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Evolution of silvicultural practices in the jarrah forest of Western Australia

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ABSTRACT: This paper examines the evolution of silvicultural practices in the jarrah forest of south-west Western Australia, from initial exploitation in the 1870s through to the silvicultural practices of 2004.
Six eras in the evolution of silvicultural practices in the jarrah forest are recognized, the first five of these being: uncontrolled cutting from the 1870s to 1920; earlier application of silvicultural principles and use of the group selection method from the 1920s to 1940; less intensive but more extensive cutting from 1940 to the mid 1960s; a slight intensification from the mid 1960s to 1984; and the reintroduction from 1984 to 2003 of silvicultural methods based on groups of trees that could be managed to achieve particular objectives i.e. promote growth on regrowth trees, establishment of regeneration or release of regeneration.
During the period 2001-2003, the silvicultural practices of the jarrah forest were reviewed through a comprehensive review process that ran in parallel with the development of the Forest Management Plan 2004-2013. A key feature of the new practices is enhanced provision for conservation of biodiversity through increased retention of habitat, limits on culling and greater controls on disturbance to the secondary storey, understorey and the soil. Other key changes include more systematic monitoring and surveying of seed crops, greater use of sprouts from cut stumps for stand regeneration, selective use of planting of seedlings, refinements to target stand density levels, adaptations to apply in the eastern jarrah forest, and refined management of areas infested with *Phytophthora cinnamomi*. These changes to silvicultural practice represent the start of the sixth era in the evolution of silvicultural practices in the jarrah forest.
Silvicultural practices have evolved over the last century in response to factors such as improved or new information on the silvics of jarrah or elements of biodiversity, availability of resources to undertake silvicultural treatments, demand for wood products, the desire to increase access to facilitate fire management, management of forest health, the introduction of bauxite mining, the recognition of the need to specifically cater for a range of non-wood forest values such as water and landscape values, and community perceptions in relation to issues such as waste of wood resources and biodiversity conservation.

1 THE JARRAH FOREST

The forests of the lower south-west of Western Australia are dominated by two tree species, jarrah (*Eucalyptus marginata*) and karri (*Eucalyptus diversicolor*). The jarrah forest has a current extent of some 1.8 M hectares compared to its estimated pre-1750 extent of some 2.8 M hectares. Nearly

1.6 M hectares occur on land vested in the Conservation Commission of Western Australia and managed by the Department of Conservation and Land Management (CALM) (Conservation Commission 2004). The jarrah forest is classified as medium open forest on the basis of height and canopy density (10-30 m in height, 30-70 % canopy cover) and is dominated by the jarrah tree although marri (*Corymbia calophylla*) also occupies a large part of this area. On more fertile and well watered sites jarrah can grow to 40 m in height, with a straight bole to 18 m and a diameter of up to 2 m, whereas at the dry end of its range it occurs as a tall shrub, often with a mallee habit. In contrast to the floristic paucity of the tree strata, the jarrah forest floor is covered by a diverse subshrub and shrub layer to 2 m in height (Bell and Heddle 1989).

2 HISTORY OF SILVICULTURAL PRACTICES

Silviculture is concerned with the theory and practice of managing the establishment, composition, growth, health and quality of forests to achieve specified management objectives. The history of silvicultural practices in jarrah forest has been described by Havel (1989), Stoneman *et al.* (1989) and Bradshaw (1999) and can be considered as forming a number of eras. The following sections give a brief summary of the silvicultural history, for the purpose of providing context for the later sections on the more recent evolution of silvicultural practices. The focus of the sections 2.1 to 2.5 is on areas that have remained as Crown land rather than cutting associated with clearing for agriculture. A glossary is provided to assist understanding of technical terms.

2.1 *Prior to 1920*

This period is characterized by largely uncontrolled timber cutting (Robertson 1959, Mills 1989) resulting in very heavy cutting (effectively a clearfell) on high quality sites ranging to a light selective cut on sites with a low density of trees that sawmillers wished to cut. Because of the uncontrolled nature of the industry at this time, there was in effect no silvicultural component to the cutting practices.

Most of the areas cut during this period were in the western part of the northern jarrah forest (Heberle 1997). This cutting generally produced effective regeneration in the heavily cutover areas, resulting from ground coppice that was present on the forest floor at the time of cutting. In the more lightly cutover areas the uncut trees impeded regeneration and the need for post-harvest silvicultural treatment to remove these culls was recognized by some, though not implemented at other than an experimental scale.

The management of fire for silvicultural purposes was not undertaken and uncontrolled post-harvest fires caused extensive damage to both the regrowth and to the remaining trees in selectively cut stands.

