FOREST MANAGEMENT PLAN 1994–2003

Final Compliance and Progress Report

February 2003

GOVERNMENT OF WESTERN AUSTRALIA
DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

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BACKGROUND

Pursuant to Condition 18.1 of the Minister for the Environment's statement of 24 December 1992, this report summarises progress with implementation of the Forest Management Plan 1994-2003 (the Project) and compliance with the conditions attached to the *Statement That A Proposal May Be Implemented (Pursuant To The Provisions Of The Environmental Protection Act 1986) - Amendments To The 1987 Forest Management Plans And Timber Strategy And Proposals To Meet Environmental Conditions On The Regional Plans And The WACAP ERMP*, published by the Minister for the Environment on 24 December 1992.

This is a report submitted to the Environmental Protection Authority (EPA) by the Department of Conservation and Land Management (the Department) in accordance with Condition 18.1. This report builds on information provided in earlier reports, particularly the major Progress and Compliance Report to the EPA in December 1997, and subsequent brief annual reports to the EPA in 1998, 1999 and 2000. This report addresses both implementation of the proponent commitments as well as compliance with the Ministerial Conditions. This will be the final report by the Department on progress and compliance with commitments and Ministerial Conditions attached to implementation of the Forest Management Plan 1994-2003 as a Draft Forest Management Plan (2002) has been released for public consultation and a new plan is intended to be in place during 2003.

In November 2000, the *Conservation and Land Management Amendment Act 2000* and the *Forest Products Act 2000* came into effect. Consequently, a Forest Products Commission (FPC) was established to undertake the commercial production, allocation and sale of forest products from the State's native forests, and from State-owned and State-managed plantations. The Conservation Commission of Western Australia also came into effect at this time as a result of the legislative changes. Key functions of the Conservation Commission include to submit management plans for vested lands to the Minister for the Environment and Heritage, and to set performance criteria for assessing and auditing the performance of the Department and the FPC, in carrying out and complying with management plans.

Commitments and Ministerial Conditions relate to the responsibilities of both the Department and the FPC. This report provides information in relation to the responsibilities of the Department and notes the responsibilities of the FPC.

This report focuses on reporting in relation to the commitments and Ministerial Conditions for the year 2000, 2001 and the first half of 2002 (data for the remainder of 2002 have yet to be collated). One of the purposes of this report is to provide a link between the experiences gained in implementing the current plan and the development of the new plan. Consequently, where there are issues that the EPA has indicated require wider reporting to demonstrate compliance or to facilitate development of the new plan, then this report addresses such issues.

As many of the Ministerial Conditions relate directly to specific commitments, an effort has been made in this report to draw together related commitments and conditions for the purposes of reporting. At the same time, progress on compliance with specific Ministerial Conditions is identified. Appendix 1 details the structure of this report in relation to each of the commitments and Ministerial Conditions.

1. PROPONENT COMMITMENTS

Following Mr Codd's report to the Minister in January 1999, designed to facilitate resolution of matters arising from the EPA's mid-term report on the Department's compliance with the Ministerial Conditions, a consolidated list of commitments, and the means by which progress can be audited, were agreed on by the Department and the EPA. Both the 1999 and 2000 Progress and Compliance Reports described progress with the implementation of these commitments. This final report continues this reporting as well as specifically addressing compliance with Ministerial Conditions. Where compliance with a Ministerial Condition is linked to the implementation of a particular commitment, the report notes this. The relationship between commitments and Ministerial Conditions is summarised in Appendix 1.

1.01 IDENTIFY AND PUBLISH THE VALUES TO BE MANAGED FOR IN EACH FORESTED AREA

Statement of context of the commitment - This commitment relates to all Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves.

This commitment is the responsibility of the Department.

As indicated in the 1999 report, this commitment was fulfilled by the Forest Management Plan 1994-2003, which identified and published the values to be managed for in each forested area.

Subsequently, the Regional Forest Agreement (RFA) process undertook a Comprehensive Regional Assessment (CRA) of forest values. Forty-nine reports were published, and these identify the values of the region. The RFA was signed in May 1999, and this identifies the values to be managed for in each forested area.

In February 2001, the Department began implementing the Government's *Protecting our old-growth forests* policy, which includes the following commitments with regard to values to be managed for:

- create 30 new national parks, including 12 national parks promised under the RFA, and two new conservation parks;
- create approximately 200,000 hectares of new reserves, in addition to the 150,000 protected under the RFA; and
- reinstate the 17 proposed reserves (54,000 hectares) revoked during the RFA.

1.02 IMPLEMENT LONG-TERM MONITORING PROGRAMS TO IDENTIFY AND STUDY SIGNIFICANT MANAGEMENT ISSUES IN FORESTS

Statement of context of the commitment - This commitment relates to all Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves.

The Department is responsible for the overall management of State forests and timber reserves, and carries out general monitoring as part of this responsibility. The FPC has responsibility for monitoring the impacts arising from the activities of FPC contractors, such as timber harvesting and associated fire, and road building. The Department regulates access to State forest and timber reserves by the FPC and its contractors. Other proponents such as mining companies have responsibility for monitoring the impacts arising from their activities. The Department

also has a monitoring role through its membership on liaison groups such as the Mining Management Program Liaison Group.

Department's responsibilities

In the broad sense of monitoring, all other sections of this report provide reports on monitoring in relation to particular commitments and Ministerial Conditions. This section of the report will focus on progress with the Montreal Process of criteria and indicators of sustainable forest management.

Montreal Process criteria and indicators of sustainable forest management

The Department continues to maintain involvement in the Montreal Implementation Group (MIG) for Australia. The background to the Montreal Process is described below. A brochure prepared by the MIG to explain the Montreal Process criteria and indicators for sustainable forest management is at Appendix 2.

The concept of sustainable forest management derives from the World Commission on Development, the Brundtland Report (1987): *the ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*. One of the most important international developments for forest management after the Rio Earth Summit in 1992 was the development of criteria and indicators for sustainable management. A notable development in Australia was the work on implementing national and sub-national (regional) indicators for sustainable forest management, drawing on the international Montreal Process framework.

What is the Montreal Process?

In 1993, Canada convened an International Seminar of Experts on the Sustainable Development of Boreal and Temperate Forests. This meeting, held in Montreal, resulted in the "Montreal Process", an inter-governmental process for the development of criteria and indicators for sustainable forest management. The Montreal Process aims to develop and report on a set of criteria and indicators for temperate and boreal forests. The 12 member countries are Australia, Argentina, Canada, Chile, China, Japan, the Republic of Korea, Mexico, New Zealand, the Russian Federation, the United States of America and Uruguay.

Criteria are broad categories of forest values we wish to maintain.
Indicators are measurable aspects of these criteria.

The Montreal Process identified seven broad criteria important for sustainable forest management. These are:

- Biological diversity;
- Productive capacity;
- Ecosystem health and vitality;
- Soil and water resources;
- Global carbon cycles;
- Socio-economic benefits; and
- An effective legal, institutional and economic framework.

The Montreal Process countries have identified 67 indicators for reporting against these criteria at a national level. The Montreal Process is a voluntary framework and is not legally binding. Criteria and indicators provide a set of tools that can be used over time to describe the state of a nation's forests and assess progress towards the goals of sustainable forest management.

Commonwealth, State and Territory forestry and conservation Ministers have endorsed the Montreal Process criteria and indicators for reporting on forests at a national level and as a basis for the development of regional indicators. The regional indicators, *Framework of Regional (Sub-National) Level Criteria and Indicators of Sustainable Forest Management in Australia (1998),* were developed after two years of consultation between governments and stakeholders.

The framework of regional indicators recognised that it was not possible, practical or cost-effective to fully implement and monitor all 67 indicators at this time and provided a phased approach to implementation. The indicators were put into three broad categories following an initial evaluation of Australia's capacity to report on them. They are:

- Category A – indicators which are largely implementable now;
- Category B – indicators for which new data need to be collected or some development work done (three to five years); and
- Category C – indicators that require longer-term research and development before they can be applied extensively (more than five years).

The indicators that do not have a category are not easily reported at a regional level, and will be reported at a State/Territory or national level.

The MIG continues to coordinate and provide advice on a program of research and development for Category B or C indicators. These indicators will be reviewed to establish their feasibility for long-term implementation. The Forest and Wood Products Research and Development Corporation (FWPRDC) is managing 20 sustainability indicator projects for the Commonwealth Department of Agriculture, Fisheries and Forestry – Australia. The Wood and Paper Industry Strategy provided funding for these projects, at a total cost of $2.4 million. They were scheduled for completion during 2001-02 and were expected to assist in identifying practical and cost-effective ways to report on identified Category B or C indicators.

Criteria and indicator reports and future reporting

Australia has produced three national reports on Australia's forests that draw on the Montreal Process framework. The first, *Australia's First Approximation Report for the Montreal Process* (1997), provides an initial report against the national level criteria and indicators. The second, *Australia's State of the Forests Report 1998*, is a comprehensive description of Australia's forests and covers most aspects of the Montreal Process criteria and indicators. The third is a *Vignette on Australia* included in *The Montreal Process: Year 2000 Progress Report*, and highlights accomplishments such as the development of the regional framework, links with domestic and international activities, including the regional forest agreements, and research and development projects.

In early 2001, the Department provided information to the National Forest Inventory (NFI) in response to their call for data to assist in development of the national State of the Forests Report (in 2003) and the national report (2003) on implementation of the Montreal Process criteria and indicators of sustainable forest management in Australia. Both of these major national reports are based on the Montreal criteria and indicators.

Following receipt of information from the States, the MIG prepared a Category A report focusing on practical reporting and implementation issues (Appendix 3).

Information from this Category A report will be included with other available data, particularly for Category B and C indicators, to provide core information for the next national State of the Forests Report, expected to be released in 2003. Australia, with other member countries, will

provide highlight indicators for inclusion in the first comprehensive international Montreal Process Forest Report, also scheduled for release in 2003.

Key findings of the Category A report

The evaluation of data availability and information on Category A indicators highlighted a number of important findings. These include a number of significant improvements in reporting for some indicators as well as general issues to be addressed over the longer term (e.g. coverage across specific tenures such as privately managed forests) or issues related to specific indicators.

Major improvements

The quality of spatial mapping of vegetation cover, structure and tenure has improved over the past three years as a result of new mapping initiatives put in place through the RFA process and underlying CRA; the NFI; and improvements in vegetation mapping by States and Territories.

Some projects, such as the National Plantation Inventory (NPI) as part of the NFI, and recent initiatives, such as private native forest inventory project within the Bureau of Rural Sciences, have begun to address the long-term requirement to obtain better national level information on private forests. In addition, recent developments in remote sensing, with suitable on-ground truthing and calibration, have the potential to provide reliable estimates of forest cover and forest density at reasonable costs. However, further research and pilot work is needed.

Key issues

Data for criteria and indicator reporting come primarily from State and Territory agencies, of which there are many within each jurisdiction. Identifying all relevant agencies and achieving effective coordination of data acquisition at the State/Territory level and subsequent summarisation at the national level continue to be challenges to reporting.

There are also a number of data confidentiality issues over obtaining long-term commitments from private land owners for data collection for private native and plantation forests. For plantation forests, processes such as data licence agreements are in place to address data confidentiality issues.

The preparation of the Category A report highlighted some shortfalls in the ability or capacity of some agencies to report on indicators for particular forest values and tenures. Category A indicators are a small subset of the 67 regional level indicators for Australia, representing those indicators that are considered largely implementable now. Continuing refinement of data standards, such as clarifying definitions of key terms, will improve capacity for some indicators. Improved methods to educate and promote the value of criteria and indicator processes will also help clarify and expedite future Montreal Process reporting.

Data comparability

Data provided for the Category A report are not necessarily compatible with information contained in *Australia's State of the Forests Report 1998*. Direct comparison and inferences about trends may not be appropriate where the data were collected from different sources, by different methods or for different purposes. A more detailed evaluation of relative changes in the value of indicators and trend information will be provided in the next State of the Forests Report.

The NFI is pursuing the development of a Continental Forest Sampling Framework, which will provide a coordinated approach to data collection across all States and Territories. Two key objectives of the framework are to create a responsive, flexible, efficient system to provide authoritative national-level data for all forests; and establish a standardised and repeatable system to conduct successive inventories and make statements about change, relevant for five-yearly reporting.

FORESTCHECK

Long-term monitoring of FPC activities has also been proposed by the Department through the FORESTCHECK framework. This is dealt with under Ministerial Condition 11 in section 2.11 of this report.

1.03 REGULATE THE PRODUCTION OF FOREST RESOURCES TO LEVELS THAT CAN BE SUSTAINED INDEFINITELY

Statement of context of the commitment - This commitment is to ensure that the harvesting of timber from State forest and timber reserves is less than or equal to the sustained yield of timber.

The Department is responsible for undertaking strategic yield scheduling, preparing regional indicative timber harvesting plans and maintaining the databases on forest structure, composition and history of treatment. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans, and monitoring forest product removals to ensure they do not exceed the set levels.

Department's responsibilities

During the RFA process independent reviews were undertaken of the data and methods used in the calculation of sustained yields, of ecologically sustainable forest management, and of the calculation of the final sustained yield. The RFA established a new sustained yield (confirmed by the independent experts) using the land base available after the establishment of the conservation reserve system and management practices that provide for ecologically sustainable forest management.

Draft terms of reference for a further review of sustained yield to ensure consistency with the principles of ecologically sustainable forest management were released for public comment in December 1999. In June 2000, the Department released an analysis of public submissions on the draft terms of reference (CALM 2000) and the Minister for the Environment announced the terms of reference for the review. The purpose of the review is to fulfill the recommendation in the Codd Report and the commitment in clause 50 of the RFA, as well as to facilitate the development of the new management plan covering the forests of the south-west. The review focuses on the calculation of sustained yields within the context of the principles of ecologically sustainable forest management. The review documents and examines management practices and their integration with the process for estimating sustained yields, examines the data and methods used for calculating sustained yields, examines timber resource estimates, and examines yield projection systems in terms of consistency with forest growth rates and objectives of management. The review is being undertaken in three stages. The terms of reference for the review are at Appendix 4.

The independent panel undertaking the review provided their report on stage one to the Conservation Commission in April 2001 (Appendix 5). The report, subsequently released publicly by the Conservation Commission, makes a number of recommendations which are progressively being addressed by the Conservation Commission or the Department. Some of

the recommendations will be addressed before the new management plan is finalised and others will be addressed during the period of implementation of the new management plan.

Stage two of the review process involved the independent panel observing and participating in the calculation of sustained yield levels for native forests for inclusion in the draft of the new management plan. The independent panel met and prepared a preliminary report on stage two of the review process during September 2001. The Conservation Commission did not request a final report after it was decided to include a range of possible sustained yields in the 2002 Draft Forest Management Plan.

Stage three of the review process involves the independent panel observing and participating in any recalculation of sustained yield levels for native forests for inclusion in the draft final of the new management plan undertaken in response to public and agency submissions.

1.04 PRESERVE THE QUALITY OF POTABLE WATER SUPPLIES FROM FORESTS

Statement of context of the commitment - This commitment relates to potable water supplies from all Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves. Ministerial Conditions 12 and 16 represent a conservative, precautionary approach to the management of forests to ensure the protection of potable water supplies, based on extensive research. Meeting the intent of these conditions provides a useful surrogate to audit attainment of this commitment, due to the impracticality of extensive monitoring regimes.

The Department is responsible for preparing regional indicative timber harvesting plans that allow for phased harvesting, research on hydrologic response to phased harvesting, research and determination of high salt risk catchments, and monitoring the performance of the FPC in meeting prescribed forest management standards. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans that allow for phased harvesting, and ensuring that field operations are in compliance with the requirements of this commitment, associated Ministerial Conditions and compliance with the code of practice and manual of management guidelines.

Department's responsibilities

Phased harvesting

Planning by the Department for phased harvesting in the intermediate and low rainfall zones of the jarrah forest is continuing to be implemented in accordance with Ministerial Condition 12. This Ministerial Condition requires that at least 30 per cent of each second order catchment has a retained basal area of greater than 15 m^2/ha for a period of at least 15 years after harvesting of the remainder.

As reported in the Progress and Compliance Report of 1998, the Department has been implementing a paired catchment experiment to monitor the hydrologic effects of timber harvesting in the intermediate rainfall zone of the jarrah forest. The study, which is currently in progress, has a 'before – after – control – impact' experimental design based on three second-order catchments. Two catchments were harvested in 2000/01 following a long pre-treatment calibration period, one according to standard timber harvesting and silvicultural treatments and the second to a more intensive treatment. The third catchment remains untreated as a control. Records exist of groundwater level, stream flow, stream salinity, and salt load for at least the previous 10 years and monitoring is ongoing.

Pre-treatment hydrological data are used to establish regressions with the control catchment. The regressions are then used to make post-harvest predictions of hydrological parameters and the response to harvesting is calculated as the difference between observed and predicted. The catchments are expected to provide different levels of hydrological response that will enable an estimate of changes to the hydrology in relation to changes in vegetation density.

The results of this study will have potentially important implications for forest management, in particular for the intermediate rainfall zone. The full implications will not be apparent until groundwater levels and stream salinities peak and start to decline, which may take four to five years following treatment. It is important that monitoring continues to at least this point.

The report on the study (Appendix 6) concluded:

> *Timber harvesting was expected to result in rises in groundwater level. However, the results have generally shown the opposite trend, that is, small declines in groundwater levels in the harvested catchments relative to groundwater levels in the control catchment. Since the results presented here are very early in the expected response of groundwater level to timber harvesting, and are influenced by the very low rainfall in 2001, it is important that monitoring continue for at least another three years and the results be evaluated at that time.*

High salt risk catchments

A research project aimed at assisting in the identification of which of the second-order catchments considered environmentally sensitive to rises in saline groundwater are of a high salt risk (Ministerial Condition 16) was completed in 2001. The specific aims of this project were:

- evaluate the effectiveness of an EM31 Ground Conductivity Meter for estimating average soil salt concentration to four metres depth, and if found to be suitable;
- determine an appropriate method of surveying the streamzone of a catchment with an EM31 to cover adequately the spatial variation in stored salt; and
- use an EM31 to survey the length of the streamzone of second-order catchments which drain into areas 'environmentally sensitive to rises in saline groundwater', to determine the average soil salt concentration to four metres.

The project demonstrated that the EM31 Ground Conductivity Meter is effective for estimating average soil salt concentration to four metres depth. Highly significant linear regression equations were established between mean soil solute content in the upper four metres of the soil profile and apparent electrical conductivity measured by the EM31.

EM31 surveys were conducted in four second-order catchments, within an area 20 metres either side of the streambed, to determine where the highest soil apparent electrical conductivity levels were most likely to be encountered. The highest apparent electrical conductivity was mostly within 10 metres of the stream centre. However, there was considerable spatial variation in apparent electrical conductivity along the length of the second-order stream and the highest levels were not necessarily near the catchment outlet. An appropriate method of surveying streamzones is to conduct a survey along the length of the stream and as close to the stream as possible (within 10 metres).

Twenty-four 'environmentally sensitive' catchments were surveyed with an EM31 to determine the average soil salt concentration. Twenty-two catchments had soil apparent electrical conductivity at levels that indicated that soil salt exceeded 2000 mg/L along at least half of the length of the second-order streambed. In nine of the catchments, apparent electrical conductivity levels indicated that soil salt exceeded 2000 mg/L along the entire length of the

streambed. In two of the 'environmentally sensitive' catchments, in which only part of the length of the streambed was surveyed, i.e. 75 per cent and six per cent, apparent electrical conductivity levels suggested soil salt was below 2000 mg/L.

The information from the project has been used to update earlier information in relation to the environmentally sensitive catchments and to make determinations as to which catchments are of a high salt risk. Of the 56 second-order catchments previously identified as environmentally sensitive to rises in saline groundwater:

- 20 are now considered not a high salt risk catchment because the second-order catchment is no longer available for timber harvesting or only a small portion is available for timber harvesting and the other parts of the second-order catchment would satisfy the more precautionary management requirements for a high salt risk catchment;

- three are now considered not a high salt risk catchment because soil salt concentration is below the 2000 mg/L threshold or depth to groundwater is greater than four metres at the catchment outlet;

- 14 have soil salt concentration above the 2000 mg/L threshold – in the absence of information on the depth to groundwater at the catchment outlet being greater than four metres assume the second-order catchment to be of a high salt risk;

- 10 have had no survey or limited survey of soil salt concentration and no information on depth to groundwater – in the absence of further information assume the second-order catchment to be of a high salt risk; and

- nine are where the area available for timber harvesting is dependent on reserve design now being undertaken and associated Government decisions. Defer making a determination as to high salt risk status until final reserve design is decided.

Audits of compliance

The Department's Management Audit Branch audits compliance with this commitment. The 2001 and 2002 audits examined coupes harvested in the year 2000, and 2001 and 2002 years respectively. The audits included examination of the logging planning process, examination of the logging plans of the coupes being sampled, verification of the retention of the required stream zones and verification that the planned 30 per cent of the catchment was retained unlogged or selectively harvested.

The audits verified that the procedures in the logging planning system that identify and mark stream zones, second order catchments in the intermediate and low rainfall zones (Condition 12), and high salt risk catchments (Condition 16) on the logging plan were in place and working. The audits verified that required stream zones were retained in the field. The audits verified that harvest plans for the sampled coupes in the intermediate and low rainfall zones had the required 30 per cent of the catchment retained unlogged or selectively harvested. The audits verified that the areas were appropriately demarcated in the field and were excluded from gap creation. The audits identified that no high salt risk catchments were harvested in the 2001 or 2002 calendar years. Further details of the audit program are contained in Appendices 7 and 8.

Report of the Ministerial Condition 11 Expert Panel

The Ministerial Condition 11 Expert Panel report of September 2001 (Appendix 9) provided advice to the Department in relation to a number of issues including research and monitoring related to salinity management and the bases this research and monitoring provide to adjust management.

The Panel summarised the current understanding of the impacts of timber harvesting and regeneration on hydrology as:

- *Increases in groundwater levels of 3.5 – 4.5 m in high (greater than 1100 mm mean annual rainfall) and intermediate rainfall zones (900 – 1100mm mean annual rainfall), and 1 m in the low rainfall zone (less than 900 mm mean annual rainfall).*

- *Increases in stream salinity have been greatest from catchments without stream buffers or phased logging.*

- *Return to pre-logging conditions was expected to take 10-15 years, depending on regeneration.*

- *The potential for increases in stream salinity resulting from logging is greatest in the intermediate rainfall zone (IRZ) due to the possible shallow depth to groundwater and the high salt storage.*

The Panel noted the research and monitoring currently undertaken in relation to phased harvesting and high salt risk catchments. The Panel concluded:

> *There is no hydrological evidence to vary the existing silvicultural guideline in the salt-sensitive intermediate rainfall zone. These should be reviewed when data from current research programs are available in four to five years.*

Other evidence of preservation of the quality of potable water supplies from forests

The Water and Rivers Commission has undertaken a study to update the Schofield *et al.* (1988) report on salinity of surface water resources in the south-west. The draft WRC report (Ruprecht *et al.* in preparation) identifies the status and trends in stream salinity during the 1990s in south-west streams and rivers using data to 1997. The report shows that stream salinity continues to increase in most streams emanating from areas that are at least partially cleared for agriculture. However, a number of the streams reported emanate from catchments where clearing for agriculture is not a factor influencing the trend in stream salinity. Consequently, the trend in stream salinity for these streams provides an indication of the impact on stream salinity of other (excluding clearing) land management practices. Appendix 10 (extracted from Ruprecht *et al.* in preparation) shows that stream salinity for these streams is generally steady, or with very small increases or decreases.

1.05 UNDERTAKE RESEARCH TO IMPROVE A SCIENTIFIC BASIS FOR THE PROTECTION OF BIODIVERSITY

Statement of context of the commitment - This commitment relates to all Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves.

The Department is responsible for general research on biodiversity of State forests and timber reserves. The FPC has responsibility for researching the impacts on biodiversity arising from the activities of FPC contractors, such as timber harvesting and associated fire, and road building. Other proponents such as mining companies have responsibility for researching the impacts on biodiversity arising from their activities.

Department's responsibilities

Active science project plans relevant to biodiversity protection in the jarrah and karri forests are listed Appendix 11. Reports and publications in 2000, 2001 and the first half of 2002 are listed in Appendix 12.

The Department conducted an internal two-day workshop in May 2001 with the following objectives:

- to provide forest managers and policy-makers with a comprehensive overview of research findings relevant to the environmental effects of timber harvesting in the jarrah forest; and
- to identify mechanisms by which current research findings can be incorporated in the revision of silvicultural guidelines and the new forest management plan.

Issues discussed at the workshop were divided into three categories according to whether they were relevant to meeting compliance requirements for the Forest Management Plan 1994-2003, providing direction to or constraints on the new plan, or modification of silvicultural guidelines and codes of practice. A summary of the workshop is included as Appendix 3 to the Ministerial Condition 11 Expert Panel report, which is at Appendix 9.

1.06 CONDUCT PRESCRIBED BURNS IN RIVER AND STREAM ZONES SO AS TO BE OF LOW INTENSITY

Statement of context of the commitment - This commitment relates to stream zones adjoining clearfell karri coupes. A part of the process of achieving regeneration of the forest ecosystem of these coupes is usually a high intensity slash burn. The intention in making the commitment was to ensure that the planning process for the high intensity burn in the clearfell coupe considered the protection of the stream zone.

The Department is responsible for planning and conducting prescribed burns consistent with the values of the area. The FPC is responsible for silvicultural burns resulting from FPC timber harvesting activities.

Department's responsibilities

The planning process for post harvesting silviculture requires the approval of the Regional Manager before river and stream zones can be included as part of a karri silviculture burn. Appendix 13 shows that in the 2000 calendar year, there were 31 prescribed burns for forest regeneration purposes in clearfell karri coupes adjoining stream reserves, 16 of which planned for the inclusion of the stream reserve in these burns. Eleven of the stream zones were actually included in the burn, with 10 burns resulting in low fire intensity and one burn in these river and stream zones exceeding low fire intensity. During 2001, there were 22 prescribed burns for forest regeneration purposes in clearfell karri coupes adjoining stream reserves, 11 of which planned for the inclusion of the stream reserve in these burns. Eight of the stream zones were actually included in the burn and part of one of the burns in these river and stream zones exceeded low fire intensity.

The EPA wrote to the Department on 9 May 2001 in response to the previous Progress and Compliance Report, stating: *Could you please indicate in the next PCR whether the burns conducted in stream reserves were of 'low intensity' as specified in the commitment. In the interests of transparent and precise reporting it would be useful for CALM, in its next PCR to provide an objective and scientifically based definition of 'low intensity' in the context of the commitment.* Low fire intensity is considered as being less than 500 kW m^{-1} and a maximum

flame height of 1.5 metres (Cheney 1981), which would result in crown scorch to a maximum of 10 metres.

1.07 CONDUCT PRESCRIBED BURNING IN DIVERSE ECOTYPE ZONES IN ACCORDANCE WITH HABITAT REQUIREMENTS OF THE SITE

Statement of context of the commitment - This commitment is to ensure that where diverse ecotype zones are known to have special requirements with respect to fire, that these requirements are considered in the planning process for prescribed burns. However, the commitment in the proposal document also noted the needs of the fuel reduction strategy as part of the strategic fire protection system.

The Department is responsible for planning and conducting prescribed burns consistent with the values of the area. The FPC is responsible for silvicultural burns resulting from FPC timber harvesting activities, some of which may include or be influenced by proximity to diverse ecotype zones. The FPC is also responsible for its EMS, which assists in delivering its environment policy including identifying the environmental impacts of its operations and setting objectives and standards to keep potentially significant impacts to acceptable levels.

Department's responsibilities

A corporate data set of diverse ecotype zones is used to identify diverse ecotype zones for planning purposes and to enable delineation of diverse ecotype zones on the ground when harvest coupes are established. Where these diverse ecotype zones have special requirements with respect to fire, these are taken into account during the planning and implementation of silvicultural burns. These treatments include either total fire exclusion, or mild intensity patch burns that prevent wet/moist diverse ecotype zone sites from being burnt, or hot autumn/summer burns where it is necessary to regenerate fauna habitat. The specific treatment to be applied is based on advice from several sources. There is heavy reliance on fire response information developed by fire ecologists including Drs Burrows, Christensen, Wardell-Johnson, Burbidge and Friend, and Regional Program Leaders for Nature Conservation. The available information includes life history, vital attributes, and regeneration processes and mechanisms. Data-bases accessed include FIREBASE (Burrows), DESCAT (Herbarium) and threatened species and communities data-bases managed by the Wildlife Conservation Section of the Department.

During the planning and preparation phase of a prescribed burn, a Pre-Burn Checklist and a District Manager's Prescribed Burn Confirmation Checklist are filled out which identify the conservation issues that need to be taken into account in the planning and implementation of the burn. The Pre-Burn Checklist requires the burn planners to consider the following:

- identified diverse ecosystem types;
- known threatened/endangered flora and fauna;
- special requirements for flora/fauna habitats;
- recovery plans for flora and fauna, e.g. fauna reintroduction areas, fauna study sites, etc;
- river/stream reserve, road reserves;
- fragile areas; and
- scientific reference areas.

Once a diverse ecotype zone has been identified then its requirements will be catered for in the burn prescription and burn implementation. Examples of specific burns that have catered for habitat requirements of diverse ecotype zones are listed in Appendix 14.

The EPA wrote to the Department on 9 May 2001 in response to the previous Progress and Compliance Report, stating: *please indicate whether the proposed EMS procedures will specify*

the specific information and expertise necessary to be drawn on to determine appropriate treatments for respective DEZs. The EMS referred to in this letter is that developed by the FPC and accordingly is not the Department's responsibility. Nevertheless, the proposed Departmental EMS that is under development is intended to include procedures that specify information and expertise necessary to be drawn on to determine appropriate fire treatment for diverse ecotype zones that occur within or adjacent to silvicultural burns. See Appendix 15 for status of development of the Department's EMS.

During 2001, the Department conducted an internal fire review, including prescribed burning policy and practices and the wildfire threat analysis. The review (Muller 2001) was released in July 2002 together with the Department's response to the recommendations of the review (CLM 2002a). Muller (2001) concluded:

> *Historically the primary focus for fire management planning has been protection against wildfire, particularly for life and property, with, in recent years, an increased emphasis on conservation values. This report recommends a fundamental change: that fire management be based primarily on the attainment of the Department's core outputs, supplemented by additional works only as and if necessary to meet the Department's duty of care to in relation to providing community protection.*
>
> *An adaptive management approach to fire planning is advocated, which includes an approach to determining an idealised fire distribution to meet nature conservation outcomes, utilising bio-indicators.*
>
> *An analysis of the present situation has identified that insufficient burning is being undertaken to maintain an optimum fire distribution to meet either biodiversity or protection objectives. There is currently potential for large areas to be burnt in wildfires that would be uncontrollable during severe weather conditions. Whilst limited high intensity fires are a desirable component of the overall fire distribution, there is currently a significant risk of loss of biodiversity through extensive high intensity wildfires, particularly in the Southern Forest Region. Such wildfires would also pose a threat to community values.*
>
> *To achieve sufficient fire diversity, this report recommends that larger (minimum 5-10,000 ha) individual burn envelopes be applied where possible, with the objective of creating mosaics of unburnt and burnt areas within the burn envelope. It is recognised that there are inherent risks associated with such a strategy. For example if conditions are not as predicted, the planned mosaic may not be achieved. It is considered, however, that the potential for extensive high intensity fires through not being able to implement sufficient smaller burns to provide the desired fire distribution carries a much greater risk of loss of biodiversity.*

In its response to the recommendation to maximise the size of individual burn operations where possible, the Department stated (CLM 2002a):

> *Discussion: It is noted that this recommendation may be considered contentious unless it is recognised that the intention is to adopt a more natural and therefore less interventionist approach to planned burning. The intention is that burn boundaries will be larger allowing for the establishment of mosaic burning patterns over larger burn areas.*
>
> *Response: This issue will require careful consideration in the context of the development of a new Departmental policy and strategies on fire management. Other bodies with a key interest in this matter including the Conservation Commission should be consulted. This will also be a key issue in the forthcoming EPA review.*

1.08 PREVENT LOGGING IN RIVER AND STREAM ZONES FOR OTHER THAN LEGITIMATE ROAD CONSTRUCTION AND THE REMOVAL OF DANGEROUS TREES

Statement of context of the commitment - This commitment relates to all Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves.

The Department is responsible for preparing regional indicative timber harvesting plans that allow for river and stream zones, and monitoring the performance of the FPC and its contractors in meeting prescribed forest management standards. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans that allow for river and stream zones, and ensuring that field operations are in compliance with the requirement to prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees.

Department's responsibilities

The felling of trees in stream zones was part of a broader audit on a range of coupe management requirements undertaken by Management Audit Branch in 2001 and 2002 on coupes harvested during 2000, and 2001 and 2002, respectively.

The 2001 audit sampled 10,156 metres of stream zone boundary and found that 95.5 per cent of the sampled stream zone boundary was intact. Of the 4.5 per cent of the stream zone boundary that had been crossed, 2.4 per cent was associated with minor vehicle incursions and 2.1 per cent with illegal felling and snigging. There were seven incidents of illegal felling in stream zones within three coupes. Each of the seven incursions was treated as a major environmental incident under the FPC EMS. The incidents were subject to formal investigation, the designation of corrective action and closure by a senior manager following the completion of the action. In this case the three contractors involved received warnings. However, a subsequent similar breach by one of the operators responsible for a breach identified in the audit has resulted in the contractor dismissing him.

The 2002 audit sampled 13,285 metres of stream zone boundary and found that 97 per cent of the sampled stream zone boundary was intact. Of the 400 metres of the stream zone boundary that had been crossed, 266 metres were associated with minor vehicle incursions. The remainder involved three major incidents: one instance of a tree being felled and snigged; and two cases where vegetation in the stream zone had been cleared or scrub rolled.

Further details of the audit program are contained in Appendices 7 and 8.

The follow up of these audit findings has shown that the introduction of the EMS and the formalised process contained in it for the recognition of environmental incidents, their documentation, investigation and associated corrective action has strengthened the system of environmental protection in timber harvesting.

1.09 IDENTIFY AREAS OF HIGH VALUE OLD-GROWTH FOREST

Statement of context of the commitment - This commitment is to ensure that old-growth karri forest with high aesthetic, social or environmental value is identified and considered for protection.

This commitment was fulfilled by actions under the RFA process.

In July 1999, the then Government announced there would be a cessation of timber harvesting in old-growth karri and tingle forests when the current contracts expired in 2003. In February 2001, the old-growth forest policy was implemented with an immediate end to timber harvesting in 99 per cent of the remaining old-growth forest on Department managed land, and a moratorium on the balance until it could be determined whether current contracts could be honoured without harvesting this area. In November 2001, the Government announced that the other one per cent of old-growth forest would also be protected from timber harvesting.

1.10 FURTHER ENHANCE THE SECURITY AND REPRESENTATION OF THE CONSERVATION RESERVE SYSTEM

Statement of context of the commitment - The intent of this commitment was that implementation of the proposal to add specified areas to the conservation reserve system would enhance the security and representation of the conservation reserve system.

This commitment is the responsibility of the Department, within its legal powers. It is important to note that the implementation of proposed amendments to the conservation estate is not a process over which the Department has complete control.

The 1997 Progress and Compliance Report (CALM 1997) provided a detailed summary of progress on the implementation of amendments to the conservation estate. As stated, the Department does not control the process, but has initiated all recommendations.

Under the RFA, the State and Commonwealth governments agreed that a comprehensive, adequate and representative reserve system would be established, and identified some 150,000 hectares to be added to the conservation reserve system. The RFA provided for 12 new national parks, 25 additions to existing national parks, and overall some 90 additions to the conservation reserve system.

The State also provided commitments in the RFA to establish formal conservation reserves under the *Land Administration Act 1997* where these reserves were proposed in the Forest Management Plan 1994-2003 and they were reaffirmed in the RFA, and to classify other proposed formal conservation reserves as Forest Conservation Areas under section 62 of the *Conservation and Land Management Act 1984* (CLM Act). Action to achieve this is well advanced.

Under the *Protecting our old-growth forests* policy of February 2001, the Government committed to creating 30 new national parks, including the 12 new national parks promised under the RFA, and two new conservation parks. Some 200,000 hectares of new reserves, in addition to the 150,000 protected under the RFA, will be created. The policy also commits to reinstating the 17 proposed reserves (54,000 hectares) revoked by the Government during the RFA. Progress in implementing this commitment is described at Appendix 8 of Draft Forest Management Plan (Conservation Commission, 2002).

Appendix 16 provides a detailed report on progress with implementation of proposals in the Forest Management Plan 1994-2003 for changes to land category.

1.11 ALLOW IDENTIFIED AREAS OF REGROWTH KARRI TO ACQUIRE OLD-GROWTH CHARACTERISTICS, INCLUDING 25 PER CENT OF PRE-1940 REGROWTH, ALL REGROWTH STANDS REGENERATED IN THE PERIOD BETWEEN 1940 AND 1975 LESS THAN 200 HECTARES IN AREA, AND 50 PER CENT OF ALL STANDS REGENERATED AFTER 1990

Statement of context of the commitment - This commitment was made to meet the structural goal for the karri forest, namely that the minimum proportion of the area of karri

forest dominated by the mature and senescent stages of development would be retained at approximately 40 per cent. The objective of this structural goal was to ensure there would be adequate karri forest progressing into the mature and senescent development stages in the future to replace that returned to the establishment stage because of harvesting and natural causes. (The wording of this commitment is discussed under 2.1 Ministerial Condition 1 – Proponent commitments.)

The Department is responsible for undertaking strategic yield scheduling, preparing regional indicative timber harvesting plans that provide for the commitment, and monitoring the performance of the FPC in meeting prescribed forest management standards. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans that provide for the commitment, and ensuring that field operations are in compliance with the commitment.

Department's responsibilities

This commitment is accommodated through the harvest scheduling undertaken for the karri regrowth estate. Within the computer-based scheduling system (called KARSCHED), the following proportions of each respective regeneration year are allocated a 'senescent' yield regime:

- 20 per cent for annual areas regenerated pre-1940;
- 30 per cent for 1940-1974;
- 10 per cent for 1975-1990; and
- 50 per cent for post-1990 areas.

Within these cohorts the clearfell age is set at 250 years.

The implementation and monitoring of the commitment is through the annual logging plan and the systems that record this logging, SILREC (a computer based record of harvesting and silvicultural treatments, based on post-harvesting records) and FMIS (Forest Management Information System).

In terms of the overall goal that the minimum proportion of the area of karri forest dominated by the mature and senescent stages of development would be retained at approximately 40 per cent, Bradshaw (2002) found that about 50 per cent of the karri forest was in the mature and senescent stages of development at the time of the last data update in 2000. In addition to the mature and senescent stages of development, the implementation of the Government's *Protecting our old-growth forests* policy results in the proposed new conservation reserves containing a portion of regrowth forest that will provide for a succession of development stages in the reserve system.

The strategy in the Forest Management Plan 1994-2003 of establishing a structural goal for karri forest so as to maintain the mature and senescent growth stages, and this commitment that implements that strategy, have been overtaken by State Government policy decisions. In July 1999, the then Government announced that there was to be a cessation of timber harvesting in old-growth karri and tingle forests when the current contracts expired in 2003, and in February 2001 the new *Protecting our old-growth forests* policy was implemented. This will result in a greater proportion of the karri forest remaining in the mature and senescent growth stages.

The Draft Forest Management Plan (Conservation Commission, 2002) proposes additional measures to manage the structural diversity of the forest.

1.12 RETAIN AN AVERAGE OF (AT LEAST) THREE LARGE TREES ON EVERY HECTARE HARVESTED TO PROVIDE HABITAT

Statement of context of the commitment - This commitment was made in relation to areas of jarrah forest subject to the cutting of gaps during timber harvesting operations. The intent of the commitment was to provide, where possible, habitat for hollow nesting species.

The Department monitors the performance of the FPC in meeting this commitment. The FPC is responsible for ensuring that field operations are in compliance with the commitment.

Department's responsibilities

Management Audit Branch audits compliance with this commitment. As part of the 2001 audit, 63 hectares in jarrah coupes were sampled to test for habitat retention in 11 coupes, which represented a 12 per cent sample of harvested coupes. This audit found that the average retention rate of trees marked as habitat trees in the sampled coupes was 5.8 trees per hectare, which is well in excess of the minimum standard. However, in one coupe the average failed to meet the standard having an average of 2.6 trees per hectare.

As part of the 2002 audit, 77 hectares were assessed for habitat tree retention in 11 coupes, which represented a 14 per cent sample of harvested coupes. The audit found an average of 5.2 marked habitat trees per hectare, however, one coupe (O'Neil) failed to meet the standard having 2.6 marked habitat trees per hectare.

Further details of the audit program are contained in Appendices 7 and 8.

1.13 RETAIN, AND PROTECT AS FAR AS POSSIBLE, AT LEAST ONE SUITABLE GROUND HABITAT, I.E. HOLLOW LOG, PER HECTARE

Statement of context of the commitment - This commitment was made in relation to areas of the jarrah forest subject to timber harvesting where this included extraction of logs on the forest floor for charcoal production.

The Department monitors the performance of the FPC in meeting this commitment. The FPC is responsible for ensuring that field operations are in compliance with the commitment.

Department's responsibilities

Management Audit Branch audits compliance with this commitment. The 2001 audit program specifically included auditing for compliance with this commitment. Although auditors noted suitable habitat logs existed in coupes there was poor compliance with the requirement to identify them for protection. Of the 12 coupes sampled, seven had no ground habitat marked, four had it marked but below the stipulated level and one met the specifications. In response to this FPC management issued new instructions to treemarkers on meeting standing and ground habitat.

As part of the 2002 audit, 77 hectares were assessed for ground habitat retention in 12 coupes. The audit found an average of 0.5 marked ground habitat per hectare. Ground habitat had been marked at or above the required rate in four of the 12 coupes, below the required rate in three coupes and five coupes had no habitat marked although the auditors noted suitable habitat.

Further details of the audit program are contained in Appendices 7 and 8.

1.14 UNDERTAKE HABITAT REGENERATION BURNS IN FORESTS WHERE SPECIAL REQUIREMENTS FOR THREATENED OR ENDANGERED SPECIES ARE IDENTIFIED

Statement of context of the commitment - This commitment is to ensure that where threatened species are known to have special requirements with respect to habitat regeneration burns, that these requirements are documented in the relevant recovery plans or wildlife management programs, and implemented where possible. This commitment was made with the stated understanding that the principal fire management goal was to protect community (life and property) and environmental values on and adjacent to Department managed land from damage or destruction from wildfire. Implementation of the commitment is therefore subject to constraints imposed by the goal of protection of life and property.

This commitment is the responsibility of the Department.

The following recovery plans, with the specified actions mentioned, are applicable to the area covered by the Forest Management Plan 1994-2003:

- Chuditch Recovery Plan (1994)
  The actions required under the recovery plan have been completed and the plan is no longer in effect.

- Western Swamp Tortoise Recovery Plan (1994)
  Habitat regeneration burns are not a specified action in the recovery plan.

- Orange-bellied and White-bellied Frogs Recovery Plan (1995)
  Fire management is specified in the recovery plan. For the orange-bellied frog, the objective is to exclude fire from specific swamp habitat and to burn other sites in early spring to reduce the likelihood of intense summer fire. During 2000, 2001 and the first half of 2002, no planned or unplanned fires occurred within the known populations of this species. For the white-bellied frog, the plan is to exclude fire from specific swamp habitat. Habitat regeneration burns are not a specified action in the recovery plan. During 2000, 2001 and the first half of 2002, a bushfire in February 2002 burnt the habitat of four populations. Suppression strategies and techniques employed during the fire were modified to minimise impact on frog habitat and post fire survival of animals.

- Noisy Scrub-bird Recovery Plan (1996)
  The recovery plan proposes translocations of noisy scrub-birds in the area covered by the Forest Management Plan 1994-2003, however no actions in relation to fire management in this area are specified.

- Numbat Recovery Plan (unpublished)
  The recovery plan specifies actions to evaluate the effect of hazard reduction burning in jarrah forest. No planned burns for this purpose were undertaken in 2000, 2001 or the first half of 2002.

The Wildlife Management Program for management of Declared Rare Flora (DRF) in the Swan Region recommends conducting research into the fire ecology of several species. In 2000, 2001 and to mid-2002, while no new fire plots were established, several plots that were burnt in previous years were re-surveyed to gain information on the regeneration and fire ecology of these DRF species.

The Wildlife Management Program for management of DRF in the Central Forest (South West) Region also recommends management actions and research into the fire ecology of several species.

A new Wildlife Management Program for Threatened Flora in the Swan Region, and a Wildlife Management Program for Threatened Flora in Warren Region are currently being written. The species descriptions in this plan will include recommendations relating to any known special requirements of the species with respect to habitat regeneration burns.

An additional measure undertaken by the Department to consider the requirements of threatened flora species in the planning process for prescribed fire involves applications to take DRF. Where DRF occur or are likely to occur in a proposed burn area, an application to take the DRF is prepared and forwarded to Wildlife Branch for assessment. The application is to include an evaluation of options, including not burning, or excluding the DRF population from the burn. Assessment of the application includes reviewing information on the regeneration strategy of the species, the impact of the burn at that time of the year, and the conservation status of the species at other locations. The assessment may result in negotiation with the proponent to amend the burn plan. The application is then forwarded to the Director of Nature Conservation (as the delegate of the Minister for the Environment and Heritage) with a recommendation either supporting or rejecting the application. The Director of Nature Conservation may then either approve or reject the application to take declared rare flora.

1.15 FOR THOSE HIGH SALT RISK SECOND ORDER CATCHMENTS IDENTIFIED IN FULFILLMENT OF MINISTERIAL CONDITION 16, CALM WILL REACH AGREEMENT WITH WATER AND RIVERS COMMISSION REGARDING THE PRECAUTIONARY MANAGEMENT AND PROTECTION MEASURES TO BE IMPLEMENTED. THE OBJECTIVE OF THE MEASURE WILL BE TO PREVENT SALINE DISCHARGE INTO THESE WATER COURSES.

Statement of context of the commitment - This commitment relates to all types of forests that are the high salt risk second order catchments identified in fulfillment of Ministerial Condition 16.

As noted in the earlier progress and compliance reports, this commitment has been fulfilled. Compliance with implementation of the precautionary management and protection measures is reported under Commitment 4 above.

1.16 LIMIT GAP SIZE IN KARRI AND KARRI/MARRI FORESTS TO A MAXIMUM AREA OF 80 HECTARES

Statement of context of the commitment - This commitment was made in relation to karri forest on Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves.

The Department monitors the performance of the FPC and its contractors in meeting this commitment. The FPC is responsible for ensuring that field operations are in compliance with the commitment.

Department's responsibilities

Management Audit Branch audits compliance with this commitment. As part of the 2001 audit, auditors assessed the gap sizes in the karri coupes in a sample of four coupes in the field. No gap exceeded the 80-hectare limit. SILREC (a computer-based record of harvesting and silvicultural treatments, based on post-harvesting records) was also analysed and showed that

no gap exceeded the 80-hectare limit for year 2000 harvesting. The SILREC analysis showed maximum gap size was 39 hectares and average gap size was 11 hectares.

As part of the 2002 audit, the size of karri gaps for 2001 harvesting was evaluated from SILREC records. Maximum gap size was 35 hectares and average gap size was 10.6 hectares.

1.17 WHERE POSSIBLE, ENSURE THE DISTANCE BETWEEN AREAS OF RETAINED MATURE FOREST IS A MAXIMUM OF 400 METRES

Statement of context of the commitment - This commitment was made in relation to karri forest on Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves. The intent was to ensure where possible the distance between areas of retained mature forest is a maximum of approximately 400 metres, thereby providing mature forest habitat across the landscape in a manner that provides for the needs of the avifauna.

The Department monitors the performance of the FPC and its contractors in meeting this commitment. The FPC is responsible for ensuring that field operations are in compliance with the commitment.

Department's responsibilities

As part of the 2001 and 2002 audits, auditors checked the coupe planning process, field sampled three karri coupes in each audit and scanned other cutting records. Application of the 400-metre requirement is built into the coupe planning process and the audit verified that this was in place. Field sampling verified that the 400-metre rule had been applied successfully, in some cases requiring additions to stream zones or the retention of mature forest. The use of SILREC data to evaluate all cut over areas for compliance with this requirement could not be achieved. The project to write and test the algorithms that were to generate it was not completed due to higher priority projects associated with the development of the new plan.

1.18 FORMALISE KARRI SILVICULTURAL CHANGES IN A CALM SILVICULTURAL PRESCRIPTION

Statement of context of the commitment - This commitment was made in relation to karri forest on Department managed land categories covered by the Forest Management Plan 1994-2003, i.e. native vegetation on State forest and timber reserves.

As noted in earlier progress and compliance reports, changes to karri silviculture proposed in the Forest Management Plan 1994-2003 have been incorporated into the Department's silviculture guidelines for karri *Silviculture Guidelines 2/95 - Silvicultural practice in the karri forest.* The commitment has been fulfilled by this action.

2. MINISTERIAL CONDITIONS

Progress and compliance with specific Ministerial Conditions is reported below. It is noted that compliance with a number of the conditions has been achieved and previously acknowledged. Where these conditions were time bound and do not require further implementation or ongoing compliance, no further reporting is presented. Where progress and compliance is closely linked to implementation of an agreed commitment, this may have been covered in Section 1 above.

A full reconciliation between commitments and conditions detailing coverage in this report is shown in Appendix 1.

2.1 MINISTERIAL CONDITION 1 - PROPONENT COMMITMENTS

Ministerial Condition 1

1.1 In implementing the proposal, the proponent shall fulfil the commitments (which are not inconsistent with the conditions or procedures contained in this statement) made in the proposal and in response to issues raised following public submissions.

Progress in relation to reporting against proponent commitments is reported on in Section 1 of this report.

The consolidated list of commitments was developed in consultation with the Department. However, the words used in Commitment 11 in the set of commitments agreed as a consequence of the Codd Report and published in EPA Bulletin 983 in June 2000, reflect the 1992 Draft Forest Management Plan, not the Forest Management Plan 1994-2003. The Department wrote to the then Minister for the Environment on 14 July 2000 regarding this issue and suggested that the final table of commitments reflect the approved Forest Management Plan 1994-2003. No response was received. The two previous progress and compliance reports, and this report, have therefore included the working for Commitment 11 that was published in EPA Bulletin 983.

In response to the Progress and Compliance Report 2000, the EPA by letter of 9 May 2001 suggested: *that in view of the imminent development of the next Forest Management Plan, rather than initiate a process to amend the agreed commitment, it may be more practical in any future reporting of this condition, to make reference to the degree of success in achievement of the overall structural objective for the karri forest (40% of the forest by area to be in the mature and senescent growth phase).* This report provides the information suggested by the EPA in section 1.11 in relation to Commitment 11.

2.2 MINISTERIAL CONDITION 2 - IMPLEMENTATION

Ministerial Condition 2

2.1 An expert scientific and administrative committee will be established by the Minister for the Environment to review and report on the implementation of this proposal by June 30 1993. The terms of reference of the committee will be to consider:

- *reserve recommendations within multiple use forest involving those proposals related to temporary exclusion from timber production and potential reserves to act as wildlife corridors;*
- *the environmental, economic and social implications of such proposals for:*
- *nature conservation in WA's native forests;*
- *the maximum sustainable timber supply*

- *the existing and future timber industry*
- *the potential to increase plantation estate on cleared agricultural land to contribute to the production of timber products.*

2.2 Subject to these Conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal.

Where in the course of that detailed implementation, the proponent seeks to change those designs, specifications plans or other technical material in any way that the Minister for the Environment determines on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.

The Department is responsible for the overall management of State forests and timber reserves, and regulates access to State forest and timber reserves by the FPC and its contractors. The FPC has responsibility for compliance of the activities of FPC contractors. Other proponents, such as mining companies, have responsibility for monitoring the impacts arising from their activities. The Department also has a monitoring role through its membership on liaison groups such as the Mining Management Program Liaison Group, with the requirement of this Ministerial Condition.

Ministerial Condition 2.1

The EPA concluded in Bulletin 912 that this Condition had been complied with.

Ministerial Condition 2.2

Department's responsibilities

The Department is continuing to implement the Project, as required under the CLM Act, in accordance with the Ministerial Conditions and relevant legislation. Condition 2.2 requires that changes in designs, specifications, plans or other technical material considered by the Minister, on the advice of the EPA, that are not substantial may be effected. The Department has not sought to change in a substantial manner the designs, specifications, plans technical or other material contained in the Project. However, over the period reported in this report the following matters are relevant to Condition 2.2.

Shelterwood silvicultural guidelines

EPA Bulletin 912 drew attention, in relation to jarrah harvesting, to the increase in the use of the shelterwood silvicultural guidelines and the increase in area harvested and suggested that these matters required consideration as to whether this constituted a significant change in forest management under Ministerial Condition 2.2. The Department's Response to EPA Bulletin 912 provided a detailed explanation and rationale for the silvicultural treatments employed. However, as an outcome of the Codd Report to the Minister of 24 January 1999, the Department was required to produce a report to the EPA within 12 months on the reasons, research and implications of the increased use of the prescription. The Department submitted a report to the EPA on 21 January 2000. The report presented detailed information to support the view that neither the increased use of the shelterwood treatment nor the increase in area of forest cut-over represented a substantial change to the Forest Management Plan 1994-2003. The EPA sought clarification by letter on 14 February 2000 and the Department provided this additional information in a letter dated 15 March 2000.

The changes were accepted by the EPA in correspondence to the Minister for the Environment dated 23 June 2000.

Management of karri and tingle forests

On 11 August 1999, the Minister for the Environment appointed an expert group, chaired by Professor Ian Ferguson, to examine ways of improving the management of karri and tingle forests. Key recommendations of the Ministerial Advisory Group the Government committed to implement include:

- An immediate end to logging in karri/tingle old growth and karri/tingle two-tiered forest.
- No logging in sensitive areas of karri old-growth within 16 blocks (Beavis, Burnett, Carey, Dawson, Deep, Gardner, Giblett, Jane, Keystone, Northcliffe, Ordnance, Sharpe, Swarbrick, Thomson, Wattle and Wye).
- The maximum old-growth karri coupe size to be 40 hectares (half the current size) with the average expected to be 13-15 ha.
- Clearfelling to be the preferred harvesting method for karri old-growth and karri two-tiered forest due to the safety hazards associated with mature karri trees.
- The commencement of buy-out negotiations with the aim of reducing the annual karri sawlog harvest to an annual average of 149,000 cubic metres in the period to the end of 2003. From 2004 it will drop to 50,000 cubic metres.

On 22 December 1999, the Department referred the Report of the Ministerial Advisory Group on Karri and Tingle Forests to the EPA for consideration and subsequent advice to the Minister on whether implementation of the recommendations would constitute a significant change in forest management under Ministerial Condition 2.2 which would then require further EPA assessment.

On 19 January 2000, the Minister for the Environment requested the EPA to inquire into changes to environmental conditions required to permit implementation of the recommendations.

The EPA provided its assessment in Bulletin 983 of June 2000. EPA advice to the Minister for the Environment was that implementation of the recommendations did not require any changes to existing environmental conditions.

Changes to conservation estate to give effect to the Regional Forest Agreement

The Department referred the issue of whether or not a number of changes proposed to the conservation reserve system as a result of the RFA constituted a substantial change to the Forest Management Plan 1994-2003 statement of conditions.

The Minister for the Environment determined on 23 May 2000, on the advice of the EPA, the changes in the forest conservation estate proposed by the Department to give effect, in part, to the RFA were not substantial.

2.3 MINISTERIAL CONDITION 3 - PRECAUTIONARY APPROACH AND ADAPTIVE MANAGEMENT

Ministerial Condition 3

3.1 The proponent shall manage the karri and karri-marri forest in accordance with a precautionary approach. This approach requires that where there is a significant risk that a particular forest management measure could lead to an irreversible consequence appropriate

monitoring and subsequent adjustments to management within an acceptable time frame be carried out.

3.2 The proponent shall manage the jarrah forest in accordance with the following general principles:

(1) a precautionary approach
(2) adaptive and flexible management practices based on research and monitoring of environmental monitoring of operations (see Condition 17);
(3) implementation as a trial, with reassessment by the Environmental Protection Authority after 10 years - the period of the Management Plans and the Timber Strategy (see Condition 11); and
(4) no commitment of all of the wood resource in the long term (see Conditions 9 and 10).

The Department is responsible for general management of State forests and timber reserves. Proponents such as the FPC and mining companies, also have responsibilities for compliance of their activities with the requirement of this Ministerial Condition.

Department's responsibilities

The Codd Report noted that the RFA was the appropriate avenue for addressing the central issues of the long-term sustainable yields and the application of the precautionary principle. The Codd Report also noted that a key element for setting the framework for a new forest management plan would be the requirement for an EMS. The Department notes the FPC has an ISO 14001 accredited EMS in place and the Department has initiated the development of an EMS. A progress report on the status of the Department's EMS is at Appendix 15.

Progress in relation to Ministerial Condition 17 is reported in section 2.17 of this report.

Progress in relation to Ministerial Condition 11 is reported in section 2.11 of this report.

In the broad sense of monitoring, all other sections of this report provide reports on progress and monitoring in relation to particular commitments and conditions.

2.4 MINISTERIAL CONDITION 4 - AMENDMENTS TO THE CONSERVATION ESTATE

Ministerial Condition 4

4 The proponent shall initiate the Government processes required to implement the proposed amendments to the conservation reserve estate as agreed to by the Minister for the Environment and defined in the approved forest management plans.

This Ministerial Condition is the responsibility of the Department, within its legal powers. It is important to note that the implementation of proposed amendments to the conservation estate is not a process over which the Department has complete control.

The Department's previous progress and compliance reports noted that all of the recommendations from the Forest Management Plan 1994-2003 had been initiated. Progress with implementation of the reserve system defined in the approved Forest Management Plan 1994-2003 is addressed in relation to Commitment 10 in section 1.10 of this report.

2.5 MINISTERIAL CONDITION 5 - REVISED TRAVEL ROUTE, RIVER AND STREAM RESERVES

Ministerial Condition 5

5.1 The proponent shall implement the revised system of travel route (road), river and stream reserves consistent with Condition 15 [should be 16]. It is noted that the minimum combined width (both sides of a first, second or third order stream) of the proposed zones is 60 metres.

5.2 The proponent shall ensure that the travel route (road), river and stream reserves remain unharvested in perpetuity, except for those portions of regrowth forest within road zones where thinning can be undertaken in a manner consistent with, and so as to enhance in the longer term, the defined visual quality objectives.

5.3 The proponent shall monitor the effectiveness of the travel route (road), river and stream reserves for nature conservation and protection of water quality to requirements of the Minister for the Environment.

The Department is responsible for research on hydrologic response to phased harvesting, research and determination of high salt risk catchments, monitoring the performance of the FPC in meeting prescribed forest management standards, and preparing regional indicative timber harvesting plans that allow for travel route, river and stream reserves. The Department is responsible for the overall management of State forests and timber reserves, and carries out general monitoring as part of this responsibility. Proponents such as the FPC and mining companies also have responsibilities. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans that allow for travel route, river and stream reserves, and ensuring that field operations are in compliance with the requirements of this Ministerial Condition and associated commitment. The FPC is also responsible for its EMS and for monitoring the impacts arising from the activities of FPC contractors, such as timber harvesting and associated fire, and road building. Other proponents such as mining companies are responsible for monitoring the impacts arising from their activities.

Ministerial Condition 5.1

Department's responsibilities

EPA Bulletin 912 concluded that the Department had complied with Condition 5.1 by implementing the reserve system. The Department continues to implement the reserve system in compliance with this condition. The requirements for travel route, river and stream reserves are specified in the Forest Management Plan 1994-2003 and referred to in the Manual of Management Guidelines for Timber Harvesting in Western Australia (CALM 1999a) and the Code of Practice for Timber Harvesting in Western Australia (CALM 1999b). Informal reserves, including travel route, river and stream reserves, are identified during the timber harvest planning process on the coupe harvest plans and the concept maps.

Ministerial Conditions 5.2 and 5.3

Department's responsibilities

The Codd Report noted that implementation of Conditions 5.2 and 5.3 would be detailed through the EMS that was under development at that time and that this part of the EMS would be completed as a priority. The EMS referred to in the Codd Report is now the FPC EMS and accordingly is not the Department's responsibility.

Monitoring in relation to stream and river reserves and water quality protection is also reported in sections 1.04, 2.12 and 2.16 of this report.

Monitoring in relation to nature conservation is also reported in section 1.02, 1.06, 1.07, 1.08, 1.14, 1.15 and 2.11 of this report.

In particular, the Department's audits of forest management specifically target Commitment 4 (Preserve the quality of potable water supplies from forests) and Commitment 8 (Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees). Reports on the audit program are at Appendices 7 and 8.

2.6 MINISTERIAL CONDITION 6 - DIVERSE ECOTYPE CONSERVATION AREAS

Ministerial Condition 6

6.1 Diverse ecotype conservation areas shall be identified by the proponent and those greater than five hectares shall be identified on publicly available maps.

6.2 The proponent shall ensure that Diverse Ecotype Conservation areas remain protected from timber harvesting and associated activities in perpetuity.

The Department is responsible for preparing regional indicative timber harvesting plans that recognise diverse ecotype zones, maintaining the databases on forest structure, composition and history of treatment, and monitoring the performance of the FPC in meeting prescribed forest management standards. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans that recognise diverse ecotype zones, and ensuring that these areas are protected in accordance with the requirements of the Ministerial Condition.

Ministerial Condition 6.1

Department's responsibilities

EPA Bulletin 912 concluded that the Department has complied with this condition. The Department continues to implement Condition 6.1. A publicly available map of diverse ecotype zones greater than five hectares was produced at Appendix 6 of the 1997 Progress and Compliance Report (CALM 1997). Informal reserves, including diverse ecotype zones, are identified during the timber harvest planning process on the coupe harvest plans and the concept maps. These maps are publicly available on request and are used as part of the public consultation process associated with annual timber harvest plans.

Ministerial Condition 6.2

Department's responsibilities

Commitment 7 in section 1.07 of this report describes progress with prescribed burning in diverse ecotype zones being conducted in accordance with the habitat requirements of these sites.

2.7 MINISTERIAL CONDITION 7 - OLD-GROWTH KARRI AREAS OF HIGH SOCIAL OR ENVIRONMENTAL VALUE

Ministerial Condition 7

7.1 The proponent shall identify and protect areas of old-growth karri (up to 3200 hectares) with a high aesthetic, social or environmental value. This is to be implemented on a regional basis and with the benefit of public involvement. These areas shall:

(1) include those trees in Beavis, Carey and Giblett forest blocks protected from clearfelling by Environmental Conditions related to the Manjimup-Beenup power line proposal (EPA Bulletin 603)
(2) be identified publicly and progressively from the adoption of the Management Plans, with the proponent reporting to the Minister on progress towards implementation within three years; and
(3) shall not be harvested, and shall be managed to retain their values (other than timber production).

7.2 The proponent shall report on the implementation and management of these special areas at the next Forest Management Review.

The Codd Report noted that this Condition would be given attention through the RFA process. Progress with the identification and protection of old-growth forest is reported in relation to Commitment 9 in section 1.09 of this report. The commitment was fulfilled by actions under the RFA process.

As a result of the Government's *Protecting our old-growth forests* policy, in February 2001 the Department implemented:

- an immediate end to harvesting in nearly 99 per cent of old-growth forest on State-owned land;
- an immediate moratorium on the remaining one per cent of old-growth forest.

In November 2001, the Government announced that the one per cent of old-growth forest placed under moratorium would be permanently set aside from timber harvesting.

2.8 MINISTERIAL CONDITION 8 - SUSTAINABLE YIELD ESTIMATES

Ministerial Condition 8

8.1 The allocated timber resource for the period ending 30 June 1993, prior to the consideration by the Minister for the Environment of the report of the committee referred to in Condition 1 (should be 2) will not exceed the 1993 level described in the 1987 Timber Strategy together with an additional amount of the timber resource that was approved in the 1987 Timber Strategy but remained uncut. This additional amount may be allocated by the proponent with the approval of the Minister for the Environment on a needs basis up to a total level not exceeding that proposed by the proponent in its 1992 proposals.

8.2. Following consideration of the report of the committee referred to in Condition 2, the Minister for the Environment shall determine the annual sustainable timber resource available for allocation.

The Department is responsible for undertaking strategic yield scheduling, preparing regional indicative timber harvesting plans and maintaining the databases on forest structure, composition and history of treatment. The FPC is responsible for participation in the

preparation of the regional indicative timber harvesting plans and preparation of the annual plans, and monitoring forest product removals to ensure they do not exceed the set levels.

Ministerial Condition 8.1

The EPA noted in Bulletin 912 that the Minister had made determinations in accordance with Condition 8.1.

It is noted that the condition refers to the period up to 30 June 1993 and has been reported on previously.

Ministerial Condition 8.2

Department's responsibilities

The EPA noted in Bulletin 912 that the Minister had made determinations in accordance with Condition 8.2.

The Department notes the EPA advice in its letter of 9 May 2001, that '*in view of the findings of the EPA in Bulletin 912, this Condition will not be audited further by the EPA pending the next forest management plan.*'

2.9 MINISTERIAL CONDITION 9 - COMMITMENT OF WOOD

Ministerial Condition 9

9.1 Subject to Condition 8, in the letting of contracts for wood supply from the jarrah forest, the proponent shall;

(1) not exceed the annual levels of timber supply defined in Condition 8 above; and
(2) recognise the possibility of the necessity to reduce wood supply beyond 2002 as a result of monitoring and adaptive management following the trial implementation of the jarrah forest silvicultural prescription.

The Department is not responsible for compliance with this Ministerial Condition.

2.10 MINISTERIAL CONDITION 10 - COMMITMENT OF NEW RESOURCE TO BE REFERRED

Ministerial Condition 10

10.1 Notwithstanding Section 38 of the Environmental Protection Act, the proponent shall refer to the Environmental Protection Authority any proposal to enter into a contract for a substantial portion (as determined by the Minister for the Environment) of forest produce identified as other logs (jarrah) or forest residue (marri) in the revised Timber Strategy (Table 13 of the proposals document).

The Department is not responsible for compliance with this Ministerial Condition.

2.11 MINISTERIAL CONDITION 11 - JARRAH SILVICULTURAL TRIAL

Ministerial Condition 11

11.1 The proponent shall implement the jarrah silvicultural prescription so that monitoring of the environmental impacts on a representative range of treated sites and localities in the forest can be carried out to the requirements of the Minister for the Environment. This shall include long-term monitoring which quantifies the impacts of silvicultural practices on environmental elements and values in the forest and provide bases to adjust management.

11.2 The proponent shall give all necessary assistance to the Monitoring and Research Committee (Condition 16) [should be 17] to enable it to have an active and fully informed role in the planning and oversight of the scientific monitoring of this trial period.

11.3 The proponent shall report to the Minister for the Environment on outcomes of this implementation and monitoring and on any modifications to the prescriptions by 2002 as part of the next review of the Forest Management Plans and Timber Strategy.

The Department is responsible for the overall management of State forests and timber reserves, and carries out general monitoring as part of this responsibility. Proponents such as the FPC and mining companies also have responsibilities. The FPC is responsible for monitoring the impacts arising from the activities of FPC contractors, such as timber harvesting and associated fire, and road building. Other proponents such as mining companies are responsible for monitoring the impacts arising from their activities.

Ministerial Condition 11.1

Department's responsibilities

Following the Department's Progress and Compliance Report of December 1997, the EPA advised the Minister for the Environment in November 1998 (EPA Bulletin 912):

> *The EPA concludes that CALM has not complied with Condition 11-1 to the extent that the monitoring has only been carried out on one of the trial areas and has proposed actions to enable CALM to achieve compliance as soon as possible.*

The Department's response to Bulletin 912 provided additional information concerning the extent of monitoring and noted that the Minister had not yet made the determination required by Condition 11.1.

In December 1998, the Department reported to the Minister for the Environment seeking a determination in relation to the requirements for monitoring of environmental impacts of the jarrah silvicultural prescription. The report focused on the precursor to what is now known as the FORESTCHECK system. FORESTCHECK is a system for data collection and monitoring of environmental impacts of the jarrah silvicultural prescription. Following the Department's report to the Minister, the Minister sought the advice of the EPA before making a determination.

The Codd report of January 1999 noted that the Department's report had been referred to the EPA, which was to provide its advice to the Minister within three months.

The EPA advised the Minister for the Environment in August 1999 that she should defer making any determination in relation to Ministerial Condition 11.1 until a number of associated matters were finalised. These matters included the future of the Forest Monitoring and Research Committee, referral of the Department's monitoring proposal to the Forest Monitoring

and Research Committee or its equivalent, and advice to the Minister from the Committee and the EPA on the Department's monitoring proposal. The EPA advice was based on its view that the Department's proposed monitoring required discussion at the detailed level by an array of scientists.

Prior to the EPA advice, the FORESTCHECK plan had been developed with the assistance of a workshop within the Department (April 1999). Subsequent to the EPA advice the FORESTCHECK plan has been developed with the assistance of two workshops involving scientists from universities, CSIRO, the Department and other State Government agencies, as well as privately employed scientists (October 1999, March 2000).

On 11 July 2000, the Department wrote to the EPA enclosing a copy of FORESTCHECK and seeking advice as to whether the framework satisfied the EPA's understanding of the requirements for a forest monitoring system.

On 27 September 2000, the Department wrote to the Minister recommending that the Conservation Commission would be the appropriate body to provide the Minister with advice on the Department's proposed forest monitoring and that the views of the Conservation Commission and the EPA be sought on this course of action. The Minister wrote to the EPA on 16 October 2000, seeking advice regarding this recommendation.

On 13 October 2000, the EPA wrote in response to the Department's letter of 11 July 2000, seeking a briefing on FORESTCHECK and greater clarity on how the proposed monitoring addresses environmental elements and values which would be impacted on by silvicultural practices. Further correspondence between the Department and the EPA on 27 November 2000, 11 December 2000 and 11 January 2001 led to a briefing by the Department on 5 February 2001 on FORESTCHECK. Following the briefing to the EPA on FORESTCHECK, the Department wrote to the EPA on 23 February 2001, seeking confirmation that FORESTCHECK adequately addressed the monitoring requirements of the 1992 Ministerial Conditions.

In March 2001, the EPA and Conservation Commission had discussions and correspondence regarding an agreed approach to addressing Ministerial Condition 11. The Chairman of the EPA suggested that a group chaired by the Department's Director of Science could be bought together to provide the Department with the best advice for inclusion in the progress and compliance report. On 23 May 2001, the Department wrote to the EPA and Conservation Commission seeking feedback on the details of the proposed scope, membership, timelines, cost and reporting of the proposed group to be chaired by the Department's Director of Science. The EPA responded by letter of 5 June 2001 providing endorsement subject to consideration by the Department of a number of matters. The Conservation Commission responded to the Department's letter of 23 May 2001 on 22 June 2001 requesting that the proposed terms of reference be submitted to the Conservation Commission's Forest Management Plan Steering Committee for endorsement. The Steering Committee discussed the issue, including the EPA letter of 5 June, at its 2 July 2001 meeting and an agreed terms of reference was developed. An expert panel chaired by Dr Neil Burrows, the Department's Director of Science, was appointed in July 2001.

Ministerial Condition 11.2

This Ministerial Condition is discussed under the related Ministerial Condition 17 in section 2.17 of this report.

Ministerial Condition 11.3

Department's responsibilities

Outcomes of implementation of Ministerial Condition 11

The Expert Panel chaired by Dr Neil Burrows was asked to provide advice covering:

- A summary of relevant research and monitoring programs and projects undertaken by the Department, including -
  - regeneration adequacy and methods of assessment,
  - salinity constraints for silvicultural guidelines,
  - habitat provision for the maintenance of biodiversity and ecological processes.
- Outcomes of research and monitoring of the environmental impacts of silvicultural practices on environmental elements and values in the forest.
- A summary of the bases these outcomes provide to adjust management.
- The sufficiency of the proposed monitoring project (FORESTCHECK) as a future means of data collection and monitoring the impacts on biodiversity of the application of silvicultural guidelines in the jarrah forest.

The Panel provided its Stage 1 report, in relation to Ministerial Condition 11, in October 2001. The Panel's report, which provides the outcomes of implementation of Ministerial Condition 11, is at Appendix 9. The Executive Summary of the report is quoted below:

The purpose of this report is to assist the Department of Conservation and Land Management with its compliance reporting requirements in relation to Ministerial Condition 11.1 attached to the Forest Management Plan 1994-2003. This Condition relates to the requirement by the Department of Conservation and Land Management to monitor the environmental impacts of silvicultural treatments applied to jarrah forests. The Panel was asked to provide advice to the A/Executive Director covering relevant research and monitoring programs undertaken by the Department, with particular reference to regeneration, salinity and biodiversity conservation issues. The panel was also asked to summarise bases that these outcomes provide for altering forest management and to comment on the sufficiency of FORESTCHECK as a protocol for monitoring the environmental impacts of jarrah forest silvicultural systems.

The key recommendations of the Panel are:

- *Jarrah forest regeneration standards need to be refined to reflect the variability and capability of site types throughout the range of jarrah. The method for assessing regeneration appears adequate over the limited range of site types under which it has been evaluated, but further validation across a broader range of site types may be warranted.*
- *There is no hydrological evidence to vary the existing silvicultural guideline in the salt-sensitive intermediate rainfall zone. These should be reviewed when data from current research programs are available in 4-5 years.*
- *Conservation objectives for forests are poorly defined in various Departmental planning documents. The Panel presents draft objectives for consideration by the Department.*
- *The outcomes of recent research and monitoring provides bases for a number of changes to the silvicultural guidelines to further ensure that forest management is consistent with the principles of ecologically sustainable forest management. These relate to improving the provision of habitat for hollow-dependent and arboreal fauna, better protection of soil and enhancing the protection of understorey vegetation. Detailed recommendations are appended to this report.*

- *FORESTCHECK is a workable, implementable and commendable monitoring protocol. However, it requires a considerable amount of detail to be collected at each site and because resources are limited, lacks geographical representation. The Panel recommends a 12-month trial to compare the cost-effectiveness of FORESTCHECK (as proposed) and a monitoring system based on a subset of species (indicators) that would enable better geographic representation.*
- *The Department of Conservation and Land Management has made considerable progress with auditing and should consider preparing summary reports on its auditing of activities relevant to timber harvesting in jarrah forests as part of its compliance report to the Environmental Protection Authority.*

Part 2 of the Panel's deliberations will deal with the revised jarrah forest silvicultural guidelines with respect to how the proposed new guidelines take account of environmental values (especially regeneration, salinity and biodiversity conservation). The Panel, which will report to the Conservation Commission, will also make recommendations about future forest research and monitoring priorities.

On the basis of the recommendation above, FORESTCHECK was implemented on a trial basis in spring 2001 and autumn 2002 at three locations in the southern jarrah forest. An internal Departmental review of the FORESTCHECK trial took place in July 2002 prior to the intended installation of more sites in the northern jarrah forest in spring 2002 and autumn 2003. A report on the 2001/02 program is at Appendix 17. The Executive Summary of the reported is quoted below:

This document includes the results of the first year of sampling under the FORESTCHECK initiative (Concept Plan available at http://www.naturebase.net/science/science.html). Three FORESTCHECK sites (10 grids) were established in jarrah forests near Manjimup in spring 2001 and autumn 2002. Further sites will be established throughout the forest each year over the next four years.

Particularly notable is the large number of forest organisms recorded and the advance in our understanding of the biodiversity, distribution and disturbance ecology of a broad range of organisms for relatively little effort. This underlines the benefits of well integrated projects that draw together multi-disciplinary teams of skilled people working to a common goal at the landscape scale. I believe that this and the other information collected will serve as a solid foundation for a very important monitoring program to support ecologically sustainable forest management in WA.

In devising FORESTCHECK, we deliberately adopted a 'belt and braces' strategy. Initially, the FORESTCHECK team was asked to err on the side of collecting too much information. We strived to avoid not sampling or undersampling relevant factors or processes, all of course in the context of a finite budget. Although recognising that an indicator species approach would be warranted for cryptogams, invertebrates and fungi, we were reluctant to commence with a list of species that was too short in case valuable information was omitted. Experience with the Kingston project (1994-9) had demonstrated that there was no cost saving involved with counting only nominated indicator species of birds or trapping only nominated indicator species of mammals, reptiles and frogs. With vascular flora, there is a significant risk that an a priori list of indicator species may not be relevant to most parts of the forest, given the marked beta diversity evident with ground flora.

I am confident that reliable lists of indicator species of vertebrates and vascular flora will be able to be assembled after FORESTCHECK has operated for several years and data have been collected from a range of representative sites.

As the data presented in this progress report are from only the first year of monitoring at a small number of sites, it is too early to carry out any meaningful analysis and interpretation. However, a number of interesting observations have emerged. As expected, the species richness and composition of birds at each of the sites varied according to the maturity and structural complexity of the vegetation; generally, bird recovery following timber harvesting parallels that of the vegetation structure. A most striking result is the contrast in the abundance of mammals east and west of the South West Highway. Mammal capture rates were very high on the eastern grids, but very low on the western grids, regardless of treatment. This is probably attributable to natural environmental factors affecting habitat suitability such as climate, landform and vegetation structure and to management history including Western Shield (fox control). At the Kingston monitoring sites, ground dwelling vertebrate and invertebrate fauna are recovering well. Fox control and the extensive network of buffers (temporary exclusion areas – TEAs) have facilitated a relatively rapid recovery following timber harvesting at these sites. While relatively abundant prior to timber harvesting, Western Ringtail Possums were not detected in any of the treatments on the Kingston sites, including the buffers, but Common Brushtail Possums were abundant. Some 588 invertebrate morphospecies were collected including at least 24 with Gondwanan affinity. Good baseline data for more than 200 vascular plant species, 170 fungi species and 160 cryptogams (mosses and lichens) were gathered and further sampling will provide information about the role, recovery and successional pathways of these taxa. Data collected on vascular plants supports the Kingston Project findings, that annual herbs, grasses and weeds are generally favoured by disturbances associated with timber harvesting, but some woody shrubs, perennial herbs and geophytes especially are disadvantaged and may take some time to recover. Monitoring soil damage is not straight forward and further thought needs to be given to developing an efficient but meaningful protocol.

We learned some valuable lessons from this round of sampling; the following points have been collated from the reports submitted by the teams:

- *Need to sample mammals with wire cages in spring as well as autumn.*
- *Need to voucher specimens of mammal species for which taxonomic limits are ill-defined (e.g. Sminthopsis).*
- *Need to refine the sampling procedure for estimating the abundance of vascular flora.*
- *Need to increase the number of 1m x 1m vegetation sampling quadrats to reduce the standard error.*
- *Need to ensure that sites have not been burnt more recently than 2 years, otherwise identification of vascular flora is impeded.*
- *Need to standardise soil damage assessment techniques.*
- *Need to collate details of management history (logging, fire and fox control) for each site.*

It is my intention to subject all of the data collected in the first five years of the program to a rigorous, integrated analysis, report and external review.

I extend my congratulations to all staff involved in the FORESTCHECK team for their professionalism. The project was carried out on time and within budget.

At the time of writing, we are selecting sites for sampling this spring and next autumn. These sites will be in the Collie-Harvey area.

Dr Neil Burrows
Director Science Division
October 2002

Review of Silvicultural Guidelines

In July 2001 the Department appointed a consultant to collate, update and consolidate its current silvicultural guidelines for the management of native forests available for timber harvesting in the south-west.

In September 2001, the consultant provided the Department with a report, *Recommended changes to the silvicultural guidelines for jarrah forest* (Appendix 18), which included comments on issues raised by the EPA, Dr Christine Sharp and the Ministerial Condition 11 Expert Panel report.

In December 2001, the consultant provided the Department with draft updated and collated silvicultural guidelines for jarrah, karri and wandoo. The Department subsequently sought advice from the consultant regarding goals for forest structure, as this was one of the issues raised by the Expert Panel chaired by Dr Burrows (Appendix 19).

The Department has sought and received comments on the draft guidelines from the Conservation Commission, as well as a range of staff within the Department. Major changes proposed in the draft guidelines were summarised in the Draft Forest Management Plan (Conservation Commission, 2002), which was open for public comment for two months. The Sustainable Forest Management Division is currently finalising the guidelines.

The main changes proposed to the existing jarrah guidelines are summarised as follows:

Exclusion of old-growth areas from harvesting

This complies with Government policy. An interim management guideline has been prepared and is reported at Appendix 14 of the Draft Forest Management Plan (Conservation Commission, 2002).

Revised habitat retention requirements

In the light of the results from the Kingston research project, retention of primary habitat trees is proposed to increase from four to six trees per hectare. The characteristics required for these trees have also changed from senescence class 2-5 to 3-8. This will have the effect of retaining less vigorous more senescent trees than before. This change in number of primary habitat trees has also changed the required success criteria for retention from 20 primary per five hectares to 30 primary per five hectares which reflects above.

An additional requirement to mark explicitly for retention of balga (grass trees) has been included. The intent of this is to provide greater diversity of retained habitat for, in particular ring tail possums. The work that has been completed in Kingston has identified balga as an important refuge site for ringtail possums. Where available four large balga per hectare are to be marked for retention.

A requirement to retain all natural hollow logs with a pipe greater than 10 centimetres diameter, and length three metres has also been introduced.

There has also been a greater emphasis placed on the protection of retained habitat from fire applied during the regeneration process.

Predator control

A significant addition is the proposed fox baiting to achieve predator control. This complements the greater emphasis on habitat retention at the coupe level and is intended to remove predator

pressure on sensitive species during the period of regeneration of the forest when they are most vulnerable.

Planting jarrah in gaps in the southern high rainfall forest

Results of research conducted in the high rainfall southern forests has shown that planted jarrah seedlings can successfully grow into well formed saplings and poles without passing through a prolonged lignotuber phase. One silvicultural issue that has been identified in the high rainfall southern forests is the proliferation of marri regeneration following harvesting, which can preclude adequate jarrah regeneration. The introduction of planting jarrah seedlings allows for a means of ensuring adequate, successful regeneration of jarrah on these sites.

Refinement to shelterwood retained basal area

Based on the results achieved with the application of the current silvicultural guideline the retained basal area in shelterwood treatments has been reduced from 15 square metres per hectare to eight to 10 square metres per hectare. This provides for less competition from the retained overstorey with seedlings, allowing more seedlings to establish successfully.

Management of dieback infested areas

The proposal provides for a precautionary approach to the management of dieback on sites where any intensification of the disease is likely to result in high impact to forest values. On these sites it is proposed to retain 15 square metres per hectare of overstorey cover.

On those sites where intensification of the disease is unlikely, as defined by rainfall and vegetation complex, silvicultural application will be the same as dieback-free forest. On these sites there is greater confidence that their productive capacity can be maintained.

Definition of an eastern jarrah type

This is a new concept and an attempt to define that area of the eastern jarrah forest where the expectations of its capacity to establish regeneration following standard application of silvicultural guideline 1/95 have been over ambitious. The main components of the proposed management of these areas is to accept a lower stocking level of regeneration, a uniform retention of retained tree cover, maximise the use of existing regeneration through coppice treatments and accepting a longer period of recruitment of seedlings through multiple regeneration events.

Eastern jarrah has been defined on the basis of rainfall zone and vegetation complexes.

Application of coppice treatments

Greater emphasis is proposed to be placed on applying coppice treatments in gap application to achieve acceptable stocking levels. Coppice treatments have the advantage that the coppice regeneration already has a very well developed root system. Because of this the growth of coppice shoots is rapid.

Jarrah planting

A guideline for jarrah planting is provided. Two seed collection zones are recognised, one north of the Preston River the other south of the Preston River. This represents a precautionary approach as current data on genetic variability suggests minimal variation within the main jarrah belt.

Landing rehabilitation

Requirements and success criteria for landing rehabilitation are explicitly recognised.

Regeneration surveys

A requirement to survey at least a five per cent sample of gap release regeneration in the first year following release burning has been introduced. The intent of this is to provide for a formal measure of the success or otherwise of gap regeneration.

A measurement of retained forest structure (thinned forest) or measure of retained basal area has also been introduced particularly into establishment surveys in areas harvested to shelterwood. The requirement for this has been introduced on the basis that if the forest has been subject to a thinning or remains at full stocking of overstorey, establishment of regeneration cannot be expected and is not required. The retained basal area suggested is 12 square metres per hectare.

Management of fire damaged regrowth

Where wildfire has seriously damaged the growth potential of regrowth jarrah forest guidelines for remedial treatments have been introduced. Where damage is serious coppice treatments are suggested.

It is intended that the guidelines be finalised with the new forest management plan. This will allow changes to silviculture incorporated in the plan as a result of the public consultation, environment, or social and economic assessment processes, to be reflected in the guidelines.

Draft Forest Management Plan (2002)

The development of the Draft Forest Management Plan (Conservation Commission, 2002) has involved consideration of the three key issues of concern to the EPA as expressed through Bulletin 912, being:

- regeneration adequacy and methods of assessment;
- salinity constraints for silvicultural guidelines; and
- habitat provision for the maintenance of biodiversity and ecological processes.

The draft plan addresses these issues in the following ways.

Regeneration adequacy and methods of assessment

The following text is from pages 77, 78 and 82 of the Draft Forest Management Plan (Conservation Commission, 2002).

Management strategy
Monitor and ensure that post-timber harvesting regeneration is consistent with targets set.

Background

Sustaining the productive capacity of the forest requires the re-establishment of growing stock on the site following harvesting. In addition, to meet biodiversity conservation objectives regeneration of the tree component should be done in such a way that all other flora species

also have the opportunity to regenerate. This generally means regeneration must be accomplished using techniques that copy natural processes.

Most karri timber supply comes from single-storied mature stands or two-tiered stands where regeneration is required following harvesting. Regeneration can be achieved using seed trees, seeding or planting. Clearfelling to a minimum area of two hectares is necessary to ensure a suitable environment for regeneration to develop. The maximum clearfelled area is currently 40 hectares.

Jarrah trees are regrown after harvesting predominantly from the release of advance growth present on the forest floor and coppice from felled stems following removal of the overstorey. This is known as gap treatment. In some instances, small areas that are inadequately stocked with advance growth are hand-planted with seedlings. If adequate advance growth or coppice material is not present the removal of the overstorey will result in understocked stands and the loss of productivity. In this case, advance growth needs to be established before the overstorey is completely removed in what is known as a shelterwood operation.

Similar degradation of the commercial productivity of the stand could occur with a selective or partial cut, where the size of the gap or the level of disturbance was insufficient for a species to adequately regenerate. This leaves the stand dominated by the non-preferred species. The potential for this occurs in jarrah and karri stands mixed with marri now that marri is no longer saleable in its traditional woodchip market. Amendments to the silvicultural guidelines have been proposed to ameliorate the problem and the Forest Products Commission is actively seeking new markets for marri. The Conservation Commission will monitor the results of harvesting and regeneration in these stands.

The ease with which jarrah regeneration can be accomplished using gap or shelterwood treatment varies according to rainfall zone with drier areas generally more difficult to regenerate than those in the high rainfall areas (more than 1,100 millimetres). In some cases it is necessary to reduce understorey competition to enable seedlings to become established or advance growth to be released. The silvicultural guidelines take this into account and prescribe different treatments. Limits to the amount of soil disturbance during this process are prescribed to prevent excessive loss of soil-stored seed and regenerative propagules of understorey species for biodiversity reasons.

The methodology and standards for pre- and post-harvest regeneration surveys are documented in the silvicultural guidelines. Regeneration adequacy is a performance indicator and will be stratified by site type so that early warning of inadequate regeneration in previously identified sites (e.g. eastern jarrah forest) will be apparent.

Potential threats	1. *Loss of productivity should forest harvested with intent to regenerate, fail to regenerate.* 2. *Decrease in the productive capacity for timber if dieback-affected area expands and is not rehabilitated.*
Management actions	1. *Set standards for the time between harvest completion and regeneration and the stocking and composition of regeneration.* 2. *Assess regeneration adequacy and re-establish where necessary.* 3. *Monitor regeneration adequacy, particularly for identified sites within eastern jarrah and dominant marri areas and review the adequacy of guidelines and practice where standards are not met.*

Key performance indicator 9	*Unproductive area.*
Performance measure	*The time between commencement of native forest harvesting for regeneration and the completion of regeneration operation.*
Performance target(s)	*More than 50 per cent within one year.* *More than 75 per cent within two years.* *More than 100 per cent within three years.*
Reporting	*Annual.*
Response to target shortfall	*Investigate and report to the Conservation Commission.*

Key performance indicator 10	*The area and per cent of harvested forest treated for regeneration (gap and clearfell) that is effectively regenerated.*
Performance measure	*The proportion of the sampled annual regeneration program that does not met the prescribed standard.*
Performance target(s)	*No more than five per cent of the regenerated area requiring remedial action.*
Reporting	*Annual.*
Response to target shortfall	*Investigate and report to the Conservation Commission.*

Salinity constraints for silvicultural guidelines

The following text is from pages 97, 98, 101 and 102 of the Draft Forest Management Plan (Conservation Commission, 2002).

Degradation of surface and groundwater quality by salinity is a risk for water quality for aquatic ecosystems and for human use, particularly in the intermediate (900-1,100 mm/year) and low (less than 900 mm/year) rainfall zones of the draft plan area. Stream salinity occurs when water tables rise through soil-stored salt, and intersect the ground surface, bringing salt to streams. The major cause of these groundwater rises is reduced water use from transpiration, when native perennial vegetation is cleared and replaced with annual agricultural crops. Where evapotranspiration levels are restored quickly by regenerating native vegetation, the risk of increasing stream salinity is low (Borg et al. 1988).

Because the degrading impacts and consequences of salinity on surface and groundwater quality are significant, timber-harvesting activities are conducted with a high degree of sensitivity to salinity management. Recognition of this potential impact was reflected in Ministerial Conditions 12 and 16 on the Forest Management Plan 1994-2003 whereby timber harvesting was to be more precautionary in the intermediate and low rainfall zones and high salt risk areas. Salinity is managed during timber harvesting by the retention of enough vegetation cover to prevent water tables from rising and salt in the soil and groundwater, does not significantly contribute to stream flow. This is achieved by sustaining sufficient basal area on harvested areas and provision of buffers around all streams. The specifications are detailed in Appendix 3.

The drying trend experienced in the south-west over the past 30 years continues to shift the location of the isohyet lines that determine the high, intermediate and low rainfall zones used to differentiate management practices for salinity. However, management does not need to reflect the changing isohyet lines as they are only a coarse correlation with the important variables of soil stored salt and depth to water table. Soil-stored salt is insensitive to rainfall fluctuations except over the very long term and depth to water table is declining making the existing boundary of the intermediate rainfall zone more precautionary than it was in the past.

Because salinity management measures are based on past silvicultural practice, research is currently in progress to evaluate the hydrological response to timber harvesting in the intermediate rainfall zone using the current silvicultural practices. Timber harvesting of the trial catchments has taken place but results will not be available until groundwater levels have peaked and subsequently declined. This will be mid-term of the approved plan.

