
Yeo Lake	A36271	"	321 946	Flora & Fauna	Scattered sandalwood.
Mangkili Clay Pan	A34604	"	3 635	"	Isolated stems.
Gibson Desert	A34606	"	1 859 286	"	Scattered stems in south and west (600 000 ha).
Part Jilbadgi	A24049	"	208 863	"	Scattered sandalwood in north (58 000 ha).
Toolonga	40628	"	405 424	"	Isolated sandalwood stems, scattered stems in west.
Other Reserves					
Part Peron Pastoral Lease	3114/761	PL	105 200	Proposed pastoral lease and national park.	Good sandalwood in south, scattered in north and east.
Boolardy Station	3114/406	PL	16 000	Sandalwood Flora and Fauna	Conservation area, open country paddock.

Appendix IV (Continued)

Region/Type/ Name	*Number*	*Vesting*	*Area (ha)*	*Purpose*	*Sandalwood Occurrence*
'D' YILGARN DISTRICT					
Sandalwood Reserves					
Kangaroo Rocks	C30445	L Act (NV)	8 814	Sandalwood Conservation	Good sandalwood.
Sandalwood Occurrence					
Nature Reserves					
Duladgin Rock	C2179	NPNCA	1 363	Conservation Flora & Fauna	Isolated sandalwood stems.
	C2112	MWR	259	Water, Conservation Flora & Fauna	"
Wedwarie Rock	C3112	MWR	259	Water, Conservation Flora & Fauna	"
Deborah East	A36918	NPNCA	13 750	Conservation Flora & Fauna	Good sandalwood in patches.
Mt Manning Range	C36208	NPNCA	153 293	"	Good sandalwood.
Biljahnie Rock	C29920	NPNCA	1 036	"	Isolated stems.
Condarnin Rock	C29823	NPNCA	323	"	"
Walyahmoning Rock	A35752	NPNCA	20 925	"	Scattered sandalwood.
Other Reserves					
Jaurdi Station	3114/1072	PL (CALM)(g)	321 399	Sandalwood conservation.	Excellent sandalwood.
Mt. Elvire Station	3114/679	PL (CALM)	154 267	"	"
'P' PLUMRIDGE LAKE					
Part Plumridge Lake Nature Reserve	A34605	NPNCA	308 990	Conservation, Flora & Fauna	Excellent sandalwood in east (107 000 ha).
'O' NORTHERN PASTORAL LANDS, SOUTHERN EUCALYPT WOODLANDS AND NULLARBOUR					
Part Plumridge Lake Nature Reserve	A34605	NPNCA	308 990	Conservation, Flora & Fauna	Isolated stems only in west (202 000 ha).
Part Jilbadgi	A24049	"	208 863	Flora and Fauna	Isolated stems only in south (150 000 ha).
Part Great Victoria Desert	A30490	"	2 495 777	Conservation, Flora & Fauna	Isolated stems only in the west and south (1 000 000 ha.)
National Parks					
Frank Hann	A27023	NPNCA	61 420	Cross section of inland sand plain and heath flora, east of the Wheatbelt.	Isolated sandalwood only.
Mt. Augustus	A41051	NPNCA	9 170	Mt. Agustus major rock feature.	Isolated stems only.
Part Hammersley Range	A30082	"	617 606	Gorges, watercourses, hills and mountains in the Pilbara	Isolated sandalwood in the south (30 000 ha).

FOOTNOTES

(a) NPNCA - National Parks and Nature Conservation Authority
(b) LFC - Lands and Forests Commission
(c) L Act (NV) - Lands Act (Non Vested)
(d) COF - Executive Director of CALM
(e) MWR - Minister for Water Resources
(f) MW - Minister for Works
(g) PL - Pastoral Lease

Appendix V

CALCULATION OF ANNUAL SANDALWOOD INGROWTH FROM 75-125 MM SIZE CLASS TO MERCHANTABLE SIZE STEMS (>125 MM DIAMETER).

Region	*Area available for harvesting (ha x 10^3) (a)*	*Average stocking (s.p.h.) of 75-125mm diameter* size class (b)	*Total No. of 75-125 mm size class* (x 10^3)	*Number ingrowing annually* (x 10^3) (c)	*Weight of annual ingrowth (tonnes)* (d)
Goldfields					
'A'	4 160	0.73	3 040	61	670
Murchison					
'B'	2 400	0.331	790	16	170
Other pastoral lands and deserts					
'C'	29 000	0.126	3 650	73	800
Yilgarn					
'D'	910	1.202	1 090	22	240
Plumridge Lake					
'P'	260	0.86	220	4	40
Northern pastoral lands, southern Eucalypt woodlands and Nullarbor					
'O'	15 200	0.004	50	1	10
TOTAL	51 930	0.17	8 840	177	1 930

(a) Available area as calculated by regions see Table 3.

(b) Average stocking (stems per hectare - s.p.h.) of 75-125 mm diameter size class from 1980-84 assessment data.

(c) Number ingrowing annually calculated using a growth rate of 1 mm per annum (Loneragan 1990). Annual ingrowth to >125 mm size class = Total No. in size class ÷ 50.

$$50 = \frac{\text{Size class width (125-75 = 50 mm)}}{\text{Annual growth rate (1 mm)}}$$

(d) Weight of annual ingrowth is calculated as number of annual ingrowth x weight per stem (11 kg). A weight of 11 kg per stem derived from Figure 2 using 125 mm diamter.