Whilst regulations established in 1896 and 1905 specified that only jarrah trees greater than 48 cm diameter and 72 cm diameter, respectively, could be felled, the lack of resources and political commitment meant that these regulations were not enforced (Robertson 1959).

2.2 *1920s to 1940*

With the establishment of the Forests Act (1919) came the first opportunity for any control of timber harvesting and silvicultural management. The general management objective was to establish the sawmilling industry in the jarrah forest on a sustained yield basis, with more specific objectives for the Mundaring and Collie working circles (Forests Department 1926, 1929). Initially, a girth limit method was used, whereby only jarrah trees greater than 72 cm diameter could be felled. A group selection method was implemented and by 1927 resources were sufficient to ensure it was implemented in most areas. The method focused on harvesting groups of senescent trees and leaving groups of younger trees uncut. Most of the areas cut during this period were east of the areas cut in the previous period, and in the middle part of the northern jarrah forest (Heberle 1997). The following sequence of operations became standard practice for the groups of senescent trees:

advance burning; treemarking by a trained officer; harvesting by industry; tops disposal; regeneration burn; and fire exclusion for a period. A fire management plan was also implemented and this supported the other silvicultural practices, given the constraints on a more active fire management policy (McCaw and Burrows 1989).

The size of gaps used in the group selection method was highly variable during this period, varying from 0.2 hectares to more than 1000 hectares (Bradshaw 1999).

A substantial program of thinning, coppice cleaning and cull removal was undertaken in sapling and pole stands, particularly during the Depression years of the early 1930s when up to 1500 men were employed to undertake these operations. During this period of the 1930s the area that received such treatment was greater than the area being cutover, thus addressing to some extent the backlog of areas suitable for this type of silvicultural treatment. Some 169,000 hectares was treated during the period 1922 to 1941 (Bradshaw 2004).

The silvicultural practices in this period also included the partial ringbarking of seed trees in areas with an insufficient stocking of advance growth. The ringbarking was intended to induce seedfall and lead to establishment of jarrah seedlings.

The main intent of silvicultural practices was to sustain an ongoing supply of timber. The group selection method was used as it suited the silvicultural characteristics of jarrah, the condition of the forest, and the industry requirements. Stoate (1923) argued that a clearfell method would have better suited the silvicultural characteristics of jarrah but that this was not appropriate because of the waste of timber that would be associated with the method under the prevailing industry conditions. In the Mundaring area a primary silvicultural objective was to maintain water values (Forests Department 1926), and in the Collie area the objective was to provide mining timber for the coal mines.

2.3 *1940 to mid 1960s*

Management objectives focused on stabilizing the timber industry to ensure continuity of operations and regular employment, and the long life for the timber trade on which the development of the south west relied (Forests Department 1945, 1956). The silvicultural method moved to a single tree selection method during this period with little emphasis on creation of gaps and groups of regeneration. This resulted in an increase in the area cut-over each year for an equivalent volume of timber removed. Tops disposal and post-harvest burning were still undertaken. However, the post-harvest silvicultural treatments of cull removal, regeneration cleaning and thinning were discontinued, with the exception of some work undertaken by internees in forest camps during World War II. The changes in practice were associated with a desire to open up access for fire management, a shortage of labour and funds for post-harvest silvicultural treatments, a desire not to waste cull jarrah and marri trees for which a market may eventuate, and to conform to management criteria of a 30 year cutting cycle. A rotation length of about 180 years was considered appropriate (Meachem 1962).

The fire protection strategy for regrowth began to falter and prescribed fires were introduced regardless of the status of regeneration.

2.4 *Mid 1960s to 1983*

The objective of management of the 1956 plan was to stabilize the timber industry, ensure continuity of timber getting operations, and bring the cutting of the forest to a sustained yield basis (Forests Department 1956). The objectives of the 1971 plan was to

> … regulate the cut from Crown lands so as to provide for anticipated demands in the next 20 years and to ensure the greatest degree of continuity in terms of economic production and employment in the timber industry within the framework of estimated longterm yield (Forest Department 1971).

Management objectives broadened considerably in later plans into a clear emphasis on multiple use management objectives in the plans of 1977 and 1982 (Forests Department 1977, 1982). During this period the silvicultural method remained as a single tree selection in stands with a mature stand structure, although the intensity of the harvest increased relative to the 1940 to mid 1960s era. Harvest intensity increased following the 1961 fires, to reduce the area of regeneration requiring protection from fire, and later to reduce the risk of spread of *Phytophthora cinnamomi* which had been identified as the cause of jarrah dieback, and also to salvage the smaller sized trees rather than risk this resource not being utilised. Development of regeneration was generally ineffective because of competition from remaining trees, with the exception of some high quality stands where commercial harvest was sufficient to create small but effective gaps for regeneration. The harvesting of marri for pulpwood led to the introduction of a heavier cut from 1976 in the southern forest.