Turbid run-off from roads and other soil-moving operations such as mining and timber harvesting in hardwood and softwood forests and contamination from petroleum products, fertilisers, herbicides, pesticides and human waste have the potential to reduce water quality if adequate controls are not in place. Management systems use a defence in depth approach to protect water quality. This approach entails limiting access by pollution sources to sensitive areas of the catchment, controlling operations to minimise potential problems for water quality, containing contaminants in engineered traps and filtering overland flow through stream side vegetative barriers. The Department works with the Water and Rivers Commission, the Water Corporation and industries active in the forests in the ongoing improvement of each of the defensive measures. In particular, some softwood forests are established in Public Drinking Water Source Areas with no retained native vegetation on the streamline. Special care is needed in these areas to prevent loss of water quality when harvesting and replanting are undertaken.

In that regard the Water and Rivers Commission has reviewed the efficacy of the current stream and river reserve system, as an appropriate water quality protection strategy (Water and Rivers Commission 2001). Responses and proposed actions to each of the 23 recommendations of the report are provided in Appendix 19. Implementation of the proposed actions will be through the review of existing guidelines within the first year of the approved plan and the undertaking of trials to be completed within the first five years of the plan. The field trials are to evaluate the possibility of zoning streams based on their association with sensitive water values and varying stream buffer width by zone. The outcomes will form part of the mid-term review of the plan and any water quality gains will be assessed in relation to the biodiversity and visual amenity values of the stream buffers.

Potential threats	*Poor road location and maintenance that resulted in turbid run off.* *Poor erosion control in operations that resulted in stream turbidity.* *Saline groundwater that contributed significantly to streamflow as a result of timber harvesting.* *Human activity that resulted in bacterial contamination of streams.* *Balance between water quality and quantity focused only on quality.* *High density of trees that restricted water available for harvest.*
Management Actions	1. *Establish informal reserves on all streams to the standard prescribed in the draft plan (Appendix 3) and code of practice and provide guidelines on their protection and management.* 2. *Protect the integrity of informal reserves and the catchment through the use of guidelines of best practice management for the maintenance of water quality in all operations.* 3. *Incorporate appropriate standards for the retention of tree cover in silvicultural guidelines to control potentially saline ground water.* 4. *Review and manage access and activities on Public Drinking Water Source Areas to meet water quality guidelines.* 5. *Cooperate with water authorities where they seek to enhance water yield, subject to maintenance of other ecologically sustainable forest management values.* 6. *Undertake trials on buffer definition and width as recommended by the Water and Rivers Commission (Appendix 19).*

Key performance indicator 14	*The annual flow weighted mean salinity and the trend for streams in fully-forested catchments.*
Performance measure	*The annual flow weighted mean salinity and the trends for gauging stations on the following rivers:** *Mitchell River (603005)* *Weld River (606002), (606195)* *Shannon River (606185)* *Barlee Brook (608151)* *Carey Brook (608002)* *Margaret River North (61008)* *Harvey River (613002)* *Tallanalla Creek (613005)* *Falls Brook (613008)* *South Dandalup (614043), (614007)* *Little Dandalup (614017)* *Wilson Brook (614021)* *North Dandalup River (614036)* ** Some of these gauging stations have been shut down. Reporting on the indicator will be dependent on water authorities maintaining gauging stations and supplying analysed data at appropriate times.*

Performance target(s)	*All streams to remain fresh (less than 500mg/litre TSS).* *Salinity trends to be neutral.*
Reporting	*Every five years.*
Response to target shortfall	*Investigate cause in report to Conservation Commission, particularly with respect to climate and disturbance in the catchment.*

Key performance indicator 15	*The implementation of operational measures designed to protect water and soil.*
Performance measure	*The extent of compliance with measures in silvicultural and operational guidelines designed to protect soil and water values.*
Performance target(s)	*85 per cent of sampled areas to be in compliance.*
Reporting	*Annual.*
Response to target shortfall	*Investigate cause and report to the Conservation Commission.*

Key performance indicator 16	*Percent of stream kilometres in catchments in which stream flow and timing has significantly deviated from the historic range of variation.*
Performance measure	*The length of streams inundated by impoundments or dams.* *The length of forested streams below impoundments.* *The length of streams above impoundments.*
Performance target(s)	*Increase in streams impacted by impoundments limited to public water supply needs.*
Reporting	*Mid term.*
Response to target shortfall	*Investigate cause and report to the Conservation Commission.*

Key performance indicator 17	*Per cent of water bodies (e.g. stream kilometres, lake hectares) with significant variance of biological diversity from the historic range of variability.*
Performance measure	*The diversity of aquatic macro-invertebrate fauna at a selected number of monitoring sites.*
Performance target(s)	*No sites with fauna significantly different from the reference condition.*
Reporting	*Mid term.*
Response to target shortfall	*Investigate cause and report to Conservation Commission.*

Habitat provision for the maintenance of biodiversity and ecological processes

The Draft Forest Management Plan (Conservation Commission, 2002) includes strategies to implement an expanded system of conservation reserves and informal reserves; to manage State forest and timber reserves so as to complement the formal and informal reserve system; and to develop forest structural goals. The following text from pages 58, 59, 61, 62, 65, 66 and 67 details other strategies to conserve biological diversity, including the proposal for additional mature habitat zones.

Management strategy
Ensure that the capacity to retain or regain original habitat elements over time is not compromised, including the retention of adequate habitat trees and potential habitat trees.

Background

While a system of formally and informally reserved areas in which disturbance is restricted is the first important step in conserving fauna populations, it is not sufficient to fully meet the objective of sustaining populations of fauna at the operational scale post-disturbance from timber harvesting. Such populations can be sustained by supplementing the main strategies with the retention of key habitat components that might otherwise be lost.

The Department has conducted research over the past seven years on the impact of the current silvicultural prescriptions for jarrah on a range of biodiversity components (Kingston study) including:

- *ground-dwelling mammals e.g. woylie and chuditch;*
- *arboreal mammals e.g. western ringtail and common brushtail possums;*
- *herpetofauna;*
- *invertebrates;*
- *birds;*
- *vascular plants; and*
- *cryptograms.*

The ongoing study is providing information on the retention of habitat components at the operational scale to meet the objective to sustain viable fauna populations. Results to date indicate that 42 species of birds, mammals and reptiles use hollows in standing trees although seven of these mainly use hollows in logs on the ground (Abbott and Whitford 2002). Species identified as most vulnerable to loss of tree hollows include rufous tree-creeper, common

brush-tail possum, wambenger, sacred kingfisher, red-capped parrot, and western rosella. Habitat components that require retention to provide for all species include:

- *mature trees with hollows and intermediate age trees that provide or can produce hollows in the mid term; and*
- *logs, stumps and balga (grass trees) for ground habitats.*

The Department's silvicultural guidelines provide for the retention of habitat components in timber harvesting operations. The current review and update of silvicultural guidelines examines retention levels in the light of ongoing research and recommends amendments where research suggests it is prudent to do so. See Appendix 5 for a summary of proposed changes.

When forest is harvested in advance of clearing for mining (Map 4), specifications for retention of habitat components in the silvicultural guidelines do not apply.

Scenario A considers setting aside even further areas of State forest to increase the proportion of mature habitat elements retained in forest blocks. These areas, termed additional mature habitat zones, would provide additional sources for species to recolonise harvested patches. A target of 200-hectare patches per 1000 hectares across each forest block is considered, based on the range considered necessary for a viable sub-population of western ring-tail possums. It should be stressed that the mature habitat zones are intended to protect a full range of biodiversity values and are not solely for the conservation of a few species. These patches are selected for their mature habitat characteristics, although it is recognised that because of past cutting, mining and dieback extent, a range of stand structures may contribute to the 200-hectare patch. Mature forest within areas already set aside from timber harvesting, such as formal reserves, old-growth, stream zones and other informal reserves, can contribute to mature habitat zones. While the selection of additional zones to meet the target patch size would aim to consolidate or link with formal and informal reserves, the additional habitat zones would eventually be available for harvest once their habitat function could be succeeded by older patches of adjacent regenerated forest.

The Conservation Commission recognises that further work is needed to refine the proposal for additional mature habitat zones before they could be adopted. Issues to be explored include the need for additional zones in close proximity to large reserves, the distribution of the additional mature habitat zones, and whether it would be necessary to retain habitat trees as well as additional mature habitat zones.

Potential threats	1. *Inadequate information on habitat requirements of species that led to ineffective retention standards.* 2. *Non-compliance with the retention guidelines that led to a loss of some populations at the landscape scale.*
Management actions	1. *Undertake research on the effect of habitat loss on key faunal species and review the habitat requirements as information becomes available.* 2. *Maintain standards for the protection of selected habitat components in codes of practice and other guidelines.* 3. *Audit the implementation of the habitat protection requirements.*

Management strategy

Identify, and ensure that management actions lead to the survival of all populations of threatened species and threatened ecological communities.

Background

Threatened flora, fauna and ecological communities occur throughout State forest and timber reserves, and on other lands. Their continued survival and ability to recover is potentially affected by a range of independent processes, such as, inappropriate fire regimes, predation by feral animals, salinity and introduced plant pathogens. In addition, activities associated with land use and management have the potential to threaten them. These activities include road and dam construction, open cut mining, timber harvesting, wildflower harvesting, planned burning, recreational facility development and public use and access.

The Department prepares recovery plans (Appendix 15) for threatened flora, fauna and ecological communities, on a priority basis (Department Policy No. 50). Management procedures and systems have been developed that address the protection of threatened species and ecological communities. These include:

- *Maintaining databases of the locations of threatened species and ecological communities, conducting searches where high impact disturbance such as road making is proposed, and maintaining licensing systems and compliance checking programs where any threatened flora is proposed to be 'taken' (Department Policy No. 9, 'Conservation of Threatened Flora in the Wild'; Department Administrative Instruction No. 24, 'Protection of Endangered Flora in Departmental Operations'; Department Policy No. 33, 'Conservation of Threatened Fauna in the Wild'; Department Administrative Instruction No. 44, 'Protection of Endangered and Specially Protected Fauna in Departmental Operations').*
- *The development of the Forest Vertebrate Fauna Distribution Information System (Christensen et al. 2001). The system combines the vegetation complexes mapped for the RFA into 52 fauna habitats and correlates those habitats with the likely presence in them of 297 vertebrate fauna species. It can then be used to predict the likely occurrence of sensitive species, relative to forest management activities.*

Broadscale programs to address threatening processes, such as Western Shield to control foxes, have proved markedly successful and will be maintained.

Potential threats	1. *Not all threatened species or ecological communities identified and listed.* 2. *Listed threatened species decline or threatened ecological communities reduce in area and composition.* 3. *Listed threatened species taken in a management activity.*
Management actions	1. *Maintain a process for identifying and listing threatened species and ecological communities and for listing priority species and ecological communities (those that may be threatened but for which there are insufficient survey data and those that are rare but not threatened).* 2. *Develop and implement recovery plans for threatened species and ecological communities.* 3. *Maintain and implement procedure, based on risk assessment, to identify threatened species and ecological communities requiring protection from proposed management activities.*

Management strategies

Undertake a comprehensive biological survey of the forest regions as soon as resources permit.

Research the response of forest ecosystems to natural disturbance, with a view to improving forest management practices.

Continue to develop knowledge of the impacts of forest management practices on the key components of biological diversity and ecosystem function and maintain guidelines and other subordinate documents that prescribe measures to limit impacts to within acceptable levels.

Background

Biological survey

While there have been local surveys of the fauna and flora in the draft plan area and it is considered that there is a good broad understanding of the biodiversity, a systematic biological survey has never been undertaken. Systematic biological surveys are the best means of assessing the biodiversity of a region and designing a conservation reserve system.

A systematic regional biological survey of a broader range of taxonomic groups than is currently available would provide better information on which to base management for the conservation of biodiversity. However, the conservation knowledge in the forests is higher and the risks to biodiversity lower than in many other areas in the State.

Disturbance of forest ecosystems

Understanding the effect of natural and human-induced disturbance on ecosystems and their functioning is fundamental to management. This knowledge is used to plan the timing, scale and mechanics of operations so that the objectives for biodiversity can be met while achieving other objectives. Reviews of the response of components of the biodiversity to disturbance, both natural and human caused, were undertaken and published in the RFA process.

Knowledge on the response of ecosystems to disturbance is gained through research and monitoring. Research is ongoing and is described under the strategy Generate and transfer knowledge and develop the necessary skills and competencies in staff in the 'Plan implementation' chapter of the draft plan. Systematic monitoring has not been undertaken previously and is an initiative of this draft plan. The monitoring proposed is discussed under the strategy Monitor key characteristics of the environment and management operations and continually improve forest management both routinely and through adaptive management trials as previously identified. This strategy is also in the 'Plan implementation' chapter.

Potential threats	*1. Some biodiversity components not adequately catered for.*
Management actions	*1. Prepare a case for a biological survey of the draft plan area.* *2. Undertake the survey when resources and priorities permit.*

Key performance indicators	
Key performance indicators	*are being used to track the achievement of the approved plan's objectives and its implementation. The background to the development of key performance indicators is described in the 'Plan implementation' chapter under the*

	heading key performance indicators.
Five indicators	*have been selected to provide a broad cross-section of the objectives related to conserving biodiversity*

Key performance indicator 1	*The representation of forest ecosystems in reserves.*
Performance measure	*Area of each forest ecosystems by land category (existing and proposed separately).*
Performance target(s)	*25 per cent of the individual areas proposed for the reserve system to have security of land category and purpose by the end of the plan.*
Reporting	*Biennial.*
Response to target shortfall	*Identify reasons for reserve not being established in report for Conservation Commission and address those within the control of the Department.*

Key performance indicator 2	*The status of (critically endangered, endangered, vulnerable, conservation dependent) forest-dwelling species and ecological communities at risk of not sustaining viable breeding populations as determined by listing.*
Performance measure	*List of species and ecological communities and their status that tracks movements of species between protection categories.*
Performance target(s)	*No species or ecological community will move to a higher category of threat as a result of management activities.*
Reporting	*Every time the lists are revised.*
Response to target shortfall	*Investigate the cause and report to the Conservation Commission.*
Key performance indicator 3	*The status of selected threatened or conservation dependent species that are the subject of management actions to protect them.*
Performance measure	*The trap success for animals at selected monitoring sites.*
Performance target(s)	*As per recovery plans.*
Reporting	*Annual.*
Response to target shortfall	*Investigate the cause and report to the Conservation Commission.*

Key performance indicator 4	*The extent of compliance by forest users with requirements to protect informal reserves and habitat prescribed in codes of practice and guidelines.*
Performance measure	*Proportion of samples in compliance.*
Performance target(s)	*More than 85 per cent of areas sampled to be in compliance.*
Reporting	*Annual.*
Response to target shortfall	*Investigate the cause and report to the Conservation Commission.*

Key performance indicator 5	*Compliance with the size and distribution of timber harvesting cells (gaps in jarrah and clearfelled areas in karri), excluding areas harvested in advance of mining.*
Performance measure	*The proportion of cells in compliance with the prescribed limits.*
Performance target(s)	*More than 85 per cent of areas sampled to be in compliance.*
Reporting	*Annual.*
Response to target shortfall	*Investigate the cause and report to the Conservation Commission.*

The implementation of monitoring programs is further discussed in relation to Commitment 2 in section 1.02 of this report.

2.12 MINISTERIAL CONDITION 12 - PHASED LOGGING

Ministerial Condition 12

12.1 The proponent shall ensure that, in all second order catchments in the intermediate and low rainfall zones of the multiple use jarrah forest subject to logging, at least 30 per cent of each second order catchment has a retained basal area of greater than 15 m^2ha^{-1} for a period of at least 15 years after harvesting the remainder of the catchment.

12.2 This retained forest shall be selected to enhance wildlife, water resource and visual objectives.

12.3 The proponent shall monitor, to the requirements of the Minister for the Environment, and report by 2002 on the status and effectiveness of these measures to protect nature conservation values and water quality at the time of the next Forest Management Plans and Timber Strategy.

The Department is responsible for preparing regional indicative timber harvesting plans that allow for phased harvesting, research on hydrologic response to phased harvesting, research and determination of high salt risk catchments, and monitoring the performance of the FPC in meeting prescribed forest management standards. The Department is responsible for the overall management of State forests and timber reserves, and carries out general monitoring as part of this responsibility. Other proponents such as the FPC and mining companies also have responsibilities. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans that allow for phased harvesting, and ensuring that field operations are in compliance with the requirements of this commitment and associated Ministerial Conditions. The FPC is responsible for monitoring the impacts arising from the activities of FPC contractors such as timber harvesting and associated fire, and road building. Mining companies are responsible for monitoring the impacts arising from their activities.

Ministerial Condition 12.1

Department's responsibilities

The Department is not responsible for compliance with this Ministerial Condition. However, the Department monitors the FPC's compliance with the requirements of this Ministerial Condition. This is reported in section 1.04 of this report.

Ministerial Condition 12.2

EPA Bulletin 912 concluded that the Department had complied with Condition 12.2.

Ministerial Condition 12.3

Department's responsibilities

Monitoring in relation to stream and river reserves and water quality protection is reported in sections 1.04, 2.11 and 2.16 of this report.

Monitoring in relation to nature conservation is reported in section 1.02, 1.06, 1.07, 1.08, 1.14, 1.15 and 2.11 of this report.

In particular, the Department's audits of forest management specifically target Commitment 4 (Preserve the quality of potable water supplies from forests), at section 1.04 of this report, and Commitment 8 (Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees), at section 1.08. Reports on the audit program are at Appendices 7 and 8.

2.13 MINISTERIAL CONDITION 13 - HABITAT TREES

Ministerial Condition 13

13.1 The proponent shall ensure that the number, condition and age of trees retained on sites subject to gap treatment is sufficient, as determined by the Minister for the Environment to adequately provide habitat function throughout the cutting cycle of the forest.

The Department monitors the performance of the FPC in meeting this Ministerial Condition. The FPC is responsible for ensuring that field operations are in compliance with the Ministerial Condition.

EPA Bulletin 912 noted that the determination of the Minister had not been obtained. The Codd Report noted that the Department had submitted a report to the Minister recommending specifications for habitat tree retention in the jarrah forest. On the advice of the EPA, the Minister has approved the specifications recommended by the Department. Compliance with Condition 13.1 is reported in relation to Commitment 12 in section 1.12 of this report.

2.14 MINISTERIAL CONDITION 14 - *BANKSIA GRANDIS* REDUCTION

Ministerial Condition 14

14.1 The proponent shall concentrate the proposed Banksia grandis reduction in specific areas where the environmental circumstances suggest that treatment will have the greatest impact on reducing the spread and intensification of Phytophthora cinnamomi in the jarrah forest and where required to establish jarrah and marri regeneration.

14.2 The proponent shall establish a programme, to the requirements of the Minister for the Environment, to identify and evaluate the environmental implications of the proposed reduction and that the results of that evaluation shall be reported on, at or before the time of the next review of the Forest Management Plans by 2002.

EPA Bulletin 912 noted that the Department had not implemented the *Banksia grandis* reduction program. The Department continues not to implement the *Banksia grandis* reduction program.

The Department notes the advice of the EPA in its letter of 9 May 2001 that: *Given the findings of the EPA in Bulletin 912, this Condition will not be audited further by EPA pending the next forest management plan.*

2.15 MINISTERIAL CONDITION 15 - FIRE MANAGEMENT

Ministerial Condition 15

15.1 The proponent shall ensure that the fire management objectives related to the jarrah forest prescription include the minimisation of air pollution in urban areas, to the requirements of the Minister for the Environment.

15.2 The proponent shall inform the public about its fire management on a regional basis each year in its annual report. This shall include but not be limited to the following:

(1) occurrences and causes of wildfires
(2) purposes of burns
(3) areas burnt under different regimes of season and periodicity
(4) escapes; and
(5) the contribution of prescribed burning to reducing wildfire hazard.

15.3 Within 12 months of this proposal being given authority to be implemented the proponent shall initiate a public review of its prescribed burning policy and practices and the wildfire threat analysis. This should be done with the close involvement of the Research and Monitoring Committee. If possible, it should be linked with a review of the provisions of the Bush Fires Act.

Ministerial Condition 15.1

EPA Bulletin 912 concluded that the Department had complied with Condition 15.1. The Department continues to comply with this condition.

Ministerial Condition 15.2

EPA Bulletin 912 concluded that the Department had complied with Condition 15.2. The Department continues to comply with this condition.

Ministerial Condition 15.3

EPA Bulletin 912 noted that the review required under Condition 15.3 had been initiated and completed.

The Department is continuing to implement the smoke management guidelines approved by the Minister on 29 November 1996 and continues to produce and publish information on fire management in its Annual Reports.

The Department applied smoke management systems for all planned burns. This required careful analysis of forecast weather, atmospheric conditions, the condition of forest fuel, ignition patterns and timing, size and locations of burns relative to population centres.

Specialist weather forecasters from the Bureau of Meteorology continued to provide the Department with detailed information on weather and atmospheric conditions on a regular basis.

The Department facilitated the development of cooperative research with the Bureau of Meteorology and the Bureau of Meteorology Research Centre on a range of studies aimed at improving prediction and accuracy of weather forecasting for smoke management.

During 2001, the Department conducted an internal fire review, including prescribed burning policy and practices and the wildfire threat analysis. The review (Muller 2001) was released in July 2002 together with the Department's response to the recommendations of the review (CLM 2002a).

In April 2002, the Department organised a symposium on *Fire in South-West Australian Ecosystems: Impacts and Management*, to which some 350 people registered (CLM 2002b). Also in April 2002, it was announced that the EPA would undertake a public review of the Department's fire management activities and policies.

2.16 MINISTERIAL CONDITION 16 - HIGH SALT RISK CATCHMENTS

Ministerial Condition 16

16.1 Within three years, or such other period as the Minister for the Environment shall nominate, the proponent, on advice from the Water Authority of Western Australia, shall identify second order catchments with a high salt risk.

16.2 Within each catchment identified according to the requirements of Condition 16.1, the proponent shall retain additional river and stream buffers and locate areas temporarily reserved during phased logging operations to the requirements of the Water Authority of Western Australia.

The Department is responsible for research and determination of high salt risk catchments, preparing regional indicative timber harvesting plans that allow for phased harvesting, and monitors the performance of the FPC in meeting prescribed forest management standards. The FPC is responsible for participation in the preparation of the regional indicative timber harvesting plans and preparation of the annual plans that allow for phased harvesting and any additional stream reserves, and ensuring that field operations are in compliance with the requirements of this Ministerial Condition.

Ministerial Condition 16.1

EPA Bulletin 912 concluded that the Department had complied with this condition.

Ministerial Condition 16.2

Ongoing implementation of measures to protect potable water supplies is discussed in relation to Commitment 4 in section 1.04 of this report. Commitment 15 also relates to high salt risk catchments and compliance with this commitment is reported in section 1.15 of this report.

Department's responsibilities

The Department's audits of forest management specifically target Commitment 4 (Preserve the quality of potable water supplies from forests), at section 1.04 of this report, and Commitment 8 (Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees), at section 1.08. Reports on the audit program are at Appendices 7 and 8.

2.17 MINISTERIAL CONDITION 17 - FOREST MONITORING AND RESEARCH COMMITTEE

Ministerial Condition 17

17.1 The Minister for the Environment will set up a committee having objectives which include:

(1) identification, prioritisation and approval of monitoring and research programmes and projects on environmental impacts of forestry management
(2) the granting of funds towards such monitoring and research
(3) receipt of progress reports
(4) reporting to the Minister for the Environment
(5) publication of results.

17.2 The Committee shall include the heads (or nominees) of the Department of Conservation & Land Management, the Environmental Protection Authority, the Western Australian Forest Industries Federation, the Conservation Council and the Water Authority of Western Australia, and the Chairpersons of the Lands and Forest Commission and National Parks and Nature Conservation Authority.

17.3 The committee shall appoint working groups of scientists to recommend and report to the Committee on the design and funding of research projects, the identification, prioritisation and review of monitoring and research programmes and projects relating to the environmental impacts of forest management.

17.4 The committee shall provide brief annual progress reports to the Minister for the Environment, with major reports in 1997 and 2002, at the time of the next review of the Forest Management Plans and Timber Strategy.

Ministerial Condition 17.1 and 17.2

The Minister for the Environment established the Committee in December 1993. The Committee was established by the Minister in accordance with the membership requirements of Condition 17.2.

The Codd Report in January 1999 noted that the Forest Monitoring and Research Committee was not workable in the manner envisaged when the condition was set. The Minister for the Environment sought advice from the EPA on changes to Condition 17. The EPA provided advice to the Minister in March 1999 in regard to a proposed amendment to Condition 17. Following the establishment of the Conservation Commission, the Department considered the issue of this committee at the meeting of the Corporate Executive on 28 June 2001 and recommended that the Conservation Commission set up a Forest Research Advisory Committee. The Conservation Commission considered this issue at its meetings of 28 September and 19 October 2001 and resolved to recommend to the Minister that the Conservation Commission set up a Research Advisory Committee. Accordingly, the Chair of the Conservation Commission wrote to the Minister on 6 December 2001 and the Minister approved the Commission's proposal on 9 July 2002. On 12 August 2002, the Commission resolved to advertise an expression of interest for the proposed Research Advisory Committee.

Ministerial Condition 17.3

A working group of scientists was appointed in 1997 to review and identify gaps in research and monitoring programs. The report of the working group of scientists appointed by the Forest Monitoring and Research Committee was released on 7 February 2000.

Ministerial Condition 17.4

An annual report of the Forest Monitoring and Research Committee for the calendar year 2000 was submitted to the Minister for the Environment on 6 March 2001.

2.18 MINISTERIAL CONDITION 18 - REPORTING ON COMPLIANCE

Ministerial Condition 18

18.1 Reporting on compliance
The proponent shall prepare "Progress and Compliance Reports", to help verify the environmental performance of this project, in consultation with the Environmental Protection Authority. These shall include brief annual progress reports to the Environmental Protection Authority, and major public reports in 1997 and 2002.

Both the Department and the FPC are responsible for reporting on compliance.

The EPA concluded in Bulletin 912 that this condition had been complied with. This report is a report submitted in accordance with Condition 18.

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APPENDIX 1

Structure and coverage of 2002 Progress and Compliance Report in relation to Ministerial Conditions and proponent commitments

STRUCTURE AND COVERAGE OF 2002 PROGRESS AND COMPLIANCE REPORT IN RELATION TO MINISTERIAL CONDITIONS AND PROPONENT COMMITMENTS

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
1.1 *In implementing the proposal, the proponent shall fulfil the Commitments (which are not inconsistent with the Conditions or procedures contained in this statement) made in the proposal and in response to issues raised following public submissions.*	A consolidated list of 18 separate Commitments has been prepared and agreed between CLM and the EPA, as follows:	Commitments are addressed in section 1 of this report.
	Identify and publish the values to be managed for in each forested area.	Addressed in section 1.01 of this report.
	Implement long-term monitoring programs to identify and study significant management issues in forests.	Addressed in section 1.02 of this report. In the broad sense of monitoring, all other sections of this report provide reports on monitoring in relation to particular commitments and conditions.
	Regulate the production of forest resources to levels that can be sustained indefinitely.	Addressed in section 1.03 of this report. See also section 2.8.
	Preserve the quality of potable water supplies from forests.	Addressed in section 1.04 of this report. See also sections 2.12 and 2.16.
	Undertake research to improve a scientific basis for the protection of diversity.	Addressed in section 1.05 of this report.
	Conduct prescribed burns in river and stream zones so as to be of low intensity.	Addressed in section 1.06 of this report. See also section 2.5.
	Conduct prescribed burning in diverse ecotype zones in accordance with habitat requirements of the site.	Addressed in section 1.07 of this report. See also section 2.6.
	Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees.	Addressed in section 1.08 of this report. See also section 2.5.
	Identify areas of high value old-growth forest.	Addressed in section 1.09 of this report. See also section 2.7.
	Further enhance the security and representation of the conservation reserve system.	Addressed in section 1.10 of this report. See also section 2.4.
	Allow identified areas of regrowth karri to acquire old-growth characteristics, including 25% of pre-1940 regrowth, all regrowth stands regenerated in the period between 1940 and 1975 less than 200 hectres in area, and 50% of all stands regenerated after 1990.	Addressed in section 1.11 of this report.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
	Retain an average of (at least) three large trees on every hectare harvested to provide habitat.	Addressed in section 1.12 of this report. See also section 2.13.
	Retain, and protect as far as possible, at least one suitable ground habitat, i.e. hollow log, per hectare.	Addressed in section 1.13 of this report.
	Undertake habitat regeneration burns in forests where special requirements for threatened or endangered species are identified.	Addressed in section 1.14 of this report.
	For those high salt risk second order catchments identified in fulfillment of Ministerial Condition 16, CALM will reach agreement with Water and Rivers Commission regarding the precautionary management and protection measures to be implemented. The objective of the measure will be to prevent saline discharge into these water courses.	Addressed in section 1.15 of this report.
	Limit gap size in karri and karri/marri forests to a maximum area of 80 hectares.	Addressed in section 1.16 of this report.
	Where possible, ensure the distance between areas of retained mature forest is a maximum of 400 metres.	Addressed in section 1.17 of this report.
	Formalise karri silvicultural changes in a CALM silvicultural prescription.	Addressed in section 1.18 of this report.
2.1 *An expert scientific and administrative committee will be established by the Minister for the Environment to review and report on the implementation of this proposal by June 30 1993. The terms of reference of the committee will be to consider:* • *reserve recommendations within multiple use forest involving those proposals related to temporary exclusion from timber production and potential reserves to act as wildlife corridors;* • *the environmental, economic and social implications of such proposals for:* • *nature conservation in WA's native forests;* • *the maximum sustainable timber supply* • *the existing and future timber industry* • *the potential to increase plantation estate on cleared agricultural land to contribute to the production of timber products.*		Addressed in section 2.2 of this report.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
2.2 *Subject to these Conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal.* *Where in the course of that detailed implementation, the proponent seeks to change those designs, specifications plans or other technical material in any way that the Minister for the Environment determines on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.*		Addressed in section 2.2 of this report.
3.1 *The proponent shall manage the karri and karri-marri forest in accordance with a precautionary approach. This approach requires that where there is a significant risk that a particular forest management measure could lead to an irreversible consequence appropriate monitoring and subsequent adjustments to management within an acceptable time frame be carried out.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.* Commitment 3 – *Regulate the production of forest resources to levels that can be sustained indefinitely.*	Addressed in section 2.3 of this report. See also sections 1.02 and 1.03. In the broad sense of monitoring, all other sections of this report provide reports on monitoring in relation to particular commitments and conditions.
3.2 *The proponent shall manage the jarrah forest in accordance with the following general principles:* (1) *a precautionary approach* (2) *adaptive and flexible management practices based on research and monitoring of environmental monitoring of operations (see Condition 17);* (3) *implementation as a trial, with reassessment by the Environmental Protection Authority after 10 years - the period of the Management Plans and the Timber Strategy (see Condition 11); and* *(4) no commitment of all of the wood resource in the long term (see Conditions 9 & 10).*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.* Commitment 3 – *Regulate the production of forest resources to levels that can be sustained indefinitely.*	Addressed in section 2.3 of this report. See also sections 1.02, 1.03, 2.11 and 2.17. In the broad sense of monitoring, all other sections of this report provide reports on monitoring in relation to particular commitments and conditions.
4 The proponent shall initiate the Government processes required to implement the proposed amendments to the conservation reserve estate as agreed to by the Minister for the Environment and defined in the approved Forest Management Plans.	Commitment 10 – *Further enhance the security and representation of the conservation reserve system.*	Addressed in sections 1.10 and 2.4 of this report.
5.1 *The proponent shall implement the revised system of travel route (road), river and stream reserves consistent with Condition 15* [should be 16]. *It is noted that the minimum combined*	Commitment 8 – *Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees.*	Addressed in sections 2.5 of this report. See also section 1.08.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
width (both sides of a first, second or third order stream) of the proposed zones is 60 metres.		
5.2 *The proponent shall ensure that the travel route (road), river and stream reserves remain unharvested in perpetuity, except for those portions of regrowth forest within road zones where thinning can be undertaken in a manner consistent with, and so as to enhance in the longer term, the defined visual quality objectives.*	Commitment 8 – *Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees.*	Addressed in sections 2.5 of this report. See also section 1.08.
5.3 *The proponent shall monitor the effectiveness of the travel route (road), river and stream reserves for nature conservation and protection of water quality to requirements of the Minister for the Environment.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.* Commitment – *Preserve the quality of potable water supplies from forests.* Commitment 6 – *Conduct prescribed burns in river and stream zones so as to be of low intensity.* Commitment 8 – *Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees.* Commitment 15 – *For those high salt risk second order catchments identified in fulfillment of Ministerial Condition 16, CALM will reach agreement with Water and Rivers Commission regarding the precautionary management and protection measures to be implemented. The objective of the measure will be to prevent saline discharge into these water courses.*	Addressed in sections 2.5, 1.02, 1.04, 1.06, 1.08, 1.15, 2.11, 2.12 and 2.16 of this report.
6.1 *Diverse ecotype conservation areas shall be identified by the proponent and those greater than five hectares shall be identified on publicly available maps.*		Addressed in section 2.6 of this report.
6.2 *The proponent shall ensure that Diverse Ecotype Conservation areas remain protected from timber harvesting and associated activities in perpetuity.*	Commitment 7 – *Conduct prescribed burning in diverse ecotype zones in accordance with habitat requirements of the site.*	Addressed in section 2.6 of this report. See also section 1.07.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
7.1 *The proponent shall identify and protect areas of old-growth karri (up to 3200 hectares) with a high aesthetic, social or environmental value. This is to be implemented on a regional basis and with the benefit of public involvement. These areas shall:* (1) *include those trees in Beavis, Carey and Giblett forest blocks protected from clearfelling by Environmental Conditions related to the Manjimup-Beenup power line proposal (EPA Bulletin 603)* (2) *be identified publicly and progressively from the adoption of the Management Plans, with the proponent reporting to the Minister on progress towards implementation within three years; and* (3) *shall not be harvested, and shall be managed to retain their values (other than timber production).*	Commitment 9 – *Identify areas of high value old-growth forest.*	Addressed in sections 1.09 and 2.7 of this report.
7.2 *The proponent shall report on the implementation and management of these special areas at the next Forest Management Review.*		
8.1 *The allocated timber resource for the period ending 30 June 1993, prior to the consideration by the Minister for the Environment of the report of the committee referred to in Condition 1* (should be 2) *will not exceed the 1993 level described in the 1987 Timber Strategy together with an additional amount of the timber resource that was approved in the 1987 Timber Strategy but remained uncut. This additional amount may be allocated by the proponent with the approval of the Minister for the Environment on a needs basis up to a total level not exceeding that proposed by the proponent in its 1992 proposals.*		Addressed in section 2.8 of this report.
8.2 *Following consideration of the report of the committee referred to in Condition 2, the Minister for the Environment shall determine the annual sustainable timber resource available for allocation.*	Commitment 3 – *Regulate the production of forest resources to levels that can be sustained indefinitely.*	Addressed in section 2.8 of this report. See also section 1.03.
9.1 *Subject to Condition 8, in the letting of contracts for wood supply from the jarrah forest, the proponent shall;* (1) *not exceed the annual levels of timber supply defined in Condition 8 above; and* (2) *recognise the possibility of the necessity to reduce wood supply beyond 2002 as a result of monitoring and adaptive management following the trial*	Commitment 3 – *Regulate the production of forest resources to levels that can be sustained indefinitely*	Addressed in section 1.03 of this report. See also section 2.9.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
implementation of the jarrah forest silvicultural prescription.		
10.1 *Notwithstanding Section 38 of the Environmental Protection Act, the proponent shall refer to the Environmental Protection Authority any proposal to enter into a contract for a substantial portion (as determined by the Minister for the Environment) of forest produce identified as other logs (jarrah) or forest residue (marri) in the revised Timber Strategy (Table 13 of the proposals document).*	Commitment 3 – *Regulate the production of forest resources to levels that can be sustained indefinitely*	Addressed in section 2.10 of this report.
11.1 *The proponent shall implement the jarrah silvicultural prescription so that monitoring of the environmental impacts on a representative range of treated sites and localities in the forest can be carried out to the requirements of the Minister for the Environment. This shall include long-term monitoring which quantifies the impacts of silvicultural practices on environmental elements and values in the forest and provide bases to adjust management.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.*	Addressed in section 2.11 of this report. See also section 1.02.
11.2 *The proponent shall give all necessary assistance to the Monitoring and Research Committee (Condition 16)* (should be 17) *to enable it to have an active and fully informed role in the planning and oversight of the scientific monitoring of this trial period.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.*	Addressed in section 2.17 and 2.11 of this report.
11.3 *The proponent shall report to the Minister for the Environment on outcomes of this implementation and monitoring and on any modifications to the prescriptions by 2002 as part of the next review of the Forest Management Plans and Timber Strategy.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.*	Addressed in section 2.11 of this report. See also section 1.02.
12.1 *The proponent shall ensure that, in all second order catchments in the intermediate and low rainfall zones of the multiple use jarrah forest subject to logging, at least 30 per cent of each second order catchment has a retained basal area of greater than 15 m^2ha^{-1} for a period of at least 15 years after harvesting the remainder of the catchment.*	Commitment 4 – *Preserve the quality of potable water supplies from forests.*	Addressed in section 1.04 of this report. See also section 2.12.
12.2 *This retained forest shall be selected to enhance wildlife, water resource and visual objectives.*	Commitment 4 – *Preserve the quality of potable water supplies from forests.*	Addressed in section 2.12 of this report. See also section 1.04.
12.3 *The proponent shall monitor, to the requirements of the Minister for the Environment, and report by 2002 on the status and effectiveness of these*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.*	Addressed in sections 1.02, 1.04, 1.06, 1.08, 1.15, 2.05, 2.11, 2.12 and 2.16 of this report.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
measures to protect nature conservation values and water quality at the time of the next Forest Management Plans and Timber Strategy.	Commitment 4 – *Preserve the quality of potable water supplies from forests.* Commitment 6 – *Conduct prescribed burns in river and stream zones so as to be of low intensity.* Commitment 8 – *Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees.* Commitment 15 – *For those high salt risk second order catchments identified in fulfillment of Ministerial Condition 16, CALM will reach agreement with Water and Rivers Commission regarding the precautionary management and protection measures to be implemented. The objective of the measure will be to prevent saline discharge into these water courses.*	
13.1 *The proponent shall ensure that the number, condition and age of trees retained on sites subject to gap treatment is sufficient, as determined by the Minister for the Environment to adequately provide habitat function throughout the cutting cycle of the forest.*	Commitment 12 – *Retain an average of (at least) three large trees on every hectare harvested to provide habitat.*	Addressed in sections 2.13 and 1.12 of this report.
14.1 *The proponent shall concentrate the proposed Banksia grandis reduction in specific areas where the environmental circumstances suggest that treatment will have the greatest impact on reducing the spread and intensification of Phytophthora cinnamomi in the jarrah forest and where required to establish jarrah and marri regeneration.*		Addressed in section 2.14 of this report.
14.2 *The proponent shall establish a program, to the requirements of the Minister for the Environment, to identify and evaluate the environmental implications of the proposed reduction and that the results of that evaluation shall be reported on, at or before the time of the next review of the Forest Management Plans by 2002.*		Addressed in section 2.14 of this report.
15.1 *The proponent shall ensure that the fire management objectives related to the jarrah forest prescription include the minimisation of air pollution in urban areas, to the requirements of the Minister for the Environment.*		Addressed in section 2.15 of this report.
15.2 *The proponent shall inform the public about its fire management on a regional basis each year in its annual report. This shall include but not be limited to the following:* *(1) occurrences and causes of wildfires*	Commitment 6 — *Conduct prescribed burns in river and stream zones so as to be of low intensity.* Commitment 7 — *Conduct prescribed burning in diverse ecotype zones in accordance with habitat requirements of the site.*	Addressed in section 2.15 of this report. See also section 1.06, 1.07 and 1.14.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
(2) purposes of burns *(3) areas burnt under different regimes of season and periodicity* *(4) escapes; and* (5) *the contribution of prescribed burning to reducing wildfire hazard.*	Commitment 14 – *Undertake habitat regeneration burns if forests where special requirements for threatened or endangered species are identified.*	
15.3 *Within 12 months of this proposal being given authority to be implemented the proponent shall initiate a public review of its prescribed burning policy and practices and the wildfire threat analysis. This should be done with the close involvement of the Research and Monitoring Committee. If possible, it should be linked with a review of the provisions of the Bush Fires Act.*		Addressed in section 2.15 of this report.
16.1 *Within three years, or such other period as the Minister for the Environment shall nominate, the proponent, on advice from the Water Authority of Western Australia, shall identify second order catchments with a high salt risk.*	Commitment 4 – *Preserve the quality of potable water supplies from forests.* Commitment 15 – *For those high salt risk second order catchments identified in fulfillment of Ministerial Condition 16, CALM will reach agreement with Water and Rivers Commission regarding the precautionary management and protection measures to be implemented. The objective of the measure will be to prevent saline discharge into these water courses.*	Addressed in section 2.16 of this report. See also sections 1.04 and 1.15.
16.2 *Within each catchment identified according to the requirements of Condition 16.1, the proponent shall retain additional river and stream buffers and locate areas temporarily reserved during phased logging operations to the requirements of the Water Authority of Western Australia.*	Commitment 4 – *Preserve the quality of potable water supplies from forests.* Commitment 15 – *For those high salt risk second order catchments identified in fulfillment of Ministerial Condition 16, CALM will reach agreement with Water and Rivers Commission regarding the precautionary management and protection measures to be implemented. The objective of the measure will be to prevent saline discharge into these water courses.*	Addressed in sections 2.16 and 1.04 of this report. See also section 1.15.
17.1 *The Minister for the Environment will set up a committee having objectives which include:* *(1) identification, prioritisation and approval of monitoring and research programmes and projects on environmental impacts of forestry management* *(2) the granting of funds towards such monitoring and research* *(3) receival of progress reports* (4) *reporting to the Minister for the Environment* (5) *publication of results.*	Commitment 2 – *Implement long term monitoring programs to identify and study significant management issues in forests.* Commitment 5 – *Undertake research to improve a scientific basis for the protection of diversity.*	Addressed in section 2.17 of this report. See also sections 1.02, 1.05 and 2.11.

Ministerial Condition	Related Commitments	Coverage in Final Progress and Compliance Report
17.2 *The Committee shall include the heads (or nominees) of the Department of Conservation & Land Management, the Environmental Protection Authority, the Western Australian Forest Industries Federation, the Conservation Council and the Water Authority of Western Australia, and the Chairpersons of the Lands and Forest Commission and National Parks and Nature Conservation Authority.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.* Commitment 5 – *Undertake research to improve a scientific basis for the protection of diversity.*	Addressed in section 2.17 of this report. See also sections 1.02, 1.05 and 2.11.
17.3 *The committee shall appoint working groups of scientists to recommend and report to the Committee on the design and funding of research projects, the identification, prioritisation and review of monitoring and research programmes and projects relating to the environmental impacts of forest management.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.* Commitment 5 – *Undertake research to improve a scientific basis for the protection of diversity.*	Addressed in section 2.17 of this report. See also sections 1.02, 1.05 and 2.11.
17.4 *The committee shall provide brief annual progress reports to the Minister for the Environment, with major reports in 1997 and 2002, at the time of the next review of the Forest Management Plans and Timber Strategy.*	Commitment 2 – *Implement long-term monitoring programs to identify and study significant management issues in forests.* Commitment 5 – *Undertake research to improve a scientific basis for the protection of diversity.*	Addressed in section 2.17 of this report. See also sections 1.02, 1.05 and 2.11.
18.1 Reporting on compliance *The proponent shall prepare "Progress and Compliance Reports", to help verify the environmental performance of this project, in consultation with the Environmental Protection Authority. These shall include brief annual progress reports to the Environmental Protection Authority, and major public reports in 1997 and 2002.*		Addressed in section 2.18 of this report.

APPENDIX 2

Brochure prepared by the Montreal Implementation Group (MIG) on Assessing the sustainability of forest management

Assessing the sustainability of forest management

The concept of sustainable forest management

The concept of sustainable forest management has a long and evolving history in Australia. During the 20th Century, public forested areas — initially set aside to stop conversion to agricultural use — were managed to protect a range of forest values. With increased understanding of forest ecology and changing community attitudes, Australia developed management practices to meet sustainable wood yield strategies and, progressively, to encompass other forest values. These management practices apply to public and private natural forests and plantations.

Today's concept of sustainable forest management derives from the World Commission on Development, the Brundtland report (1987): *the ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*. To this can be added the focus on all forest values coming from the Rio de Janeiro Earth Summit in 1992. A great deal of international effort has gone into developing criteria and indicators to help assess progress in achieving sustainable forest management.

What are criteria and indicators?

Criteria are the broad forest values that managers seek to maintain, while indicators, over time, provide measures of change in these criteria. Criteria and indicators embody the essential components of sustainable forest management, providing a framework to answer the fundamental question, "*What is important about forests*?" Criteria and indicators recognise forests as ecosystems that deliver a wide, complex and dynamic array of environmental and socio-economic benefits and services. Together, they are a useful ongoing monitoring tool to provide necessary information to assess trends in forest conditions and management. This information is required for the policy decisions that will move us toward sustainable forest management.

The national level criteria agreed by the Montreal Process Working Group (a group of 12 countries, including Australia) involve maintaining:

1. biological diversity;
2. productive capacity;
3. ecosystem health and vitality;
4. soil and water resources;
5. global carbon cycles;
6. socio-economic benefits; and
7. an effective legal and institutional framework.

In Australia, Government, forest managers and other stakeholders have agreed that the above seven criteria address all the forest values the broader community seeks to maintain. They have reviewed the associated indicators to determine which can be applied usefully at the regional level. However, the criteria and indicators are not static. They will be reviewed and refined as a result of research findings, advances in technology and an increasing capability to measure indicators.

What is the relationship between the Montreal Process and RFAs?

The Montreal Process and Regional Forest Agreements (RFAs) are separate processes and are not directly linked. However, there is Commonwealth, State and Territory endorsement by environment and forestry Ministers that the framework of indicators, based on the Montreal Process indicators, will be used in the RFA monitoring process.

Governments see the RFA process as a means of confirming sustainable forest management for the future. A key component of the RFAs is to monitor sustainable forest management practice over time. Monitoring is based on the seven Montreal Process criteria and will see the development of RFA indicators based on the regional indicators. Figure 1 (opposite page) shows the links between the Montreal Process, the activities of the Montreal Process Implementation Group for Australia (MIG) and the RFA process.

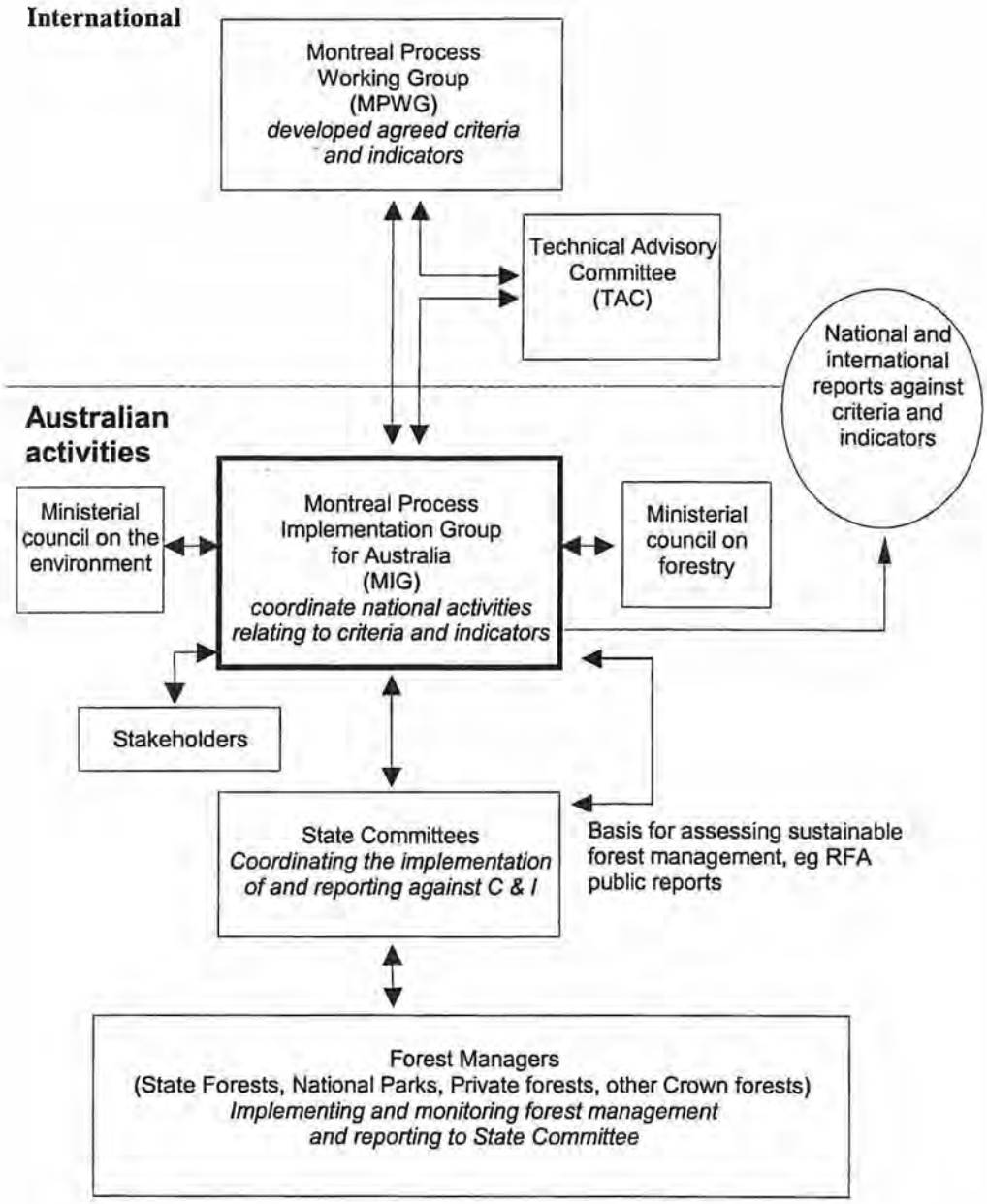
Why is there a need for a framework of regional level (sub-national) indicators?

The framework of regional indicators is a mechanism for collecting information at a scale and in a manner that can be aggregated transparently and credibly to a national level in RFA and non-RFA regions. The framework provides an internationally agreed basis for reporting. However, its flexibility allows for development of specific regional indicators, where necessary. The framework of regional indicators can also be used for other reporting (e.g. the State of the Forests and State of the Environment reports).

Duplication can be avoided by pooling reporting efforts at the regional and national levels. Each State and Territory has its own reporting requirements. At the national level, Australia — as a member of the Montreal Process — has a commitment to reporting against the Montreal Process criteria and indicators. The RFA and the Montreal Process, however, give Australia an ideal opportunity to streamline reporting arrangements by using the common framework for all reports on forest sustainability.

Figure 2 (opposite page) provides a schematic representation of the volume of data available and the amount of information required by different stakeholders. The Montreal Process criteria and indicators, including the framework of regional indicators, creates the link that ensures complementarity between the information required at the various levels, and avoids duplication in data gathering and subsequent reporting.

Figure 1


International
Montreal Process Working Group (MPWG) developed agreed criteria and indicators
Technical Advisory Committee (TAC)
National and international reports against criteria and indicators
Australian activities
Ministerial council on the environment
Montreal Process Implementation Group for Australia (MIG) coordinate national activities relating to criteria and indicators
Ministerial council on forestry
Stakeholders
State Committees Coordinating the implementation of and reporting against C & I
Basis for assessing sustainable forest management, eg RFA public reports
Forest Managers (State Forests, National Parks, Private forests, other Crown forests) Implementing and monitoring forest management and reporting to State Committee

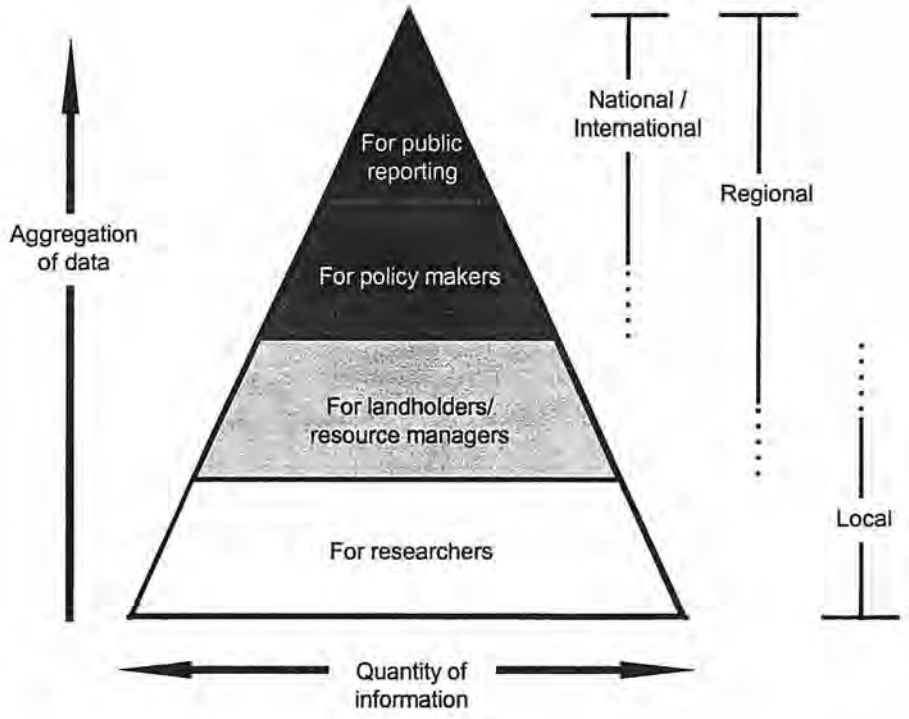
What do we achieve by implementing regional sustainability indicators?

Forests are one of the keys to a healthy environment and a healthy economy. Governments and the community expect Australia's forests to be sustainably managed. By implementing and reporting on sustainability indicators, forest managers and the community are able to interpret the present status of sustainable management and changes in status through time, whether the management objectives are conservation, ecotourism, clean water, timber production or agroforestry. There is an increasing demand and, in some cases, a marketplace requirement for all forest outputs and products to be obtained in a manner consistent with sustainable forest management. This applies regardless of whether they are social, economic or environmental outputs.

How do we implement regional indicators?

The framework of regional indicators is a starting point in assessing the sustainability of forest management. It is not possible, practical or cost effective to implement and monitor all the indicators in the framework in all parts of Australia at the present time. For example, some indicators may not be sensitive or relevant in certain regions or particular forests.

Figure 2 Schematic representation of the volume of data available and the amount of information required by various players



All seven high-level criteria of the Montreal Process (national level) have been accepted as valid at the regional (sub-national) level. Of the 67 Montreal Process (national) indicators, 30 have been accepted as regional level indicators. Twelve of the 30 indicators (Table 1, pages 6 and 7) are considered largely implementable now in many parts of Australia. However, not all 12 indicators — also known as Montreal Process Category A indicators — are relevant to every area of forest. The number of recreational visits, for example, may not apply to private forest. The other 18 indicators require more research and development before implementation.

One of the most important parts of implementation is to encourage forest managers to establish a knowledge base for the forest area under their stewardship, based on agreed criteria and indicators. We recognise the need to protect industry's and private-forest owners' personal and commercial confidentiality.

What are the links with certification and labelling?

The Montreal Process criteria and indicators have no formal links to certification and labelling. However, Australia is developing an Australian Forestry Standard that will reflect Australia's commitment to the Montreal Process criteria and indicators, and to Australia's regional framework. The Australian Forestry Standard will encompass the seven Montreal Process criteria – the forest values we seek to maintain. The detail associated with using indicators will be addressed through the work of the Technical Reference Committee being established under the Australian Forestry Standard.

Table 1: Montreal Process Category A indicators – largely implementable now

(From *A Framework of Regional (Sub-National) Level Criteria and Indicators of Sustainable Forest Management in Australia* [1988])

1.1a Extent of area by forest type and tenure.
1.1b Area of forest type by growth stage distribution by tenure.
1.2a A list of forest dwelling species.
1.2b The status (threatened, rare, vulnerable, endangered or extinct) of forest dwelling species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment.

2.1a Area of forest land and net area of forest land available for timber production.
2.1d Annual removal of wood products compared with the sustainable volume.
2.1f Area and percentage of plantation established meeting effective stocking one year after planting.
2.1g Area and percentage of harvested area of native forest effectively regenerated.

3.1a Area and percentage of forest affected by processes or agents that may change ecosystem health and vitality. (Narrative reporting as interim.)

4.1a Area and percentage of forest land systematically assessed for soil erosion hazard and for which site-varying scientifically based measures to protect soil and water values are implemented. (Interim indicator until information available for original indicator.)

6.2c Number of visits per annum. (Recreation and tourism.)
6.5a Direct and indirect employment in the forest sector, and forest sector employment as a proportion of total employment.

7.1 *Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests. (Narrative reporting.)*
7.2 *Extent to which the institutional framework supports the conservation and sustainable management of forests. (Narrative reporting.)*
7.4 *Capacity to measure and monitor changes in the conservation and sustainable management of forests. (Narrative reporting.)*
7.5 *Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services. (Narrative reporting.)*

Total: 12 indicators and *4 sub-criteria*

Montreal Process Implementation Group for Australia (MIG)

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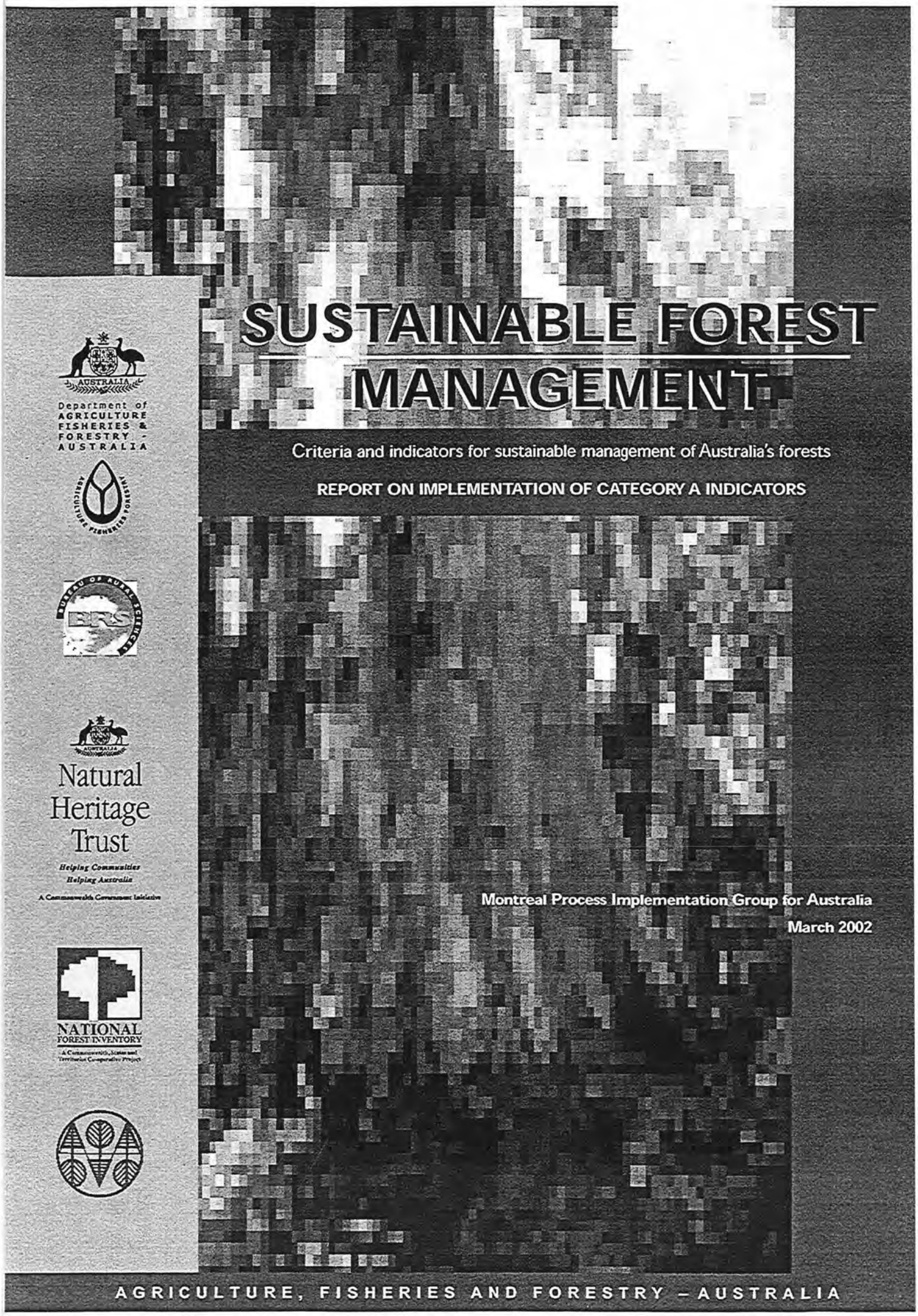
APPENDIX 3

Criteria and indicators for sustainable management of Australia's forests – Report on implementation of Category A indicators



SUSTAINABLE FOREST MANAGEMENT

Criteria and indicators for sustainable management of Australia's forests

REPORT ON IMPLEMENTATION OF CATEGORY A INDICATORS

Department of AGRICULTURE FISHERIES & FORESTRY - AUSTRALIA

Natural Heritage Trust

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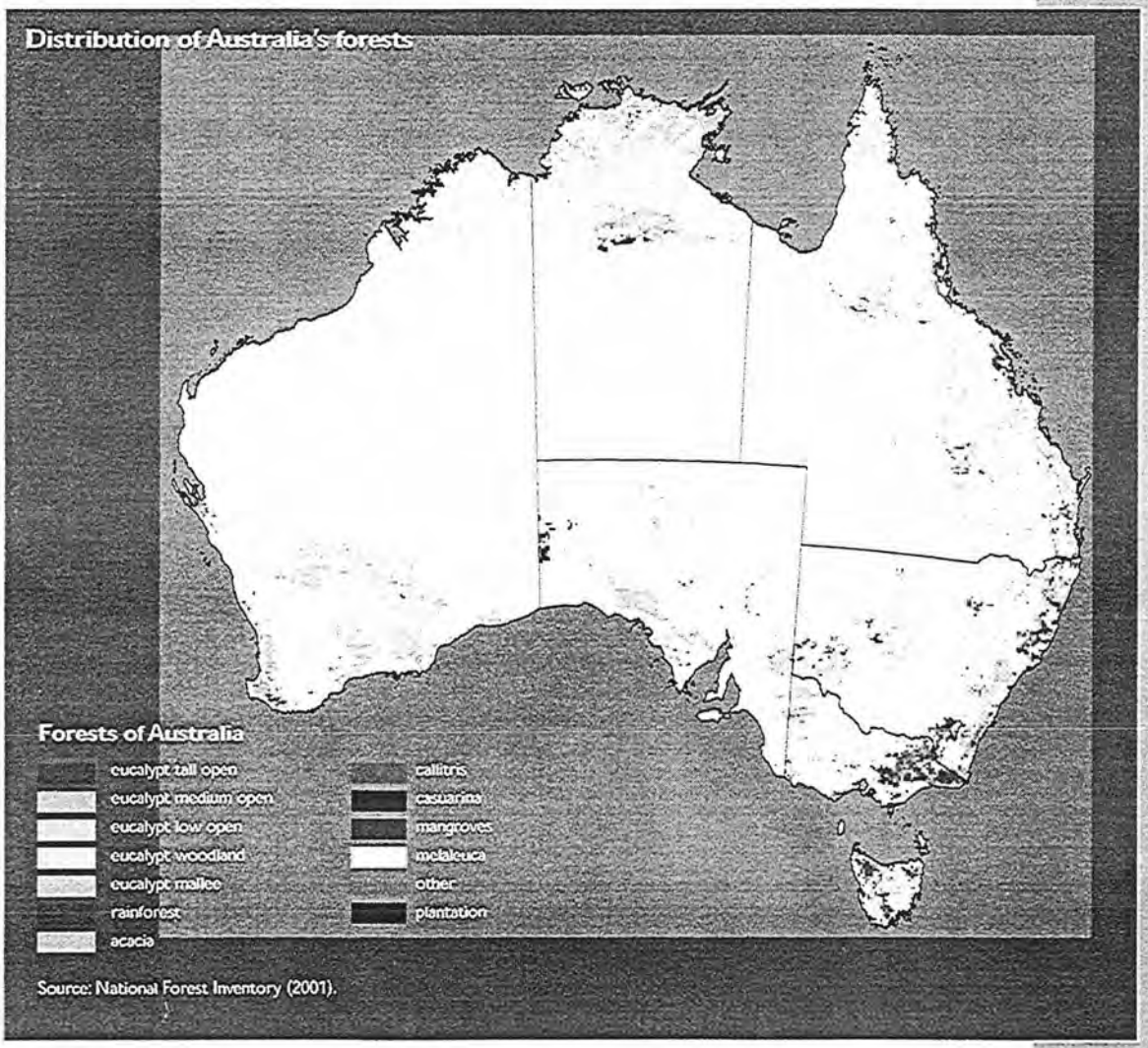
NATIONAL FOREST INVENTORY

A Commonwealth, States and Territories Cooperative Project

Montreal Process Implementation Group for Australia

March 2002

AGRICULTURE, FISHERIES AND FORESTRY – AUSTRALIA



Acknowledgements

Data in this report was collected by the National Forest Inventory (NFI) and provided by State and Territory agencies as the best available data as of September 2001 unless another source is listed. The Montreal Process Implementation Group for Australia (MIG) would like to thank the NFI steering committee members for their coordination of data collection within their State/Territory. The MIG would also like to thank the NFI staff and MIG reporting subgroup members for their time in collating data and writing this report.

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REPORT ON IMPLEMENTATION OF CATEGORY A INDICATORS

Purpose

This report provides an overview of Australia's capacity for monitoring and reporting against Category A indicators. The Standing Committee on Forestry in 1999 requested that periodic reports be presented to relevant standing committees on Category A indicators and progress towards implementation. Production of these reports is overseen by the Montreal Process Implementation Group for Australia which has representatives from all State and Territory governments, as well as the Commonwealth. This report also serves as the first step in data collection and collation for Australia's 2003 State of the Forests report.

Background

Sustainable forest management requires managing forests to maintain their full range of benefits—environmental, economic and social. The relative importance of these benefits or values has the potential to vary depending on the nature of forests and community expectations.

Through involvement in the Montreal Process, Australia has agreed to report on seven criteria (biological diversity; productive capacity; ecosystem health and vitality; soil and water resources; global carbon cycles; socioeconomic benefits; and an effective legal, institutional and economic framework). The criteria are broad categories of forest values that we wish to maintain. Commonwealth, State and Territory forestry and conservation Ministers have endorsed the Montreal Process for reporting on forests.

Australia's regional framework contains the seven criteria as well as 67 indicators which are similar to the Montreal Process national level indicators. Indicators are measurable aspects of the criteria. The indicators in the regional framework have been grouped into three broad categories following an initial evaluation of Australia's capacity to report on indicators. These are:

Category A Indicators which are largely implementable now (12 indicators and four subcriteria);

Category B Indicators for which new data needs to be collected or some development work done, implementable in 3–5 years (8 indicators); and

Category C Indicators that require longer-term research and development before they can be applied extensively, implementable in over five years (13 indicators).

The remaining 34 indicators do not have a category because they are not easily reported at a regional level, and will be reported at a State, Territory or national level.

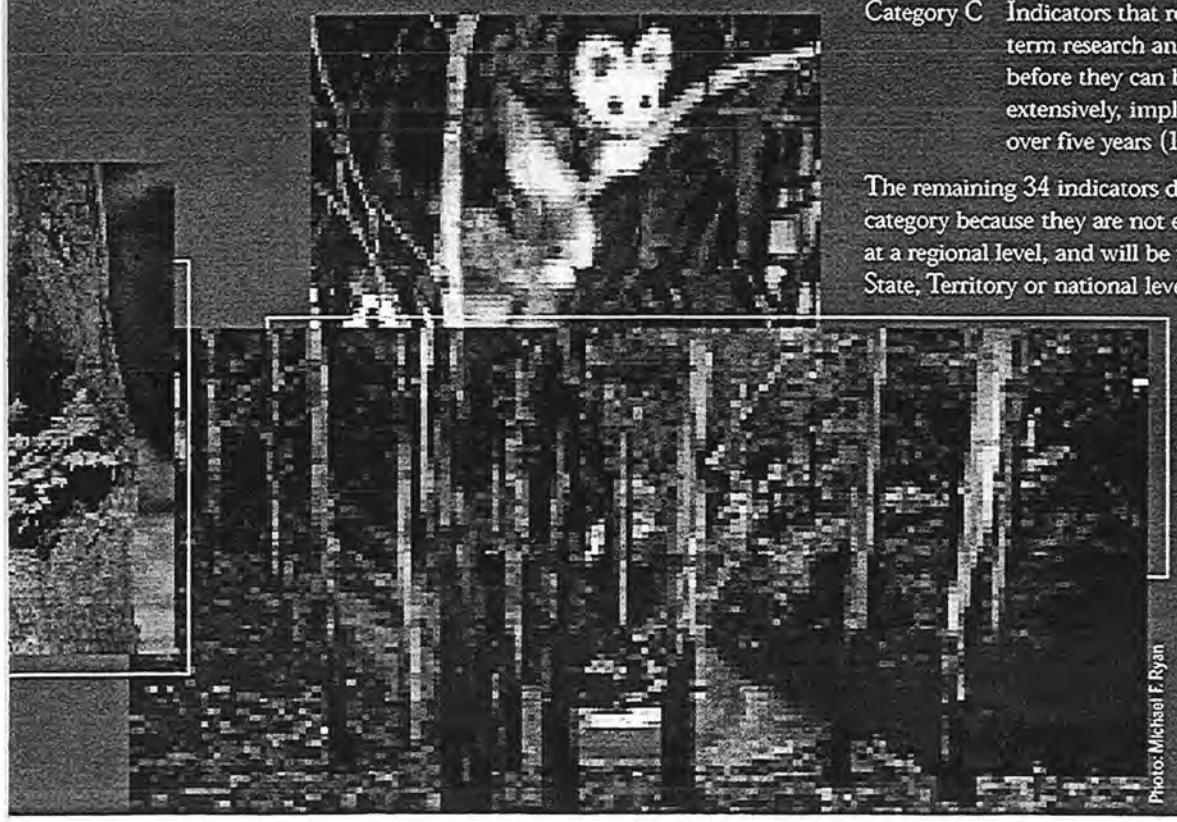


Photo: Michael F. Ryan

Key issues across all criteria

- Achieving effective coordination of data acquisition across all tenures at the State and Territory level and subsequent summarisation at the national level continue to be a challenge to reporting. The priority given to data collection for Montreal Process reporting varies highly between States and Territories.
- In areas where Regional Forest Agreements (RFAs) have not been established, the data availability or quality may be significantly lower than for those areas covered by RFAs (12 per cent of Australia's forest). However, even in RFA areas there are less data available for non-multiple-use forests, especially conservation reserves and private lands, due to low resourcing for data collection.
- Spatial data is inconsistent or unavailable nationally for some of the indicators. For example, growth stage data are only available spatially for some tenures in some States and Territories.

In many of the States and Territories there are differences in definitions for data types reported under Montreal Process indicators. Standard national definitions and classification systems need to be developed and utilised to enable States and Territories to develop the capacity to translate their systems into national level systems. For example, all States and Territories have already adopted standard national classification systems and definitions, for indicators such as forest type, tenure and plantation regions.

The way forward

The production of this report has highlighted shortfalls in the capacity of some agencies to report on indicators for particular forest values and tenures. Category A indicators represent only a small number of the 67 regional level indicators for Australia, representing those indicators that were considered in 1998 to be largely implementable now. Attempting to report on Category A indicators has highlighted difficulties in reporting in a consistent manner at a national level (Table 1), which the Montreal Process Implementation Group for Australia will work to improve in the future.

One of the major investments by the Commonwealth government in data collation in recent years has been through the National Land and Water Resources Audit. This information will be very useful in the future for addressing some Category B and C indicators, in particular those dealing with maintenance of soil and water resources.

Over the longer term, a key source of data for the State of the Forests report will be the five-yearly RFA reviews. The first RFA review is for Tasmania, which is due to be finalised in 2002.

As it is presently not possible to report with any confidence on trends in many of the Montreal Process attributes using currently available inventory methods, the National Forest Inventory is leading the establishment of a continental forest sampling framework to monitor the condition and use of Australia's forests and woodlands. This will constitute a change in approach to the collection of forest data from largely static and passive inventories based on compilation and mapping approaches, to a plot-based continental forest sampling framework.

The framework will comprise a cost-effective, flexible and repeatable inventory design based on a strategic network of relocatable sites representative of all Australia's forests and woodlands. Common key environmental attributes will be measured to consistent standards at each site

Continued on page 6

Table 1 Data available for Category A indicators by tenure

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
1.1a Extent of area by forest type and tenure								
Multiple-use forest	●	●	●	●	●	●	●	●
Nature conservation reserve	●	●	●	●	●	●	●	●
Other	●	●	●	●	●	●	●	●
1.1b Area of forest type by growth stage distribution by tenure								
Multiple-use forest	▲	▫	▲	▫	▲	▫	▫	▲
Nature conservation reserve	▲	▫	▲	▫	▲	▫	▫	▲
Other	▲	▫	▲	▫	▲	▫	▫	▲
1.2a A list of forest dwelling species								
Multiple-use forest	▫	●	●	●	●	●	●	▫
Nature conservation reserve	▫	●	●	●	●	●	●	▫
Other	▫	●	●	●	●	●	●	▫
1.2b The status of forest dwelling species								
Multiple-use forest	●	▫	●	●	●	●	●	●
Nature conservation reserve	●	▫	●	●	●	●	●	●
Other	●	▫	●	●	●	●	●	●
2.1a Area of forest land and net area of forest land available for wood production								
Multiple-use forest	N/A	●	N/A	●	N/A	●	●	●
Other	▲	▲	▫	●	▲	▲	●	▲
2.1d Annual removal of wood products compared to sustainable volume								
Multiple-use forest	N/A	▫	N/A	▫	N/A	●	●	▲
Other	▫	▫	▲	▫	▲	●	▲	▲
2.1f Area and per cent of plantation established meeting effective stocking one year after planting								
Other	▲	▫	▫	●	▫	▫	▫	▫
2.1g Area and per cent of harvested area of native forest effectively regenerated								
Multiple-use forest	N/A	●	▲	●	N/A	▲	●	▲
Other	▲	●	▲	●	▲	▲	●	▲
3.1a Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality								
Multiple-use forest	▫	●	▲	●	●	▫	●	●
Nature conservation reserve	▫	▲	▫	●	▲	▫	●	●
Other	▫	▲	▲	▲	●	▲	●	▲
4.1a (interim) Area and per cent of forest systematically assessed for soil erosion hazard								
Multiple-use forest	●	●	▲	●	●	●	●	●
Nature conservation reserve	●	▲	▲	●	▫	▲	▲	▲
Other	●	▲	▲	●	▫	●	●	●
6.2c Number of visits per annum								
Multiple-use forest	●	▲	▲	▲	●	▲	●	▲
Nature conservation reserve	▲	▫	▲	●	●	▫	●	▲
Other	▲	▲	▲	▲	▲	▲	▲	▲
6.5a Direct and indirect employment in the forest sector								
Multiple-use forest	●	●	●	●	●	●	●	●
Nature conservation reserve	●	●	●	●	●	●	●	●
Other	●	●	●	●	●	●	●	●
7.1 Extent to which the legal framework supports the conservation and sustainable management of forests								
All tenures	▫	●	▫	●	●	●	●	●
7.2 Extent to which the institutional framework supports the conservation and sustainable management of forests								
All tenures	▲	▲	▲	●	▫	▫	▲	▲
7.4 Capacity to measure and monitor changes in the conservation and sustainable management of forests								
All tenures	▲	▲	▲	▫	▫	▫	▲	▲
7.5 Capacity to conduct and apply research and development aimed at improving forest management and delivery forest goods and services								
All tenures	▲	▫	▲	●	▫	▫	▲	▲

Note

Criterion 2 not applicable to nature conservation reserves

● The full amount of data expected for the indicator was provided to the National Forest Inventory

▫ Part of the data expected for the indicator was provided to the National Forest Inventory

▲ No data was provided to the National Forest Inventory

N/A Not applicable

at regular intervals and the Montreal Process Criteria and Indicator framework presents a logical point for defining these sets of inventory attributes. The framework will also provide important information to support other present requirements and future needs to report trends in our forests and woodlands. Whilst focused at meeting national goals the framework will also provide a consistent nationwide basis upon which monitoring programs to address regional and local goals may be built.

CRITERION 1

Conservation of biological diversity

Biodiversity is a broad concept intended to capture the variability among living organisms and the ecological systems of which they are a part. It includes diversity between ecosystems, between species and within species.

This criterion contains the following Category A indicators:

1.1a Extent of area by forest type and tenure

1.1b Area of forest type by growth stage distribution by tenure

1.2a A list of forest dwelling species

1.2b The status (threatened, rare, vulnerable, endangered or extinct) of forest dwelling species at risk of not maintaining viable breeding populations as determined by legislation or scientific assessment

Capacity for reporting

The quality of spatial mapping of vegetation cover, structure and tenure has improved over the past three years as a result of new mapping initiatives put in place through the Comprehensive Regional Assessments underlying the RFA process; the National Forest Inventory (NFI); the National Plantation Inventory; and developments in vegetation mapping by States and Territories. The changes in the area of forest reported, compared with the information in *Australia's State of the Forests Report 1998*, are due to a combination of factors including actual changes in land use, significant improvements in mapping and changes in inventory methods. Future development of a proposed continental forest sampling framework by the NFI will provide a standardised and repeatable system to conduct successive forest inventories for reporting trends across all tenures.

Data for growth stages are only available for native forests managed primarily for timber production in New South Wales, Queensland, Tasmania and Victoria, and the RFA area of Western Australia. These States have different methods for measuring growth stage and age class. However, they all measure the growth stage of the overstorey, which can be used to obtain a consistent measure of successional stage. There is a need to refine the definition of growth stages used at a national level to better accommodate the concepts being used by States and Territories to classify forests.

All States and Territories can provide partial data on forest dwelling species and their status. The list of species provided for Western Australia covers the RFA area, about 15 per cent of Western Australia's forest area. Varying collection methods and differences in the definition of forest dwelling species may affect the consistency of results between the States and Territories. A coordinated production of the State, Territory and national lists of forest dwelling species and standards for describing the life form and habitat will increase the accuracy of these data. The terminology used to describe the status of forest dwelling species differs between States and Territories and the Commonwealth. The categories used for national reporting need to accommodate the different terminology used.

AUSTRALIA'S FOREST AREA AND TENURE

Australia has almost 166 million hectares of forest, of which 99 per cent is native forest and the remainder plantation (Table 2). The native forest is dominated by eucalypt species, with significant areas of *Acacia* species, while the plantations are predominantly softwood species, the majority of which is *Pinus radiata*. However, the softwood proportion of plantations is decreasing as the hardwood area rapidly expands.

More than two-thirds of native forest is on private freehold or leasehold land with the remaining area under public ownership (Table 3). The majority of plantations are now estimated to be on private land.

While the six major tenure classes (Table 4) are useful for understanding broad land management, they mask a range of land uses or management arrangements that occur within different tenures. In particular, the broad tenure category of nature conservation reserves excludes areas under conservation management that have not been formally gazetted under State or Territory and/or Commonwealth legislation. In recognition of this, Australia now reports on protected forest, which includes reserves on other tenures (Table 5). However, very little is known about management intent on private native forests, so private forests informally managed for conservation are not included in the protected forest areas. This issue is being addressed through the recently introduced Private Native Forest Inventory.

Table 2 Area of forest type by State and Territory ('000 ha)

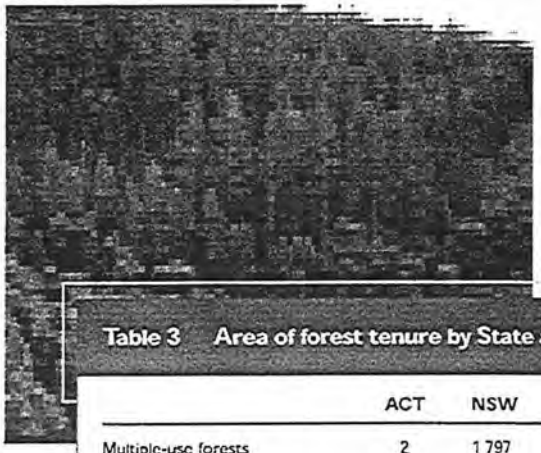
	ACT	NSW[1]	NT	QLD	SA	TAS	VIC	WA	TOTAL
Acacia	0	12	3 513	7 127	1 826	73	63	3 986	16 600
Callitris	0	261	0	387	248	1	50	0	948
Casuarina	0	67	0	140	728	1	4	40	982
Eucalypt	121	25 523	28 841	31 778	7 942	2 444	7 358	29 390	133 397
tall	29	3 946	0	1 073	1	1 116	2 396	171	8 732
woodland	0	91	0	1 012	0	275	114	0	1 493
open	29	3 855	0	61	1	840	2 282	171	7 239
medium	84	18 288	22 117	28 790	625	1 266	3 483	20 815	95 468
woodland	18	10 267	16 432	25 529	582	1 259	721	19 038	73 847
open	65	8 021	5 685	3 261	43	7	2 762	1 777	21 621
low	8	186	6 724	1 789	1 206	62	435	3 431	13 840
woodland	3	114	6 715	1 676	1 206	62	209	3 431	13 417
open	5	72	8	112	0	0	225	0	423
mallee	0	3 102	0	127	6 110	0	1 045	4 973	15 357
woodland	0	9	0	127	4 841	0	1 045	3 918	9 940
open	0	3 093	0	0	1 269	0	0	1 055	5 417
Mangrove	0	3	445	154	20	0	3	173	798
Melaleuca	0	44	1 708	2 094	1	1	90	155	4 092
Other[2]	0	363	55	1 622	23	19	132	1 048	3 263
Rainforest	0	467	318	2 926	0	598	16	7	4 332
NATIVE TOTAL	121	26 742	34 879	46 228	10 789	3 137	7 716	34 800	164 411
Plantation	15	319	7	191	136	185	319	314	1 485
TOTAL FOREST	136	27 061	34 886	46 419	10 924	3 322	8 034	35 113	165 896

Note

All values have been rounded, hence, column and row totals may not tally exactly

1 NSW forest type figures yet to be finalised, total area of forest for NSW is correct

2 Other forest includes mixed species, unknown and minor genera, including *Adansonia, Angophora, Brachychiton, Flindersia, Heteroendrum, Leptospermum* and *Lysiphyllum*



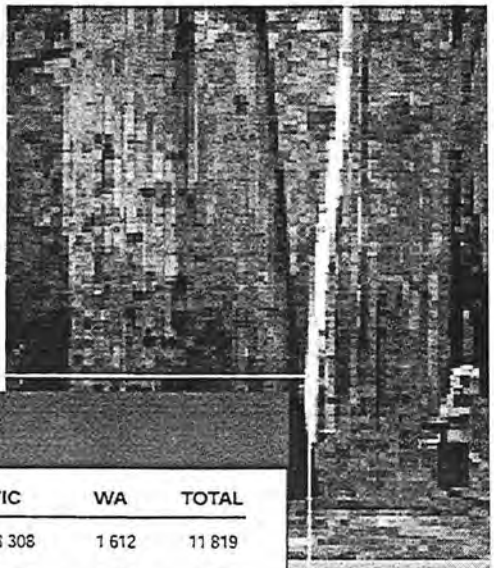


Table 3 Area of forest tenure by State and Territory ('000 ha)

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	TOTAL
Multiple-use forests	2	1 797	0	3 884	5	1 212	3 308	1 612	11 819
Nature conservation reserves	108	4 899	46	3 225	3 933	926	3 006	4 364	20 506
Other crown land	0	1 801	332	1 682	373	98	175	13 206	17 669
Private land	0	6 985	16 694	9 182	852	900	1 183	1 502	37 299
Leasehold land	11	9 144	17 804	28 199	5 227	0	43	14 025	74 454
Unresolved tenure	0	2 117	3	54	399	0	1	90	2 664
NATIVE TOTAL	**121**	**26 742**	**34 879**	**46 228**	**10 789**	**3 137**	**7 716**	**34 800**	**164 411**
Plantations all tenures	15	319	7	191	136	185	319	314	1 485
TOTAL FOREST	**136**	**27 061**	**34 886**	**46 419**	**10 924**	**3 322**	**8 034**	**35 113**	**165 896**

Note

All values have been rounded, hence, column and row totals may not tally exactly

Table 4 Tenure classes

Multiple-use forests	State forest, timber reserves and other forest areas on public land where timber harvesting is permitted. They are managed by State and Territory agencies in accordance with State and Territory Acts and regulations.
Nature conservation reserves	Crown lands that are formally reserved for environmental, conservation and recreational purposes. They include national parks, nature reserves, State and Territory recreation and conservation areas, and crown lands reserved to protect water supply catchments.
Private land	Land held under freehold title and is under private ownership. It includes land held under freehold title with special conditions attached by designated Indigenous communities.
Leasehold land	Land under leasehold title and is generally regarded as 'privately managed'. It includes land held under leasehold title with special conditions attached by designated Indigenous communities.
Other crown land	Crown land reserved for a variety of purposes (e.g. utilities, scientific research, education, stock routes, mining, use by the armed forces, use by Indigenous communities).
Unresolved tenure	No data or areas where tenure is unknown.

Table 5 Protected native forest by State and Territory ('000 ha)

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	TOTAL
Area of protected forest	108	5 720	2 500	3 665	3 960	1 261	5 189	4 364	26 766
Per cent of total native forest	89	21	7	8	37	40	67	13	16

Photo: Michael F. Ryan

CRITERION 2

Maintenance of productive capacity of forest ecosystems

This criterion assesses the degree to which management systems are effective in maintaining the productive capacity of forests for timber and non-timber products. Services provided by forests in terms of biodiversity, ecosystem health and vitality, soil and water, carbon, and economic and social benefits are covered by other criteria.

This criterion contains the following Category A indicators:

2.1a Area of forest land and net area of forest land available for timber production

2.1d Annual removal of wood products compared to the sustainable volume

2.1f Area and per cent of plantation established meeting effective stocking one year after planting

2.1g Area and per cent of harvested area of native forest effectively regenerated

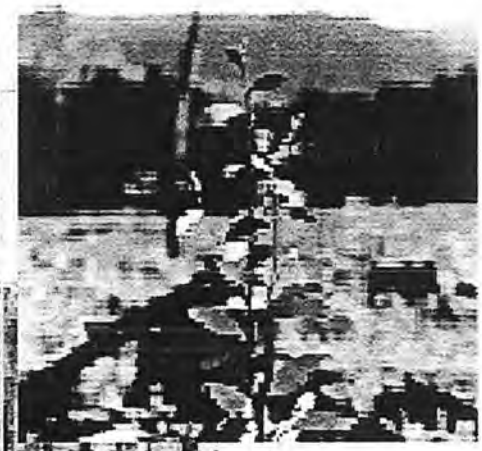


Photo: Michael F. Ryan

Capacity for reporting

The method used for determining the total net harvestable area differs between States and Territories according to underlying management guidelines or codes of practice for timber harvesting activities. Precise figures on the areas of private native forests available for timber production are not known. A clear definition of net harvestable area and a consistent application of that definition between States and Territories would assist with national reporting.

Data provided for sustainable yield for public multiple-use forests have a high level of confidence given legislative and forest management planning requirements. Sustainable yield for public multiple-use native forests is calculated differently by each State or Territory due to differences in available inventory information and to regional differences in the nature of forest types and products harvested. Data on the sustainable yield for non-multiple-use forest tenure are only available for a few States and Territories.

Measures of effective stocking rates vary according to a range of factors including species planted and site conditions. While comprehensive information on total area under plantation is available (Table 6), the degree of effective stocking is not widely reported.

Data are available for native forest regenerated for public multiple-use forests where timber harvesting occurs. Each State and Territory has its own method of assessing the success or effectiveness of regeneration in native forests. The variation in methods is due to regional differences in the nature of forest types and management objectives, and reflects a range of different regeneration survey methods and procedures.

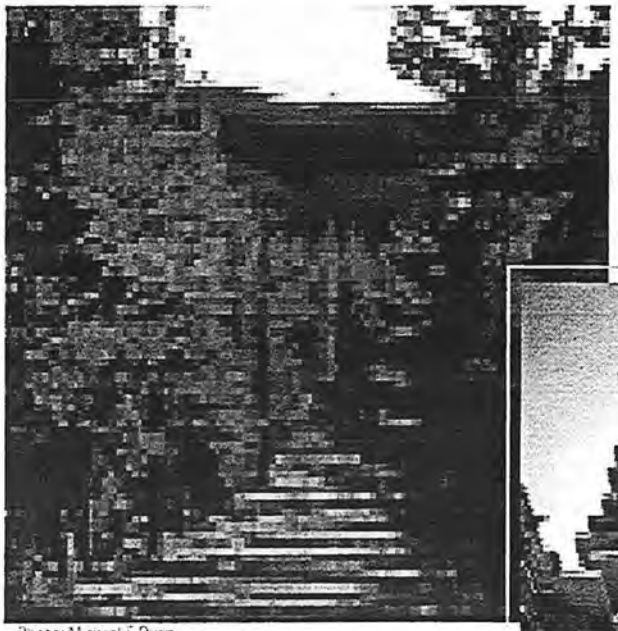


Photo: Michael F. Ryan

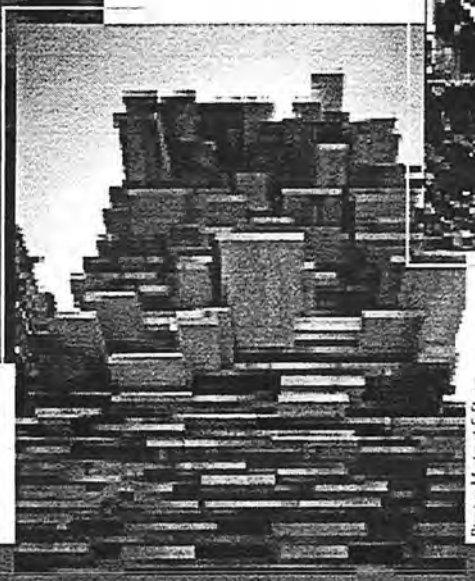


Photo: Michael F. Ryan

Photo: Michael F. Ryan

AUSTRALIA'S PLANTATIONS

The combined standing plantation resource in Australia (as at September 2000) is 1.5 million hectares, of which 972 170 ha (65 per cent) are softwood species and 502 620 ha (34 per cent) are hardwood species. Five per cent (66 980 ha) of total plantation resource is reported as farm forestry (defined as wholly owned and managed by individual landholders), and 95 per cent (1 417 769 ha) is reported as industrial plantations.