Mapping of dieback occurrence was introduced and areas severely impacted by jarrah dieback were salvage cut and converted to stands of resistant exotic eucalypts or pine. In the western part of the northern jarrah forest the rehabilitation of dieback-affected areas was phased out because of the importance of these areas for water supply (Havel 1989). Later in the period 70 mm aerial photography was implemented to map dieback occurrence and assist in the silvicultural decision.

The Intensive Management Unit concept was developed to focus silvicultural resources onto high quality forest with the least occurrence of jarrah dieback. The advent of hormone herbicides meant that effective thinning could be undertaken by notching standing cull trees with herbicide and some 25,000 hectares of pole stands were non-commercially thinned using unemployment relief funds (Havel 1989, Kimber 1967). Post-harvest silvicultural treatments were not implemented more widely because of the uncertain future for the forest because of jarrah dieback and the advent of bauxite mining.

Late in this period the Forest Improvement and Rehabilitation Scheme was implemented to thin the jarrah overstorey and remove the dieback susceptible secondary storey, mainly in areas around those mined for bauxite. A bauxite mining company funded the scheme. According to Havel (1989) areas treated under this silvicultural method peaked in 1980 at nearly 7,000 hectares per year.

The recognition and demand for non-wood values of the forest increased through this period and led to the introduction of Management Priority Areas for conservation of flora, fauna and landscape values in State forest (Forests Department 1977, 1982). The heavier cut in the southern forest from 1976 also led to the adoption of road, river and stream zones in the Woodchip Licence Area to protect water, aesthetic and fauna values (Forests Department 1973, CALM 1987a).

2.5 *1984 to 2003*

2.5.1 *Management objectives*

The multiple use and priority use management objectives of the 1982 General Working Plan were further developed in the 1987 regional management plans (Forests Department 1982, CALM 1987a,b,c). The 1994 Forest Management Plan continued the multiple use management objective, and included objectives for ecological sustainability, community consultation, biodiversity conservation, best practice management, tourism and recreation, and a knowledge objective including awareness and appreciation of forest values. The 1994 plan also outlined the silvicultural approach to be used in the jarrah forest, which included a forest structure goal, limits on size of gaps, retention of habitat trees, management of visual impacts and constraints on harvesting intensity and coverage to manage potential impacts on water quality.

2.5.2 *Review of 1983/84*

In 1983 and 1984 an internal departmental review of silvicultural knowledge and practices concluded that the single tree selection method used for the previous four decades had not effectively developed or released regeneration in cut-over areas and that subsequent fires in areas with a mixture of growth stages resulted in damage to the younger growth stages. The review led to the reintroduction of silvicultural methods based, wherever possible, on groups of trees that could be managed to achieve particular objectives e.g. promote growth on regrowth trees (thinning), establish

regeneration (shelterwood) or release regeneration (gap) (Bradshaw 1985, 1986). A period of fire exclusion was also introduced for regrowth at this time. A Silviculture Branch was established in 1985 with responsibilities for development of silvicultural strategies and guidelines, staff training and monitoring the standard of silvicultural practice.

2.5.3 *Silvicultural methods*

Five silvicultural methods were employed during this period.

Thinning was undertaken in regrowth stands where trees would respond in growth. Gap cutting was used where stand structure was mature and sufficient numbers of advance growth for immediate release were present. Shelterwood cutting was undertaken where stand structure was mature and where sufficient numbers of advance growth were not present and regeneration needed to be established. This was the first time that this method was used in jarrah forest, although the use of seed trees to establish regeneration had been undertaken in the 1920s and 1930s. Cutting of areas impacted by dieback was undertaken with a selective cut. The fifth silvicultural method was a single tree selection method, which was really a consequence of the high component of culls in thinnings, gaps and shelterwoods resulting in the objectives of these methods not being achieved and a single tree selection being the outcome. Additionally, specific silvicultural treatments around bauxite mining areas continued to be implemented. To 1989 the main treatment in terms of areal coverage was the banksia population reduction treatment (part of the Forest Improvement and Rehabilitation Scheme), but this ceased after 1990 whereas the treatment of graveyard dieback areas continued under a program that became known as Dieback Forest Rehabilitation.

The reintroduction of more intensive silvicultural methods led to consideration of what would be an appropriate maximum size for gaps and the recognition of the need to consider a range of non-wood forest values. A 10-hectare maximum size was adopted in 1981. Rotation length was set at about 200 years for most of the regrowth jarrah forest (Turner *et al.* 1999). Non-wood values were catered for through setting aside areas from timber harvesting, through the formal and informal reserve system, which were expanded in 1987, 1994 and 1999 (CALM 1987a,b,c, LFC 1994, Commonwealth of Australia and State of Western Australia 1999) and later in this period through silvicultural practices that addressed stand structure, habitat, water and aesthetic values.

2.5.4 *Changes in silvicultural practice over the period*

The range of values for which silvicultural methods were designed to specifically address increased through this period and the application of silviculture became more complex through the rapid development of a series of silvicultural guidelines and adaptive changes to practice. Through the 1980s these adaptive changes focused on facilitating regeneration, appropriate stand density for tree growth, protection from fire and management of dieback-affected areas. During the 1990s, changes to practice focused to a greater extent on providing for other forest values, namely aesthetics, water and biodiversity, as well as further refining practices developed during the 1980s in relation to regeneration, stand density, fire and dieback. The series of adaptive changes to silvicultural practices are described further below.

The silvicultural methods of creation of gaps to develop regeneration, and thinning to promote growth on retained trees, for application to the northern jarrah forest were developed in 1983 (Forests Department 1983). In 1985, integrated harvesting operations were proposed as a means to ensure that harvesting was integrated with the required post-harvest silvicultural treatment. A 10-hectare limit on gap size was recognized in the Northern Forest Region and a training brief was published which guided the application of thinning, gaps and shelterwood to all jarrah forest (CALM 1985). In 1986, silvicultural guidelines for the southern jarrah forest were implemented, which included temporary exclusion areas between gaps, advance burning to detect advance growth to facilitate the use of the appropriate regeneration method, minimum stocking standards for regeneration, and fire protection for released regeneration (Bradshaw 1986). 1986 also saw the introduction of a variation to thinning intensity according to tree size whereby the target stand density increased with increasing tree size class (CALM 1986).

In 1987 the training brief was revised and included a decision model for when to apply particular silvicultural methods (CALM 1987d). Two silvicultural guidelines were also prepared, which included guidelines for application of silviculture to dieback-infested areas, based on the impact of the disease on the site (CALM 1987e,f). The intent of Silvicultural Specification 2/87 was to treat dieback infested areas with 'conservative optimism'. On low to moderate impact sites, a basal area of 15 square metres per hectare was to be retained, focusing on dieback tolerant species, whereas on high and very high impact sites dieback tolerant species and other non-merchantable small jarrah crop trees were to be retained with planting of dieback tolerant species in understocked patches. In 1988 a more generalized approach to silvicultural treatment of dieback-affected areas was adopted (CALM 1988), where under Silvicultural Specification 2/88 a basal area of 15 square metres per hectare was to be retained, focusing on dieback tolerant species on high impact sites and jarrah on low impact sites, retention of any healthy jarrah that had survived for a long period on very high impact sites, and with planting of dieback tolerant species in understocked patches. In 1989, four silvicultural guidelines were published. Silvicultural Specification 3/89 was for dieback affected areas in the Central and Northern Forest Regions, and included the need to protect existing regrowth, and the standard for stocking of regrowth was reduced from 1000 to 400 stems per hectare (CALM 1989a). Silvicultural Specification 4/89 also concerned dieback affected forest, and provided for seeding in prepared swathes, to a defined standard (CALM 1989b). Silvicultural Specification 5/89 introduced the requirement to retained habitat trees at the rate of 15 per 5 hectares, and ground habitat logs at the rate of one per hectare, so as to maintain habitat for hole nesting fauna species in jarrah forest used for timber production (CALM 1989c). Silvicultural Specification 7/89 defined the requirements for temporary exclusion area between gaps and post-harvest silvicultural treatment (CALM 1989d).

In 1990, methods for surveying regeneration and the standards of regeneration were established (CALM 1990). Silvicultural Specification 3/90 required pre-logging surveys to demonstrate adequate advance growth before a decision to cut to a gap, required initial establishment surveys in shelterwood cut areas to determine whether remedial measures would be needed, and required surveys to monitor the development of regeneration in shelterwood cut areas. Silvicultural Specification 1/91 identified a range of fire regimes to achieve specific silvicultural outcomes (CALM 1991a) and covered pre-harvest burns, post-harvest burns, rotational fuel reduction burns and strategic fuel reduced buffers. The specification included the requirements for tops disposal burning, burning to release regeneration in areas cut to gaps, and regeneration burning to establish regeneration in shelterwood cut areas. The specification also included guidance on how to achieve integrated fire management in area cut to a range of silvicultural methods. Silvicultural Specification 2/91 incorporated habitat requirement into the main guideline, specified how thinning would cater for the risk of salinity by retaining more trees than in areas with a low salinity risk, and how gap size and thinning intensity would be reduced to accommodate aesthetic values in management zones with higher aesthetic values (CALM 1991b).