Table 6 Total area under plantation by State and Territory (ha)

State/Territory	Hardwood	Softwood	Mixed hardwood and softwood	TOTAL
ACT	194	14 585	0	14 779
NSW	44 626	270 672	2 678	318 898 [1]
NT	1 649	5 235	29	6 913
QLD	9 435	178 620	2 660	190 907 [1]
SA	20 703	113 871	718	135 553 [1]
TAS	109 567	75 630	0	185 197
VIC	101 453	215 110	2 035	318 633 [1]
WA	214 993	98 441	430	313 864
TOTAL	502 620	972 164	8 549	1 484 743 [1]

Source: National Forest Inventory *Plantations of Australia 2001*

Note

1 Total area figures include areas of plantation of unknown plantation type

CRITERION 3

Maintenance of ecosystem health and vitality

Ecosystem 'health' is the state of the ecosystem processes—energy, nutrient, hydrological and biological—that maintain the vitality of the system; ecosystem 'vitality' is the ability of the ecosystem to perpetuate itself.

This criterion contains the following Category A indicator:

3.1a Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality

Capacity for reporting

All States and Territories have the capacity to report on at least some elements of ecosystem health and vitality. Most agencies can report against major impacts such as fire, animal and plant pests and diseases and exotic biota (Table 7) to varying degrees.

For this criterion to be reported effectively at a national level, clear definitions and guidelines are required covering species of concern, how to indicate what they are affecting and a threshold for reporting. Further research is required on the long-term impacts of these processes and agents on ecosystem health with guidelines developed not only for multiple-use forest but all forest tenures.

Table 7 Availability of information at the State and Territory level on forest areas affected by processes or agents that may change ecosystem health and vitality

Process/agent	State/Territory							
	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
Fire	▪	●	●	●	●	●	●	▲
Climatic events	▲	▲	▪	▲	▲	▲	▲	▲
Animal pests	▲	●	●	●	●	●	●	●
Insects pests	▲	▲	▲	▪	▪	▪	▪	▪
Plant pests	▲	●	●	●	▲	●	●	●
Diseases/pathogens	▲	▪	▲	▪	▪	▪	▪	▲
Introduction of exotic biota	▲	▲	▲	▲	▪	▪	▲	▲
Clearing	▲	▲	▪	▲	▲	▪	▲	▲
Grazing	▲	●	▲	▲	▲	▲	▲	▲
Salinisation and soil acidification	▲	▲	▲	▲	▲	▪	▲	▲
Mining operations	▲	▲	▲	▲	▲	▪	▲	▲
River regulation	▲	▲	▲	▲	▲	▲	▲	▲

Note

● Quantitative data on forest areas affected (may also include qualitative information)

▪ Qualitative information

▲ Data not available for this report

CRITERION 4

Conservation and maintenance of soil and water resources

This criterion encompasses the conservation of soil and water resources and the protective and productive functions of forests with respect to soil and water resources.

It contains the following Category A indicator:

4.1a (interim)

Area and per cent of forest systematically assessed for soil erosion hazard and for which site-varying scientifically-based measures to protect soil and water values are implemented

Capacity for reporting

Soil erosion hazard is reported mainly on public forest lands with multiple-use tenure. This is because soil erosion assessments are required as part of harvesting and road planning operations under codes of practice. Soil erosion assessments are also commonly undertaken in conservation reserves in relation to roading and other site developments. There is a need to ensure consistency in the interpretation of forest area assessed for soil erosion hazard: in some States and Territories, the actual forest area assessed has been reported for that year, while in others total area that is covered by a code of practice has been reported.

CRITERION 5

Maintenance of forest contribution to global carbon cycles

There are three indicators under this Criterion and, although they are not Category A, there has been considerable research and development work undertaken as part of the Australian Greenhouse Office National Carbon Accounting System program. These indicators will be reported on in the next State of the Forests report.

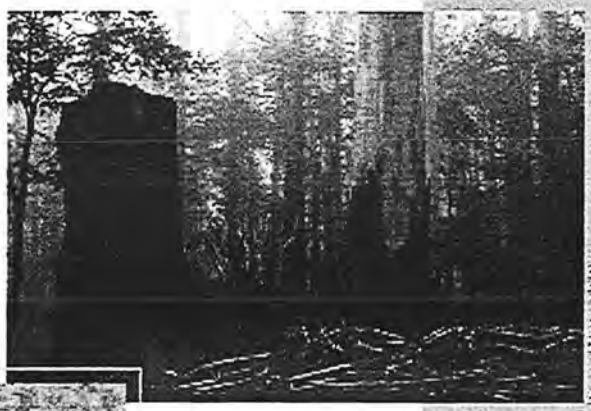


Photo: Michael F. Ryan

CRITERION 6

Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

The adoption of sustainable forest management has significant implications for the use and management of forests to provide for a wide variety of social and economic benefits.

This criterion contains the following Category A indicators:

6.2c Number of visits per annum

6.5a Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment

Photo: Forestry Tasmania

Capacity for reporting

Visitor data are generally available for public forests under multiple-use and conservation reserve tenures, with additional visitor numbers being reported in Victoria and Tasmania on other tenures such as privately managed recreation areas. The data are a mixture of counts and estimates. One issue to consider is the treatment of visitors whose primary purpose is not directly related to forest-based recreation. Another issue is that data on annual visits are often available for only part of the total forest area where recreation activities are taking place. Continued effort is required in the development and implementation of monitoring and sampling systems to ensure that sites selected for data collection of visitor numbers are representative and extrapolation to other areas within the State is statistically valid.

There is good employment data for wood-based forest industries. However, employment data in non-wood-based forest industries tends to be *ad hoc* or incomplete, as it is not systematically collected on a regular basis by government agencies or national industry groups. Some industry classifications used by central agencies, such as the Australian Bureau of Statistics, are often too aggregated (e.g. tourism as a sector) to identify the proportion of employment related to forest contact industries.

EMPLOYMENT IN AUSTRALIA'S FORESTS

The level of forest employment provides a useful measure of the economic and social importance of forests to regional communities and State-level economies. Direct employment includes employment in traditional forest industries (e.g. forestry and logging, and wood and paper products), forest management in government and industry, and other forest contact industries (e.g. eco-tourism and beekeeping). Indirect employment is employment that is generated within a community as a result of direct forest employment (i.e. the multiplier effect from direct forest employment such as employment in service-based industries including shops, schools and hospitals).

In 1999, the wood-based industries directly employed approximately 75 000 people nationally. Of the two main sectors, forestry and logging employed 14 000 people, while the wood and paper products manufacturing industries employed around 61 000 people (Table 8).

Indirect employment at the State, and national levels represent the overall State employment generated by an increase in employment in the State forestry and logging, and wood and paper manufacturing industries (Table 9). For example, one job in forest-based industries in New South Wales generates 1.88 jobs in indirect employment within the State and 2.72 jobs in indirect employment at a national level.

Table 8 Direct employment in forest wood based industries

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	TOTAL
Forestry and logging [1]	200	4 600	50	1 300	800	2 600	1 400	3 200	14 100
Log sawmilling and timber dressing	np	2 600	np	2 500	1 400	1 700	2 900	np	12 500
Other manufactured wood products	np	9 200	np	7 800	2 600	600	8 100	2 200	30 900
Total paper and paper products	np	5 400	np	2 000	1 600	1 100	6 600	np	17 300
Total wood and paper products manufacturing	300	17 100	200	12 400	5 600	3 400	17 600	4 100	60 700
Total forest-based industry	**500**	**21 700**	**250**	**13 700**	**6 400**	**6 000**	**19 000**	**7 300**	**74 800**
Total employment all sectors [1]	157 600	2 795 700	91 800	1 622 900	666 600	197 500	2 120 500	893 300	8 545 400

Source: Australian Bureau of Statistics

Note

1 Average across Australia 1998/99, rest at end of May 1999

np Not available for publication but included in totals where applicable, unless otherwise stated

Table 9 State employment multiplier effects of forest-related industries

	Total forest-based industries	
	State	National
NSW	1.88	2.72
QLD	1.64	2.31
SA	1.65	2.86
TAS	1.44	2.24
VIC	1.80	2.79
WA	1.67	2.38

Source: Australian Bureau of Agricultural and Resource Economics

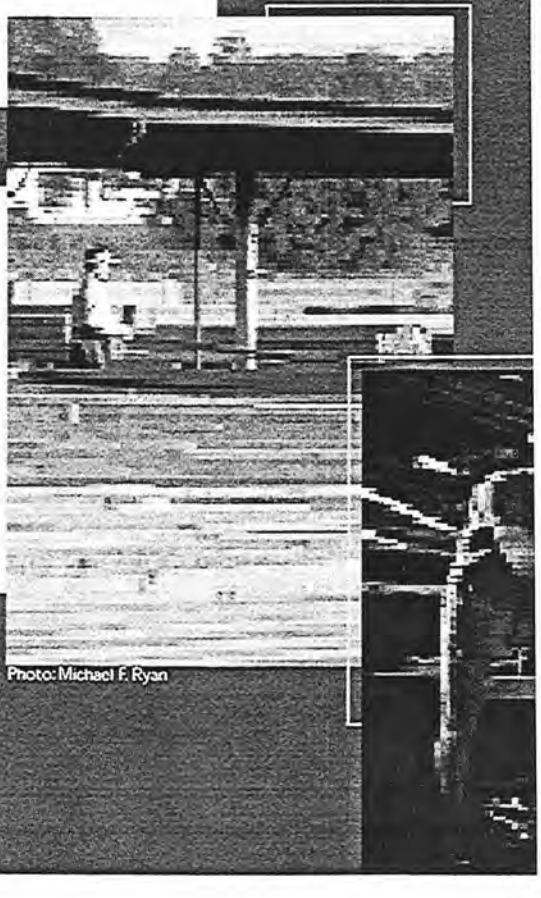


Photo: Michael F. Ryan

CRITERION 7

Legal, institutional and economic framework for forest conservation and sustainable management

Criterion 7 captures the overall ability of legal, institutional and economic frameworks, including research and monitoring capacity, to implement long-term sustainable forest management. By focusing on legal and social institutions for achieving sustainable forest management, this Criterion is different in nature from Criteria 1–6, which represent particular categories of values considered important for sustainable forest management.

This criterion contains the following Category A indicators:

7.1a Provides mechanisms to clarify property rights and establish appropriate land tenure arrangements that recognise traditional management practices and self management as well as the existence of native title and the customary and traditional rights of Indigenous peoples

7.1b Provides for periodic forest-related planning, assessment and policy review that recognises the range of forest values, including coordination with relevant sectors

7.1c Provides opportunities for public participation in public policy and decision making related to forests and public access to information

7.1d Encourages the development and application of best practice codes for forest management

7.1e Provides for the management of environmental, cultural, social and/or scientific values in forests and ensures the participation of Indigenous peoples in all aspects of forest planning and management processes

7.2a Provide for public involvement activities and public education, awareness and extension programs and make available forest-related information

7.2b Undertake and implement periodic forest-related planning, assessment, and policy review including cross-sectoral planning and coordination

7.2c Develop and maintain human resource skills across relevant disciplines

7.2e Enforce laws, regulations and guidelines

7.4a Availability and extent of up-to-date data, statistics and other information important to measuring or describing indicators associated with Criteria 1 to 7

7.4b Scope, frequency and statistical reliability of forest inventories, assessments, monitoring and other relevant information

7.5a Development of scientific understanding of forest ecosystem characteristics and functions

7.5d Enhancement of ability to predict impacts of human intervention on forests

7.5f Per cent of native forests and plantations that are formally supported by silvicultural and utilisation research support

Continued on page 16

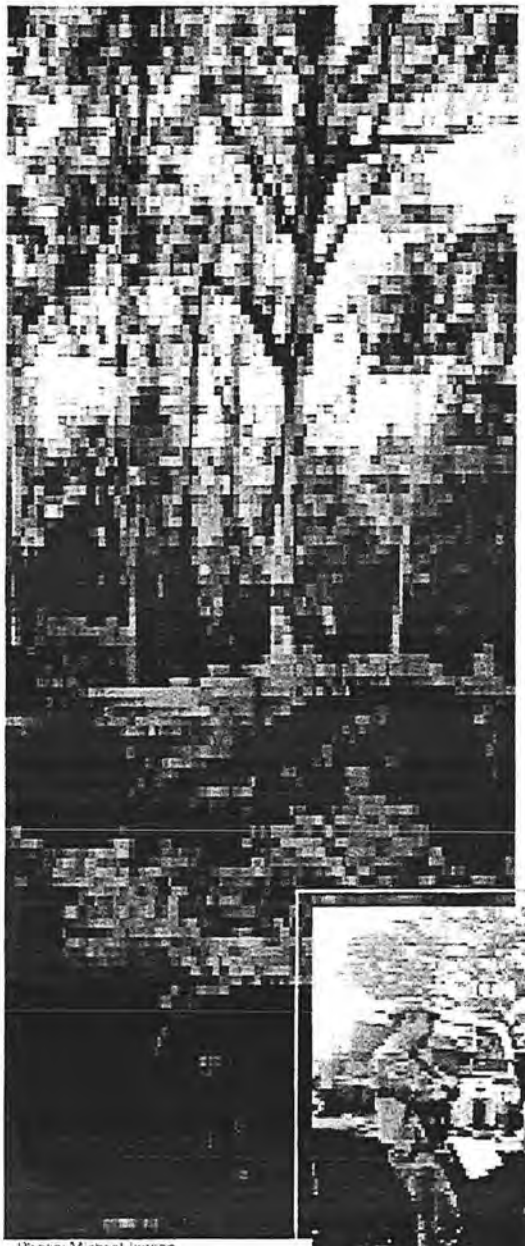


Photo: Michael Jensen

Capacity for reporting

All States and Territories provided partial data for these indicators. The narrative form used by the States and Territories were incompatible in terms of detail and format of data. There was often confusion between legal (Criterion 7.1) and institutional issues (Criterion 7.2). This issue will be resolved as more experience is gained in reporting on these indicators.

The majority of inventory programs cover predominantly publicly owned land reflecting an extensive historical investment in forest productivity and timber production inventories by State and Territory forest agencies. The Private Native Forest Inventory will address a need for inventory programs for private forests.

For the portion of native forests and plantations formally supported by silviculture and utilisation research, it is unclear if the research is focused on the impacts of utilisation on forest values or on increasing productivity.

Photo: Mike Smith

WHERE TO FROM HERE

The Montreal Process Implementation Group for Australia and the National Forest Inventory Steering Committee will work together over the next year to produce Australia's 2003 State of the Forests report.

For further information about the Montreal Process Criteria and Indicators or the National Forest Inventory, see the Agriculture, Fisheries and Forestry – Australia website (www.affa.gov.au/forestry) , the National Forest Inventory website (www.affa.gov.au/nfi) and the Montréal Process website (www.mpci.org).

APPENDIX 4

Terms of reference for the Review of Sustained Yield Within the Context of Ecologically Sustainable Forest Management

Terms of Reference

for the

Review of Sustained Yield

Within the Context of

Ecologically Sustainable Forest Management

1. Preamble

The review has its origins in commitments contained in the report by Mr Mike Codd of January 1999 and the Regional Forest Agreement of May 1999.

The report by Mr Codd included the following statement:

> *"it is acknowledged that the RFA process will establish an expert panel to provide independent scientific advice on the provisional sustained yield figure consistent with the principles of ecologically sustainable forest management, and with appropriate provision for potential improvements in utilisation; with such a panel expected to take some 12 months to report"*

Clause 50 of the RFA of May 1999 stated:

> *"The Commonwealth accredits the process described in An Appraisal of Methods and Data used by CALM to Estimate Wood Resource Yields for the South-West RFA Region of Western Australia (Turner B.J., Department of Forestry, Australian National University, December 1997) and being used by CALM in the calculation of Sustained Yield of wood products from the public native Forest and plantation estate on the understanding that the improvements recommended in that report will be addressed prior to the development of the next Forest Management Plan. Western Australia agrees that the methods and data to be used in the calculation of the Sustained Yield of wood products from the public native Forest and the Sustained Yield figures to be included in the Forest Management Plans will be reviewed by a panel of suitably qualified independent experts as part of the development of each Forest Management Plan under the CALM Act and improvements incorporated during the Forest Management Planning process. Western Australia confirms that its current standard of inventory will be maintained and yield and planning databases and systems, as amended by this Agreement, will be enhanced."*

The purpose of this review is to fulfill the above requirements and to facilitate the development of the next Forest Management Plan. The intent of the next Forest Management Plan is to implement the outcomes of the RFA and subsequent forest policy statements. It is not the purpose of this review to examine the RFA process and outcomes.

The review will focus on the calculation of sustained yields within the context of the principles of ecologically sustainable forest management (ESFM). The review will document and examine management practices and their integration with the process for estimating sustained yields, examine the data and methods used for calculating sustained yields, examine timber resource estimates, and examine yield projection systems in terms of consistency with forest growth rates and objectives of management.

The agreed principles of ecologically sustainable forest management are:

(a) *planning and management of forests should maintain the suite of forest values for present and future generations:*
- *maintain and enhance long-term multiple socio-economic benefits to meet the needs of societies;*
- *protect and maintain biological diversity;*
- *protect and maintain natural and cultural heritage;*
- *maintain the productive capacity and sustainability of forest ecosystems;*
- *maintain forest ecosystem health and vitality;*
- *protect soil and water resources;*
- *maintain forests' contribution to global carbon cycles; and*

(b) *planning and management of forests should be guided by the precautionary principle;*
(RFA Attachment 5)

The establishment and maintenance of a comprehensive, adequate and representative reserve system contributes to many of the above principles.

The precautionary principles is defined:

> *"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by*
> *I. careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment;*
> *II. an assessment of the risk-weighted consequences of various options."*
> (Commonwealth of Australia 1992)

In considering application of the precautionary principle, the panel should pay particular attention to forest management processes and practices dealing with 'risk assessment' and 'risk management' to minimise environmental impacts and avoid serious or irreversible damage to the environment.

The objectives for management of CALM-managed lands are as specified in the Forest Management Plan 1994-2003. The overall objective is:

> *"To manage the native forests of the south-west of Western Australia, in consultation with the community, so that they provide the values required by society while sustaining indefinitely their biological and social diversity."*

The conservation objective is:

> *"To maintain biological diversity at the genetic, species and ecosystem level in the forest, with special emphasis on the protection and conservation of threatened, rare and uncommon taxa and communities."*

The management objective is:

> *"To protect and enhance identified forest values and to employ the best practices in managing forest ecosystems."*

The production objective is:

> *"To manage the forest to produce the range of commercial values approved by Government, in a manner which is ecologically sustainable and provides a fair return to the State."*

The tourism and recreation objective is:

> *"To facilitate the public enjoyment of the forest in a manner that is consistent with the nature conservation and other objectives."*

The knowledge objective is:

> *"To seek a better understanding of the composition and function of forest ecosystems and to promote awareness and appreciation of their values."*

The practices that are used to provide for ecologically sustainable forest management are as specified in the Forest Management Plan 1994-2003, the RFA and the State Government forest policy of December 1999.

2. Geographic Extent - Location of Work

CALM's three forest regions - Swan Region, Central Forest Region and Southern Forest Region.

3. Scope

The scope of this review is to focus on the calculation of sustained yields of wood from CALM-managed native forest in the context of the principles of ecologically sustainable forest management.

Whilst ecologically sustainable forest management deals with the management of all types of forest (native forest, plantations) across all tenures (public, private) and for all values and uses (timber harvesting, mining, conservation, recreation etc) only those aspects of ecologically sustainable forest management that directly impinge on the calculation of sustained yields are within the scope of this review.

4. Terms of Reference

The review will be undertaken in three stages.

Stage 1 Review

The panel of independent experts will:

1. Document and examine the management practices that are used to implement the principles of ecologically sustainable forest management and their integration with the process for establishing sustained yield levels;
2. Examine the methods and data used in the calculation of sustained yields in terms of the requirements of clause 50 of the Regional Forest Agreement;
3. Examine the timber resource estimates in terms of their consistency with the areas of native forest available for timber harvesting;
4. Examine the yield projection system in terms of their consistency with variability in growth rates on varying landforms, soils, climatic zones and forest ecosystems; and
5. Examine the yield projection system in terms of consistency with the objectives for management of the CALM-managed estate, as specified in the Forest Management Plan.

The panel will seek technical, industry and community input into these issues.

Stage 1 Report

The panel will provide a single written report to the Conservation Commission by 30 April, 2001, including:

- Recommendations, as appropriate, for future improvements in matters arising from the terms of reference and indicating:
  (a) Those improvements that may be feasible to implement in the period leading to the next Forest Management Plan; and
  (b) Those improvements that could be implemented in the longer term; and
- Identification of priorities and relative resources required to implement each recommendation within the context of existing priorities for improvements to Western Australia's forest management systems.

Stage 2 Review

The panel of independent experts will observe and participate in the calculation of sustained yield levels for native forests for inclusion in the draft Forest Management Plan for 2004 and beyond.

Stage 2 Report

The panel will provide a single written report to the Conservation Commission that confirms whether:

- The sustained yield levels calculated for defined forest types are consistent with:
  (a) Findings of the Stage 1 report;
  (b) The area of forest that is proposed to be available for timber harvesting;
  (c) The practices that are used to provide for ecologically sustainable forest management as set out in the draft Forest Management Plan for 2004 and beyond;
  (d) The data, assumptions and methods used; and
- The calculations have been carried out objectively and in an operationally realistic manner.

This report is anticipated to be required in February 2002.

Stage 3 Review

The panel of independent experts will observe and participate in any recalculation of sustained yield levels for native forests for inclusion in the draft final Forest Management Plan undertaken in response to public and agency submissions.

Stage 3 Report

The panel will provide a single written report to the Conservation Commission that confirms whether:

- The sustained yield levels calculated for defined forest types are consistent with:
  (a) Findings of the Stage 1 report;
  (b) The area of forest that is proposed to be available for timber harvesting;
  (c) The practices that are used to provide for ecologically sustainable forest management as set out in the draft final Forest Management Plan;
  (d) The data, assumptions and methods used; and
- The calculations have been carried out objectively and in an operationally realistic manner.

The report is anticipated to be required in December 2002.

APPENDIX 5

Calculating Sustained Yield for the Forest Management Plan (2004-2013), A Preliminary Review. Report for the Conservation Commission of Western Australia by the Independent Panel

Calculating Sustained Yield for the Forest Management Plan (2004-2013)

A Preliminary Review

Report for the
Conservation Commission
of Western Australia
by the Independent Panel

I.Ferguson, M. Adams, J. Bradshaw, S. Davey, R. McCormack, and J. Young

April 2001

EXECUTIVE SUMMARY

1 Introduction

The purpose of this review is to fulfil the requirements of the recommendations by Mr Mike Codd and the related clause in the Regional Forest Agreement, and to facilitate the development of the next Forest Management Plan. The review focuses on the calculation of sustained yields within the context of the principles of Ecologically Sustainable Forest Management. However, only those aspects that directly impinge on the calculation of sustained yield are within the prescribed scope of the review. It is not the purpose of this review to examine the Regional Forest Agreement process and outcomes.

In addressing these issues, the Panel has attempted to ensure that goals and indicators for principles of Ecologically Sustainable Forest Management should be set for the 'whole of forest', not just the State forest. The Panel also considered that the calculation of sustained yield should include individual Regions (Swan, Central and Southern), as well as the entire forest estate, with iteration from one level to the other being necessary.

Recommendation 1.1, Regional Calculations
The underlying inventory and calculation of sustained yield is carried out initially on a regional basis but with provision for aggregation over the CALM-managed native forests. However, iteration from Zone to the Region and back again will be needed to refine the calculation of sustained yield.

2 Stakeholder consultation

Stakeholder involvement in the process commenced in 1999 when a large number of stakeholders had input on the composition and terms of reference of the independent panel. The Minister for the Environment announced the membership and terms of reference of the Panel in July 2000.

The Panel sought public input to the review process by means of written and oral submissions. Organisations and individuals known to have an interest in the subject of the review were invited to make submissions. A total of 42 written submissions was received and 24 stakeholders gave oral presentations as Manjimup, Bunbury and Perth.

Since the process began, a number of significant changes has affected both the organisations responsible for conservation and forest management, and forest policy.

The ALP assumed Government in February 2001. Many of the submissions received by the Panel before the election focused on the issue of 'old-growth' logging, which is no longer relevant in the light of the policies introduced by the new Government. The Government has also indicated its wish to see the development of the next Forest Management Plan fast-tracked. As a result, this report has been completed without the opportunity to provide feedback to stakeholders. The Chairman of the Conservation Commission has indicated that feedback will be facilitated in Stage II of the planning process. The newly formed Conservation Commission is now the agreed proponent of the next Forest Management Plan.

Recommendation 2.1
As part of the process involved in preparing the next Forest Management Plan, the Conservation Commission should ensure that recent changes in Government policy, the principles of Ecologically Sustainable Forest Management, and the key elements supporting the planning process and calculation of sustained yield, are widely promulgated and understood.

3 Calculating Sustained Yield

The recommendations of the Panel follow the steps in the calculation of sustained yield are:

- identifying net areas;
- estimating standing sawlog volume;
- predicting future growth or volume;
- modelling potential wood flows to calculate sustained yield.

The term 'net areas' refers to the areas of publicly-owned native forest on which timber production is a permitted activity, i.e. the gross areas **minus** all those areas of reservations and other exclusions in which timber production is not permitted. Net areas can be estimated precisely where boundaries can be clearly identified, either from cadastral data or photo-interpretation. The identification of low volume patches of forest has recently improved and generally no longer presents a risk. Related issues of local and site-specific reservations and temporary exclusions are discussed in a later section.

In jarrah inventory, the application of jarrah silvicultural systems over broad areas of a stratum will vary in places from the planned silvicultural prescriptions for the stratum, and therefore may result in either more or less volume per hectare being removed than was anticipated. The residual risk is low because small continuing biases in the volume per hectare removed principally impact on the cutting cycle and affect the sustained yield very little. Nevertheless, some improvements should be pursued.

Recommendation 3.1, Jarrah Silviculture
Progressive improvement of jarrah stratification for silvicultural and growth prediction purposes should be initiated during the next Plan period This work needs to be closely integrated with a later recommendation on jarrah growth models.

The dependence on regrowth karri will rapidly accelerate in the light of recent policy changes. This dependence will involve a dramatic increase in the relative supply of small logs after 2003. Utilisation of these is uncertain for sawing, because of size and the greater impact of insect- and fungal-induced defects. A conservative approach to calculating yield should therefore be adopted in the current revision of the Plan.

Recommendation 3.2, Karri Inventory and Utilisation
(1) The karri inventory should continue to be adapted to handle changing utilisation standards in log recovery, especially with respect to size and quality, during the next Plan period.
(2) The current revision of the Plan should take a conservative approach in the estimation of karri sustained yield based on current standards of small log utilisation.
(3) Research on the utilisation of small karri logs should be initiated as soon as possible.

In jarrah, the shift to smaller and/or poorer quality sawlogs will be more gradual reflecting the progressive tightening of supply of larger logs and utilisation of regrowth logs. In addition to continued monitoring, research is needed in the next Plan period on the best forms of utilisation and technologies for processing smaller and lower grade jarrah.

Recommendation 3.3, Jarrah Utilisation
During the next Plan period:

(1) monitoring of the actual utilisation of jarrah log sizes and grades should be maintained and used in adjusting volumes in coupes to be logged on the simulation of wood flows.

(2) research on the utilisation and technologies for processing smaller and lower grade jarrah logs should be pursued.

The Panel believes that CALM should complete its responses to the Ministerial Conditions 11, 12 and 16 as soon as possible. The Conservation Commission should then provide, as a matter of urgency, a more integrative review of silvicultural guidelines. The aim of this review should be to inform the public to facilitate the revision of the Plan, including the likely impacts on sustained yield.

Recommendation 3.4, Jarrah Silviculture

(1) The Conservation Commission should, as a matter of urgency, and following the completion of the CALM reports on the Ministerial Conditions, prepare a review of the silvicultural guidelines with respect to regeneration adequacy, salinity constraints, and habitat considerations to inform decision in the current revision of the Plan.

(2) The review should also indicate monitoring and research, priorities and funding needed in the next Plan period.

Regeneration on some jarrah-marri sites (especially in the south) often initially favours marri, resulting in the dominance of marri in the earlier stages of stand development, though this balance may shift with age. Silvicultural intervention by way of early 'crown release' and by thinning can be used to alter subsequent stand composition. The economic viability of thinning in marri-dominated stands depends on markets for small marri logs.

Recommendation 3.5, Jarrah-Marri
Calculations of sustained yield for jarrah-marri forest in the current revision of the Plan should determine the sensitivity of the yield to the possible lack of commercial thinning opportunities.

While some marri sawlog will still be available from cut-over southern forests, the Panel believes that this will be negligible in terms of its contribution to the overall sustained yield. The yield of marri sawlogs should not be formally considered in the current revision of the Plan but monitoring of, and research on, the utilisation of marri sawlogs should continue. Blackbutt and wandoo represent similar issues with respect to the calculation of sustained yield – both being in such small volumes that they are negligible in relation to the calculation of sustained yield for individual regions or the whole forest.

Recommendation 3.6, Marri Sawlogs
Calculation of the sustained yield of marri sawlogs should not be formally considered in the current revision of the Plan but monitoring of, and research on, the utilisation of marri and other minor species sawlogs should continue.

Recent reports indicate that new growth models are required for a wider array of silviculture and sites. Research on new growth models reflecting a wider array of silviculture and sites should be initiated in the next Plan period.

Recommendation 3.7, Jarrah Growth
Research on new jarrah growth models reflecting a wider array of silviculture and sites should be initiated in the next Plan period, closely integrating that process with the corresponding recommendation on jarrah inventory, and maintaining transparency of the models used.

In purer karri forest, reliable growth models exist for clear-felling systems and take account of variations in site productivity but further research to improve the growth models in the second half of the period of the Plan will be fruitful.

Recommendation 3.8, Karri Growth
Further research should be pursued to improve the karri growth models in the second half of the period of the Plan.

Karri regrowth forests are fire sensitive and opportunities for salvage from regrowth is less than that from mature forest. The allowance made for losses due to fire in the calculation of sustained yield should be reviewed. Because of the vulnerability of the karri regrowth forest, and in light of the uncertainty in institutional arrangements that prevails, the Government needs to ensure that the institutional arrangements between CALM and the Forest Products Commission provide adequately for continuing fire protection of the regrowth karri estate.

Recommendation 3.9, Regrowth Karri Fire Risk
(1) A recalibration of the allowance accorded to the risk of fires relating to the karri regrowth resource should be carried out in the current revision of the Plan.
(2) The Government needs to ensure that the institutional arrangements between CALM and the Forest Products Commission provide adequately for continuing fire protection of the regrowth karri estate as soon as possible.

Timber removals from bauxite and other mining sites are accounted for in yield estimates based on company plans of mining operations over a five-year period and anticipated operations between five and 25 years. Currently, growth rates and rotation lengths for the rehabilitated forest are assumed to be the same as the pre-mined productivity classification. Uncertainty surrounds growth rates of forests on mined sites.

Recommendation 3.10, Rehabilitated Mining Sites
Research should be undertaken comparing growth rates and net area estimates on rehabilitated mining sites with those used in yield calculations during the next period of the Plan.

Rotation length is a fundamental variable in the calculation of sustained yield. Some 85 to 90% of the respective areas of jarrah and karri forest are cut (or scheduled to be cut) under rotations of 200 and 100 years respectively. Very small proportions of high productivity forest are cut (or scheduled to be cut) using rotations as low as 100 and 60 years respectively. While major general changes in rotation lengths would not be desirable, because of their impact on other forest values, the wider application of shorter rotations, up to (but not exceeding) 25 years less than the current predominant rotation lengths for both jarrah and karri may be acceptable to other values.

Recommendation 3.11, Shorter Rotations
The wider use of shorter rotation lengths for jarrah and karri respectively should be explored, and the consequent impacts on yield and Ecologically Sustainable Forest Management evaluated during the current revision of the Plan.

Structural goals are an important element of the current Forest Management Plan. The next step in the development of structural goals is their refinement to the landscape level. Specific structural goals represent a direct approach to maintaining a full suite of age and structurally related values, rather than attempting to achieve them using sustained yield as a mechanism. Structural goals are also useful in balancing the structural attributes between those found in the reserve system and those in production forests.

Recommendation 3.12, Structural Goals
Specific objectives need to be formulated in the current revision of the Plan for appropriate forest structures in terms of the mix of age or size classes and their spatial distribution across the whole forest, together with the structural goals that must then be applied in the calculation of sustained yield.

Future sites of reservations or temporary exclusions in areas not yet harvested cannot always be identified geographically. Allowances therefore have to be made. In some cases, the simulation models incorporate ingenious and realistic simulations of the spatial constraints for areas that are scheduled to be harvested in the future. Other exclusions such as those to protect locally rare and endangered species, or local visual amenity zones are virtually impossible to predict geographically much in advance of pre-logging survey and harvesting. They are therefore addressed by making a reduction in net area or sustained yield, based on past experience.

Recommendation 3.13, Allowances for Local Reservations and Exclusions
Monitoring of logged coupes with respect to the areas of local reservation and temporary exclusions should be maintained to refine allowances in the calculation of sustained yield during the next Plan period.

Existing processes require areas of visual amenity to be identified and managed under protocols defined by professional landscape architects. Trade-offs are inevitably involved in consideration of such areas. The trade-offs have to weigh the social net benefit foregone to the community as a whole from the loss or modification of logging against the social net benefit accruing to the individual and/or local community.

Recommendation 3.14, Local Reservation and Exclusion Trade-offs
Research should be pursued to value the social net benefits and to determine effective processes for making trade-offs in local exclusions and reservations during the next Plan period.

The use of supplementary systems for scheduling wood flows should be pursued during the period of the next Forest Management Plan. This will also require greater effort in the collection of data on non-timber values for use in these models. Embarking on a shift to such an advanced scheduling system, with its attendant workload, would not be practicable within the current revision of the Forest Management Plan.

Recommendation 3.15, Supplementary Scheduling
Supplementary scheduling of wood flows should be examined and pursued, if practicable, though the use of more advanced systems during the next Plan period.

Yield estimates are based on the presumption that silvicultural practices match the prescriptions. Departures do not arise solely from inadequacies in the modelling system. Changes in responsibilities resulting from the creation of the Forest Products Commission and the present limited silvicultural expertise in CALM, represents a potential risk to the appropriate development and application of silviculture. The reduced size of the industry beyond 2003 may exacerbate this problem through reduced income from sales of wood and consequent possible loss of staffing in the new administrative structures.

Recommendation 3.16, Staff Training and Resources
CALM should commit to the maintenance of staff training and expertise in silviculture through the provision of adequate resources and delineation of responsibilities during the next period of the Plan.

Continuation of a residue market to facilitate karri thinning is of particular importance. Without such an industry, sawlog-thinning yields will be delayed and the total sawlog yield will be dramatically reduced.

Recommendation 3.17, Karri Residue Utilisation
The Government should encourage industries that utilise the residues from thinnings in regrowth forests during the next Plan period.

Consideration should be given to altering the relative royalties of Grades 1 and 2 so that to make sawmillers and loggers indifferent to different grades and to writing contracts in terms of the combined volumes of Grade 1 and 2 sawlogs.

Recommendation 3.18, Sawlog Prices and Contracts
The prices of Grade 1 and 2 sawlogs and corresponding logging contract rates should be examined to remove the present biases that favour the use of Grade 1 logs. Renegotiation of contracts should move toward sale of the combined volumes of Grade 1 and 2 in keeping with the basis for sustained yield.

If a 'whole bole logging' system is introduced for sale and yield regulation, it will be critical to demonstrate that it provides a better approach than the present system. A dual track (new and old) system of calculating sustained yield would need to be used, to provide transparency between the old and new. Collaborative trials with the industry should be continued to 2002, at which time the decision to pursue this system should be taken. If implemented, it should also be subject to a review after some dual track experience has been gained.

Recommendation 3.19, Whole Bole Logging
(1) Collaborative trials with the industry of 'whole bole' logging should be continued to 2002.
(2) A decision to pursue this system should be taken as part of the current revision of the Plan.
(3) If implemented, a dual track basis should be used and reported during the period of the Plan, with a review regarding its exclusive adoption thereafter.

4 Other Issues and Values

Without explicit targets for important whole of forest outputs, no benchmarks exist to adequately evaluate trade-offs between competing values. These are required to better define any prescription variations needed to accommodate non-timber outputs, or to judge progress toward the achievement of Ecologically Sustainable Forest Management. The resulting risk is in setting inefficient yield levels and thus not achieving the inherent potential in terms of social net benefit. Another hazard relates to unresolved expectations held by stakeholders for the level of outputs of other non-timber values. Many of these might be resolved if explicit targets existed.

The Conservation Commission should develop processes to determine and communicate both 'whole of forest' and landscape level targets for as many forest outputs as possible. These targets must be effectively communicated to stakeholders both during the development process for the Forest Management Plan as a basis for informed comment, and at its conclusion as a matter of public record.

Recommendation 4.1, Whole of Forest
The Conservation Commission should develop processes to make explicit both 'whole of forest' and landscape level targets for as many forest outputs as possible. These targets must be effectively communicated to stakeholders both during the development process for the Forest Management Plan as a basis for informed comment, and at its conclusion. The Forest Management Plan must take a whole of forest perspective and not focus solely on the areas available for timber production.

A major shortcoming in the application of fire for vegetation management is the absence of specific management objectives at an appropriate scale. For biodiversity, this is a particular concern in reserved areas that are now a much more significant proportion of the forest estate and where biodiversity values might be expected to have a high priority. Without agreed objectives at this level there is no way of judging whether fire management practices are appropriate or successful.

CALM, in association with the Fire Emergency Services, has initiated a revision of Wildfire Threat Analysis system that gives explicit weightings to a full range of values at risk. This revised system is intended to be used as a decision support tool for both prescribed burning and fire suppression activities across all managed lands and adjacent influence zones and provides a vehicle for implementing fire management based on explicit objectives.

Recommendation 4.2, Fire Management
(1) In the current revision of the Plan, the development of specific fire management objectives should be initiated for subsequent completion during the period of the Plan. The Plan should incorporate explicit objectives such as species or community priorities, the proportion of the area maintained in a particular post fire seral stage, regrowth protection or the maintenance of diversity at the landscape level versus the site level.

(2) The revision of the Wildfire Threat Analysis, incorporating consideration of operationally meaningful management objectives and strategies, and communication with the urban electorate and ecological expertise, should be extended to cover all land and ownerships during the next Plan period.

The Panel supports the key recommendations of the EPA in commenting on the recent dieback protocol, as they accord with the precautionary principle.

Dieback areas that have not been logged are credited with the standing volumes involved but are not taken into account in predicting future volume beyond the real or simulated time of logging The impact of future infection is not currently taken into account. This risk should be taken into account by sensitivity testing in the simulation models, assuming variously (a) no spread and (b) the apparent past spread over the last decade for the various strata, or minor modifications.

Recommendations 4.3, Dieback

(1) The key points of the EPA advice on the Protocol for the identification and prioritisation for the management of *Phytophthora cinnamomi* 'protectable areas' endorsed by the Minister should be implemented as soon as possible.

(2) The impact of future infection should be taken into account by sensitivity testing in the simulation models, assuming variously (a) no spread and (b) the apparent past spread over the last decade for the various strata.

The future impact of the honey fungus on regrowth karri is of concern because, like other *Armillaria species,* it can impact on regrowth forests causing mortality of trees retained after thinning. As thinning of regrowth stands proceeds, deaths of retained crop trees should be monitored. This will enable the allowances for the calculation of sustained yield to be refined.

Recommendation 4.4, Honey Fungus

Honey fungus mortality and damage arising from thinning operations, especially in karri regrowth operations, should continue to be monitored during the next Plan period to enable allowances to be develop for the future calculation of sustained yield.

Reports have drawn attention to the high incidence of decay and borer holes in regrowth karri. There is a moderate risk that the proportion of wood recovered from small diameter logs will be lower than expected or that some of the regrowth resource will be downgraded as unacceptable as sawlogs.

Recommendation 4.5, Karri Borers and Rots

An appropriate survey should be conducted across the thinnable karri regrowth estate to assess the potential impact on yield and to develop an appropriate allowance during the next Plan period.

Both leaf miner and skeletonizer are likely to impact on trees in the inventory and growth plots and thus their effects on growth will be integrated into models. The residual risk of chronic infestations of leafminer, causing reduced growth rate, is uncertain. Comparison of growth rates in inventory plots known to be infested with leafminer and those without, could assist in quantifying impacts of the leafminer.

Recommendation 4.6, Jarrah Pests

Research should be pursued to compare growth rates in inventory plots known to be infested with leafminer and those without, to assist in quantifying impacts of the leafminer during the next Plan period.

The principal hazard to the carbon cycle is associated with the fire regimes and the uncertainty surrounding their impact or changes to soil carbon changes. The likelihood of this hazard having an impact on, and posing a risk to, the global cycle is currently low for the South West Zone, but the Australia-wide or global implications of this issue do merit research.

Recommendation 4.7, Carbon Cycle
Research should be pursued on the impact of fire management and logging regimes on the global carbon cycle during the next period of the Plan.

Greater attention needs to be paid to the trade-offs between new mining sites and biodiversity values. Given the much greater weight the community is according these values, it should no longer be assumed that mining is pre-eminent in the social net benefit it provides from every viable bauxite reserve. Reservation of any areas for biodiversity and other conservation values would actually lead to a reduction in the cut from areas that would otherwise have been clear-felled prior to mining. The resolution of these trade-offs is important in relation to calculating the sustained yield. It is most unlikely that all such areas could be so reviewed for the current Plan revision but a process should be initiated to deal progressively with these areas, according to the planned schedule of mining operations.

Recommendation 4.8, Bauxite Mining Sites
The Conservation Commission should initiate a formal process for a more detailed examination of areas mooted for bauxite mining with respect to biodiversity conservation and hydrological values and an evaluation of the trade-offs with mining involved.

The calculated sustained yield in the new Forest Management Plan is likely to be substantially lower than that in the Regional Forest Agreement, as a result of the subsequent increases in reservation. Due consideration, analysis and reporting needs to be given to the likely social and economic impacts particularly in rural communities. The Regional Forest Agreement committed the parties to an independent economic and social impact assessment of the draft Forest Management Plan. However, the process to be followed needs to be developed well in advance and needs to be initiated as soon as possible if it is to contribute adequately to the development of the Plan.

Recommendation 4.9, Social Impact Study
An independent and robust social impact study be initiated as soon as possible as part of the current revision of the Plan.

The need for some development of the operational and support aspects of the Visual Management System and some further consideration of geo-heritage issues was identified during the Regional Forest Agreement. The major impacts of heritage values in relation to the estimation of sustained timber yield comes through the exclusion of timber harvesting (reduction in net harvestable area), delay in harvesting, or through the application of modified harvesting prescriptions.

The current databases and approaches appear to provide a generally sound basis for modifying the estimated timber yield for the purposes of preparing the next Forest Management Plan. However, both the concepts of natural heritage and the relative community values of different aspects or examples natural and cultural heritage do change through time.

Recommendation 4.10, Heritage Values
Consultative mechanisms need to be enhanced to ensure that the guidelines for natural and cultural heritage used in forest planning and management are kept in step with changing community values during the next Plan period.

The need for a more effective engagement of indigenous communities in relation to forest management and the impacts of forest management on indigenous communities and their

cultural heritage has been identified by several recent forestry enquiries. The results from future engagement with indigenous communities may result in changes to the basis for estimation of sustained yield.

Recommendation 4.11, Indigenous Communities
Specific consultative processes, in addition to those used for general community, should be further developed with the relevant indigenous communities during the development of the next Forest Management Plan to ensure effective input in relation to management proposals that have impacts on indigenous cultural or other interests during the current revision of the Plan.

Databases and modelling of flora and fauna species in the context of planning requires further development. Information from these database help to inform biodiversity goals, targets and performance criteria that can then be translated through to indicators and measurement of Ecologically Sustainable Forest Management outcomes. The risk of not being able to meet biodiversity objectives is reduced through commitments made in the Regional Forest Agreement to improving the knowledge base by appropriate sampling.

Recommendation 4.12, Biodiversity Databases
The Conservation Commission should commit to the maintenance of databases for biodiversity on a 'whole of forest basis' as a pre-requisite for Ecologically Sustainable Forest Management on areas available for timber production and elsewhere.

5 Priorities and Resources

The Panel has provided a summary of the priorities for its recommendations in terms of timing. It has not had time to examine the resources required, other than in a very general manner.

1 INTRODUCTION

1.1 Background

The review has its origins in commitments contained in the report by Mr Mike Codd of January 1999 and the Regional Forest Agreement (RFA) of May 1999. The report by Mr Codd included the following statement:

> *"it is acknowledged that the RFA process will establish an expert panel to provide independent scientific advice on the provisional sustained yield figure consistent with the principles of ecologically sustainable forest management, and with appropriate provision for potential improvements in utilisation; with such a panel expected to take some 12 months to report"*

Clause 50 of the Regional Forest Agreement of May 1999 stated:

> *"The Commonwealth accredits the process described in An Appraisal of Methods and Data used by CALM to Estimate Wood Resource Yields for the South-West RFA Region of Western Australia (Turner B.J., Department of Forestry, Australian National University, December 1997) and being used by CALM in the calculation of Sustained Yield of wood products from the public native Forest and plantation estate on the understanding that the improvements recommended in that report will be addressed prior to the development of the next Forest Management Plan. Western Australia agrees that the methods and data to be used in the calculation of the Sustained Yield of wood products from the public native Forest and the Sustained Yield figures to be included in the Forest Management Plans will be reviewed by a panel of suitably qualified independent experts as part of the development of each Forest Management Plan under the CALM Act and improvements incorporated during the Forest Management Planning process. Western Australia confirms that its current standard of inventory will be maintained and yield and planning databases and systems, as amended by this Agreement, will be enhanced."*

The purpose of this review is to fulfil the above requirements and to facilitate the development of the next Forest Management Plan. The intent of the next Forest Management Plan is to implement the outcomes of the Regional Forest Agreement and subsequent forest policy statements. It is not the purpose of this review to examine the Regional Forest Agreement process and outcomes.

The review focuses on the calculation of sustained yields within the context of the principles of Ecologically Sustainable Forest Management. The agreed principles of Ecologically Sustainable Forest Management set out in the Terms of Reference of the review are:

(a) planning and management of forests should maintain the suite of forest values for present and future generations:

- *maintain and enhance long-term multiple socio-economic benefits to meet the needs of societies;*
- *protect and maintain biological diversity;*
- *protect and maintain natural and cultural heritage;*
- *maintain the productive capacity and sustainability of forest ecosystems;*
- *maintain forest ecosystem health and vitality;*
- *protect soil and water resources;*
- *maintain forests' contribution to global carbon cycles; and*

(b) *planning and management of forests should be guided by the precautionary principle;*
(Regional Forest Agreement: Attachment 5)

A discussion of these principles may be found in the Ecologically Sustainable Forest Management report of the Regional Forest Agreement. The precautionary principle is defined[1] thus:

> *"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by*
> *I. careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment;*
> *II. an assessment of the risk-weighted consequences of various options."*

In considering application of the precautionary principle, the Panel was required to pay particular attention to forest management processes and practices dealing with 'risk assessment' and 'risk management' to minimise environmental impacts and avoid serious or irreversible damage to the environment. However, only those aspects of Ecologically Sustainable Forest Management that directly impinge on the calculation of sustained yield are within the prescribed scope of the review.

The principles of Ecologically Sustainable Forest Management state that planning and management should maintain the full suite of forest values for future and present generations through a set of principles relating to the management of various of those values. Sustainability for future generations is clearly a key factor that addresses the equity of resource use between generations. Mention of the long-term multiple socio-economic benefits makes it clear that the review not confined to commercial net benefits. All values or uses have to be considered in addressing both the equity and efficiency of sustainable resource use.

Neither the Ecologically Sustainable Forest Management principles nor the CALM objectives throw much light on the mix of values or uses to be sought from a particular area of forest. Zoning does exclude some uses and values. It may also guide the priorities to be accorded to various forest uses, where the priorities are explicit in the rationale or basis used for zoning and the prescriptions to be applied in those Zones.

As noted earlier, the review necessarily focuses on the calculation of sustained yields of wood from CALM-managed native forest in the context of Ecologically Sustainable Forest Management. For those areas where wood production is to be permitted, the question remains as to what mix of wood and other values is appropriate. There is no single answer to this question, because the intrinsic worth (or social net benefit) of different uses varies widely within that part of the forest estate available for wood production. In some places, water values may be pre-eminent – in others, landscape aesthetic, wildlife, flora conservation or mineral values may dominate. Yet across an area as vast as the native forests of the South West, there are bound to be areas for which wood production is the dominant value, others in which it provides a significant part of the mix of values, some in which it is a minor component, and many where it is not appropriate.

The role of the Panel is to try to ensure that management practices not only maintain or enhance particular forest values listed in the set of principles for Ecologically Sustainable Forest Management, but that the totality of the social net benefits across the entire forest is as

[1] Commonwealth of Australia 1992. *National Forest Policy Statement*. Australian Government Publishing Service, Canberra.

high as possible. As is well-known, neither the available data nor analytical techniques are equal to solving this task analytically, and hence the use of a panel of experts, supplementing these endeavours with public input to identify areas of concern and possibly needing further action or change.

1.2 Application of Ecologically Sustainable Forest Management Principles

As with any definition of a process, the principles of Ecologically Sustainable Forest Management are capable of differing interpretations. Numerous bodies, including intergovernmental panels, bodies and processes (IPCC, Montreal Process, Ramsar), major international research centres (e.g. CIFOR), international societies (e.g. IUCN, IUFRO), professional bodies (Ecological Society of America, Ecological Society of Australia, Institute of Foresters of Australia) have sought to help develop their own goals and indicators and to influence those set by government agencies.

The Panel recognises that a single, internationally agreed set of goals or indicators for all forests is unlikely to be achieved. Attempts are in progress to develop goals and indicators for Australia but have not reached a conclusion. Establishment of goals and indicators of Ecologically Sustainable Forest Management in Western Australia is therefore a key priority taking account of the national framework[2]. In our view, the precautionary principle remains an over-arching guide, and provides for setting of clear goals where good scientific knowledge exists, and for the refinement of goals (adaptive management) as new knowledge is acquired.

Sustainability has been defined[3] as the capacity for continued productivity where the primary requirement is for site and soil protection and for adequate regeneration and protection) and sustainable yield as the capacity to maintain relatively consistent levels of production or products over an extended period. In the case of Western Australia, the Conservation and Land Management Act refers to 'sustained yield' in exactly the same context as sustainable yield, and the Panel therefore uses the term 'sustained yield' to be consistent with the legislation and terms of reference, but noting that it regards its definition as being identical to that for sustainable yield.

As a starting point, the Conservation and Land Management Act explicitly states several goals for forest management in Western Australia that are broadly compatible with the principles of Ecologically Sustainable Forest Management. These will be refined progressively in relation to the principles of Ecologically Sustainable Forest Management, and the hazards affecting them, in later sections. In addressing these issues, the Panel has attempted to ensure that:

1. Goals and indicators for principles of Ecologically Sustainable Forest Management should be set for the 'whole of forest' (spatial scale).
2. Consideration of 'Sustainability' should involve a time frame longer than that covered by a Forest Management Plan (temporal scale). Some goals will not be achievable within that term but there will be indicators that can be used to assess progress towards those goals.
3. Setting of goals and indicators should recognise the precautionary principle.

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[2] MIG Secretariat. *A framework of regional (sub-national) level criteria and indicators of sustainable forest management in Australia.* Department of Primary Industry and Energy, Canberra, 108pp.

[3] Ferguson, I., Gardner, J., Hopper, S. and Young, J., 1999. *Report to Minister for the Environment: Ministerial Advisory Group on Karri and Tingle Management.* Department of Environment, Perth, 67pp

1.3 Risk Assessment and Management

The guiding methodology for risk assessment and management was based on the Standards Australia and Standards New Zealand publication AS/NZS 4360:1999 *Risk Management.* This was adopted because it provides a well-established and systematic approach that is compatible with the Environmental Management System adopted in the Regional Forest Agreement process, having been developed "with the objectives of providing a generic framework for identification, analysis, assessment, treatment and monitoring of risk".

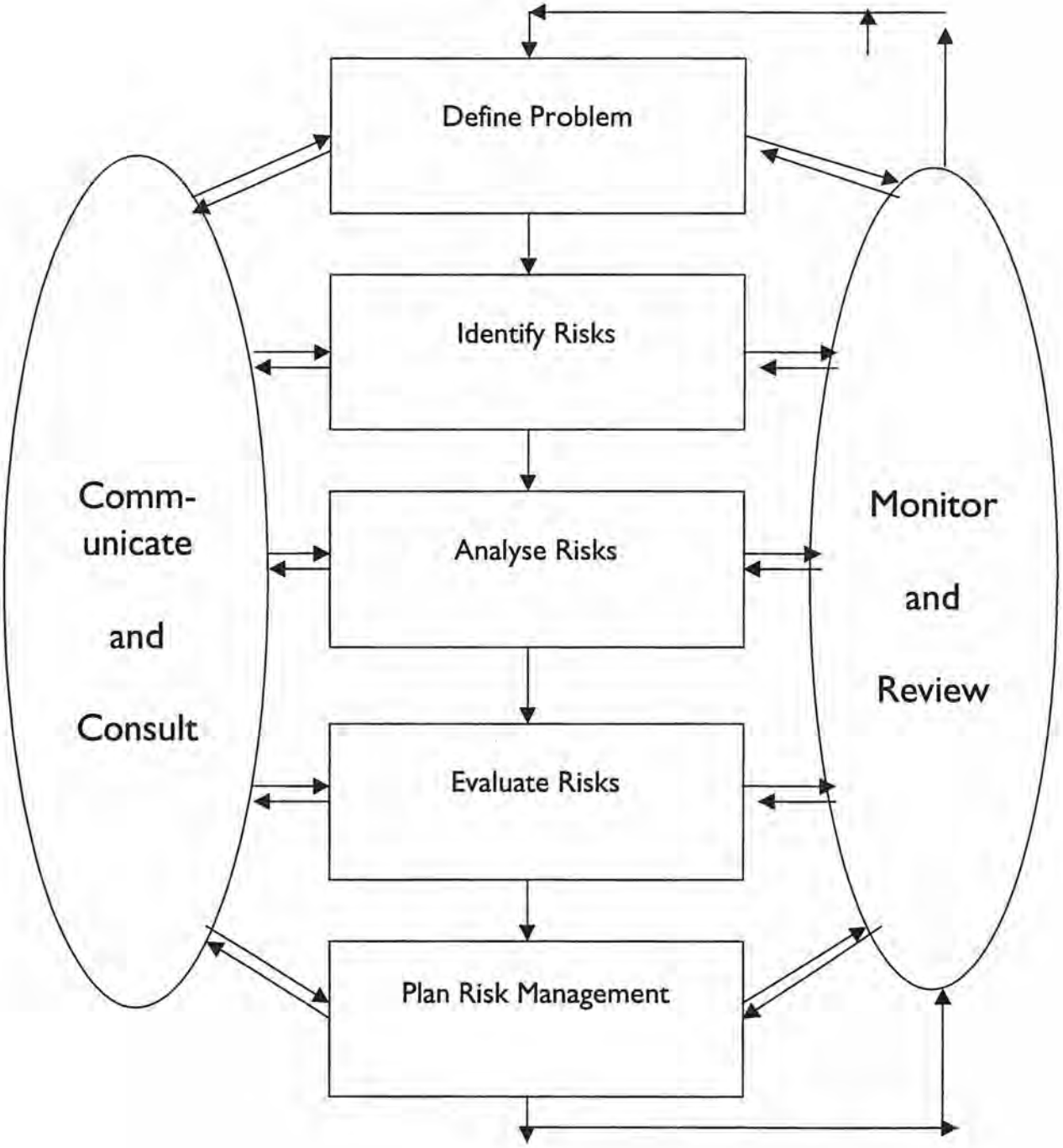
Some of the key terms are defined as follows:

Hazard: a source of potential harm or a situation with a potential to cause a loss.
Likelihood: used as a quantitative description of probability and frequency.
Risk: the chance of something happening that will have an impact on objectives.
Residual risk: the remaining levels of risk after treatment measures have been taken.

Figure 1 (opposite) illustrates the sequence of steps involved in this approach.

These follow a similar pattern to those used in systems analysis and Environmental Management Systems, commencing with the definition of the problem in terms of context and boundaries. Then follows the identification of hazards in terms of what can happen and how it might happen. Analysing hazards then involves determining the existing controls over them. Evaluating risks involved determining their likelihood and magnitude. Risk management then involves evaluating the risks against criteria, deciding on acceptable levels of risk, identifying risk management strategies, selecting the best risk management option, and implementing it. Having done so, the process follows a trial and error 'dual track' of communicating and consulting with stakeholders, and establishing processes for monitoring and review. Obviously, the present Stage 1 review cannot complete all these steps but it can initiate the processes and recommend the best initial options.

Figure 1: Steps involved in Risk Assessment and Management



1.4 Terms of Reference and Scope of the Report

The Terms of Reference of the Stage 1 Review define the problem and set the boundaries as follows:

Stage 1 Review

The panel of independent experts will:

1. document and examine the management practices that are used to implement the principles of ecologically sustainable forest management and their integration with the process for establishing sustained yield levels;
2. examine the methods and data used in the calculation of sustained yields in terms of the requirements of clause 50 of the Regional Forest Agreement;
3. examine the timber resource estimates in terms of their consistency with the areas of native forest available for timber harvesting;
4. examine the yield projection system in terms of their consistency with variability in growth rates on varying landforms, soils, climatic zones and forest ecosystems; and
5. examine the yield projection system in terms of consistency with the objectives for management of the CALM-managed estate, as specified in the Forest Management Plan.

The panel will seek technical, industry and community input into these issues.

Scope

The review includes CALM's three forest regions – Swan Region, Central Forest Region and Southern Forest Region.

The scope of the review is to focus on the calculation of sustained yields of wood from CALM-managed native forest in the context of the principles of ecologically sustainable forest management.

While ecologically sustainable forest management deals with the management of all types of forest (native forest, plantations) across all tenures (public, private) and for all values and uses (timber harvesting, mining, conservation, recreation etc) only those aspects of ecologically sustainable forest management that directly impinge on the calculation of sustained yields are within the scope of this review.

Stage 1 Report

The panel will provide a single written report to the Conservation Commission by 30 April, 2001, including:

- Recommendations, as appropriate, for future improvements in matters arising from the terms of reference and indicating –
  (a) those improvements that may be feasible to implement in the period leading to the next Forest Management Plan; and
  (b) those improvements that could be implemented in the longer term; and
- Identification of priorities and relative resources required to implement each recommendation within the context of existing priorities for improvements to Western Australia's forest management systems.

Objectives of management

The Terms of Reference note that the objectives for management of CALM-managed lands are as specified in the Forest Management Plan 1994-2003. The overall objective is:

> *"To manage the native forests of the south-west of Western Australia, in consultation with the community, so that they provide the values required by society while sustaining indefinitely their biological and social diversity."*

The conservation objective is:

> *"To maintain biological diversity at the genetic, species and ecosystem level in the forest, with special emphasis on the protection and conservation of threatened, rare and uncommon taxa and communities."*

The management objective is:

> *"To protect and enhance identified forest values and to employ the best practices in managing forest ecosystems."*

The production objective is:

> *"To manage the forest to produce the range of commercial values approved by Government, in a manner which is ecologically sustainable and provides a fair return to the State."*

The tourism and recreation objective is:

> *"To facilitate the public enjoyment of the forest in a manner that is consistent with the nature conservation and other objectives."*

The knowledge objective is:

> *"To seek a better understanding of the composition and function of forest ecosystems and to promote awareness and appreciation of their values."*

The Terms of Reference also note that the practices that are used to provide for ecologically sustainable forest management are as specified in the Forest Management Plan 1994-2003, the Regional Forest Agreement and the previous State Government's forest policy.

Some policy and administrative issues concerning the calculation of sustained yield are somewhat unclear pending the refinement of the working relationships between CALM and the Forest Products Commission in the light of the new legislation defining the respective roles and responsibilities of the regulatory and timber management agencies in the inventory, sustained yield and planning functions. Comment on these matters has therefore been held over until the Stage 2 report.

1.5 South West Zone versus Regional Planning

One question that arises in relation to the long-term multiple socio-economic benefits and the calculation of sustained yield is how well does the stratification and inventory of the forest estate serve the dual purposes of planning the sustained yield and maintaining and enhancing those multiple socio-economic benefits.

Some ambivalence is evident from past experience. Regional plans were prepared for the three forest regions in 1987 (Northern Forest, Central Forest, Southern Forest 1987-1997). Since then, some boundary changes have occurred and these three regional plans were largely replaced by the Forest Management Plan 1994-2003. However, the new Plan does not revoke

the 1987 plans. Where the new Plan and the 1987 plans cover the same issue, the provisions of the 1994 plan simply replace those in the 1987 plans.

Since 1994, it would also seem that regional (in addition to metropolitan) stakeholders and interest groups have taken a much greater interest and involvement in the planning process than was true of the past. Particular rural communities have been closely involved in concerns expressed to the review of karri and tingle management (Ferguson et al. 1999) and have a detailed knowledge of some parts of their particular regional forests. While on occasions, Statewide considerations may need to over-ride; local involvement needs to be fostered.

On the other hand, a Statewide strategy is clearly appropriate for the timber industry as a whole, especially if further processing and value adding are to be fostered. While these issues have largely been settled for the karri and tingle forests as a result of recent Government decisions, the position is more acute for jarrah.

Historically, the system of stratification and inventory was initially based purely on consideration of the productivity of wood. The three forest regions formed logical post-war geographic catchments for the supply of wood, given the centres of population, ports, and main transport routes. The forest was stratified from aerial photography into broad height classes and species mixtures that aided the efficient use of field measurement resources in measuring temporary and permanent plots. Fortunately, that stratification was highly correlated with rainfall, soils, and species richness and (sometimes inversely) diversity and it has therefore been useful for planning other forest uses or mixtures of uses.

Much more detail has been mapped subsequently, including vegetation types, disease (*Phytophthora*) zones, threatened and endangered species habitats, sensitive catchments and wetlands, visual resource management zones, strategic fire management zones, buffer strips and wildlife corridors (the latter two are referred to as road, river and stream zones in the Forest Management Plan). Geographic information systems make these details available to planners and field managers, and to the general public.

A dual system is therefore inevitable, such that the underlying inventory and calculation of sustained yield is carried out initially on a regional basis but with provision for aggregation over the South West Zone. However, iteration from Zone to the Region and back again will be needed to refine the calculation of sustained yield.

Recommendation 1.1, Regional Calculations
The underlying inventory and calculation of sustained yield is carried out initially on a regional basis but with provision for aggregation over the CALM-managed native forests. However, iteration from Zone to the Region and back again will be needed to refine the calculation of sustained yield.

2 PUBLIC CONSULTATION

2.1 Introduction

Stakeholder involvement in the process commenced in 1999 when the Acting Executive Director of CALM wrote asking a large number of stakeholders to have input on the composition and terms of reference of an independent panel to review the processes of establishing the sustained yield from the native forests consistent with Ecologically Sustainable Forest Management.

The Minister for the Environment announced the membership and terms of reference of the Panel in July 2000.

The Panel sought public input to the review process by means of written and oral submissions. Organisations and individuals known to have an interest in the subject of the review were invited to make submissions.

To assist stakeholders in framing their submissions, copies of relevant background documents were made available through public libraries in the metropolitan area and south-west communities. These documents were also accessible through the Internet.

A total of 42 written submissions was received, the main points being tabulated in Section 2.2 and 24 stakeholders gave oral presentations as Manjimup, Bunbury and Perth in the period 1-3 November 2000. Organisations and individuals who made submissions to the Panel are listed in the Appendix.

Since the process began there have been a number of significant changes that have affected both the organisations responsible for conservation and forest management, and forest policy. The newly formed Conservation Commission has taken over responsibility from CALM for this report and is now the agreed proponent of the next Forest Management Plan which will ultimately be forwarded to the EPA for consideration for its advice to the Minister for Environment and Heritage, prior to approval of the Plan.

The ALP assumed Government in February 2001. Many of the submissions received by the Panel before the election focused, among other things, on the issue of 'old-growth' logging, which is no longer relevant to this review in the light of the changes in policy introduced by the new Government.

The Government has also indicated its wish to see the development of the next forest management plan fast-tracked. As a result, this report has been completed without the opportunity to give feedback to stakeholders. However, the Chairman of the Conservation Commission has indicated that feedback will be facilitated in Stage II of the planning process (see Terms of Reference, Section 1.4).

2.2 Summary of topics raised in written submissions

Summary of comments made in submissions	*No. of submissions with this comment*
1 Ecologically Sustainable Forest Management (ESFM) Definitions and interpretation	
The determination to constrain ESFM by considering only 'sustained yield' is unacceptable.	3
The term 'sustainable yield' is more appropriate than 'sustained yield' when discussing ESFM.	2
Consideration should be given to the distinction between 'sustainable ecosystems' and 'sustained timber yield'.	
Greater clarification of the EGCRA definition of sustainability with respect to time, cost, values and area still required.	
ESFM means the maintenance of the entire floral, faunal and climatic forest eco-system over the whole of forest.	
Conflict between commercial and ecological goals is inherent in the definition of ESFM adopted for the review.	
The definition of ESFM being adopted is 'skewed' to commercial values.	
ESFM principles cannot be applied universally across conservation and production forest boundaries.	2
ESFM values should be realised in terms of the whole of forest approach.	
ESFM should involve integrating commercial and non-commercial values of forests so that the welfare of society (both material and non-material) is improved while ensuring intergenerational equity in their values.	2
Adaptive management supported where changes based on sound scientific evidence.	
Topics suggested for review and comments on approach	
Need for clear documentation as to how ESFM objectives are to be met and evaluated.	
ESFM principles as outlined in the report from the Independent Expert Advisory Group on ESFM for the RFA should be the basis of current review.	
Silvicultural techniques and other management practices with regard to ESFM and accreditation of exports should be addressed.	
The panel should ensure that they stay within their terms of reference.	
The review should build on RFA and its recommendations for ESFM	2
Yields from the three forest regions should be differentiated within the whole of forest approach.	
The Panel should give an opinion on where the "maintenance of a	

steady state diameter distribution to define a desirable ecosystem structure is a useful advance in the definition of sustainability" (Turnerand Wood 1993).	
An opinion should be provided on whether an allowable annual cut in jarrah, equivalent to estimated whole of forest annual growth increment is an acceptable basis for establishing sustainability under ESFM principles.	
The review should focus on the major issues and not pursue minor details.	
Sustainable yield should be calculated in a way that all 'end values' are accounted for rather than just wood volume or mass.	
All ESFM values should be accounted for in the determination of sustainable yield.	
ESFM should be considered in the context of the whole of forest, not with an expectation that the multiple use forest will necessarily provide the same values as the reserves.	
The yield of species such as blackbutt, marri, casuarinas should be reviewed.	
The Panel should review timber royalties.	
Views of independent biologists and ecologists should be sought.	
The panel should consult with Water and Rivers Commission as part of the process.	
The panel should make their own on-ground observations.	
The panel should inspect jarrah regrowth in a range of areas to judge whether it is satisfactory.	
The Standing Committee on Ecologically Sustainable Development has made a number of recommendations that should be heeded by the panel.	
There should be a strong emphasis on management requirements for the maintenance of values in forests now in reserves.	
The panel should also advise on the calculation of an environmentally sustainable yield from the State's plantation resource.	
2 Sustained yield **Modelling of sustained yield. Factors suggested for consideration:**	
Risk assessment of factors affecting sustained yield.	
Flexible rotation lengths to ensure smooth future wood flows.	
The very long rotation lengths currently in place offer flexibility in providing for non-timber values.	
A 200-year rotation length of jarrah should be maintained.	
A rotation length for karri of less than 100 years should be recommended.	
New silvicultural practices including those related to changing chipwood demand.	
Effects of statistical errors on arriving at total available wood.	

Review the system of allowance for negative and positive uncertainties in determining whether sustainability is verifiable.	
Review the timing of logging in jarrah temporary exclusion areas.	
The dieback status of inventory plots may not be readily available or known compromising reliability of estimates of the disease on both growth and mortality.	
Both quality and quantity of the available sawlogs.	
Effects of pests and diseases on yield, particularly karri regrowth.	3
Sawlog yields from the areas available for production should be maximised.	
The deficiencies in yield projection system identified by Turner (1998).	
Buffer strips and special requests from neighbours may require a contingency allowance in setting sustainable timber yield.	2
Allowance for visual resource management in areas of tourism potential.	
Provisions for maintaining water quality, not only in catchments for human supply.	
Climate change and decreasing rainfall.	7
Modelling of sustained yield: concerns	
The quality of inventory data for jarrah.	
Adequacy of rotation lengths for maintenance of values.	
Validity of assumptions.	
Level of sampling and distribution of growth plots.	
Data and methods used to date are considered inaccurate or inadequate and requiring verification.	3
Positive comments and conclusions reached by previous reviewers of CALM systems should be acknowledged.	3
Timber yields	
Sustained yield should not be discussed in terms of gross bole volumes but sawlogs.	
Assessment of quality and quantity relationships is apparently difficult.	
Area available for harvest	
Need for clarifications of area of State forest available for harvesting.	
Inaccuracies in mapping would suggest inaccurate resource estimates.	
Various circumstances can impact on CALM's assertion that "areas of low timber productivity which will be too expensive to adequately regenerate should not be harvested".	
Reservation in the Central forest region was inadequate in the RFA.	
The RFA/CAR reserve system was adequate.	2

Clarification sought	
Question as to how variability over landscape accounted for in models.	
Question as to how inevitable diminution of quality of timber is factored into CALM models.	
3 Forest Management Policy	
Lack of stability in government policy and its application results in adverse effects on planning and implementation.	
CALM's commitment to an EMS and the development of the Australian Forestry Standard should be noted.	
CALM policies already demonstrate commitment to the application of ESFM.	
CALM considered the most appropriate agency to consider and implement all ESFM principles.	
Planning and implementation	
Concerns expressed about current division of responsibilities between departments and commissions and thought likely to impact on delivery of ESFM in the field.	
Confidence in CALM personnel and systems strongly stated.	
Application of informed local decision making need attention given the rapid change of biodiversity across south-western landscapes.	
Monitoring and compliance	
Issue of enforcement procedures for dieback hygiene procedures raised.	
There are discrepancies between the forest management policies and actual practices with regard to protection of streams, dieback hygiene, soil protection, flora and fauna surveys.	8
Suggestions for improvement	
The current system of log sale contracts should be reviewed so there is a better match with grades available.	
The case for sale of non-sawlog material to enhance future sawlog availability should be presented. The importance of chip wood markets for ongoing management of regrowth karri.	
Independent scientists should monitor logging.	
Ongoing biological survey data ahead of logging required where the knowledge base is deficient.	
Royalties for sawlogs are set too low and encourage excess consumption of forest products.	
Contractual agreements should be non-binding under conditions of detected detrimental change.	
Independent audits of compliance with codes of practise and protocols in the bush advisable.	
Re-asses the quality of available log resources and issue contracts of	

sale in the new management plan, which better reflect the apparent lowering of average quality as harvesting moves eastwards.	
Prohibit sawmill companies from owning logging companies and further investigate a modified version of whole-bole logging.	
Introduce new harvesting practices suited to improved utilisation of regrowth forests.	
Improve the utilisation of felled trees by lowering stump heights and providing end protection.	
Change hardwood log specifications from random lengths to order lengths and remove the anomalies between species and between softwoods and hardwoods.	
Inventory should account for logs stolen and not recorded from logging coupes.	
The management and priorities of CALM's Timber Technology centre at Harvey should be reviewed.	
Prior to logging a full appraisal of quantities and grades of timber felled should be made. Quantities and grades sold off coupes should be audited.	
A licence system was recommended by the parliamentary standing committee on ecologically sustainable development to replace current system of commercial timber contract.	
4 ESFM	
The precautionary principle	
The precautionary principle should be applied to minimise risks to forest ecosystems.	
Difficult to use as a criterion of ESFM.	
Summary of Ehrlich's (1996) criteria for a precautionary approach presented.	
The precautionary principle can be interpreted in a number of ways and there is potential for it to be misapplied.	
Should not be interpreted as "when in doubt do nothing".	
Application of the precautionary principle is important as serious and irreversible damage is occurring.	
Criteria to be used to measure 'sustainability' needed. Without criteria for assessing outcomes approach adopted is not precautionary.	
Alcoa has applied the precautionary principle in relation to a range of the company's activities and procedures in the forest.	
Alcoa has made a commitment that bauxite mining will not take place in the eastern, lower rainfall portion of their mining lease until research shows that mining operations can be conducted without significantly increasing the salinity of water resources.	
Difficult to interpret.	
Difficult to apply as a criterion of ESFM.	

5 ESFM principles	
Conservation of biological diversity	
Strategies appropriate for homogenous forest environments not appropriate in areas of rapid change in biodiversity such as across south-western landscapes.	
There is a paucity of biodiversity data in relation to the eastern margins of the jarrah and wandoo forests.	
There are yet to be acknowledged values of the diverse range of plants and animals in the South West.	
Major forest corridor for faunal movements, Nannup-Walpole proposed.	
Zones free of disturbance should be included in logging plans to provide habitat in the long term.	
Extent of disturbance in jarrah forest over past ten years of concern.	
Adequacy of current provisions for fauna habitat questioned.	3
Wildlife conservation requires monitoring with real thresholds for managing change.	
Fragmentation affects the ecology of forests in various important ways.	
Clearfelling results in loss of biodiversity.	
Surveys of flora, fauna and micro-organisms should precede the determination of sustained yield.	
Logs left to rot on the ground contribute to biodiversity.	
The mix of species changes as a result of logging. Areas that supported mixed species prior to logging but planted to karri post logging of concern.	4
The CAR reserve system adopted as part of the RFA is adequate.	
Greater reservation will put increased pressure of logging on regrowth forests.	
Level of reservation recommended in RFA. In many areas criteria for reservation set by JANIS criteria exceeded.	
Provision for wildlife corridors should be made in regrowth, to link areas of reserved forest.	
Care in seed collection and selection of genotypes of seedlings used in regeneration should be taken.	
Preservation of genetic diversity crucial in the long term.	
Populations of plants and animals should not be genetically isolated.	2
Current karri regeneration methods compromise biodiversity.	
Alcoa has made a series of commitments to ensure biodiversity is maintained, including a commitment not to mine in areas of the conservation estate. They participated in the RFA process to establish a CAR system.	
Alcoa has a number of protocols for the protection of rare species and threatened communities. High value habitats such as swamps are valued.	

Significant emphasis is placed on re-establishing plant species diversity in rehabilitated bauxite mining areas.	
Bauxite mining industry has contributed to fox control.	
An ongoing woodchip industry is of great importance to ensure regeneration and provide an acceptable method of disposing of residues.	
Areas of State forest which are no longer contributing to sustained yield put enormous pressure on other areas of good stands of trees.	
Large areas of forest no longer contribute to the sustained yield because of past cutting practices and ways to redress this should be explored, even to the point of planting exotic species.	
Alcoa maintains extensive research and monitoring plots to assess the growth and development of the new forests.	
Current mine rehabilitation practices should be reviewed to determine whether future timber production can be enhanced.	
Waterlogging affects regeneration of jarrah.	
The ways of maximising growth rates and productivity in different areas should be tested.	
Diseases such as Armillaria are impacting of regrowth karri.	
Rates of karri planting suggest overstocking.	
Greater flexibility should be given to improving productivity in production areas or wood production unlikely to be economically sustainable.	
There are inadequate provisions for managing regeneration in the reserve system.	
Productivity of jarrah in areas of bauxite mining rehabilitation has recently been assessed.	
Some dieback degraded areas of jarrah forest in the vicinity of bauxite mining have been rehabilitated and treated to minimise effects of the disease.	
Amount of silvicultural, non-commercial thinning considered inadequate.	
Jarrah regeneration should be reviewed.	
Regrowth forests should be selectively logged to maintain uneven aged forest that maintains its ecological integrity.	
Wood chipping and removal of logs for charcoal required to ensure regeneration and minimise waste.	2
Regeneration should be over the total forest, not just in production areas.	
Maintenance of health and vitality of ecosystems	
Efficacy of disease prevention measured questioned.	
Protection of the total forest from fire, pests, diseases and unwise human use should be ensured.	
Management priorities for both regrowth and old-growth forests in reserves should be reviewed.	

Recent changes to long-term strategic logging plans heighten the risk of major wildfires.	
The ability to control pests and diseases in the conservation forests limited and will require changes.	
Almost all forest operations affect site hydrology and jarrah is extremely sensitive to waterlogging.	
Slowly rising ground water will reduce rooting volume and result in trees being more prone to summer drought.	
Comment that basic ecosystem processes are compromised by logging.	
Alcoa aims at restoring a self-sustaining jarrah forest ecosystem.	
Alcoa is committed to minimise spread and impacts from *P. cinnamomi.*	
Species exotic to the jarrah forest but introduced in early rehabilitation trials are being monitored to ensure that any spread is not left uncontrolled.	
Maintenance and conservation of soil and water	
Additional protection measures are being developed between Water and Rivers Commission and CALM to protect water supply catchments from chemical contamination and from soil erosion and consequent turbidity problems in wetlands and waterways.	
Water and Rivers Commission and CALM are working to ensure that sustainable ribbons of riparian vegetation are retained along streams. Timber-harvesting contractors are also being trained to understand the stream protection measures developed.	
The existing stream reserve system is adequate but could be better targeted to priority areas. Protection measures near reservoirs and at road crossings could be improved.	
Continual logging and burning will affect growth rates of all plants and soil structure will change.	
Any proposals to thin forest to increase run off for water storage should be the subject of a dedicated inquiry.	
Bauxite mining into the eastern jarrah forest where saline water tables may be present should be scrutinised.	
Lack of data on soil health of concern.	
Effects of clearfelling on soil characteristics and microbial activity raised.	
Salinity is a major issue and must be adequately addressed with respect to logging and effects on jarrah regeneration.	
Clearfelling or loss of forest canopy results in less local rainfall.	2
The sensitivity of jarrah to waterlogging and the lack of protocols for managing water within the forest should be considered.	
Alcoa implements a range of policies and gives high priority to their implementation to ensure that soil and water resources are protected in areas of mining.	

Maintenance of global carbon cycles	
Alcoa has started to develop a model that predicts that carbon losses from clearing before mining and the consequent sequestration of carbon by the rehabilitation.	
Mature forests store significant amounts of carbon.	
Alcoa has tried to develop ways to minimise 'burning to waste' forest products prior to mining.	
Protection of natural and cultural heritage values	
The heritage values of forests should be protected.	
Large granite outcrops are left undisturbed along with 50m wide buffers around them in areas of bauxite mining.	
Alcoa conducts Aboriginal and European heritage surveys on areas proposed for mining.	
Adequate surveys to ensure CALM does not breach the Aboriginal Heritage Act.	
Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies	
The impacts of the level of harvesting on the socio-economic structure of communities must be considered.	
Impacts on timber industry viability of any reduction in size of logs supplied should be considered.	
Yield regulation on sawlogs likely to maximise the community benefits to be derived.	
Wood should be valued more highly and used with care.	
Reduction in volumes of wood available will create unemployment.	
Restructuring of the timber industry should result in a fewer, better resourced companies with the capacity to invest in greater downstream processing.	
Different socio-economic circumstances apply to the question of logging in different forest regions. Therefore with respect to some issues whole of forest approach not appropriate.	
1,313 people are employed directly in the native forest timber industry.	
The costs, to the people of Western Australia associated with logging of native forests, are not adequately accounted for. Some are quantifiable but many adverse environmental effects are not.	
The attitude that "you can chop down someone else's forest as long as it's not in my backyard" most strongly objected to.	
If the sustained yield of logs is set too low the timber industry will not be economically viable.	
Changing social attitudes to the use of forests and factors affecting use of different products as substitutes for timber.	
There are substantial costs related to forestry that are not met by CALM but the public of WA.	

The perceived profits the State makes from logging native forests have resulted in unsustainable logging levels.	
The economic benefits of logging are questionable and forests may of greater value left standing.	
Balanced multiple use of our forests is for the benefit of all Australians.	
Questions raised as to how community values taken into account when logging coupes designed.	
The community and societal values of the South West timber towns must be considered. Consultation with them essential.	
Time frames for implementation of ESFM and the calculation of sustained yield and effects on socio-economic structure of communities.	
Alcoa (bauxite mining) employs 3,800 people in WA and injects $1.1 billion a year into the State's economy.	
6 Tourism and recreation	
The benefit of large-scale areas of forest reservation is that they can be promoted internationally.	
Tourism opportunities within the Northcliffe area have already been compromised by the level of logging in the area.	
Impacts of timber harvesting must be taken into account in the South West.	
Tourism and recreation values must be included in any assessment of the forest.	
The value to communities of the forests for tourism, recreation and water has been undervalued.	
There is a shifting focus to tourism in areas that have relied on the timber industry for income generation in the past.	
Forests as a resource for tourism raised.	2
Tourism can ensure long-term economic survival of local communities.	
7 Specific timber industry issues	
Greater value adding of WA timbers should be encouraged.	
The timber industry must have security and certainty of log supply.	4
Waste should be minimised.	
Ways should be identified to foster greater uptake of lower grades of logs.	
Concerns expressed about declining quality of logs available to industry.	
Whole bole logging if adopted should be tried to determine the acceptability of the system to industry and to explore issues associated with its regulation within the context of ESFM.	
Research and development should be undertaken to foster greater industry update of smaller regrowth logs.	

Sustainable level of cut needs to be determined to provide for a secure future for the timber industry in WA in perpetuity.	
Relevance of the forest industry structural adjustment guidelines should be assessed with respect to outcomes of current review.	
There should be a greater reliance on plantation timbers.	4
The Whittakers mill in Greenbushes should not be jeopardised by a reduction in the sustainable yield.	
The timber industry has already suffered major reductions in wood to be supplied and this should be taken into consideration.	
More flexible silvicultural prescriptions could result in a doubling of wood production.	
The small and short log, resource offers the best opportunity for a sustainable expansion of the jarrah industry.	
Industry must try new methods to improve the quantity of each grade of marketable timber recovered from all logs milled.	
There should be greater uptake of non-sawlog material.	
Regrowth jarrah logs cut in a trial had a high incidence of defect.	
The quality of regrowth logs of a rehabilitated bauxite pit were of superior wood quality than 60-year-old natural regrowth logs.	
It is difficult to eliminate in forest waste totally.	
Security of available resource for the timber industry is essential for any ongoing investment in the industry.	2
As much of the RFA should be retained as possible.	2
Funds for research and development are essential, as technologies for coping with a small log resource have to be developed.	
The timber industry has already voluntarily stepped down the timber it will take as part of the RFA, to provide for an ongoing sustainable jarrah timber industry.	
8 Mining	
Since 1962 Alcoa has mined 12,000 hectares of the jarrah forest and rehabilitated 9,500 hectares. The company has committed to implementing ESFM principles.	
9 Public consultation and transparency	
Frustration with lack of response to past submissions on forests expressed.	
Lack of trust expressed in CALM figures on which asked to comment.	
Time to properly address issues often limited.	
Public spectators not participants in decision making.	
None of the issues raised in submission on draft terms of reference was addressed.	
10 Next Forest Management Plan (FMP)	
The panel should not become involved in the formulation of the next Forest Management Plan.	

Local resistance to logging in particular areas should be countered by aiming for a greater appreciation of the values of the overall FMP.	
Conflict between values should be dealt with during development of next FMP.	
A wish expressed to see the current review expedite implementation of the new FMP.	
Review should be finalised before the development of the next FMP.	
More importance should be given to the social and economic impacts in developing the next FMP.	
Further planning should be based on the RFA gaols and objectives.	
Responsibility for next FMP should remain with the foresters of CALM and the Forest Products Commission.	
The RFA agreement should not be 'watered down further' and should be basis of next FMP.	
The next FMP should embrace a new approach to the management and utilisation of our native forests.	
RFA knowledge base on ecology of both jarrah and karri forest was inadequate.	
11 Protection of old-growth, two tiered forests and forests of high conservation value	
Old-growth and ancient forests should not be logged.	16
Two-tiered forests should be protected.	9
High conservation value forests should not be logged.	3
12 General comments	
The types of conclusions stated in Meagher (1993) quite unsatisfactory.	
A Royal Commission or inquiry should be held into forestry in WA.	4
The timber industry is the most sustainable industry in the world.	
Current logging levels are ecologically unsustainable.	
Current logging is at unsustainable levels.	5
Further reduction of logging in native forests will affect imports from unsustainably managed forests elsewhere, increase the pressure on farmlands for plantations, see a rise in exploitation of private forests, increase the State's dependence on imported resources, increase the use of steel which is a non-renewable resource.	
There should be less prescribed burning if management was focused on improved fire suppression capability and the use of new aerial suppression aircraft.	
If the native forest timbers are under valued just to compete with imports, our economic, social and ecological standards will decrease to those of poorer nations.	

2.3 Main themes

There was considerable discussion on the definition of Ecologically Sustainable Forest Management and perceptions varied greatly as to the relative weighting of values for different areas including reserves and production forests. There was little consensus as to the scale at which allowance for Ecologically Sustainable Forest Management values should be made.

The main themes, of relevance to the Panel's deliberations were as follows:

- Issues that relate to the maintenance of biodiversity.
- The importance of forests for tourism and recreation.
- The many challenges in managing the reserve systems for the maintenance of Ecologically Sustainable Forest Management values and resources. Resources will be required to tackle a wide range of problems including diseases, feral animal control, weeds, fire and structural diversity.
- Concerns about global warming and trends in rainfall.
- The maintenance and enhancement of productivity over the regrowth estate. Suggestions were various and ranged from sawlog expectations off mining rehabilitation areas in the northern jarrah to silvicultural systems for karri regeneration.
- The importance of monitoring, compliance reporting and audit were also referred to with respect to a number of issues.
- Questions and concerns about the size and quality of regrowth logs. The need to foster greater uptake of lower grade logs from the forest was acknowledged by a number of parties. Many suggestions were made with regard to minimising waste and maximising recovery.
- The importance of security and stability for the timber industry and planners.
- The Forest Management Plan needs to clearly document how Ecologically Sustainable Forest Management objectives are to be met, managed for and evaluated.

The Panel is aware that the implications of the recent major changes in forest policy are not yet widely appreciated. There are major ramifications for the timber industry yet to be grappled with. Some effort will be required during the development of the next Forest Management Plan to increase public understanding of some of the issues associated with the withdrawal of substantial areas of forest from sustained yield calculations.

Recommendation 2.1
As part of the process involved in preparing the next Forest Management Plan, the Conservation Commission should ensure that recent changes in Government policy, the principles of Ecologically Sustainable Forest Management, and the key elements supporting the planning process and calculation of sustained yield, are widely promulgated and understood.

3 CALCULATING SUSTAINED YIELD

3.1 Introduction

Native forests, totalling approximately 2.42[4] million hectares, are vested in the Conservation Commission of Western Australia and managed by CALM. The Forest Products Commission manages commercial logging, thinning and associated regeneration and protection activities. Logging is only permitted on that portion identified for multiple use purposes in State Forest and Timber Reserves. About 36% of the public land managed by CALM within the Regional Forest Agreement boundaries (or 45% of the native forest managed by CALM) is available for logging. A sustained yield of sawlogs is derived from these areas.

To preface the more technical review of the calculation of sustained yield, a more general commentary may be useful. In Chapter 1, sustained yield was defined to be the capacity to maintain relatively consistent levels of production or products over an extended period. One way of approaching that would be to measure growth over the entire forest available for wood production and to set the sustained yield at that level. But that presumes that the forest is everywhere in an ideal condition to provide that level of production. In places it carries too few standing trees and in places too many, reflecting the chequered history of human and natural disturbances. Hence it is necessary to take account both of the growth and the current inventory of standing trees.

Various reports in and subsequent to the Regional Forest Agreement process[5] have provided detailed descriptions of the methods used in calculating sustained yield. They identify the steps in the calculation of sustained yield as:

- identifying net areas;
- estimating standing sawlog volume;
- predicting future growth or volume;
- modelling potential wood flows to calculate sustained yield;

The following sections provide brief abstracts of these steps involved in the calculation of sustained yield updated, where necessary, to reflect more recent changes. These sections focus on what the Panel believes are the key estimates in the calculation of sustained yield, the hazards to them and their likelihood, and the risks and recommended responses to those risks.

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[4] The area of native forest (as at December 2000) within the Regional Forest Agreement and vested in the Conservation Commission of WA was:

Public land within the RFA boundary	2.42 million ha
Public land managed by CALM	2.35 million ha
Native forest managed by CALM	1.91 million ha
Native forest available for timber prodn.	0.856 million ha

[5] Turner, B.J., 1998. *An Appraisal of Methods and Data used by CALM to Estimate Wood Resource Yields for the South-West RFA Region of Western Australia.* Cwlth & WA RFA Steering Committee. 36pp.; Ferguson et al (1997, Assessment of Ecologically Sustainable Forest Management in the South-West Forest Region of Western Australia: Report of the Independent Expert Advisory Group. Commonwealth and Western Australian Regional Forest Agreement (RFA) Steering Committee, Bentley, 119pp.; Turner, B., Ferguson, I. and Fitzpatrick, N., 1999. *Report By The Expert Panel On The Calculation of a Sustainable Sawlog Yield for the Jarrah and Karri Forests of WA.* Cwlth & WA RFA Steering Committee. 16pp.; Ferguson *et al.*,1999. *op. cit.*

3.2 Identifying net areas

The term 'net areas' refers to the areas of publicly-owned native forest on which timber production is a permitted activity, i.e. the gross areas **minus** all those areas of reservations and other exclusions in which timber production is not permitted.

The net areas available for wood production represent key variables in the calculation of sustained yield. Using a Geographic Information System, the net areas are derived by superimposing known reserves and exclusions, such as the prescribed buffers on streams, on a map showing roads, rivers, streams and property boundaries. Additional information on forest types is derived from interpretation of aerial photography, followed by field checking, and is of quite high accuracy by world standards.

The interpretation includes detailed delineation of strata by species mixtures (e.g. jarrah, jarrah-marri, karri, karri-marri, karri-marri-jarrah, etc) and broad height classes. The species mixtures are broadly reliable but cannot be expected to be highly accurate locally in the more subtle distinctions (e.g. jarrah vs jarrah-marri, karri-marri, vs karri-marri-jarrah, etc) given the difficulty of identifying these and the variability inherent in these forest types. From the viewpoint of the sustained yield, these finer distinctions between species are of lesser concern if the field inventory system adequately and representatively sample the strata, because the overall species composition is then adequately reflected in the data for the stratum concerned. Some 600 strata are recognised in the jarrah forest, based on tenure, region, rainfall, height, history of cutting, current structure and whether or not mined. Within each stratum, there is further subdivision into six silvicultural classes (called cohorts) – thinned, gap creation, shelterwood, temporary exclusion areas, selective logging and dieback. Some 80 strata are recognised in the karri forest based on species mix and cutting history, together with four silvicultural classes – three site quality levels and a fourth of predominantly senescent forest. Wherever boundaries can be clearly identified, either from cadastral data or photo-interpretation, net areas can be calculated accurately.