Forest structural goals, stand structural complexity requirements, and constraints on the intensity and areal extent of harvesting to protect water values in lower rainfall areas were introduced in 1994 through the Forest Management Plan 1994-2003 (LFC 1994). The structural goals aimed to maintain: at least 25 percent on the total area of jarrah forest managed by CALM as minimally disturbed areas (conservation reserves); at least 5 percent as low disturbance areas (informal reserves and exclusion areas); moderate disturbance areas where no more than an average of one percent of the multiple use jarrah forest would be converted to the establishment phase per year, which in time would provide 40 percent of this disturbance class as mature and senescent stands, 40 percent as immature stands, 15 percent as juvenile stands and 5 percent in the establishment stage; and a high disturbance category that provided for the loss of native forest to land uses such as open cut mining. Water values in lower rainfall areas were addressed by requiring a minimum of 30 percent of the forest be retained unharvested, or thinned to a minimum basal area of 15 square metres per hectare, in any 15-year period.

In 1995, changes were made to the jarrah guidelines to include extensively managed areas,

improved definition of habitat trees, and changes to visual resource management in relation to protection of water values (CALM 1995). Silvicultural Specification 1/97 amended the requirement for advance burning and also for post-harvest burning (CALM 1997a). 1997 also saw the introduction of records of forest structure during regeneration surveys, regeneration standards that included marri and a wider range of forms of advance growth, and stocking standards for infill planting (CALM 1997b). Silvicultural Guideline 1/99 was applicable to all areas of jarrah forest and introduced requirements for the timing of fire in shelterwood cut areas to facilitate seed-fall and seedbed preparation (CALM 1999). Under this guideline dieback infested jarrah forest was to be treated to the same silvicultural objective (gap, shelterwood or thinning) as uninfested forest, but with an additional requirement to retain dieback resistant species.

2.5.5 *Areas cut to silvicultural methods*

Over the period 1990 to 2003, the average annual area cut to each of the silvicultural methods was: 2,400 hectares to thinning; 3,700 hectares to gaps; 5,200 hectares to shelterwood; 2,200 hectares to selective; and 1,200 hectares to single tree selection. Clearing for mining and utilities accounted for about 600 hectares per annum of State forest areas harvested for timber. The application of these silvicultural methods varied markedly across the jarrah forest with an emphasis on cutting to gaps and shelterwood in the southern forest, and to shelterwood and thinning in the northern forest. This variation in use of methods was related to stand structure with the more mature stands of the southern forest being suitable for regeneration methods and the regrowth stands of the northern forest being more suitable for thinning. The emphasis on cutting to gaps, and the perception that this was implemented with insensitivity to non-wood values in the southern forest, led to considerable community concern. In 2001, Government policy changed and all old growth forest were reserved or otherwise set aside from harvesting.

Some 5,000 hectares was treated under the Forest Improvement and Rehabilitation Scheme over the period 1979 to 2003 and some 3,000 hectares of dieback graveyard was also treated (Alison Steele, Alcoa Australia, personal communication). The Dieback Forest Rehabilitation program treated an average of between about 100 and 150 hectares per year over the period 1994 to 2003 (Alison Steele, Alcoa Australia, personal communication).

Unlike thinning undertaken in earlier times, the treatment had become standard practice as part of timber harvesting (commercial thinning) with a follow-up non-commercial treatment. The shelterwood treatment was not extensively implemented initially but then became widely used (CALM 2000).

2.5.6 *Community interest in silvicultural practice*

From the 1970s community interest in forest management increased (Routley and Routley 1973) with much of this being directed at establishment of a conservation reserve system, concerns at clearing native forest for establishment of plantations, wood utilization, and woodchipping and clearfelling in karri forest (Oldfield 1977, Thamo and Sharp 1984, Mulcahy *et al.* 1988, EPA 1992). Little community interest in silvicultural practices in the jarrah forest was evident until the late 1980s.