Low volume patch identification

The difficulty of identifying patches of forest, generally of less than 1.5 ha in extent, that do not carry sufficient volume to be harvested economically, poses a hazard to the calculation of sustained yield. Considerable progress has been made in recent months to identify patches that are too small to harvest but which in aggregate contain significant volumes of timber. These areas are removed from consideration as volume available for harvest or deferred for later harvest when adjacent larger patches of regrowth or other species are to be logged. Similarly, areas that are artefacts of mismatching databases have been identified and corrected.

There are however relatively large patches of forest in some areas that contain marginal volumes in terms of economic harvest. These are often difficult to determine with precision well into the future because operational and economic constraints may change over time. Estimates of these areas are made on the basis of past harvesting data and applied as percentage reduction in available resources, or mapped by specific surveys and removed from the resource base as a mapped unit. The residual risk to yield estimation is low provided that harvested areas are monitored and adjustment to databases maintained. Related issues of local and site-specific reservations and temporary exclusions are discussed in Section 3.5.

3.3 Estimating standing sawlog volume

Jarrah inventory

In the jarrah forest, initial estimates of standing sawlog volume for a stratum are derived from the product of the net area of a particular stratum times the average volume per hectare derived from periodic field sampling with temporary inventory plots. The estimates of standing volume are by far the most critical data in the calculation of sustained yield because the existing jarrah forest is slow-growing. CALM currently has a well developed system of field inventory in the jarrah forest based on 26,830 photo plots and over 2,900 field plots which is capable of producing resource estimates of standing volumes with a precision adequate for the calculation of sustained yield, assuming current standards of utilisation prevail. A key feature of the inventory system is the complete measurement and description of sample trees to enable reprocessing of the datasets as product or utilisation specifications vary. Changes in utilisation standard can be analysed, if required.

However, the Panel has noted that for a variety of reasons, the application of jarrah silvicultural systems over broad areas of a stratum will vary in places from the planned silvicultural prescriptions for the stratum, and therefore may result in either more or less volume per hectare being removed than was anticipated. While this poses a low likelihood hazard to the inventory, it suggests that attempts should be made to refine the stratification for silvicultural and later growth prediction purposes (see Section 3.3). The residual risk is low because small continuing biases in the volume per hectare removed principally impact on the cutting cycle and affect the sustained yield very little.

Recommendation 3.1, Jarrah Stratification
Progressive improvement of jarrah stratification for silvicultural and growth prediction purposes should be initiated during the next Plan period. This work needs to be closely integrated with a later recommendation on jarrah growth models.

Karri inventory and utilisation standards

In the karri forests, the inventory system used for mature forest is not appropriate to the utilisation of regrowth forest, whose use will rapidly accelerate in the light of recent policy changes introduced by the current Government.

The large increase in reservation of old growth and other forest in Western Australia not only results in a large reduction in yield but also a dramatic increase in the reliance on smaller karri logs after 2003. The result is that a much higher proportion of the sawlog supply will be in logs at the low end of or below the current specification. Not only is there a lower recovery of sawn product from small logs, but they do not produce the same range of products that is possible from larger logs. Size and quality are also strongly associated; more defect being tolerable in a large log than in a small one for the economic recovery of sawn timber.

Unlike jarrah, changes in karri log size and quality will be sudden and substantial. The likelihood of this hazard is therefore high. Because sawlog utilisation standards are to some extent unknown, because of the very different technology and economic conditions pertaining, the inventory needs to be designed to permit continuous review of the changing utilisation standards, especially with respect to size. This highlights that the risk is high.

The marked change in the size of karri sawlogs after 2003 poses an immediate and significant hazard in estimating the proportion of the total future yield of karri that will be accepted as sawlogs. These logs will not only be smaller but a greater proportion may be affected by defect associated with borer activity (see Section 4.2). The new utilisation

standards will not be known in time for the current revision of the Plan. A conservative approach to calculating yield should therefore be adopted in current revision of the Plan, until more experience has been gained with the utilisation of small logs and realistic specifications can be confirmed. The risk to the sustained yield calculation of log volume is not high because the stratification and inventory of the regrowth component can reliably estimate total log volumes and product assortments within them to current specifications. For example, the same log assortment processing routines as used in the jarrah inventory have been adapted for use in estimating regrowth karri log size and quality assortments.

Recommendation 3.2, Karri Inventory and Utilisation

(1) The karri inventory should continue to be adapted to handle changing utilisation standards in log recovery, especially with respect to size and quality, during the next Plan period.

(2) The current revision of the Plan should take a conservative approach in the estimation of karri sustained yield based on current standards of small log utilisation.

(3) Research on the utilisation of small karri logs should be initiated as soon as possible.

Jarrah utilisation standards

In jarrah, the shift to smaller and/or poorer quality sawlogs will be more gradual reflecting the progressive tightening of supply of larger logs and utilisation of regrowth logs following the cessation of logging old growth and the additional reservation of jarrah forest introduced by the current Government. The direction of the risk in jarrah is more favourable in that utilisation standards are more likely to embrace somewhat smaller and poorer grades of logs in the future. This reflects the more diverse markets for jarrah furniture and appearance grades of relatively short length. Thus the residual risk to the calculated sustained yield is low, because the changes are more likely to increase the standing volume and hence the sustained yield.

Monitoring utilisation is a critical step in volume estimation. The feedback from these data is used to adjust estimates and can have a significant impact on the estimated volume available. Monitoring is particularly complex where partial cutting is involved, as in the jarrah forest, because it is not possible to simply compare total volume removed with total volume estimated on a whole coupe. Comparison can only be achieved by detailed post-harvest field sampling. There is a need to ensure that this monitoring is adequately resourced. In addition to continued monitoring, research is needed in the next Plan period on the best forms of utilisation and technologies for processing smaller and lower grade jarrah.

Recommendation 3.3, Jarrah Utilisation

During the next Plan period:

(1) monitoring of the actual utilisation of jarrah log sizes and grades should be maintained and used in adjusting volumes in coupes to be logged on the simulation of wood flows.

(2) research on the utilisation and technologies for processing smaller and lower grade jarrah logs should be pursued.

Jarrah silvicultural guidelines

The jarrah silvicultural system currently in use was approved for application by the Minister for Environment in 1992 on a trial basis, subject to review. The guidelines include gap creation, shelterwood and thinning. Following CALM's major Progress and Compliance Report of December 1997, the Environmental Protection Authority (EPA) Bulletin 912 of November 1998 provided advice to the Minister for the Environment in relation to compliance with Ministerial Conditions attached to the Forest Management Plan.

The EPA raised concerns regarding a number of issues in relation to Condition 11 relating to:

- the Kingston forest ecology research not having been carried out on a representative range of sites;
- information on the success of establishment and release of regeneration.

The report by Mr Michael Codd (January 1999) noted that CALM had submitted a report to the Minister recommending approval of requirements for Condition 11. CALM's report focussed on using the proposed Forestcheck monitoring system to provide compliance with this Condition. The EPA was to provide advice to the Minister within three months regarding CALM's proposal. The EPA advised the Minister in August 1999 that a determination should not be made until the issue is referred to the Forest Monitoring and Research Committee. However, this committee has been inactive and the issue remains unresolved.

CALM must report to the Minister for the Environment on the outcomes of the implementation of the silvicultural prescriptions and on monitoring and any modifications required by 2002 as part of the Ministerial Condition 11 in preparation for revision of the Plan.

CALM must also report on Ministerial Condition 12 on phased logging and its impact on salinity and Ministerial Condition 16 on catchments of high salt risk. While it would be unproductive and contrary to the legislation to vary these requirements at this stage, responses to Ministerial Conditions tend to be somewhat arcane and may not be helpful in informing the public. The Panel believes that there is public concern about three key elements of the silvicultural guidelines relating to:

- regeneration adequacy, including methods of assessment;
- salinity constraints for silvicultural prescriptions;
- habitat provision for the maintenance of biodiversity and ecological processes including the outcomes of the forest ecology study in the Kingston area.

The Panel therefore believes that CALM should complete its responses to the Ministerial Conditions as soon as possible. The Conservation Commission should then provide, as a matter of urgency, a more integrative review of silvicultural guidelines with respect to the three key elements listed above. The aim of this review should be to inform the public to facilitate the revision of the Plan, including the likely impacts on sustained yield.

Given the time available and the need for wide circulation, the Panel recognises that this review will require resources beyond those immediately available to the Conservation Commission. However it believes this is one of several critical elements in the current revision of the Plan that the Conservation Commission needs to lead and promote.

A review of this scope and complexity will address a number of hazards that collectively have a moderate to high likelihood, and risk of impacting on the calculation of sustained yield. Given the short period of time available to complete this review, some matters will not be capable of final resolution, and the review should also indicate monitoring and research needs and priorities needing to be implemented in the next Plan period.

Recommendation 3.4, Jarrah Silviculture

(1) The Conservation Commission should, as a matter of urgency, and following the completion of the CALM reports on the Ministerial Conditions, prepare a review of the silvicultural guidelines with respect to regeneration adequacy, salinity constraints, and habitat considerations to inform decision in the current revision of the Plan.

(2) The review should also indicate monitoring and research, priorities and funding needed in the next Plan period.

Allowances for habitat trees are factored into the calculation of yield by applying the retention rate specifications in silvicultural guidelines to stand tables used in yield prediction. If retention rates were modified as a result of this review, the specifications and allowances applied to stand tables would need to change.

Regeneration on some jarrah-marri sites (especially in the south) often initially favours marri, resulting in the dominance of marri in the earlier stages of stand development, though this balance may shift with age[6]. The species have different growth rates, and different commercial uses. Silvicultural intervention by way of early 'crown release' and by thinning can be used to alter subsequent stand composition.

Early non-commercial 'crown release' has the potential to improve jarrah dominance in these stands but has yet to be evaluated because there are few stands of suitable age available. This should be done in the next Plan period.

The economic viability of thinning in marri-dominated stands depends on markets for small marri logs. At present chipwood is the only market for these logs. The importance of encouraging the continuation of markets for thinnings from silvicultural operations is discussed elsewhere in this report.

There is a low likelihood of this hazard and a low residual risk that future sawlog availability will be predicted less precisely than is desirable, if some areas of jarrah-marri forest change composition towards more marri. Nevertheless, yield predictions for jarrah-marri forest should consider this possibility, and sensitivity analyses should be conducted in calculating the sustained yield in the current revision of the Plan.

Recommendation 3.5, Jarrah-Marri
Calculations of sustained yield for jarrah-marri forest in the current revision of the Plan should determine the sensitivity of the yield to the possible lack of commercial thinning opportunities.

Marri sawlog utilisation

The changes in reservation in the southern forests have significantly affected the yield for marri sawlogs. The Ministerial Advisory Group Report on karri and tingle management[7] noted the difficulties in assessing the sawlog volume in standing marri without destructive sampling. By far the greater amount of potential marri sawlog was located in recent reservations in the Southern Region. In the Swan and Central Regions, marri is much more affected by fire and other factors and prolific kino veins and water shakes are much more common in these regions. Only a minute fraction of standing marri from favourable sites in these regions is likely to be suitable for sawlogs. While some marri sawlog will still be available from cut-over southern forests, the Panel believes that this will be negligible in terms of its contribution to the overall sustained yield. It therefore recommends that the yield of marri sawlogs should not be formally considered in the current revision of the Plan but monitoring of, and research on, the utilisation of marri sawlogs should continue.

Blackbutt and wandoo represent similar issues with respect to the calculation of sustained yield – both being in such small volumes that they are negligible in relation to the calculation of sustained yield for individual regions or the whole forest.

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[6] Stoneman, G. L., Rose, P. W. and Borg, H. 1988. *Recovery of forest density after intensive logging in the Southern Forest of Western Australia.* Department of Conservation and Land Management Technical Report No 19.
[7] Ferguson *et al.*, 1999. *op. cit.*

Recommendation 3.6, Marri Sawlogs
Calculation of the sustained yield of marri sawlogs should not be formally considered in the current revision of the Plan but monitoring of, and research on, the utilisation of marri and other minor species sawlogs should continue.

3.4 Determining future growth or volume

Jarrah growth models

Future volume is based on a model of predicted standing volume over time varied according to the strata and its silvicultural history. The yield at each harvest is based on a nominated silvicultural practice (e.g. thinning, partial harvest, clear fell etc) at a particular time. No growth is attributed to mature jarrah (over 200 years) or karri forest (over 100 years). Jarrah forests are covered by a series of growth plots and the system of establishment, research and re-measurement are generally appropriate.

The reliability of the wood flow estimates is heavily dependent on the predictions of harvest yields per hectare in terms of timing as well as level. These estimates are derived from a combination of standing inventory, growth plot data, yield models, feedback from harvest records, utilisation monitoring and expert judgement. As noted earlier, there is a need for more growth data to inform this process, especially relating to current jarrah silviculture. However growth plots can never be expected to represent every variant in site and structure and will always lag behind current silvicultural practice. Nor does growth directly equate to yield. For these reasons a combination of data sources will always be necessary to arrive at yield estimates. The transparency of the present system is a valuable feature in this respect.

Predictions of standing volumes and yields for karri have a relatively high degree of precision. Jarrah forest, which has a more complex structure and to which more complex silviculture is applied, has lower precision. Because of its complexity and the more variable site-by-site silviculture that is applied, there are realistic limits to the precision that may be achieved by modelling. Continuous monitoring, maintenance of databases and regular reviews of yield predictions (at least every 10 years) represent an important safeguard.

The hazards, risks and recommendations are similar to those of Section 3.3. The Panel draws attention to similar recommendations in recent reports[8] that new growth models are required for a wider array of silviculture and sites. Research on new growth models reflecting a wider array of silviculture and sites should be initiated in the next Plan period, closely integrating that process with the corresponding recommendation on jarrah inventory, and maintaining transparency of the models used.

Recommendation 3.7, Jarrah Growth
Research on new jarrah growth models reflecting a wider array of silviculture and sites should be initiated in the next Plan period, closely integrating that process with the corresponding recommendation on jarrah inventory, and maintaining transparency of the models used.

Karri growth models

In purer karri forest, reliable growth models exist for clear-felling systems and take account of variations in site productivity. Continued monitoring of and adjustment to growth models will be required to incorporate new data and take account of the effect of initial stocking on

[8] Turner, 1998; Ferguson *et al.*1997; and Turner *et al* 1999, *op. cit.*

the growth and clear bole development of karri. Although the likelihood of hazard to the karri sustained yield in currently low, the rapid acceleration of harvesting in the regrowth forest after 2003 will increase the hazard to high by the end of the next Plan period, and the risk correspondingly. Further research is needed to improve the growth models in the second half of the period of the Plan.

Recommendation 3.8, Karri Growth
Further research should be pursued to improve the karri growth models in the second half of the period of the Plan.

Fire allowances

Both prescribed fire and wildfire can impact on log quality and sustained yield in a number of ways and represent hazards to future sawlog volume, especially in karri. Planning and fire management operations aim to minimise extent of fires by keeping strategic areas at low fuel levels and by maintaining effective fire detection and suppression capability.

A reduction of 0.1% in the area of jarrah forest harvested per year is made in recognition of the average losses incurred in wildfires. This may seem small, but accords with the historical statistics, remembering that jarrah is a hardy species, which may be damaged but is seldom killed by fire. The risk to jarrah from prescribed fire is generally low, as the immediate dependence on regrowth forest is less, and the period of fire sensitivity is largely confined to the first ten to 15 years after regeneration.

Karri is much more fire sensitive, as regrowth stands are vulnerable to low intensity fires until their age exceeds 20 years, and a reduction of 1% of the area harvested per year has been made in the calculation of sustained yield. In view of the increased risk associated with dependence on a more vulnerable regrowth resource, this allowance should be reviewed. The issue of protection of regrowth also needs to be resolved as it is now critical to the future sustainability of the industry. For example, a loss of 2,000 ha (not a large fire) of 20 to 30 year-old regrowth would create a very serious gap in the later capacity to sustain the sawmilling. Few possibilities for salvage of this material currently exist. As in the jarrah forest, decisions will need to be guided by the precautionary principle – in particular, by the risk-weighted consequences of the options.

Because of the vulnerability of the karri regrowth forest, and in light of the uncertainty in institutional arrangements that prevails, the Government needs to ensure that the institutional arrangements between CALM and the Forest Products Commission provide adequately for continuing fire protection of the regrowth karri estate.

Recommendation 3.9, Regrowth Karri Fire Risk
(1) A recalibration of the allowance accorded to the risk of fires relating to the karri regrowth resource should be carried out in the current revision of the Plan.
(2) The Government needs to ensure that the institutional arrangements between CALM and the Forest Products Commission provide adequately for continuing fire protection of the regrowth karri estate as soon as possible.

Bauxite mining sites

Timber removals from bauxite and other mining sites are accounted for in yield estimates based on company plans of mining operations over a five-year period and anticipated operations between five and 25 years. Such sites are identified as mined sites and are subsequently treated as jarrah-regrowth forests. Growth information from rehabilitating forest is collected by companies. After the standard logging allowances have been made for the loss

of area in roads etc, the net areas are carried forward as areas of production forest, with due allowance for the time lag due to mining and completion of regeneration operations. Growth rates and rotation lengths for the rehabilitated forest are the same as the pre-mined productivity classification. Uncertainty surrounds how well growth rates of forests on mined sites mirror those of regenerating natural forest. The likelihood of hazard to the calculation of sustained yield is high given the annual areas involved and the long-term extent of mining. The recommended response is to institute a program of comparing growth rates and net area estimates on rehabilitated mining sites with those used in yield calculations during the next period of the Plan.

Recommendation 3.10, Rehabilitated Mining Sites
Research should be undertaken comparing growth rates and net area estimates on rehabilitated mining sites with those used in yield calculations during the next period of the Plan.

3.5 Modelling potential wood flows to determine sustained yield

The system used by CALM to predict wood flows into the future is based on a simulation process. The forest is divided up into different strata; a silvicultural and harvest regime is determined for each stratum; and the yield at each simulated harvest is estimated. The summation of these simulated yields over all the strata provides the predicted wood flow over time. Different regimes can be applied to all or part a stratum to generate different wood flows. A major advantage of this system is that the assumptions are transparent and yields are based on silvicultural prescriptions and experience rather than on theoretical growth rates. This reduces the risk of calculating unrealistic yield estimates.

An array of areas is excluded from harvesting within the areas available for timber production, in order to protect other values. They include at the landscape level:

- retention of patches of mature karri forest at least every 400m – *biodiversity conservation*;
- travel route zones – *landscape aesthetics*;
- stream buffer zones – *turbidity, salinity, conservation and aesthetics*.

And at the coupe level:

- maximum specified gap size (jarrah 10 ha, karri 40 ha) reducing in sensitive landscape zones – *landscape aesthetics*;
- reservation of areas to protect rare and endangered species – *flora and fauna conservation*.

In addition to area reservation there are permanent reservation of some individual trees (habitat trees) and temporary reservation that impacts on wood flow over time:

- retention of habitat and potential habitat trees – *fauna conservation* (permanent reservation);
- limitation on intensity and timing of harvest in salt sensitive zones at second order catchment scale – *salinity protection*;
- retention of overwood while regeneration establishes – *landscape aesthetics, timber production, conservation*;
- temporary exclusion zones to protect fire sensitive regeneration – *productivity*;
- retention of temporary buffers where required – *landscape aesthetics*.

These elements are not intended to operate in isolation but to complement each other in protecting non-wood values. Taken together with the conservation reserves (both outside and

within State forest) in which timber production is excluded, they provide a comprehensive and integrated system.

Different simulation models are used for jarrah and karri forests. These have been reviewed in recent reports[9]. Both models have been substantially upgraded since these reports and the Panel is satisfied that they are appropriate for the purpose and represent a high standard of practice.

Rotations

Rotation length is a fundamental variable in the calculation of sustained yield.

In the current Plan the predominant rotation lengths are 200 and 100 years, although they range from to 100 to 220 years and 60 to 250 years for jarrah and karri respectively[10], reflecting the constraints set by the current structural goals. The 200 and 100-year rotations were used or scheduled to be used on about 85 to 90% of the respective areas of jarrah and karri forest.

Increased reservation resulting from new government policies means that structural goals are less constraining at the whole of forest level, though not necessarily at the landscape level, enabling consideration of a wider application of shorter rotation lengths. While major changes in rotation lengths would not be desirable, because of their impact on other forest values, the wider use of shorter rotation, not exceeding 25 years less than the current predominant rotation lengths for both jarrah and karri may be acceptable to other values. The Panel therefore recommends that the current revision of the Plan should explore a greater variation around the present predominant rotation lengths for jarrah and karri, and evaluate the consequent impacts on yield and Ecologically Sustainable Forest Management. This represents another critical element in the revision of the Plan.

Recommendation 3.11, Shorter Rotations
The wider use of shorter rotation lengths for jarrah and karri respectively should be explored, and the consequent impacts on yield and Ecologically Sustainable Forest Management evaluated during the current revision of the Plan.

Structural goals

Structural goals are an important element of the current Forest Management Plan. Consideration of structural goals and how such goals are to be accommodated across the whole forest estate for biodiversity purposes will be an important element of the new Plan. These goals are used to help maintain and ensure appropriate forest structures in terms of the mix of age or size classes The next step in the development of structural goals is their refinement to the landscape level. Specific structural goals represent a direct approach to maintaining a full suite of age and structurally related values, rather than attempting to achieve them using sustained yield as a mechanism, and are therefore an important means to managing biodiversity (among other values) over a rotation. Structural goals are also useful in balancing the structural attributes between those found in the reserve system and those in production forests. In terms of whole-of-forest structural goals, recent additions to the reserve system have increased the relative proportions of the mature and senescent growth stages.

Examples of values affected by these goals include the mix of habitat and ecosystem attributes associated with maintaining particular flora and fauna populations. At a more

[9] Turner, 1998; Turner *et al.*,1999; and in broader aspects by Ferguson *et al.*,1998 and 1999. *op. cit.*
[10] Turner *et al.*, 1999. *op. cit.*

detailed level, trees that are important as nest and refuge resources for hollow-dependent fauna provide another example. It is important to plan for a suitable configuration and pattern of hollow-bearing trees across the production forest to help manage biodiversity values and ecosystem processes across the whole forest estate. CALM has the information and systems to predict, manage and plan for hollow-bearing trees in both space and time.

Recommendation 3.12, Structural Goals
Specific objectives need to be formulated in the current revision of the Plan for appropriate forest structures in terms of the mix of age or size classes and their spatial distribution across the whole forest, together with the structural goals that must then be applied in the calculation of sustained yield.

Allowances for local reservations and exclusions

Future sites of reservations or temporary exclusions in areas not yet harvested cannot always be identified geographically. Allowances therefore have to be made. In some cases, the simulation models incorporate ingenious and realistic simulations of the spatial constraints for areas that are scheduled to be harvested in the future. Examples include recognition of stream buffers, maximum gap size, temporary exclusion zones to protect karri regeneration, and reservation of patches of mature karri and linking corridors. The Panel commends this work which, by any standard, is state-of-the-art.

Exclusions for dieback are discussed in Chapter 4. Other exclusions such as those to protect locally rare and endangered species, or local visual amenity zones[11] are virtually impossible to predict geographically much in advance of pre-logging survey and harvesting. They are therefore addressed by making a reduction in net area or sustained yield, based on past experience. These are hazards of relatively low likelihood, and widespread but low risk. The allowances can only be improved by monitoring of experience on logged coupes of similar character and applying that experience to make similar allowances for future reductions in yield, as is currently done. Monitoring of logged coupes with respect to the areas of local reservation and temporary exclusions should be maintained to refine allowances.

Recommendation 3.13, Allowances for Local Reservations and Exclusions
Monitoring of logged coupes with respect to the areas of local reservation and temporary exclusions should be maintained to refine allowances in the calculation of sustained yield during the next Plan period.

Local reservation and exclusion trade-offs

When considering harvesting of a particular coupe, local interests are often affected. For example, existing processes require areas of visual amenity to be identified and managed under protocols defined by professional landscape architects. Trade-offs are inevitably involved in consideration of such areas. The trade-offs have to weigh the social net benefit foregone to the community as a whole from the loss or modification of logging against the social net benefit accruing to the individual and/or local community. Often the precautionary principle will apply, since there may be no clear answer in the weighing of benefits but the logging can be deferred, perhaps for many years, without major immediate impact. However, deferral may involve some impact on the calculation of sustained yield. The problem is then what allowance to make for the likelihood that the area may be available for harvesting at a much later date or alternatively may not be available at all. The assumption of equal probabilities would seem appropriate, so the allowance would then be based on the future availability of half the area or future volume concerned. The recommended response is

[11] Ferguson *et al.*, 1999, *op. cit.*

contingent on the previous item and involves, in the case of local visual management exclusions, making an allowance equivalent to half of the expected area being available for harvesting at a later cutting cycle.

Research should also be undertaken to develop suitably controlled variations to the rules concerning other exclusions and reservations. These are areas in which trade-offs between values can be exercised, given transparency and suitable safeguards, to the benefit of all values. The residual risks are low. The recommended response requires research to value the social net benefits and the effective processes to be used in making trade-offs during the next Plan period.

Recommendation 3.14, Local Reservation and Exclusion Trade-offs
Research should be pursued to value the social net benefits and to determine effective processes for making trade-offs in local exclusions and reservations during the next Plan period.

Supplementary scheduling models

Earlier reports[12] recommended the adoption of the linear programming SPECTRUM model as a supplement to the existing simulation models. The reports pointed out the benefits in being able to test other alternatives more rapidly and to 'smooth' the yield outputs but acknowledged its hazards in terms of reduced transparency that increases the difficulties of understanding the underlying assumptions.

The present Panel agrees that the use of supplementary systems for scheduling wood flows should be pursued during the period of the next Forest Management Plan. This will also require greater effort in the collection of data on non-timber values for use in these models (see also discussion of whole-of-forest issues in Chapter 4). Embarking on a shift to such an advanced scheduling system, with its attendant workload, would not be practicable within the current revision of the Forest Management Plan.

Recommendation 3.15, Supplementary Scheduling
Supplementary scheduling of wood flows should be examined and pursued, if practicable, though the use of more advanced systems during the next Plan period.

3.6 Overview

While there are no components of this process that the Panel perceives to have significant hazards beyond those elements already alluded to, each component discussed in previous sections lends itself to continued refinement and improvement. The priorities for the further development of these different components should be gauged by the contribution they make to yield at critical times in the future, as informed by sensitivity analysis.

These priorities will change from time to time. For example the recommendation to revise the mature karri inventory[13] is no longer relevant because of recent changes to Government policy. The almost total dependence on regrowth beyond 2003 has now shifted the emphasis to regrowth yield models for karri. Sufficient new growth data has accumulated to justify a further revision of these models, as earlier recommended.

The intimate link between silviculture and yield is often overlooked when policy changes to silviculture or yield are proposed. Yield estimates should be re-calculated whenever changes

[12] Turner, 1998; Turner *et al.*, 1999. *op. cit.*
[13] Turner, 1998; *op. cit.*

to silviculture are proposed so that changes to the yield are included in the evaluation of the proposal.

Staff training and resources

The success of these systems depends on maintaining the necessary monitoring and databases, and enhancing the models for each of the components. The resources and staff to develop and maintain these systems are more or less independent of the level of harvest.

As noted earlier, yield estimates are based on the presumption that silvicultural practices match the prescriptions. However, such departures do not arise solely from inadequacies in the modelling system. Changes in responsibilities resulting from the creation of the Forest Products Commission and the present limited silvicultural expertise in CALM, represents a potential risk to the appropriate development and application of silviculture. The reduced size of the industry beyond 2003 may exacerbate this problem. The greatest hazard to continued improvement in these areas is the likelihood of reduced income from sales of wood and consequent possible loss of the funding and staffing in the new administrative structures. The risk is high. CALM should commit to the maintenance of staff training and expertise in silviculture through the provision of adequate resources. This is a project requiring additional resources.

Recommendation 3.16, Staff Training and Resources
CALM should commit to the maintenance of staff training and expertise in silviculture through the provision of adequate resources and delineation of responsibilities during the next period of the Plan.

Residue-utilisation in karri

Current sawlog yield estimates for karri assume that a market for woodchip or other non-sawlog residue will exist to facilitate regeneration of two-tiered stands and thinning of regrowth stands. The continuation of a residue market to facilitate karri thinning is of particular importance and the likelihood of hazard is high. Without such an industry, sawlog-thinning yields will be delayed and the total sawlog yield will be dramatically reduced. If the Government wishes to maintain a karri sawlog industry, then it needs to actively develop residue-using industries if it wishes to avoid a high risk of failure of the sawn karri industry. The Government should encourage industries to utilise the residues from thinnings in regrowth karri forests during the next Plan period.

Recommendation 3.17, Karri Residue Utilisation
The Government should encourage industries that utilise the residues from thinnings in regrowth forests during the next Plan period.

Log grades

Sustained yield is currently expressed as the combined yield of Grade 1 and 2 sawlogs. However, log sales are based on separate contracts for each grade. If the ratio of Grade 1 to Grade 2 in log sales is more than that calculated in the estimated long-term yield flows, there is a risk that the harvest will exceed that which was intended, while still appearing to be within the permitted level. Similar results will occur if the harvested areas contain a lower than average proportion of Grade 1 logs.

Consideration should be given to altering the relative royalties of Grades 1 and 2 so that to make sawmillers and loggers indifferent to different grades and to writing contracts in terms of the combined volumes of Grade 1 and 2 sawlogs.

The volumes of lower grade material are capable of prediction by the current system of scheduling wood flows with the same precision and rigour as higher grades. However, such estimates are potentially valuable for policy makers in the light of the reduction in the cut of Grade 1 and 2 sawlogs. If there are unwanted impacts from the amount of material removed under such a system, these should be controlled through the silvicultural guidelines.

Recommendation 3.18, Sawlog Prices and Contracts
During the next Plan period, the prices of Grade 1 and 2 sawlogs and corresponding logging contract rates should be examined to remove the present biases that favour the use of Grade 1 logs. Renegotiation of contracts should move toward sale of the combined volumes of Grade 1 and 2 in keeping with the basis for sustained yield.

Whole bole logging

As mooted in clause 77 of the Regional Forest Agreement, the Forest Products Commission is examining a possible change to log sales based on a 'whole bole' system, in which the entire bole is sold and transported to a central log yard or the sawmill, where the purchaser should be in a better position to make the best use of that bole. Recent trials of a modified system seem promising and place less of the risk on the purchaser, by allowing some docking in the forest. The system has the potential to reduce forest residues and reduce log-grading costs. Trials so far have involved the removal of the whole bole of trees that contain sawlogs.

Whatever the virtues of using such a system for improving the utilisation of the resource, very careful consideration would be required before it could be used as a basis for yield regulation. Should the Forest Products Commission wish to proceed with using the system for yield regulation, it will be critical to demonstrate that it provides a better approach than the present system that is based on product yield. If introduced, a dual track (new and old) system of calculating sustained yield would need to be used, so that transparency between the old and new outcomes can be maintained. Collaborative trials with the industry should be continued to 2002, at which time the decision to pursue this system should be taken. If implemented, a dual-track basis should be used and reported during the period of the Plan, with a review regarding its exclusive adoption thereafter.

Recommendation 3.19, Whole Bole Logging
(1) Collaborative trials with the industry of 'whole bole' logging should be continued to 2002.
(2) A decision to pursue this system should be taken as part of the current revision of the Plan.
(3) If implemented, a dual track basis should be used and reported during the period of the Plan, with a review regarding its exclusive adoption thereafter.

4 OTHER ISSUES AND VALUES

A number of diverse issues and hazards, as well as other forest values, potentially affect the calculation of sustained yield. They include:

- 'Whole of forest' issues
- Fire
- Diseases and pests
- Climate change
- Mining
- Socio-economic values
- Water values
- Heritage values
- Biodiversity values

In preparing the preceding chapter, the Panel found itself repeatedly referring to the need for a 'whole of forest' approach in relation to the hazards, especially with respect to the impact on associated non-wood values and hence this chapter commences with this issue. The direct impact of hazards such as fire and diseases and pests on site productivity, timber quality and the like has generally been addressed through the processes described in the previous chapter to estimate the net areas available for timber production, the product volumes, the future growth and product volumes, and the predicted wood flows to determine sustained yield. But timber values are neither the sole nor necessarily the pre-eminent values that these forests supply, even on those areas designated as being available for timber production. Finally, there are indirect impacts on sustained yield stemming from biodiversity, water, heritage, greenhouse or socio-economic values. Trade-offs between timber production and these other values, in some places, may take the form of additional local constraints on timber production. These additional constraints may also lead to further reductions in sustained yield of timber. In some cases, the trade-offs may work in favour of timber production but not in others.

4.1 'Whole of forest' issues

Under Ecologically Sustainable Forest Management, timber production is recognised as only one of a wide range of forest outputs. Sustained yield of timber can only be estimated as part of a system that also considers requirements for other forest functions and outputs. While determination of sustained yield is conventionally founded on an estimate of the net area of productive forests available for timber production, management toward Ecologically Sustainable Forest Management requires closer consideration of the 'yields' of all forest outputs (e.g. biodiversity protection, water yield, recreation and visual amenity) and these relate to the whole of forest.

Some outputs are compatible with timber production while others are not. Yet others are capable of mixture but at some sacrifice to one, or the other, or both uses. So forests are partitioned into reserved (timber harvesting excluded) and production (harvesting permitted) forest for simplicity. Even within the production forest, many important non-timber forest values need to be considered (e.g. biodiversity protection, water yield, recreation, visual amenity). Most of these values (excluding timber) are produced in both the reserved and the production forest. Goals and objectives for the various forest outputs and uses must be set first at a 'whole of forest' level to estimate the different requirements for the reserved and production forest. Explicit setting of these 'whole of forest' goals must be an integral part of the Forest Management Plan development process; it will be important to determine the

respective roles of the reserve system and production forest estate and their interrelationship in meeting non-timber goals and objectives.

A major shortcoming of the present planning system is the lack of specific non-timber objectives, at either the landscape or 'catchment' level in which each of the above elements may be differentially represented, or at the whole of forest level. Landscape level goals inform, for example, the local prescriptions to be applied, possibly differentially, to coupes within the block of local landscape unit. 'Whole of forest goals' inform choices and decisions between different landscape (or catchment) elements. Biodiversity management provides a good example of such a requirement; particularly how populations or communities are preserved locally within the landscape, and how representative reservation is addressed across the whole forest.

In the absence of specific landscape or 'whole of forest' objectives, there are no benchmarks against which to measure success, or to adequately evaluate the trade-offs between conflicting or complementary values. These conflicts may occur not only between wood and non-wood values but between the various non-wood values as well. The development of prescriptions requires specificity in objectives. Tacit assumptions about objectives held by different people are a potential source of on-going conflict. Processes to develop measurable objectives are seen to be an important task of the forthcoming Forest Management Plan.

Two important hazards arise in relation to the calculation of sustained yield. The first is that without explicit targets for important forest outputs, there are no benchmarks to adequately evaluate or seek the most efficient trade-offs between competing values. This would be required to better define any prescription variations needed to accommodate non-timber outputs, or to judge progress toward the achievement of Ecologically Sustainable Forest Management. The resulting risk is in setting inefficient yield levels and thus not achieving the inherent potential in terms of social net benefit. The second hazard relates to unresolved expectations held by stakeholders for the level of outputs of other non-timber values. These lead to risks of future loss of production area during the planning period as new demands are made resulting in changes in timber production priority or reservation.

As a critical part of the development of its sustained timber yield estimate for the 2004 Forest Management Plan, the Conservation Commission should develop processes to determine and communicate both 'whole of forest' and landscape level targets for as many forest outputs as possible. These targets must be effectively communicated to stakeholders both during the development process for the Forest Management Plan as a basis for informed comment, and at its conclusion as a matter of public record.

Arriving at the appropriate integration of objectives will be a fundamental consideration in management planning. The strategic issue of integrating forest use in meeting social, environmental and economic values and services so as to deliver Ecologically Sustainable Forest Management is important. To help guide and inform its delivery, a more comprehensive modelling framework is required to help integrate forest values and goals, as noted earlier.

Recommendation 4.1, Whole of Forest
The Conservation Commission should develop processes to make explicit both 'whole of forest' and landscape level targets for as many forest outputs as possible. These targets must be effectively communicated to stakeholders both during the development process for the Forest Management Plan as a basis for informed comment, and at its conclusion. The Forest Management Plan must take a whole of forest perspective and not focus solely on the areas available for timber production.

4.2 Fire

In Western Australia's Mediterranean climate, fire plays a significant role in the natural process of development and maintenance of forest flora and fauna, and their characteristics. Balancing the often-conflicting requirements of protecting human life and property, wildfire protection, regeneration, wildlife and vegetation management, and air quality control is a demanding issue for forest managers. There are potentially significant risks to all values (including biodiversity, heritage, landscape aesthetic, timber production, water, greenhouse and socio-economic values) from the application of inappropriate fire regimes.

In recent years there has been increasing attention and concern about the impact of fire on biodiversity values. Concerns have been expressed about the scale, intensity, frequency and season of prescribed fire regimes. Concerns have also been expressed (especially by fire brigade members) about fire regimes that result in very long periods between fires, which is the other side of the coin. There is however no dispute that different fire regimes impact on vegetation composition and structure in different ways. Whether these impacts are positive or negative depends on the degree to which they support the management objectives for the area.

The inhabitants of urban areas (most specifically of Perth) have become increasingly intolerant of occasional and short duration bush fire smoke which, when added to industrial and vehicle emissions in these areas, result in highly visible air pollution and hazards to socio-economic values. Despite agreement that may be reached among stakeholders on the need and application of fire for a variety of purposes, the ability to manage fire appropriately is likely to be severely curtailed in the future as a result of continued complaints about its perceived contribution to air pollution, and the reduced resources for fire management stemming from changes in Government policy[14] This may have an adverse impact on the management for biodiversity as well as for other values.

The net effect of the growing number of constraints on the application of prescribed fire has been a decrease in the areas that are burnt by prescribed fire each year and an increase in the area containing heavier fuel loads throughout the forest area. A continuation of this trend will result in more severe wildfires impacting on the forest over the longer term. This may advantage some values (some elements of biodiversity) but disadvantage others (socio-economic values, in terms of possible losses of life and property, and some other biodiversity values).

The diversity of fire history is relatively high throughout the forest as whole. The jarrah and mature karri forest each have more than 20% of their area that has not been burnt for 20 years or more, while 40% of other vegetation is in the same category. However, this variation is not necessarily best located for biodiversity values in a site specific or spatial sense.

CALM has given increasing recognition to the importance of developing fire regimes to suit elements of biodiversity and has attempted to incorporate these into its burning programs taking account of its other fire obligations. The results have not satisfied all sections of the community. In response to this, CALM, in association with the Fire Emergency Services, has initiated a revision of Wildfire Threat Analysis system that gives explicit weightings to a full range of values at risk. This revised system is intended to be used as a decision support tool for both prescribed burning and fire suppression activities across all managed lands and adjacent influence zones.

[14] See Ferguson *et al*, 1999, *op. cit.*

A major shortcoming in the application of fire for vegetation management is the absence of specific management objectives at an appropriate scale. For biodiversity, this is a particular concern in reserved areas that are now a much more significant proportion of the forest estate and where biodiversity values might be expected to have a high priority. Till now there has been a tendency to prescribe a fire regime but without explicit and measurable objectives – for example, without an explicit statement of species or community priorities, the proportion of the area to be maintained in a particular post fire seral stage, or the maintenance of diversity at the landscape level versus the site level. Without agreed objectives at this level there is no way of judging whether fire management practices are appropriate or successful.

Fire is no respecter of lines on maps and it is therefore essential to view these management issues across all forests. Steps should be taken in the development of the new Forest Management Plan to begin addressing the question of explicit management objectives and strategies for all forests at a level that provides meaningful guidance for managers and auditable outcomes. This is a project requiring additional resources during the next Plan period.

Recommendation 4.2, Fire Management

(1) In the current revision of the Plan, the development of specific fire management objectives should be initiated for subsequent completion during the period of the Plan. The Plan should incorporate explicit objectives such as species or community priorities, the proportion of the area maintained in a particular post fire seral stage, regrowth protection or the maintenance of diversity at the landscape level versus the site level.

(2) The revision of the Wildfire Threat Analysis, incorporating consideration of operationally meaningful management objectives and strategies, and communication with the urban electorate and ecological expertise, should be extended to cover all land and ownerships during the next Plan period.

4.2 Diseases and pests

Dieback

Dieback caused by *Phytophthora cinnamomi* represents one of the greatest hazards to ongoing productivity of the jarrah forest in certain areas and to the maintenance of biodiversity. Impact from *P. cinnamomi* varies greatly with soil and hydrological status of sites. Epidemics are also most commonly associated with major summer rainfall events. Disease expression in jarrah tends to be episodic, in some years jarrah mortalities occur at low frequencies in other years mortalities are significant across quite large areas.

As *P. cinnamomi* has the potential to impact over a large area of the forest it is important that adequate allowance is made for its affects on both growth and mortality of jarrah. It may be true that the epidemic has largely run its course in the northern jarrah forest with most high impact sites already degraded by the disease but changes and more long-term insidious effects on growth in the cooler southern forests could occur.

Further review and monitoring of the impacts of *P. cinnamomi* is needed. The extent to which roading and logging and general access is spreading the fungus in different ecosystems should be known. There are areas that have been comprehensively mapped before and after logging, and the results of such mapping should be analysed. The extent and role of waterlogging in jarrah mortality should also be pursued further[15]. If generally applicable, it raises issues for the management of logging with respect to hydrological flows.

[15] Davison, E. M. 1997. *Are jarrah (Eucalyptus marginata) trees killed by Phytophthora cinnamomi or waterlogging.* Australian Forestry 60 (2): 116-124.

Recent changes in dieback policies[16], first initiated in 1996, and related to logging have led to a changes in hygiene prescriptions under some circumstances. Logging in areas deemed to be 'unprotectable' and in buffers around 'protectable' areas may proceed under conditions known to be conducive to spread of the fungus. Seasonal constraints on operations in areas most secure from the fungus and referred to as 'protectable' will not be mandatory, relying on the requirement that operators be clean on entry.

The Environment Protection Authority (EPA) in commenting on the revised policy, has highlighted the need to hasten action on the development and assessment of dieback management strategies. The key points of the Environment Protection Authority (EPA) advice[17] that impinges on the calculation of sustained yield are:

- The EPA endorses the Dieback Review Panel (1996)[18] protocol for identifying 'protectable' areas and their priority for management, on a trial basis for three years.
- That industry, institutions and government agencies jointly address the extent to which operational schedules can be modified to ensure that activity on the protectable areas is focussed on minimising access during conditions which are conducive to dispersal of the pathogen and its establishment.
- A system should be developed to ensure adequate protection is given to high conservation areas. Criteria to define high conservation status areas should be developed as a matter of urgency.
- Losses caused by *Phytophthora cinnamomi* should be estimated in terms of industries affected, the implications of their sustainability be reported on, together with the assumptions underlying the estimates.

The Minister is expected to consider these recommendations shortly.

Currently with regard to the calculation of sustained yield, dieback areas that have not been logged are credited with the standing volumes involved but are not taken into account in predicting future volume beyond the real or simulated time of logging The impact of future infection is not currently taken into account. The Panel believes this hazard of high likelihood and risk should be taken into account by sensitivity testing in the simulation models, assuming variously (a) no spread and (b) the apparent past spread over the last decade for the various strata, or minor modifications thereof. This is a project requiring relatively few additional resources.

Recommendations 4.3, Dieback

(1) The key points of the EPA advice on the Protocol for the identification and prioritisation for the management of *Phytophthora cinnamomi* 'protectable areas' endorsed by the Minister should be implemented as soon as possible.

(2) The impact of future infection should be taken into account by sensitivity testing in the simulation models, assuming variously (a) no spread and (b) the apparent past spread over the last decade for the various strata.

[16] Initiated by Podger, F. D., James, S. H. and Mulcahy, M. J., 1996. *Review of Dieback in Western Australia. Volume 1. Report and Recommendations.* Report by the Western Australian dieback Review Panel to the Hon. Minister for the Environment. Minister for the Environment, Perth.

[17] Environment Protection Authority (2001) Protocol for the identification and prioritisation for management of *phytophthora cinnamomi* 'protectable areas'. Dieback Consultative Council. *EPA Bulletin* 1010.

[18] Podger, *et al.*, 1996. *op cit.*

Honey fungus

Allowance is currently made in simulation models for known areas of induced mortality due to the honey fungus. Patches of mortality are removed from the net area. Areas with scattered mortality are mapped and predicted separately. Areas with widely dispersed mortality are covered by sampling by growth plots. Allowance for the impact on log quality is incorporated in the general reduction made to initial calculated yield for all minor hazards posed by various insects and diseases, including honey fungus, borers, and brown rot.

Armillaria luteobubalina is a naturally occurring organism widespread in jarrah, karri and wandoo forests. This fungal disease primarily infects root systems and stumps and experience in other forests suggests that it may take on greater significance in regrowth forest or areas with a history of repeated selection harvests.

The future impact of *A. luteobubalina* on regrowth karri is of concern because, like other *Armillaria species,* it can impact on regrowth forests causing mortality of trees retained after thinning. A database on incidence and areas of different forest types affected by this pathogen is required. Disease interpreters mapping dieback have collected some records. The control strategy being considered by CALM is to thin using stump-pulling techniques rather than leave a large food base of root and stump material in ground which would favour a build up in inoculum of this straw rotting fungus.

As thinning of regrowth stands proceeds, deaths of retained crop trees should be monitored to enable the allowances for the calculation of sustained yield to be refined. The likelihood of some impact from this fungus after thinning is high but incidence is localised and therefore risk to and impact on timber yield is likely to be low.

Recommendation 4.4, Honey Fungus
Honey fungus mortality and damage arising from thinning operations, especially in karri regrowth operations, should continue to be monitored during the next Plan period to enable allowances to be developed for the future calculation of sustained yield.

Bullseye borer, Cossid moth and brown wood

Reports[19] have drawn attention to the high incidence of decay and borer holes in regrowth karri. The likelihood of significant impact by these agents is moderate and possibly localised in terms of site and climatic conditions. Nevertheless, there is a moderate risk that the proportion of wood recovered from small diameter logs will be lower than expected or that some of the regrowth resource will be downgraded as unacceptable as sawlogs. An appropriate survey should be conducted across the thinnable karri regrowth estate to assess the potential impact on yield and to develop an appropriate allowance during the next Plan period.

Recommendation 4.5, Karri Borers and Rots
An appropriate survey should be conducted across the thinnable karri regrowth estate to assess the potential impact on yield and to develop an appropriate allowance during the next Plan period.

[19] Abbott, I., Smith, R., Williams, M., Voutier, R., 1991. Infestation of regenerated stands of karri (*Eucalyptus diversicolor*) by bullseye borer (*Tryphocaria acanthocera, Cerambycidae*) in Western Australian. *Australian Forestry* **54** pp64-74
and Farr J. D., Dick S. D., Williams M. R., and Wheeler J. B., 2000. Incidence of bullseye borer (*Phoracantha acanthocera,*(Macleay) *Cerambycidae*) in 20-35 year old regrowth karri in the south west of Western Australia. *Australian Forestry* **63** No 2 107-123

Jarrah leafminer and gumleaf skeletonizer

Abbott[20] mapped the extent of jarrah leafminer and gumleaf skeletonizer in the jarrah forest and woodlands of the South West. Currently the jarrah leafminer impacts on forests from the South Coast to the north near Collie. Gumleaf skeletonizer was most prevalent between 1983-89, a major outbreak has not been recorded since and recent work suggests a correlation between below average rainfall and outbreaks. Future outbreaks are to be expected. In the case of jarrah leafminer recent impact also has been less obvious than that observed in the past. Research on factors associated with major infestations is continuing.

It is assumed that both leaf miner and skeletonizer, have and will impact, on trees in the inventory and growth plots and thus their effects on growth will be integrated into models. The residual risk of chronic infestations of leafminer causing reduced growth rate is uncertain but comparison of growth rates in inventory plots known to be infested with leafminer and those without, could assist in quantifying impacts of the leafminer.

Recommendation 4.6, Jarrah Pests
Research should be pursued to compare growth rates in inventory plots known to be infested with leafminer and those without, to assist in quantifying impacts of the leafminer during the next Plan period.

4.4 Climate change and carbon cycle

Maintaining the forest's contribution to the global carbon cycle is the only one of the principles of Ecologically Sustainable Forest Management that has a global context; all others being either explicitly or implicitly applicable at the coupe, region or 'whole of forest' scale. The wording of this principle reflects the desire to protect the world from, or at least reduce the impact of, the Greenhouse Effect caused by increasing concentrations of carbon dioxide, methane and other gases in the upper atmosphere and manifested by climate change, notably but not only by way of increasing ground-level temperatures.

Stakeholder input suggested that the calculation of sustained yield itself should factor in the effects of, or risks of climate change. Their concerns were associated with changes in species densities and distribution, and forest productivity, health and vitality attributed to changing climate. Such change is a very slow process. The growth data used in the simulation models already reflect the effects of past climate change and continued monitoring of growth through remeasurement of permanent plots in jarrah, or stem-analysis in the case of karri, provides an adequate means of ensuring that the impact of climate change is accounted for and that yield is adjusted.

The principal hazard to the carbon cycle is associated with the fire regimes and the uncertainty surrounding their impact or changes to soil carbon changes. The likelihood of this hazard having an impact on, and posing a risk to, the global cycle is currently low for the South West Zone, but the Australia-wide or global implications of this issue do merit research. Research should be pursued on the impact of fire management and logging regimes on the global carbon cycle during the next period of the Plan.

Recommendation 4.7, Carbon Cycle
Research should be pursued on the impact of fire management and logging regimes on the global carbon cycle during the next period of the Plan.

[20] Abbott, I, 1992. Ecological implications of insect pests in jarrah and karri forests. In: Research on the Impact of Forest Management in South West Western Australia. *CALM Occasional Paper* No 2/92 pp 77-97.

4.5 Mining

Of all the future changes to the native forests of the South West Zone, mining constitutes one of the biggest potential hazard because it results in a reduction of the forest area for a long period, and an uncertain future role for the rehabilitated areas following mining, especially for bauxite. Mining for coal is far more restricted in area and impact. This is not to denigrate mining itself, because it clearly contributes to socio-economic values in other ways. Furthermore, bauxite-mining companies are to be applauded for their efforts in rehabilitation, and appear to have succeeded in regenerating jarrah and associated tree and understorey species on former bauxite mining sites. Nevertheless, if Ecologically Sustainable Forest Management is to be taken seriously, there are values associated with productive capacity, biodiversity, and hydrology of rehabilitated sites that warrant attention, as the recommendations of the Ecologically Sustainable Forest Management Panel[21] show.

Greater attention also needs to be paid to the trade-offs between new mining sites and biodiversity values. Notwithstanding the excellent planning, research and rehabilitation that the bauxite mining companies have done, the growing concerns of stakeholders with respect to biodiversity and other conservation values need to be recognised. Given the much greater weight the community is according these values, it should no longer be assumed that mining is pre-eminent in the social net benefit it provides from every viable bauxite reserve. In raising this issue, the Panel is aware that reservation of any areas for biodiversity and other conservation values would actually lead to a reduction in the cut from areas that would otherwise have been clear-felled prior to mining. Thus, in terms of this review, the resolution of these trade-offs is important in relation to calculating the sustained yield. It is most unlikely that all such areas could be so reviewed for the current Plan revision but a process should be initiated to deal progressively with these areas, according to the planned schedule of mining operations. The possibility of more intensive timber management on former bauxite pits should also be examined.

Recommendation 4.8, Bauxite Mining Sites
The Conservation Commission should initiate a formal process for a more detailed examination of areas mooted for bauxite mining with respect to biodiversity conservation and hydrological values and an evaluation of the trade-offs with mining involved.

4.6 Socio-economic values

The Regional Forest Agreement process, through economic and social analysis, established baselines for resource, industry and rural community issues. These analyses explored the contribution of commercially valuable forest ecosystems to regional and State industries, and opportunities to enhance production and the value in using resources. The main approach for analysing social and economic implications was through measuring employment levels, economic value of wood and changes in rural communities associated with forecasted wood supply (sustained yield).

Wood supply levels will be considerably reduced from those presented in the Regional Forest Agreement following implementation of State Government forest policies. The calculated sustained yield in the new Forest Management Plan is likely to be substantially lower than that in the Regional Forest Agreement, as a result of the subsequent increases in reservation. Due consideration, analysis and reporting needs to be given to the likely social and economic impacts particularly in rural communities. To meet the intent of Ecologically Sustainable Forest Management, it is recommended that the Conservation Commission ensure that an independent and robust social impact study be undertaken as part of the current revision of

[21] Ferguson *et al.*, 1998.

the Plan. The Regional Forest Agreement committed the parties to an independent economic and social impact assessment of the draft Forest Management Plan. However, the process to be followed needs to be developed well in advance and it needs to be initiated as soon as possible if it is to contribute adequately to the development of the Plan. This type of study is also needed to provide advice on impacts to State and local government and the public, as reflected in the Conservation and Land Management Act.

Recommendation 4.9, Social Impact Study
An independent and robust social impact study be initiated as soon as possible as part of the current revision of the Plan.

4.7 Water values

Most of the present planning of forest management and silvicultural practices for water quality (mainly salinity) and quantity rests properly on detailed research programs completed in the last 20 years. Equally, most of the on-going efforts in water monitoring in forested catchments are directed towards those catchments where detailed measurements were conducted for many years. Water monitoring by the Water and Rivers Commission in many of these catchments has been suspended or placed on long time reviews because responses to disturbance have slowed.

As a consequence of this work, prescriptions have been developed and progressively modified over a number of years. Essentially forest harvesting and regeneration does not appear to present a problem for water values provided that the following is done:

- buffers of varying width are retained on all streams;
- thinning intensity in the intermediate and low rainfall zones is reduced relative to the high rainfall zone that is comparatively salt free;
- the extent and timing of gap harvesting is limited on the second order catchments;
- phased logging is conducted throughout the intermediate and low rainfall zones;
- additional constraints to harvesting are applied in specifically identified high salt risk sub-catchments.

The Water and Rivers Commission is currently engaged in a review of guidelines and constraints on logging with respect to its possible impact on water quality. It is expected that the results of this will be incorporated in the Forest Management Plan and that monitoring programs be restored in the Swan and Central Regions in consequence of the mining operations in the next ten years.

4.8 Heritage values

There has been increased activity in the identification and classification of natural and many aspects of cultural heritage value during the last decade, with the most recent comprehensive assessment being undertaken as part the Regional Forest Agreement process. The need for some development of the operational and support aspects of the Visual Management System and some further consideration of geo-heritage issues was identified during the Regional Forest Agreement. The major impacts of heritage values in relation to the estimation of sustained timber yield comes through the exclusion of timber harvesting (reduction in net harvestable area), delay in harvesting, or through the application of modified harvesting prescriptions.

The current databases and approaches appear to provide a generally sound basis for modifying the estimated timber yield for the purposes of preparing the next Forest Management Plan. However, both the concepts of natural heritage and the relative

community values of different aspects or examples natural and cultural heritage do change through time.

Recommendation 4.10, Heritage Values
Consultative mechanisms need to be enhanced to ensure that the guidelines for natural and cultural heritage used in forest planning and management are kept in step with changing community values during the next Plan period.

The need for a more effective engagement of indigenous communities in relation to forest management and the impacts of forest management on indigenous communities and their cultural heritage has been identified by several recent forestry enquiries. This is also in line with evolving community attitudes. The results from future engagement with indigenous communities may result in changes to the basis for estimation of sustained yield.

Recommendation 4.11, Indigenous Communities
Specific consultative processes, in addition to those used for general community, should be further developed with the relevant indigenous communities during the development of the next Forest Management Plan to ensure effective input in relation to management proposals that have impacts on indigenous cultural or other interests during the current revision of the Plan.

4.9 Biodiversity values

Maintenance of biodiversity is a fundamental goal of conservation management and is one of the prerequisites for achieving Ecological Sustainable Forest Management. Biodiversity means the variety of all life-forms, the genes they contain, and the ecosystems of which they are a part. Biodiversity has regard to genetic diversity, species diversity and ecosystem diversity. Biodiversity is provided for through a Comprehensive Adequate and Representative (CAR) Reserve System that includes Formal Reserves, CAR Informal Reserves, areas on public land protected through prescriptions and CAR Values protected under secure management arrangements by agreement with private landholders.

Together, the Expert Advisory Group[22] report and Regional Forest Agreement[23] document the Forest Management System applying to the biodiversity principle. The following commitments in the Regional Forest Agreement directly or indirectly affect consideration of biodiversity in the context of sustained yield:

- management and recovery of threatened fauna and flora;
- implementation of plant disease, weed and feral animal control strategies, including monitoring and evaluation procedures;
- maintenance and enhancement of fauna and flora databases;
- developing and implementing a system of pre-logging fauna assessment to predict fauna on forest blocks and document habitat requirements of threatened and sensitive fauna;
- prioritise collection of fauna data and develop a consolidated database;
- appraise and consider data requirements to support assessment of risks to biodiversity.

The Conservation and Land Management Act recognises the conservation of biodiversity (flora and fauna) as a key objective. The biodiversity principle is factored into the calculation of sustained yield through managing planning goals such as structural goals, netting down of

[22] *Assessment of Ecologically Sustainable Forest Management in the South-West Forest Region of Western Australia*, Report of the Expert Advisory Group chaired by Professor Ian Ferguson, Commonwealth of Australia and Western Australian Government, 1997.
[23] *Regional Forest Agreement for the South-West Forest Region of Western Australia between the Commonwealth of Australia and the State of Western Australia, May 1999.*

area removed through biodiversity prescriptions, applying a reduction to yield to accommodate the retention of habitat trees and conservation through the informal and formal reservation system.

Biodiversity exemplifies the characteristic of many non-wood values, which demand a whole-of-forest approach to data collection. As with a number of the other forest values, biodiversity management and protection is addressed primarily through prescriptions and guidelines applied at the coupe level. The risk is that this will fail to take account of whole of forest issues or, worse still, lead to a neglect of data collection on areas other than those available for timber production.

Databases and modelling of flora and fauna species in the context of planning requires further development. Information from these database help to inform biodiversity goals, targets and performance criteria that can then be translated through to indicators and measurement of Ecologically Sustainable Forest Management outcomes. The risk in terms of not being able to meet biodiversity objectives is reduced through commitments made in the Regional Forest Agreement to improving the knowledge base by appropriate sampling.

Recommendation 4.11, Biodiversity Databases
The Conservation Commission should commit to the maintenance of databases for biodiversity on a 'whole of forest basis' as a pre-requisite for Ecologically Sustainable Forest Management on areas available for timber production and elsewhere.

5 PRIORITIES AND RESOURCES

In framing its recommendations the Panel has attempted to make clear the timing involved. To assist review of the priorities and resources, the following list summarises the recommendations in this report according to their timing.

Timing, and Number and Title of Recommendation

Initiate and complete as soon as possible
3.2 (3) Karri Inventory and Utilisation
3.4 Jarrah Silviculture
3.9 (2) Regrowth Karri Fire Risk
4.3 (1) Dieback
4.9 Social Impact Study

During current revision of Plan
1.1 Regional Calculations
3.2 (2) Karri Inventory and Utilisation
3.5 Jarrah-Marri
3.9 (1) Regrowth Karri Fire Risk
3.11 Shorter Rotations
3.12 Structural Goals
3.19 (1) & (2) Whole Bole Logging
4.1 Whole of Forest
4.2 Fire Management
4.3 (2) Dieback
4.11 Indigenous Communities

During next Plan period (2004-2013)
3.1 Jarrah Stratification
3.2 (1) Karri Inventory and Utilisation
3.3 Jarrah Utilisation
3.6 Marri sawlogs
3.7 Jarrah Growth
3.10 Rehabilitated Mining Sites
3.13 Allowances for Local Reservations and Exclusions
3.14 Local Reservation and Exclusion Trade-offs
3.15 Supplementary Scheduling
3.16 Staff Training and Resources
3.17 Karri Residue Utilisation
3.18 Sawlog Prices and Contracts
3.19 (3) Whole Bole Logging
4.4 Honey Fungus
4.5 Karri Borers and Rot
4.6 Jarrah Pests
4.7 Carbon Cycle
4.8 Bauxite Mining Sites
4.10 Heritage Values
4.12 Biodiversity Databases

During the second half of the next Plan period (2009-2013)
3.8 Karri Growth

At the conclusion of the Plan (2013)
4.1 Whole of Forest

In the time at our disposal, the Panel was unable to provide estimates of the resources required for these recommendations. As a broad generalisation, those to be completed as soon as possible will require additional resources because of the urgency. Those to be undertaken during the revision of the Plan generally do not require substantial additional resources, although collectively they may pose a problem, as in the case of the multiplicity that fall on the Forest Management Scheduling Team. The recommendations to be carried out during the next Plan period vary greatly in resources from very few to substantial additional resources, the latter being associated with major new research or monitoring projects.

APPENDIX: LIST OF SUBMITTORS

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APPENDIX 6

Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the jarrah forest

PROGRESS REPORT ON SPP 2000/03

Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the jarrah forest

by

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August 2002

Introduction

There has been a large number of studies of catchment hydrology in the forests of south-western Australia and these studies have provided an adequate understanding of hydrologic processes and the impact of forest management on catchment hydrology. A review of these studies was undertaken as a part of developing the Forest Management Plan (1994-2003) and changes in practice were adopted as a result. The current practices represent a conservative, precautionary approach to the management of forests to ensure the protection of potable water supplies. Nevertheless, there have been no catchment studies on the hydrologic impacts of the current silvicultural practices in jarrah forest.

This project aims to investigate the hydrologic impacts of timber harvesting and the associated silvicultural treatments in the intermediate rainfall zone (IRZ, 900 – 1100 mm/year) of the jarrah forest. The results of the project will also address part of Ministerial Condition 12-3 attached to Forest Management Plan 1994-2003, which states that CALM shall monitor and report on the status and effectiveness of silvicultural measures in the IRZ to protect water quality.

Methods

Experimental treatment
The study is based on a before and after/control and impact design in which two catchments have been treated, and one catchment remained untreated as a control. The study is located on three second-order catchments that form part of the Yarragil Brook catchment area in the IRZ of the jarrah forest about 20 km SE of Dwellingup. 4X (2.73 km^2) and 6C (4.58 km^2) catchments were subjected to a timber harvesting operation and associated silvicultural treatments and Wuraming catchment (4.4 km^2) remained untreated as a control. Timber harvesting was conducted from Dec 2000 to Feb 2001, and the subsequent silvicultural treatments from April to May 2001.

The timber harvesting treatment applied to 4X was the standard phased-logging prescription and follow-up silviculture for second order catchments in the IRZ (hereafter termed the standard treatment-catchment). The standard prescription includes the retention of at least 30% of the catchment at a basal area of at least 15m^2ha^{-1} for a period of at least 15 years after harvesting the remainder of the catchment. The standard post-logging treatment involves the removal of trees not marked for retention (cull trees) by notching with herbicide in thinned areas or by

pushdown in shelterwood areas within a 4m radius of each crop tree. 6C was treated with a more intensive prescription than the standard (hereafter termed the intensive treatment-catchment), by omitting the requirement to retain 30% of the catchment with a basal area of $>15 m^2 ha^{-1}$. The follow-up silviculture in 6C was also more intensive than that for 4X whereby all cull trees were notched or pushed down.

Hydrological measurement
Monitoring of groundwater levels, stream flow and stream salinity has been ongoing for at least the previous 14 years in the three catchments. Stream discharge and conductivity have been monitored continuously at automated stream gauging stations at the catchment outlets. Groundwater levels have been monitored approximately monthly since mid 1999 in a network of bores in the three catchments - six in 4X (two valley and four hillslope), 18 in 6C (six valley and 12 hillslope) and ten in Wuraming (five valley and five hillslope). Prior to 1999, bore water levels were measured less frequently, but usually at least twice annually -once in late autumn/early winter in the usual period of minimum groundwater levels, and again in late spring/early summer in the usual period of maximum groundwater levels. Water collected as grab samples or by an automatic water sampler immediately upstream of the weir at the catchment outlet have been analysed for turbidity.

Forest density measurement
To assess changes in overstorey density, resulting from the timber harvesting operation and associated silvicultural treatments, measures of crown cover, crown density index, basal area, and stocking were taken before and after the treatments in the three catchments. A description of the techniques used to take each of these measures, except for stocking, is given in Stoneman *et al.* 1988. Stocking was assessed by allocating each tree, which was included in the basal area sweep and whose diameter over bark was measured at 1.35 m above ground, into one of the size classes: < 15 cm, 15-45 cm, 45-60 cm, >60 cm.

In the treatment catchments, the forest density measurements were taken along transects, permanently marked at 100m intervals. There were nine transects 200 m apart in the standard treatment-catchment, and eight transects 300 m apart in the intensive treatment-catchment. The transects were orientated north-south and spanned the catchments. Crown cover was measured at 20m intervals and the other measures at 100m intervals. In the control catchment, all measures were taken at permanently marked points on a 50 m by 100 m grid. This resulted in 625 records of crown cover, and 127 records of the other measures in the standard treatment-catchment, and 759 records of crown cover and 156 records of the other measures in the intensive treatment-catchment. In the control catchment there was a total of 927 records of each of the forest density measures.

Rainfall measurement
Monitoring of rainfall has been ongoing for the last 17 years in each of the standard and intensive treatment-catchments by automatic rain gauges recording at 5-minute intervals.

Data analysis

Groundwater level

To assess changes to groundwater levels in response to the treatments, linear regressions of annual minimum bore groundwater levels for the pre-treatment period were determined in pair-wise combinations between each bore in the treated catchments with each of the control catchment bores. The regressions were based on bore records from 1988 to 2000, however, some records were not available for some bores in some years hence there were between 4 and 10 data points in the regressions. For each treatment bore, the linear regression of the paired combination with the highest R^2 (all $R^2 \geq 0.93$) was used to predict the annual minimum water level in that treatment bore from the annual minimum water level occurring in the corresponding control bore after the treatment, i.e. the minimum bore water level expected in the treatment bore as if no timber harvesting or associated silvicultural treatment occurred. The difference between the predicted water level and the observed treatment bore water level is attributed to the treatment. In 2001 and 2002, the two years following treatment, the water level in most bores in all three catchments continued to decline throughout the year (Fig. 1). To enable the regression analysis to be applied to these bores, the "minimum" water level is considered to have occurred on 30/06, the median date on which the minimum groundwater level occurred in all bores in 2000. Minimum groundwater levels were used in the analysis because they are less subject to between-year changes in response to variable weather patterns than maximum groundwater levels.

For two hillslope bores in 4X, there were insufficient records to enable a regression against control bores. Hence a (secondary) regression was determined between these bores and two other bores in 4X (both $R^2 = 0.99$, n=6, 1989 –2002) for which there were good (primary) regressions with control bores ($R^2 = 0.95$, n=10, 1988 –2000; $R^2 = 0.99$, n=6, 1989 –2000). For these two bores, the primary and secondary regressions were used in a stepwise manner to predict the water levels in the treatment bores from post-treatment control bore minimum water levels.

Streamflow, stream salinity and stream turbidity

In 2001 there was no streamflow in the intensive treatment-catchment or in the control catchment and an insignificant few hours of stream flow in the standard treatment-catchment. Presently (August 2002) the streams are flowing in the treated catchments and since the analysis of stream discharge is based on annual totals, the stream responses are not reported here.

Vegetation

Pre and post-treatment overstorey density has been assessed but the data have not yet been analysed and so are not reported here.

Results

The total rainfall at the study sites in the first year following treatment was 515 mm. This was substantially lower than the average of 913 mm for the preceding 16 years (Fig. 2).

The groundwater hydrograph of a hillslope bore in the intensive treatment-catchment shown in Fig. 1 is representative of the hydrographs of hillslope bores in the three catchments. Two trends are evident in this hydrograph - a long-term progressive fall in groundwater levels, and the absence of a late spring/early summer peak in water level in 2001. Groundwater levels in all bores in the three catchments have continued to fall since the treatments were applied.

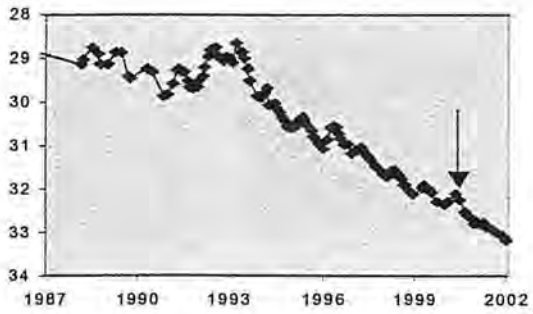

Fig 1. Groundwater levels in a hillslope bore in 6C catchment. Arrow indicates time of treatment.

Table 1 shows the average change in groundwater levels in boreholes in the treated catchments, relative to the groundwater levels in boreholes in the control catchment, following timber harvesting and associated silviculture. It was anticipated that timber harvesting would result in rises in groundwater level. However, the following results generally show the opposite trend, that is, small declines in groundwater level in boreholes in the harvested catchments relative to groundwater levels in boreholes in the control catchment.

In the first winter following the treatments, groundwater levels fell relatively more in both the standard and intensively treated catchments than in the control catchment. However, the magnitude of the average fall was small and ranged between 0.03 m in the valleys of the intensively treated catchment, and 0.15 m in the valleys of the standard treatment-catchment. Groundwater levels fell more in the standard than in the intensive treatment-catchment, however, the magnitude of the difference in average responses between the two catchments was small, i.e. about 0.12 m in the valleys and almost no difference on the hillslopes.

In the second winter following treatment, the difference in response between the two treated catchments, was greater than after the first winter. Groundwater levels in the standard treatment-catchment continued to fall relative to the control, and the magnitude of the fall was greater in the valleys (0.36 m) than after the first winter following treatment (0.15 m). In the intensive treatment-catchment, groundwater levels fell by a further 0.05 m in the valleys but rose by about 0.19 m on the hillslopes.

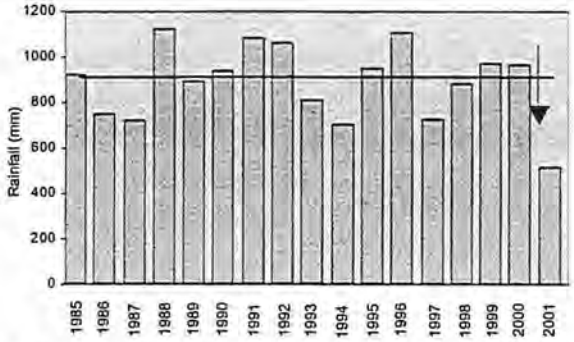

Fig 2. Annual rainfall (bars) and average annual rainfall for the period 1985 to 2000 (line) at the study site. Arrow indicates time of treatment

After two winters following treatment, the largest cumulative response in each of the catchments was an average fall of about 0.5 m in the valleys in the standard treatment-catchments and a rise of about 0.1 m on the hillslopes in the intensive treatment-catchments.

Table 1. Average change in groundwater levels in treated catchments, following treatment in the summer of 2000/01, relative to the control catchment

			Change after first winter		Cumulative change after second winter	
	No of bores	Bore location	Average (m)	Range (m)	Average (m)	Range (m)
Standard treatment	2	Valley	-0.15	-0.13 to -0.16	-0.51	-0.25 to -0.78
	4	Hillslope	-0.10	+0.01 to -0.14	-0.22	+0.45 to -0.36
	6	All	-0.11		-0.32	
Intensive treatment	6	Valley	-0.03	+0.19 to -0.14	-0.08	+0.41 to -0.55
	12	Hillslope	-0.08	+0.26 to -0.75	+0.11	+0.58 to -1.11
	18	All	-0.06		+0.05	

Discussion

The atypically low rainfall in the first year following the timber harvesting and associated treatments had a greater effect on the water balance, and consequently groundwater level, in the catchments than the treatments. There was a small net fall in groundwater levels, and of a similar magnitude in the valleys and hillslopes, in both treatments.

In the second year following treatment, some trends in groundwater response have become apparent. The standard treatment continued to have less influence on groundwater recharge than climate and groundwater levels have continued to fall. The falls were greatest in the valleys. In contrast, groundwater levels have risen about 0.1 m on the hillslopes in response to the intensive treatment. However, the magnitude of these changes is much smaller than the changes in groundwater level in response to the timber harvesting and associated silvicultural practices of the early 1980's (Borg *et al.* 1987) where average groundwater levels rose more than 1.7 m in the valleys and hillslopes in the first two years following treatment.

Conclusion

Timber harvesting was expected to result in rises in groundwater level. However, the results have generally shown the opposite trend, that is, small declines in groundwater levels in the harvested catchments relative to groundwater levels in the control catchment. Since the results presented here are very early in the expected response of groundwater level to timber harvesting, and are influenced by the very low rainfall in 2001, it is important that monitoring continue for at least another three years and the results be evaluated at that time.

Reference

Borg, H., King, P.D. and Loh, I.C. (1987) Stream and groundwater response to logging and subsequent regeneration in the southern forest of Western Australia. Interim results from paired catchment studies. Water Authority of Western Australia Report No. WH 34.

Stoneman, G.L., Rose, P.W. and Borg, H. (1988) Recovery of forest density after intensive logging in the southern forest of Western Australia. Department of Conservation and Land Management, Technical Report No. 19.

APPENDIX 7

Details of the 2001 audit of environmental protection in native forest harvesting

DETAILS OF THE 2001 AUDIT OF ENVIRONMENTAL PROTECTION IN NATIVE FOREST HARVESTING

SAMPLE

The sample included both northern and southern supply areas. The following coupes were sampled.

Coupe	Status	Species	Rainfall Zone
Boronia	Completed/Active	Jarrah	Intermediate
Harrington	Completed/Active	Jarrah	Intermediate
Boonering	Completed	Jarrah	Low/Intermediate
Butler	Completed	Jarrah	Intermediate
Woop Woop	Active	Jarrah	Low
Lang	Active	Jarrah	High
Leona	Completed	Jarrah	Low
Leach	Active	Jarrah	Low
Palmer	Active	Jarrah	Intermediate
Collins	Completed	Jarrah/Karri	High
Kin Kin	Completed	Jarrah	Low/Intermediate
Stoate	Completed	Jarrah	Low
Wheatley	Completed	Jarrah/Karri	High
Netic	Completed	Jarrah/Karri	Intermediate/High
Crowea	Active	Karri	High

Following are the findings relevant to compliance with Commitments 4, 8, 12, 13, 16 and 17 from the Ministerial Statement that the 1992 Forest Management Proposals may be implemented.

FINDINGS

Commitment 4 – Preserve the quality of potable water supplies from forests

The audit included examination of the harvesting planning and field implementation process, examination of the harvesting plan of the coupes in the sample, verification of the retention of required stream zones and verification that the planned 30 per cent retained forest was unharvested.

The audit verified that the procedures in the harvesting planning system that identify and mark on the harvesting plan:

- stream zones;
- second order catchments in the intermediate and low rainfall zone (Condition 12); and
- high salt risk catchments (Condition 16).

were in place and working.

All stream zones required had been retained in the field.

The audit verified that harvest plans for coupes sampled that were in the intermediate and low rainfall zone had the required 30 per cent of the catchment excluded from planned cutting.

The areas planned for retention under the 30 per cent requirement were refined when demarcated in the field and FPC silvicultural officers were undertaking compliance monitoring.

The field sample verified that the demarcated areas were excluded from harvesting. No high salt risk catchments were harvested in the 2000 calendar year.

Commitment 8 – Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees

Auditors sampled 10,156 metres of stream zone boundary. The audit found 95.5 per cent of the sampled stream zone boundary intact.

Of the 4.5 per cent of the stream zone boundary that had been crossed approximately half was associated with minor machine incursions and half with major incursions where trees were illegally felled and snigged. The tree felling and snigging incursions comprised seven incidents in three coupes and involved 28 trees.

Commitment 12 – Retain an average of (at least) three large trees on every hectare harvested to provide habitat.

Auditors sampled 12 jarrah coupes to test for habitat tree retention. The overall results were:

No. of coupes assessed for habitat trees	**Area sampled**	**No. of habitat trees in samples**	**Average no. of habitat trees per hectare**
12	63ha	366	5.8

One coupe (Lang) failed to meet the minimum specification averaging 2.6 habitat trees per hectare.

Commitment 13 – Retain, and protect as far as possible, at least one suitable ground habitat, i.e. hollow log per hectare

Auditors used the same sample area for habitat logs as for habitat trees.

No. of coupes assessed for habitat	**Area sampled**	**No. of marked ground habitat in samples**	**Average no. of ground habitat per hectare**
12	63ha	15	0.2

The average value of 0.2 habitat logs per hectare is meaningless because sampling was unable to locate any marked ground habitat in seven coupes. Only one coupe had marked ground habitat at the required retention rate while four had it marked but below the required level.

In 1999 auditors evaluated residual logs and stumps against the ground habitat criteria and identified an average of 2.12 ground habitat elements per hectare available following harvesting. No such assessment was conducted in the 2001 audit although the presence of suitable unmarked habitat was noted by the auditors.

Commitment 16 – Limit gap size in karri and karri/marri forests to a maximum of 80 hectares

The size of karri gaps in the field sample was assessed. SILREC records were not able to be used in this audit because the required data were not able to be generated, given the higher priority for data for the new forest management plan.

Commitment 17 – Where possible, ensure the distance between areas of retained mature forest is a maximum of 400 metres

Auditors checked the coupe planning process, field sampled three karri coupes and scanned other cutting records. Application of the rule is built into the coupe planning process and the audit verified that this was in place. Field sampling verified that the 400-metre rule had been applied successfully, in some cases requiring additions to stream zones or the retention of buffers of mature forest.

The potential exists to use the SILREC data to evaluate all cut-over coupes for the 400-metre rule rather than a sample. To effect such a systematic analysis satisfactorily, the variables require stricter definition and suitable algorithms will need to be written. Although this project was commenced it was not completed due to the higher priority given to projects associated with the development of the new plan. Therefore it was not possible to use SILREC to verify compliance with the 400-metre rule in all coupes.

APPENDIX 8

Details of the 2002 audit of environmental protection in native forest harvesting

DETAILS OF THE 2002 AUDIT OF ENVIRONMENTAL PROTECTION IN NATIVE FOREST HARVESTING.

SAMPLE

The sample included both northern and southern supply areas. The following coupes were sampled.

Coupe	Status	Species	Rainfall Zone
O'Neil	Completed	Jarrah	Intermediate
Plavins	Completed	Jarrah	High
Geddes	Completed	Jarrah	Low
Hovea	Completed	Jarrah	Intermediate
Bovell	Completed	Jarrah	Intermediate
Barrabup	Completed	Jarrah	Intermediate
Barrabup	Completed	Jarrah	Intermediate
Barrabup	Completed	Jarrah	Intermediate
Roseneath	Completed	Jarrah	Low
Red Gully	Active	Jarrah	Intermediate
Dingup	Active	Jarrah/Karri	Intermediate
Collins	Actice	Jarrah/Karri	High
Andrew	Completed	Jarrah	High
Brockman	Completed	Jarrah/Karri	High

Following are the findings relevant to compliance with Commitments 4, 8, 12, 13, 16 and 17 from the Ministerial Statement that the 1992 Forest Management Proposals may be implemented.

FINDINGS

Commitment 4 – Preserve the quality of potable water supplies from forests

The audit included examination of the harvesting planning and field implementation process, examination of the harvesting plan of the coupes in the sample, verification of the retention of required stream zones and verification that the planned 30 per cent retained forest was unharvested.

The audit verified that the procedures in the harvesting planning system that identify and mark on the harvesting plan:

- stream zones;
- second order catchments in the intermediate and low rainfall zone (Condition 12); and
- high salt risk catchments (Condition 16);

were in place and working.

All stream zones required had been retained in the field.

The audit verified that harvest plans for coupes sampled that were in the intermediate and low rainfall zone had the required 30 per cent of the catchment excluded from planned cutting.

The areas planned for retention under the 30 per cent requirement were refined when demarcated in the field and FPC silvicultural officers were undertaking compliance monitoring.

The field sample verified that the demarcated areas were excluded from harvesting. No high salt risk catchments were harvested in the 2001 calendar year.

Commitment 8 – Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees

Auditors sampled 13,285 metres of stream zone boundary. The audit found 97 per cent of the sampled stream zone boundary intact.

Of the 400 metres of the stream zone boundary that had been crossed approximately 266 metres (66 per cent) was associated with minor machine incursions. The remainder involved three major incidents involving one instance of a tree being felled and snigged and two cases where vegetation in the stream zone had been cleared or scrub rolled.

Commitment 12 – Retain an average of (at least) three large trees on every hectare harvested to provide habitat

Auditors sampled 12 jarrah coupes to test for habitat tree retention. The overall results were:

No. of coupes assessed for habitat trees	**Area sampled**	**No. of habitat trees in samples**	**Average no. of habitat trees per hectare**
12	77ha	399	5.2

One coupe (O'Neil) failed to meet the minimum specification averaging 2.6 habitat trees per hectare.

Commitment 13 – Retain, and protect as far as possible, at least one suitable ground habitat, i.e. hollow log per hectare

Auditors used the same sample area for habitat logs as for habitat trees.

No. of coupes assessed for habitat	**Area sampled**	**No. of marked ground habitat in samples**	**Average no. of ground habitat per hectare**
12	77ha	39	0.5

Ground habitat had been marked at or above the required rate in four of the 12 coupes, below the required rate in three coupes and five coupes had no habitat marked although suitable habitat was noted by the auditors.

Commitment 16 – Limit gap size in karri and karri/marri forests to a maximum of 80 hectares

The size of karri gaps for the 2001 harvesting was evaluated from SILREC records. In all 120 gaps were harvested in 2001 with the average gap size being 10.6 hectares and the largest gap 35 hectares.

Commitment 17 – Where possible, ensure the distance between areas of retained mature forest is a maximum of 400 metres

Auditors checked the coupe planning process, field sampled three karri coupes and scanned other cutting records. Application of the rule is built into the coupe planning process and the audit verified that this was in place. Field sampling verified that the 400-metre rule had been applied successfully, in some cases requiring additions to stream zones or the retention of buffers of mature forest.

The potential exists to use the SILREC data to evaluate all cut-over coupes for the 400-metre rule rather than a sample. To effect such a systematic analysis satisfactorily, the variables require stricter definition and suitable algorithms will need to be written. Although this project was commenced it was not completed due to the higher priority given to projects associated with the development of the new forest management plan. Therefore it was not possible to use SILREC to verify compliance with the 400-metre rule in all coupes.

APPENDIX 9

Ministerial Condition 11: Panel Report Part 1

Ministerial Condition 11: Panel Report Part 1
October 2001

Executive Summary

The purpose of this report is to assist the Department of Conservation & Land Management with its compliance reporting requirements in relation to Ministerial Condition 11.1 attached to the Forest Management Plan 1994-2003. This Condition relates to the requirement by the Department of Conservation & Land Management to monitor the environmental impacts of silvicultural treatments applied to jarrah forests. The Panel was asked to provide advice to the A/Executive Director covering relevant research and monitoring programs undertaken by the Department, with particular reference to regeneration, salinity and biodiversity conservation issues. The panel was also asked to summarise bases that these outcomes provide for altering forest management and to comment on the sufficiency of FORESTCHECK as a protocol for monitoring the environmental impacts of jarrah forest silvicultural systems.

The key recommendations of the Panel are:

- Jarrah forest regeneration standards need to be refined to reflect the variability and capability of site types throughout the range of jarrah. The method for assessing regeneration appears adequate over the limited range of site types under which it has been evaluated, but further validation across a broader range of site types may be warranted.
- There is no hydrological evidence to vary the existing silvicultural guideline in the salt-sensitive intermediate rainfall zone. These should be reviewed when data from current research programs are available in 4-5 years.
- Conservation objectives for forests are poorly defined in various Departmental planning documents. The Panel presents draft objectives for consideration by the Department.
- The outcomes of recent research and monitoring provides bases for a number of changes to the silvicultural guidelines to further ensure that forest management is consistent with the principles of ecologically sustainable forest management. These relate to improving the provision of habitat for hollow-dependent and arboreal fauna, better protection of soil and enhancing the protection of understorey vegetation. Detailed recommendations are appended to this report.
- FORESTCHECK is a workable, implementable and commendable monitoring protocol. However, it requires a considerable amount of detail to be collected at each site and because resources are limited, lacks geographical representation. The Panel recommends a 12-month trial to compare the cost-effectiveness of FORESTCHECK (as proposed) and a monitoring system based on a subset of species (indicators) that would enable better geographic representation.
- The Department of Conservation & Land Management has made considerable progress with auditing and should consider preparing summary reports on its auditing of activities relevant to timber harvesting in jarrah forests as part of its compliance report to the Environmental Protection Authority.

Part 2 of the Panel's deliberations will deal with the revised jarrah forest silvicultural guidelines with respect to how the proposed new guidelines take account of environmental values (especially regeneration, salinity and biodiversity conservation). The Panel, which will report to the Conservation Commission, will also make recommendations about future forest research and monitoring priorities.

1. Introduction

1.1 Terms of Reference

The Department of Conservation & Land Management has sought the advice of an expert panel to facilitate reporting in relation to Ministerial Condition 11.1 attached to the Forest Management Plan 1994-2003. Ministerial Condition 11.1 states;

"The proponent shall implement the jarrah silvicultural prescription so that monitoring of environmental impacts on a representative range of treated sites and localities in the forest can be carried out to the requirements of the Minister for the Environment. This shall include long-term monitoring which quantifies the impacts of silvicultural practices on environmental elements and values in the forest and provide bases to adjust management".

The panel, comprising Dr Neil Burrows (Chair), Dr Per Christensen, Dr Steve Hopper, John Ruprecht and Dr Joanna Young, was appointed in mid July 2001 and was asked to report to the A/Executive Director of the Department of Conservation & Land Management by early September 2001. Specifically, the panel was asked to provide advice covering;

- A summary of relevant research and monitoring programs and projects undertaken by the Department, including;
    - Regeneration adequacy and methods of assessment,
    - Salinity constraints for silvicultural guidelines,
    - Habitat provision for the maintenance of biodiversity and ecological processes.
- Outcomes of research and monitoring of the environmental impacts of silvicultural practices on environmental elements and values in the forest.
- A summary of the bases these outcomes provide to adjust management
- The sufficiency of the proposed monitoring project (FORESTCHECK) as a future means of data collection and monitoring the impacts on biodiversity of the application of silvicultural guidelines in the jarrah forest.

This report summarises material, findings and recent initiatives considered relevant for inclusion in the Department of Conservation & Land Management's final report to the Environmental Protection Authority (EPA) on the implementation of the Forest Management Plan 1994-2003, with particular reference to the silvicultural guidelines for the harvesting of jarrah forest.

While audit was not part of the terms of reference of this Panel, the Department has made considerable progress with operational audits on forest operations. Systems audits are an important facet of management quality control, so the Panel has included a summary of relevant audits carried out since 1999 in this report.

1.2 Context

An ongoing and unresolved issue has been how and to what degree the Department of Conservation & Land Management should monitor environmental elements and values that may be affected by timber harvesting in the jarrah forest. Regeneration adequacy post logging, the risks of rising water tables with associated salinisation of streams or surface soil profiles, the maintenance of biodiversity, and the maintenance of ecological processes are issues that have been repeatedly identified as requiring focused attention. In a definition of ecologically sustainable forest management (ESFM), the National Forest Policy Statement

(Commonwealth of Australia 1992) defines "*ecological processes*" as the formation of soil, energy flows, and the carbon, nutrient and water cycles.

The Department of Conservation & Land Management is required to report publicly to the EPA on compliance and progress with respect to seventeen Ministerial Conditions attached to the current Forest Management Plan (FMP). It is intended that a final public report should help verify environmental performance with regard to implementation of the 1994-2003 FMP. This plan signalled a shift away from the selective removal of commercial trees in jarrah forest to the creation of gaps up to approximately 10 hectares. This treatment aimed to facilitate the release and development of jarrah and marri regeneration that existed beneath the forest canopy. In 1992 the EPA accepted the silvicultural rationale for gap creation but it stated (EPA Bulletin 652, 1992) that adoption of the silvicultural guidelines proposed for wide scale use, should be conditional on monitoring of environmental impacts on a range of sites. This was embodied in the Ministerial Condition 11.1, which was to ensure that information from monitoring was available for an evaluation of the environmental impacts of this more intensive treatment prior to the drafting of the next FMP.

There are five additional environmental conditions that are related to the jarrah silvicultural systems adopted post 1992:

- Ministerial condition 3: Precautionary approach and adaptive management
- Ministerial condition 12: Phased logging
- Ministerial condition 14: Banksia grandis reduction
- Ministerial condition 16: High salt risk catchments.
- Ministerial condition 17: Forest Monitoring and Research committee.

Significant public documents that provide background to the processes that have resulted in the Department of Conservation & Land Management giving high priority to reporting on implementation and impacts of the jarrah silvicultural systems are at Appendix 1. In addition, the Department of Conservation & Land Management has provided the EPA with annual progress and compliance reports for 1998, 1999 and 2000.

A major shortcoming that became evident during 1997 and which was addressed by Codd (1999), was that environmental commitments, or objectives, were not clearly stated in the 1994-2003 FMP. A clear statement of agreed commitments could have facilitated the Department of Conservation & Land Management's mid term reporting to the EPA as well as facilitating ongoing audit of progress with implementation.

As a consequence of Codd's report (1999), the Department of Conservation & Land Management and the EPA agreed to a set of environmental commitments, which the EPA published in Bulletin 983 June 2000 (see Appendix 2). The Department of Conservation & Land Management has reported to the EPA on implementation of the current FMP against these commitments in its annual progress and compliance reports of 1998 and 1999. It is assumed that in the drafting of the final compliance report the Department will further address how the commitments have been addressed.

The Regional Forest Agreement (RFA) process resulted in some of these commitments being fulfilled, e.g Commitment 9 "*Identify areas of high value old growth forest*". The old growth forests were mapped and such areas are now being protected from timber harvesting in line with current government policy.

Other commitments remain relevant with respect to evaluating the impacts of jarrah silviculture during the last decade and they include the following from the full list:

1. Identify and publish the values to be managed for in each forest area.
2. Implement long term monitoring programs to identify and study significant management issues in (all types of) forest.
3. Regulate the production of forest resources to levels that can be sustained indefinitely.
4. Preserve the quality of potable water supplies from forests.
5. Undertake research to improve the scientific basis for the protection of biodiversity.
12. Retain an average of (at least) 3 large trees on every hectare harvested to provide habitat.
13. Retain, and protect as far as possible, at least one suitable ground habitat, ie hollow log, per hectare.
15 For those high salt risk second order catchments identified in fulfilment of Ministerial condition 16, the Department of Conservation & Land Management will reach agreement with the Water and Rivers commission regarding the precautionary management and protection measures to be implemented. The objective of the measures will be to prevent saline discharge into these watercourses.