Thamo and Sharp (1984) supported an increase in the amount of thinning and intensification of silvicultural practices in jarrah forest in preference to pine plantation establishment because of the conservation values provided by native forests and their tolerance to fire relative to plantations. This represented the first time there was significant interest in silvicultural practice in jarrah forest by other than scientists, field foresters or those involved in the timber industry. Over the late 1980s and subsequent years the level of community interest in relation to silvicultural practices in jarrah forest increased markedly (Sharp 1995, WAFA 1991, WAFA 1998, Sharp 2001). The main issues related to the cutting of gaps, the increased use of the shelterwood method, protection of biodiversity values, consideration of non-wood values, use of herbicides, and removal of cull trees.

3 2001 TO 2004 REVIEW OF JARRAH SILVICULTURE

Over the period 2001 to 2004 a major review of silvicultural practices in jarrah forest was undertaken. A number of existing silvicultural guidelines were reviewed and incorporated into the Forest Management Plan 2004-2013 (Conservation Commisison 2004) and the proposed new guideline *Silvicultural Practice in the Jarrah Forest* (CALM in prep).

3.1 *The review process*

The process of review of the existing guidelines and development of the proposed new guideline has been extensive and included the following steps: consideration of numerous changes proposed within the Department over the previous seven years; a departmental workshop on environmental effects of timber harvesting in the jarrah forest (CALM 2003); the Department's final compliance and progress report on the Forest Management Plan 1994-2003, including reporting on recommended modifications to guidelines (CALM 2003); the report by Burrows *et al.* (2001) 'Ministerial Condition 11: Panel Report Part 1'; the report by Burrows *et al.* (2002) 'Towards ecologically sustainable forest management in Western Australia – A review of draft jarrah silvicultural guideline 1/02 – Panel Report Part 2 for the Conservation Commission of Western Australia; advice and reports by F.J. Bradshaw, a consultant to the Department; the process of development of the Forest Management Plan 2004-2013, including its consultation processes and opportunity for public comment and consultation on silvicultural practices and proposed changes to silvicultural guidelines; the development of the proposed new guideline by a working group of senior officers from the Sustainable Forest Management Division, and a representative from the Forest Products Commission, including consultation with numerous experts from other sections of the Department; consultation with appropriate State Government agencies on the January 2004 draft of the guideline; and a review of the proposed new guideline by representatives of several branches within the Department.

The proposed new guideline will be released for public consultation. Following consideration of comments on the guideline, the document will be submitted to the Conservation Commission for advice and approved by the Minister for the Environment.

3.2 *Key changes to practice*

Some of the more significant changes to silvicultural practices included in the new guideline are described below. Most of these changes were introduced in the Forest Management Plan 2004-2013 (Conservation Commission 2004).

3.2.1 *Changes introduced in the Forest Management Plan 2004-2013*

The guideline places greater emphasis on protection of understorey and mid-storey elements than previous guidelines. The requirements include: pushing of understorey species by heavy machinery to promote regeneration of jarrah will only be undertaken in areas where there is clear evidence of the past presence of jarrah, such as old stumps; the preserving of thickets of balga (*Xanthorrhoea preissii*); push down treatments of the understorey are to focus on groups or clumps of species such as bull banksia (*Banksia grandis*) and sheoak (*Allocasuarina fraseriana*) that are impeding regeneration establishment and require the retention of elements as small clumps or as scattered individuals; scattered mature individuals of a range of mid-storey species are to be retained; disturbance of the topsoil is to be avoided to protect the understorey seed store, except in the situation where heavy rootstock regenerating understorey occurs. In this situation, physical disturbance of the topsoil to remove competing rootstock is necessary up to a limit of 50 percent of the harvested area in a configuration to facilitate even seedling establishment.

A retention rate of five habitat trees per hectare has been adopted. The characteristics required for these trees was refined, having the effect of retaining less vigorous more senescent trees than before. A further six to eight secondary habitat trees per hectare are retained in addition to the five primary habitat trees. An additional requirement to explicitly mark for retention of balga is

introduced, to provide greater diversity of retained habitat for, in particular, ring-tail possums. Where available, four large balga per hectare are marked for retention. A requirement to retain all natural hollow logs with a pipe of more than 10 centimetres diameter, and length of more than three metres is introduced. A greater emphasis is also placed on the protection of retained habitat from fire applied during the regeneration process.

The guideline provides for increased retention of marri, whilst allowing for some culling to reduce competition and facilitate release of regeneration and release of retained trees in thinned areas. In areas cut to a gap, removal of culls is allowable down to a minimum retained basal area for the gap of 6 square metres per hectare.

Planting of jarrah seedlings in the southern jarrah forest is introduced to provide a means of ensuring adequate regeneration of jarrah on these sites. Greater emphasis is placed on applying coppice treatments in areas cut to gap to provide sprouts from existing advance growth. A requirement to manage seed collection and planting on the basis of seed zones is also introduced.