The Department of Conservation & Land Management and the Conservation Commission have the responsibility for implementing a number of the key recommendations made by Ferguson *et al* (April 2001), especially those suggested as requiring attention during the development and drafting of the new FMP. Some of the actions relate to the Department fulfilling, at least in part, some of the EPA/ Department of Conservation & Land Management agreed commitments. That is, there are a number of cross-linkages and a degree of commonality with the various processes to assess forest management.

The need for ongoing research and monitoring has been long recognised but resource constraints and priority setting processes have severely limited activity. Research priorities and the monitoring approach to be adopted for the period of the new FMP (2002-2012) must be agreed to and funds committed. The panel recognises that major changes in the timber industry and a reduction in levels of harvest, places further pressure on the availability of resources to carry out research and monitoring. However, the panel is of the view that government and industry must cooperate to give these activities a high priority if Western Australia is to benefit from a sustainable forest industry.

The results of research and monitoring of some environmental impacts of jarrah forest harvesting since the implementation of 1994-2003 FMP are summarised in this report and provide a sound basis for improving jarrah forest management. Proposed improvements will be discussed further in a complementary report to be prepared by this Panel for the Conservation Commission of WA.

A review of the outcomes of the post-1992 jarrah silvicultural guidelines (gap creation, shelterwood and thinning), must recognise the influences of changing market in timber and forest products. The objectives of minimising waste, enhancing regeneration and ensuring that operations are economic and environmentally sound, can be more readily achieved when there is a strong demand for residues or low grade logs. The implications of decreased demand for marri chipwood must be considered in the planning and implementation process. The ways (if any) in which on-ground activities may have been modified beyond the operational instructions and guidelines in response to changing market forces, must be acknowledged in any review of changes made during the last forest management plan.

In preparation of the Department of Conservation & Land Management's final progress and compliance report, numerous advances in environmental auditing and reporting should be acknowledged. In some areas the Department will have exceeded standards envisaged in 1994, partly as a result of the Regional Forest Agreement (RFA) and strengthened State and National commitments to the maintenance of biodiversity and environmental protection. The

RFA bound all parties to a commitment to practise ecologically sustainable forest management (ESFM) with a framework based on the Montreal Criteria and Indicators.

1.3 Approach

While Ministerial Condition 11.1 specifically refers to monitoring, the panel, guided by the terms of reference, has focused on both research and monitoring undertaken by the Department of Conservation & Land Management that is relevant to impacts of jarrah silviculture post-1992. A summary of relevant research and monitoring has been made with particular reference to a) regeneration adequacy and methods of assessment, b) salinity constraints, and c) habitat provision for the maintenance of biodiversity and ecological processes. We have also noted information and observations to emerge from field visits and audit reports. The Panel relied heavily on the Department of Conservation & Land Management's records for information about relevant research and monitoring. Much of this was synthesised at a workshop convened by the Department earlier this year. A summary of research and monitoring information that forms a sound basis for adjusting management (silvicultural) practices is provided.

A review of FORESTCHECK, a proposed system for monitoring biodiversity and some ecosystem processes on a range of sites has also been made. Various suggestions are made in light of budgetary constraints and the problems associated with the many sources of variation, which can plague interpretation of trends found in long term monitoring.

2. Research and Monitoring Programs

Regeneration adequacy and methods of assessment, salinity constraints, habitat provision for the maintenance of biodiversity and maintenance of ecological processes have been identified as issues requiring review prior to adoption of the next FMP. These topics are covered by this report in relation to current silvicultural treatments that were last reviewed in 1995. In jarrah forest available for timber harvesting, one of three silvicultural objectives will usually be applied to patches of the forest depending on the existing stand structure and density of regeneration. These are;

- Thinning to promote growth on retained trees.
- Removing the overstorey (creating gaps) to release and promote the development and growth of existing regeneration (seedlings, ground coppice and small saplings). Maximum gap size is 10 ha, with most gaps being 4-7 ha.
- Cutting to a shelterwood to establish regeneration where it does not exist in sufficient density. Seedlings will be encouraged to establish and develop into ground coppice by reducing the competition from the overstorey. A forest canopy is maintained to provide a continuity of forest values until the ground coppice is developed and capable of responding to release following canopy removal.

The choice of silvicultural treatment applied to a patch of forest is determined following a ground survey of the extent and nature of existing regeneration. Habitat trees and logs are identified and marked for retention, permanent reserves are retained along roads and certain streams and buffers, or temporary exclusion areas (TEAs) 50-100m wide, are retained between logged areas. These TEAS areas may be scheduled for harvest within 15-20 years of the harvest of the adjacent forest. Details of silvicultural treatments and associated prescriptions are provided by CALM (1995).

2.1 Regeneration adequacy

2.1.1 Background

Issues raised in the report of the EPA advisory committee on Forest Management Plans (1998) with regard to factors affecting jarrah regeneration in gaps included:

- poor regeneration of jarrah on some soil types;
- dominance of marri and stump coppice in some southern jarrah forest areas;
- large quantities of jarrah waste material after logging and follow-up treatment;
- lack of post harvest treatments in some areas; and
- frost damage.

The report noted that *"the critical assessment of regeneration is important for the ongoing development of harvesting prescriptions. The standards of post-harvest treatments will also affect future sawlog quality and should be continually assessed"*.

The Independent Expert Advisory Group (IEAG) (Ferguson *et al.* 1997) also made comment on regeneration requirement with respect to the implementation of ESFM. With regard to the systems used for monitoring regeneration success at the coupe level, comments were primarily in relation to Silviculture Specification 3/90 for jarrah and it was stated that *"records are maintained and summaries of performance are compared to specific performance indicators in the annual report of the Business Unit"*, which existed within the Department of Conservation & land Management prior to the formation of the Forest Products Commission.

The IEAG further commented that: *"Systematic assessment of early growth rates following the successful establishment of regeneration after logging or mining activities is not undertaken. Routine inventory does not commence until about age twenty to twenty five years. As a result, there is no procedure for the assessment of early growth, which would enable an early determination of whether site productivity has been maintained. The Forest Management Branch recognises this shortcoming, but believes that it has no standard productivity or species composition benchmarks to compare any such measurements with in order to make meaningful conclusions. Similarly, there is no procedure for the monitoring of changes in species composition and dominance on sites that contain a mixture of species. This may be a particularly important criterion of forest productivity on sites where the initial stocking of species during the regeneration phase is significantly different to the natural, mature stage composition."*

The IEAG report concluded that *"the Department of Conservation & Land Management should monitor and report on the adequacy of stocking in jarrah forests which have been treated for the release of advance growth or crop trees, and the early growth and composition (commencing at age five to ten years) of tree species on sites after harvesting or mining activities."*

Ensuring adequate regeneration is fundamental to silviculture. It determines the overstorey stocking, structure and species composition of the future forest . It is a key objective of both jarrah gap creation and the shelterwood treatments.

2.1.2 Observations, research and monitoring

An understanding of the regeneration requirements of jarrah has been gained by experimental research, observation and experience, particularly for higher quality jarrah forest. Summaries of this knowledge have been presented elsewhere (e.g., Abbott & Loneragan 1986, Dell *et al.* 1989, Stoneman 1993 and in the 'Implementation of the Codd Report' (Department of

Conservation & Land Management 2000), including previous compliance reports by the Department. Bradshaw (1985) developed a training document outlining the basis for choosing an appropriate approach for different areas and types of forest and the Department of Conservation & Land Management (1995) produced a revised silvicultural guideline.

Research to date has shown that the key factors affecting the rate of jarrah seedling establishment include the amount of viable seed, the condition or receptiveness of the seedbed (soil surface), the level of seed predation and post-seedfall moisture and temperature regimes. Research (and field experience) has highlighted the importance of fire, particularly in summer/autumn, in providing suitable conditions for seed dispersal, germination and development. Seedling survival and development was found to be greatest where the overstorey had been removed, soils were "heavily" disturbed and understorey competition was removed or reduced (Stoneman 1993).

The panel found little evidence of new or ongoing research by the Department specifically focussed on jarrah regeneration (or jarrah silviculture generally) since that reported in the mid-term compliance report (CALM 1997). Due to limited resources, a relatively new project on jarrah seedfall (Inglehope forest block) initiated several years ago has been delayed to enable the completion of projects considered higher priority. The Kingston Project, a multi-disciplinary investigation into the ecological impacts of timber harvesting in jarrah forest (Burrows *et al.* 1994), revealed through survey that while the various silvicultural treatments resulted in adequate regeneration on most sites, on some sites the abundance of jarrah (and marri) regeneration actually declined following the shelterwood cutting treatment. This suggests inappropriate or incorrect application of treatment, or uncertainties about jarrah regeneration requirements in low rainfall forests. The Kingston Project confirmed that gap cutting to release existing regeneration was successful on these sites.

Surveys to estimate stocking, density and (tree) species composition of regeneration (lignotuberous seedlings, ground coppice/advance growth and saplings) and are carried out before logging and about 12 months and 10 years after logging. The results of these surveys determine how a patch will be treated and what follow-up treatment (if any) is needed to ensure adequate regeneration. Procedures for carrying out these surveys are provided in Department of Conservation & Land Management Silvicultural Guideline 4/97.

Sampling of coupes (cut to gaps) to be surveyed (post-logging) is based initially on a field inspection to assess whether there is likely to be a problem with regeneration adequacy. If the coupe is deemed to be near or below the stocking standard, then a formal survey is carried out using the triangular tessellation method (described in Department of Conservation & Land Management Silvicultural Guideline 4/97). In recent years, about 5% of coupes (cut to gaps) have been formally surveyed, indicating that regeneration adequacy in areas cut to gaps has not been a major issue. Where regeneration has not been adequate following gap cutting, or the regeneration is virtually completely dominated by marri, then this probably suggests incorrect selection of silvicultural treatment. It is the Panel's understanding that all areas cut to shelterwood are surveyed for adequacy of regeneration. The results of these surveys indicate that on lower productivity sites (low rainfall, poorer soils) it is difficult to establish regeneration to the standards and within the time frame specified by Silvicultural Guideline 4/97 (Allan Seymour, *pers. comm.*). The survey data also suggest that regeneration on these sites is patchy, or clumped, rather than evenly distributed. This is also typical of woodlands in lower rainfall areas.

2.1.3 Management Implications & Recommendations

Comment:
Silvicultural Guideline 4/97 defines a sample point to be adequately stocked (with regeneration) if it is found to have the following densities when measured about 12 months after the silvicultural treatment:

- 500 or more stems per hectare (spha) of jarrah or marri saplings, or
- 1 000 or more spha of jarrah ground coppice or marri advance growth, or
- 1 000 or more spha of a combination of jarrah or marri saplings and jarrah ground coppice or marri advance growth.

The basis for these stocking standards is unclear to the panel. This is the same standard used for pre-logging surveys to determine the silvicultural treatment to be applied. This raises two key questions. Firstly, is it biologically sound to set a standard that applies across the range of the jarrah forest given the great variability in site productivity (climate, soils, landforms), therefore reproduction/recruitment potential, and past management history and stand structure, and secondly, is it biologically sound to expect this standard to be reached on all sites within 12 months of logging? This standard will be achievable on some sites, but not on others. Clearly, it is the latter that is of greatest concern, particularly if a significant area of these sites is available for timber harvesting under the new FMP.

Fire and light (competition) sensitive species such as karri and to a lesser extent, wandoo, have developed regeneration strategies such as synchronous and often massive seed release resulting in dense, rapidly developing regeneration following a calamitous disturbance event such as an intense fire that kills the overstorey (or a logging operation and associated regeneration burn). The critical factors affecting regeneration and survival are availability of seed, follow-up rainfall and cohort competition. On the other hand, jarrah, and to a lesser extent, marri, are able to survive even high intensity fires, so have no requirement (biologically) for ensuring 'dense' or 'adequate' regeneration following a single disturbance event. That is, they have developed regeneration/recruitment strategies on the basis of a mature (seed producing) overstorey persisting for centuries. While disturbance (such as fire and logging) favours the establishment of jarrah and marri regeneration, the fire resilience and longevity of the species (350-400 years) does not require them (particularly jarrah) to establish a significant (adequate) pool of regeneration following a single disturbance event. This pool can steadily accumulate on the forest floor and develop (lignotuber, root system) over decades, or even centuries, in response to fires or other disturbances that occur over this time. The rate of establishment and development of regeneration will ultimately be constrained by intrinsic site factors.

Thus, the 'failure' of jarrah stands on some sites to meet regeneration standards defined above is unlikely to be of any ecological consequence in the long term in the absence of timber harvesting. However, it could have significant ecological and timber production consequence where the intention is to return to areas cut to shelterwood in a relatively short time (10-15 years) to remove the mature (seed producing) overstorey. That is, on some sites, the ecology of jarrah may not be well suited to overstorey removal at the scale and time frames required by timber harvesting schedules without management intervention to meet the above regeneration standards. If management intervention aims to 'force' the rate of accumulation and development of regeneration (by removal of competition, soil disturbance, in-fill planting etc.) then this is likely to have impacts on other elements of the forest biota. This may not be an issue, depending on the extent and severity of impact and on the management objectives. The panel is aware that an allowance is made in the sustained yield calculations for the unavailability of forest previously cut to shelterwood, but which has not reached the regeneration standards prior to the scheduled removal of the shelterwood. The Panel also

noted that on some occasions, silvicultural treatments were modified to meet economic objectives.

Species composition (species mix), particularly the dominance of marri regeneration following logging of forest in which the overstorey was predominantly jarrah, is an issue on some sites. Silvicultural Guideline 4/97 states *"where the existing overstorey is predominately jarrah but less than 20% of the regeneration is jarrah, the stand is to be marked as shelterwood with the preference for retention given to jarrah"*. There is no scientific (research) basis for this, but clearly the intent is to maintain jarrah as a significant component of the overstorey of the future forest. The panel visited a site that had been 'gapped' and which had resulted in a dominance of marri regeneration, even though jarrah was represented in the overstorey. We could not ascertain whether the guideline was not adhered to in this instance (this site should have been cut to shelterwood and not gapped) or the jarrah regeneration failed to release, allowing a virtual total dominance of marri.

With the transfer of staff from the Department of Conservation and Land Management to the Forest Products Commission, it is of concern to the panel that there is a lack of native forest silviculture expertise and no ongoing silviculture research in the Department of Conservation and Land Management

Recommendations

- Regeneration survey data should be analysed for trends in regeneration adequacy and site type to identify those sites unlikely to meet regeneration standards.

- The current regeneration (adequacy) standards should be reviewed to better reflect site variability and the recruitment strategies of jarrah. This review may identify a need for further silviculture research across a broader range of site types.

- There is no basis for changing the basic silvicultural treatments with respect to promoting regeneration in areas cut to shelterwood until further research results are available. However, there may be a need to vary the regeneration standards to suit various site types.

- Where economic considerations are likely to affect choice of silvicultural treatment, then the longer-term silvicultural and environmental impacts of this treatment need to be evaluated.

- Better training of field officers is required to ensure that appropriate silvicultural prescriptions are applied.

- The Department of Conservation and Land Management should develop and retain native forest silvicultural expertise.

2.2 Methods of assessing regeneration.

2.2.1 Background

The Department of Conservation and Land Management's Silvicultural Guideline 4/97 outlines the rationale and methodology for post-logging surveys (initial establishment surveys) to assess the adequacy of regeneration, therefore the success of the silvicultural treatment. Surveys are carried out about 12 months after the silvicultural burn, with recommendations that further monitoring be carried out at about 10 years after, and thereafter, 5 years if harvesting of the shelterwood is contemplated.

The Department of Conservation and Land Management is participating in a national project that, in part, aims to develop cost-effective, standardised methods to determine regeneration success in native forests (Wood and Paper Industry Strategy – WAPIS). Part of this project involves a review of regeneration survey methods (accuracy, reliability) currently employed by forest management agencies across Australia. This review found that triangular tessellation, the method used in jarrah forests for estimating seedling density and stocking, was accurate and unbiased (WAPIS 2001).

2.2.2 Observations, research and monitoring

Methods for assessing regeneration have been formally reviewed (see above). No further research into methods appears necessary. Further validation of the method across a wider range of site types may be warranted (see below).

2.2.3 Management implications & Recommendations

Comment
The current method of assessing regeneration in jarrah forests are appropriate. However, the Panel was unable to determine the standard of field implementation of the method or the effectiveness of the method across a range of site types and spatial distributions of regeneration. A significant issue is specifically how the sustained yield calculations deal with the availability, or non-availability of forest previously cut to shelterwood if these forests fail to meet regeneration standards prior to the next scheduled cutting cycle. Failure to meet these standards may not be due to failure of the silvicultural treatment *per se*, but due to intrinsic site factors, as discussed in 2.1.4 above.

Recommendations

- Continue with existing methods for assessing regeneration in jarrah forests but evaluate application and implementation standards. Validation of the methods across a wider range of jarrah forest site types may also be warranted.

2.3 Salinity constraints

2.3.1 Background

Evidence to date from the observed changes in the hydrological responses of several small catchments following timber harvesting and regeneration can be summarised as follows:

- Increases in groundwater levels of 3.5 – 4.5 m in high (greater than 1100 mm mean annual rainfall) and intermediate rainfall zones (900 – 1100 mm mean annual rainfall), and 1 m in the low rainfall zone (less than 900 mm mean annual rainfall).

- Increases in stream salinity have been greatest from catchment without stream buffers or phased logging.

- Return to pre-logging conditions was expected to take 10-15 years, depending on regeneration.

- The potential for increases in stream salinity resulting from logging are greatest in the intermediate rainfall zone (IRZ) due to the possible shallow depth to groundwater and the high salt storage.

2.3.2 Observations, research and monitoring

Research and monitoring as part of the conditions associated with the Forest Management Plan 1994-2003 includes:

- Salt storage assessment using EM31 (see Appendix 3) was assessed to assist in identifying high salt risk catchments. The EM31 was demonstrated to be suitable for estimating soil salinity in valleys and as a basis for determining high salt risk catchments.

- A Paired catchment study in the IRZ using current timber harvesting guidelines has been established. This study will provide important information about impacts on stream salinity from the current approach to timber harvesting and is essential that this study continues.

- Ongoing monitoring in relation to Ministerial Condition 12 includes a) the paired catchment study at Yarragil, which is monitoring rainfall, stream flow, salinity and groundwater, and b) monitoring to ensure that at least 30% of each second order catchment has retained a basal area greater than 15 m^2 ha^{-1} for a period of at least 15 years after harvesting of the remainder.

- The Management Audit Branch within the Department of Conservation & land Management verified in 1999 that the procedures in the logging planning system that identify and mark stream zones, second order catchments in the IRZ, and high salt risk catchments (Ministerial Condition 16) on the logging plan were in place and working. The audit verified that required stream zones were retained in the field, that harvest plans for the sampled coupes had the required retained basal area and that significantly more than 30% of each second order catchment has retained a basal area of greater than 15 m^2 ha^{-1}.

2.3.3 Management implications

Comment
The issue of salinity associated with logging in the IRZ is the substance of Ministerial Condition 16 that has required joint action by the Department of Conservation and Land Management and the Water and Rivers Commission. This action is defined in a record of agreement between the two agencies. Pursuant to this agreement, the Department of Conservation and Land Management has developed an electronic induction technique to determine soil salt loads in environmentaly sensitive catchments, and has surveyed 22 of the 56 drainages within these catchments (see below). In addition, the Department of Conservation and Land Management has commenced a field experiment to investigate the impacts of logging on hydrology and stream water quality in the IRZ (see below).

The methodology adopted to identify second order streams with a high salt risk incorporated:

- A second order catchment with a high salt risk occurs in the intermediate rainfall zone, but excluding the Whicher Scarp, Donnybrook Sunklands and Leeuwin-Naturaliste Ridge (which do not have high salt storage in the soil profile) and have a depth to groundwater of less than 4 m, soil solute concentrations above the groundwater table of greater than 2000 mg/L TSS, and drain into an area environmentaly sensitive to rises in groundwater salinity.
- An area environmentaly sensitive to rises in saline groundwater is one which:

- In part or in its entirety falls within the intermediate rainfall zone, but excluding the Whicher Scarp, Donnybrook Sunklands and Leeuwin-Naturaliste Ridge
- Fed by catchments which remain more than 90% naturally vegetated
- Has no past forest or plantation harvesting which would have yielded groundwater rise sufficient to have raised the salinity of headwater streams in the past

The general protection measures to prevent saline discharges into these watercourses include:

- A permanent 50 m stream buffer on either side of the stream for the portion of the stream that occurs in the intermediate rainfall zone, and

- A two- phased logging operation that ensures an unlogged portion of at least 30% of the upslope cutover area is maintained adjacent to the watercourse during both logging phases, and each logging phase in separated by at least 15 years.

Recommendations

- There is no basis for changing the current silvicultural guidelines that apply in environmentaly sensitive catchments in the IRZ, as defined and agreed to by the Department of Conservation and Land Management and Water and Rivers Commission. The panel agrees that these conditions are conservative and should minimise the risk of logging-induced salinity. Research results should be available in 4-5 years, at which time prescriptions should be reviewed.

2.4 Environmental impacts of silvicultural practices

2.4.1 Background

Conservation of forest biodiversity and maintenance of ecosystem processes is fundamental to achieving ecologically sustainable forest management (ESFM). Timber harvesting has a complex and diverse range of environmental impacts that vary in space and time. Some of these impacts are reasonably well understood while others are not. However, in the absence of clear conservation objectives that are consistent with the principles of ESFM, and that recognise the multiple use purpose of state forests, it is difficult to assess whether or not some of these impacts are in fact ecologically significant in time and space, and therefore warrant changing silvicultural practices.

Unlike silvicultural objectives for commercial timber species, the conservation objectives for other forest taxa and communities are not clear. Setting objectives to conserve and protect the forest biota (in time and space) is far more complex conceptually, operationally and politically. Devising and implementing appropriate strategies and monitoring protocols is equally challenging. These issues confront forest managers world-wide.

The absence of clearly defined biodiversity conservation objectives for forests was of concern to the panel who were of the opinion that there is a need for some agreement as to the identity of the "*environmental elements and values*" referred to in Ministerial condition 11.1. It is in everyone's interests that any negative impacts of timber harvesting be minimised in the long term, which is embodied in the Department of Conservation and Land Management's stated objective of 1992, to manage the native forests:

> *"...in consultation with the community so that they provide the values required by society while sustaining indefinitely their biological and social diversity".*

In the review of 'Management Strategies for the South-West Forests of Western Australia' (Department of Conservation and Land Management 1992) the following values are referred to either directly or indirectly, and the panel agrees that they should be considered in any evaluation of harvesting methods, including scale and spatial distribution of forest operations, over the last 10 years.

- Water, nutrient and carbon cycles
- Diversity through forest structure
- Biodiversity
- Heritage
- Water yield and quality.
- Wood production
- Aesthetics of forests used for tourism and recreation
- Minerals.
- Honey, wildflowers and seed

These values are now most commonly referred to in the context of the six principles adopted for Ecologically Sustainable Forest Management (ESFM) expressed under the Intergovernmental agreement on the environment and the National Forest Policy statement. These are often referred to as the Montreal Criteria. The precautionary principle and intergenerational equity are two additional and overriding principles giving guidance for management decision making and now embodied in the Department of Conservation and Land Management Act amendments of 2000.

2.4.2 Proposed Conservation Objectives for Forests

The maintenance of biodiversity and of the ecological processes upon which it depends is fundamental to the principle of ESFM. Setting forest biodiversity conservation objectives is not straight forward because of the complexity of biodiversity through space and time and because knowledge of biodiversity and disturbance ecology is incomplete. Notwithstanding this, having clear conservation objectives for forests is of key strategic importance. It will assist with setting silvicultural objectives and standards, with determining sustained yield and with assessing the acceptability or otherwise of the environmental impacts of timber harvesting as they are understood from the research and monitoring. The following is a proposed hierarchical set of conservation objectives for forests for consideration (some objectives could be considered as strategies). These objectives should complement (rather than replace) existing codes of practice and silvicultural objectives. An important strategic issue for the Department is the resolve with which conservation objectives are set. For example, should the objectives explicitly state that "*no species will become extinct as a result of management activities*", or should the objective be "*to take all reasonable measures to ensure that no species become extinct*"?

At the landscape scale: A definition of a landscape:

"A mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area. Several attributes, including geology, soil types, vegetation types, local faunas, climate and natural disturbance regimes tend to be similar and repeated across the whole area" (Forman 1995). *Scale is usually tens of thousands of hectares.*

Bio-physically-based amalgamations of the Mattiske & Havel (1998) vegetation complexes form a basis for identifying landscape units.

Landscape scale conservation objectives: *Take all reasonable measures to:*

- *Ensure adequate reservation of forest landscapes.*

- *Ensure that no species declines to irretrievably low levels as a result of forest management activities.*
- *Ensure a diverse representation of forest structures/habitats and seral stages through time and space with an interlocking mosaic of forest at different stages of development including new growth and old growth stages.*
- *Protect ecologically sensitive areas and niches such as riparian zones, aquatic ecosystems, wetlands, granite outcrops and other non-forested complexes.*
- *Ensure maintenance of water quality.*

At the forest patch scale: A definition of a forest patch:
A spatial element within a landscape. It could be a (sub) catchment or a mapped management boundary, such as a forest block - it could contain a representation of landforms and ecosystems common to the landscape unit. Scale usually several hundred to several thousand hectares

Forest patch (block) scale conservation objectives: *To take all reasonable measures to:*
- *Ensure biodiversity (species richness) recovers before the next rotation length.*
- *Ensure that the capacity of the block to provide the range of habitat elements that it provided before timber harvesting is not permanently compromised due to timber harvesting.*
- *Ensure at least 20% (including road and stream reserves) of the forest block retains mature or old growth overstorey structural characteristics.*
- *Prevent the introduction and spread of dieback.*
- *Minimise the introduction and spread of weeds and other aliens*

At the coupe scale: A definition of a coupe:
An area contained within a cutting boundary (including a gap, an area cut to shelterwood or thinned).Scale usually from a few hectares to several hundred hectares.

Coupe scale conservation objectives: *To take all reasonable measures to:*
- *Ensure that the capacity of the coupe to provide the range of habitat elements that it provided before timber harvesting is not permanently compromised due to timber harvesting.*
- *Prevent soil erosion*
- *Minimise soil damage (compaction, profile-mixing, puddling).*

Threatened / listed taxa: These have legislative protection:
- To take all reasonable measures to protect (retain at viable levels) **all** populations of threatened/listed taxa/communities. (note: viable population levels will be unknown for most species – scientists will need to provide 'best bet' in absence of hard data).

We reiterate that the above is a starting point for the complex but necessary task of defining forest conservation objectives in the context of multiple use forests and ESFM. This process requires wide public debate and should be an important issue addressed by the current forest management planning process.

2.4.3 Observations, research and monitoring

Research undertaken by the Department can be characterised as being directly applicable to understanding the impacts of jarrah silvicultural systems on elements of the biota, or research that adds to a knowledge and understanding of jarrah forest ecosystems generally. While the panel acknowledges that there has been an ongoing program of research that adds to a body of knowledge of jarrah forest ecosystems, there was limited research activity focussed specifically on the ecological effects of timber harvesting in jarrah forests prior to 1994,

beyond hydrological and silvicultural studies. At this time, the Department commenced a major, muliti-disciplinary scientific investigation into the impacts of timber harvesting on jarrah forest ecosystems in Kingston, Warrup and Winnejup State forests (the Kingston Project). The details of this investigation are contained in Burrows *et al.* 1994. The objective of this study was to investigate the acute (five years post-logging) impacts of timber harvesting on a jarrah forest ecosystem. Key elements of the study can be summarised as:

- Detailed investigation of a routine, operational-scale timber harvesting in low to intermediate rainfall (800 mm) jarrah forest (Unicup Plains vegetation complexes - Mattiske & Havel 1998).
- A wide range of taxonomic groups was studied including mammals, birds, herpetofauna, litter/surface–dwelling invertebrates, vascular plants and cryptogams. The level and extent of soil disturbance/damage was also documented.
- Sampling was integrated (fixed grids) to better understand and interpret impacts.
- The study was a BACI (before, after, control, impact) design with replicates.
- Treatments included gap cutting (with and without retained habitat trees), shelterwood cutting, internal controls (unlogged buffers between coupes, temporary exclusion areas) and external controls (uncut or lightly cut forest up to five km from the silvicultural treatments).
- Multi-disciplinary
- In addition to Department of Conservation and Land Management scientists, the study involved three PhD students form local tertiary institutions and numerous volunteers.
- The Kingston Project is one of only a few projects to comprehensively investigate the ecological impacts of timber harvesting in Australian eucalypt forests.

An internal (Department of Conservation and Land Management) workshop on the environmental effects of timber harvesting in the jarrah forest was held at the Perup Forest Ecology Centre in May this year. A report on the outcomes of this workshop, including a synthesis of research findings and recommendations to forest managers is provided at Appendix 3. As the data collection/field component of much of this research has only recently been completed, there are few publications in scientific journals as yet. Research into the environmental impacts of timber harvesting in jarrah forests are summarised in Table 1.

Table 1: A summary of relevant research and monitoring that focus specifically on the environmental impacts of timber harvesting on jarrah forest ecosystems since 1992.

Project title	Supervising Scientist
Short-term impacts of logging on understorey vegetation in the jarrah forest	Dr Neil Burrows (Conservation & Land Management)
A survey of cryptogam response to logging	Ray Cranfield (Conservation & Land Management)
Overstorey structural changes following gap and shelterwood cutting	Bruce Ward (Conservation & Land Management)
A survey of soil disturbance following logging	Bruce Ward (Conservation & Land Management)
Evaluation of key soil indicators of sustainability in Australian Mediterranean forests	Kim Whitford (Conservation & Land Management)
Using electronic induction to estimate soil salt storage	Joe Kinal (Conservation & Land Management)
Hydrological response to logging in the intermediate rainfall zone of the jarrah forest	Joe Kinal (Conservation & Land Management)
Short-term effects of timber harvesting on jarrah forest invertebrates	Karen Strehlow (Murdoch University)
Logging and burning impacts on cockroaches, crickets and grasshoppers, and spiders in the jarrah forest (3-5 yrs post-logging)	Dr Ian Abbott (Conservation & Land Management)

Short-term impacts of timber harvesting on jarrah forest birds	Mike Craig (UWA)
Short-term impacts of logging on birds in the jarrah forest at Kingston (3-5 yrs post-logging)	Graeme Liddelow (Conservation & Land Management)
Tree hollows in jarrah and marri	Kim Whitford (Conservation & Land Management)
Response of small terrestrial vertebrates to timber harvesting at Kingston	Adrian Wayne (Conservation & Land Management)
Response of medium-size ground dwelling mammals to harvesting at Kingston	Adrian Wayne (Conservation & Land Management)
Effects of timber harvesting on brushtail phascogale	Susan Rhind (Murdoch University)
Brushtail Possum responses to timber harvesting at Kingston	Adrian Wayne (Conservation & Land Management)
Western Ringtail Possum responses to timber harvesting at Kingston	Adrian Wayne (Conservation & Land Management)
Chuditch habitat requirements	Keith Morris (Conservation & Land Management)
Fox control in the jarrah forest	Paul deTores (Conservation & Land Management)
Western ringtail possum habitat requirements – northern jarrah forest	Paul deTores (Conservation & Land Management)
Woody debris (logs) on the jarrah forest floor before and after logging	Bruce Ward (Conservation & Land Management)
Monitoring forest red-tail black cockatoos	Dr Ian Abbott (Conservation & Land Management)
Monitoring response of water catchment following logging and burning (Yarrigal)	Joe Kinal (Conservation & land Management)
Monitoring tree regeneration after harvesting in jarrah	Mark Virgo (FPC)
Seedfall in jarrah pole stands.	Kim Whitford (Conservation & Land management)
Monitoring forest & woodland owls	G. Liddelow (Conservation & Land Management)

In addition to projects listed in Table 1 above, there are a number of related projects that are not specifically focussed on the environmental impacts of contemporary silvicultural systems, but add to a knowledge of jarrah forest ecosystems. These are listed in Table 2 below.

Table 2: Summary of research and monitoring activities that adds to knowledge of jarrah forest ecology and management.

Project title	Supervising Scientist
Impacts of prescribed burning on the vertebrate fauna of the jarrah forest	Adrian Wayne, (Conservation & land Management)
Impacts of prescribed burning on litter invertebrates of the central jarrah forest.	Paul Van Heurck (Conservation & land Management)
Annual monitoring of Western Grey Kangaroo and Brush Wallaby in eastern jarrah forest.	Graeme Liddelow (Conservation & land Management)
Monitoring medium size mammals in the eastern jarrah forest.	Graeme Liddelow (Conservation & land Management)
Monitoring the effects of fire regimes on understorey plants of the jarrah forest.	Neil Burrows (Conservation & land Management)
Survival and growth of dieback-resistant jarrah.	Mike Stukely (Conservation & land Management)

Impact of Phytophthora cinnamomi deliberately introduced to vegetation of jarrah forests.	Neil Gibson (Conservation & land Management)
Monitoring expansion of jarrah leafminer	Tom Burbidge (Conservation & land Management)
Levels of infestation by jarrah leafminer.	Ian Abbott (Conservation & land Management)
Monitoring Uraba lugens populations	Janet Farr (Conservation & land Management)
Growth of jarrah pole trees and stands.	Kim Whitford (Conservation & land Management)
Western Shield – monitoring native fauna in response to fox control and re-introductions	Peter Mawson (Conservation & land Management)
Monitoring numbats in northern jarrah forests.	Tony Friend (Conservation & land Management)
Monitoring rare flora populations	Wildlife Branch (Conservation & land Management)
Monitoring Chuditch recovery	Nature Conservation Officer, Mundaring (Conservation & land Management)
Monitoring Woylies in the Hills Forest	Nature Conservation Officer, Mundaring (Conservation & land Management)

The following summarises key research findings 4-5 years after timber harvesting associated with the Kingston Project. More detail is provided in Appendix 3:

- Woylie (*Bettongia penicillata*) and Quenda (*Isoodon obesulus*): Were not adversely affected. Abundance of these species increased across all treatments following routine fox control carried out as part of Western Shield.
- Brushtailed phascogale (*Phascogale tapoatafa*): Declined across all sites (including controls), and regionally, before logging occurred. No Phascogales have been captured on any grids since 1995. The impacts of timber harvesting on this species remain unresolved.
- Frogs and reptiles: Capture rates were too low across all sites to draw statistical conclusions about the impacts of timber harvesting. No evidence of adverse impacts. Species present before timber harvesting were present after timber harvesting.
- Chuditch (*Dasyurus geoffroii*): Because of the large home range of this species compared with the scale of logging treatments, the response of chuditch was examined at the landscape scale. Strong populations of chuditch persist in the study area and do not appear to have been adversely affected by timber harvesting.
- Brushtail Possum (*Trichosurus vulpecula*): Increased significantly across all sites in response to fox control then declined by 30-35% in logged areas. Habitat trees important. *Banksia, Gastrolobium* and other understorey species seasonally important food source. Unlogged patches (reserves and TEAS buffers) were important for upholding abundance. Valuable information on refuge sites will help modification of silvicultural prescriptions.
- Western Ringtail Possum (*Psuedocheirus occidentalis*). A total of 17 treatment animals (in logged areas) and 12 control animals (in unlogged areas) were radio collared prior to timber harvesting. Eighteen per cent of radio-collared animals in logged areas died during falling operations. Within 3 weeks of logging, 70% of radio collared animals in the logged areas had died; all were dead within 20 months of logging but before burning. Most deaths post-logging were due to predation (fox and feral cat). Animals in the unlogged control area eventually died, but lived for considerably longer (up to 40 months) than those on the logged sites. Regular spotlighting surveys showed a decline across all sites (including unlogged areas) since logging, with greatest declines in logged areas. Spotlight surveys carried out in the Perup Nature Reserve some 20 km to the west of the study site showed no significant fluctuations in populations of WRP. Increased exposure

to predation following logging and burning and reduced recruitment were probable causes of overall decline at the landscape scale. Unlogged buffers (reserves and TEAS) were important for maintaining populations. New and important data on habitat requirements (refuges, food sources, breeding shelters) of WRP are important for modifying silvicultural prescriptions to minimise logging impact on WRP populations.

- Birds: In logged areas, no significant change in species richness - some species decreased (canopy dependent), some increased, some remained about the same. Significant decrease in overall abundance following logging in gap treatment but slowly recovering. Shelterwood recovering to near pre-logging levels. Unlogged buffers (reserves and TEAS) important for maintaining populations of species that prefer overstorey and complex forest structures.
- Leaf litter arthropods: Most species resilient to logging and burning. Immediate post-treatment decrease but rapid recovery. Minimal changes in community structure. Seasonal (climatic) variation influenced community structure.
- Tree Hollows: Reliable relationships developed to enable prediction of hollows occurrence across forest for a wide range of hollow-dependent fauna. Enables better selection of habitat tress for retention.
- Hydrological response to logging in IRZ: Links with Ministerial condition 16. Study in early stages – treatments have been carried out, no results to date.
- Identifying "*high salt risk - environmentally sensitive catchments*" in the IRZ: Links with Ministerial Condition 16: Fifty-six catchments in the IRZ have been identified by CALM and Water & Rivers Commission as environmentally sensitive. Twenty-two of these have been surveyed using electromagnetic induction to estimate soil salt storage. Salt levels in the upper 4m soil horizon exceed 2000 mg/L TSS along at least half the length of the second order stream. The technique provides a good basis for identifying high salt risk catchments.
- Evaluation of key soil indicators of sustainability: Relates to Montreal Process Criteria and Indicators of ESFM: Inverse relationship between fine earth bulk density and surface soil carbon. Increase in % C content of the surface soil with decreasing fire frequency, but also decrease in fine earth bulk density with increase in fire interval.
- Impact of logging on soil physical properties: 30-80% of the area of logged coupes shows visual signs of soil disturbance. Snig tracks are a major cause of disturbance/damage on logging coupes. About 10% of coupe area exceeds acceptable bulk density increases.
- Understorey vegetation: No loss of species richness or significant differences in native species assemblages in logged areas. Overall 20-35% reduction in abundance of native plants. Reductions across variety of life forms, but geophytes most susceptible. Reduction in abundance due to physical/mechanical impacts of logging, post-logging treatments and localised super-heating of the topsoil associated with burning of logging debris. Increase in abundance and richness of weed species. Cover reduced from about 65% to 15% in gaps, but recovering with time.
- There is no evidence that forest red-tailed black cockatoos are declining in response to timber harvesting. Forest-dwelling owls are widely distributed but at low densities throughout the forest and adjacent woodlands. There is no evidence that numbers are declining in response to timber harvesting.

2.4.4 Management implications and recommendations

Comment

Recommended changes or modifications to forest management practices in order to protect biodiversity and ecological processes can best be made a) with the benefit of good science and b) with a clear understanding of the conservation objectives for forests as a whole. Some of the findings of the research and monitoring programs listed above provide a sound scientific basis for modifying or changing forest management practices. The following recommendations are made in the context of the conservation objectives proposed above. An internal (Department of Conservation & land Management) working group recently

developed a detailed set of suggested changes to the existing silvicultural guidelines based on recent research findings. These are at Appendix 4; the Panel recommends the adoption of these suggested changes. The following is a summary of the bases for adjusting management practices to reduce negative environmental impacts of timber harvesting in jarrah forests.

Issue: Management of habitat for arboreals and hollow dependent fauna:

Comment
The studies carried out as part of the Kingston Project have shown that ground dwelling fauna (invertebrates and vertebrates) appear little affected by logging and associated burning activities. However, logging has had some short-term adverse impacts on some arboreal fauna.

Observations and Recommendations:

- Retained forest (reserves and TEAS) are important for buffering vertebrate fauna (birds and mammals particularly) against the acute impacts of logging and associated burning. There is merit in retaining a proportion of mature forest, or forest with old growth attributes, on forest blocks (see below).
- Logging (and associated burning) predisposes Western Ringtail Possums to predation by foxes and feral cats because a) it enhances access for predators and b) possums spend longer periods on the ground when tress are removed, so are vulnerable to predation. Current fox control measures need to be reviewed.
- Radio tracking data show Western Ringtail Possums utilise more 'habitat' trees than first thought. There is a good basis for increasing the number of retained habitat trees on logged coupes.
- There is now better information available for the selection of appropriate habitat trees. This should be incorporated into the guidelines.
- Balga, or grass trees, are an important refuge for Western Ringtail Possums so should be protected during logging operations and subsequent silvicultural burns where possible.
- Brushtail Possums also declined following logging but not to the same extent as Western Ringtail Possums. Measures taken to provide for the Western Ringtail Possums should also benefit Brushtail Possums and other arboreals.
- Understorey trees such as *Banksia grandis* are a seasonally important food source. Scattered mature individuals should be retained.
- There is good evidence for retaining a portion of the forest block as uncut, or with mature characteristics to provide refuge for birds and mammals that require this type of habitat. Retained, uncut patches of mature or old growth forest are important sources of recolonisation for some species. The extent of retention of uncut forest should be determined on the basis of the condition and tenure of adjacent forest. The literature on viable populations for forest fauna is limited. Alliances with island and remnant habitat studies suggest retaining 50-200 individuals for mammals (e.g., see Main 1971, Bennet 1987, Friend 1987). Western Ringtail Possums have a home range of about 3-5 ha, and using this species as an indicator, retaining mature (or old growth) patches of about 200 ha (minimum) in a matrix of regrowth forest on a forest block, preferably continuous or connected (eg, creek lines), should be considered until better information is available.
- Silviculturalists and field officers involved with coupe management should be trained in basic biology and ecology of hollow users and arboreal fauna particularly, and in recognising the best habitat trees for retention.

Issue: Flora conservation:
Comment:
In the short term, logging causes a significant reduction in the abundance and cover of native understorey vegetation. The primary cause of this is mechanical damage and disturbance/damage to subterranean organs (rootstocks, bulbs, corms, rhizomes, and tubers) during logging operations and post-logging disturbance to prepare a seedbed for tree species

or to reduce "competition" to tree species, as specified in the silvicultural guidelines (1/95). The time to recovery of the understorey, and the longer-term ecological consequences of this are unknown. The current silvicultural guideline (1/95) requires that these activities be restricted to patches of forest where "severe competition" (thickets) from species such as banksia (*Banksia grandis*), tea tree (*Agonis parviceps*) and sheaoak (*Allocasurina fraseriana*) is likely to impede the regeneration and development of tree species. It appears that there is some uncertainty about what constitutes severe competition, with the knockdown of understorey tree species and reduction of understorey vegetation being applied more widely.

Recommendations:

- Better definition of what constitutes severe competition to tree species and better training of silviculturalists and field staff to enable them to determine what constitutes severe competition to minimise unnecessary disturbance/damage to the understorey vegetation.
- Banksias are a seasonally important food base for many animals. Scattered individuals (as opposed to thickets) of understorey tree species such as banksias, sheoaks, snottygobble (*Persoonia longifolia*, *P. elleptica*), woody pear (*Xylomelum occidentale*) should not be removed.

Issue: Soil damage:
Comment:
The topsoil of the ancient, highly weathered and nutrient depleted soils of the jarrah forest is critical for sustaining life. Therefore, protection of the topsoil is fundamental to ESFM, including the long-term productivity of the forest. Soil is considered 'damaged' when its bulk density is increased by more than 20% or when profiles are mixed (see Appendix 3). The above research (Table 1) has shown that around 10% of the soil surface area on logging coupes is damaged and up to 70% is disturbed. Knowing the importance of soil conservation, many forest management agencies in other parts of the world have in place comprehensive codes of practice to minimise soil damage (see Ministry of Forests 2000).

Recommendations:

- The Department of Conservation & Land Management develop a comprehensive Forest Practices Code for the conservation of forest soils. The following interim measures should be considered.
- The layout of snig tracks and landings should be designed in such a way as to minimise machine traffic on the coupes, thereby minimising soil damage.
- Restrict logging to dry soil conditions to minimise soil damage and the spread of dieback.

2.5 Audits on forest operations

Audit is an important component of management quality control in that it reports on the extent, effectiveness and efficiency of management systems in place. While the Panel was not specifically asked to address auditing, it is our view that the Department of Conservation & Land Management has made good progress in internal auditing of key forest operations. and that this should be recognised. Forest activity audits undertaken over the period January 1st 1999 to June 30th 2001 are summarised in Table 3 below.

Recommendation:

The Department should consider including a summary of forest management audits in its compliance report to the EPA as a further demonstration of management systems in place to ensure high standards of forest management.

Table 3: A summary of forest activity audits for the period January 1st 1999 to June 30th 2001 (courtesy P. Ryan, Management Audit Branch, Department of Conservation & Land Management).

No	Description	Objective
99_04	Noxious weed control	Audit and review the effectiveness and efficiency of the management system in place for noxious weed control. The audit was conducted as a part of the Management Audit requirement to audit all activities associated with forest operations in the Southwest.
99_08	Mining other than bauxite	Audit and review the effectiveness and efficiency of the management system in place for mining, other than bauxite mining, and for basic raw materials. The audit was conducted as a part of the Management Audit requirement to audit all activities associated with forest operations in the Southwest.
99_12	Native forest establishment & tending	Audit was to examine the effectiveness and efficiency of the management system in place to re-establish karri forest after logging and manage the stand until maturity. The examination tested in relation to the six standard audit objectives
99_14	Native forest harvesting and soil protection	Audit examined the processes involved for the protection of soil during native forest harvesting operations in winter, including rehabilitation measures, in the Southern Supply Area.
99_36	Native forest harvesting - utilisation	Audit was to examine the effectiveness of measures in place, which are designed to maximize utilization of timber product, in the round, at in-forest landings.
99_38	Dieback mapping	Audit was to review the effectiveness and efficiency of the management system in place for dieback mapping.
2000_03	Native forest harvesting coupe management	Audit and review the effectiveness and efficiency of the management system in place for coupe management and environmental protection aspects during timber harvesting operations.
2000_04	Native forest harvesting – dieback hygiene	Audit examined the processes in place for environmental protection from the soil-borne pathogen Phytophthora cinnamomi in harvesting operations applied in native forests.
2000_15	Native forest establishment & tending	Evaluate the effectiveness of the system in place for jarrah establishment, and to evaluate compliance with jarrah establishment and tending specifications and guidelines.
2000_38	Native forest harvesting – jarrah utilisation	Audit was to examine the effectiveness of measures in place, which are designed to maximize utilisation of timber product, in the round, at in-forest landings.
2001_15	Dieback hygiene management	Evaluate the effectiveness of the system in place for Dieback Hygiene Management, and to evaluate compliance with hygiene procedures and guidelines.
2001_31	Native forest harvesting coupe management & environmental protection	Determine whether the Forest Products Commission's harvesting operations meet the requirements of the Forest Management Plan 1994-2003, the Ministerial Conditions and Proponent Commitments on its implementation and CALM's Environmental Code of Practice and management guidelines.

3. Monitoring and the Adequacy of FORESTCHECK

3.1 Background

Ministerial Condition 11.1 specifically refers to the need to monitor the environmental impacts of jarrah silvicultural prescriptions on a representative range of treated sites. This approach could require that where there is a significant risk that a particular forest management measure could lead to an irreversible consequence, appropriate monitoring and subsequent adjustments to management within an acceptable time frame be carried out. Monitoring is also referred to in other Ministerial Conditions:

3-1 *The proponent shall manage the jarrah forest in accordance with the following general principles....;*
(2) adaptive and flexible management practices based on research and monitoring of environmental monitoring of operations...;

5-3 *The proponent shall monitor the effectiveness of the travel route (road) river and stream reserves for nature conservation and protection of water quality to the requirements of the Minister for the Environment.*

12-3 *The proponent shall monitor, to the requirements of the Minister for the Environment, and report by 2002 on the status and effectiveness of these measures to protect nature conservation values and water quality at the time of the next review of the Forest Management Plans and Timber Strategy.*

In signing the RFA, the WA Government agreed to:

42. *Within 5 years of the date of this Agreement, Western Australia will further improve its Forest Management System and processes through the development and implementation of environmental management systems in accordance with the principles specified in Attachment 13 and the actions identified in Attachment 5 and acknowledges that its objective for native forest management under the CALM Act is system certification comparable with ISO 14000 series. The Parties note that such a system would include independent auditing of compliance with Codes of Practice and the Forest Management Plan.*

46. *Western Australia will report on the results of monitoring of sustainability indicators as part of each 5-year review and report in accordance with Clauses 36 and 37.*

47. *Comprehensive Regional Assessments, the development of criteria and indicators for sustainable forest management through the Montreal Process and the development of this Agreement have provided extensive opportunities for public participation and reporting. Parties note the range of reporting and consultative mechanisms that currently exist in Western Australia (see Attachment 4) and agree that Western Australia will further develop these by implementing the improvements specified in Attachment 4.*

51. *The Parties agree that the current Forest Management System will be enhanced by further developing appropriate mechanisms to monitor and review the sustainability of Forest management practices. To ensure that this occurs, in consultation with the Commonwealth, the State agrees to establish an appropriate set of sustainability indicators to monitor Forest changes. Any indicators established will be consistent with the Montreal Process Criteria (as amended from time to time), the current form of which is specified in Attachment 7, and will take into account the framework of*

regional indicators developed by the Montreal Process Implementation Group. Western Australia will implement those indicators, which are practical, measurable, cost-effective and capable of being implemented at the regional level and will monitor them at an appropriate frequency determined in consultation with the Commonwealth.

52. *Development of indicators, and collection of results for those indicators, which can be readily implemented, will be completed in time to enable reporting during the first five-yearly review of this Agreement.*

These formal requirements to monitor the environmental impacts of timber harvesting reflect community concern and expectations that forest management agencies can provide evidence by way of data gathered through monitoring, that timber harvesting is ecologically sustainable and does not permanently diminish the ecological integrity of forests (biodiversity, productivity, soils and water).

The Kingston Project (outlined above) has provided valuable information about the impacts of timber harvesting at a particular site. However, it does not represent the diverse range of jarrah forest sites that have been logged since 1994, or that will be logged beyond 2003. The Kingston Project has also provided a road map to the development of a forest monitoring protocol. Using the knowledge gained from Kingston, and via a series on internal and external workshops, the Science Division of the Department of Conservation & land Management have developed FORESTCHECK, a framework devised in 1999 to quantify, record, interpret and report on the status of key forest organisms, communities, and processes in response to both forest management activities and natural variation

The terms of reference require the Panel's view on the sufficiency of FORESTCHECK as a future means of data collection in monitoring the impacts on biodiversity of the application of silvicultural guidelines in the jarrah forest.

The Panel is aware of the extensive consultation and workshops with scientists that has underpinned the present draft of FORESTCHECK. The strategy advocated is one that targets a broad range of organisms for initial monitoring at relatively few sites in logged jarrah forest. This approach is based on the premise that it is difficult to forecast which organisms are least resilient to timber harvesting and, therefore, it is best to document as wide a range of species as possible in the monitoring program.

The Panel is satisfied that FORESTCHECK is workable and implementable. However, it may be unnecessarily complex in that it requires gathering a considerable amount of detailed information at relatively few sites. Resource limitations will constrain the number of sites, or replications, at which this detail can be gathered. A limitation of this approach is that it sacrifices geographical replication in favour of taxonomic comprehensiveness. The Panel is concerned that such a strategy overlooks a fundamental biogeographical attribute of the less fragile components of the jarrah forest biota – a relatively high rate of geographical replacement of species across the landscape. Indeed, this is a pattern for which the whole south-west botanical province is world-renowned.

Consequently, the Panel considers that a more strategic approach to monitoring after timber harvesting would be to target a smaller number of species, or guilds, and achieve greater geographical replication across the jarrah forest. The choice of species should focus on a) threatened and listed taxa, and b) those whose life histories and reproductive biology suggest low resilience to the impacts of timber harvesting based on the best available biological knowledge (indicator species). While such a strategy has the advantage of focussing effort on taxa most vulnerable to timber harvesting, there is a risk that present biological knowledge is

insufficient to identify some such taxa at risk. Therefore, the Panel recommends regular review of this strategy under an adaptive management model so that the list of monitored taxa remains current in terms of those least resilient to timber harvesting.

The Panel recommends a 12 month trial operation of FORESTCHECK on several sites where both strategies (that proposed by FORESTCHECK and that proposed by the Panel) can be evaluated to compare and contrast the cost-effectiveness of the two techniques. The trail should aim to identify indicators species, to evaluate their usefulness and utility, and to recommend which of the two strategies is most informative, cost-effective and representative. The results of this trail should be reported to the Conservation Commission and to the EPA.

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Appendix 1

Significant Public Documents as background to Department of Conservation & Land Management's reporting requirements.

- Department of Conservation & Land Management (1992). Management Strategies for the South-West forests of Western Australia: A Review.
- Department of Conservation & Land Management (1994). The Forest Management Plan 1994-2003.
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- Department of Conservation & Land Management Response (1998). CALM's Compliance with Ministerial Conditions on the Forest management Plans 1994-2003. A Response to the EPA Bulletin 912.
- Codd, M. (1999). Forest Management Plans 1994-2003: Mid-term EPA Report on Compliance.
- EPA Bulletin 983. Advice regarding changes to Environmental conditions in relation to recommendations of the Ministerial advisory group on karri and tingle management
- EPA Bulletin 928 Amendments to the 1987 forest Management Plans and Timber Strategy and proposals to meet environmental conditions of the regional plans and the WACAP EMP - Change to Environmental condition 17.
- Department of Conservation & Land Management (2000). Implementation of the Codd Report. The reasons leading to the expanded use of Shelterwood silvicultural prescription, the research being undertaken and the implications for forest Yield
- Commonwealth of Australia and Western Australian government (1997) Report of the Independent Expert Advisory Group. Assessment of Ecologically sustainable forest management in the south-west forest region of Western Australia

Appendix 2

Proponent's Consolidated Commitments
Forest Management Plan 1994-2003

Number Commitment	Commitment
1	Identify and publish the values to be managed for in each forest area.
2	Implement long term monitoring programs to identify and study significant management issues in (all types of) forests.
3	Regulate the production of forest resources to levels that can be sustained indefinitely.
4	Preserve the quality of potable water supplies from forests.
5	Undertake research to improve a scientific basis for the protection of biodiversity.
6	Conduct prescribed bums in river and stream zones so as to be of low intensity.
7	Conduct prescribed burning in diverse ecotype zones in accordance with habitat requirements of the site.
8	Prevent logging in river and stream zones for other than legitimate road construction and the removal of dangerous trees.
9	Identify areas of high value old growth forest.
10	Further enhance the security and representation of the conservation reserve system.
11	Allow identified areas of regrowth Karri to acquire old growth characteristics, including 25% of pre 1940 regrowth, all regrowth stands regenerated in the period between 1940 and 1975 less than 200 ha in area, and 50% of all stands regenerated after 1990.
12	Retain an average of (at least) 3 large trees on every hectare harvested to provide habitat.
13	Retain, and protect as far as possible, at least one suitable ground habitat, ie hollow log, per hectare.
14	Undertake habitat and regeneration bums in forests where special requirements for threatened or endangered species are identified.
15	For those gh salt risk second order catchments identified in fulfilment of MCI6, CALM will reach agreement with the Water and Rivers Commission regarding the precautionary management and protection measures to be implemented. The objective of the measures will be to prevent saline discharge into these water courses.
16	Limit gap size in Karri and Karri/Marri forests to a maximum of 80 ha
17	Where possible, ensure the distances between areas of retained mature forest is a maximum of 400 m.
18	Formalise Karri Silvicultural changes in a CALM Silvicultural prescription.

APPENDIX 3

A WORKSHOP ON ENVIRONMENTAL EFFECTS OF TIMBER HARVESTING IN THE JARRAH FOREST

Perup Forest Ecology Centre
7&8 May 2001

A synthesis of recent research by the Science Division, Department of Conservation & Land Management

1. Objectives of the workshop

a) To provide forest managers and policy-makers with a comprehensive overview of research findings relevant to the environmental effects of timber harvesting in the Jarrah forest;

b) To identify mechanisms by which current research findings can be incorporated in the revision of silvicultural guidelines and the next Forest Management Plan (FMP).

2. Format for sessions

Presenters were asked to:
- Briefly overview the methodology used in their study, sufficient to make results interpretable.
- Summarise the key findings, giving priority to those that have implications for management and that can be manipulated by future silvicultural practices.
- Make recommendations for changes to management practices that could be considered in the context of the next Forest Management Plan.

3. Summary of presentations

Attached are brief summaries of most presentations made at the workshop, together with a statement from the authors regarding the key management implications of their findings:

- *Short term impacts of logging on understorey vegetation in the Jarrah forest* (Neil Burrows, Bruce Ward & Ray Cranfield).
- *Evaluation of key soil indicators of sustainability in Australian Mediterranean forests* (Kim Whitford)
- *Using electromagnetic induction to estimate soil salt storage* (Joe Kinal)
- *Hydrological response to logging in the intermediate rainfall zone of the jarrah forest* (Joe Kinal)
- *Logging and burning impacts on cockroaches, crickets and grasshoppers, and spiders in Jarrah forest* (Ian Abbott and colleagues)
- *Short-term Impacts of Logging on Birds in a Jarrah Forest at Kingston* (Graeme Liddelow)
- *Tree hollows in Jarrah and Marri* (Kim Whitford)
- *Response of terrestrial vertebrates to timber harvesting at Kingston* (Adrian Wayne and colleagues)

- *Brushtail Possum (Koomal) responses to timber harvesting at Kingston* (Adrian Wayne and colleagues)
- *Western Ringtail Possum (Ngwayir) responses to timber harvesting at Kingston* (Adrian Wayne and colleagues)

Summaries of presentations made by Keith Morris on management of the Chuditch, and by Paul de Tores on fox baiting and on the ecology and conservation status of the Western Ringtail Possum are currently being prepared.

4. Issues identified and discussed

4.1 Issues were divided into three categories according to whether they were relevant to:

- meeting compliance requirements for the current FMP,
- providing direction to or constraints on the new FMP,
- modification of silvicultural guidelines and codes of practice.

4.2 Issues relating to compliance requirements for the current FMP

All of the information presented from the Kingston study and associated projects is relevant to demonstrating compliance with conditions placed on the current plan, notably:
- Ministerial Condition 3 - Precautionary approach and,
- Ministerial Condition 11 - Jarrah silvicultural trial.

Specific projects have also provided information relevant to:
- Ministerial Conditions 12 and 16 – Phased logging and high salt risk catchments,
- Ministerial Condition 13 – Habitat trees

4.3 Issues relating to preparation of the next FMP

An appropriate and achievable scale for managing and monitoring achievement of ESFM needs to be determined. Suitable scales could include the forest block, catchment (3^{rd} or 4^{th} order), or some other landscape unit.

Conservation objectives for species, guilds and communities of plants and animals that are specific enough to be measured at intervals over time need to be developed. This would provide guidance to forest managers about the success in achieving ESFM. Focus groups comprised of scientists and managers may be used to develop initial objectives. Science Division staff with specific expertise on particular aspects of ESFM should liaise with staff from SFM Division and with the team responsible for preparation of the draft plan. This needs to happen over the next 2-3 months.

Management of TEAS in the second cutting cycle under the current silvicultural prescription needs to be reviewed, in particular:
- length of time between initial gap creation and TEAS removal,
- silviculture for the second cut.

There may be merit in conducting some experimental studies at Kingston where TEAS are removed at a ten-year interval following the initial harvest, in order to determine the sensitivity of different plant and animal guilds to this disturbance. To allow ongoing silvicultural experimentation, the design of the proposed Greater Kingston National Park should aim to exclude the central group of experimental grids. Aspects of provisional reserve design have been discussed with Geoff Stoneman.

Shelterwood harvesting in the intermediate and low rainfall zone during the next planning period will be a significant influence on ecological outcomes. Important issues include:

- the extent of shelterwood silviculture that will be required because of the forest types scheduled for harvesting,
- distribution of unharvested forest retained within shelterwood areas,
- related issues of the scale and intensity of post-harvest burning, and the potential impacts on other forest values.

Adaptive management and monitoring will become even more important, including the need to monitor during the period of the next plan so that new practices can be developed as required.

Linkages between research findings and inventory databases need to be strengthened so that issues can be examined in a "whole-of-forest" context. For example, availability of hollows in standing trees can now be modelled and displayed for the public forest estate, based on Kim Whitford's algorithms and the Jarrah inventory database.

There is a need for an explicit statement about the importance of minimising undesirable forms of soil disturbance that may lead to loss of soil structure, accelerated erosion, or loss of ecological integrity of soil flora and fauna.

4.4 Modification of silvicultural guidelines and codes of practice

Ecological principles and results from research studies highlight the need to minimise the extent of disturbance in areas of the forest landscape that are excluded from harvesting (eg. TEAS, stream buffers, Diverse Ecotype Zones). Prescriptions should be specific about this requirement, and there should be provision for monitoring and enforcement during field operations.

Guidelines for management of soil disturbance during harvesting operations should be revised and expanded to include measures to minimise long-term loss of plant species richness and abundance. Factors including silvicultural treatment, season of harvesting and type of equipment used need to be taken into account.

Regeneration stocking standards need to be reviewed to determine whether a single stocking standard should be applied to all Jarrah sites, regardless of site productivity and rainfall zone. In stands with a high component of Marri, retention of a substantial number of mature standing trees may make it difficult to meet the current regeneration standard. Some future wood growth potential may need to be foregone if there are good ecological reasons for retaining a high number of mature trees.

In the light of the above three points, there is a sound case for establishing studies to compare the adequacy of regeneration and stand development under different levels of JSI treatment, including a 'no-treatment' option. Because of scaling issues, these studies will need to be conducted on an operational scale, with good liaison between Science Division and FPC staff.

Guidelines for management of habitat components in Jarrah silvicultural operations are currently being reviewed, with changes likely to:

- the definition and number of habitat trees and potential habitat trees retained,
- recommend retention of mature Balga grasstrees,
- recommend increased frequency of fox baiting in harvest areas adjacent to private property.

Marking potential habitat trees may be a useful measure in improving public perceptions of silviculture.

The process for revision and approval of changes to silvicultural guidelines needs to be made explicit and be endorsed by the Department's Corporate Executive, the Conservation Commission and Forest Products Commission.

5. Providing information to the public and broader scientific community about the Department's ecologically sustainable forest management research program

During the initial planning for the workshop it was envisaged that the presentations prepared by Science Division staff could provide the framework for subsequent seminars intended to provide information to the scientific community and general public. The change of State government in February and resulting acceleration in preparations for the next Forest Management Plan have made this initial proposal inappropriate. However, there will be an excellent opportunity to present an overview of ESFM research in conjunction with the public consultation phase for the Forest Management Plan. This will require development of a package of succinct and complementary presentations on a range of ecological issues affecting forests. Expertise in design and presentation should be used to assist in the development of presentations, ideally targeted appropriately for different interest groups (eg. general community, scientific community, policy makers, media).

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10 July 2001

Short-term impacts of logging on understorey vegetation in a jarrah forest

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Summary

In 1985, modified silvicultural treatments were implemented in jarrah (*Eucalyptus marginata*) forests available for wood production. As part of a scientific investigation into the ecological impacts of two of these treatments, gap cutting and shelterwood cutting, a retrospective survey was conducted four years after logging to examine the effects of these treatments on understorey vegetation species richness and abundance. Sampling scale was found to be an important factor affecting the results and subsequent interpretation of impacts. At the coupe scale, native plant species richness in unlogged coupe buffers was similar to that in logged patches. However, analysed at a scale of 1 m^2, species richness in the buffers was 20-30% higher than in the logged patches. At all sampling resolutions, the abundance (number of plants) of native plants was 20-35% higher in the buffers, but the abundance of introduced (weed) species was significantly higher in the logged patches. Given the low fecundity and low dispersal capacity of many native species, it is our view that many woody shrubs and perennial herbs are unlikely to return to pre-logging abundance levels in the medium term. We attribute the reduction in the abundance of native plants to mechanical soil disturbance, which ranged from 60-80% of the area on logged coupes, and to physical/mechanical damage to the vegetation associated with the logging and post-logging activities.

Management Implications

We recommend modifying logging practices in jarrah forests to minimise soil disturbance, therefore impact on the understorey. This could be achieved by:

a) Reviewing the practice of mechanically disturbing the soil to create a receptive seedbed for commercial tree species.
b) Reviewing the practice of removing understorey competition by mechanically downing/removing non-commercial tree, lower tree and shrub species.
c) Investigating new systems for accessing, felling and extracting timber that minimises machine traffic on the coupes.
d) Investigating options for utilising machinery with lower ground bearing pressures.
e) Investigating the importance of soil moisture as a factor affecting the extent of soil damage during logging operations.
f) On-going monitoring (perhaps five-yearly) to check that the recommended modifications to logging practices are achieving the desired outcome.

Evaluation of key soil indicators of sustainability in Australian Mediterranean forests (Indicators 4.1d, 4.1e)

Kim Whitford
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A joint Department of Conservation & land Management, Forest and Wood Products Research and Development Corporation project

This projects examines the application of Montreal Process Indicators 4.1d and 4.1e to the forest of south west WA with the aim of developing practical, cost-effective and sensitive indicators.

Part 1. The effect of fire on soil organic matter and bulk density in jarrah and karri forests.

We used rretrospective studies to examine the impact of fire frequency on soil carbon, nitrogen and bulk density at three sites in the jarrah and karri forests. Fire frequencies studied included 36 and 26 years unburnt and a regular 8 year cycle at the high rainfall Strickland site (karri), 23 years unburnt and regular 4 and 5 year cycles at the intermediate rainfall McCorkhill site (jarrah), and 18 years unburnt and 5 and 7 year cycles at the low rainfall Yackelup site (jarrah).

The greatest response of soil carbon and nitrogen to the effects of fire frequency occurred in the surface soil layer (0-75mm), and the response of soil nitrogen generally followed that of soil carbon. Across all sites, and within individual sites, there was a general increase in the percentage carbon content of the surface soil with decreasing fire frequency. Clay content was not useful as a covariate to explain natural soil variation. The strongest relationship observed in this study was a negative relationship between fine earth bulk density and surface soil carbon content, ($r = -0.80$). There was also a decrease in fine earth bulk density as the period between fires increased. The correlation between soil carbon and bulk density indicates that the changes with fire frequency are likely expressions of changes to soil biological processes that incorporate organic matter into the soil and lower the bulk density of the fine earth fraction.

Part 2. The impact of logging on soil physical properties at three sites in the northern jarrah forest.

We examined a variety of displacement and coring techniques for measuring bulk density in gravelly soils and found the smallest corer provided efficient and accurate estimates of bulk density in these soils.

Large differences in estimates of snig track area occurred between three different methods of estimating snig track area. GPS provided the most efficient and accurate estimate. Snig tracks are the major disturbance on jarrah logging coupes and planning and managing the layout of snig tracks could significantly reduce the area of disturbance within the coupe.

Soil disturbance and the draft Montreal Indicator.

Within the jarrah forest approximately 30% of the total area of logging coupes show visual signs of soil disturbance, however relatively small areas of these logging coupes (~10%) exceeded the 20% increase in bulk density proposed by Rab (1999) as a threshold for Montreal Indicator 4.1e. Fine earth bulk density provides a more meaningful basis for interpreting the indicator than total bulk density. Bulk density measurements are time consuming and costly to collect and soil strength and visual classification provide simpler and more efficient means of identifying disturbed soil.

Management Implications

- Soil carbon is difficult to measure because of the high charcoal content of Australian forest soils and therefore Indicator 4.1d (Soil Organic Matter) is unlikely to be implemented in native forests
- Visual assessments of soil disturbance have received general acceptance as a valid method for identifying changes in soil physical properties caused by logging
- National soil indicators project group recommended staged implementation and calibration of visual assessment against bulk density on case study and representative sites
- The soil disturbance classification used for WA native forests should be revised in line with the draft national protocol
- Improved design and control of snig track layout can be effective in minimizing soil disturbance

Using electromagnetic induction to estimate soil salt storage

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Summary

This study was conducted to determine the suitability of an EM31 electromagnetic induction meter for estimating soil salt storage in the jarrah forest and consequently to help identify which "*environmentaly sensitive catchments*" may be regarded as "*high salt risk*".

The Department of Conservation & Land Management and Water and Rivers Commission nominated 56 second order catchments in the intermediate rainfall zone as being "*environmentaly sensitive*" in a Record of Agreement that relates to Ministerial Condition 16 attached to Forest Management Plan 1994-2003. The Agreement also determined that "*environmentaly sensitive*" catchments would be regarded as "*high salt risk*" if they met both the following criteria

1. depth to groundwater at the catchment outlet of less than four metres, and
2. soil solute concentration above this groundwater table greater than 2000 mg/L total soluble salts.

The results of this study confirmed that the EM31 is suitable for estimating salt storage in the upper 4m of the soil profile. However, moisture significantly increased the response of the EM31 in spring compared with autumn hence the appropriate seasonal regression equation must be used when estimating soil salinity.

EM31 surveys of the streamzone of 22 "*environmentaly sensitive*" catchments indicated soil salt levels in the upper 4m which exceeded 2000 mg/L TSS along at least half of the length of the second order stream. The highest levels of salt storage were not necessarily near the catchment outlet. A further two catchments which could only be surveyed along part of the length of the second order streamzone had soil salt levels in the upper 4m which did not exceed 2000 mg/L TSS. The remaining 32 "*environmentaly sensitive*" catchments could not be surveyed because access to or along the streamzone was not feasible because of dense vegetation.

Management Implications

The EM31 was demonstrated to be suitable for estimating soil salinity and an appropriate method for estimating soil salinity in valleys was developed and applied to a selected number of catchments. The results provide a basis for determining high salt risk catchments.

Hydrological response to logging in the intermediate rainfall zone of the jarrah forest

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Summary

Forest logging has greatest potential impact on stream salinity in the intermediate rainfall zone (IRZ) of the jarrah forest. Recognition of this impact on water resources is reflected in Forest Management Plan 1994-2003 and Ministerial Condition 12 whereby logging practices in the IRZ have been modified to a more precautionary, conservative approach. This study has been undertaken since there have been no catchment studies on the hydrologic impacts of the current silvicultural practices in IRZ jarrah forest.

The study, which is currently in progress, is a Before, After, Control and Impact based on three second order catchments in the IRZ jarrah forest. Two catchments have been logged in 2000/01, one according to standard IRZ logging and silvicultural treatments, and the second a more intensive treatment. The third catchment remains untreated as a control. Records exist of groundwater level, stream flow, stream salinity, and salt load for at least the previous ten years and monitoring is ongoing.

Pre treatment hydrological data are used to establish regressions with the control catchment. The regressions are then used to make post-logging predictions of hydrological parameters and the response to logging is calculated as the difference between observed and predicted. The catchments are expected to provide different levels of hydrological response that will enable an estimate of changes to the hydrology in relation to changes in vegetation density.

Management Implications

The results of this study will have potentially important implications for forest management in the IRZ. These will not be apparent until groundwater levels and stream salinities peak and decline and may take four to five years. Until this occurs it is vital that monitoring continues.

Logging and burning impacts on cockroaches, crickets and grasshoppers, and spiders in Jarrah forest, Western Australia

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Summary

In 1985 modified silvicultural prescriptions for managing Jarrah *(Eucalyptus marginata)* forest in south-west Western Australia came into operation. The most extreme treatment involved removal of most of the overstorey from 10 ha patches, followed by a regeneration fire. This paper, part of a broader integrated study, reports on the impact of these disturbances on more than 400 species of leaf litter arthropods captured in pitfall traps one year before logging, one year before burning, and three years after burning.

Most species of cockroaches (Blattodea), crickets and grasshoppers (Orthoptera), and spiders (Araneae) were resilient to logging and burning, and immediate decreases in species richness or total abundance were rapidly reversed. Changes in community structure caused by the imposed disturbances were also minimal or short-term. Community structure in treatment and control sites at the end of the study was different from that at the beginning of the study, perhaps indicative of the overriding importance of climatic variation.

The results of the study have broader relevance to understanding the long-term resilience of forest ecosystems in south-west Western Australia. Because of the role of the taxa studied in mediating decomposition, herbivory and predation, these ecosystem processes appear to be robust to the logging and burning prescriptions applied.

Management Implication

Invertebrate ecosystem processes appear to be robust to the logging and burning treatments applied, and therefore no modifications to current prescriptions are required to maintain invertebrate biodiversity in Jarrah forest.

Short-term Impacts of Logging on Birds in a Jarrah Forest at Kingston

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Summary

The introduction of modified silvicultural treatments in jarrah forest (*Eucalyptus marginata*) in 1985 raised some concerns on the impact of these treatments on the avian population. A combined study was set up in Kingston Block looking at aspects of these impacts on fauna and vegetation in 1994. Mike Craige (Phd student UWA) commenced the study on the birds in autumn 1994 and continued until 1996. The area was logged in summer 1994/95 and silvicultural burnt in November 1996. The Science Division, Department of Conservation & Land Management, took over the censuses in autumn 1997.
A total of 54 species of bird have been recorded on the grids with a further 8 being recorded in the vicinity.
Mike Craig found in his study (BACI) there was a significant decrease in the bird density in all the treated areas after logging, a non-significant decrease in species numbers and no change in the diversity of species in the treated areas. Since the Science Division has continued with the study (to Spring 2000) the Buffer areas have changed from a 30% decrease to a 10% decrease(BACI), the Shelterwood from 22% decrease to a 25% increase(BACI) and the Gap showing no change at around 25% decrease(BACI).
Overall the individual treatment trends show no change in abundance in the Control, Buffer and Gaps with a slightly increasing trend in the Shelterwood.
Some individual bird species are showing decreasing trends ie. Western Yellow Robin in the treated areas, but this species prefers open understorey and would be disadvantaged by the dense regeneration at this time. In contrast the Inland Thornbill and the White- browed Scrubwren are showing increasing trends at this stage of the forest regeneration.
Even though we have recorded over 12000 individuals during this study there are still too few numbers for any meaningful statistical analysis, we can only show trends within the treatments with time since treatment.

Management Implications

This study should be continued as it will be the only long-term study on the impact of logging on the avian fauna in the jarrah forest, and can be compared with a similar study in karri forest at Grey block. The study should be continued on an annual basis until at least 10yrs since the silvicultural burn (2006) or until there is crown separation in the regeneration. Censuses should then continue on 5yr intervals from that time.
We should look at modifying our logging practice in the Shelterwood areas by retaining unlogged refuge areas within the coupes. The spacing of these unlogged refuges should be approximately 300 m.

Tree Hollows in jarrah and marri

Kim Whitford
Science Division, Dwellingup

This work covered three areas: the occurrence and abundance of hollows, the longevity of hollow bearing trees, and strategic risk assessment.

Key findings:

- Defined the relationship between tree age and diameter for jarrah and marri
- Determined the age of hollow bearing jarrah and marri and the ages of trees bearing hollows suited to various bird and mammal species.
- Identified 130 years as a realistic minimum age to hollow formation for forest management purposes.
- Determined that the minimum Primary Habitat tree diameter (70 cm) corresponds to a tree age of 171 years.
- Developed descriptions of the ranges of hollow sizes used by various species of birds and mammals
- Developed an improved method of defining the dimensions of hollows used by fauna
- Produced basic data on: hollow occurrence, distributions of hollow sizes, interrelationships between hollow dimensions, shapes of hollows, hollow orientations, and the order and sizes of branches bearing hollows.
- 90% of hollows in the forest are borne on trees with diameters between 20 and 100 cm.
- Approximately 100 hollows/ha in the jarrah forest. About 90% of these are small, ie. about 10 hollows/ha are potentially useable.
- Identified the relationship between hollow occurrence and the following tree attributes: tree age, DBH, crown size, crown condition, tree status (alive/dead), tree species, amounts of dead wood in the crown, termite damage, and tree lean. These are the basis of the current prescription.
- **Predictive relationships developed. These enable predictions of hollows occurrence across the forest for individual fauna species and allow investigation of different H tree retention strategies for specific fauna goals, eg. Preferential stand management for particular species modelling population viability across forest**
- Examined factors affecting habitat tree longevity and determined the relationship between probability of tree fall and tree and stand attributes.
- Identified relationship between log attributes and occurrence of hollows (CWD component by Matt Williams).
- Assessed risk to different species as a basis for determining hollow management strategies.

Management Implications and Recommendations

- Core information has already been included in Habitat tree prescriptions.
- The progression of fauna management requires the establishment of explicit fauna management goals where possible.
- Include crown senescence in future forest inventory work to enable and improve the Department of Conservation & Land Management's ability to predict hollow availability across the forest.
- Distinctively mark Potential Habitat trees to distinguish them from actual Habitat trees for the uninformed observer

- With fox baiting fauna populations are dynamic. We need to monitor fauna and adapt management to cater for the changes in habitat demand as fauna populations increase. Predictive models allow modeling of these scenarios.

Response of terrestrial vertebrates to timber harvesting at Kingston

A. Wayne, C. Ward, J. Rooney and I. Wheeler
Science Division, Manjimup

Summary

Small vertebrates

Capture rates of most small vertebrate species were too small to take analyses beyond descriptive trends and species richness tests;

• For those taxa with >40 capture records, all (except the brushtailed phascogale), were present after disturbance within each treatment that were present prior to harvesting;

• For taxa with <40 records, the sample sizes were too small to comment on the impacts of logging;

• Species Richness:

- small mammals declined over time (phascogale and dunnarts)
- frogs and reptiles recovered to pre-logging levels within 5 years
- logging is not likely to be the principle cause for these trends as external controls behaved similarly;
-

•*Brushtailed phascogale*:

- none have been caught on Kingston grids since June 1995,
- declines began before logging and occurred regionally,
- logging impacts remain unresolved.

Implications for Management

Small Vertebrates

•Extensive trap effort provided only limited data and it was only possible to draw conclusions about the impacts of harvesting on a few species

• No evidence of direct negative impacts of logging on native small vertebrates BUT the limitations of the data do not negate the possibility of impacts

• House mouse is a disturbance opportunist, which may have implications for native small vertebrates (competition & predation)

• Phascogale and Dunnart populations declined over the period of the study, but this did not appear to be related to timber harvesting

Quenda

• Populations responded positively to fox baiting

• No evidence of negative impacts from logging on population size (treatment populations equal or greater than control after logging)

• Recent declines on controls and treatments, although not directly related to logging, remain to be resolved

Woylie

• Populations responded very positively to fox baiting

• No evidence of negative impacts from logging on population size

• High densities of Woylies can affect the effectiveness of trapping other species because of trap saturation and future monitoring studies should take account of this

Brushtail Possum (Koomal) responses to timber harvesting at Kingston

A. Wayne, C. Ward, J. Rooney and I. Wheeler
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Implications for Management

Landscape level management

- Conservation objectives for arboreal fauna should be developed in the context of the full range of species that may potentially inhabit an area;
- Unharvested areas (including TEAS) within coupes are important in maintaining Koomal populations because of declines in gap and shelterwood cells;
- *Banksia, Gastrolobium,* and others shrubs are seasonally important food for Koomal that is impacted by logging and therefore may impose greater pressure on other resources (if available) and affect Koomal population abundances.

Habitat tree retention

- A few trees are used more extensively and are therefore more valuable to protect, in particular Marri, leaning trees, short & fat trees;
- Standing trees with a wider range of crown senescence should be considered for retention;
- Preliminary results show at least 3.5 standing trees per hectare are utilized by Koomal;
- Appropriate retention rates will be dependent on habitat type, possum density, and competition, all of which are dynamic over time.

Habitat log retention

- Koomal use of hollow logs will be dependent on possum densities, competition and habitat
- In some circumstances, Koomal may limit hollow log availability for other species such as Chuditch and possibly Numbats if hollow log densities are low;
- Hollow log recruitment in regrowth will be very low for a long period following harvesting;
- Natural hollow logs are used more extensively than logs from felled trees.
- Hollow log selective criteria could be expanded to include logs with:
  - external diameter >20 cm (currently 30-100cm)
  - internal diameter 6 to >30 cm (currently 6-15cm)
  - preference for natural hollow logs.

Monitoring and Research

- Environmental, Habitat, Observer and Survey variables affect Koomal spotlight detection and therefore need to be measured and accounted for in surveys;
- Survivorship of leaning habitat trees and hollow logs needs to be quantified;
- Continuing analysis of current data and further proposals for possum ecology research.

Western Ringtail Possum (Ngwayir) responses to timber harvesting at Kingston

A. Wayne, C. Ward, J. Rooney and I. Wheeler

Science Division, Manjimup

Logging impacts on Ngwayir Survivorship

• Two weeks after harvesting completed within the ranges of radio collared animals
- 31% treatment animals alive within coupe
- 80% control animal alive
• All 17 treatment animals were dead before the silvicultural burn (<2 years).
• Average breeding lifespan of Ngwayir was reduced by about 50%).
• Difference in survivorship difference between control and treatment animals was marginally significant (p=0.0559), but statistical power was low (e.g. 80% probability of detecting a 40% difference with 95% confidence).
• Up to 18% of treatment animals died from falling.
• Increased vulnerability to predation during harvest activities (generally acute) was the principal cause of the survivorship decline. Logging impacts on Ngwayir Survivorship

- 85% decline throughout greater Kingston since 1997

Refuges used by Ngwayir

• above-ground nests
  - typically dreys, more common in dense and/or riparian vegetation
  - In jarrah (45%), marri (31%), *Melaleuca incana* (17%)
• forest harvesting debris
  - mainly harvest debris, some road piles, rarely natural
  - use of debris confined to harvested areas

Nocturnal Habitat Use

- Ngwayir sighted on the ground more than twice as often in harvested forest (ie. increased vulnerability to predation)
- Saplings (Jarrah and Marri) are used more extensively than more mature trees

Daytime Refuge Use

- Broader range of refuge types used than Koomal
- Standing trees with hollows are the most extensive form of refuge
- Balga grass-trees are important refuge
- Use of forest debris problematical during silvicultural burning
- A few refuges are used more extensively than most; these should be targeted for protection
- At least 7.7 refuges/ha (4 to 6 ST/ha)

Modification recommended to Jarrah Silvicultural Guidelines

- Additional fox baiting particularly adjacent to the interface between forest and cleared land
- Retention of balga grass trees, in clumps or large solitary plants
- Schedule advanced burns before harvesting to minimize the intensity of post-harvest burning

Habitat tree retention rates

To provide possum refuges for Koomal and Ngyawir at their current level of demand in Kingston at least 8 habitat trees (>70cm DBH) per hectare should be retained. This figure does not factor in competition by other species for these trees/hollows (e.g. cockatoos, Phascogales and bees), inefficiency of suitable habitat tree selection, future increased densities of recovering fauna populations.

APPENDIX 4

CRITERIA FOR MANAGEMENT OF FAUNA HABITAT

PREAMBLE

Retention of elements of fauna habitat within jarrah forest subject to timber harvesting needs to be viewed in the broader context of whole of forest conservation. This includes formal reserves (National Parks, Nature Reserves), informal reserves (stream zones, Diverse ecotypes) from which timber harvesting is excluded as well as temporary reserves (TEAS) in which timber harvesting activity is deferred. Retention of informal reserves and TEAS provide for a fine scale network of uncut forest that supports the larger scale formal reservation system. Measures undertaken within a harvesting coupe are important in maintaining structural diversity of the forest available for timber harvesting, over time at the local level, particularly if and when retained TEAS are removed in later cutting cycles.

Habitat retention within coupes can provide the opportunity for hollow dependent fauna to persist at the time of harvest as well as the potential for re colonisation at a later time. However it does not imply that any particular population levels of individual species will be maintained. Populations are known to fluctuate according to climatic factors, predation and disease, even in undisturbed forest.

Conservation strategies also need to bear in mind the impact of predators such as the fox on fauna populations and the value of timely predator control.

OBJECTIVE

To ensure the sustained availability of suitable refuge sites, in particular for hollow dependent fauna, through the retention of a sufficient number and age structure of trees, Balga and ground logs within timber harvesting coupes.

1. STRATEGIES TO BE APPLIED TO ALL TIMBER HARVESTING COUPES

1.1 STANDING TREES AS HABITAT

1.1.1 Definitions

Two types of habitat trees are recognised, viz primary habitat trees, being those which currently may offer refuge to fauna; and potential habitat trees, being those which may develop suitable refuges for fauna in the future.

Depending on the silvicultural objective of harvesting both types of habitat tree may need to be retained to ensure the sustained availability of refuges.

1.1.2 Primary habitat trees

- Priority should go to large trees which are likely to bear hollows and have obvious signs of fauna use (eg, possum scratch-tracks). Where signs of use are not evident select the largest trees with the most suitable crowns (see Whitford and deTores crown classifications).

- Trees should be mature to senescent, >70cm DBHOB. Crowns should have the types of deterioration shown in crown structure categories 4-7 (see Whitford and deTores).

- Death and damage to the intermediate size branches in large trees is most likely to result in hollow formation. Death and damage of small limbs and twigs is least likely to result in hollow formation. Crowns should include old and large dead branches with signs of hollow formation. These are branches of categories 4 and greater in the attached dead branch illustrations (Whitford and deTores).

- Trees should be wind-firm. Trees with major termite infestations, trees within 1 m of a termite mound, and trees with extreme lean (likely to fall) should be avoided. Avoid trees with hollow-butt, and do not select trees with hollow butts >30% of diameter at ground level.

- No tree species preference need be shown.

1.1.3 Potential habitat trees

Trees in this category should be immature to mature, 30-70cm DBHOB. Some small hollows and/or broken branch stubs with the potential to develop holes should be visible.

Crowns should show some potential for deterioration, and be within structure categories 2-4.

1.2 Rate of Retention

- On all areas harvested an average of 4 primary habitat trees are to be retained per hectare.

- On areas where harvesting creates gaps separated by retained TEAS strips *6 to 8 potential habitat trees* if present are to be retained per hectare in addition to the retention of primary habitat trees.

  Potential habitat trees to meet this requirement should be selected only from cull trees, including those that may otherwise be removed in cull removal operations.

- Where suitable trees are not present on every hectare, a retention rate of 20 *primary habitat trees* per 5 hectares must be retained.

NOTE: If insufficient primary habitat trees exist which meet the above criteria, retain mature to senescent trees as potential habitat.

The required number of primary habitat trees must be marked regardless of their commercial value.

During logging and subsequent silvicultural operations (including regeneration burns) care should be exercised to avoid disturbance to habitat trees.

1.3 Pattern of retention

- Habitat trees must be deliberately marked for retention with a large "H".
- Habitat trees should preferably be retained in small groups.
- In areas harvested to gaps and TEAS strips:
  - small groups should ideally comprise both primary habitat trees and potential habitat trees, and be distributed randomly throughout a coupe.
  - primary habitat trees at the boundary of the gaps are to be considered as part of the retained rate per hectare
- If trees that meet the required criteria are not positioned to facilitate marking as a group, mark individually at the required retention rate. The emphasis is on habitat quality rather than pattern of retention.
- In forest that consists of small thinning patches and regeneration gaps of one hectare or less, aim to mark habitat trees to form groups near the boundaries of these patches.
- Isolated large merchantable trees frequently occur in thinning patches. These may be difficult to remove as part of a harvesting operation without damaging the integrity of the thinning patch. Where this situation occurs it is preferable to retain these large trees as habitat trees if they meet habitat requirements than to attempt to remove them.

2. BALGA (GRASS TREES) AS HABITAT

Research has shown that where Western ringtail possum (ring tail possum) occur in the jarrah forest the dead grass skirts beneath the live heads of Balga are regularly used as refuge sites.

Where possible in harvesting coupes Balga is to be retained.

2.1 Characteristics of Balga for retention

Any Balga may be used as refuge if adequate grass skirts are present. All live healthy Balga are suitable for retention.

As Balga are very slow growing the larger Balga particularly those with multiple heads will take the longest to be replaced if removed and because of their size they are also likely to provide the greatest potential as refuge.

Where Balga occur the largest (greater than 2 metres tall) should be chosen for retention, preferably with multiple heads and intact grass skirt.

2.2. Rate of retention

Where Balga occur, provide for the retention of at least 4 large Balga per hectare(eg greater than 2 metres tall with multiple heads). Where possible these are to be clearly marked with a white painted ring. These Balga are to be protected during harvesting and follow-up silvicultural operations.

If all Balga are less than a metre in height individual retention as described above is not required.

Avoid disturbance to other large Balga in addition to the above and to clumps or groups of Balga irrespective of individual Balga size during timber harvesting and follow-up silvicultural operations.

Harvesting contractors and machine operators are to be briefed on requirements.

2.3 Pattern of retention

Balga should preferably be retained in groups. Where groups occur 4 groups of 2 to 3 large Balga per group is preferable to 4 individual Balga. Groups or individuals should be evenly dispersed over each hectare if possible.

Retain groups and clumps undisturbed where these can be separated from the harvesting operation.

Where possible mark retained Balga with habitat trees. Groups should ideally comprise both primary habitat trees, potential habitat trees and Balga and be randomly distributed throughout the coupe.

3. GROUND HABITAT

Ground habitat in the form of hollow logs, stumps and leaning trees are also important refuge sites for forest fauna such as Chuditch, Brush Tail Possum and Quenda.

3.1 Characteristics

Logs:

Diameter: 30-100cm
Pipe diameter: 6-15cm diameter extending into log
Length of log: pipe at one end – 1.5 metres minimum pipe at both ends - 3 metres minimum

Stumps and Leaning Trees:

Stumps that have been lifted creating a protection underground cavity due to a leaning tree or some other agency.

3.2 Rate of Retention

Where available, retain at least one suitable ground habitat log or stump per hectare, even if it shows no obvious sign of use.

If necessary, they are to be marked by the treemarker with a large "H".

All marked logs or stumps should be retained undisturbed.

3.3 Training

Operators should be trained to recognise and retain suitable logs and stumps.

3. REFUGE SITE PROTECTION

4.1 Tops Disposal

As for protection of crop trees, tops and other residues larger than 7.5cm diameter are to be removed for at least 1 metre from around habitat trees and groups and ground refuge sites to ensure subsequent protection from fire.

Harvesting debris should not be placed beneath the crowns of retained habitat trees or adjacent to retained Balga.

4.2 Advance Burning

In forest known to contain populations of Western ringtail possum or where there is a high likelihood of populations existing advance burning prior to timber harvesting is recommended. This is more likely to provide a mosaic of vegetation age within the landscape, is more likely to leave large Balga with unburnt heads and reduces the likelihood that riparian vegetation will be burnt at high intensity during the post harvest burn. Advance burns should be prescribed to achieve low fire intensities and leave patches unburnt in creeks and swamps.

5.0 PREDATOR CONTROL

Increased vulnerability to introduced predators following disturbance has been identified as the principal factor threatening the persistence of Western ringtail possum through the timber harvesting process. Increased control of predators before, during and after timber harvesting activity is likely to provide for greater Western ringtail possum survivorship.

Where populations of Western ringtail possum are known to exist or have a high likelihood of existence within harvesting coupes the following fox baiting program is recommended.

Within one kilometre of cleared farmland

- bait all tracks within a 5 kilometre radius of the coupe once per month during the summer fox dispersal period from December to May. From June to November bait once every two months.

Greater than one kilometre from cleared farm land

bait all tracks within a 5 kilometre radius of the coupe once every two months.

The baiting program should commence at least 2 months prior to timber harvesting activity occurring. Baiting will then be ongoing and will continue for a period of 2 to 3 years following the completion of harvesting and post harvest operations until the regrowth in the coupe is judged to provide sufficient cover.

Baiting requirements can incorporate baiting programs implemented under the Western Shield program.

APPENDIX 10

Trends in Stream Salinity in the 1990s for catchments where clearing for agriculture is not a factor (extracted from Ruprecht *et al.* in preparation)

TRENDS IN STREAM SALINITY IN THE 1990S FOR CATCHMENTS WHERE CLEARING FOR AGRICULTURE IS NOT A FACTOR (EXTRACTED FROM RUPRECHT ET AL. IN PREPARATION)

Station Number	River and Location	Clearing (%)	Salinity (mg/L)	Salinity Trend (mg/L/yr)	Salinity Status
606002	Weld River, Wattle block	0	140	Increasing, 5	Fresh
606195	Weld River, Ordnance road crossing	0	170	Decreasing, 1	Fresh
606185	Shannon River, Dog Pool	2.5	130	Steady 0	Fresh
610008	Margaret River North, Whicher Range	0	150	Steady, 0	Fresh
613002	Harvey River, Dingo Road	0	100	Steady, 0	Fresh
613005	Tallanalla Creek, Blackbutt Point	0	200	Steady, 0	Fresh
613008	Falls Brook, Dee Tee 59	0	120	Decreasing, 1	Fresh
614043	South Dandalup Trib, Pindalup	0	130	Decreasing, 5	Fresh
614007	South Dandalup Trib, Del Park	0	110	Steady, 0	Fresh
614017	Little Dandalup Trib, Warren catchment	0	110	Steady, 0	Fresh
614021	Wilson Brook Trib, Lewis catchment	0	100	Increasing, 2	Fresh

APPENDIX 11

Active Science Project Plans (SPP) relevant to biodiversity protection in the jarrah and karri forests during 2000, 2001 and 2002

ACTIVE SCIENCE PROJECT PLANS (SPP) RELEVANT TO BIODIVERSITY PROTECTION IN THE JARRAH AND KARRI FORESTS DURING 2000, 2001 AND 2002

SPP No	Title	Supervising Scientist
93/0005	WA threatened flora descriptive database	N Lander
93/0008	Taxonomy and inventory of WA flora	Herbarium
93/0010	Taxonomic review and conservation status of WA plant groups	Herbarium
93/0011	Taxonomic studies of species on the declared rare and priority flora list	Herbarium
93/0013	Flora of the lower south-west	J Wheeler, N Marchant
93/0015	Systematics zoogeography and phylogeny of the terrestrial Amphipods of Australia	T. Friend
93/0042	Conservation biology of WA rare and threatened flora.	D Coates
93/0053	Recovery Plan for the Chuditch (*Dasyurus geoffroii*)	K Morris
93/0054	Effect of fox control on habitat utilisation of the mainland quokka	P De Tores
93/0060	Monitoring of wetlands in nature reserves and national parks of south-western Australia	J Lane
93/0075	Effects of spring and autumn prescribed burns on small vertebrates in jarrah forest.	A Wayne
93/0093	Conservation biology of vulnerable frogs	A Wayne
93/0094	Establishment of jarrah (*Eucalyptus marginata*) in shelterwood areas and on dieback 'graveyard' sites	K Whitford
93/0095	Characteristics of hollow-bearing jarrah and marri trees and course woody debris, their use by selected species of fauna, and the effect of logging-and-burning jarrah forest on them.	K Whitford
93/0097	Control of Jarrah leaf miner JLM: Selective retention of JLM resistant trees and ground coppice in a demonstration forest plot.	I Abbott
93/0098	Effects of timber harvesting operations (fire and logging) on the floristics, structure and some habitat characteristics of intermediate rainfall jarrah forest.	N Burrows
93/0099	Fire regime effects on the structure and floristics of jarrah forests.	N Burrows
93/0101	Preliminary survey of the effectiveness of *B. grandis* removal in reducing potential *Phytophthora cinnamomi* host material in the northern jarrah forest in the medium term	S Crombie
93/0103	Quantitative population monitoring of gumleaf skeletonizer and impact assessment on jarrah crowns	J Farr
93/0104	Distribution of gum-leaf skeletonizer in the central and southern forest regions	J Farr

SPP No	Title	Supervising Scientist
93/0112	Selection screening and field testing of jarrah resistant to *Phytophthora cinnamomi*.	M Stukely
93/0115	Effects of timber harvesting on terrestrial vertebrates in medium rainfall jarrah forest.	A Wayne
93/0154	Impact of wood boring insects on wood quality in regrowth Karri in relation to site quality.	J Farr
93/0155	The effects of logging and fire (edge effects, habitat trees) on birds of the jarrah forest.	A Wayne
93/0142	Conservation management of the Western ringtail possum	P De Tores
93/0157	Control and ecology of the red fox in WA native fauna.	P De Tores
94/0006	Dieback-resistant jarrah establishment in operational forest rehabilitation sites.	M Stukely
94/0007	Effects of timber harvesting on invertebrates in jarrah forest.	A Wayne
95/0001	To compare chemical and biological methods for the control of *Armillaria* in regrowth karri.	R Robinson
95/0008	Taxonomy of new, rare and priority plant species of the southern forest.	T Macfarlane
95/0012	Reconstructing fire history from leafbase patterns on grass tree stems.	D Ward
96/0010	Fire history and impact of *Phytophthora cinnamomi* in jarrah forests.	N Burrows
96/0011	Molecular marker aided selection of jarrah for resistance to *Phytophthora cinnamomi*.	M Stukely
97/0001	Incidence of wood borers in 20-35 yr old regrowth karri over a rainfall gradient.	J Farr
97/0002	Weeds of WA: advice, liaison, public	G Keighery
97/0003	Project Vesta - Prediction of high intensity fire behaviour in dry eucalypt forest	L McCaw
97/0007	The impact of timber harvesting and associated activities on the Western ringtail possum (*Pseudocheirus occidentalis*) in Kingston jarrah forest	A Wayne
98/0003	Genetics and biosystematics for the conservation, circumscription and management of WA flora	M Byrne
98/0006	Below ground incidence of *Armillaria luteobubalina* in regrowth karri.	R Robinson
98/0015	The effect of fire on the fruiting of fungi in karri regrowth forests.	R Robinson
99/0007	First national assessment of river health – south- west forests.	S Halse
2000/03	Hydrological response to logging in the intermediate rainfall zone of the northern jarrah forest	J Kinal
2001/03	Regeneration success measures and monitoring methods for sustainable forest management, criteria	L. McCaw

SPP No	Title	Supervising Scientist
	2.1g	
2001/05	Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity	I. Abbott
02/0002	Assessing the distribution and status of the Wambenger (Phascogale nov. sp)	N Marlow
Core Function	Curation of specimens of all forest species of flora, including the collection and documentation of forest threatened taxa	
Core Function	Taxonomic studies on species in the forest region	

APPENDIX 12

Publication information relevant to biodiversity protection in the jarrah and karri forests for calendar year 2000, 2001 and to June 2002

PUBLICATION INFORMATION RELEVANT TO BIODIVERSITY PROTECTION IN THE JARRAH AND KARRI FORESTS FOR CALENDAR YEAR 2000, 2001 AND TO JUNE 2002

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APPENDIX 13

Prescribed burns for forest regeneration purposes in clearfell karri coupes adjoining stream and river reserves in 2000 and 2001 calendar year

PRESCRIBED BURNS FOR FOREST REGENERATION PURPOSES IN CLEARFELL KARRI COUPES ADJOINING STREAM AND RIVER RESERVES IN 2000 AND 2001 CALENDAR YEAR

2000	Manjimup	Pemberton	Walpole	Total
Number of prescribed regeneration burns	Autumn – 2 Spring – 6	Autumn – 12 Spring – 6	Autumn – 4 Spring – 1	Autumn – 18 Spring – 13
Number of burns that planned to include stream zones	Autumn – 2 Spring – 3	Autumn – 6 Spring – 5	0	Autumn – 8 Spring – 8
Number of stream zones actually included in prescribed burns	Autumn – 0 Spring – 3	Autumn – 3 Spring – 5	0	Autumn – 3 Spring – 8
Number of burns with low fire intensity*	Spring – 3	Autumn – 3 Spring – 4		Autumn – 3 Spring – 7
Number of burns exceeding low fire intensity*	nil	Autumn – 0 Spring – 1**		Autumn – 0 Spring – 1**

* Low fire intensity is <500 kW m^{-1}, maximum flame height of 1.5 metres (Cheney 1981) which would result in crown scorch to a maximum of 10 metres.

** Crowns scorch exceeded prescribed limits in a stream reserve adjoining harvested karri forest within Aerial Prescribed Burn P25 at Kin-Kin forest block.

2001	Donnelly (Manjimup)	Donnelly (Pemberton)	Frankland (Walpole)	Total
Number of prescribed regeneration burns	Autumn – 2 Spring – 4	Autumn – 9 Spring – 3	Autumn – 4 Spring – 0	Autumn – 15 Spring – 7
Number of burns that planned to include stream zones	Autumn – 1 Spring – 4	Autumn – 4 Spring – 2	0	Autumn – 5 Spring – 6
Number of stream zones actually included in prescribed burns	Autumn – 0 Spring – 4	Autumn – 2 Spring – 2	0	Autumn – 2 Spring – 6
Number of burns with low fire intensity*	Autumn – 0 Spring – 4**	Autumn – 2 Spring – 2		Autumn – 2 Spring – 6
Number of burns exceeding low fire intensity*	Autumn – 0 Spring – 1**	Autumn – 0 Spring – 0		Autumn – 0 Spring – 1**

* Low fire intensity is <500 kW m^{-1}, maximum flame height of 1.5 metres (Cheney 1981) which would result in crown scorch to a maximum of 10 metres.

** Part of the prescribed burn in Lewin 1, along the eastern edge of the coupe, exceeded an intensity of 500 k W m-1, and caused complete crown scorch to some mature trees. The stream zone along the southern edge of the coupe was burnt at low intensity.

APPENDIX 14

Examples of prescribed burns undertaken during 2000 and 2001 that catered for habitat requirements of diverse ecotype zones

EXAMPLES OF PRESCRIBED BURNS UNDERTAKEN DURING 2000 AND 2001 THAT CATERED FOR HABITAT REQUIREMENTS OF DIVERSE ECOTYPE ZONES

District	Location	Consideration of habitat requirements of diverse ecotype zones
Mundaring	Dobaderry Nature Reserve	To increase the mosaic outcome, the burn was split by completing only half in autumn. The area contains many species of rare and endangered flora. Some areas had fire completely excluded to provide information on flora response by comparison with burnt areas.
Mundaring	Dobaderry Nature Reserve	The remaining portion was burnt in spring to increase mosaic pattern (other half was previously burnt in autumn 2000/2001). The area contains many species of rare and endangered flora.
Jarrahdale	Within Monadnocks Park	Burn operations modified so that burning occurred under mild conditions in early spring to provide an increased mosaic burn on steep slopes.
Dwellingup	Nanga Block	Icy Creek Environmental Campsite – exclusion of area containing known population of *Banksia seminuda*. Ridge lighting only in autumn 2000 to ensure mosaic effect achieved. Lower slopes were programmed for burning in autumn 2001.
Dwellingup	Park Block	This area abuts the Nanga Recreation area. Ridge lighting only in autumn 2000 to ensure mosaic effect. Lower slopes were programmed for burning in spring 2000, then rescheduled for autumn 2001.
Dwellingup	Keats and Young Blocks	The Murray River and the Bibbulmun Track dissect this area. To minimise impact on the Bibbulmun Track and the riparian zone the burn area has been divided into three discreet cells that will be burnt in varying seasons over a number of years. Some burning of upland sections was carried out in autumn 2000.
Dwellingup	Yalgorup National Park Lake Pollard	Tuart regeneration experimental burn. Balgas burnt under mild conditions in winter specifically to limit fire intensity and to ensure that the larger regeneration burn is well contained and able to be burnt under best conditions.
Dwellingup	Holyoake Block – D169	Burn planned for 2000 but not yet achieved. Area containing known quokka habitat has been excluded from proposed burn area.

District	Location	Consideration of habitat requirements of diverse ecotype zones
Wellington	Driver	Burn conducted for purpose of maintaining a suitable habitat for noisy scrub-birds in release site. Habitat/release area protected by excluding areas of habitat from burn area using a network of tracks surrounding release site and excluding fire from these areas. Adjacent areas of forest prescribed burnt to establish low fuel buffer under mild conditions using modified lighting techniques which achieved 60-70 per cent burn-out of buffer area.
Wellington	Lennard	Burn conducted adjacent to Collie River which includes tributaries into river system and associated riparian zones. Burn also included significant areas of granite outcrops. Modified lighting techniques used to minimise introduction of fire onto rock outcrops and associated vegetation complexes as well as minimise introduction of fire into riparian zones. Result in approximately 80 per cent burn-out of forested areas with majority of outcrops and associated vegetation complexes protected or burnt under mild conditions. Approximately 60 per cent of riparian zones associated with tributaries were protected from fire.
Wellington	Wild Horse Swamp Nature Reserve	Trial burn to establish regeneration and increase population of *Rulingia sp* by applying fire for purpose of raising soil temperature and hence stimulating seed germination. Areas also fenced to protect from post germination grazing by native fauna.
Mornington	Clarke	Some 600 hectares were excluded from this burn to protect habitat where the noisy scrub-bird has been reintroduced.
Blackwood	Proposed St John's Conservation Park	Low - moderate intensity burn in area of woylie translocation with aim of only partially burning habitat. Burn split into two halves with northern half left unburnt to provide refuge for recolonisation of southern half of burn. Majority of burn area conducted under mild conditions into evening resulting in low intensity burn with significant areas adjacent to streams and swamps remaining unburnt. Monitoring of woylie translocation site is ongoing by District personnel.
Blackwood	Gayndah	Burn conducted in two parts commencing in

District	Location	Consideration of habitat requirements of diverse ecotype zones
		autumn 2000 with edging of low open swamps, plus open areas of woodland in late autumn after significant rain. Burn completed in late autumn 2001 after significant rain resulting in approximately 60 per cent burn in low open woodland areas and significant area of karri vegetation remaining unburnt. An area containing priority two species *Andersonia auriculata* was excluded from burn.
Blackwood	Bovelle	Modified lighting technique used to minimise introduction of fire into Sabina River system and tributaries. Resulted in approximately 50 per cent of diverse ecotype and riparian zones being excluded from the fire.
South West Capes	Yallingup Siding Road	Trial burning of an area where the critically threatened species *Caladynia busseliana* was previously known to exist. The objective of the trial is to test whether the species will regenerate in response to the burn.
South West Capes	Abba	The rare species *Grevillia elongata* and *Dryandra nivea* subsp *uliginnsn* and a threatened ecological community were excluded from this burn.
Manjimup	Beavis/Gray	Moderate to high intensity fire was applied to promote regeneration of scrub, herb and sedgeland diverse ecotype zone for browsing and grazing fauna.
Manjimup	Chariup	Mosaic burn planned for and achieved so as to protect heartleaf thickets which are required as habitat for the tammar wallaby and other fauna.
Manjimup	Mersea	Diverse ecotype zone of scrub, herb and sedgeland on the western boundary of the burn adjacent to the South-West Highway was deliberately left unburnt. This was achieved by lighting around the margins of the shrubland early in spring. Excluding fire from this area provided a refuge for fauna adjacent to cleared private property and minimised the visual impact of the burn on the highway, but did not adversely affect burn security or effectiveness. The remainder of the block was burnt at low to moderate intensity.
Manjimup	Thornton	Low intensity burn in autumn was used to achieve a patchy burn so that diverse ecotype zones, particularly swamps and creek-lines,

District	Location	Consideration of habitat requirements of diverse ecotype zones
		would remain unburnt.
Manjimup	Yackelup	Low intensity burn in autumn was used to achieve a mosaic burn over most of burn envelope so as to promote a food source for browsing fauna. Some flats containing melaleuca thickets were later burnt at a higher intensity for fauna habitat development purposes.
Donnelly (Manjimup)	Talling	Shrublands and wetlands associated with Tone River and Lake Muir catchments were burnt at low intensity during early spring (October 2001), resulting in a mosaic of burnt and unburnt patches.
Pemberton	Eastbrook	Possible habitat for quokkas, major gully patchy burnt for habitat retention.
Pemberton	Sutton	Patchy burn planned and achieved along creeklines within the burn envelope so as to maintain possible quokka habitat. Possible quokka habitat in gullies, but similar unburnt habitats in adjacent forest, combined with unburnt pockets in gullies within the burn offered fauna adequate protection.
Donnelly (Pemberton)	Quinninup 7	Fire was excluded from several hectares of Blackbutt streamside vegetation adjoining private property on northern boundary of the burn unit. Diverse ecotype zone of open jarrah (less than 30 per cent canopy) with balga grasstrees was burnt at low intensity.
Donnelly (Pemberton)	D'Entrecasteaux National Park DC12/13 Windy Harbour	Prescribed burning was undertaken within a 9,800-hectare block of coastal shrubland and wetland north of Windy Harbour. Under the Shannon/D'Entrecasteaux National Park Management Plan the purpose of burning in this area is identified as park protection and flexible management area. Ignition was undertaken in mid-May 2001 following substantial opening rains, and about 2,200 hectares of the block were burnt. Mild burning conditions were selected in order to avoid the development of extensive fronts of high intensity fire, and to minimise the risk of fire-caused mortality of tree species such as *Agonis juniperina* which grow adjacent to wetlands and creeks. The resulting mosaic of burnt and unburnt vegetation reduces the chances of the entire area being burnt during a single fire event, and has provided diversity in

District	Location	Consideration of habitat requirements of diverse ecotype zones
		vegetation age within this large management block. Landsat imagery has been used to map the extent of burnt area within the block. Further ignitions were scheduled for autumn 2002 to add to the mosaic of vegetation age within the block.
Donnelly (Pemberton)	D'Entrecasteaux National Park DC5 Chesapeake block	Patch burning was undertaken during July 2001 within a 7,400-hectare block of karri and coastal shrubland, resulting in about 20 per cent of the area of the block being burnt at a wide range of fire intensities. Landsat imagery has been used to map the extent of burnt area within the block.
Walpole	Amarillup	Sedgelands and wetlands within parts of the boundary and the south-east area of the burn were left unburnt.
Walpole	(Coalmine)	Modified lighting techniques and hand trail construction were used to exclude fire from Declared Rare Flora habitat. A significant proportion of the riparian zone and fringing forest vegetation was left unburnt to provide cover and habitat for quokka and quenda populations.
Walpole	Giants	Early planned edging of karri/tingle forests produced low scorch levels and small unburnt pockets so as to maintain habitat for quokka during later planned ignitions. Late afternoon ignition, and subsequent evening burnout under mild conditions considered local quokka population protection requirements.
Walpole	Nuyts (Mt Clare)	Red tingle trees within practical reach of the burn boundary were raked around and protected with water during lighting operations to prevent hollow butted trees from igniting. Tree fall of red tingle following the burn is being monitored.
Walpole	Nuyts (Rest Point)	Jarrah forest fuels around the burn boundary were lit early under mild conditions, and fire was allowed to gradually progress into the karri forest type without further ignitions.
Walpole	Thames	Shrublands and swamps, known to contain the sunset frog, were ignited early in spring when organic soils were still saturated and/or under water. An increase in the number of frogs calling was noted post burn and two new populations were detected (both sites had been visited several times prior to burning).

District	Location	Consideration of habitat requirements of diverse ecotype zones
		Lighting patterns were designed to ensure that two populations of *Lambertia rariflora* subsp *Lutea* (Priority 3) were excluded from burning.
Frankland (Walpole)	D'Entrecasteaux National Park DC1 Inlet block	Ignition was undertaken during mild conditions on several occasions between July and September 2001. The northern and eastern edges of the block were burnt at low to moderate intensity to a depth of 100-800 metres from the boundary track. This has achieved a burn out of about 20 per cent of the block, most of this being coastal heath vegetation. The ignition pattern employed for this burn has sought to minimise the extent of fire spread into woodlands of *Agonis flexulosa* and *Eucalyptus cornuta*.

Note: Details of burns conducted during summer and autumn 2000 at Chariup, Eastbrook, Giants, Sutton, Thornton and Yackelup were included in the Progress and Compliance Report for 2000

APPENDIX 15

Development of a formal Environmental Management System by the Department of Conservation and Land Management

DEVELOPMENT OF A FORMAL ENVIRONMENTAL MANAGEMENT SYSTEM BY THE DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Introduction

The Department of Conservation and Land Management formally approved the process of developing an Environmental Management System (EMS) for the Sustainable Forest Management output in native forests in January 2001. This followed the establishment of the Forest Products Commission (FPC) in November 2000.

Status of development of the ISO 14001 conforming EMS in native forests

The EMS development has involved the following steps:

- preparation of a project plan;
- commencement of the work on the completion of the Implementation Tasks;
- commencement of the review of operations that can have a significant impact on the environment (431 - Aspects); and
- identification of Government, Ministerial and departmental documents that guide or direct operations (432 – Legal and Other Requirements).

Additionally, the process of developing the EMS has required a review of the following documents:

- the Draft Forest Management Plan;
- the draft guideline, *Silvicultural practice in the jarrah forest*;
- the draft guideline, *Silvicultural practice in the karri forest*;
- the draft guideline, *Silvicultural practice in the wandoo forest*;
- Section 1 – Planning of *Manual of Management Guidelines for Timber Harvesting in Western Australia* (March 1999); and
- Memorandum of Understanding CALM / FPC.

APPENDIX 16

Progress with implementation of proposals in the Forest Management Plan 1994-2003 for changes to land category

PROGRESS WITH IMPLEMENTATION OF PROPOSALS IN THE FOREST MANAGEMENT PLAN (1994-2003) FOR CHANGES TO LAND CATEGORY

In 1987 the original regional management plans for the Department of Conservation and Land Management's Northern Forest, Central Forest and Southern Forest Regions (now Swan, South West and Warren Regions) were approved in accordance with the *Conservation and Land Management Act 1984* (CLM Act), and work began to implement their recommendations on changes to land category. Tables were drawn up to record the progress of the implementation. The work continued after the Forest Management Plan 1994-2003 (FMP) was approved, with the tables amended to incorporate the new or amended recommendations in the FMP.

The geographical scope of the FMP is the area comprising the Department's then Swan, Central Forest and Southern Forest Regions. Recommendations on changes to land category applied to lands subject to the CLM Act, i.e. terrestrial reserves at that time vested in the National Parks and Nature Conservation Authority (NPNCA) or the Lands and Forests Commission (LFC) (now vested in the Conservation Commission of Western Australia), and freehold land held in the name of the Department's Executive Director that contains native vegetation. Such lands comprise State forest, CLM Act timber reserves, national parks, conservation parks, nature reserves and lands vested in the NPNCA or the LFC for conservation purposes under (then) section 5(g) of the CLM Act. Some recommendations on changes to land category in the FMP concerned lands not vested in either the NPNCA or the LFC and are therefore outside the legal scope of the FMP, but are indicative of broader policy commitments and are relevant to the plan.

Implementing the land category recommendations

For many areas proposed to be excised from State forest, the boundaries were not adequately defined in the FMP. The first step in those cases was to define the boundary, with reference as far as possible to features on the ground (tracks, streams, etc.). The process involved referring the areas concerned to the district office and to the Department's then Director of Forests.

The Department wrote to the various bodies whose agreement to the changes in land category was needed, particularly local government, the Water and Rivers Commission (WRC) and the Department of Mineral and Petroleum Resources [formerly the Department of Minerals and Energy (DME)]. Where any of those bodies raised concerns about or objected to the proposal, the Department then had to undertake discussions and correspond further with the body concerned.

Once the approvals were obtained from the bodies concerned, the Department of Land Administration (DOLA) was approached to have the reserve created. Where the land was State forest, the excision of land to create the conservation reserve involved a revocation motion to be passed by Parliament, in accordance with the CLM Act. DOLA then arranged to have a reserve created from the cancelled State forest.

Factors that delayed implementation

While many of the proposed changes in land category in the FMP have been fully implemented, concerns raised by the local government, WRC or DME stalled the implementation of other recommendations.

DME preferred to assess many of the recommendations in groups, rather than individually. In November 1995, DME provided tables that set out its response to all the recommendations. This was the first advice that this Department had received on many of the proposals. DME still had to refer the proposals to the mining industry for comment, prior to referring them to the then Minister for Mines for approval. The matter lapsed there, since the mining industry was reluctant to comment until it knew what was proposed in the coming Regional Forest Agreement (RFA).

Another factor that delayed the implementation of recommendations was the Commonwealth's *Native Title Act 1993 (NTA)*, which came into effect in January 1994. Following discussions with the Department, DOLA drafted a policy paper that had the effect of allowing the reservations to proceed, taking the paper to the State Cabinet for its approval. The policy was finalised in July 1996. By then, however, it had become apparent that the RFA, which covered most of the area apart from the Swan Coastal Plain, was likely to change many of the recommendations in FMP. It was therefore decided to postpone work on implementing the outstanding recommendations likely to be affected. Since the change of Government in 2001, the effect of native title on land reservation has been reassessed, which has once again delayed the creation of conservation reserves.

Additionally, DOLA has had delays in creating new reserves in areas of forest that Parliament agreed to cancel years ago (e.g. the addition of the Valley of the Giants to Walpole-Nornalup National Park). Complexities of dealing with the *Land Administration Act 1997* and the closure of unwanted roads have contributed.

Some proposals could not be progressed within the time-frame of the plan. Camballan and Goonac (South West Region, formerly Central Forest) are pastoral leases: the land category cannot be changed until 2015, when the pastoral leases expire.

The *Protecting our old-growth forests* policy committed to create 30 new national parks, including the 12 new national parks promised under the RFA, and two new conservation parks. Some of these proposals built on earlier proposals. For example, Perup (Warren Region, formerly Southern Forest) is currently State forest. Parliament gave its approval for the area of State forest to be cancelled to allow the creation of Perup Nature Reserve. The Government's old-growth forests policy, however, proposes that Perup should become a national park.

Actions taken after the RFA was signed

Once the RFA was signed, in May 1999, the Government's priority was the land category proposals in the RFA. Of the RFA recommendations, the priority was to implement those that came under Clause 70(b): proposals in the FMP that were endorsed, and thus able to proceed without the production of a new management plan.

The Department wrote to the local governments, DME and WRC to seek their comments on the recommendations in the RFA's Clause 70(b). Negotiations with WRC and the Water Corporation took place for the proposals to create conservation reserves from Crown reserves and freehold land held by those bodies (e.g. land bordering the catchment area at Wellington Dam). For those recommendations where the FMP proposed a nature reserve or a conservation park but the RFA proposed a national park (e.g. Monadnocks, Wandoo, Milyeannup), approval was sought and gained from the Environmental Protection Authority that the recommendation in the RFA was not a significant change from that in the FMP (see Section 2.2 of this report). The recommendations in Clause 70(b) were then incorporated in a proposed *State Forest Excisions and Reserves Bill 2000.*

The proposed Bill included cancellation of State forest and reserves, both class A and unclassified, and creation of the required conservation reserves. The Parliamentary Counsel's Office (PCO) has drafted clauses for 24 reserves; a further 20 reserves need some work before they can go back to the PCO. The maps for the Bill have been prepared.

Many of the recommendations for areas of State forest to become conservation reserves in the FMP were, under the RFA, not to proceed for the time being but remain as State forest, as Interim Forest Conservation Zones (now called Forest Conservation Areas).

Action taken since February 2001

Priority has been given to the fine-scale reserve design for the 30 new national parks. Indicative boundaries for these proposed parks are progressively being released, and by the end of December 2002, indicative boundaries for 15 of the new parks had been announced. Public consultation will occur prior to the finalisation of the boundaries of the new national parks. Comment is currently being sought from stakeholders, interested community groups and individuals, as well as local Government authorities and relevant Government agencies on seven of the proposed parks. The indicative boundaries for the proposed Walpole Wilderness Area, comprising three existing national parks and a further four new national parks, have been considered by a stakeholder reference group, and recommendations from the group have been referred to the Minister for the Environment and Heritage for consideration.

The Department proposes to seek Cabinet approval to amend the State Forest Excisions and Reserves Bill to carry forward approximately 12 of the clauses not affected by commitments in the *Protecting our old-growth forests* policy; to finalise work on the 20 further reserves; and to include up to 11 new national parks proposed under the old-growth policy. The other new national parks will be the subject of future Bills, as public consultation progresses.

Current status of individual proposals

The table attached shows progress on implementation of the remaining recommendations, some, as explained above, are broader policy commitments outside the formal scope of the FMP. Those recommendations that have not been implemented, are not in the proposed Bill and are within the legal scope of the FMP are highlighted in

bold, and are commented on by means of a footnote or a remark in the 'Comments' column.

Progress with implementation of proposed changes to land category in the Swan Region.

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
Burnside	1		NR(unvested) to NR(CC)	YES				
Goegrup Lakes	2-6		other to NR	YES				
Marrarup	8		NR(unvested) to NR(CC)	YES				
North Dandalup	9-13		other to NR	YES (9,10,11,12) NO (13)			YES(13)	
Duncan	14		SF to CP	NO	24/25	24(Monadnocks NP) 25(SF)	YES	
Duncan	15		UCL to CP	NO	part 24	Monadnocks NP	YES	
Gyngoorda	**16**		**SF to CP**	**NO**	**26**	**retain as SF**		**Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress.**
Lane Poole	17-21		5(g) to CP	YES				
Lane Poole	22	12	Exec Dir to 5(g)	NO			YES	
Lane Poole	23-25		5(g) to CP	YES				
Wandering	27		other to CP	NO			YES	
Wandering	28-31		timber reserve to CP	NO			YES	
Yalgorup	32		Ex Dir to NP	YES				
George		13	SF to CP	NO	34	retain part as SF	part YES	Part was proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress.
Karnet	33		NR (unvested) to NP	NO			YES	
Boyagarring	35		UCL to CP	YES				
Gooralong	36		5(g) to NP	YES (as CP)			YES	
Lupton	37,38		other to CP	YES				
Monadnocks	39	5	5(g) to NP	NO			YES	
Monadnocks	**39**	**6,7**	**5(g) to 5(g) different purpose**	**NO**				**6 is for area of inundation near Canning Dam; 7 is for an Alcoa access corridor. Relevant local governments invited to comment on whole Monadnocks proposal. One had not replied when work on FMP proposals was halted because of the coming RFA.**
Serpentine	40		5(g) to NP	YES				

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
Serpentine	41		other to NP	NO			YES	
Strange Rd	43-44		NR(unvested) to NR(CC)	YES				
Gibbs		**9**	**SF to CP**	**NO**	**19**	**retain as SF**		**Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress.**
Gibbs		**10**	**timber reserve to CP**	**NO**	**19**	**retain as SF**		**Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress.**
Beechina North	45		NR(unvested) to NR(CC)	YES				
Bullsbrook	47		other to NR	YES				
Clackline	48,49		NR(unvested) to NR(CC)	YES				
Clackline	50		UCL to NR	YES				
Hoddy Well	51		NR(unvested) to NR(CC)	YES				
Lesmurdie Falls	**52,53**		**NP to CP**	**NO**				**Will no longer be pursued**
Nanamoolan	54-55		NR(unvested) to NR(CC)	YES				
Parkerville	56		NR(unvested) to NR(CC)	YES				
Wandoo CP	57-59		VCL to CP	YES	13	NP	YES	
Wooroloo	60		other to NR	YES				
Wundowie	61-64		other to NR	YES				
Dale	65		5(g) to CP	YES	9	NP	YES	
Dale	66		Exec Dir to CP	NO	10	NP	YES	
Dobaderry	67-69		NR to CP	YES				
Gooseberry Hill	**70**		**NP to CP**	**NO**				**Will no longer be pursued**
Greenmount	**71**		**NP to CP**	**NO**				**Will no longer be pursued**
Gunapin	72		SF to CP	YES	13	NP	YES	
Julimar	73-76		other to CP	NO	1	IFCA		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Julimar	**77-80**		**SF to CP**	**NO**	**1**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest**

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
								Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.
Kalamunda	**81**		**NP to CP**	**NO**				**Will no longer be pursued**
Lake Leschenaultia	82		SF to CP	YES				
Lesmurdie Falls	**83**		**NP to CP**	**NO**				**Will no longer be pursued**
Moondyne	84		UCL to NP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Mundaring	85-90		other to CP	NO	5	NP	YES	
Mundaring	91		SF to CP	NO	5	NP	YES	
Mundaring	92-93		other to CP	NO	5	NP	YES	
Russell	94-95		SF to CP	NO	14/15	14(NP) 15(retain as SF)	YES	
Sullivan	96		SF to CP	YES	13	NP	YES	
Toodyay	97		timber reserve to NP(Ex. Dir)	NO	2	(part) IFCA	YES (part)	The part that was not IFCA was in the proposed Bill. Land not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94.
Moondyne	**127**		**NR to NP**	**NO**				**DMPR objection given exploration by BHP Minerals Ltd for bauxite, base metals and gold. These two are already nature reserves.**
Morangup	**128**		**NR to NP**	**NO**				
Julimar	129		other to CP	NO	1	IFCA		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
John Forrest		2	freehold to NP	YES				
Gingin-Boonanarring	98-101		UCL to NR	YES(98) NO(99-101)				Shire implications - gravel
Neerabup	102		NP to CP	Made into a NR				
Yeal Swamp	104		UCL to NR	YES				
Bampanup	105-107		NR(unvested) to NR(CC)	YES				
Caraban	**108-110**	**8(a), 8(b)**	**8(a) SF to 5(g), 8(b) SF to CP**	**NO**				**Comments invited from local governments, WAWA and DMPR. WAWA has interests in groundwater and DMPR in protecting the limestone resource. Purpose of part of the expanded to include 'Groundwater**

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
								Protection' and 'Strategic Limestone Development'. Aspects of boundary are being investigated.
Caraban	**111**	**8(b)**	**SF to CP**	**NO**				
Lake Muckenburra	112		other to NR	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Melalueca Park	**113**		**SF to NR**	**NO**				**Comments invited from DOLA, WAWA, DMPR & local governments. Letters written to claimants of native title and their representative bodies, but no reply. DMPR was opposed because of petroleum interests, but opposition withdrawn 16/4/02. Parliamentary approval, 12/4/94.**
Moore River	114-117		UCL to NR	YES except 117				Shire objection to 117
Moore River	**118**		**NP to NR**	**NO**				**Will no longer be pursued**
Neerabup	**119**		**NP to CP**	**NO**				**Will no longer be pursued**
Pinjar	120		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Ridges	**121**		**SF to NP**	**NO**				**City of Wanneroo supports. DMPR opposed because of high-quality limestone and existence of several mining tenements.**
Ridges	**122**		**SF to NP**	**NO**				
Wabling	**123-125**		**SF to NR**	**NO**				**Comments invited from DOLA, WAWA, DMPR & local governments. Shire of Gingin concerned about a proposed gravitational observatory. No reply from DMPR.**
Yanchep	**126**		**SF to NR**	**NO**				
Mogumber	130,131		Exec Dir to NR	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94

Abbreviations

CC Conservation Commission
CP conservation park
DMPR Department of Mineral and Petroleum Resources
Exec Dir Freehold vested in the Executive Director
IFCA Interim Forest Conservation Area, to be converted later to the land category proposed in the FMP
NP national park
NR nature reserve
SF state forest
WAWA Western Australian Water Authority
5(h) miscellaneous reserves under section 5(1)(h) of the *CLM Act 1984*

Footnotes

(1) The proposed *State Forest Excision and Reserves Bill*

Progress with implementation of proposed changes to land category in the South West Region.

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
Blue Rock Cave	1		other to NP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Blackwood	2		SF to CP	NO	97	NP	YES	
Boranup	3,4		SF to NP	YES				
Chester	5		SF to NR	NO			YES	
Leeuwin-Naturaliste	6		UCL to NP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Ludlow	7-11		SF to NP	YES				
Mowen	**12**		**SF to CP**	**NO**	**93**	**retain as SF**		**Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress.**
Paget	13		SF to NR	NO			YES	
Rapids	14		SF to CP	NO	part 92	retain part as SF	YES	
Leeuwin-Naturaliste	15		timber reserve to NP	YES				
Whicher	16		SF to NR	NO	part82, 84	retain part as SF	YES	
Witchcliffe	17,18		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Leeuwin-Naturaliste		43	other to NP	NO			YES	
Capercup Rd North	19		NR(unvested) to NR(CC)	YES				
Coalfields Rd	20		NR(unvested) to NR(CC)	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Lennard	21-23	26,27	SF to CP	NO	49	IFCA		22 was proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress. 21 & 23 were proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.
North Boyanup Rd	24		NR(unvested) to NR(CC)	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Wyvern Rd	25		NR(unvested) to	YES				

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
			NR(CC)					
Bennelaking	26		other to CP	NO			YES	
Bennelaking	27-29		SF to CP	NO			YES	
Bennelaking	30		UCL to CP	NO			YES	
Dardanup	31		SF to CP	NO	part 50	part SF, part CP	YES	
Goonac	32	29	other to CP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Goonac	**33**	**29**	**SF to CP**	**NO**				**Pending surrender of pastoral leases**
Goonac	34-35	29	UCL to CP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Lane Poole Reserve	36-37	25	WAWA to NP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Lane Poole Reserve	38-39	25	other to NP	NO			YES	
Lane Poole Reserve	40	25	5(g) to NP	NO			YES	
Muja	41		other to CP	NO			YES	
Muja	42-46		UCL to CP	NO			YES	
Muja	47		timber reserve to CP	NO			YES	
Westralia	48-49		SF to CP	NO	46	IFCA (48)	YES (49)	Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.
Roseneath		28	SF to CP	NO			YES	
Falls Brook	50		NR(unvested) to NR(CC)	YES				
Benger Swamp	51		Exec Dir to NR	YES				
Clifton	**52**		**SF to NP**	**NO**				**Comments invited from local government, WAWA & DMPR. DMPR has objected.**
Falls Brook	53		NR(unvested) to NR(CC)	YES				
Kemerton	54	16	Ex Dir to industrial site	n/a				
Kemerton	55,56	18,19	Ex Dir to part 5(g), part ind site	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Lane Poole Reserve	57-58	23	5(g) to part CP, part NP	NO			YES	
Myalup	**59-60**		**SF to NP**	**NO**				**Comments invited from DOLA, WAWA, DMPR and local governments. DMPR**

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
								objected owing to heavy mineral sands and exploration licences held by Cable Sands Pty. Ltd.
McLarty	**61**		**SF to NP**	**NO**				
Riverdale	62		NR(unvested) to NR(CC)	YES				
Stene	63	part 23,24	SF to NP	NO			YES	
Wagerup	64	15	NP (unvested)to NR	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Clarke (Falls Brook)		**22**	**SF to NR**	**NO**	**36,37**	**part SF, part IFCA**		**Part was proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity. Part was proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress**
Kemerton		17	freehold to 5(g)	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Kemerton		20	freehold to 5(g)	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Leschenault Peninsula		21	freehold & CP to CP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Donnybrook-Boyup Rd	65		NR(unvested) to NR(CC)	YES				
Golden Valley	66		Exec Dir to 5(g)	NO	69	SF		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Noggerup	67	31,35	SF to CP(31) retain as SF(35)	NO			YES (31)	
Preston	**68**	**32**	**SF to CP**	**NO**	**53**	**retain as SF**		**Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress**
Wournbelup	69-72		UCL to SF	NO	part 58	part NR		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Bridgetown (Maslin)	73-74	41	NP(unvested) to shire	YES				
Camballan	75-79	36,37,38	UCL to CP	NO	56	retain (37) as SF		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Goonac	80	30	other to CP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Greenbushes	81-83		SF to NR	NO	61	part IFCA	part YES	
Mullalyup	**85-87**		**SF to CP**	**NO**	**72/70**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the**

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill (1)	Comments for those recommendations that: . are within the legal scope of FMP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
								FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.
Nollajup	88		SF to NR	NO			YES	
Chowerup	103-104		other to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Hester (East)		40	SF to CP	NO			YES	
Ryall		**33**	**SF to CP**	**NO**	**74**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.**
Hester (west)		**42**	**SF to CP**	**NO**	**60**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.**
Ellis Creek	**89**		**SF to CP**	**NO**	**67**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.**
Blackwood	90		Exec Dir to CP	NO			YES	
Blackwood	91-98		SF to CP	NO			YES	
Dalgarup	**99**		**SF to NR**	**NO**	**65**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.**
Milyeannup	100		SF to NR	NO	101	NP	YES	
St John Brook	**101,102**		**SF to CP**	**NO**	**81**	**retain as SF**		**Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress**
Beaton		**44**	**SF to CP**	**NO**	**66**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.**

Abbreviations

CC Conservation Commission
CP conservation park
DMPR Department of Mineral and Petroleum Resources
Exec Dir Freehold vested in the Executive Director
IFCA Interim Forest Conservation Area, to be converted later to the land category proposed in the FMP
NP national park
NR nature reserve
SF state forest
WAWA Western Australian Water Authority
5(h) miscellaneous reserve reserved under section 5(1)(h) of the *CLM Act 1984*

Footnotes

(1) The proposed *State Forest Excision and Reserves Bill*

Progress with implementation of proposed changes to land category in the Warren Region.

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill(1)	Comments for those recommendations that: . are within the legal scope of FP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
Blackbutt Reserve	1	45	SF to CP	NO			YES	
Bockarup	2,3		UCL to NR	NO			YES	
Bolbelup	4		timber reserve to NR	YES				
Dickson	**5,13**		**SF to NR**	**NO**	**104**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity. The Government's *Protecting our old-growth forests* policy now proposes the area as a NP.**
Lewin	7		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Wournebelup	8,9		UCL to SF	NO	part 58	part NR		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Bokarup	10		other to NR	NO			YES	
Bolbelup	12		timber reserve (unvested) to NR	YES				
One Tree Bridge	15		other to CP	NO	105	IFCA		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
One Tree Bridge	**16**		**SF to CP**	**NO**	**105**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.**
Perup	17		SF to NR	NO			YES	
Perup	18		timber reserve to NR	NO			YES	
Quillben	19		other to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Shannon	20		SF to NP	YES				
Sir James Mitchell	**21,22**		**NP to SF**	**NO**				**Is a narrow strip of land along the South-West Highway, unsuitable as a NP.**
								It is being added to SF where that is the adjoining land category
Solai	23		other to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Strickland	**24**		**SF to NR**	**NO**	**114**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the**

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill(1)	Comments for those recommendations that: . are within the legal scope of FP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
								CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity. The Government's *Protecting our old-growth forests* policy now proposes the area as a NP.
Topanup	25		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Unicup	26		other to NR	YES				
Dingup		**48**	**SF to CP**	**NO**	**113**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity.**
Keninup		46	SF to NR	NO	part 108	retain part as SF	part YES	Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress
Talling		53	SF to NR	NO	part 110	retain part as SF	part YES	Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress
Talling		52	other to NR	NO			YES	
Chitelup (Mt Roe)		**55**	**SF to NP**	**NO**	**135**	**IFCA**		**Proposed in the RFA for all or part to become an Interim Forest Conservation Area, initially to be an area of State forest classified under section 62 of the CLM Act as a forest conservation area, later to be converted to the land category proposed in the FMP 94, subject to established State Government processes, including a review of mineral exploration and prospectivity. The Government's *Protecting our old-growth forests* policy now proposes part of the area as a NP.**
King Jarrah Reserve		49	other to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Mickalarup Swamp		47	other to NR	NO			YES	
D'Entrecasteaux	27	56	SF to NP	NO	part 116	retain part as SF	part YES	Proposed in the RFA to remain as State forest. The new Government has reinstated the proposal of the FMP. See the draft Forest Management Plan (2002) for more details of progress
D'Entrecasteaux	28		NR to NP	YES				
Boorara	31		SF to CP	NO			YES	
Brockman	32		SF to NP	YES				
Cleave	33		UCL to SF	YES				
D'Entrecasteaux	34		UCL to NP	YES				

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill(1)	Comments for those recommendations that: . are within the legal scope of FP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
D'Entrecasteaux	35		NR to NP	YES				
D'Entrecasteaux	36		other to NP	YES				
D'Entrecasteaux	37-78	58	UCL to NP (62 to SF)	YES (62 remained as NP)				62 went from UCL to NP, as proposed in 1987,
				NO - 45,46,77				but was not then converted to SF, as proposed in 1994
Gardner	79		UCLto SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Dombakup	80		SF to CP	NO			YES	
Gardner	81		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Hawke	82		SF to NP	YES				
Jane	83		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Mossop	84		UCL to SF	YES				
Muirillup	85		SF to CP	NO			YES	
Nairn	86		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Northcliffe	87,88		other to SF	NO	119/120	NP		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Northcliffe	89-92		UCL to SF	NO	part 119/120	NP		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Shannon	93-103		SF to NP	YES, NO(103)			YES (103)	
Shannon	104-109		UCL to NP	YES				
Sir James Mitchell	**111,112**		**NP to SF**	**NO(111) YES(112)**				**Is a narrow strip of land along the South- West Highway, unsuitable as a NP.**
								It is being added to SF where that is the adjoining land category
Treen	113-114		SF to NP	YES				
Hawke		57	SF to NP	NO			YES	Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94.
Burnett	116,117		other to SF	YES				
Chorkerup	118		NR(unvested) to NR(CC)	YES				
Collis	119		other to SF	YES				
D'Entrecasteaux	120-123		UCL to NP	YES				
Denbarker	124-126		NR(unvested) to NP	NO	131	IFCA		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Denbarker	127		timber reserve (unvested) to NP	NO	131	IFCA		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Gully	128		other to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94

Name	FMP ID No		FMP 1994 Proposal	Fully Implemented	Different Categories proposed by RFA		Originally included in proposed Bill(1)	Comments for those recommendations that: . are within the legal scope of FP 94; . have not been implemented; and . are not in the proposed *State Forest Excisions and Reserves Bill.*
	1987	1994			ID	Proposal		
Gum Link Road	129,130	69	NR(unvested) to NR(CC)	YES				
Kordabup	131		other to NR	NO			YES	
Kordabup	132-136		timber reserve (unvested)to NR	NO			YES	
Mitchell River	137		other to NP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Pardelup	138,139		other to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Randell Rd	140		NR(unvested) to NR(CC)	YES				
Styx	141,151		other to SF	No				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94.
Thames	152		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Thames	153		NR(unvested) to NR(CC)	YES				
Thames	154	70	other to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Walpole-Nornalup	155		UCL to NP	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Wattle-Soho	156-157		other to NP	YES				
Wattle-Soho	158-160		UCL to NP	YES				
Blue Gum Creek	161		other to NR	YES				
D'Entrecasteaux	163		SF to NP	YES				
D'Entrecasteaux	164-166		UCL to NP	YES				
D'Entrecasteaux	167-174		UCL to NP	YES				
Mt Lindesay	175-177		other to NP	NO	131	IFCA	YES	
Mt Lindesay	178,179		SF to NP	NO	131	IFCA	YES	
Dixie	180		UCL to SF	YES				
Giants	181,182		SF to NP	NO			YES	
Hiker-Crossing	183		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Kwornicup Lake	184		other to NR	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Mossop-Sutton	185		UCL to SF	YES				
Mt Frankland	186		SF to NP	YES				
Rate-Clear Hills	188		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94

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	1987	1994			ID	Proposal		
Shannon	189-199		SF to NP	YES				
Shannon	200-202		UCL to NP	YES				
Sheepwash	203		SF to NP	NO			YES	
Sir James Mitchell	205-209		NP to SF	YES				
Sleeman Creek	210		NR(unvested) to NR(CC)	YES				
Table Hill	211	part 67	SF,UCL to NP	NO		YES		
Thames	212	part 66	other to WAWA	NO	132	SF		Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94.
Wamballup	213,214		NR(unvested) to NR(CC)	YES				
Wattle-Soho	215		UCL to NP	YES				
Wattle-Soho	216-218		SF to NP	YES				
Wattle-Soho	219		UCL to NP	YES				
Wye	220		UCL to SF	NO				Not vested in the NPNCA or LFC and therefore outside the legal scope of FMP 94
Sheepwash Creek	**221**		**NR to NP**	**NO**				**Comments invited from WAWA and the local governments. WAWA wanted to exclude areas on the Denmark and Kent Rivers, as possible future damsites. All three local governments raised matters of concern or requested more information. The present harvesting of wildflowers in the area will be phased out gradually over several years.**
Pardelup	222		NR(unvested) to NR(CC)	YES				
Mattaband		59	SF to NP	NO			YES	
Mt Roe		60	UCL to multi purpose	NO	130/135	part IFCA, part NP	YES	
Mt Roe		61	SF to multipurpose	NO	130/135	part IFCA, part NP	YES	
Mt Roe		62	other to multipurpose	NO	130/131	part IFCA, part NP	YES	
Mt Lindesay		**63**	**SF to NP**	**NO**				**Comments invited from WAWA and the local governments. WAWA wanted to exclude areas on the Denmark and Kent Rivers, as possible future damsites. All three local governments raised matters of concern or requested more information. The present harvesting of wildflowers in the area will be phased out gradually over several years.**

Abbreviations

CC Conservation Commission
CP conservation park
DMPR Department of Mineral and Petroleum Resources
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SF state forest
WAWA Western Australian Water Authority
5(h) miscellaneous reserve reserved under section 5(1)(h) of the *CLM Act 1984*

Footnotes

(1) The proposed *State Forest Excision and Reserves Bill*

APPENDIX 17

FORESTCHECK – Report on Progress 2001-2002

REPORT OF PROGRESS
2001 - 2002

Science Division

October 2002

Government of Western Australia

DEPARTMENT OF Conservation AND LAND MANAGEMENT

Conserving the nature of WA

CONTENTS

Executive Summary

This document includes the results of the first year of sampling under the FORESTCHECK initiative (Concept Plan available at http://www.naturebase.net/science/science.html). Three FORESTCHECK sites (10 grids) were established in jarrah forests near Manjimup in spring 2001 and autumn 2002. Further sites will be established throughout the forest each year over the next four years.

Particularly notable is the large number of forest organisms recorded and the advance in our understanding of the biodiversity, distribution and disturbance ecology of a broad range of organisms for relatively little effort. This underlines the benefits of well integrated projects that draw together multi-disciplinary teams of skilled people working to a common goal at the landscape scale. I believe that this and the other information collected will serve as a solid foundation for a very important monitoring program to support ecologically sustainable forest management in WA.

In devising FORESTCHECK, we deliberately adopted a 'belt and braces' strategy. Initially, the FORESTCHECK team was asked to err on the side of collecting too much information. We strived to avoid not sampling or undersampling relevant factors or processes, all of course in the context of a finite budget. Although recognizing that an indicator species approach would be warranted for cryptogams, invertebrates and fungi, we were reluctant to commence with a list of species that was too short in case valuable information was omitted. Experience with the Kingston project (1994-9) had demonstrated that there was no cost saving involved with counting only nominated indicator species of birds or trapping only nominated indicator species of mammals, reptiles and frogs. With vascular flora, there is a significant risk that an *a priori* list of indicator species may not be relevant to most parts of the forest, given the marked beta diversity evident with ground flora.

I am confident that reliable lists of indicator species of vertebrates and vascular flora will be able to be assembled after FORESTCHECK has operated for several years and data have been collected from a range of representative sites.

As the data presented in this progress report are from only the first year of monitoring at a small number of sites, it is too early to carry out any meaningful analysis and interpretation. However, a number of interesting observations have emerged. As expected, the species richness and composition of birds at each of the sites varied according to the maturity and structural complexity of the vegetation; generally, bird recovery following timber harvesting parallels that of the vegetation structure . A most striking result is the contrast in the abundance of mammals east and west of the South West Highway. Mammal capture rates were very high on the eastern grids, but very low on the western grids, regardless of treatment. This is probably attributable to natural environmental factors affecting habitat suitability such as climate, landform and vegetation structure and to management history including Western Shield (fox control). At the Kingston monitoring sites, ground dwelling vertebrate and invertebrate fauna are recovering well. Fox control and the extensive network of buffers (temporary exclusion areas – TEAs) have facilitated a relatively rapid recovery following timber harvesting at these sites. While relatively abundant prior to timber harvesting, Western Ringtail Possums were not detected in any of the treatments on the Kingston sites, including the buffers, but Common Brushtail Possums were abundant. Some 588 invertebrate morphospecies were collected including at least 24 with Gondwanan affinity. Good baseline data for more than 200 vascular plant species, 170 fungi species and 160 cryptogams (mosses and lichens) were gathered and further sampling will provide information about the role, recovery and successional pathways of these taxa. Data collected on vascular plants supports the Kingston Project findings, that annual herbs, grasses and weeds are generally favoured by disturbances associated with timber harvesting, but some woody shrubs, perennial herbs and geophytes especially are disadvantaged and may take some time to recover. Monitoring soil damage is not straight forward and further thought needs to be given to developing an efficient but meaningful protocol.

We learned some valuable lessons from this round of sampling; the following points have been collated from the reports submitted by the teams:

- Need to sample mammals with wire cages in spring as well as autumn.
- Need to voucher specimens of mammal species for which taxonomic limits are ill-defined (e.g. *Sminthopsis*).
- Need to refine the sampling procedure for estimating the abundance of vascular flora.
- Need to increase the number of 1m x 1m vegetation sampling quadrats to reduce the standard error.
- Need to ensure that sites have not been burnt more recently than 2 years, otherwise identification of vascular flora is impeded.
- Need to standardise soil damage assessment techniques.
- Need to collate details of management history (logging, fire and fox control) for each site.

It is my intention to subject all of the data collected in the first five years of the program to a rigorous, integrated analysis, report and external review.

I extend my congratulations to all staff involved in the FORESTCHECK team for their professionalism. The project was carried out on time and within budget.

At the time of writing, we are selecting sites for sampling this spring and next autumn. These sites will be in the Collie-Harvey area.

Dr Neil Burrows
Director Science Division
October 2002

INTRODUCTION

Scope

FORESTCHECK is an integrated monitoring system that has been developed to provide information to forest managers in south-west Australia about any changes and trends in key elements of forest biodiversity associated with a variety of forest management activities. As such, it represents the most comprehensive systematic forest monitoring program in Australia and is one of a few of its kind in the world. Although the initial focus of FORESTCHECK will be on timber harvesting and silvicultural treatments in Jarrah forest, the intention is to extend the scale of monitoring over time to include other forest ecosystems, fire (prescribed and wildfire), mining, the effects of forest disturbance for utility corridors (e.g. roads, power transmission lines), and the impacts of recreation uses. Note, however, that the Forest Products Commission will only fund the part of FORESTCHECK that is specific to its activities consistent with Ministerial Conditions on the Forest Management Plan.

FORESTCHECK has been developed to meet a range of compliance conditions placed on the Forest Management Plan 1994-2003 through Ministerial Conditions and the Codd Report of 1999. Integrated monitoring is a fundamental component of Ecologically Sustainable Forest Management (ESFM), and is necessary for reporting against some of the Montreal Process criteria for ESFM. In addition, monitoring forms the basis for adaptive management, which is recognized as an appropriate strategy for managing under conditions of uncertainty and change.

The development of FORESTCHECK has taken place over two years and has included input from scientists and managers within the Department of Conservation & Land Management, and from a number of external scientific agencies. Background to this process is described in the FORESTCHECK Concept Plan with details provided in the FORESTCHECK OPERATING PLAN. Science Division of the Department of Conservation and Land Management has primary carriage of FORESTCHECK.

Sampling Strategy

Timber harvesting in jarrah forests is currently undertaken according to Silvicultural Guideline 1/95 (being revised), which recognizes three silvicultural objectives:

Thinning – to promote growth on retained trees,

(1) Release of regeneration by gap creation, where existing advance growth is encouraged to develop unimpeded by the removal of competing overstorey,

(2) Regeneration establishment by shelterwood, where seedlings are encouraged to establish and develop into the lignotuberous ground coppice stage. This is achieved by reducing the competition from the overstorey, but retaining sufficient overstorey to provide a seed source and maintain other forest values until the ground coppice is developed and capable of responding to release.

Monitoring will focus on the gap creation and shelterwood treatments initially as these are the most widespread operations and involve the greatest extent of disturbance to the forest. Thinning is more limited in extent, and only results in relatively minor disturbance of the overstorey, understorey or soil.

Monitoring will take place at a number of locations throughout the forest, which are referred to as FORESTCHECK sites. Sites will be stratified according to recognized ecological gradients of rainfall, evapo-transpiration and soil fertility and will be allocated according to mapped forest ecosystems. Allocation of sites will also take account of scheduled future harvesting within the jarrah forest, with priority given to those ecosystems likely to be subject to harvesting on an extensive scale in the next decade.

Each FORESTCHECK site consists of up to four sampling grids, depending on the range of silvicultural prescriptions applied. Grids are established in forest subject to the following treatments:

(1) gap release,
(2) shelterwood,
(3) coupe buffer or internal reference forest i.e. temporary exclusion areas (TEAS) between adjacent gaps or shelterwood forest,
(4) external reference or control forest i.e. not recently harvested, or has had minimal harvesting, and will not be subject to harvesting in the foreseeable future.

Grids are closely matched in terms of site characteristics (climate, geomorphology, soils, topography, altitude, aspect), pre-harvest forest structure and vegetation attributes in order that differences between grids reflect the effects of harvesting, rather than inherent site differences. Not all treatment types are found in the one locality and there will be occasions when external reference forest may have to be located some distance from their harvested counterparts. It is not always be possible to find gap and shelterwood treatments together, because underlying relationships between rainfall, soil fertility and jarrah lignotuber development influence the broad pattern of silvicultural treatment across the jarrah forest, as have previous silvicultural activities.

During spring 2001 and autumn 2002, three FORESTCHECK sites (ten sampling grids) were established in the Darling Plateau subregion (Bevan, Mattaband, Corbalup, Collis, Yanmah and Warren vegetation complexes of Mattiske and Havel 1998) in Kingston, Thornton, Carter and Easter forest blocks. Four additional sites are scheduled for establishment each year in 2002, 2003, 2004 and 2005 and will probably be located in the Blackwood Plateau subregion (Kingia vegetation complex of Mattiske and Havel 1998) and in the Darling Plateau subregion (Dwellingup and Yalanbee vegetation complexes of Mattiske and Havel 1998). By 2005, up to 80 sample grids will be established throughout the Jarrah forest. It is envisaged that each site will be resampled about every 5 years.

Methodology

A range of ecosystem attributes will be monitored at each site, as follows:

1. Vertebrate fauna (birds, reptiles, frogs, mammals)
2. Invertebrate fauna
3. Vascular plants and cryptogams
4. Macrofungi and coarse woody debris
5. Foliar nutrients and tree growth
6. Forest regeneration and structure
7. Soil disturbance

Sampling methodologies for each set of ecosystem attributes are described in detail in the Operations Plan, together with examples of protocols for data collection and storage. General site attributes such as geology, soils, landform, climate, fire history, logging history, extent of *Phytophthora* impact etc. are also recorded.

Monitoring of biodiversity is based on a sample grid. The main grid is 100 m x 100 m, with 30 m x 30 m vegetation sample plots at each corner. Details of sample design and protocols for each element of the biota and sampling schedules, are provided in the Operating Plan.

Before commencing measurements, each FORESTCHECK site is located in the field, the sample grids installed and then the various monitoring protocols for each taxonomic group (discipline) established on the grid. The figures below are a breakdown of the cost of establishing and assessing the sites for 2001/02.

Reference

Mattiske, E.M. and Havel, J.J. 1998. Regional Forest Agreement Vegetation Complexes (6 maps). Government of Western Australia and Commonwealth Government, Department of Conservation and Land Management, Como.

Consolidated Budget Table

Cost of establishing and monitoring FORESTCHECK sites 2001/02

Task/Activity	OIC	[1]One off	Materials (incl. travel)	Vehicles	Data Entry	Ord OT	[2]Salary + OH	TOTALS
Grid establishment	McCaw		7 080	3 375			29 229	**39 684**
Spotlight Road surveys (verts.)	Liddelow			3 420		10 710		**14 130**
Birds (diurnal)	Liddelow		300	3 300	1 000		12 178	**16 778**
Birds (nocturnal)	Liddelow	500		1 350	500	3 600		**5 950**
Fauna (grid trapping)	Liddelow		1 800	1 800	1 000		12 178	**16 778**
Invertebrates	Farr	2 900	2 400	3 000	900		9 635	**18 8355**
Flora (vasc. plants & cryptogams)	Ward	2 000	450	2 700	4 000		9 220	**18 370**
Forest structure and regeneration	McCaw		1 800	900	3 000		6 286	**12 085**
Soils	Whitford	5 000	9 000	3 000	3 000		20 059	**42 542**
Macrofungi	Robinson		1 980	3 000	2 000		5 982	**12 962**
TOTALS		**10 400**	**24 8100**	**25 845**	**15 400**	**14 310**	**104 767**	**195 532**

GRAND TOTAL (Division and Corporate OH) = 195 532 x 1.4375 = <u>281 077</u>

- [1]One-off costs include: bird census equipment (1 set); invertebrate sampling and storage equipment; digital camera; dust extraction system for processing of soil bulk density cores.
- [2]Salary+ OH = salary x 1.194

SITES STUDIED AND GRID ESTABLISHMENT – 2001/02

The following three tables detail where and when the sampling grids were established.

Table 1.

	Location	Monitoring Grid No.	Start Date [Day]	Start Date [Month]	Start Date [Year]	Recorder(s)	Treatment
1	Kingston	M1	8	10	2001	RJC & BGW	External control
	Kingston	M2	15	10	2001	RJC & BGW	Gap release 1996
	Kingston	M3	8	10	2001	RJC & BGW	Shelterwood 1996
	Kingston	M4	12	10	2001	RJC & BGW	Buffer (Coupe buffer)
2	Yornup	M5	15	10	2001	RJC & BGW	External control
	Thornton	M6	16	10	2001	RJC & BGW	Gap release 1990
	Thornton	M7	16	10	2001	RJC & BGW	Buffer (Coupe buffer)
3	Carter	M8	17	10	2001	RJC & BGW	Gap release 1999
	Carter	M9	17	10	2001	RJC & BGW	Buffer (Coupe buffer)
	Easter	M10	18	10	2001	RJC & BGW	External control

Table 2.

Location	Aspect Code	Aspect Description	Slope (degree)	Latitude	Longitude	GPS
Kingston	NW	Surrounding ha mostly faces north west	1	34°04'03"	116°19'34"	Yes
Kingston	S	Surrounding ha mostly faces south	0.5	34°04'59"	116°21'29"	Yes
Kingston	E	Surrounding ha mostly faces east	±2	34°05'20"	116°22'00"	Yes
Kingston	S	Surrounding ha mostly faces south	0.5-1	34°05'20"	116°21'36"	Yes
Yornup	S	Surrounding ha mostly faces south	3	34°06'24"	116°08'33"	Yes
Thornton	E	Surrounding ha mostly faces east	0.5	34°07'17"	116°03'31"	Yes
Thornton	S	Surrounding ha mostly faces south	0.5	34°07'17"	116°03'26"	Yes
Carter	SE	Surrounding ha mostly faces south east	1	34°05'27"	116°01'46"	Yes
Carter	SE	Surrounding ha mostly faces south east	1	34°05'27"	116°01'46"	Yes
Easter	N	Surrounding ha mostly faces north	3	34°12'43"	115°47'49"	Yes

Table 3.

Location	Locality	Other Site Descriptive	General Comments
Kingston	Winnejup Forest Block, North Boundary Road, 1 km N of Kingston Road	Jarrah/Marri Forest, gravelly clay	Light logging (old), burnt (old 6-8 years), GN80/4 Shield tree on left hand side of track, plot on right hand side of track (E) 132° E, Trapline NB5 right hand side of track.
Kingston	Kingston Forest Block, off S side of Kingston road, 2.5 km E off Lejeune Road,	None	Regrowth - heavily logged and burnt. Brown loam gravel.
Kingston	Tinkers Flat Road, 800 m S of Kingston Road, Kingston Forest Block	Jarrah/Marri disturbed forest, loamy clay gravel.	Moderately logged, highly disturbed (scarified), burnt tops (recent).
Kingston	Kingston Forest Block	Jarrah/Marri Forest. Brown loamy gravel.	Light logging. Burtn 5-6 years. 50 m off track to Line 3.
Yornup	N side of Wagelup Road, 1.4 km W of railway line, Yornup Forest Block	Brown loamy gravel, laterite exposure.	Lightly logged (old).
Thornton	10.7 km on Wagelup Road from railway crossing, Thornton Forest Block	Brown gravel	Highly disturbed - regrowth.
Thornton	10.8 km W on Wagelup road from railway Crossing, Thornton Forest Block	Jarrah/Marri Forest. Brown gravelly clay.	Heavy litter.
Carter	1 km N of intersection of Donnelly Mill Road and Swamp Road, to track (2 km to plot), Carter Forest Block	Jarrah/Marri regrowth forest. Brown clay loam gravel.	No Comment
Carter	1 km N of intersection of Donnelly Mill Road and Swamp Road - track to plot 2 km, next to M8. Carter Forest Block.	None	No Comment
Easter	Dickson Tower, Easter Forest Block	Unlogged Jarrah Forest. Brown loam, some gravel.	No Comment

Plates 1 - 10 demonstrate the appearance of the vegetation at each of the 10 sites

Control M1 Kingston

Gap M2 Kingston regenerated 1996

Shelterwood M3 Kingston regenerated 1996

Buffer M4 Kingston

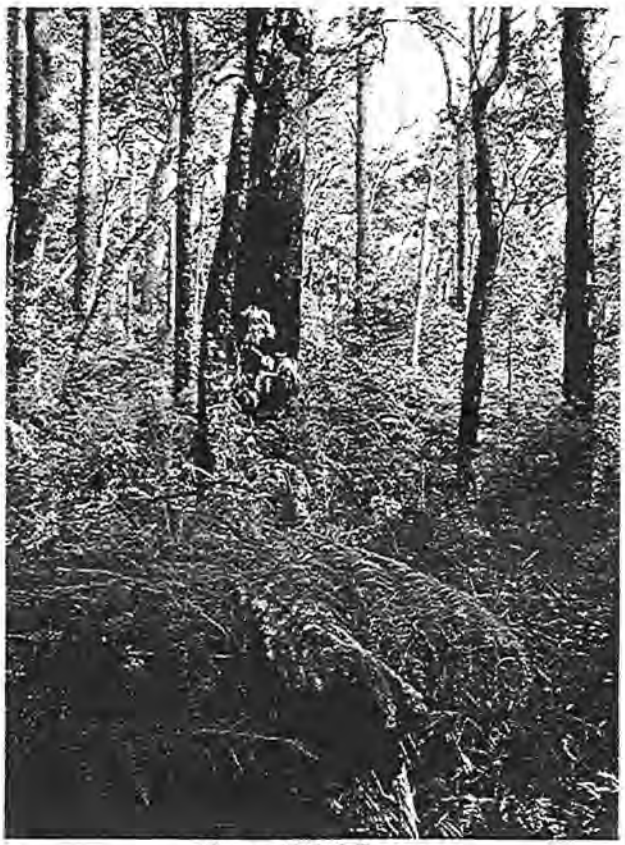
Control M5 Thornton

Gap M6 Thornton regenerated 1990

Buffer M7 Thornton

Gap M8 Carter regenerated 1999

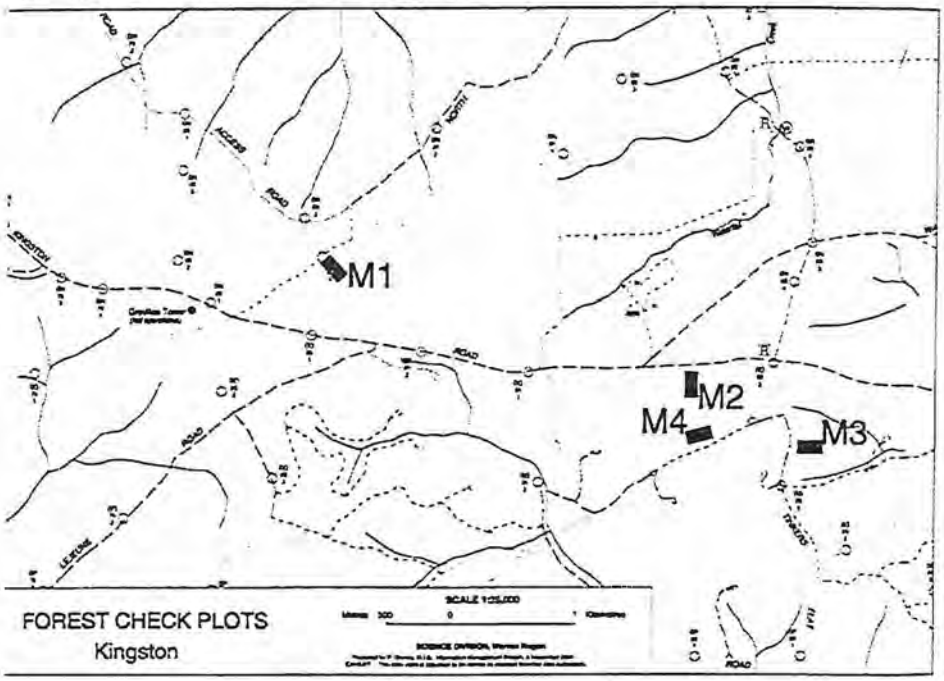
Buffer M9 Carter

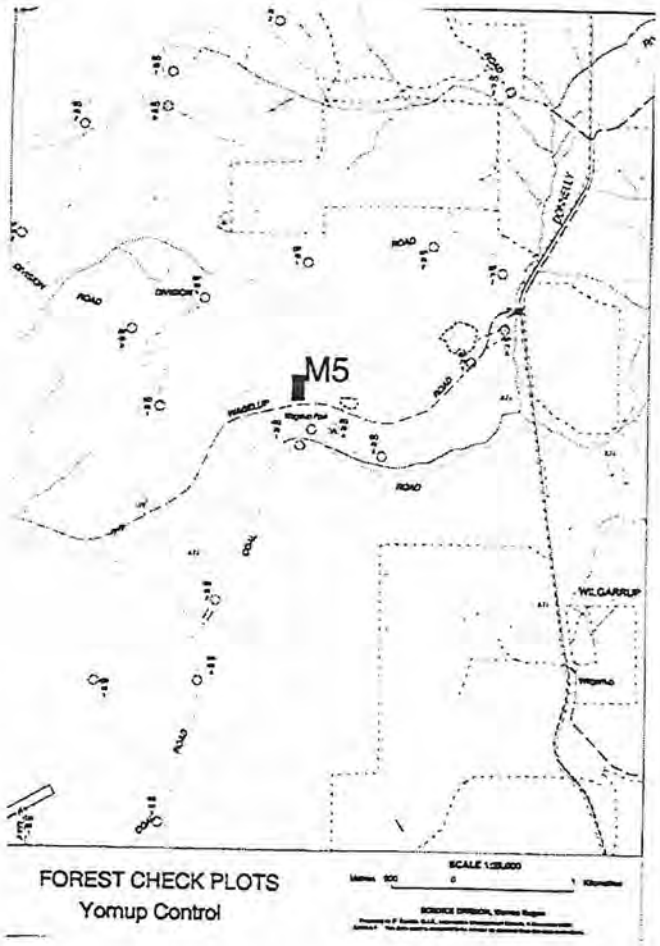


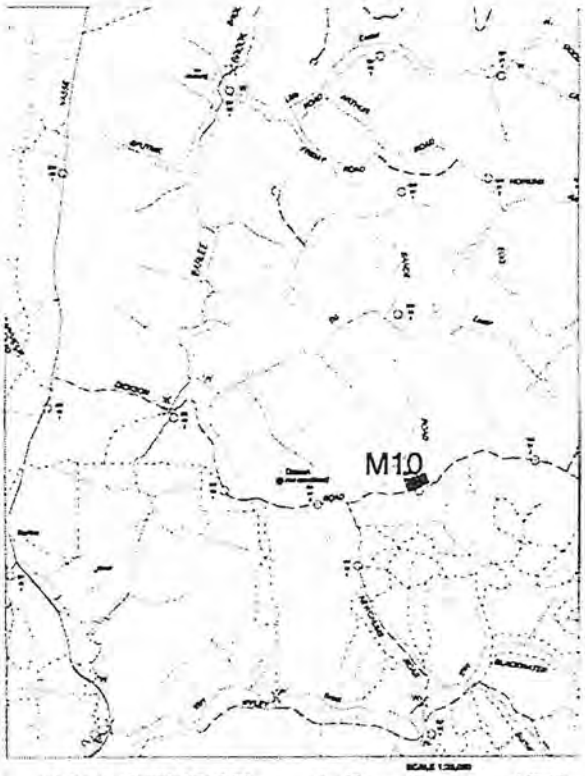
Control M10 Easter

CONTENTS

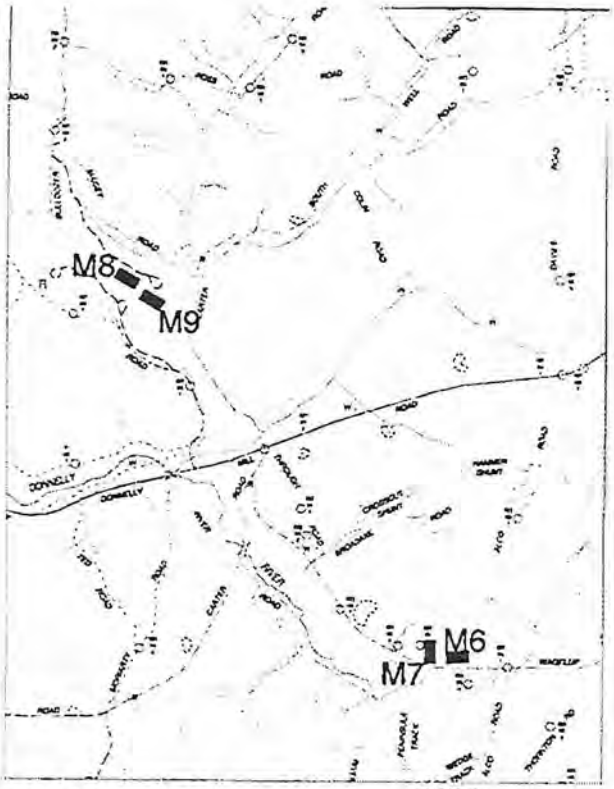
The following maps show the location of each grid.





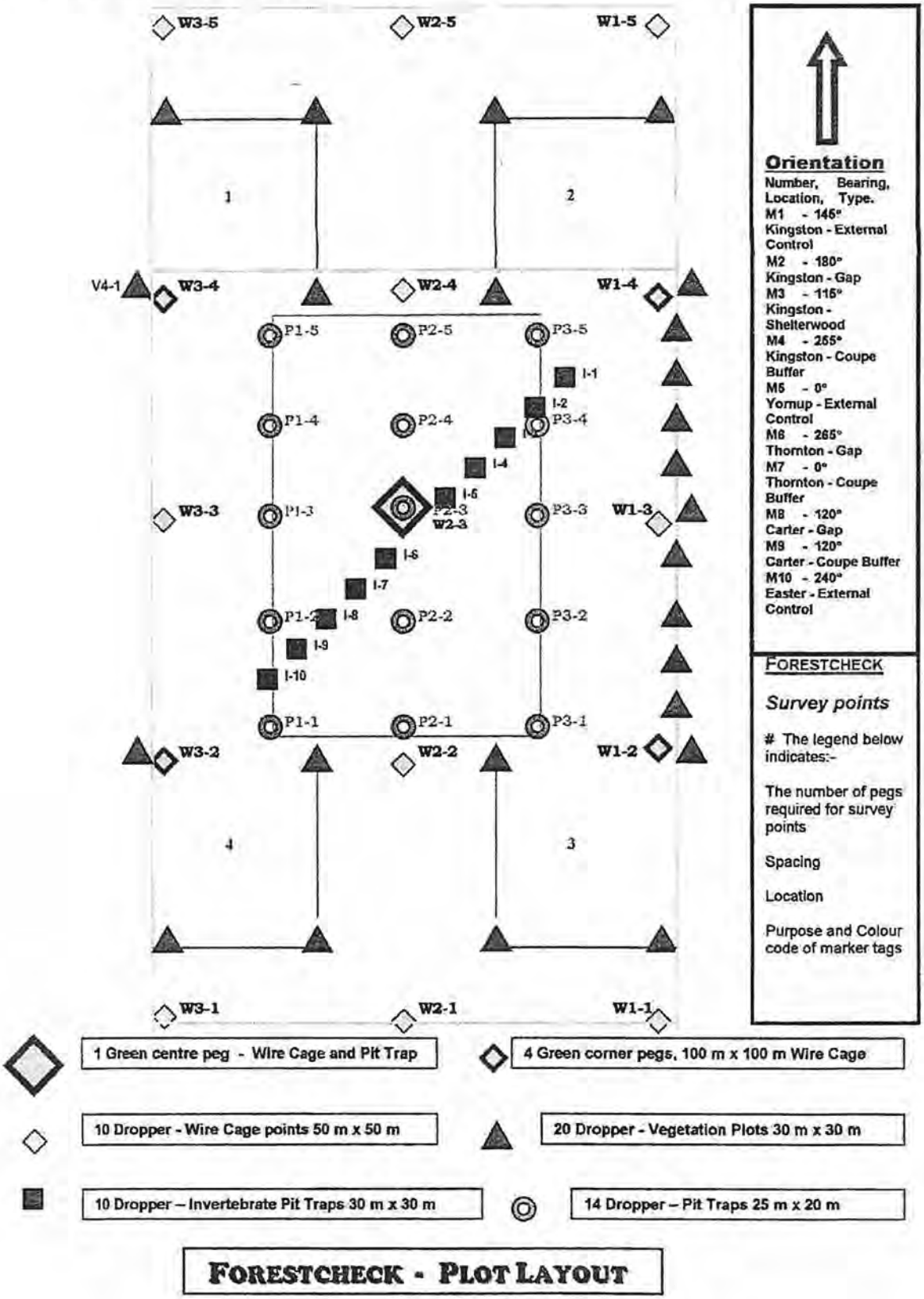


FOREST CHECK PLOTS
Dickson Tower



FOREST CHECK PLOTS
Carter / Thornton

This diagram shows the layout of a sampling grid.



BIRDS

Graeme Liddelow

Introduction

Ten FORESTCHECK grids selected during early spring 2001 were sampled for diurnal birds to monitor the impacts of logging and associated burning on their composition and abundance.

Sampling

The sampling strategy selected by the consultative group and as outlined in the FORESTCHECK Operating Plan, has worked well in this study and no problems have been encountered nor should any occur in the future.

The program was not too ambitious and was flexible enough to overcome any inclement weather that occurred.

Specimen Processing

It has not proved necessary to collect any specimens. Discussions are carried out on the day if there is a problem with identification and that species is followed up immediately to overcome any further discrepancy.

Database Establishment

The entry protocols have been developed over a number of years with Grey Bird Study and Kingston Bird Study. We are using these standard procedures and do not envisage any problems.

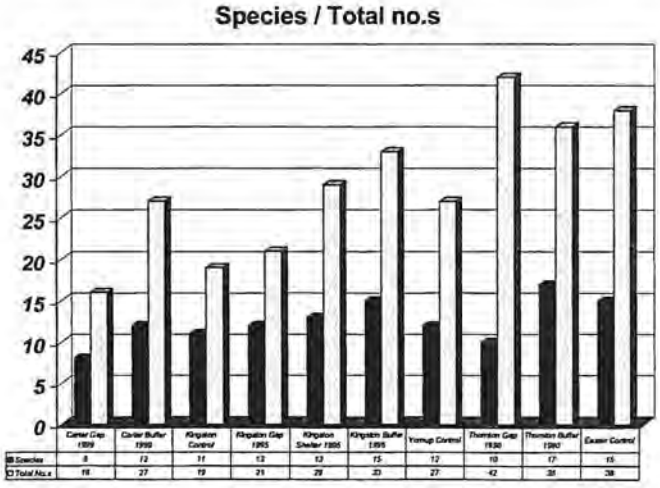
Preliminary Results

We recorded 29 bird species in the ten grids, with only 9 species having at least 9 individuals counted (Table 1).

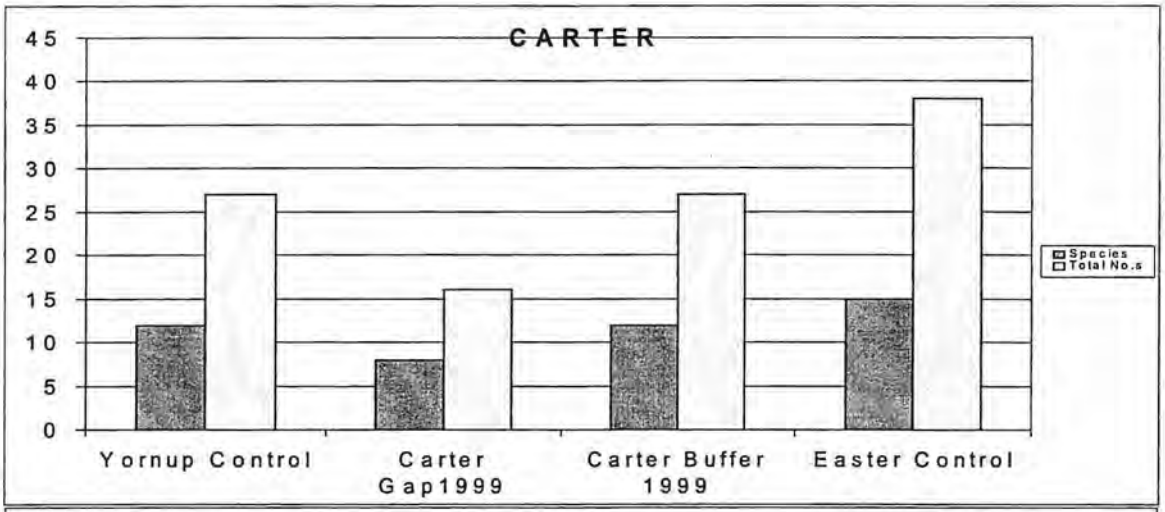
Table 1. Birds species and number of individuals recorded at all 10 grids.

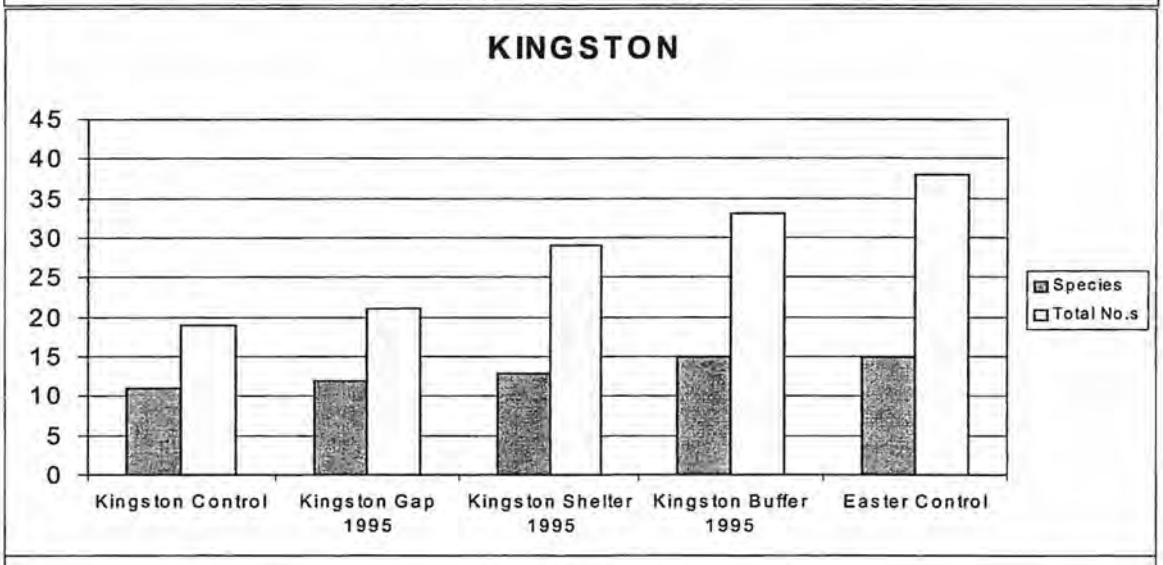
RAOU No.	COMMON NAME	SCIENTIFIC NAME	COUNT OF TOTAL
1	Emu	*Dromaius novaehollandiae*	1
34	Common bronzewing	*Phaps chalcoptera*	3
259	Purple-crowned lorikeet	*Glossopsitta porphyrocephala*	3
266	White-tailed black cockatoo	*Calyptorhynchus baudinii*	2
289	Western rosella	*Platycercus icterotis*	3
290	Red-capped parrot	*P. spurius*	4
294	Australian ringneck	*P. zonarius*	5
322	Laughing kookaburra	*Dacelo novaeguineae*	1
338	Fan-tailed cuckoo	*Cacomantis flabelliformis*	5
344	Shining bronze cuckoo	*Chrysococcyx lucidus*	3
359	Tree martin	*Hirundo nigricans*	7
361	Grey fantail	*Rhipidura fuliginosa*	24
380	Scarlet robin	*Petroica multicolor*	3
387	White-breasted robin	*Eopsaltria georgiana*	2
398	Golden whistler	*Pachycephala pectoralis*	29
408	Grey shrike-thrush	*Colluricincla harmonica*	6
424	Black-faced cuckoo-shrike	*Coracina novaehollandiae*	6
463	Western gerygone	*Gerygone fusca*	33
472	Western thornbill	*Acanthiza inornata*	11
476	Broad-tailed thornbill	*Acanthiza apicalis*	30
488	White-browed scrubwren	*Sericornis frontalis*	16
538	Red-winged fairy-wren	*Malurus elegans*	10
549	Varied sittella	*Daphoenositta chrysoptera*	2
556	Rufous treecreeper	*Climacteris rufa*	5
574	Grey-breasted white-eye	*Zosterops lateralis*	5
578	Western white-naped honeyeater	*Melithreptus chloropsis*	9
597	Brown honeyeater	*Lichmera indistincta*	2
930	Australian raven	*Corvus coronoides*	1
976	Striated pardalote	*Pardalotus striatus*	32

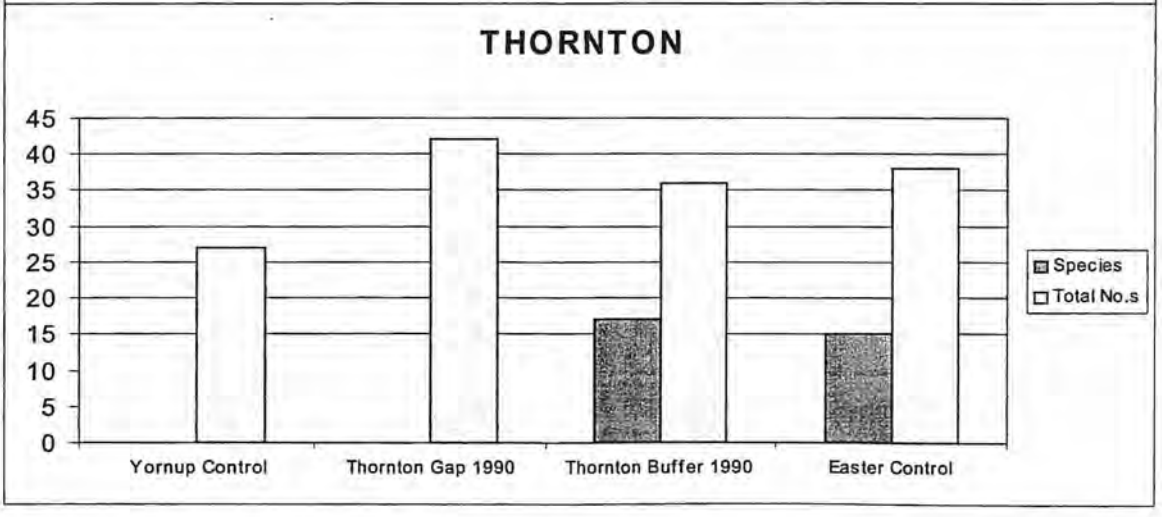
The following graph shows the number of species and the number of individuals recorded in each of the treatments. As expected, the grid with the least was the 1999 Gap at Carter.



The series of graphs below show changes in number of bird species and number of individuals with time since treatment from 1999 at Carter to the 1990 at Thornton. From previous studies (Gray/Kingston) bird species composition and numbers of individuals change as the understorey structure develops following cutting. These changes will continue for some considerable time and may not stabilise until crown separation occurs. Changes will continue even after this time in response to fires.

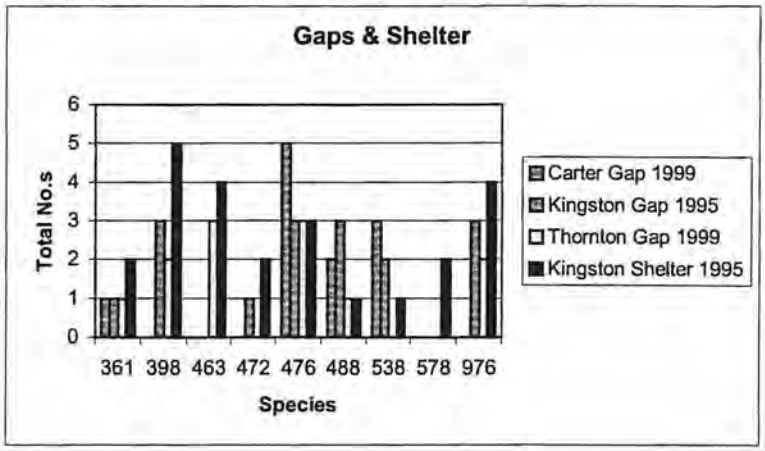


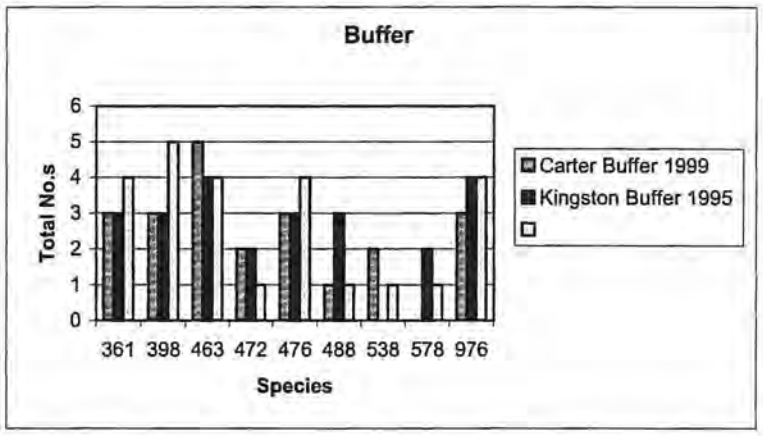


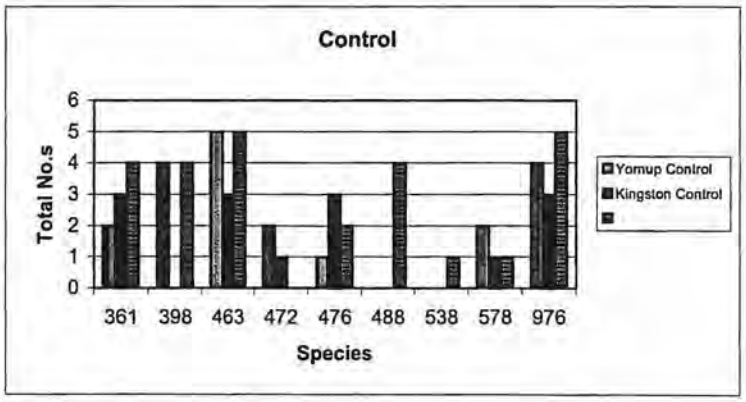


These following graphs focus on the most commonly recorded bird species (9 or more individuals) and the area where they occurred.