The retained basal area in shelterwood cut areas is reduced from 15 square metres per hectare, to eight to 10 square metres per hectare, so that jarrah seedlings have an improved chance of survival under less competition from the overstorey.

A more precautionary approach to silvicultural treatment on sites where any intensification of dieback is likely to result in high impact to forest values is introduced. On these sites a selective cut is to be undertaken, with 15 square metres per hectare of overstorey basal area to be retained. On those sites where intensification of dieback is unlikely, as defined by rainfall and vegetation complex, silvicultural application is to be the same as for forest uninfested with dieback.

The guideline recognizes the eastern jarrah forest as an area where a particular application of the silvicultural objectives is to be implemented. Eastern jarrah forest is identified on the basis of specific vegetation complexes located in a specific rainfall zone.

The requirements for surveys of regeneration in areas cut to a gap or shelterwood have been clarified. In gaps, surveys of the effectiveness of regeneration are required and these provide information for reporting required by the Forest Management Plan 2004-2013. Surveys are also necessary to plan remedial treatments. In shelterwood cut areas, surveys of regeneration establishment are required, as are targeted surveys of regeneration development.

Where wildfire has seriously damaged the growth potential of regrowth jarrah forest, guidelines for remedial treatments are introduced and coppice treatments are to be considered.

3.2.2 *Other key changes in the proposed new silvicultural guideline*

Four primary silvicultural methods and a number of particular applications are provided for in the new guideline. The language used to describe the four primary silvicultural methods has been refined to reflect the increased emphasis on habitat, with the methods being 'thinning with retained habitat', 'gaps with retained habitat', 'shelterwood with retained habitat' and 'selective cut in dieback'.

A major development in the guideline is the requirement to undertake forecasts and surveys of flower buds, flowering and seed crops, to determine the seed requirements for the stand and to use the results to determine the silvicultural options to consider at a stand level. The application of these requirements is aimed to improve the establishment of regeneration in areas where the 'shelterwood with retained habitat' method is used.

3.3 *A new era (2004 to ?)*

Many of the changes to silvicultural practices reflect a changing emphasis or a more formal recognition of the values for which the forest is being managing, with the emphasis moving towards the conservation of biodiversity. This is seen in requirements for increased retention of habitat, limits on culling, greater controls on disturbance to the secondary storey, understorey and the soil, and a greater focus on ensuring effective regeneration and monitoring regeneration success.

It is argued that the changes in practice represent the start of a new era of silvicultural practice in the jarrah forest. This interpretation is reinforced by other recent changes in forest management.

3.4 *Other recent changes in forest management*

The Forest Management Plan 2004-2013 (Conservation Commission 2004) is framed around the principles of ecologically sustainable forest management, rather than the multiple use principles of earlier plans. The overall objective of the plan is for

> … biodiversity to be conserved, the health, vitality and productive capacity of ecosystems to be sustained, and social, cultural and economic benefits valued by the community to be produced in a manner taking account of the principles of ecologically sustainable forest management.

The plan introduced a number of other changes to forest management. These changes also reflect a changing emphasis in the values for which the forest is being managed, with the emphasis moving towards the conservation of biodiversity. The plan includes: substantial additions to the conservation reserve system, in addition to the increases committed to in 1987, 1994 and 1999; a network of fauna habitat zones to be dispersed across State forest available for timber harvesting, to improve protection of wildlife; an increase in the types of values to be protected through informal reserves; strict limits on soil disturbance associated with timber harvesting and restrictions on winter harvesting; no timber harvesting in old growth forest; a reduced level of harvest; greater emphasis on monitoring, auditing and compliance; and the commitment to establish an environmental management system for forest management undertaken by the Department of Conservation and Land Management.

4 CONCLUSIONS

Silvicultural practices in the jarrah forest of Western Australia have evolved over the past 85 years and can be categorized into six eras: 1870s to 1920 - uncontrolled cutting; 1920s to 1940 - earlier application of silvicultural principles and use of the group selection method; 1940 to the mid 1960s - less intensive but more extensive cutting; mid 1960s to 1983 – a slight intensification of methods; 1984 to 2003 - the reintroduction of silvicultural methods based on groups of trees that could be managed to achieve particular objectives i.e. promote growth on regrowth trees, establishment of regeneration or release of regeneration, and the progressive introduction of specific measures to protect values such aesthetics, water quality and habitat for fauna; and 2004 – continued use on silvicultural methods based on groups of trees, but with greater explicit focus on non-wood forest values, particularly biodiversity.

It is concluded that silvicultural practices in the jarrah forest of Western Australia have been flexible and responsive to the influence of a range of factors including new information on the silvics of jarrah or elements of biodiversity, availability of resources to undertake silvicultural treatments, demand for wood products, the desire to increase access to facilitate fire management, management of forest health, the introduction of bauxite mining, the recognition of the need to specifically cater for a range of non-wood forest values such as water and landscape values, and community perceptions in relation to issues such as waste of wood resources and biodiversity conservation.

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GLOSSARY

Advance burn - A burn undertaken ahead of timber harvesting.
Advance growth - Advance growth is any tree regrowth that has become established in advance of substantial removal of the upper canopy trees. The term covers a number of components that have accumulated over time, probably in response to past disturbance, including fire.
Basal area - The cross-sectional area of a stem measured at a standard height (usually 1.3 m), or the cross-sectional area of all stems of a species or all stems in a stand and expressed per unit of land area.
Coppice - A shoot (or shoots) arising from adventitious buds at the base of a woody plant that has been cut near the ground or burnt back.
Coppice cleaning – The thinning of the many shoots arising from the base of a woody plant, usually to one or two stems per plant.
Cull - A tree that because of fault or degrade has no commercial value at present or in the near future.
Dieback - In the south-west of Western Australia a disease of plants caused by infection by the soil-borne organisms of the genus *Phytophthora*.
Dieback graveyard – An area impacted by dieback to the extent that most of the overstorey trees have been killed.
Formal reserve – Conservation reserves where the management regime equates to specific protected area management categories defined by the IUCN. Security of tenure is required for revocation of the reserve.
Gap - A discrete opening in the overstorey canopy created by the removal of one or more trees that reduces competition and allows seedlings to become established and or develop.
Ground coppice - A growth stage of regeneration where shoot growth is up to 1.5 m in height and the lignotuber is usually at least 10 cm in diameter, although it may be as small as 5 cm in the southern forest. A ground coppice is characterized by being capable of rapid development into a sapling. There are two stages of ground coppice, incipient ground coppice and dynamic ground coppice.
Group selection – A silvicultural method where trees are removed and new age classes are established in small groups.
Informal reserve – Reserves, usually within State forest, which are managed for conservation values. Such reserves should have a sound basis in legislation or management plans, with opportunity for public comment on changes to boundaries, able to be accurately identified, and of sufficient area and adequate design to contribute to the continued viability of the values they seek to protect. Informal reserves in jarrah forest include river and stream reserves, travel route reserves, diverse ecotype zones and old growth forest.
Pole - The growth stage after a sapling and before a pile where diameter at breast height over bark is 15-45 cm, the crown has apical dominance giving way to more persistent laterals branches.
Regeneration - 1. Advance growth existing in a stand. 2. The act of renewing tree cover by establishing young trees naturally or artificially.
Regeneration burn - A post-harvest burn carried out to remove debris from timber harvesting, reduce competition from understorey and facilitate the establishment or development of seedlings of overstorey species.
Regrowth - A term covering a range of growth stages before maturity.
Salvage cut – the removal of dead trees or trees damaged or dying because of injurious agents other than competition, to recover economic value that would otherwise be lost.
Sapling - The growth stage after a dynamic ground coppice and before a pole where the plant is greater than 1.5 m in height and less than 15 cm in diameter at breast height over bark.
Selective cut – A silvicultural method where only a portion of the trees in a stand are removed for purposes other than regenerating a new age class.
Seed-bed - The soil or forest floor on which the seed falls.
Seed-fall - The shedding of seed by the plant.

Silvics - The study of the life history and general characteristics of forest trees and stands, with particular reference to environmental factors, as a basis for the practice of silviculture.
Silviculture - The theory and practice of managing establishment, composition, growth health and quality of forests to achieve specified management objectives.
Single tree selection – A silvicultural method where individual trees of all size classes are removed more or less uniformly throughout the stand, to promote growth on remaining trees and to provide space for regeneration.
Stand - A term for an area of forest with a certain homogeneity on the basis of size, age, species composition, condition or other attribute. A stand may comprise a single patch or a mosaic of patches especially if they are each relatively small.
Sustained yield – the yield that a forest can produce continuously at a given intensity of management.
Temporary exclusion areas - An area that is excluded from timber harvesting for a particular period of time.
Thinning - A felling made in an immature stand for the purpose of improving the growth of trees that remain without permanently breaking the canopy and encouraging regeneration.
Tops disposal – The removal of slash away from the base of retained trees to avoid damage in any subsequent fire.
Treemarking - The process in which trees are marked for retention or removal prior to harvesting in a forest.

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