The absence of golden whistlers (#398) from the Kingston Control is difficult to explain. It was recorded outside the area but not within the sampling area. Its absence from the Carter Gap, where regeneration is in a very early stage, is to be expected as is the absence of white-browed scrub-wrens (488) and red-winged fairy-wrens (538) from the controls at Yornup and Kingston.







Future Tasks
Select and prepare grids for this year's round of monitoring.

Revisions to Operating Plan
None required.

NOCTURNAL BIRDS

Graeme Liddelow

Introduction
The aim of this program is to monitor the impact of logging and associated burning on the composition and abundance of nocturnal birds at sites selected throughout the southern forests.

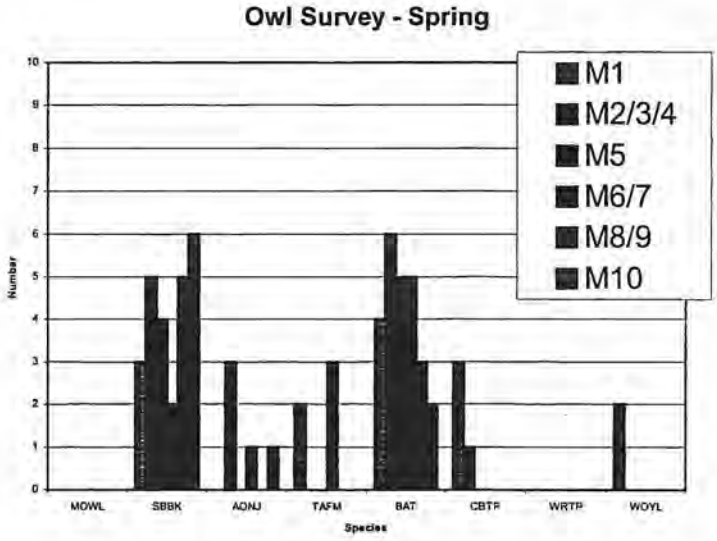
Sampling
It was not possible to monitor the nocturnal birds on an individual grid basis because of the relatively large scale at which these birds hunt. From the 10 FORESTCHECK grids it was possible to sample nocturnal birds at 6 sites. One was at the control at Easter block, one at the Carter block, Buffer and Gap; one at the Thornton block, Buffer and Gap; one at the Kingston block, Control; and the last was a combined Gap, Shelter and Buffer at Kingston. The sampling method used follows that described in Liddelow *et al.* (2002). This sampling system requires site separation by 3 km and it was not possible to achieve this in the 2001/2002 grids.

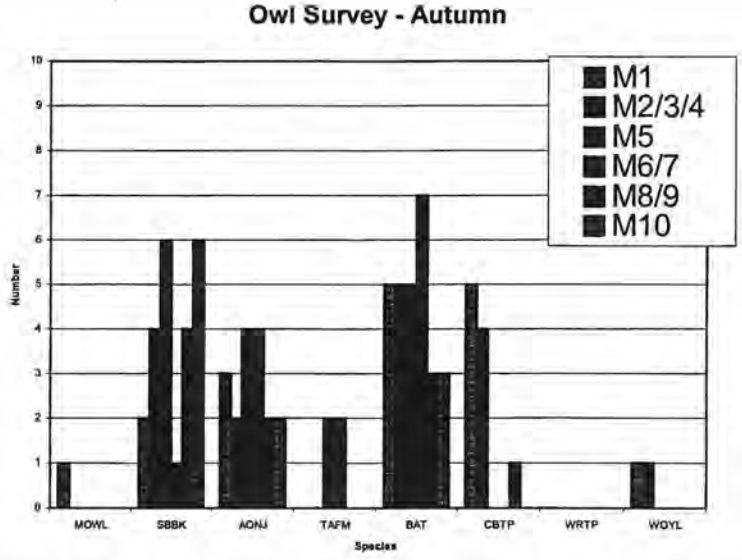
The program was realistic and flexible and no problems were encountered.

Specimen Processing
None required.

Database Establishment
The database has been established and data entry has been undertaken.

Preliminary Results
Spring sampling saw boobook owls (SBBK) recorded at all of the six sites as was expected. This is the only forest owl present in south-west Western Australia. The masked owl (MOWL) was recorded in autumn at the control in Kingston, however it is not unusual as this species has been recorded only 5 km to the east on private property boundaries. Masked owls are recorded occasionally in forest areas but are more typically seen in open forest/woodland country. The graphs below show the species recorded and the sites were they were seen.





Owlet nightjars (AONJ) and tawny frogmouths (TAFM), over the two sample periods, have similar recording rates to that found by Liddelow *et al.* (2002) and these are typical of the forest region of WA.

Future Tasks
Select and prepare this year's sites for monitoring.

Revisions to Operating Plan
Due to the large home range of owls it is not possible to assess them on an individual treatment or grid basis. We will need to monitor the nocturnal birds at the landscape scale within which the treatments have taken place.

Table 1. Nocturnal bird species recorded.

Common name	Scientific name
Boobook owl	*Ninox novaeseelandiae*
Masked owl	*Tyto novaehollandiae*
Tawny frogmouth	*Podargus strigoides*
Australian owlet-nightjar	*Aegotheles cristatus*

References

Liddelow, G.L., Wheeler, I.B. and Kavanagh, R.P. 2002. Owls in the southwest forests of Western Australia. In: Newton, I., Kavanagh, R., Olsen, J. & Taylor, I. (eds.), Ecology and Conservation of Owls, pp. 233-241. CSIRO, Melbourne.

MAMMALS AND HERPETOFAUNA

Graeme Liddelow

Introduction
To monitor the impacts of logging and associated burning practices on species composition and abundance of mammals and herpetofauna.

Sampling Issues Encountered
This program was flexible enough to allow for any inclement weather that did occur during the sampling period.

All went according to the plan and was within the budget allocated. The reason for excluding the wire (Sheffield) traps from the spring session is considered not to be an issue and they should be included in all future spring monitoring.

Specimen Processing
No specimens were vouchered during this sampling period. In future, some type specimens will be included in the sampling procedure.

Database Establishment
As we had the Kingston Study to use as a model, no problems were encountered with establishing a database for this program.

Preliminary Results
This is very early in the life of the program and no conclusions should be drawn from data. Below are a series of graphs showing the results from the wire traps in autumn, pit traps in spring and autumn, spotlight surveys in spring and autumn, road surveys for both seasons and the results of the sand pad monitoring for spring and autumn.

Of concern is the lack of Western ringtail possum (WRTP) sightings at the Kingston site. There appears to be a general decline in their numbers in this country and more work should be done to document the extent of their apparent decline.

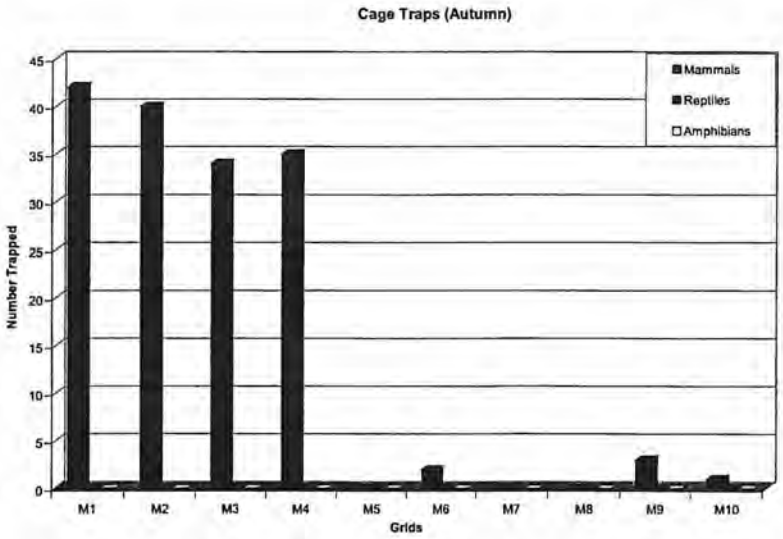
Most notable is the obvious difference in the low number of mammals captured west of the South-west Highway (grids M5-10) both in the control and treated areas. This is thought to be due to environmental factors and long-term fox baiting east of the Highway associated with Western Shield.

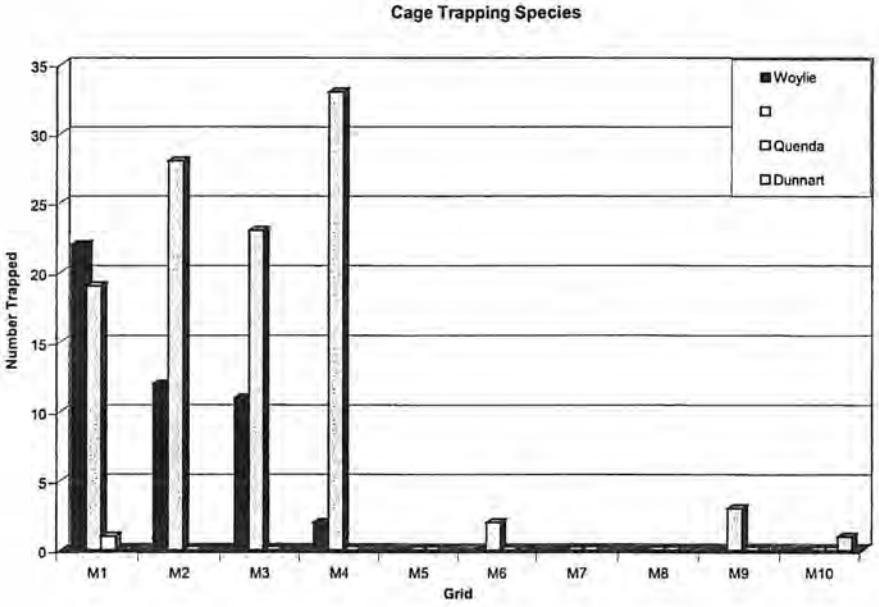
Table 1. Frog, reptile and mammal species recorded from the 10 grids.

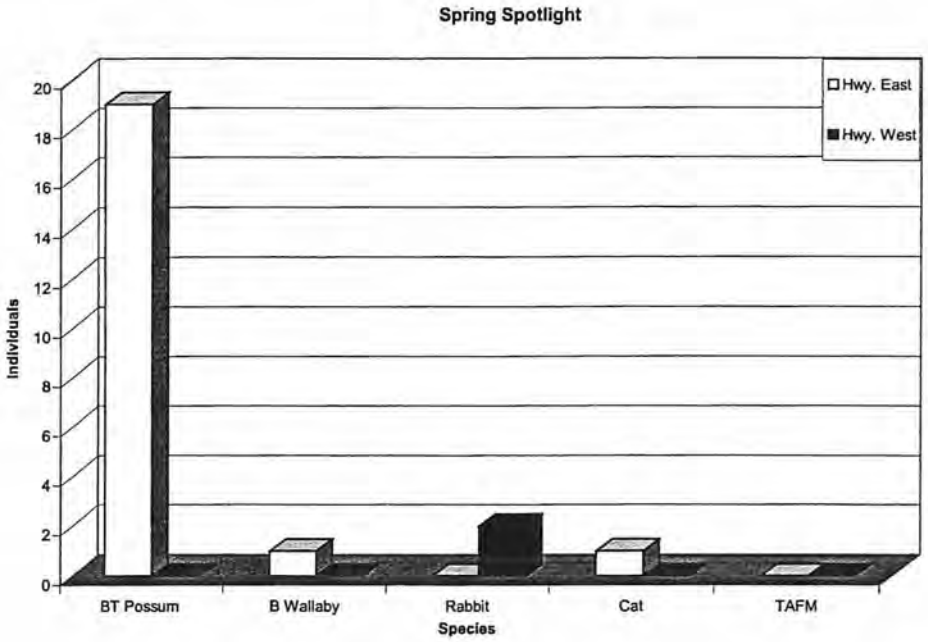
	Species (Scientific name)	Species (Common name)
Frogs	*Crinia georgiana*	Quacking frog
	Crinia glauerti	Glauert's froglet / Clicking froglet
	Crinia pseudinsignifera	Bleating froglet
	Crinia subinsignifera	South coast froglet
	Geocrinia leai	Lea's frog
	Geocrinia lutea	Nornalup frog
	Geocrinia rosea	Roseate frog
	Heleioporus albopunctatus	Western spotted frog
	Heleioporus eyrei	Moaning frog
	Heleioporus inornatus	Whooping frog
	Heleioporus psammophilus	Sand frog
	Limnodynastes dorsalis	Pobblebonk / banjo frog
	Litoria adelaidensis	Slender tree frog

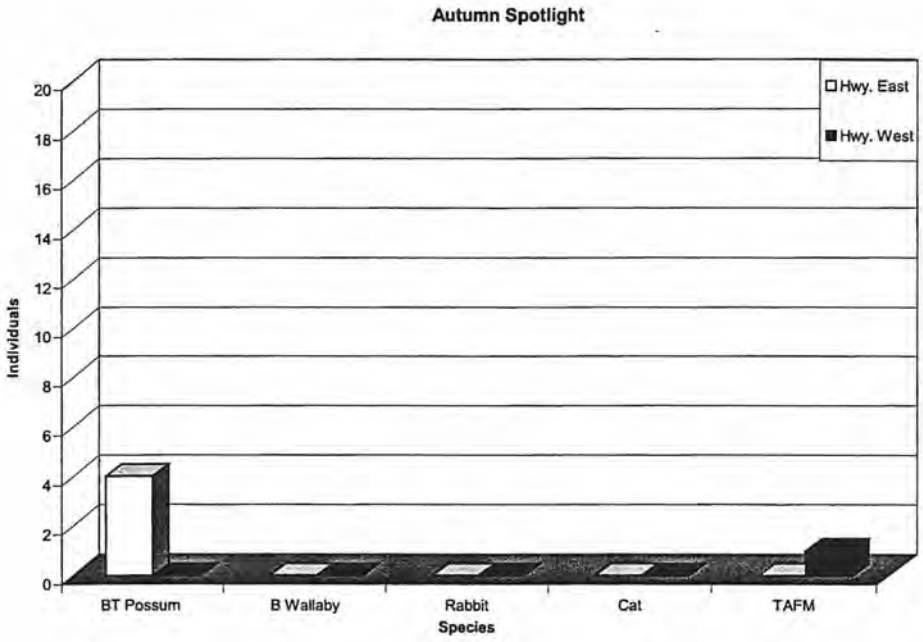
	Species (Scientific name)	Species (Common name)
	Litoria moorei	Motorbike frog / Western bell frog
	Metacrinia nichollsi	Nicholl's toadlet
	Pseudophryne guentheri	Günther's toadlet
Geckoes	*Diplodactylus polyophthalmus*	Speckled stone gecko
	Diplodactylus spinigerus	Western spiny-tailed gecko
	Phyllodactylus marmoratus	Marbled geko
	Underwoodisaurus milii	Thick-tailed geko / Barking geko
Legless lizards	*Aprasia pulchella*	Western granite worm lizard
	Apraisia repens	South western sandplain worm lizard
	Apraisia striolata	Striated worm lizard
	Antichinus flavipes	Marble-faced worm lizard
	Bettongia penicillata	Fraser's legless lizard
	Cercartetus concinnus	Burton's legless lizard
	Dasyurus geoffroii	Common scaly-foot
Monitors	Hydromys chrysogaster	Sand monitor/ Gould's goanna /Bungarra
	Isodon obesulus	Southern heath monitor
Skinks	Mus musculus	South-western cool skink
	Phascogale tapoatafa	Snake-eyed skink
	Pseudocheirus peregrinus	Chain-striped south-west ctenotus
	Rattus fuscipes	Darling range ctenotus
	Rattus norvegicus	Jewelled ctenotus
	Rattus rattus	Odd-striped ctenotus
	Sminthopsis crassidaudata	Red-legged ctenotus
	Sminthopsis griseoventor	King's skink
	Tarsipes rostratus	Mourning skink
	Trichosurus vulpecula	Southern sand skink
	Egernia napoleonis	Smiths skink
	Egernia pulchra	South western spectacled rock skink
	Glaphyromorphus gracilipes	
	Hemergis peronii	Peron's (lowland) earless skink
	Lerista distinguenda	South eestern orange-tailed slider
	Lerista microtis	South western slider
	Menetia greyii	Common dwarf skink
	Morethia lineocellata	Western pale flecked morethia
	Morethia obscura	Southern pale flecked morethia
	Tiliqua rugosa	Bobtail / Shingle back
Mammals	*Antechinus flavipes*	Mardo
	Bettongia penicillata	Woylie
	Cercartetus concinnus	Pygmy possum
	Dasyurus geoffroii	Chuditch
	Hydromys chrysogaster	Water-rat
	Isodon obesulus	Quenda
	Mus musculus	House mouse
	Phascogale tapoatafa	Brush-tailed phascogale
	Pseudocheirus occidentalis	Ngwayir / Western ringtail possum
	Rattus fuscipes	Bush rat
	Rattus norvegicus	Brown rat
	Rattus rattus	Black rat
	Sminthopsis crassidaudata	Fat-tailed dunnart
	Sminthopsis griseoventer	Dunnart
	Tarsipes rostratus	Honey possum
	Trichosurus vulpecula	Koomal / Common brushtail possum

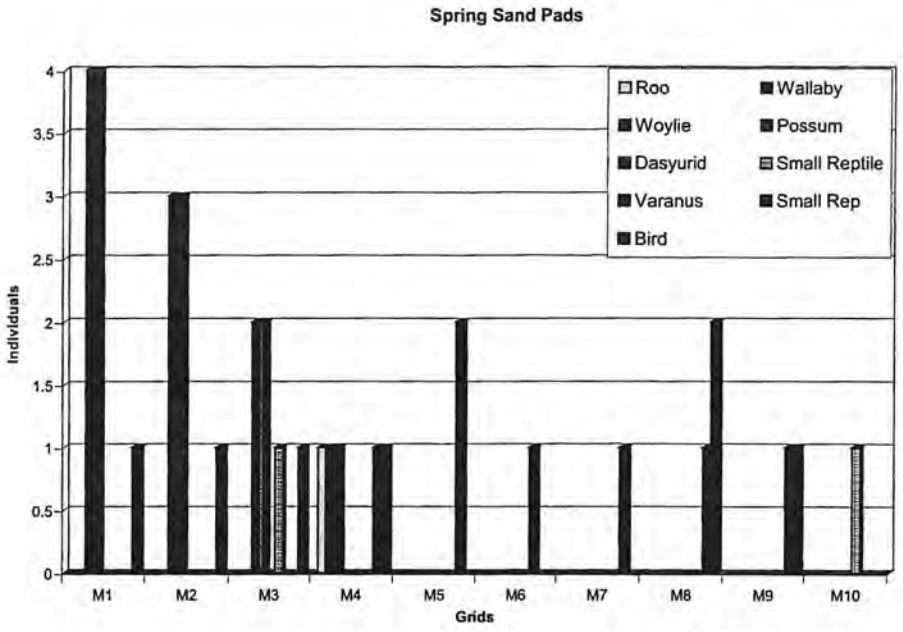
Note: Grids M1= Kingston Control; M2= Kingston Gap; M3= Kingston Shelterwood M4= Kingston Coupe buffer; M5= Yornup Control; M6= Thornton Gap; M7= Thornton Coupe buffer; M8= Carter Gap; M9= Carter Coupe buffer and M10= Easter Control.

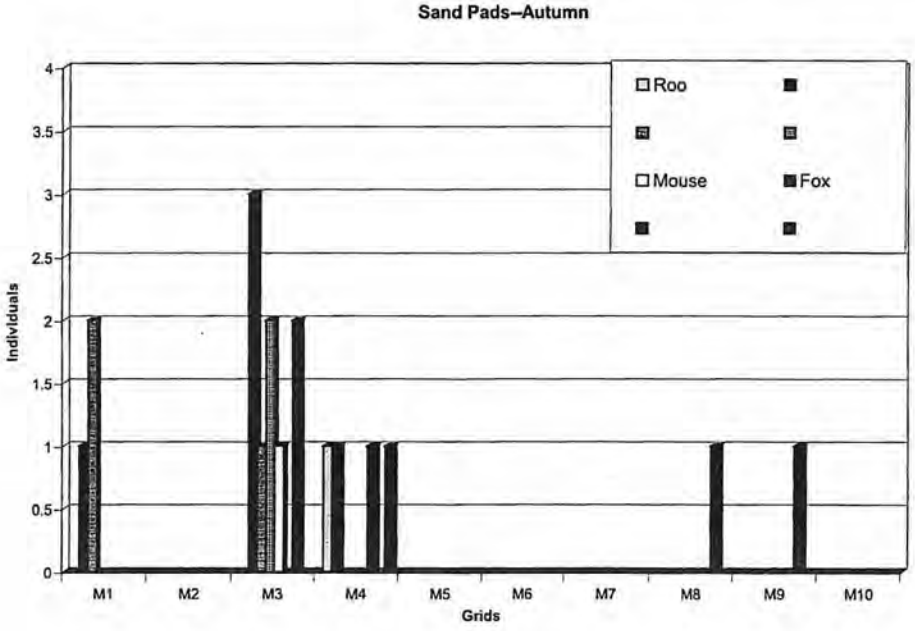




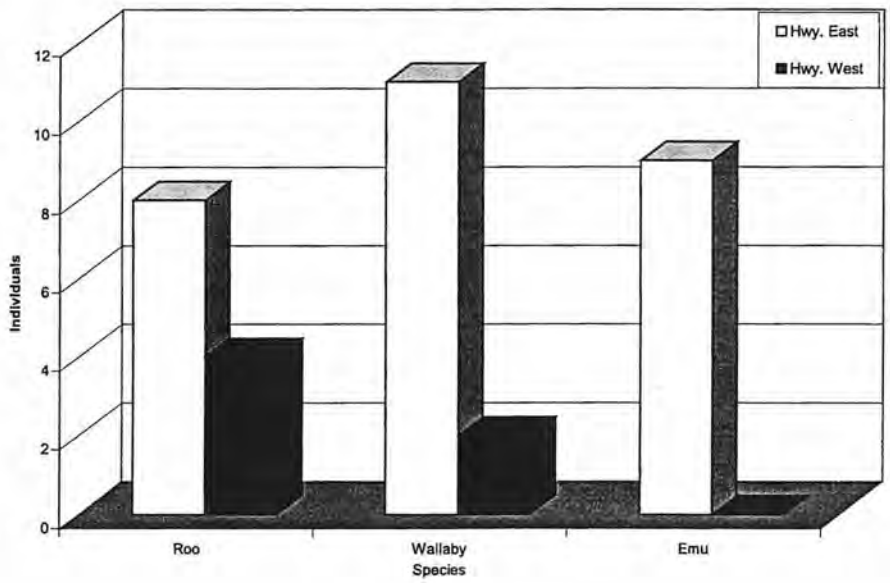

Spring Spotlight
Hwy. East
Hwy. West
Individuals
0
2
4
6
8
10
12
14
16
18
20
BT Possum
B Wallaby
Rabbit
Cat
TAFM
Species


Autumn Spotlight
Hwy. East
Hwy. West
Individuals
0
2
4
6
8
10
12
14
16
18
20
BT Possum
B Wallaby
Rabbit
Cat
TAFM
Species

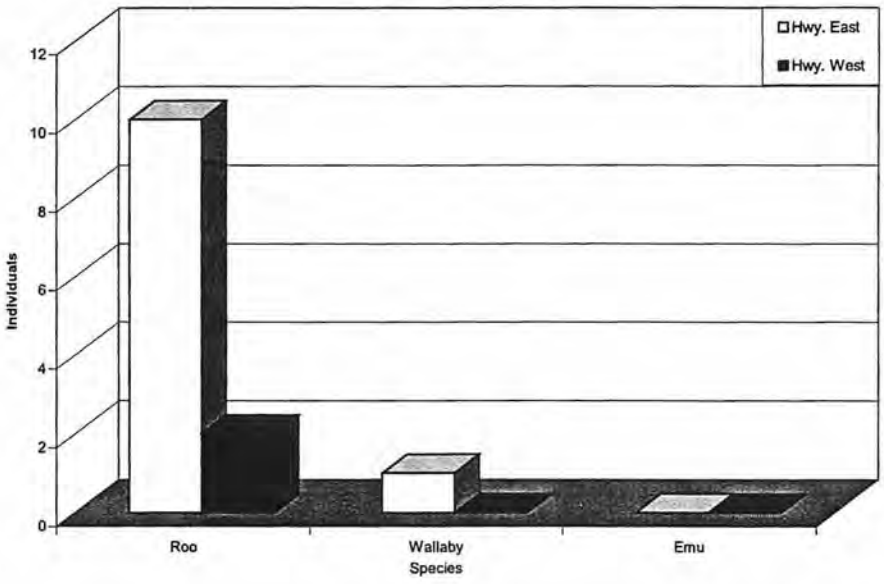

Spring Sand Pads
Roo
Wallaby
Woylie
Possum
Dasyurid
Small Reptile
Varanus
Small Rep
Bird
Individuals
0
0.5
1
1.5
2
2.5
3
3.5
4
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
Grids


Sand Pads--Autumn
Roo
Mouse
Fox
Individuals
0
0.5
1
1.5
2
2.5
3
3.5
4
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
Grids

Spring Road Survey



Autumn Road Survey



Sampling Methods
The main issue with sampling methods is the need to include wire cage trapping in spring as well as autumn.

The use of sand pads in the form used during this session was not adequate. We should revert to the approach stated in the operating plan and treat this technique as landscape monitoring and not try to impose it on individual treatments.

Future Tasks
Locate and set up next sites.

Revisions to Operating Plan
Add wire cage trapping to spring session for medium-sized mammals.

Increase sampling by sand pads to landscape scale as per macro-vertebrate survey.

It is difficult to pre-determine indicator species at this stage and it is preferred to sample all species.

INVERTEBRATES

Janet Farr, Allan Wills and Tom Burbidge

Introduction

Our objective was to sample invertebrate biodiversity for the FORESTCHECK grids in a manner that employed efficient use of available time and resources, effective coverage of habitats and thus potential diversity, and minimal specimen processing time. Two main capture techniques were employed; (1) Passive capture techniques used both light and pitfall traps; (2) Active techniques involved beating with a beating tray, sweeping with a net and habitat searches for set periods of time. Employing a wide range of habitats and sampling techniques maximized our chances of intercepting a wide range of species that may be limited by a single capture method. In addition known pest species (Gumleaf Skeletonizer, Jarrah leafminer and Bullseye borer) were recorded for each site.

Specimens from active and passive captures were sorted in the laboratory as this was considered the most efficient and accurate means of dealing with samples. Specimens were sorted to order and a morphospecies number assigned to differentiate between species. A reference collection was therefore established and a morphospecies master-list erected (Appendix 1) where Indicator Species (K) and those species with Gondwanan affinities (GA) and Gondwanan Relict (GR) species were assigned.

Sampling Issues

In our initial active sampling methods, habitat sampling was partitioned into: litter, coarse woody debris (CWD), ash beds, moss swards, tree boles and bark, and bare ground. However it very quickly became apparent that separation of habitats such as ash beds from CWD, and moss swards from litter and CWD was difficult, and in many cases sampling for each habitat was repetitive. In addition the yield from tree boles and bark was limited and therefore not time efficient. Therefore active habitat searches were reduced to 1 hr each for litter and CWD.

Beating and sweeping were initially partitioned into morning and afternoon sessions for each technique (1 hr each). This meant that for each site, beating and sweeping took 4 hrs. However morning sweeping often yielded little, if anything; and afternoon beating results could also be lean since insects were more active and difficult to catch (this was particularly evident in spring, with cool mornings and warm afternoons). Therefore beating was done in the morning and sweeping was confined to late morning or afternoon, taking a total of 2 hrs. Alternatively, we used 2 people for beating done in the afternoon to maximize insect capture. This allowed more than one plot to be done in a day and also allowed more flexibility to accommodate bad weather.

The passive capture techniques were also adjusted to more practical methods. Pitfall traps were initially to be left open for 24 hrs after which the contents would be bulked and collected for sorting. Due to low apparent capture levels during this period, we decided to open the pitfall traps for a 10 day period at all sites simultaneously. This expanded our capture window, made allowances for adverse weather, and allowed more flexibility in trap setting and closure.

Although the total effective light trap period of three nights remained unchanged, it initially involved a rotation cycle through the sites such that not all sites were trapped simultaneously. This was initially done to save on purchase of batteries; however, this method relied on more nights during the 3 week trapping period during which lights were operating and thus less opportunity for selecting good trapping nights or repeating a trapping session should there be light failure. It also required more site visits to clear traps. Also this method meant greater variability across sites as not all sites were trapped on the same night. The difficult weather during spring 2001 was in some ways fortunate as it gave us an example of a bad case sampling scenario at the outset of the project. This therefore forced us to reconsider our sampling regime to build flexibility into our system. Light traps were therefore set for 3 night periods simultaneously at

each site within the 3 week sampling period. This allowed us to adjust our trapping to accommodate lunar phases and weather extremes whilst maintaining continuity across sites. A longer period, for example a continuous trapping regime for 1 week across all sites, was considered inappropriate, as it would generate too large a sample for efficient sorting.

Specimen processing

During the initial sorting it quickly became apparent that a size threshold was required to restrict capture size to manageable levels. This was set at 10 mm with the exception of Gondwanan Relict (GR) and Gondwanan Affinity (GA) species (as identified in the Operating Plan) and in some cases some Indicator species. This size threshold halved the time needed to sort each sample. We determined indicator species as those invertebrates that were overtly distinctive, such that they are immediately recognizable and significantly notable. An attempt was also made to assign Indicator species to each major habitat (e.g. capture technique). Endemism was also considered (see also discussion on Indicator species in Operating Plan). With the exception of the pitfall samples, all samples were sorted and identified within the 3 week sampling period. An additional week was required after the sample sort and databasing to examine the reference collection, check morphospecies assignment and determine Indicator species.

Because of the large amount of material generated by the pitfall traps, the specimens in the traps from M1 and M2 areas (Kingston forest block, external control and gap treatments respectively) were enumerated. This resulted in

37 species with 1 individual specimen
11 species with 2 individual specimens
3 species with 3 individual specimens
1 species with 4 individual specimens
2 species with 5 individual specimens
1 species with 10 individual specimens and
1 species with 16 individual specimens

Of the total of 56 species, 37 were represented by only 1 specimen. We concluded that there was no merit in counting the abundance of each species.

Database establishment

It was inevitable that in the initial morphospecies assignment some specimens would be assigned a different species number when in fact they are the same. This presented the main problem in database establishment. In addition the pitfall trap samples were numbered using a different system. Thus some species can have 2 or more numbers, one of which can be from a different numbering system. Consequently we have 3 morphospecies names for each specimen, its original number, its pitfall trap number where appropriate, and its database working number. This makes database manipulation awkward.

Preliminary Results

We assigned 588 morphospecies (Table 1), of which 24 were recognized as potential Gondwanan relicts, 33 with Gondwanan affinity and 203 were Indicator species. Of the morphospecies sampled, Lepidoptera (209) and Coleoptera (111) were the most abundant and diverse orders, as would be expected (Table 1).

Light trapping resulted in the most abundant and diverse captures (Table 2), followed by pitfall trapping, sweep netting and beating (respectively). Species diversity and abundance were greatest in spring for all capture methods with the exception of coarse woody debris searches, where morphospecies numbers were comparatively similar between the two seasons and specimen abundance was greater in autumn.

Grid M9 (Carter buffer), showed the greatest spring diversity for active capture techniques, M7 (Thornton buffer) for light trapping and M1(Kingston control) for pitfall (Table 3). During autumn site M7 and M10 (Easter control) were most diverse for active capture techniques, M4 (Kingston buffer) for light trapping and M2 (Kingston gap) for pitfall (Table 3).

Spring specimen abundance was greatest at M9 for active capture techniques and M7 for light trapping (Table 4). Autumn abundance followed diversity with greatest abundance at M7 and M10 for active capture techniques and M4 for light trapping (Table 4).

The forest pest Jarrah leafminer was present at all sites and abundant at M1, M2 and M4 (Table 5). Evidence of Bullseye borer attack was present at all sites except M8. No evidence of Gumleaf Skeletonizer was found at any site.

Comparison of sampling methods used

Table 6 outlines capture efficiency and Table 7 summarizes the perceived advantages and disadvantages of techniques.

Future Tasks

All samples have been processed and data entered.

The morphospecies master list will need to be updated and revised as new information is gathered, particularly in respect to collection at new sampling sites.

Table 1. Number of morphospecies collected using active and passive capture techniques in spring-autumn 2001-2002, showing allocation of Gondwanan Relicts (GR), species with Gondwanan affinity (GA) and indicator species (K).

Order	No of Species	GR	GA	K
Amphipoda	1	1		
Annelida	1			
Araneae	7			1
Araneomorphae	7			2
Blattodea	26			15
Chilopoda	10			
Coleoptera	111	3	6	28
Dermaptera	8			5
Diplopoda	2			1
Diptera	46		12	7
Hemiptera	42			15
Hymenoptera	51		13	10
Isopoda	4	1		
Lepidoptera	209		2	99
Mantodea	3			1
Mecoptera	3	3		
Mygalomorphae	6	6		
Neuroptera	5	5		
Odonata	1	1		
Orthoptera	35			16
Phasmatodea	2			
Platyhelminthes	1			
Scorpionida	3			3
Trichoptera	4	4		
Total	588	24	33	203

Table 2. Number of morphospecies and specimen abundance in spring and autumn for each capture method (CWD = coarse woody debris search; - = not available).

Capture Method	No of Morphospecies		Abundance	
	Spring	Autumn	Spring	Autumn
Light	168	144	1511	1264
Pitfall	84	45	-	-
Sweep	78	27	150	60
Beat	77	18	119	59
CWD	24	29	50	78
Litter	36	24	72	32

Table 3. Number of morphospecies (diversity) captured at each site for active light and pit fall capture techniques in spring and autumn.

Site	Treatment	Active capture		Light trap		Pitfall	
		Spring	Autumn	Spring	Autumn	Spring	Autumn
M1	Control	13	8	59	54	30	9
M2	Gap	12	14	56	55	25	15
M3	Shelter	25	16	43	74	16	11
M4	Buffer	9	15	62	77	11	9
M5	Control	47	17	71	40	11	9
M6	Gap	29	17	66	52	15	8
M7	Buffer	27	23	84	57	23	5
M8	Gap	44	12	49	40	15	10
M9	Buffer	50	18	51	58	11	7
M10	Control	43	23	52	24	15	9

Table 4. Specimen abundance at each site for active and light capture techniques in spring and autumn.

Site	Treatment	Active capture		Light trap	
		Spring	Autumn	Spring	Autumn
M1	Control	17	9	120	92
M2	Gap	14	18	121	92
M3	Shelter	41	30	83	202
M4	Buffer	10	20	138	194
M5	Control	58	19	208	90
M6	Gap	40	22	175	150
M7	Buffer	37	30	211	154
M8	Gap	50	25	136	81
M9	Buffer	79	24	108	168
M10	Control	58	32	135	41

Table 5. Pest presence and abundance assessment at each site (JLM = Jarrah leafminer; GLS = Gumleaf Skeletonizer; BEB = Bullseye borer; 0 = absent, 1 = present, 2 = abundant).

Site	JLM	GLS	BEB
M1	2	0	1
M2	2	0	1
M3	1	0	1
M4	2	0	1

M5	1	0	1
M6	1	0	1
M7	1	0	1
M8	1	0	0
M9	1	0	1
M10	1	0	1

Table 6. Comparison of efficiency of collection methods.

Collection method	Number of individuals collected	Trap or collection time (hrs)	Process time excluding database and analysis (person hours)	Trap efficiency (individuals per collection hr)	Process efficiency (individuals per person hour)
SPRING					
Light	1511[1]	360	About 60 for trap tending About 90 for sample sort	4.2	10.1
Pitfall	84[2]	240	16 hours trap tending 150 hours sample sort	0.35	0.56
Sweep	150[1]	10	Active searches disrupted by rain.	15.0	Active searches disrupted by rain
Beat	119[1]	10	See as for Sweep above	11.9	See as for sweep above
CWD	50[1]	10	See above	5.0	See above
Litter	72[1]	10	See above	7.2	See above
AUTUMN					
Light	1264	360	About 90 for sample sort About 60 for trap tending	3.5	8.4
Pitfall	45[2] 24[2,3]	240	16 hours trap tending 120 hours sample sort	0.19 0.1[3]	0.38
Sweep	60	10	About 150 for field collection of combined active search samples. About 90 for sample sort of combined active search samples.	6.0	0.95 combined active search methods
Beat	59	10	See for sweep above	5.9	See above
CWD	78	10	See above	7.8	See above
Litter	32	10	See above	3.2	See above

Notes: 1 Includes some individuals smaller than acceptable size.
2. Number of species.
3. New species

Table 7. Summary of comparison of collection methods.

Collection method	Disadvantages of collection method	Advantages of collection method
Light	Collects only light attracted fauna. Faunal fidelity to survey site unknown	Abundant individuals collected: implies higher probabilities of collecting rare species. High process efficiency (small effort needed and overall costs are low per unit of information gathered).
Pitfall	Bias towards sampling most active species of ground fauna. Low capture and process efficiency	High faunal fidelity to survey site. Ability to capture species otherwise not captured with other methods
Sweep	Capture efficiency vulnerable to poor air temperature conditions (too hot or too cold for flying insects). Extremely low process efficiency due to small sample sizes (catch effort carries time penalty of travel between sites). Faunal fidelity to survey site unknown	Good catch efficiency in suitable conditions (acceptable samples can be gathered relatively quickly).
Beat	Extremely low process efficiency due to small sample sizes (catch effort carries time penalty of travel between sites). Upper canopy not sampled.	Good catch efficiency (acceptable samples can be gathered relatively quickly). Less affected by air temperature and rain than sweep. High faunal fidelity to survey site.
CWD	Extremely low process efficiency due to small sample sizes (catch effort carries time penalty of travel between sites). Only a superficial sample of CWD fauna.	Good catch efficiency (acceptable samples can be gathered relatively quickly). Relatively unaffected by air temperature and rain. High faunal fidelity to survey site.
Litter	Extremely low process efficiency due to small sample sizes (catch effort carries relatively large penalty of unproductive time in travel between sites). Duplication of pitfall sampling?	Good catch efficiency (acceptable samples can be gathered relatively quickly) Relatively unaffected by air temperature and rain. High faunal fidelity to survey site.

Appendix 1. Morphospecies list for invertebrates

Spec #	Order	Family	Tax 3	Genus	Species	Status
1	Lepidoptera	Carthaeidae		*Carthaea*	*saturnioides*	K
2	Lepidoptera	Geometridae	Oenochrominae	*Arhodia*	sp	K
3	Lepidoptera	Thaumetopoeidae		*Epicoma*	*melanosticta*	K
4	Lepidoptera	Notodontidae		*Destolmia*	*lineata*	K
5	Lepidoptera					
6	Lepidoptera	Arctiidae				K
7	Lepidoptera	Thaumetopoeidae		*Ochrogaster*	sp 1	K
8	Lepidoptera	Thaumetopoeidae		*Ochrogaster*	sp 2	K
9	Lepidoptera	Thaumetopoeidae		*Ochrogaster*	sp 3	K
10	Lepidoptera	Thaumetopoeidae		*Ochrogaster*	*lunifer*	K
11	Lepidoptera	Thaumetopoeidae		*Ochrogaster*	sp 4	K
12	Lepidoptera	Geometridae				K
13	Coleoptera	Dytiscidae			447	
14	Coleoptera	Hydrophilidae				
15	Coleoptera	Elateridae				
16	Diptera	Tipulidae				K
17	Coleoptera	Scarabeidae		*Onthophagus*	*ferox*	K
18	Lepidoptera	Noctuidae		*Agrotis*	*munda*	K
19	Lepidoptera	Geometridae		*Chlorocoma*	*dicloraria*	K
20	Lepidoptera					

21	Lepidoptera				
22	Lepidoptera	Geometridae	*Chlorocoma*	sp	K
23	Lepidoptera	Geometridae			K
24	Lepidoptera	Geometridae			K
25	Lepidoptera				
26	Coleoptera	Elateridae			
27	Blattodea	Blaberidae	*Cololampra*	sp	K
28	Coleoptera	Melolonthinae	*Heteronyx*	sp 1	
29	Coleoptera	Melolonthinae	*Heteronyx*	sp 2	
30	Lepidoptera	Noctuidae	*Dasypodia*	*selenophora*	
31	Lepidoptera	Geometridae	*Parepisparis*	*excusata*	K
32	Lepidoptera	Thaumetopoeidae			K
33	Lepidoptera				
34	Lepidoptera	Lymantriidae	*Teia*	*athlophora*	K
35	Lepidoptera	Thaumetopoeidae	*Ochrogaster*	sp 5	K
36	Lepidoptera	Thaumetopoeidae	*Ochrogaster*	sp 6	K
37	Lepidoptera				K
38	Lepidoptera				
39	Lepidoptera	Noctuidae			K
40	Lepidoptera	Noctuidae	*Persectania*	sp	K
41	Lepidoptera	Geometridae			K
42	Lepidoptera	Geometridae	*Gastrina*	*cristaria*	K
43	Lepidoptera	Pyralidae ?			K
6	Lepidoptera	Arctiidae			K
45	Lepidoptera	Zygaenidae	*Pollanisus*	*viridipulverulenta*	K
46	Lepidoptera	Geometridae			
47	Lepidoptera	Geometridae			
48	Lepidoptera				
49	Hemiptera	Cicadidae	*Cicadetta*	sp	
50	Lepidoptera	Geometridae			K
51	Diptera	Muscoidea			
52	Hymenoptera	Apidae	*Apis*	*melifera*	K
53	Diptera	Calliphoridae	*Calliphora*		
54	Diptera	Syrphidae			
55	Coleoptera	Dytiscidae			
56	Coleoptera	Chrysomelidae			
57	Lepidoptera	Notodontidae	*Danima*	*banksiae*	K
58	Lepidoptera	Notodontidae			K
59	Lepidoptera	Geometridae			K
60	Lepidoptera				
61	Lepidoptera				
62	Lepidoptera				K
63	Lepidoptera				
64	Lepidoptera	Oecophoridae			K
65	Lepidoptera				
66	Lepidoptera	Geometridae			
67	Lepidoptera				
68	Diptera	?			
69	Trichoptera				GR
70	Coleoptera	Melolonthinae	*Heteronyx*	sp 3	

71	Lepidoptera					
72	Lepidoptera	Geometridae				
73	Lepidoptera					
74	Lepidoptera	Noctuidae				
75	Lepidoptera	Noctuidae				
76	Lepidoptera					
77	Lepidoptera					
78	Lepidoptera	Zygaenidae		*Pollanisus*	*viridipulverulenta*	K
79	Lepidoptera	Geometridae	Oenochrominae	*Arhodia*	sp	K
80	Lepidoptera					K
81	Lepidoptera	Limacodidae		*Doratifera*	sp	K
82	Lepidoptera	Geometridae				
83	Lepidoptera	Geometridae				
84	Lepidoptera	Pyralidae		*Uresiphita*	*ornithopteralis*	K
85	Lepidoptera	Geometridae				
86	Lepidoptera	Geometridae				
87	Hymenoptera	Ichneumonidae		*Ophion*	sp	GA
88	Diptera	Pyrgotidae				K
89	Mecoptera	Meropeidae		*Austromerope*	*poultoni*	GR
90	Lepidoptera	Limacodidae				K
91	Lepidoptera	Anthelidae		*Chenuala*	sp	K
92	Lepidoptera	Tortricidae ?				
93	Coleoptera	Carabidae				
94	Coleoptera	Melolonthinae		*Heteronyx*	sp 4	
95	Lepidoptera	Geometridae				
96	Lepidoptera	Geometridae				
97	Lepidoptera	Geometridae				
98	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	sp	
99	Coleoptera	Lycidae		*Metriorrhynchus*	sp	K
100	Coleoptera	Curculionoidea	Belidae			GR
101	Coleoptera	Chrysomelidae				
102	Coleoptera	Curculionidae				
103	Coleoptera	Curculionidae				
104	Lepidoptera					
105	Hemiptera	Pentatomidae				K
106	Orthoptera	Tettigoniidae				K
107	Hemiptera					
108	Hemiptera	Membracidae				K
109	Hemiptera					
110	Hemiptera					
111	Lepidoptera					
112	Coleoptera	Chrysomelidae	Paropsinae			
113	Coleoptera	Curculionidae				
114	Coleoptera	Curculionidae				
115	Coleoptera	Chrysomelidae				
116	Coleoptera	?				
117	Hemiptera	Pentatomidae				
118	Orthoptera	Tettigoniidae				
119	Blattodea	Blaberidae		*Calolampra*	sp 1	K
120	Blattodea	Blatellidae		*Neotemnopteryx*	sp	K

121	Blattodea	Blatellidae		*Platyzosteria*	sp 1	K
122	Blattodea	Blatellidae		*Platyzosteria*	sp 2	K
123	Dermaptera					K
124	Coleoptera	Curculionidae	Gonipterinae			
125	Diptera	Drosophilidae				
126	Diptera	Tabanidae				
127	Diptera	?				
128	Diptera	Muscoidea				
129	Diptera	Syrphidae				
130	Diptera	Syrphidae				
131	Neuroptera	Hemerobeidae				GR
132	Mantodea					
133	Lepidoptera	Noctuidae				
134	Diptera	Muscoidea				
135	Coleoptera	Elateridae				
136	Diptera	Tachinidae				K
137	Lepidoptera	Noctuidae				
138	Lepidoptera					
139	Lepidoptera	Noctuidae				
140	Lepidoptera	Noctuidae				
141	Lepidoptera	Tineidae		*Moerarchis*	*australasiella*	K
142	Diptera	Therevidae				K
143	Diptera	Syrphidae				
144	Trichoptera					GR
145	Trichoptera					GR
145	Trichoptera					GR
147	Blattodea	Blaberidae		*Calolampra*	sp 2	
148	Blattodea	Blaberidae				
149	Orthoptera	Tettigoniidae				K
150	Hemiptera	Reduvidae				K
151	Trichoptera					GR
6	Lepidoptera	Arctiidae			6	K
153	Hemiptera	Pentatomidae				
154	Coleoptera	Melolonthinae		*Liparetrus*	sp	
155	Coleoptera	Chrysomelidae				
156	Coleoptera	Curculionidae				
157	Coleoptera	Curculionidae	Rhadinosominae	*Rhadinosomus*	sp	K
158	Coleoptera	?				
159	Coleoptera	?				
160	Coleoptera	Curculionidae	Gonipterinae	*Gonipterus*	sp	
161	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	*fasciata*	K
162	Coleoptera	Scarabaeidae	Melolonthinae	*Liparetrus*	*jenkinsi*	
163	Hemiptera	Reduviidae				
164	Hemiptera					
165	Diptera	Asilidae				GA
166	Hemiptera					
167	Orthoptera	Tettigoniidae				
168	Coleoptera	Belidae		*Belus*	*suturalis*	GR
169	Coleoptera	Curculionidae				
170	Hemiptera					

171	Coleoptera	Scarabaeidae	Melolonthinae	*Liparetrus*	sp	
172	Coleoptera	Scarabaeidae	Melolonthinae	*Heteronyx*	sp	
173	Coleoptera	?				
174	Orthoptera					
175	Coleoptera	Chrysomelidae	Paropsinae			
176	Hemiptera	Pentatomidae				
177	Hemiptera					
178	Diptera	Tabanidae				GA
179	Diptera	Drosophilidae				
180	Orthoptera	Grillidae				K
181	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*	sp	
182	Coleoptera	Chrysomelidae				
183	Hymenoptera	Colletidae				K
184	Hymenoptera	Doryctinae				
185	Lepidoptera	Noctuidae		*Periscepta*	*polystieta*	K
186	Hymenoptera	Colletidae				K
187	Hemiptera					
188	Hemiptera					
189	Coleoptera	Scarabeidae	Dynastinae	*Cryptodus*	sp	K
190	Blattodea	Blatidae				K
191	Coleoptera	Phycosecidae	Phycosecis			
192	Coleoptera	Tenebrionidae	Lagriinae	*Lagria*	*aneouiobcea*	GA
193	Coleoptera	Coccinellidae		*Coccinella*	*repanda*	
194	Coleoptera	?				
195	Diptera	?				
196	Hemiptera	Reduviidae				
197	Lepidoptera					
198	Coleoptera	Lycidae				
199	Coleoptera	Curculionidae				
200	Hemiptera					
201	Coleoptera	Belidae				GR
202	Orthoptera	Tettigoniidae				
203	Hymenoptera	Colletidae				
204	Diptera	Asilidae				GA
205	Diptera	Muscoidea				
206	Diptera	Syrphidae				
207	Hemiptera	Cicadidae		*Cicadetta*	sp	K
208	Coleoptera	Lycidae		*Metriorrhynchus*	sp	K
209	Coleoptera	Curculionidae				K
210	Coleoptera	Curculionidae				
153	Hemiptera	Pentatomidae				
212	Coleoptera	Scarabeidae	Melolonthinae	*Liparetrus*	sp	
163	Hemiptera	Reduviidae				
214	Coleoptera	Curculionidae				
215	Coleoptera	?				
216	Orthoptera	Gryllidae				
217	Diptera	Asilidae				GA
218	Orthoptera	Tetigoniidae				K
219	Blattodea	Blattidae		*Platyzosteria*		K
220	Coleoptera	Elateridae				

221	Hemiptera	Pentatomidae				
222	Hymenoptera	Formicidae		*Myrmecia*	sp 2	
223	Chilopoda					
224	Chilopoda					
225	Chilopoda					
226	Chilopoda					
227	Chilopoda					
228	Chilopoda					
229	Chilopoda					
230	Hemiptera	Pseudococcidae				
231	Orthoptera	Acrididae				K
232	Orthoptera	Acrididae				K
233	Orthoptera	Acrididae		*Goniaea*	sp	K
174	Orthoptera	Acrididae				K
235	Orthoptera	Acrididae				K
236	Lepidoptera					
237	Odonata	Zygoptera				GR
238	Lepidoptera					
239	Hemiptera					
240	Hemiptera	Pentatomidae				K
241	Hemiptera					
242	Diptera	Syrphidae				
243	Hymenoptera	Evaniidae				
244	Coleoptera	Curculionidae				K
245	Diptera	Bombyliidae				K
246	Orthoptera	Tetigoniidae				K
247	Coleoptera	Curculionidae				
248	Coleoptera	Chrysomelidae	Paropsinae			
249	Hemiptera					
250	Mecoptera	Bittacidae		*Harpobittacus*	sp	GR
251	Hemiptera	Pentatomidae				
252	Hymenoptera	Formicidae		*Myrmecia*	sp 1	
253	Coleoptera	Carabidae				
254	Blattodea	Blattidae		*Platyzosteria*	sp	
232	Orthoptera	Acrididae		*Goniaea*	sp	K
235	Orthoptera	Acrididae				K
257	Dermaptera					K
258	Dermaptera					K
259	Diplopoda					
260	Diplopoda					K
261	Amphipoda					GR
262	Isopoda					GR
258	Dermaptera					K
264	Coleoptera	Carabidae	Harpalinae	*?Cenogmus*	sp	GA
265	Coleoptera	Carabidae	Esydrinae			GA
266	Blattodea	Blattidae		*Platyzosteria*		K
267	Chilopoda					
268	Orthoptera	Tettigoniidae				
269	Blattodea					
270	Hemiptera	Reduviidae				

271	Araneae					
235	Orthoptera	Acrididae				K
235	Orthoptera	Acrididae				K
235	Orthoptera	Acrididae				K
275	Hymenoptera	Formicidae		*Iridomyrmex*	sp 3	
276	Orthoptera					
277	Chilopoda					
278	Orthoptera					
279	Hymenoptera	Formicidae		*Myrmecia*	sp 4	
280	Coleoptera	Carabidae		*Carenum*	sp	GA
281	Hymenoptera	Formicidae		*Myrmecia*	sp 3	
282	Blattodea	Blattidae		*Platyzosteria*	sp	K
283	Mygalomorphae					GR
284	Hemiptera	Reduviidae				K
285	Araneae					
286	Araneae	Araneomorphae	Sparassidae			
287	Coleoptera	Scarabeidae				
288	Coleoptera	Carabidae		*Chlaenius*		GA
289	Coleoptera	Scarabeidae	Melolonthinae	*Heteronyx*	sp	
290	Coleoptera	Curculionidae				K
291	Coleoptera	Curculionidae	Molytinae	*Tranes*	sp	K
292	Blattodea	Blaberidae		*Laxta*		K
293	Orthoptera	Acrididae		*Phaulacridium*	*vitatum*	K
294	Orthoptera	?				
295	Hymenoptera	Pompilidae				
296	Lepidoptera	Lycinidae				K
52	Hymenoptera	Apidae		*Apis*	*melifera*	K
297	Lepidoptera	Nymphalidae	Heteronympha	*Merope*	*duboulayi*	K
299	Coleoptera	Buprestidae				K
300	Coleoptera	Curculionidae	Amycterinae			K
301	Hemiptera	Membracidae				K
302	Hemiptera	Membracidae				K
303	Phasmatodea					
304	Orthoptera	Acrididae		*Goniae*		K
305	Neuroptera	Mermelontidae				GR
306	Lepidoptera	Nymphalidae		*Geitoneura*	*klugit*	K
307	Coleoptera	Chrysomelidae	Paropsinae			K
308	Coleoptera	Chrysomelidae	Paropsinae			K
309	Mantodea					
310	Orthoptera					
311	Hemiptera	Reduviidae				K
312	Diptera	Asilidae				GA
312	Diptera	Asilidae				GA
314	Orthoptera					
315	Lepidoptera					
316	Lepidoptera					
317	Lepidoptera	Geometridae				
318	Lepidoptera	Geometridae				
319	Lepidoptera	Tineidae		*Moerarchis*	*clathrella*	K
320	Lepidoptera	Geometridae		*Arhodia*	sp	K

321	Lepidoptera	Geometridae				K
322	Lepidoptera	Limacodidae		*Doratifera*	*quadirguttata*	K
323	Lepidoptera	Geometridae				
324	Lepidoptera	Tineidae		*Moerarchis*	sp	K
325	Lepidoptera	Psychidae		*Iphierga*	*euphragma*	K
326	Lepidoptera	Geometridae				
327	Lepidoptera	Geometridae				
328	Lepidoptera	Saturnidae		*Opodiphthera*	*helena*	K
329	Lepidoptera	Noctuidae				K
330	Lepidoptera	Geometridae		*Crypsiphora*	*ocultaria*	K
331	Lepidoptera	Oecophoridae		*Wingia*	*aurata*	K
332	Lepidoptera	Lymacodidae		*Doratifera*	sp	K
333	Lepidoptera	Pyralidae				
334	Lepidoptera	Geometridae		*Gastrina*	*cristarina*	K
89	Mecoptera	Meropeidae		*Austromerope*	*poultoni (male)*	GR
336	Lepidoptera	Noctuidae		*Chrysodeixis*	*argentifera*	K
337	Lepidoptera					
338	Lepidoptera	Geometridae				
339	Lepidoptera	Geometridae				
340	Coleoptera	Carabidae	Chlaeniiae			
341	Lepidoptera	Pyralidae				
342	Lepidoptera	Pyralidae				
343	Hymenoptera	Formicidae		*Myrmecia*	sp 5	
344	Lepidoptera	Noctuidae				K
345	Lepidoptera					K
346	Lepidoptera	Noctuidae				K
347	Coleoptera	Scarabeidae	Melolonthinae	*Heteronyx*		
340	Coleoptera	Carabidae	Chlaeniiae			
349	Coleoptera	Curculionidae				K
350	Lepidoptera					
351	Coleoptera	Cerambycidae		*Uracantha*	*triangularis*	K
352	Lepidoptera	Anthelidae		*Anthela*	sp	K
353	Coleoptera	Scarabeidae		*Colpochila*	sp	K
354	Coleoptera	Scarabeidae		*Cryptodus*	*dynastinae*	K
355	Lepidoptera	Geometridae				
356	Lepidoptera	Pyralidae				
357	Lepidoptera	Geometridae		*Eucyclodes*	*buprestaria*	K
358	Lepidoptera	Geometridae				
359	Coleoptera	Scarabeidae	Melolonthinae	*Heteronyx*		
360	Neuroptera	Hemerobiidae				GR
361	Neuroptera	Chrysopidae		*Chrysopa*		GR
362	Lepidoptera					
363	Coleoptera	Scarabeidae	Melolonthinae	*Heteronyx*		
364	Lepidoptera	Noctuidae				
365	Lepidoptera	Pyralidae				
366	Lepidoptera					
367	Lepidoptera					
368	Coleoptera	Curculionidae	Amycterinae			K
369	Lepidoptera					
370	Lepidoptera	Notodontidae		*Hylaeora*	*dilucida*	K

371	Lepidoptera	Lasiocampidae		*Entometa*	*fervens*	K
372	Lepidoptera	Hepialidae		*Abantiades*	*hydrographis*	GA
373	Lepidoptera	Hepialidae		*Abantiades*	*ocellatus*	GA
374	Lepidoptera	Notodontidae				K
375	Lepidoptera	Geometridae				K
376	Lepidoptera					
377	Lepidoptera	Geometridae		*Phallaria*	*ophiusaria*	K
373	Lepidoptera	Hepialidae		*Abantiades*	*ocellatus*	GA
379	Lepidoptera	Noctuidae		*Peripyra*	*sanguinipucta*	K
380	Lepidoptera					
381	Lepidoptera	Anthelidae				K
382	Lepidoptera					
383	Lepidoptera					
384	Lepidoptera	Geometridae		*Pholodes*	sp 1	K
385	Lepidoptera	Geometridae		*Pholodes*	sp 2	K
386	Lepidoptera	Noctuidae				
387	Lepidoptera					
388	Lepidoptera	Noctuidae		*Pantydia*	sp	
389	Lepidoptera	Geometridae				K
390	Lepidoptera	Notodontidae				K
391	Lepidoptera	Noctuidae				
392	Lepidoptera	Geometridae				K
393	Lepidoptera	Geometridae				K
394	Lepidoptera					
395	Lepidoptera	Geometridae				
396	Lepidoptera	Oecophoridae				
397	Lepidoptera	Pyralidae				
398	Lepidoptera	Limacodidae		*Doratifera*	sp	K
399	Lepidoptera					
400	Neuroptera	Myremeleontidae				GR
401	Lepidoptera	Pyralidae				
402	Lepidoptera	Geometridae				
403	Lepidoptera	Geometridae				K
404	Lepidoptera	Thaumetopoeidae		*Oenosandra*	sp	K
405	Lepidoptera	Noctuidae				
406	Lepidoptera					
407	Lepidoptera					
408	Hymenoptera					
409	Hymenoptera	Formicidae				
410	Blattodea	Blaberidae				K
411	Lepidoptera					
412	Lepidoptera	Noctuidae				K
413	Lepidoptera					
414	Lepidoptera					
415	Lepidoptera	Geometridae				K
416	Coleoptera	Scarabeidae	Melolonthinae	*Heteronyx*	sp	
417	Lepidoptera	Geometridae		*Gastrina*	sp	K
418	Coleoptera	Scarabeidae	Melolonthinae	*Heteronyx*	sp	
419	Lepidoptera					
420	Lepidoptera					

421	Lepidoptera					
422	Lepidoptera					
423	Hymenoptera	Formicidae	Dolichoderinae	*Iridomyrex*	sp 2	K
424	Lepidoptera	Geometridae				K
425	Lepidoptera	Geometridae				K
426	Lepidoptera	Lasiocampidae		*Entometa*	sp	K
427	Coleoptera	Scarabeidae	Melolonthinae	*Heteronyx*		
428	Lepidoptera					
429	Lepidoptera					
430	Lepidoptera					
431	Lepidoptera					
432	Lepidoptera	Pyralidae				K
433	Mantodea	Mantidae		*Archimantis*	sp	K
434	Lepidoptera					
435	Lepidoptera	Noctuidae				K
436	Lepidoptera	Geometridae				K
437	Coleoptera	Lucanidae		*Syndesus*	sp	K
438	Lepidoptera					
439	Coleoptera	Carabidae	Carabinae			GA
440	Coleoptera	Dytiscidae				
441	Lepidoptera					
442	Lepidoptera					
443	Lepidoptera					
444	Coleoptera	Elateridae				
445	Lepidoptera	Artctiidae	Arctiinae	*Spilosoma*	sp	K
446	Lepidoptera					K
13	Coleoptera	Dytiscidae				
368	Coleoptera	Curculionidae	Amycterinae			K
449	Lepidoptera	Noctuidae				K
450	Lepidoptera	Geometridae		*Thalaina*	*clara*	K
451	Lepidoptera	Geometridae				K
452	Lepidoptera					K
453	Lepidoptera					
454	Lepidoptera					
455	Lepidoptera	Geometridae		*Gastrina*	*cristaria*	
456	Lepidoptera					
457	Lepidoptera	Anthelidae				K
458	Phasmatodea					
459	Lepidoptera					
460	Lepidoptera					
437	Coleoptera	Lucanidae		*Syndesus*	sp	K
462	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*		
463	Coleoptera	Chrysomelidae	Paropsinae			K
464	Diptera	Tachinidae				K
465	Coleoptera	Chrysomelidae	Paropsinae			K
466	Diptera	Tabanidae				
467	Diptera	Tabanidae				GA
468	Araneae					K
469	Scorpionida				Scorpion sp 2	K
470	Coleoptera	Curculionidae	Gonipterinae	*Oxyops*		

471	Coleoptera	Chrysomelidae	Paropsinae	*Chrysophtharta*		
472	Araneae					
473	Diptera	Tabanidae				
52	Hymenoptera	Apidae		*Apis*	*melifera*	K
475	Hemiptera	Pentatomidae				K
476	Coleoptera	Cerambycidae	Laminae			
477	Hymenoptera	Formicidae		*Myrmecia*	*callima*	K
478	Hymenoptera	Formicidae		*Myrmecia*	sp 7	K
479	Blattodea	Blaberidae				
480	Diptera	Calliphoridae		*Calliphora*		
481	Hymenoptera	Pompilidae				GA
482	Hemiptera	Reduviidae				K
483	Blattodea	Blaberidae				
484	Dermaptera					K
485	Orthoptera					
486	Hymenoptera	Formicidae		*Myrmecia*	sp 1	
487	Hymenoptera	Formicidae		*Myrmecia*	sp 6	
488	Coleoptera	Curculionidae	Gonipterinae	*Gonipterus*		
489	Hemiptera					K
490	Blattodea					
491	Dermaptera					
492	Dermaptera					
493	Hymenoptera	Braconinae				K
494	Hymenoptera	Pompilidae				
495	Diptera	Tabanidae				
496	Coleoptera	Curculionidae	Amycterinae			K
497	Araneae					
498	Diptera	Muscoidea				
52	Hymenoptera	Apidae		*Apis*	*melifera*	K
500	Hymenoptera	Evaniidae				K
501	Orthoptera	Acrididae				K
502	Araneae					
503	Hemiptera	Eurymelidae		*Pogonoscopus*	sp	K
504	Hymenoptera					
505	Hymenoptera	Sphecidae				K
506	Diptera	Bombylidae				K
507	Blattodea					
508	Blattodea					K
509	Blattodea					
510	Hymenoptera	Formicidae				
511	Coleoptera	Scarabeidae		*Onthophagus*		
512	Hemiptera	Reduviidae				K
513	Hemiptera	Pentatomidae				K
514	Coleoptera	Curculionidae				
515	Hymenoptera	Ichneumonidae				GA
516	Hymenoptera	Pompilidae				
517	Lepidoptera	Geometridae				
518	Lepidoptera	Noctuidae				
519	Isopoda	collective sp				
520	Annelida	collective sp				

521	Platyhelminthes					
522	Dermaptera					
525	Blattodea	Blattidae				K
526	Orthoptera	Stenopelmatidae		*Onosandrus*	sp	K
527	Hemiptera	Gelastocoridae		*Nerthra*	sp	
528	Coleoptera	Carabidae				K
529	Coleoptera	Carabidae				K
530	Diptera	Anthomyiidae				
531	Diptera	Tabanidae				GA
532	Diptera	Asilidae				GA
533	Hymenoptera	Ichneumonidae	Branchinae	*Australoglypta*	sp	
534	Hymenoptera	Mutilidae				
535	Hymenoptera	Formicidae	Dolichoderinae	*Iridomyrmex*	sp 1	
536	Araneomorphae	Corinnidae		*Supunna*	*albopunctata*	K
537	Araneomorphae	Corinnidae		*Supunna*	*picta* sp1	K
538	Mygalomorphae	Nemesiidae			juvenile	GR
539	Isopoda					
540	Isopoda					
541	Diptera	Asilidae				GA
542	Hymenoptera	Formicidae	Ponerinae	*Prionopella*	sp	
543	Hymenoptera	Formicidae	Poneri	*Rhytidoponera*	sp	
545	Hymenoptera	Colletidae				
546	Hymenoptera	Colletidae				
547	Blattodea	Blaberidae		*Laxta*	sp 2	K
548	Orthoptera	Acrididae				
550	Coleoptera	Scarabaeidae	Melolonthinae			
552	Hymenoptera	Formicidae	Myrmeciinae	*Myrmecia*	sp 1	
553	Araneomorphae	Ctenidae				
554	Araneomorphae	Lycosidae				
555	Orthoptera	Gryllidae				
557	Coleoptera	Carabidae				K
558	Coleoptera	Carabidae	Pentagonicinae	*Scapodes*	*boops*	
560	Araneomorphae	Gnaphosidae				
562	Coleoptera	Scarabaeidae	Melololonthinae	*Heteronyx*	sp	
564	Diptera	Asilidae				GA
565	Diptera	Syrphidae				
567	Mygalomorphae	Nemesiidae		*Chenistonia*	sp 1	GR
568	Scorpionida				Scorpion sp 1	K
570	Blattodea	Blaberidae			sp 4	K
571	Coleoptera	Elateridae				
573	Hemiptera	Reduviidae				
576	Orthoptera	Acrididae		*Cedarinia*	sp 2	
577	Diptera	Tipulidae				
579	Diptera	Sarcophagidae				
580	Hymenoptera	Mutilidae				
581	Mygalomorphae	Nemesiidae		*Chenistonia*	sp 2	GR
584	Hymenoptera	Tiphiidae				GA
585	Mygalomorphae	Nemesiidae			juvenile	GR
587	Coleoptera	Carabidae				K
588	Diptera	Tipulidae				

589	Lepidoptera	Noctuidae			
590	Mygalomorphae		*Nemesiidae*	juvenile	GR
591	Blattodea	Blatellidae	*Neotemnopteryx*	sp	
592	Blattodea	Blattidae	*Polyzosteria*	sp	
593	Lepidoptera	Hesperiidae	*Hesperilla*	*chrysotricha*	K
594	Lepidoptera	Nymphalidae	*Vanessa*	*kershawi*	K
596	Hymenoptera	Colletidae			
597	Araneomorphae	Miturgidae	*genus2*	sp 1	
598	Lepidoptera	Noctuidae			
603	Diptera	Tabanidae			GA
604	Hymenoptera	Tiphiidae			GA
607	Hymenoptera	Pompilidae			GA
608	Orthoptera	Gryllidae			
609	Orthoptera	Gryllidae			
611	Hymenoptera	Pompilidae			GA
612	Hymenoptera	Pompilidae			GA
613	Orthoptera	Acrididae			
614	Hymenoptera	Tiphiidae			GA
616	Hymenoptera	Pompilidae			GA
617	Hymenoptera	Pompilidae			GA
618	Orthoptera	Gryllidae			
619	Hymenoptera	Pompilidae			GA
620	Araneomorphae	Trochanteridae	*Rebilus*	sp	
621	Coleoptera	Elateridae			
622	Hymenoptera	Pompilidae	*Cryptocheilus*	*fabricolor*	GA
623	Chilopoda				
628	Coleoptera	Staphylinidae			K
629	Scorpionida			Scorpion sp 3	K

PLANTS

Bruce Ward and Ray Cranfield

Introduction

The objective of this report is to present preliminary results of the first stage of monitoring for FORESTCHECK and to discuss any issues with the concept plan for monitoring protocols. Three sites (10 grids) from within the Donnelly District were selected and set up as monitoring sites according to the operations plan. Four plots each of 1 000 m^2 and twenty x 1 m^2 were used to record species richness and abundance of vascular plants. A point transect was used on two sides of the 30 m x 30 m plots to record vegetation structure and were vertical contacts of shrubs at every 2 m intervals for 60 m (2 sides). This gave a total of 120 records per grid.

Aim

To monitor vascular plant species richness and abundance for each of the FORESTCHECK grids.

Sampling

Vegetation in the FORESTCHECK grids was sampled in accordance with the operations plan. Species richness was assessed using four 30 m x 30 m plots in each grid (40 in total) and species abundance from twenty 1 m x 1 m plots (200 in total) (Fig. 1). 158 species were identified for the 1 m x 1 m quadrats and 203 for the 30 x 30 m quadrats and a complete list is attached (Appendix 1).

Time estimates to complete the task were accurate and were based on experience from the Kingston study where similar plots were measured. Time estimates were designed around a two-person team, which from experience is the most efficient method of sampling.

Cost estimates were also based on experience from the Kingston study and resulted in the work being completed within budget. The next site will need a careful review of the budget required as travel and accommodation costs will increase with the greater distance from Manjimup Research Centre.

Sampling Issues

Our brief was to monitor plant species abundance and species richness. We recommend that we include in addition to what is already being measured the "Bragg" system of rating cover, distribution and density for all species within the 30 m x 30 m plots. This system is quite sensitive and can provide data on all species, which will give a better measure of species abundance. Relying on the 1 m x 1 m quadrats for abundance will provide detail about the number of individual plants, but does not describe cover and does not pick up all species. Only 75% of the species were recorded in these quadrats compared with the 30 m x 30 m plots.

trend in the scatterplot (Figure 1) with little or no obvious influence of harvesting treatment. Figure 2 shows the total number of native species recorded in the 30m x 30 m quadrats at each grid and treatment. Species richness was greatest in the Yornup external control (M5) and least in the Kingston gap treatment (M2). At Kingston, which was logged in 1995/96, species richness is lowest in the logged treatments, especially the gap treatment (M2) and highest in the external control and the buffer (M1 & M4). Apart from the external control (M1), the differences between other treatments, including the buffer, are not significant. At other sites, with the exception of M5, there is no significant difference in overall species richness.

Tables 1 and 2 show the mean number of species and number of plants recorded, by life form, per m^2 in the 1 m x 1 m quadrats. Although the standard errors are high, indicating that a greater sampling intensity is required, some trends are apparent. Annual herbs and weeds (introduced species) are generally more abundant on the disturbed sites, while both the species richness and abundance of geophytes and woody shrubs is generally lowest on these sites and greatest in the buffers and the control sites. This supports earlier research findings from the Kingston project and suggests that the understorey vegetation is still recovering from logging treatments, the earliest of which was conducted in 1990.

Future Tasks

- Further detailed analysis of the vegetation data.
- Prepare and measure the next site for FORESTCHECK monitoring.
- Track any occurrence of priority species that may be present on monitoring sites (none located in current plots).

Operating Plan Revision

There is no need for any major revision to the operating plan, except to include the "Bragg abundance rating system" for the 30 m x 30 m plots (see above rating system). Consideration should be given to doubling the number of 1 m x 1 m sampling quadrats at each site.

Indicator Species

At this stage, the use of indicator species as a method of monitoring vascular plants is not recommended for the following reasons:

- While there are changes in abundance, biodiversity in terms of species richness, does not appear to be markedly changed in the logging treatments. Most variation in species richness and composition is due to site variation. If only indicator species are used, presence or absence may be site-related, not due to treatments. That is, identifying reliable indicators for each site prior to full assessment is problematical.
- Many species occur in low numbers and may or may not be present at sampling through chance.
- Time since fire effects species composition and abundance. As a result, fire frequency and intensity impacts may have more significant impact on plant abundance and dramatically affect results from a survey based solely on indicator species.

Figure 1: Non-linear mds based on species presence in 30 m x 30 m quadrats - FORESTCHECK sites

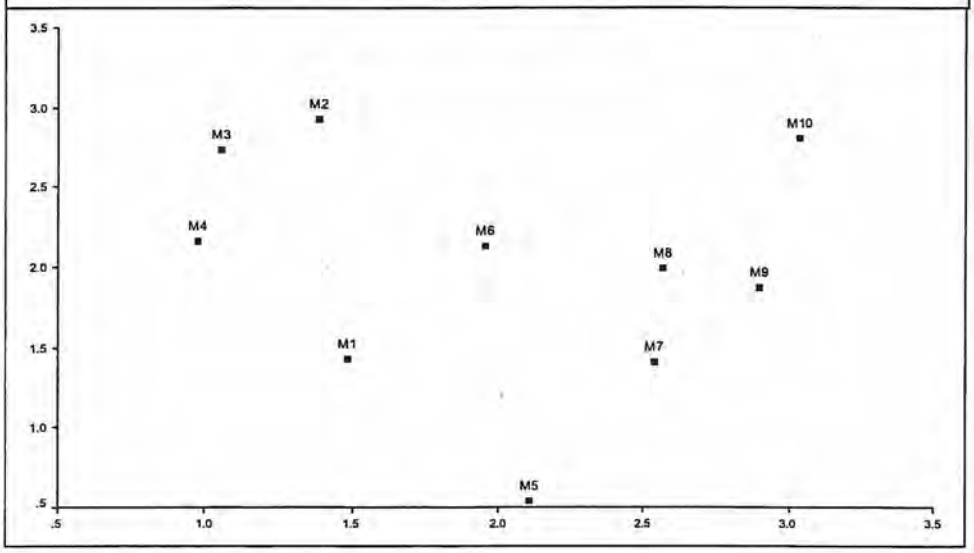
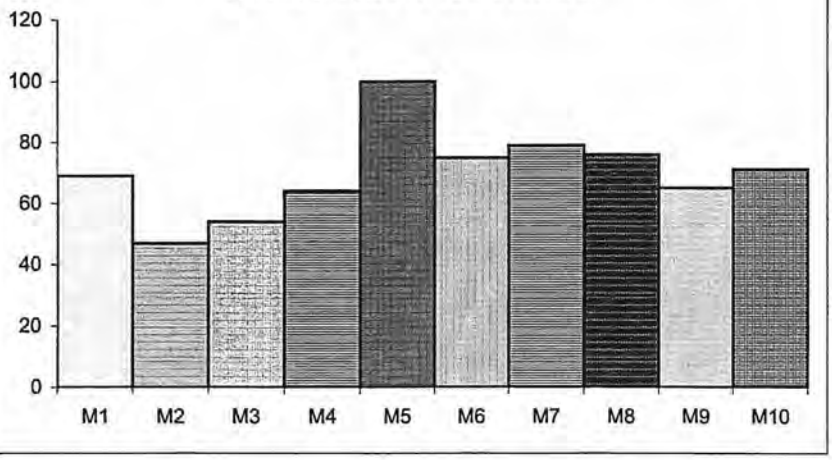


Figure 2: Total number of native vascular plant species recorded in 30 m x 30 m plots for each treatment.



FORESTCHECK - TABLE 1

Mean No. of species m^{-2} found on 1x1 m quadrats. Standard errors in parentheses

	Treatment Site									
LIFE FORM	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Annual herb	0.75 (1.25)	2.10 (2.31)	4.15 (1.63)	4.15 (2.46)	0.50 (0.69)	2.10 (1.65)	0.50 (0.76)	1.75 (1.25)	0.15 (0.37)	-
Perennial herb	1.40 (0.88)	2.15 (1.27)	2.35 (1.42)	2.55 (1.47)	3.05 (1.64)	1.85 (1.42)	1.80 (1.28)	2.00 (1.08)	1.95 (1.05)	2.45 (1.23)
Fern	0.15 (0.37)	0.35 (0.49)	0.35 (0.49)	0.55 (0.51)	-	0.05 (0.22)	0.10 (0.31)	0.05 (0.22)	0.40 (0.50)	0.70 (0.47)
Geophyte	3.40 (1.47)	1.50 (1.19)	1.35 (1.53)	2.90 (1.59)	2.30 (1.17)	1.10 (0.79)	1.65 (1.04)	0.90 (0.97)	1.95 (0.89)	1.80 (1.24)
Grass	0.65 (0.49)	1.00 (0.46)	0.40 (0.50)	1.40 (0.68)	0.30 (0.57)	0.40 (0.50)	0.45 (0.60)	0.50 (0.61)	0.15 (0.37)	0.55 (0.51)
Sedge	-	-	-	-	0.50 (0.61)	0.20 (0.41)	-	0.05 (0.22)	-	-
Tree	1.05 (0.83)	0.85 (0.59)	0.25 (0.44)	0.65 (0.59)	0.85 (0.75)	0.75 (0.72)	1.10 (0.79)	0.40 (0.60)	0.95 (0.83)	1.40 (0.60)
Shrub (woody)	4.10 (1.71)	3.20 (1.36)	1.10 (0.79)	1.95 (1.23)	5.70 (1.81)	3.70 (2.27)	5.70 (1.89)	4.25 (2.02)	5.20 (1.88)	6.25 (2.07)
Parasite	-	0.10 (0.31)	-	-	-	-	0.10 (0.31)	-	-	0.05 (0.22)
Vine	1.45 (0.76)	0.95 (0.60)	0.45 (0.60)	1.25 (0.64)	0.05 (0.22)	0.45 (0.51)	0.20 (0.41)	0.55 (0.60)	0.40 (0.50)	0.15 (0.37)
Rush	-	-	0.05 (0.22)	0.10 (0.31)	-	-	-	-	-	-
Cycad	0.05 (0.22)	0.10 (0.31)	0.30 (0.47)	0.25 (0.44)	0.05 (0.22)	0.05 (0.22)	-	-	-	0.05 (0.22)
Xanthorrhoea	-	-	-	-	0.20 (0.41)	0.05 (0.22)	0.10 (0.31)	-	-	-
Total Native	13.00 (3.61)	12.30 (4.00)	10.75 (4.04)	15.75 (4.15)	13.50 (3.62)	10.70 (3.31)	11.70 (3.08)	10.45 (3.80)	11.15 (3.12)	13.40 (2.82)
Total Weed	0.60 (0.68)	1.25 (1.52)	7.95 (2.26)	2.80 (1.74)	0.20 (0.41)	0.90 (0.97)	0.15 (0.49)	1.20 (0.83)	0.05 (0.22)	0.15 (0.37)

FORESTCHECK - TABLE 2

Mean No of plants m^{-2} found on 1x1 m^2 quadrats. Standard error in parentheses

	Treatment Site									
LIFE FORM	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**
Annual herb	7.15 (20.08)	30.55 (74.08)	46.60 (33.52)	46.80 (49.61)	2.85 (5.33)	34.20 (39.64)	1.80 (4.02)	15.50 (18.55)	0.30 (0.73)	-
Perennial herb	3.25 (2.86)	3.95 (2.84)	8.20 (9.95)	7.75 (10.96)	9.45 (11.13)	4.10 (5.63)	5.50 (4.55)	6.45 (7.55)	6.50 (4.20)	7.05 (6.25)
Fern	0.20 (0.52)	0.40 (0.60)	0.45 (0.69)	0.80 (0.83)	-	0.05 (0.22)	0.50 (1.82)	0.10 (0.45)	0.60 (0.88)	0.95 (0.83)
Geophyte	11.80 (6.19)	5.70 (6.12)	3.50 (4.84)	15.50 (10.55)	7.40 (6.44)	2.95 (3.66)	4.35 (3.47)	2.15 (3.38)	5.45 (3.90)	6.75 (6.37)
Grass	1.20 (1.20)	3.45 (2.54)	1.35 (2.58)	4.00 (2.64)	0.50 (1.19)	0.70 (0.98)	0.55 (0.83)	0.90 (1.17)	0.15 (0.37)	0.85 (0.99)
Sedge	-	-	-	-	0.85 (1.09)	0.20 (0.41)	-	0.10 (0.45)	-	-
Tree	2.55 (2.50)	1.60 (1.67)	0.35 (0.75)	0.80 (0.83)	1.25 (1.45)	1.20 (1.32)	1.85 (1.66)	0.50 (0.76)	1.50 (1.50)	2.85 (1.73)
Shrub (woody)	9 (4.8882)	6.9 (4.5294)	2.25 (1.9702)	3.65 (3.0826)	14.85 (6.36)	6.5 (4.6396)	15.5 (7.5359)	19.1 (18.8509)	19.65 (13.903)	15.25 (6.1548)
Parasite	-	0.10 (0.31)	-	-	-	-	0.15 (0.49)	-	-	0.05 (0.22)
Vine	3.15 (2.28)	2.25 (2.69)	0.80 (1.79)	2.30 (1.17)	0.10 (0.45)	0.60 (0.75)	0.20 (0.41)	0.90 (1.12)	0.55 (0.83)	0.45 (1.28)
Rush	-	-	0.05 (0.22)	0.15 (0.49)	-	-	-	-	-	-
Cycad	0.05 (0.22)	0.10 (0.31)	0.40 (0.68)	0.35 (0.75)	0.05 (0.22)	0.05 (0.22)	-	-	-	0.25 (1.12)
Xanthorrhoea	-	-	-	-	0.20 (0.41)	0.10 (0.45)	0.15 (0.49)	-	-	-
Total Native	38.35 (21.65)	55.00 (80.09)	63.95 (36.17)	82.10 (44.65)	37.50 (17.77)	50.65 (37.57)	30.55 (9.91)	45.70 (27.07)	34.70 (14.84)	34.45 (9.52)

Appendix 1. Total species list 2002 FORESTCHECK sampling

Alien Sp	Taxon Name	Voucher	SpCode	Lifeform	Fire Reponse	Lifestyle
	Acacia alata	V	ACAALA	S	A1	P
	Acacia browniana	V	ACABRO	S	A1	P
	Acacia dentifera		ACADEN	S	A1	P
	Acacia divergens	V	ACADIV	S	A1	P
	Acacia drummondii		ACADRU	S	A1	P
*	*Acaena echinata*	V	ACAECH	DS	A1	P
	Acacia extensa	V	ACAEXT	S	A1	P
	Acacia myrtifolia		ACAMYR	S	A1	P
	Acacia pulchella	V	ACAPUL	S	A1	P
	Acacia stenoptera	V	ACASTE	S	A1	P
	Adenanthos obovatus		ADEOBO	S	B2	P
	Agonis flexuosa		AGOFLE	T	U	P
	Agonis parviceps	V	AGOPAR	S	B2	P
*	*Aira cupaniana*	V	AIRCUP	AGR	A1	A
	Amphipogon amphipogonoides		AMPAMP	DS	B2	P
	Amperea ericoides	V	AMPERI	DS	B2	P
*	*Anagallis arvensis* var. *arvensis*		ANAARV	AHW	A1	A
*	*Anagallis arvensis* var. *caerulea*	V	ANAARV	AHW	A1	A
	Andersonia caerulea	V	ANDCAE	DS	A1	P
	Anigozanthos flavidus		ANIFLA	S	B3	P
*	*Arctotheca calendula*	V	ARCCAL	AHW	A3	A
	Astroloma ciliatum		ASTCIL	DS	B2	P
	Astroloma drummondii		ASTDRU	DS	B2	P
	Astroloma pallidum	V	ASTPAL	DS	B2	P
	Austrodanthonia caespitosa		AUSCAE	GR	B3	P
	Austrostipa campylachne		AUSCAM	GR	B3	P
	Banksia grandis	V	BANGRA	T	A2	P
	Billardiera floribunda		BILFLO	V	A1	P
	Billardiera variifolia		BILVAR	V	A1	P
	Boronia crenulata		BORCRE	DS	B2	P
	Boronia megastigma		BORMEG	S	A1	P
	Boronia spathulata		BORSPA	S	B2	P
	Bossiaea aquifolium subsp. *laidlawiana*	V	BOSAQULA	S	A1	P
	Bossiaea linophylla	V	BOSLIN	S	A1	P
	Bossiaea ornata	V	BOSORN	S	B2	P
*	*Briza minor*	V	BRIMIN	GRW	A1	A
	Burchardia umbellata	V	BURUMB	G	B3	P
	Caesia micrantha	V	CAEMIC	G	B3	P
	Caladenia flava subsp. *flava*	V	CALFLAF	G	B3	P
	Callistachys lanceolata	V	CALLAN	S	A1	P
	Caladenia macrostylis	V	CALMAC	G	B3	P
	Caladenia reptans subsp. *reptans*	V	CALREP	G	B3	P
	Caladenia sp.		CALSP.	G	B3	P
	Calytrix simplex	V	CALSIM	S	A1	P
	Cassytha racemosa	V	CASRAC	P	A1	P
	Centrolepis aristata	V	CENARI	H	A1	A
	Centrolepis drummondiana	V	CENDRU	AH	A1	A
*	*Centaurium erythraea*	V	CENERY	AHW	A1	A
*	*Cerastium glomeratum*	V	CERGLO	AHW	A1	A
	Chamaescilla corymbosa	V	CHACOR	G	B3	P
	Chorizema nanum	V	CHONAN	DS	A1	P
	Chorizema rhombeum	V	CHORHO	DS	A1	P

	Clematis pubescens	V	CLEPUB	V	A1	P
	Comesperma calymega		COMCAL	DS	B2	P
	Conostylis aculeata		CONACU	DS	B3	P
*	*Conyza bonariensis*	V	CONBON	AHW	A1	A
	Conospermum capitatum		CONCAP	S	B2	P
	Conostylis setigera		CONSET	DS	B3	P
	Corymbia calophylla		CORCAL	T	A2	P
	Cotula coronopifolia	V	COTCOR	AH	A1	A
	Crassula decumbens	V	CRADEC	AH	A1	A
	Crassula peduncularis		CRAPED	AH	A1	A
	Craspedia variabilis	V	CRAVAR	G	B3	P
*	*Crepis foetida*		CREFOE	AHW	A1	A
	Cyanicula deformis		CYADEF	G	B3	P
	Cyanicula sericea	V	CYASER	G	B3	P
	Cyrtostylis huegelii	V	CYRHUE	G	B3	P
	Daucus glochidiatus		DAUGLO	AH	A1	A
	Daviesia cordata		DAVCOR	S	U	P
	Daviesia preissii		DAVPRE	S	A1	P
	Desmocladus fasciculatus	V	DESFAS	Z	B3	P
	Desmocladus flexuosus	V	DESFLE	Z	B3	P
	Dodonaea ceratocarpa		DODCER	S	A1	P
	Drosera erythrorhiza		DROERY	G	B3	P
	Drosera huegelii		DROHUE	G	B3	P
	Drosera pallida	V	DROPAL	G	B3	P
	Drosera stolonifera	V	DROSTO	G	B3	P
	Elythranthera brunonis	V	ELYBRU	G	B3	P
*	*Erodium cicutarium*	V	EROCIC	AHW	A1	A
	Euchiton collinus	V	EUCCOL	AH	A1	A
	Eucalyptus marginata	V	EUCMAR	T	A2	P
*	*Galium murale*	V	GALMUR	AHW	A1	A
	Gastrolobium bilobum	V	GASBIL	S	A1	P
	Geranium solanderi	V	GERSOL	DS	A1	A
	Gompholobium marginatum	V	GOMMA	DS	A1	P
	Gompholobium ovatum	V	GOMOVA	DS	A1	P
	Gompholobium polymorphum		GOMPOL	DS	A1	P
	Gompholobium tomentosum		GOMTOM	DS	A1	P
	Gonocarpus benthamii		GONBEN	DS	A1	P
	Goodenia eatoniana		GOOEAT	DS	A1	A
	Hakea amplexicaulis	V	HAKAMP	S	B2	P
	Hakea lissocarpha		HAKLIS	S	B2	P
	Hakea oleifolia	V	HAKOLE	S	B2	P
	Hardenbergia comptoniana	V	HARCOM	V	B2	P
	Hemigenia rigida		HEMRIG	DS	B2	P
	Hibbertia amplexicaulis	V	HIBAMP	S	B2	P
	Hibbertia commutata	V	HIBCOM	S	B2	P
	Hibbertia cuneiformis		HIBCUN	S	B2	P
	Hibbertia racemosa	V	HIBRAC	S	A1	P
	Hibbertia spicata		HIBSPI	S	B2	P
	Hibbertia spicata		HIBSPI	S	B2	P
	Hovea chorizemifolia	V	HOVCHO	DS	B2	P
	Hovea elliptica	V	HOVELL	S	B2	P
	Hyalosperma cotula	V	HYACOT	AH	A1	A
	Hybanthus debilissimus	V	HYBDEB	DS	A1	P
	Hydrocotyle callicarpa	V	HYDCAL	AH	A1	A
	Hydrocotyle diantha		HYDDIA	AH	A1	A

	Hydrocotyle diantha		HYDSP.	AH	A1	A
	Hypocalymma angustifolium	V	HYPANG	S	B2	P
*	*Hypochaeris glabra*	V	HYPGLA	AHW	A1	A
	Isotropis cuneifolia	V	ISOCUN	S	A1	P
	Isotoma hypocrateriformis		ISOHYP	AH	A1	A
*	*Isolepis marginata*	V	ISOMAR	AR	A1	A
	Johnsonia lupulina		JOHLUP	G	B2	P
*	*Juncus capitatus*	V	JUNCAP	AW	A1	A
	Kennedia carinata	V	KENCAR	DS	A1	P
	Kennedia coccinea	V	KENCOC	V	A1	P
	kennedia prostrata	V	KENPRO	S	A1	P
	Labichia punctata	V	LABPUN	DS	B2	P
	Lagenophora huegelii	V	LAGHUE	G	B3	P
	Leptomeria cunninghamii		LEPCUN	S	A1	P
	Lepidosperma leptostachyum		LEPLEP	Z	B3	P
	Lepidosperma squamatum	V	LEPSQU	Z	B3	P
	Leucopogon australis	V	LEUAUS	S	B2	P
	Leucopogon capitellatus	V	LEUCAP	S	B2	P
	Leucopogon propinquus	V	LEUPRO	S	B2	P
	Leucopogon pulchellus		LEUPUL	S	B2	P
	Leucopogon verticillatus	V	LEUVER	S	B2	P
	Levenhookia pusilla	V	LEVPUS	AH	A1	A
	Lindsaea linearis		LINLIN	F	B3	P
	Logania serpyllifolia	V	LOGSER	DS	B2	P
	Logania vaginalis	V	LOGVAG	S	B2	P
	Lomandra caespitosa	V	LOMCAE	DS	B3	P
	Lomandra drummondii		LOMDRU	DS	B3	P
	Lomandra hermaphrodita	V	LOMHER	DS	B2	P
	Lomandra integra	V	LOMINT	DS	B3	P
	Lomandra pauciflora		LOMPAU	DS	B2	P
	Lomandra purpurea		LOMPUR	DS	B3	P
	Lomandra sericea		LOMSER	DS	B3	P
*	*Lotus suaveolens*		LOTSUA	AHW	A1	A
	Luzula meridionalis	V	LUZMER	R	B3	P
	Macrozamia riedlei	V	MACRIE	C	B3	P
	Microlaena stipoides	V	MICSTI	GR	A1	P
	Millotia tenuifolia	V	MILTEN	AH	A1	A
	Myoporum tetrandrum	V	MYOTET	S	A1	P
	Oligochaetochilus vittatus		OLIVIT	G	B3	P
	Opercularia hispidula	V	OPEHIS	S	B2	P
	Orthrosanthus laxus	V	ORTLAX	G	B3	P
*	*Oxalis corniculata*	V	OXACOR	G	B3	P
	Ozothamnus ramosus		OZORAM	S	U	P
*	*Parentucellia latifolia*	V	PARLAT	AHW	A1	A
	Patersonia babianoides	V	PATBAB	G	B3	P
	Patersonia occidentalis		PATOCC	DS	B3	P
	Patersonia umbrosa		PATUMB	DS	B3	P
	Patersonia umbrosa var. *xanthina*	V	PATUMB	DS	B3	P
	Pelargonium littorale	V	PELLIT	DS	A1	P
	Pentapeltis silvatica	V	PENSIL	S	B2	P
	Persoonia longifolia	V	PERLON	S	B2	P
	Phyllanthus calycinus	V	PHYCAL	DS	B2	P
	Phyllangium paradoxum		PHYPAR	AH	A1	A
	Pimelea angustifolia		PIMANG	S	A1	P
	Pimelea ciliata	V	PIMCIL	S	A1	P

	Pimelea rosea	V	PIMROS	S	A1	P
	Pimelea suaveolens		PIMSUA	S	B2	P
	Platytheca galioides	V	PLAGAL	S	U	A
	Platysace tenuissima	V	PLATEN	DS	A1	P
*	*Poa annua*		POAANN	AGR	A1	A
	Podocarpus drouynianus	V	PODDRO	S	B2	P
	Podotheca gnaphalioides		PODGNA	AH	A1	A
	Poranthera huegelii	V	PORHUE	DS	A1	P
	Poranthera microphylla	V	PORMIC	DS	A1	A
*	*Pseudognaphalium luteoalbum*		PSELUT	AHW	A1	A
	Pteridium esculentum	V	PTEESC	F	B2	P
	Pterostylis pyramidalis	V	PTEPYR	G	B3	P
	Pterostylis recurva		PTEREC	G	B3	P
	Ptilotus manglesii		PTIMAN	G	B3	P
	Ranunculus colonorum	V	RANCOL	G	B3	P
	Rhodanthe citrina	V	RHOCIT	AH	A1	A
	Scaevola striata		SCASTR	DS	A1	A
	Senecio hispidulus	V	SENHIS	S	A1	A
*	*Silene gallica*		SILGAL	AHW	A1	A
	Sollya heterophylla	V	SOLHET	S	U	P
*	*Sonchus asper*	V	SONASP	AHW	A1	A
	Sowerbaea laxiflora	V	SOWLAX	G	B3	P
	Sphenotoma capitatum	V	SPHCAP	DS	A1	P
	Sphaerolobium medium	V	SPHMED	S	B2	P
	Stackhousia monogyna	V	STAMON	S	B2	P
	Stylidium amoenum		STYAMO	DS	A1	P
	Stylidium brunonianum		STYBRU	DS	A1	P
	Stylidium calcaratum	V	STYCAL	AH	A1	A
	Stylidium ciliatum		STYCIL	DS	A1	P
	Stylidium luteum		STYLUT	DS	A1	P
	Stylidium rhynchocarpum		STYRHY	DS	A1	P
	Styphelia tenuiflora		STYTEN	S	A1	P
	Tetratheca affinis	V	TETAFF	S	A1	P
	Tetraria capillaris		TETCAP	S	B3	P
	Tetratheca hirsuta		TETHIR	S	A1	P
	Tetratheca hispidissima	V	TETHIS	S	A1	P
	Tetrarrhena laevis		TETLAE	GR	B3	P
	Thelymitra crinita		THECRI	G	B3	P
	Thysanotus manglesianus	V	THYMAN	G	B3	P
	Thysanotus sp.	V	THYSP.	G	B3	P
	Thysanotus thyrsoideus		THYTHY	G	B3	P
	Trachymene pilosa	V	TRAPIL	AH	A1	A
	Tremandra diffusa	V	TREDIF	S	A1	P
	Tremandra stelligera		TRESTE	DS	B2	P
*	*Trifolium campestre*		TRICAM	AH	A1	A
	Tricoryne humilis		TRIHUM	DS	A1	P
	Trichocline spathulata		TRISPA	G	B3	P
	Trymalium floribundum	V	TRYFLO	S	A1	P
	Trymalium ledifolium		TRYLED	S	A1	P
*	*Vellereophyton dealbatum*	V	VELDEA	AHW	A1	A
	Velleia trinervis	V	VELTRI	DS	A1	A
	Veronica calycina		VERCAL	DS	B3	P
*	*Vulpia myuros*		VULMYU	AGRW	A1	A
	Wahlenbergia gracilenta	V	WAHGRA	AH	A1	A
	Xanthosia atkinsoniana	V	XANATK	S	B2	P

Xanthosia candida	V	XANCAN	DS	B2	P
Xanthorrhoea gracilis		XANGRA	X	B2	P
Xanthosia huegelii	V	XANHUE	DS	A1	P
Xanthorrhoea preissii		XANPRE	X	B2	P

CRYPTOGAMS

Ray Cranfield

Introduction
Ten FORESTCHECK grids were visited during May 2002 and cryptogams (lichens, mosses and liverworts [LBH]) were sampled. Macro and micro habitats, species occurrence and frequency were recorded at each grid. Biodiversity of LBH was determined by using 10 cm x 10 cm grids over a 100 m transect.

Sampling
The initial sampling was carried out as a series of 4 x 100 m transects around the edge of the FORESTCHECK grid within the 300 m x 300 m area. Two collectors sampled 2 m either side of the 100 m transects, collecting all LBH independently. These site collections were sorted in the laboratory on the same day and any replicate samples combined. Species descriptions were prepared and notes made about substrates. An estimate of frequency and occurrence for each substrate and grid was made. The position occupied by each species within the stratal layers was also estimated.

Using established 100 m (1 x 1 m^2) vegetation transects for each grid, the presence or absence of the LBH groups within a grid 10 x 10 cm^2 every 10 m laterally spaced at 1 m and 2 m was mapped. This was to examine LBH diversity at each grid and establish the relevance of nominated indicator species. It soon became apparent that this was a waste of time and effort as the results were too inconsistent and were impacted upon by other external factors. Several transects resulted in zero records, which did not reflect the actual abundance obtained by the above method from the same sites. Another problem encountered was that of LBH above 1 m from ground level as these had to be ignored due to difficulty of scoring.

The sampling time appears to be on target with a window of opportunity covering many months that may improve the quality of some samples collected. The prospect of conducting an end of season re-sampling was considered but may be of little benefit as the expected species increase is low and best left to future monitoring programs.

Specimen Processing
At this stage the processing of specimens is on target with all identifications completed, with the exception of taxonomic problem species, which I have phrase-named to assist in listing and data entry. All lichen samples have been processed and are ready to send to the Herbarium. Moss and liverwort samples that require the additional step of washing and redrying are taking a bit longer, with completion expected before the start of the next set of sites. Database entry and label generation is in hand and most samples will be ready to send to the Herbarium for future reference. Once completed, problem species can be sent to experts within Australia or externally. As this will take time I consider this to be an ongoing aspect of FORESTCHECK.

Number of samples collected including repeats for all grids = 498
- Number of lichen samples = 266
- Number of moss samples = 58
- Number of liverwort samples = 33

Excluding repeat samples, 159 individual cryptogam species have been recognized from 10 grids. Note that 20 additional samples of algae and fungi were sampled and placed into the Herbarium but identified only as Genus sp.

Database Establishment

The entry protocols have been developed and data entry has been undertaken. Re-adjustment of the data recorded in the collecting book and the ranking of appropriate fields has meant that the 10 cm x 10 cm grid data can be obtained and the species diversity rated.

Preliminary Results

Table 1. FORESTCHECK Cryptogam site data

Grids		M1	M5	M10	M4	M7	M9	M2	M6	M8	M3
Type of site		C	C	C	B	B	B	G	G	G	S
	Number of samples	82	53	50	76	49	47	31	33	15	62
Groups		Number of taxa									
L	Lichen	45	28	36	45	25	22	13	20	8	28
B	Moss	8	9	8	5	7	5	4	2	6	4
H	Liverwort	3	3	4	3	3	6	6	3	1	1
		Number of species									
Habitats											
1	Wood	18	14	27	21	10	10	5	8	5	18
2	Bark	16	9	10	9	11	8	2	3	1	4
3	Ant Hill	1	0	2	5	2	1	1	0	0	2
4	Soil	6	12	5	5	4	9	12	8	4	7
5	Stone	6	7	0	6	4	2	2	4	3	2
6	Organic Material	13	5	7	10	5	8	2	4	2	3
7	Charcoal	3	2	0	4	1	2	2	1	1	3
Stratal Position											
1	0 - 30 cm	36	25	19	33	24	20	22	19	11	24
2	31 cm - 3 m	24	17	36	31	17	14	2	10	6	15
3	3.1 m +	4	4	4	1	2	3	0	1	0	1
Habitat Frequency											
1	71%+	0	0	0	0	0	0	0	0	0	0
2	50 - 70%	15	10	11	22	9	11	6	5	5	10
3	10 - 49%	20	22	23	16	15	13	12	16	3	13
4	0 - 9%	21	6	14	15	11	9	5	3	7	11
Site Frequency											
1	50%+	0	0	0	0	0	0	0	0	0	0
2	15-49%	1	1	0	2	0	1	2	0	0	2
3	3-14%	19	17	15	18	14	10	6	9	4	9
4	1-2%	36	22	34	33	21	21	15	15	11	23
Indicator species		21	15	14	17	15	15	9	10	9	14

C = control, B = coupe buffer, G = gap, S = Shelterwood timber harvest treatments.

Table 2. Combined number of Cryptogam groups located on different substrates and strata

	Microhabitats (Substrates)							Strata levels		
	1	2	3	4	5	6	7	Ground	Shrub	Tree
Grids										
M1	18	16	1	6	6	13	3	36	24	4
M2	5	2	1	12	2	2	2	22	2	0
M3	18	4	2	7	2	3	3	24	15	1
M4	21	9	5	5	6	10	4	33	31	1
M5	14	9	0	12	7	5	2	25	17	4
M6	8	3	0	8	4	4	1	19	10	1
M7	10	11	2	4	4	5	1	24	17	2
M8	5	1	0	4	3	2	1	11	6	0
M9	10	8	1	9	2	8	2	20	14	3
M10	27	10	2	5	0	7	0	19	36	4

Note that in several instances individual species of LBH were located in several habitats or several strata.

Table 3. FORESTCHECK Cryptogam Habitat and Stratal Levels Usage [Showing Number of Species in all 3 Groups: Lichens (L), Mosses (B) and Liverworts (H)].

		Habitats							Strata Levels		
Grids	Groups	Wood	Bark	Ant Hill	Soil	Stone	Organic	Charcoal	0-30cm	31cm-3m	3.1m+
M1	L	18	16	1	0	5	7	3	25	2	4
	B	0	0	0	5	1	4	0	8	0	0
	H	0	0	0	1	0	2	0	3	0	0
M5	L	13	9	0	3	5	5	1	13	14	2
	B	0	0	0	7	2	1	1	6	1	0
	H	1	0	0	3	0	0	0	2	1	0
M10	L	22	8	2	1	0	5	0	10	29	4
	B	3	1	0	3	0	2	0	6	4	0
	H	2	1	0	1	0	0	0	4	2	0
M4	L	18	9	5	1	7	8	3	25	28	1
	B	1	0	0	3	0	2	1	5	1	0
	H	2	0	0	1	0	1	0	3	2	0
M7	L	6	9	0	2	3	5	1	15	14	2
	B	3	1	2	1	1	0	0	7	1	0
	H	1	1	0	1	0	0	0	2	2	0
M9	L	10	8	1	0	2	4	1	10	13	3
	B	0	0	0	4	0	4	0	5	0	0
	H	1	0	0	5	0	0	1	4	2	0
M2	L	5	2	1	3	2	2	0	12	1	0
	B	0	0	0	4	0	0	1	4	0	0
	H	0	0	0	5	0	0	1	6	1	0
M6	L	8	3	0	3	4	4	1	14	10	1
	B	0	0	0	2	0	1	0	2	0	0
	H	0	0	0	3	0	0	0	3	0	0
M8	L	3	1	0	0	2	1	1	5	4	0
	B	2	0	0	3	1	1	0	5	2	0
	H	0	0	0	1	0	0	0	1	0	0
M3	L	15	4	2	3	2	3	3	18	15	1
	B	2	0	0	3	0	0	0	4	0	0
	H	1	0	0	1	0	0	0	2	0	0

M1, M2 &M10 control grids
M2, M6 & M8 gap grids
M4, M7 & M9 coupe buffer grids
M3 shelterwood grids

Table 4. Presence / Absence of Cryptogam taxa located on each site (Names in **bold text** are the nominated indicator species).

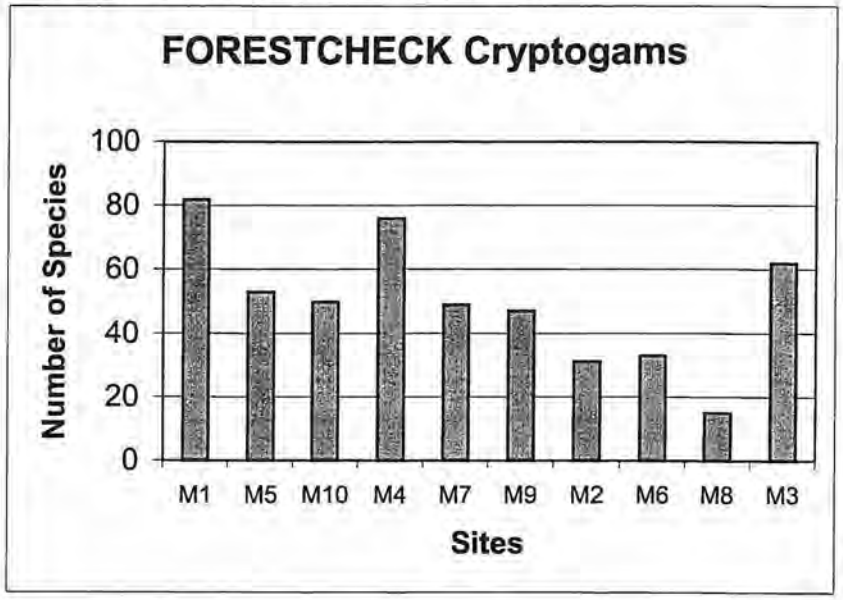
Taxa	Grids	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Mosses (B)											
Barbula calycina		*	*	*	*	*		*	*	*	*
Barbula sp.		*									
Campylopus bicolor						*					
Campylopus introflexus		*	*	*	*	*	*	*	*	*	*
Campylopus sp RJC 18080									*		
Ceratodon purpureus						*	*	*		*	
Dicranoloma diaphanoneum						*					*
Dicranoloma sp.			*					*	*		*
Fissidens tenellus		*					*	*		*	*
Fissidens sp.					*						
Funaria hygrometrica		*	*	*	*	*		*	*		*
Hypnum cupressiforme		*				*					
Racopilum cuspidigerum* var. *convolutaceus						*					*
Sematophyllum contiguum		*		*		*		*	*		*
Genus sp. RJC 17806					*						
Genus sp. (Emerald Moss)										*	
Liverworts (H)											
Anthoceros laevis		*	*			*	*			*	
Cephaloziella exiliflora		*	*	*	*	*	*	*		*	*
Chiloscyphus semiteres		*		*	*			*			*
***Fossombronia* sp. (leafy)**			*		*				*	*	
Fossombronia sp. (lettuce)			*			*	*			*	
Fossombronia sp. (purple lipped clam)			*								
Fossombronia sp. (salvinia)			*					*		*	*
Frullania sp.											*
Genus sp. RJC 18121										*	
Lichens (L)											
Buellia stellulata		*				*		*		*	
Calicium glaucellum		*			*						*
Calcium salicinum		*									
Calcium victorianum subsp. *Victorianum*		*									
Caloplaca ferruginea		*			*						
?Chaenotheca chlorella				*							
Cladia aggregata		*	*	*	*	*	*	*	*	*	*
Cladia schizopora		*		*	*	*	*	*	*	*	*
Cladonia cervicornis* var. *verticellata		*			*	*		*		*	
Cladonia ?chlorophaea		*			*						*
Cladonia crispata var. *cetrariiformis*					*		*				
Cladonia humilis var. *humilis*				*							
Cladonia kremplehuberi		*		*	*	*	*	*		*	*
Cladonia macilenta		*									
Cladonia aff. *Ochrochlora*											*
Cladonia ochrochlora											*
Cladonia ?praetermissa				*							
Cladonia ramulosa		*								*	*
Cladonia rigida		*		*	*	*	*				*
Cladonia aff. *rigida*											
Cladonia scabriuscula		*			*			*			

Cladonia ?southlandica				*						*
Cladonia sulcata		*	*	*	*		*			*
Cladonia tessellata	*				*	*	*		*	
Cladonia sp.	*									
Cladonia sp. RJC 17704			*							
Cladonia sp. RJC 18155										*
Cladonia sp. (fine)										*
Cladonia sp. (pipes)			*							
Diploschistes sp. (ant hill)		*								*
Diploschistes sp.		*								
Fuscidea cyathoides				*						
Graphis sp. (black beans)				*						
Graphis sp. (blackrays)	*		*	*		*	*		*	
Graphis sp. (black tram lines)								*		*
Graphis sp, (brown lips)				*	*					
Hypocenomyce australis	*			*	*					
Hypocenomyce foveata	*			*						
Hypocenomyce scalaris							*			
Hypocenomyce sp. (lead grey)	*						*			
Hypogymnia pulchrilobata										*
Hypogymnia pulverata					*					
Hypogymnia subphysodes var. *austerodioides*	*		*	*	*					
Hypogymnia subphysodes* var. *subphysodes	*		*	*	*		*		*	
Imshaigia aleurites					*					
?Lecidea sp. (black dots)			*	*						
?Lepraria sp.										*
Menegazzia platytrema	*						*		*	*
Neuropogon ?antarcticus	*			*						
Neuropogon ?subcapillaris									*	
Ochrolechia sp. GS (Kantavilas 306/92)	*	*	*	*	*	*	*		*	*
Ochrolechia sp. (buff doughnuts)										*
Ochrolechia sp. (cream doughnuts)								*		
Ochrolechia sp. (white pustules)	*									
Ochrolechia sp. (tan doughnuts)										*
Ochrolechia sp. (twiggy)	*			*	*				*	*
Ochrolechia sp. RJC 18056							*			
Pannaria sp. (grey flakes)				*						
Pannoparmelia wilsonii	*		*	*	*		*		*	*
Paraporpidia glauca	*			*	*	*	*	*	*	
Parmotrema cooperi				*						
Parmotrema praesorediosum	*									
Parmotrema tinctorum			*							
Peltigera didactyla		*								
Pertusaria ?pertusa			*							
Ramboldia stuartii	*		*	*	*	*	*	*	*	*
Rhizocarpon sp. (grey)	*			*			*	*		
Tephromelia atra	*			*	*					*
Thelotrema lepadinum	*									
Thysanothecium hookeri				*						*
Thysanothecium scutellatum	*		*	*	*	*	*	*	*	*
Trapeliopsis sp. (green grey chunks)			*							

Usnea inermis		*	*	*	*	*			*	*
Usnea oncodeoides			*	*					*	
Usnea pulvinata					*					*
Usnea aff. *rubicunda*	*									
Usnea scabrida subsp. *Scabrida*	*									
Usnea ?subalpine				*						
Usnea subeciliata	*				*		*			
***Xanthoparmelia* sp.**	*									
***Xanthoparmelia* sp. RJC 17992**					*					
Xylographa sp. (eye slits)				*						
Genus sp. (black chelsea buns)						*				
Genus sp. (black dots)							*			
Genus sp. (black freckels)					*	*				
Genus sp. (black ganglia)				*						
Genus sp. (black & tan dots)				*						
Genus sp. (black hairy stepping stones)				*					*	
Genus sp. (brown freckles)										
Genus sp. (brown papillae)				*						
Genus sp. (brown warts)	*						*			
Genus sp. (brown waxy dots)			*							
Genus sp. (green algae-like)				*						
Genus sp. (green flecks)			*	*		*				
Genus sp. (green powder)										*
Genus sp. (grey green)					*	*	*			
Genus sp. (green flecks ant hill)									*	
Genus sp. (grey flecks)						*				
Genus sp. (grey frosting)				*						
Genus sp. (grey powder)					*					*
Genus sp. (grey slick)	*									
Genus sp. (lead grey)									*	
Genus sp. (orange blobs)			*							
Genus sp. (orange powder)	*									
Genus sp. (pale yellow blobs)							*			
Genus sp. (pebbles)										*
Genus sp. (soot)						*				
Genus sp. (tan apo flake)						*				
Genus sp. (tan jelly caps)	*									
Genus sp. (white powder)										*
Genus sp. (yellow powdery blobs)			*							
Genus sp. RJC 17783				*						
Genus sp. RJC 17824		*								
Genus sp. RJC 17825		*								
Genus sp. RJC 17835										
Genus sp. RJC 17905	*									
Genus sp. RJC 17915	*									
Genus sp. RJC 17955						*				
Genus sp. RJC 18168										*
Genus sp. RJC 18169										*
Genus sp. RJC 18177										*

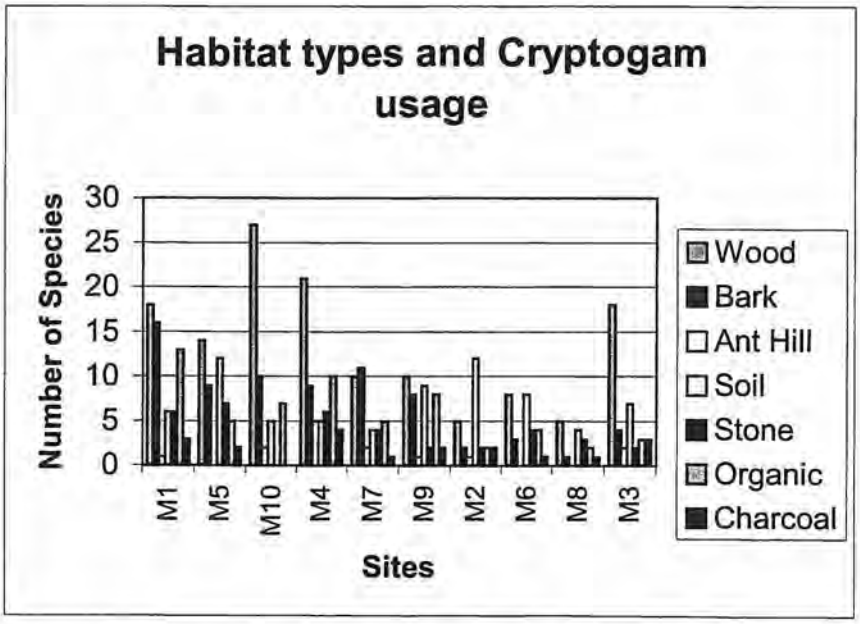
Note: The higher proportion of Genus sp. listed for the lichen section illustrates the degree of uncertainty that exists due to the limited available information.

Figure 1. Combined Cryptogam Groups, Occurrences per Grid.



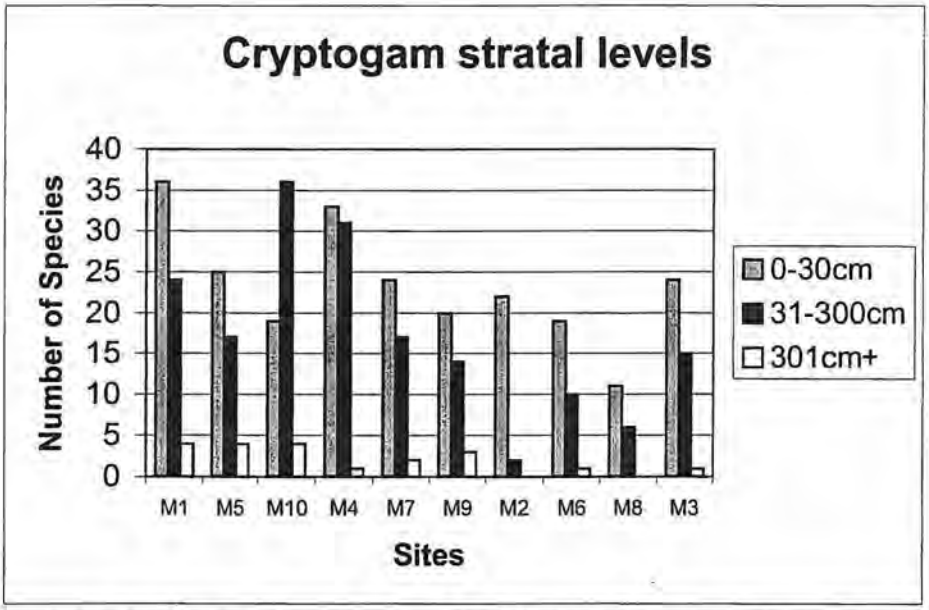
A decline in the number of species is evident with minimal changes between the control (M1, M5, M10) and the buffer (M4, M7,M9) grids. A decline is apparent in the gap grids (M2, M6, M8). The shelterwood grid (M3) shows minimal decline in species and is similar to the buffer grids. The decline in species numbers in all of the gap grids would appear to be the direct result of habitat loss or damage.

Figure 2. Available microhabitat types (substrates) and the number of cryptogams colonizing these substrates.



Preferred habitats used on all grids are 1 wood, 2 bark, 3 soil and 4 old organic materials, with other substrates not as readily colonized.

Figure 3. The occurrence of cryptogam groups and the number of species found at each stratal level.



This data indicate that the 0 - 30 cm level is preferred. M10 shows a greater preference for the shrub layer, and may reflect the observed densities of tree canopies, undergrowth and litter found on this grid.

Figure 4. Frequency and number of species of cryptogams occurring at each grid (300 m x 300 m).

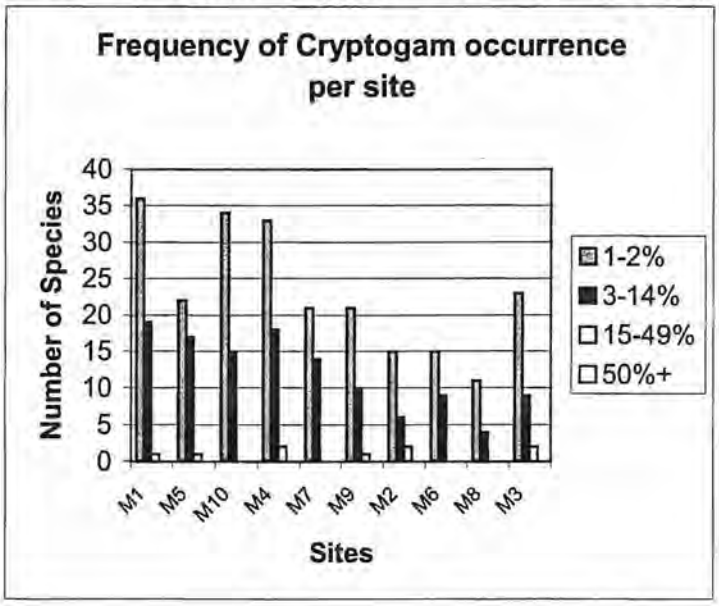
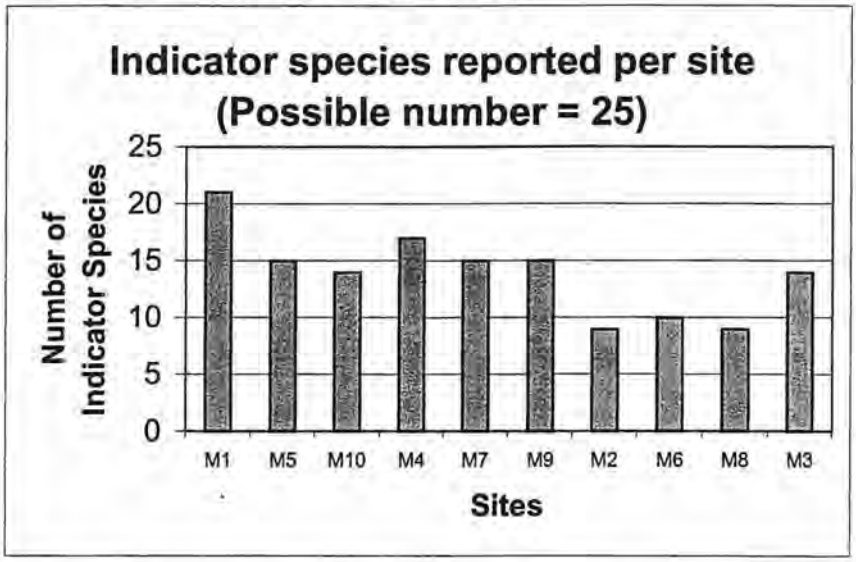


Figure 4 shows the percentage of total area per site occupied by the 3 cryptogam groups and the number of species involved. Although large number of species may be involved at each grid, the actual area occupied is only 1-2% of the total area available.

Figure 5. The number of Indicator Species located on each grid.



Indicator Species
The indicator species recommended in 2001 appeared to perform satisfactorily. It must be emphasized that this list of indicator species requires constant review as new site locations are established.

Conclusions
Although cryptogams are difficult to study and interpret in the field, the methods used proved simple and reliable.

Future Tasks
The limited available information and high degree of complex issues associated with cryptogams will necessitate the development of a backlog. It is envisaged that a portion of this material can be passed onto relevant experts for identification, though few experts are available. To address this problem I have provided phrase names for many of these unknown species that can be linked to a voucher with an exclusive Perth Herbarium identification bar code. This will facilitate future access to these samples via interrogation of Perth Herbarium databases and capture any name changes resulting from identifications supplied either by experts or from taxonomic revisions. By using phrase names it is possible to designate a specific species that can be cited in reports and publications.

It may be useful to prepare a field guide for nominated cryptogam indicator species, with illustrations and information to help recognize individual species in the field. It would also be desirable to prepare a photographic or scanned record of all cryptogam taxa identified in this initial FORESTCHECK survey and for any other sites in future surveys.

FOREST STRUCTURE AND REGENERATION STOCKING

Lachlan McCaw

Introduction

The adequacy of regeneration following harvesting and silvicultural treatment is one of the core indicators of Ecologically Sustainable Forest management (ESFM). The current framework of regional level indicators provides for assessment of the area and per cent of harvested area of native forest effectively regenerated (Indicator 2.1.g). This is recognised as a Category A indicator that can be reported upon immediately.

Regeneration outcomes have for a number of years been assessed as a matter of routine on at least a portion, and in some cases all, of the area of forest subject to harvesting. For uneven-aged forest stands, there is a need to consider the existing structure of the stand and whether sufficient sapling and advance growth is present to re-establish the stand following harvesting. Under the current silvicultural guidelines for Jarrah-Marri forest the decision as to whether the stand should be cut to gap or to a shelterwood is influenced by the density of existing lignotuberous advance growth.

Forest managers also require information about the rate of growth and species composition of stands so that future stand conditions can be projected over time. These attributes can affect the potential of forest stands to produce wood and other products, and to achieve ecological outcomes.

The objectives of this component of FORESTCHECK monitoring are therefore:

- to describe the stand structure, species composition and developmental stage of tree species present at FORESTCHECK grids, and
- to measure the contribution of mid-storey species to stand structure, density and basal area.

Fieldwork

Regeneration stocking was assessed using a sampling procedure based on triangular tessellation, similar to that applied operationally in the silvicultural guideline for Jarrah forest. The procedure used for FORESTCHECK embodies the changes that have been recommended in the current revision of the silvicultural guideline, currently in draft as Guideline 1/02 as it is expected that these will be implemented over the period of the next Forest Management Plan. Stand structure was assessed using conventional measurement techniques. Procedures are detailed in the attachment which forms an updated section for the FORESTCHECK Operating Plan. In stands cut to gap and shelterwood treatments, the height and species of regeneration was assessed at 4 locations on each grid to indicate the rate of regrowth.

Field procedures were developed and validated in May 2002, and data collected at the ten FORESTCHECK grids in Donnelly District in the period from mid-May to the end of June. A two-person team was able to complete 2 grids in a normal working day, and no particular difficulties arose during the field program. Field work is not suited to wet weather because of the need to record data and refer to calculation sheets.

The draft Operating Plan prepared in August 2001 indicated that litter depth and foliar nutrient content would be sampled in conjunction with regeneration and stand structure. Litter depth and loading have instead been incorporated in the sampling done for macrofungi, as litter forms a key substrate for fungi.

Data management

Two to three hours work are required to summarize the regeneration stocking assessment and process the stand structure data for each grid, resulting in 3 to 4 days work from the ten sites sampled this year. The design of fields for the database has been discussed with the FORESTCHECK Project Database Manager, and original paper copies of booking sheets compiled into a file record to be retained at Manjimup.

Regeneration stocking data are summarized onto a separate sheet before being entered onto the FORESTCHECK database. This sheet indicates the following key information:

- whether the grid meets current stocking standards,
- species composition,
- proportion of the grid affected by retained overwood (gap and shelterwood grids only),
- average density of saplings and ground coppice at points that meet the stocking standard.

Canopy cover is aggregated into a single value for each grid.

Stand structure information will be summarized in the form of basal area values for each species, and histograms showing stems per ha by size class for each species. This work is currently underway and will be finalized when the relevant section of the database has been finalized.

Key findings

Most grids were well stocked with sapling and ground coppice regeneration, and exceeded the current stocking standard for western jarrah forest (65 per cent stocked at 500 stems per ha of saplings, or 1000 stems per ha of ground coppice -/+ saplings). The most notable exception to this pattern was the Yornup control grid in mature forest, with only 16 per cent of sample points stocked with regeneration. This is likely to reflect unfavourable site characteristics that are apparent in the obvious laterite cap-rock occurrence and shallow soils at this location. The grid in the Coupe buffer at Carter block was only 56 per cent stocked with regeneration, and would therefore not, under current guidelines, be available for cutting to gap in the next cutting cycle.

All three grids in areas cut to gap were very well stocked with regeneration (>84 per cent).

Jarrah comprised at least 40 per cent of regeneration at all grids.

The Kingston shelterwood grid did not meet the regeneration stocking standard, and has a higher level of retained basal area than the 10 -15 m^2/ha recommended in Silviculture Guideline 1/95 which applied at the time of harvesting in Kingston block. Counts with a basal area prism (6 x factor) indicated that 84 per cent of sample points has a retained basal area of >12 m^2/ha which is regarded as excess overwood under the revised silvicultural guideline for Jarrah forest (1/02, in draft). Retained basal area measured on transects averaged 17.8 m^2/ha, with a range from 3 to 26 m^2/ha between individual 200 m^2 transects. The high level of retained overwood is likely to have restricted effective seedling regeneration.

Table 1. Regeneration stocking and species composition, and canopy cover for ten FORESTCHECK sampling grids established in May-June 2002

Grid	Treatment	Per cent stocked with regeneration	Species composition J/M/Yarri %	Per cent of grid affected by overwood	Canopy cover %
Kingston M1	Uncut control	92	59/41	[1]N/a	54
Kingston M2	Gap	84	50/50	8	53
Kingston M3	Shelterwood	52	38/62	84 (BA>12 m^2/ha)	41
Kingston M4	Coupe buffer	80	56/44	N/a	60
Yornup M5	Uncut control	16	66/34	N/a	49
Thornton M6	Gap	86	44/56	2	42
Thornton M7	Coupe buffer	82	57/43	N/a	62
Carter M8	Gap	98	48/52	6	10
Carter M9	Coupe buffer	56	70/28/2	N/a	51
Easter M10	Uncut control	98	47/53	N/a	69

1. Retained overwood is not assessed in uncut stands or Coupe buffer.

Discussion

There are obvious differences in regeneration stocking that can be attributed to site characteristics, and these need to be kept in mind when making comparisons between grids. The RFA vegetation mapping of Mattiske and Havel (1998) at 1:250 000 should provide a useful basis for stratification of sites and is currently being examined (Table 2). Two of the three uncut control grids established in this years program occur in quite different vegetation complexes to the gap and Coupe buffer grids with which they are grouped in the experimental design, as shown in Table 2. This reflects the practical problems associated with finding areas of uniform site type that reflect the full range of silvicultural treatment. Comparisons of attributes that are site-related and that vary over short distances, such as regeneration stocking, are likely to be most valid between paired gap and Coupe buffer grids.

Table 2. Allocation of FORESTCHECK sampling grids to vegetation complex based on interpolation from 1:250 000 mapping.

Grid	Treatment	Vegetation complex
Kingston M1	Uncut control	Corbalup 2
Kingston M2	Gap	Corbalup 2
Kingston M3	Shelterwood	Corbalup 2
Kingston M4	Coupe buffer	Corbalup 2
Yornup M5	Uncut control	Mattaband 1
Thornton M6	Gap	Corbalup 1
Thornton M7	Coupe buffer	Corbalup 1
Carter M8	Gap	Collis 1
Carter M9	Coupe buffer	Collis 1 & edge of Yanmah 2
Easter M10	Uncut control	Warren

FOLIAR AND SOIL NUTRIENTS

Lachie McCaw

Introduction

Foliar and soil nutrient sampling has not been completed, but has been programmed for spring 2002 and samples collected will then be submitted for processing at the Department's Kensington laboratory.

SOIL DISTURBANCE

Kim Whitford

Introduction

This report covers the 2001/2002 assessments of seven FORESTCHECK grids at Carter (gap and Coupe buffer), Thornton (gap and Coupe buffer) and Kingston (gap, shelterwood, and Coupe buffer) forest blocks. External controls were not used in this study as the variation in soil type across the landscape make these physically distant sites inappropriate as reference sites for bulk density measurements. In addition, there is no reason to suspect that disturbance on the treatment plots adjacent to the internal control plots (Coupe buffer) would alter soil physical properties on these internal control plots. Consequently, external controls are not required for the soil disturbance monitoring.

The objectives of this work were to:

1. Monitor the intensity and extent of changes to soil physical properties induced by logging.
2. Establish a database to examine the change in these properties over long time periods.
3. Examine the relationship between visual assessments of soil disturbance and soil compaction
4. Commence the establishment of a database that over time and across sites could enable the use of visual assessment as a surrogate for bulk density measurements.
5. Examine the relationship between visual assessment of soil disturbance and shear strength.
6. Examine the relationship between bulk density and soil shear strength.

Sampling issues encountered

I planned to stratify the sampling on the basis of soil disturbance classes (Rab 1989, Whitford 2001). This could only be attempted at the most recently logged site (Carter), as it is inappropriate for retrospective sites. Unfortunately the logging at Carter was not sufficiently recent for the signs of disturbance to be visibly clear. The assessment of the disturbance strata on this site was not of a high standard and consequently does not serve objectives 3, 4 and 5 well.

At the older retrospective grids sampling was stratified on the basis of operational categories (eg. landing, snig track, harvested area, etc). Though easier to identify than disturbance classes, these strata are of a lower quality and include greater variability than disturbance classes. On these older grids some snig tracks that were clear on old aerial photographs could not be identified on the ground. This failure to clearly identify some snig tracks lowers the quality of these operational category strata.

The sampling program was too ambitious. The collection of soil moisture measurements along with the shear strength measurements significantly increased the time required to collect this information. I underestimated the amount of time required for this. The intensive collection of this large number of bulk density sample was too physically demanding, and this work needs to be spread out over a greater time period, or amongst more people.

Sampling processing

No unforeseen problems occurred in sample processing. The costs of sample processing were correctly estimated. The dust extraction system installed was successful. My original proposal made greater use of Department staff. These staff were not available to assist and consequently more funds were spent on casual employees than was originally proposed.

Database establishment

There were no unforeseen problems in establishing the database.

Preliminary results

The grids and treatments assessed and measured are listed in Table 1. Table 2 gives the means and standard errors for bulk density, soil shear strength and gravel content of operational categories at seven

FORESTCHECK grids. As low numbers of measurements points occurred in some the snig track operational categories, Table 3 shows the means for combined snig track categories.

Visual assessment of disturbance classes was only possible the most recently logged site (Carter gap). This assessment is not appropriate at the retrospective sites where evidence of disturbance has changed over time.

At this stage sampling intensity appears to be adequate but the analysis needs to be completed before a definite conclusion is reached.

Table 1. The number of assessment points and sample or measurements collected at each FORESTCHECK grid. The disturbance classes and operational categories used are described in the FORESTCHECK operating plan.

Grid	Grid code	Disturbance class sample points	Operational category sample points	Shear strength sample points	Total bulk density sample points	Soil moisture samples
Kingston gap	M2		160	160	160	54
Kingston Shelterwood	M3		100	100	100	41
Kingston Coupe buffer	M4		40	40	40	14
Thorton Gap	M6		166	166	166	52
Thornton Coupe buffer	M7		40	40	40	14
Carter Gap	M8	338		152	152	51
Carter Coupe buffer	M9		40	40	40	14
TOTAL		**338**	**546**	**698**	**699**	**240**

Table 2. Bulk density, soil shear strength and gravel content of operational categories at seven FORESTCHECK grids.

Grid	Grid code	Operational category	n	Fine earth bulk density ($g\ cm^{-3}$)	SE	Gravel content (%)	SE	Shear strength (kPa)	SE	n
Kingston gap	M2	HA	68	0.798	0.023	32.0	2.4	446	24	67
		LL	20	1.123	0.037	22.4	2.8	1156	111	20
		OST	11	0.891	0.058	40.9	6.4	386	56	8
		ST0	3	1.173	0.055	12.1	2.1	824	196	3
		ST1	23	1.007	0.030	30.3	2.7	689	48	23
		ST2	30	0.935	0.040	32.5	4.7	625	38	27
		ST3	5	0.863	0.030	49.6	4.7	714	108	5
Kingston shelterwood	M3	HA	66	0.931	0.022	8.1	1.2	365	20	66
		LL	21	1.196	0.042	13.3	2.2	697	97	21
		ST1	4	0.864	0.049	19.5	5.0	1280	262	4
		ST2	9	1.100	0.045	11.7	3.3	685	112	9
Kingston Coupe buffer	M4	OST	1	1.156		9.6		490		1
		UA	39	0.925	0.022	9.8	2.9	347	21	39
Thorton gap	M6	HA	75	0.984	0.025	16.6	2.2	358	34	75
		LL	23	0.732	0.035	59.2	2.0	264	24	23
		ROAD	11	1.322	0.036	6.6	1.4	678	98	11
		ST0	7	1.205	0.025	58.9	2.5	1550	384	7
		ST1	4	1.019	0.004	22.3	0.3	775	111	4
		ST2	34	1.167	0.028	8.9	2.0	401	46	33
		ST3	12	1.144	0.053	4.1	2.4	427	47	12
Thorton Coupe buffer	M7	UA	40	0.756	0.036	46.8	3.1	306	17	38
Carter gap	M8	HA	137	0.795	0.013	35.4	1.3	383	18	137
		LL	5	0.932	0.082	29.5	3.6	628	62	5
		ST1	1	1.053		24.2		1098		1
		ST2	5	0.904	0.078	38.6	10.5	698	118	5
		ST3	4	0.959	0.124	36.5	4.3	310	53	4
Carter Coupe buffer	M9	UA	40	0.777	0.025	54.8	2.2	243	13	40

Table 3. Mean bulk density, soil shear strength and gravel content of operational categories at seven FORESTCHECK grids. Operational categories ST0 and ST1 have been grouped as category ST01, and categories ST2 and ST3 have been grouped as category ST23.

Grid	Grid code	Operational category	n	Fine earth bulk density ($g\ cm^{-3}$)	SE	Gravel content (%)	SE	Shear strength (kPa)	SE	n
Kingston gap	M2	HA	69	0.803	0.023	31.8	2.4	450	24	68
		LL	20	1.123	0.037	22.4	2.8	1156	111	20
		OST	11	0.891	0.058	49.0	6.4	386	56	11
		ST01	23	1.027	0.032	26.2	2.3	721	52	23
		ST23	37	0.926	0.033	36.2	4.1	632	34	34
Kingston shelterwood	M3	HA	66	0.931	0.022	8.1	1.2	365	20	66
		LL	21	1.196	0.042	13.3	2.2	697	97	21
		ST01	4	0.902	0.064	18.0	5.4	1393	248	4
		ST23	9	1.083	0.051	12.3	3.4	635	72	9
Kingston Coupe buffer	M4	OST	1	1.156		9.6		490		1
		UA	39	0.925	0.022	9.8	2.9	347	21	39
Thorton gap	M6	HA	75	0.984	0.025	16.6	2.2	358	34	75
		LL	23	0.732	0.035	59.2	2.0	264	24	23
		ROAD	11	1.322	0.036	6.6	1.4	678	98	11
		ST01	7	1.205	0.025	58.9	2.5	1550	384	7
		ST23	50	1.150	0.023	8.8	1.6	438	37	50
Thorton Coupe buffer	M7	UA	40	0.756	0.036	46.8	3.1	306	17	38
Carter gap	M8	HA	137	0.795	0.013	35.4	1.3	383	18	137
		LL	5	0.932	0.082	29.5	3.6	628	62	5
		ST1	1	1.053		24.2		1098		1
		ST2	5	0.904	0.078	38.6	10.5	698	118	5
		ST3	4	0.959	0.124	36.5	4.3	310	53	4
Carter Coupe buffer	M9	UA	40	0.777	0.025	54.8	2.2	243	13	40

Table 4. Mean bulk density, soil shear strength and gravel content of disturbance classes at the Carter site.

Site	Grid code	Soil disturbance class	n	Fine earth bulk density ($g\ cm^{-3}$)	SE	Gravel content (%)	SE	Shear strength (kPa)	SE
Carter gap	M8	D0	77	0.787	0.015	0.342	0.016	367	19
		D1	23	0.818	0.044	0.277	0.033	407	38
		D2	26	0.850	0.035	0.374	0.033	451	42
		D3	26	0.826	0.033	0.429	0.028	463	70
Carter Coupe buffer	M9	D0	40	0.777	0.025	0.548	0.022	243	13

Table 5. The total area of the fallers block, the area of snig tracks and landings identified at each FORESTCHECK grid, and the proportion of the block area that has been disturbed by snig tracks and landings. Snig track classes are first order (ST1), second order (ST2), third order (ST3), old snig track from a previous logging that has been reused (OST) and an old road that has been reused as a snig track. Snig track area calculations are based on measurements of snig track lengths and assumed widths of 4.90m for ST0, 4.67 for ST1, 4.46 for ST2, and 4.13 for ST3.

Grid	Grid code	ST1 (m^2)	ST2 (m^2)	ST3 (m^2)	OST (m^2)	Old Road (m^2)	Total snig track area (m^2)	Landing area (m^2)	Block area (m^2)	Proportion of block disturbed
Kingston Shelterwood	M3	1538	1635	318			3491	941		
Kingston gap	M2	2739	5251	1217	454		9662	1410		
Thorton gap west	M6	1663	2582	1605		1562	7412	1792		
Thorton gap east		1566	1998	182			3745	1942		
Thorton gap total		3229	4580	1787		1562	11158	3734	133,773	0.111

Bulk density and shear strength observation discussion points

- The results reaffirm that fine earth bulk density is a more meaningful measure of soil disturbance than total bulk density. The total bulk density at Carter Coupe buffer is higher than the total bulk density for harvest area (HA) at Carter gap. This is not the case for fine earth bulk density highlighting the reasons for using fine earth bulk density.
- The use of reference sites for comparisons of soil impacts is problematic as the undisturbed soil at the reference site can have higher bulk density than disturbed soil on a logged site.
- The Kingston Coupe buffer site seems to provide a good reference site.
- It makes more sense to use the undisturbed harvested area as a reference rather than the Coupe buffer, even though the HA will have some increase in bulk density due to disturbance.
- The bulk density on the log landings (LL) is highly variable because the landings have been ripped.

Relationship between bulk density, and shear strength and soil moisture

Several regressions were developed to examine the relationship between soil shear strength and bulk density. Additional variables included in this analysis were soil gravel content, and soil moisture content at the time of the shear strength measurement.

Regression relationships

1. Strength = -71.879 + 84.756*FEBD + 53.361*Gravel% + 128.748*Moisture content $r^2 = 0.224$ n = 234
2. FEBD = 1.149 + 0.00234*Strength - 0.571*Gravel% - 0.892*Moisture content $r^2 = 0.482$ n = 234
3. FEBD = 0.937 + 0.002197*Strength + 0.6087*Moisture content $r^2 = 0.152$ n = 234
4. TBD = 1.168 + 0.00239*Strength + 0.471*Gravel% - 1.127*Moisture content $r^2 = 0.467$ n = 234
5. TBD = 1.343 + 0.00251*Strength - 1.360*Moisture content
   $r^2 = 0.301$ n = 234

Equations 2 and 4 are the only regressions with reasonable r^2. These relate bulk density to shear strength and moisture content. However the r^2 of these relationships indicates that they would provide poor predictions of bulk density. I conclude that shear strength cannot provide worthwhile estimates of soil bulk density.

Comparison of sampling methods used

I attempted to identify sampling strata and stratify the sampling in a single survey operation. There were some problems in doing this. This resulted in some strata being over sampled and other strata being under sampled. This was a relatively minor problem. There were inefficiencies in the system I used to identify the sampling strata and in stratifying and labelling the sample points. I am not sure how to improve this, as other methods would be less efficient.

As noted previously the visual assessment of soil disturbance needs to occur soon after logging has finished, and is not well suited to sites where a post logging treatment is applied. Even the most recently logged site (Carter gap) was too old for visual assessment to be of a high standard.

Future tasks

Data entry and summary is complete. The areas of the Kingston gap and shelterwood treatments need to be determined to complete Table 5.

Discussion

Stratification

- The description and measurement of soil disturbance across a logging site requires the grouping of measurement points into identifiable strata with common intensity of disturbance.
- Soil disturbance classes are best determined a short time after completion of logging. The required delay of 2 to 3 years between logging and vegetation assessment on Forestcheck sites makes the use of disturbance classes inappropriate for this monitoring system.
- Operational classes are distinguished more readily than disturbance classes for a longer period after logging. However post logging treatments can obscure these classes. At the Carter gap treatments the post logging machine disturbance and fire made identification of operational classes impossible.
- Operational categories were difficult to distinguish at all sites.
- Few snig tracks could be identified on the Kingston shelterwood treatment. Consequently bulk density and shear strength were measured at regularly spaced grid points rather than at points of known operational categories on the grid.

Shear strength

Fine earth bulk density could be related to shear strength gravel content and soil moisture. However the r^2 was low indicating that FEBD predicted in this manner would have large errors associated with it. In addition this predictive model required soil moisture and gravel content which are difficult and expensive to collect. The necessity of determining these values reduces the efficiency of using shear strength measurements to an extent that the more expensive but considerably more meaningful bulk density measurements are cost effective.

- Shear strength measurements were clearly effected by gravel (particularly large and angular gravel) and plant roots in the soil. This necessitated repeated measures at most measurement locations and the rejection of unusually high values. This repeated measurements and the judgement required to identify erroneous measurements lower the value of shear strength measurements.
- All of these factors indicate that these shear strength measurements have limited value for long term monitoring of soil disturbance in gravely soils.

Conclusions

- The extent of soil disturbance cannot be readily determined on retrospective sites or recently logged sites that have experienced post harvest silvicultural treatments and/or fire.
- The intensity of soil disturbance cannot be successfully determined from visual assessment on retrospective sites or recently logged sites that have experienced post harvest silvicultural treatments and/or fire.
- On retrospective sites, operational categories are best identified when good quality aerial photography collected a short time after the completion of logging is available, and no post harvest soil disturbance, such as machine knock down, has occurred.
- Soil shear strength is unlikely to provide meaningful information on the long term changes in soil condition because of the influence of soil moisture and the effect of gravel and roots in the soil.
- The design of FORESTCHECK, which is intended to accommodate a wide variety of monitoring exercises, is unsuited to monitoring the extent of soil disturbance. This is best done shortly after the completion of logging operations.
- Similar the intensity of disturbance from logging operations is best determined shortly after the completion of logging operations.
- Soil disturbance monitoring within FORESTCHECK is best confined to measurements of bulk density at known locations with clearly identified operational categories or disturbance classes that could be used to determine the changes in the intensity of disturbance over time at representative sites.

MACROFUNGI, COARSE WOODY DEBRIS, AND LEAF LITTER DEBRIS

Richard Robinson and Bob Smith

Introduction

Fungi are considered some of the most important forest organisms in terms of both biodiversity and forest function. Soil, litter and wood inhabiting fungi play major roles in decomposition and nutrient cycling. Mycorrhizal fungi enhance nutrient uptake of plants and may enhance plant resistance to some pathogens. In addition, underground truffle-like fungi are an important food source for small mammals, especially following disturbance such as fire.

Species richness has a close relationship with habitat structure. Coarse woody debris and litter are not only vital as substrates for fungi and many invertebrates but also as refugia for larger invertebrates, reptiles and mammals. Many organisms rely on a habitat mosaic for development and persistence when confronted with disturbance and for recolonization following disturbance. Litter cover and the recovery of this cover following disturbance such as logging and regeneration burning is also important in the maintenance of soil moisture regimes.

Research on fungi in Western Australia's southern forests is in its infancy. Knowledge on fungal diversity and the ecological roles that fungi play and the maintenance and/or recovery of a diverse habitat for both ground dwelling organisms and as substrates for nutrient enhancing organisms is of vital importance to forest managers making decisions on sustainable forest management.

The objective of this component of the FORESTCHECK program was to:

1. Monitor and record the species of macrofungi in the various treatments of managed jarrah forest (gap, shelterwood, coupe buffer) and in uncut forest. Trends in species composition, richness and abundance and substrate utilization will be analysed over time.
2. Measure and record the amount of litter, small wood and twigs (SWT) and coarse woody debris (CWD) on the ground in the various treatments of managed jarrah forest (gap, shelterwood, coupe buffer) and in uncut forest. Trends within and between the treatments will be analysed over time.

Field and Lab Work 2001/2002

Litter and CWD assessment was carried out from Feb-April and the SWT assessment in July 2002.

Macrofungi transects were installed at all sites during Feb - April 2002. Assessment of all the sites was carried out in June 2002. Voucher specimens have been processed and where possible identified. An overall species list and one for each individual site has been determined.

Weather disrupted and significantly increased the time period over which the macrofungal assessment was done. Normally light rain is not too disruptive but during June frequent heavy rain was encountered. In addition to difficulties in recording data and negotiating often-difficult terrain (logs, discarded tops etc), voucher specimens deteriorate rapidly if collected wet.

In total, 314 voucher specimens were collected representing 170 species. Processing had to be completed almost immediately as they deteriorate rapidly. This proved to be a more time consuming task than anticipated as the vast majority of species had not been encountered previously and detailed descriptions were necessary to validate their identity.

Data Management

All fungi data have been entered onto a Microsoft Excel worksheet. Species diversity and abundance at each site and a frequency rating of 1 (rare) to 8 (very common) for each species at each site has been

determined. The data includes a complete list of 192 species recorded across all the sites, their life modes (mycorrhizal, saprotrophic, parasitic) and the substrate on which they were fruiting. Analysis is ongoing.

The litter, small wood and twigs (SWT) and CWD data have been entered onto a Microsoft Excel worksheet. Litter and SWT loads (t ha^{-1}) and CWD volumes (m^3 ha^{-1}) have been calculated for each site.

Key Findings

1. Macrofungi

A total of 192 species of macrofungi were recorded across all the sites. Preliminary analysis shows that there were no obvious differences in species diversity between the treatments, but the abundance in the gap treatment appears to be higher (Fig. 1). Species diversity and abundance on the Kingston gap treatment, however, does appear to be higher than the same treatment at Thornton and Carter.

Species composition at each site has not yet been investigated. This may have some bearing on the higher abundance in the gap treatments. Field observation suggests that within these treatments there was a higher number of wood decay species, such as *Calocera* sp., *Gymnopilus* spp. and *Pholoiota* spp., which tend to fruit in high numbers. These species may also reflect the state of decay of the wood on these sites as they appear to be early colonisers of wood and are not found in such large numbers on well-rotted wood. Some species may also prefer burnt wood.

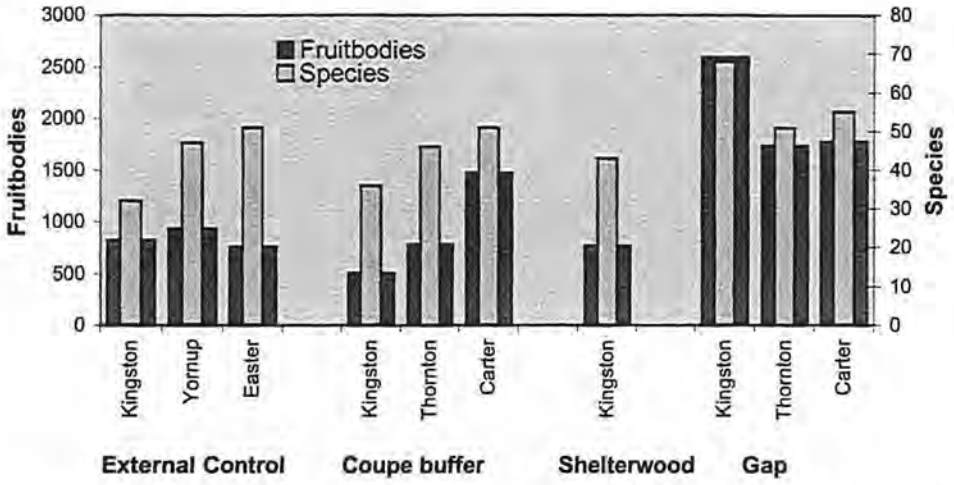


Figure 1. Macrofungi species diversity and abundance at each FORESTCHECK site in June 2002.

2. Litter, Small Wood and Twigs (SWT) and Coarse Woody Debris (CWD)

Litter loads on all sites ranged from 2.1 t ha^{-1} to 10.2 t ha^{-1} (Fig.2), and generally reflect the ages of the various treatments. The uncut control at Easter is an old growth site and has the greatest accumulation of litter, while the gap at Carter has only recently been cut and burnt and has the lowest litter load. The coupe buffer treatments have similar litter loads to those on the uncut controls. Litter is rapidly accumulating on the older gap treatments at Kingston and Thornton.

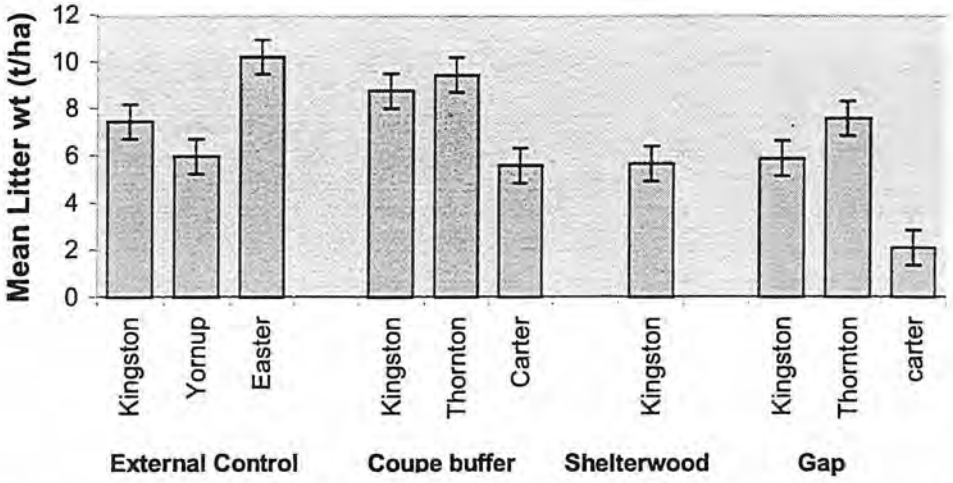


Figure 2. The mean litter loads (t ha^{-1}) calculated at each FORESTCHECK grid in April 2002.

As was the case with the litter, the SWT loads generally reflected the age of the forest within the treatments (Fig. 3). Loads ranged from 2.0 t ha^{-1} to 11.1 t ha^{-1}, with the heaviest load on the old growth site at Easter and the lowest loading on the gap at Thornton. Coupe buffers have similar loads to those on the uncut controls. This component of the ground cover is very variable, as indicated by the large standard errors.

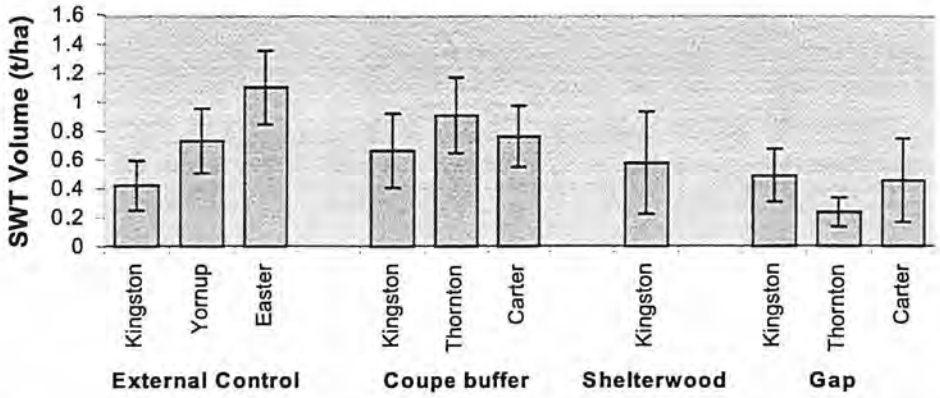


Figure 3. The weight (t ha^{-1}) of SWT measured at each FORESTCHECK site in July 2002.

The greatest volume of CWD was measured at the Thornton gap site (Fig. 4). This may be due to the fact that one end of this transect was close to the road where logs and debris had been pushed into heaps. Generally, however, all treatment sites had volumes of CWD within the range of that found on the uncut control sites, about 110-300 m^3 ha^{-1}. The quality or state of decay was not assessed, but observation suggests that the wood on the gap and shelterwood sites was more solid that that generally found on the uncut controls.

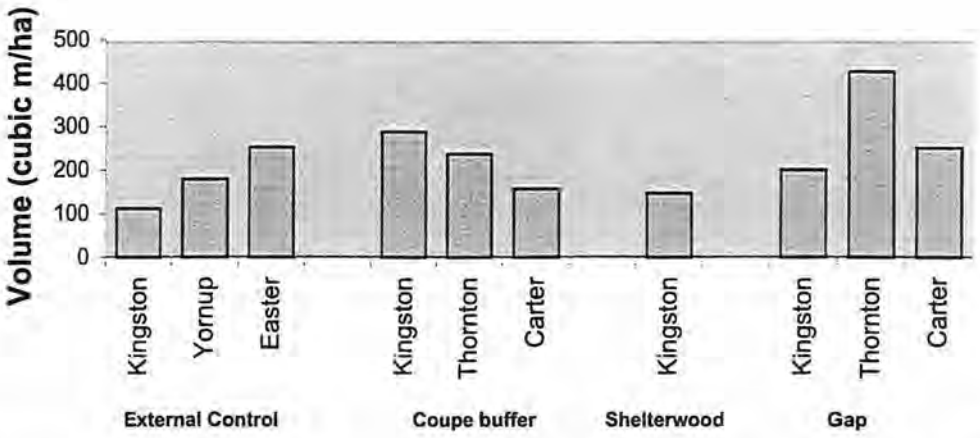


Figure 4. The volume (m^3 ha^{-1}) of CWD measured at each FORESTCHECK grid in April 2002.

Further analysis will examine the relationship between litter loads and CWD volumes and the composition of the fungal community found in each treatment. Data pertaining to litter and CWD can also be incorporated in the analyses of the data collected by other FORESTCHECK teams.

Indicator Species Approach

At present we do not have sufficient of knowledge of the fungal flora present in WA forests or the roles that individual species play in ecosystem function that would enable an indicator species approach to be taken for monitoring. Also, it is especially difficult to take this approach with fungi. The only practical method of recording fungi is on the presence of fruit bodies, and many species do not produce fruit bodies regularly. Therefore the absence of fruit bodies does not indicate the absence of the fungus. For now, at least, the more appropriate approach to monitoring fungi is to record diversity.

Modification to Methods, Difficulties

The position of transects was modified from the original proposal. Due to site constraints in several of the treatments, transects were surveyed at 60 m either side of the centre line instead of 90 m as stated in the original proposal. Each transect was divided into 4 sectors (0-50, 50-100, 100-150 and 150-200 m) on which the fungi species frequency rating (1-8) was based.

Originally 3 visits to each grid to collect fungal data were proposed on a fortnightly basis. This proved to be very ambitious. The amount of data collected, voucher collection and processing and species identification all proved to be an enormous amount of work. Inclement weather often halted field work but it also made available the extra time needed to process voucher collections. A maximum of 2 grids could only be completed in one day, followed by a full day to process voucher collections. This resulted in taking 3 weeks to do a single circuit of all 10 grids. However, it appears that the timing of assessment coincided with the peak of the fruiting season, resulting in a large number of species being recorded.

Litter SWT and CWD measurements went smoothly. The measurement of small wood and twigs (10-25 mm diam.) on each grid has been added to the operating plan.

Appendix 1. List of fungal species recorded in FORESTCHECK survey, June 2002.

Sp #'	Species
46	Agaric "creamy white"
115	Agaric "orange frosty"
82	Agaric "Lepiota-like, cream-grey"
156	Agaric "light brown - red scales on stem"
18	Agaric "light brown-olive"
12	Agaric "olive"
76	Agaric "orange with brick red scales/white gills"
97	Agaric "pure white"
174	Agaric "red/yellow/red"
170	Agaric "yellow brown-moist"
23	Agaric ?*Clitocybe*
71	*Agaricus* sp. "small - flat- red stain"
38	*Agaricus* sp. "small"
33	*Agaricus* sp. "yellow stainer"
39	*Agaricus* sp. "large cap, purplish scales"
120	*Aleuria rhenana*
114	*Amanita* sp. "apricot-pink margin"
186	*Amanita* sp. "grey-brown"
45	*Amanita* sp. "white, deeply rooted"
28	*Amanita* sp. "white, stout"
6	*Amanita xanthocephala*
35	*Amanita xanthocephala* forma *macalpiniana*
180	*Armillaria luteobubalina*
188	*Austroboletus laccunosa*
103	*Boletellus obscurecoccineus*
93	*Boletus ananiceps*
29	*Boletus* sp. "dull maroon"
49	*Boletus* sp. "red pores and stem"
95	*Boletus* sp. "small yellow/cream pores"
99	*Boletus* sp. "yellow-red, stains blue"
9	*Calocera* sp. "yellow"
140	*Clavaria* sp. "pink-buff coral"
81	*Clavulina* sp. "grey-brown"
14	*Clitocybe* sp.
181	*Collybia* aff. *butracea*
143	*Collybia* sp. "buff funnel"
151	*Collybia* sp. "large"
15	*Coltricia oblectans*
32	*Coprinus* sp.
128	*Coprinus* sp. "basal hairs"
147	*Cortinarius* (*Dermocybe*) *austroveneta*
34	*Cortinarius (Dermocybe)* sp. "olive-yellow gills"
168	*Cortinarius* (*Dermocybe*) sp. "brown with mustard yellow gills"
40	*Cortinarius (Dermocybe)* sp ."chestnut"
110	*Cortinarius* (*Dermocybe*) sp. "red orange"
146	*Cortinarius* (*Myxacium*) sp. "orange-brown"
125	*Cortinarius (Phlegmacium)* sp. "purple-grey"
158	*Cortinarius* aff. *micro archerii*
173	*Cortinarius basirubescens*

172	*Cortinarius* sp. "banded stem"
73	*Cortinarius* sp. "brown with purplish tints"
68	*Cortinarius* sp. "brown" ?(34)
154	*Cortinarius* sp. "chestnut"
57	*Cortinarius* sp. "dark brown/lemon-yellow gills"
7	*Cortinarius* sp. "rooting stem"
121	*Cortinarius* sp. "slender brown"
131	*Cortinarius* sp. "slender lilac"
124	*Cortinarius* sp. "yellow-olive"
184	*Cortinarius* spp. (unidentified)
171	*Cortinarius vinaceolamellatus*
22	*Crepidotus* sp. "dark brown"
118	*Crepidotus* sp. "large creamy-tan"
83	*Crepidotus* sp. "on marri stag"
61	*Crepidotus* sp. "small brown"
21	*Crepidotus* sp. "small white"
148	*Crucibulum laeve*
138	*Daldina concentrica*
187	*Dictyoporus* sp.
123	*Discomycete* "yellow stalked"
31	*Entoloma* (*Leptonia*) *sp.* "blue-black"
153	*Entoloma* (*Leptonia*) sp. "small dark grey-brown"
30	*Entoloma* sp. "creamy white"
167	*Entoloma* sp. "dark grey - blue gill edge"
25	*Entoloma* sp. "grey-brown - blue stem"
77	*Entoloma* sp. "grey-brown - brown stem"
135	*Entoloma* sp. "tall, grey-brown"
78	*Entoloma/Leptonia* "grey - decurrent gills"
159	*Exidia glandulosus*
41	*Fistulina hepatica*
91	*Fistulinella mollis*
11	*Galerina* sp. "hanging gills" and "conic"
111	*Galerina* sp. "large"
58	*Galerina* sp. "small cap, eccentric stipe - on wood"
42	*Galerina* sp. "small on bark"
8	*Gymnopilus austrosapineus*
43	*Gymnopilus* sp.
105	*Gymnopilus* sp. "chestnut scales, forked gills"
26	*Gymnopilus* sp. "reddish cap, orange gills"
85	*Gymnopilus* sp. "slender"
117	*Hebeloma* sp.?
56	*Heterotexus peziziformis*
132	Hydnoid crust "light yellow"
100	*Hypholoma australe*
59	*Hypholoma brunneum*
108	*Hypomyces chrysospermus*
1	*Incoybe australiensis*
20	*Incoybe* sp. "scaly cap" see sp. 277 Fire Fungi
53	*Incybe* sp. "tan skirt"
137	*Inocybe* sp. "creamy-brown"
48	*Inocybe* sp. "grey"
65	*Inocybe* sp. "large scaly cap"
113	*Inocybe* sp. "radially fibrillose, pink stem"

169	*Inocybe* sp. "shaggy stem"
162	*Inocybe* sp. "small light brown, fibrillose"
74	*Laccaria* aff. *masonii*
36	*Laccaria lateritia*
142	*Lactarius eucalypti*
185	*Lepiota cristata*
166	*Lepiota* sp. "creamy-brown"
24	*Lycoperdon* sp.
190	*Macrolepiota konradii*
55	*Marasmius crinis-equi*
183	*Marasmius elegans*
191	*Marasmius* sp. "white umbrella"
75	*Marasmius* sp. "large brown, on Zamia stems"
101	*Merulius* sp."pink-buff"
50	*Mycena* aff. *rorida*
134	*Mycena* aff. *subcapillaris*
44	*Mycena* aff. *subgallericulata*
66	*Mycena pura*
144	*Mycena sanguinolenta*
163	*Mycena* sp. "brown-grey, on wood"
51	*Mycena* sp. "buff umbrella"
80	*Mycena* sp. "ginger foot"
27	*Mycena* sp. "long stem"
165	*Mycena* sp. "small grey - bleach"
88	*Mycena* sp. "tiny white with decurrent gills"
64	*Mycena* sp. "tiny white, on twigs"
182	*Mycena* spp. (unidentified)
164	*Nidula candida*
112	*Omphalina chromacea*
122	*Omphalina* sp. "orange in moss - on log"
127	*Omphalina*sp. "flesh-brown"
130	Orange parasite on white resupinate polypore (sp.116)
104	*Panellus ligulatus*
179	*Paxillus* sp. "yellow, brown scales"
126	*Peziza* sp ."small khaki cup"
37	*Phellinus* sp.
136	*Phellinus* sp. "resupinate"
70	*Phellodon niger*
87	*Phellodon* sp. "brown, white margin"
160	*Pholiota highlandensis*
119	*Pholiota multicingulata*
192	*Plectania* sp. "black"
133	*Pluteus attromarginata*
47	*Pluteus lutescens*
4	*Pluteus* sp. "brown velvet"
157	*Podoserpula pusio*
13	Polypore "brown with white margin"
3	Polypore "long white shelf"
116	Polypore "white resupinate"
145	*Poronia ericii*
155	*Protubera canescens*
17	*Psathyrella* sp.
98	*Psathyrella* sp. "very tall, slender"

177	*Psilocybe coprophila*
129	*Pulvinula* sp.
176	*Pycnoporus coccineus*
52	*Ramaria* aff. *aurea* "yellow, flat tops"
102	*Ramaria ochroceosalmonicolor*
139	*Ramaria* sp. "lemon-yellow"
86	*Ramaria* sp. "orange-red, yellow stem"
72	*Ramaria* sp. "purple-pink"
79	*Resupinatus* sp. "grey with light margin"
69	*Russula adusta*
89	*Russula clelandii* group
90	*Russula* multicolor (aff. *cyanothanxa)*
92	*Russula neerimea*
178	*Russula persanguinea* (white stem)
107	*Russula* sp. "grey-white"
10	*Russula* sp. "white/white/white"
150	*Scutellina* aff. *margaritacea*
106	Slimy white marri nuts
62	*Stereum hirsutum*
84	*Stereum* sp. "black, hirsute, purplish hymenium"
141	*Stereum* sp. "chocolate borwn"
152	*Stereum* sp. "chocolate brown with cream underside"
149	*Stereum* sp. "dark brown - yellowish margin"
5	*Stereum* sp. "grey-brown white hirsute, purple fertile layer"
109	*Stereum* sp. "purpureum"
67	*Stropharia semiglobata*
94	Thelephore "shelved hydnoid"
16	Thelephore "translucent funnels"
19	*Trametes lilacino-gilva*
63	*Trametes versicolor* (brown or grey)
60	*Tremella mesentericia*
161	*Tricholoma* sp. "grey-white"
96	*Tricholoma* sp.? "beige slimy cap'
54	*Tricoloma eucalypticum*
189	*Tubaria rufofulva*
2	*Xerula australis*
175	*Xylaria hypoxylon*

DATA MANAGEMENT AND STORAGE

Amanda Mellican

Introduction
The group is responsible for entering the collected data into electronic format for Macro Vertebrates, Birds, Nocturnal Birds, Mammals, Reptiles and Amphibians, Plants and Cryptogams, and the collected specimens (Flora, Cryptogams and Fungi), and obtaining the electronic data from the remaining groups.

Data Entry
An Excel program applying Visual Basic was developed for each of the survey sheets. There are two parts in the program; Data entry and Data correction. The aim is to save time and to reduce typing errors during the data entry process.

As an example, in the Trapping Field Data Sheet, there are 12 fields for the data entry (Location, Treatment, Personnel, Date, Trap point, Species, Weight, Tag #1, Tag #2, Sex, Breeding condition and Comments). Places of location, names of treatment, names of personnel and gender are known and they are created as drop-down lists. As for the species, common names were pre-listed in the program. Date as in Day, Month and Year (from 2001 to 2010) was also created as drop down lists. Thus, location, treatment and personnel are only entered once for all the records for a particular data sheet. If there was nothing to comment on, then the program will automatically record in the Comments section as "No comment". If any one of the fields is missing or left it as blank, an error message is given and the data would not be inserted into the data file until the fields are selected or filled. Species code, scientific name and common name are also automatically recorded into the data file depending upon the selected common species. Record number is automatically written into the data file.

To date, all survey sheets except cryptogams were completed by Verna Tunsell. Only M8, M9 and M10 grids were left to complete. The Metadata form as shown in Appendix A is also completed.

Currently, I am writing two data entry programs for the Forest Structure group and am completing one of the programs. The electronic data for Invertebrates has been received. Data from the remaining groups will be received in a short time.

Data Validation
As soon as the programs for Forest Structure are finalized, I will validate the data for all the groups that we are responsible for. The validation date will be recorded in the metadata form. Then, a DESCRIPTIONS file (which indicates the lists of an individual field, and codes and descriptions of an individual field), and the validated DATA file will be sent to the leader of each group.

Data Storage
All the individual sampling data will be saved and backed up as individual files on the network drive. The data are saved and secured since the network drive is backed up at COB everyday. The final version of the validated data will be printed and kept in a filing cabinet and eventually archived with the library at the completion of the project.

Collected Specimens
Of the 781 flora and cryptogam specimens collected during the period, all of the flora specimens have been identified, prepared and lodged at the Herbarium. The cryptogams collected from two sites have also been prepared and have been lodged. The remaining sites have been prepared and are ready for databasing. The fungi are still progressing as these are later collections.
The specimens that have been lodged at the Herbarium have been databased on the "Max" system and submitted electronically. Max is used as the primary means of submitting specimen information to the

Herbarium. There are many facets to Max but the main ones relevant to FORESTCHECK are the collection book, specimen tables and reporting facilities. (Examples are illustrated in Appendices B, C and D).

Mosses are washed prior to drying to remove debris, Cryptogams are dried. All friable specimens are stabilized with emulsion. Specimens are placed on a card with adhesive to keep them together. The specimens are then secured in cardboard boxes to prevent damage. Fungi specimens are also dried wrapped in paper and placed into zip lock bags. Those small enough are then placed in similar boxes to cryptogams. Larger specimens remain unboxed. Flora specimens are pressed and dried, then mounted, with specialized herbarium tape, on card, and placed in separate folders.

All these specimens then have levels and barcodes attached. Each specimen is allocated its own barcode so that each is unique and is readily located by electronic means or by physical means as required.

Appendix A. Example of Metadata Form.

Group Name →

Leader →

Contact Officer →

No	File Name	File Size (KB)	File Type	Date (completed)	Name of Data Entry Person	Validated Date

Appendix B. Example of Flora labels generated by Max.

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Persoonia longifolia R.Br.

Proteaceae

Identified by:

Erect to compact perennial shrub, height to 2.6 m, width to 1.7 m; fruiting only. State Forest; plain; brown to black clay. Frequent. Forest with associated Corymbia calophylla, Eucalyptus marginata, Persoonia longifolia.

Loc.: North Boundary Road, 1 km N of Kingston Road, Winnejup Forest Block,

Lat. 34° 4' 3"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield, B.G. Ward. 1 **Date:** 08/10/2001

Voucher: FORESTCHECK

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Macrozamia riedlei (Gaudich.)C.A.Gardner

Zamiaceae

Identified by:

Erect open to compact perennial cycad, height to 1 m, width to 1.5 m; some in fruit. State Forest; plain; brown black clay. Frequent. Forest with associated Corymbia calophylla, Eucalyptus marginata, Persoonia longifolia.

Loc.: North Boundary Road, 1 km N of Kingston Road Winnejup Forest Block,

Lat. 34° 4' 3"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield, B.G. Ward. 3 **Date:** 08/10/2001

Voucher: FORESTCHECK

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Rhodanthe citrina (Benth.)Paul G.Wilson

Asteraceae

Identified by:

Erect annual herb, height to 7 cm, width to 0.5 cm; flowers yellow; shallow tap root. State Forest; plain; brown to black clay. Locally abundant. Forest with associated Corymbia calophylla, Eucalyptus marginata, Persoonia longifolia.

Loc.: North Boundary Road, 1 km N of Kingston Road, Winnejup Forest Block,

Lat. 34° 4' 3"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield, B.G. Ward. 2 **Date:** 08/10/2001

Voucher: FORESTCHECK

WESTERN AUSTRALIAN HERBARIUM, PERT
Flora of Western Australia

Caladenia flava R.Br. subsp. ***flava***

Orchidaceae

Identified by:

Erect open dwarf shrub, height to 30 cm, width to 20 c flowers yellow; modified root system. State Forest; pla brown to black clay. Frequent. Forest with associated Corymbia calophylla, Eucalyptus marginata, Persoonia longifolia. Population flowering: 30%.

Loc.: North Boundary Road, 1 km N of Kingston Roa Winnejup Forest Block,

Lat. 34° 4' 3"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield, B.G. Ward. 4 **Date:** 08/10/2001

Voucher: FORESTCHECK

Appendix C. Example of Cryptogam labels generated by Max.

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Hypogymnia subphysodes var. ***austerodioides***

Hypogymniaceae

Identified by: R.J. Cranfield 23/05/2002

Lichen: active growth phase; grey with black lower surface, tan fruiting bodies present; growing in sheltered wet positions on dead wood in ground layer (0cm - 30 cm) and shrub layer (31 cm-3 m). Plain running east to west with 1° slope; bare to littered gravelly, cryptogamic moist brown to black clay over laterite with 5% outcropping, and a litter depth of 3 cm comprising, new old and decomposed litter. Frequent on occasional sites. Forest with five stratal layer and associated Eucalyptus marginata, Corymbia calophylla, Persoonia longifolia and Banksia grandis with a few weed species present..

Loc.: Winnejup Forest Block, North Boundary Road, 1 km N of Kingston Road,

Lat. 34° 4' 30"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield and K. Knight 17852 **Date:** 15/05/2002

Voucher: Forestcheck Monitoring Program.

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Cladonia ? macilenta

Cladoniaceae

Identified by: R.J. Cranfield 23/05/2002

Lichen: active growth phase; tan fruiting bodies present; growing in sheltered wet positions on dead wood in shrub layer (31 cm-3 m).
Chemistry: Cortex K+ yellow, C-, KC-. Plain running east to west with 1° slope; bare to littered gravelly, cryptogamic moist brown to black clay over laterite with 5% outcropping, and a litter depth of 3 cm comprising, new old and decomposed litter. Occasional on isolated sites. Forest with five stratal layer and associated Eucalyptus marginata, Corymbia calophylla, Persoonia longifolia and Banksia grandis with a few weed species present..

Loc.: Winnejup Forest Block, North Boundary Road, 1 km N of Kingston Road,

Lat. 34° 4' 30"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield and K. Knight 17854 **Date:** 15/05/2002

Voucher: Forestcheck Monitoring Program.

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Hypogymnia subphysodes var. ***subphysodes***

Hypogymniaceae

Identified by: R.J. Cranfield 23/05/2002

Lichen: active growth phase; grey with black lower surface; growing in sheltered wet positions on live and dead bark of Leucopogon capitellatus in shrub layer (31 cm-3 m). Plain running east to west with 1° slope; bare to littered gravelly, cryptogamic moist brown to black clay over laterite with 5% outcropping, and a litter depth of 3 cm comprising, new old and decomposed litter. Frequent on occasional sites. Forest with five stratal layer and associated Eucalyptus marginata, Corymbia calophylla, Persoonia longifolia and Banksia grandis with a few weed species present..

Loc.: Winnejup Forest Block, North Boundary Road, 1 km N of Kingston Road,

Lat. 34° 4' 30"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield and K. Knight 17853 **Date:** 15/05/2002

Voucher: Forestcheck Monitoring Program.

WESTERN AUSTRALIAN HERBARIUM, PERTH
Flora of Western Australia

Thysanothecium scuttellatum

Cladoniaceae

Identified by: R.J. Cranfield 23/05/2002

Lichen: active growth phase; tan fruiting bodies present; growing in sheltered wet positions on charred dead wood in ground layer (0 cm-30 cm). Plain running east to west with 1° slope; bare to littered gravelly, cryptogamic moist brown to black clay over laterite with 5% outcropping, and a litter depth of 3 cm comprising, new old and decomposed litter. Frequent on occasional sites. Forest with five stratal layer and associated Eucalyptus marginata, Corymbia calophylla, Persoonia longifolia and Banksia grandis with a few weed species present..

Loc.: Winnejup Forest Block, North Boundary Road, 1 km N of Kingston Road,

Lat. 34° 4' 30"S **Long.** 116° 19' 34"E (WGS84)

Coll. R.J. Cranfield and K. Knight 17855 **Date:** 15/05/2002

Voucher: Forestcheck Monitoring Program.

Appendix D. Example of specimen table generated in Max.

Forestcheck Vegetation LFR

Taxon Name	TaxonID	SpCode	Lifeform	Fire Reponse
		HYDSP.	AH	A1
		CALSP.	G	B3
Acacia alata	3207	ACAALA	S	A1
Acacia browniana	3247	ACABRO	S	A1
Acacia dentifera	3294	ACADEN	S	A1
Acacia divergens	3307	ACADIV	S	A1
Acacia drummondii	3311	ACADRU	S	A1
Acacia extensa	3331	ACAEXT	S	A1
Acacia myrtifolia	3453	ACAMYR	S	A1
Acacia pulchella	3502	ACAPUL	S	A1
Acacia stenoptera	3557	ACASTE	S	A1
* *Acaena echinata*	3184	ACAECH	DS	A1
Adenanthos obovatus	1791	ADEOBO	S	B2
Agonis flexuosa	5316	AGOFLE	T	U
Agonis parviceps	5324	AGOPAR	S	B2
* *Aira cupaniana*	185	AIRCUP	AGR	A1
Amperea ericoides	4585	AMPERI	DS	B2
Amphipogon amphipogonoides	194	AMPAMP	DS	B2
* *Anagallis arvensis* var. *arvensis*	19404	ANAARV	AHW	A1
* *Anagallis arvensis* var. *caerulea*	19405	ANAARV	AHW	A1
Andersonia caerulea	6306	ANDCAE	DS	A1
Anigozanthos flavidus	1407	ANIFLA	S	B3
* *Arctotheca calendula*	7838	ARCCAL	AHW	A3
Astroloma ciliatum	6323	ASTCIL	DS	B2
Astroloma drummondii	6325	ASTDRU	DS	B2
Astroloma pallidum	6334	ASTPAL	DS	B2
Austrodanthonia caespitosa	17950	AUSCAE	GR	B3
Austrostipa campylachne	17233	AUSCAM	GR	B3
Banksia grandis	1819	BANGRA	T	A2
Billardiera floribunda	3157	BILFLO	V	A1
Billardiera variifolia	3165	BILVAR	V	A1
Boronia crenulata	4413	BORCRE	DS	B2
Boronia megastigma	4428	BORMEG	S	A1
Boronia spathulata	4441	BORSPA	S	B2
Bossiaea aquifolium subsp. *laidlawiana*	14397	BOSAQU	S	A1
Bossiaea linophylla	3713	BOSLIN	S	A1
Bossiaea ornata	3714	BOSORN	S	B2
* *Briza minor*	245	BRIMIN	GRW	A1
Burchardia umbellata	1387	BURUMB	G	B3
Caesia micrantha	1276	CAEMIC	G	B3
Caladenia flava subsp. *flava*	15348	CALFLAF	G	B3
Caladenia reptans subsp. *reptans*	15377	CALREP	G	B3
Callistachys lanceolata	10861	CALLAN	S	A1
Cassytha racemosa	2957	CASRAC	P	A1
* *Centaurium erythraea*	6539	CENERY	AHW	A1
Centrolepis aristata	1121	CENARI		
Centrolepis drummondiana	1125	CENDRU	AH	A1
* *Cerastium glomeratum*	2889	CERGLO	AHW	A1
Chamaescilla corymbosa	1280	CHACOR	G	B3
Chorizema nanum	12765	CHONAN	DS	A1
Chorizema rhombeum	3761	CHORHO	DS	A1
Clematis pubescens	2929	CLEPUB	V	A1
Comesperma calymega	4550	COMCAL	DS	B2

* = Alien species

Example of Flora File Report generated in Max.

22/07/2002 **Forestcheck Flora Nos 1 - 50** 1

COLLECT_NO	FAMILY	GENUS	SPECIES	INFSP_TYPE	INFSP_NAME
1	Proteaceae	Persoonia	longifolia		
2	Asteraceae	Rhodanthe	citrina		
3	Zamiaceae	Macrozamia	riedlei		
4	Orchidaceae	Caladenia	flava	subsp.	flava
5	Papilionaceae	Hardenbergia	comptoniana		
6	Ranunculaceae	Clematis	pubescens		
7	Droseraceae	Drosera	pallida		
8	Dilleniaceae	Hibbertia	amplexicaulis		
9	Dilleniaceae	Hibbertia	commutata		
10	Epacridaceae	Leucopogon	capitellatus		
11	Papilionaceae	Isotropis	cuneifolia		
12	Poaceae	Briza	minor		
13	Epacridaceae	Leucopogon	verticillatus		
14	Asteraceae	Craspedia	variabilis		
15	Oxalidaceae	Oxalis	comiculata		
16	Rosaceae	Acaena	echinata		
17	Asteraceae	Lagenophora	huegelii		
18	Ranunculaceae	Ranunculus	colonorum		
19	Apiaceae	Platysace	tenuissima		
20	Epacridaceae	Astroloma	pallidum		
21	Euphorbiaceae	Poranthera	huegelii		
22	Myrtaceae	Hypocalymma	angustifolium		
23	Epacridaceae	Leucopogon	propinquus		
24	Myrtaceae	Agonis	parviceps		
25	Anthericaceae	Chamaescilla	corymbosa		
26	Orchidaceae	Pterostylis	pyramidalis		
27	Orchidaceae	Caladenia	reptans	subsp.	reptans
28	Euphorbiaceae	Amperea	ericoides		
29	Papilionaceae	Chorizema	nanum		
30	Tremandraceae	Tetratheca	affinis		
31	Gentianaceae	Centaurium	erythraea		
32	Dasypogonaceae	Lomandra	integra		
33	Colchicaceae	Burchardia	umbellata		
34	Juncaceae	Luzula	meridionalis		
35	Euphorbiaceae	Phyllanthus	calycinus		
36	Dennstaedtiaceae	Pteridium	esculentum		
37	Rubiaceae	Opercularia	hispidula		
38	Asteraceae	Senecio	hispidulus		
39	Myrtaceae	Eucalyptus	marginata		
40	Orchidaceae	Caladenia	macrostylis		
41	Proteaceae	Banksia	grandis		
42	Proteaceae	Hakea	amplexicaulis		
43	Dasypogonaceae	Lomandra	caespitosa		
44	Crassulaceae	Crassula	decumbens		
45	Euphorbiaceae	Poranthera	microphylla		
46	Caryophyllaceae	Cerastium	glomeratum		
47	Anthericaceae	Sowerbaea	laxiflora		
48	Proteaceae	Hakea	oleifolia		
49	Asteraceae	Millotia	tenuifolia		
50	Poaceae	Austrostipa	elegantissima		

Example of Cryptogam File Report generated in Max

* = Alien species

31/05/2002 M1 Cryptogams 1

COLLECT_NO	FAMILY	GENUS	SPECIES	INFSP_TYPE	INFSP_NAME
17850	Parmeliaceae	Xanthoparmelia	sp.		
17849	Fungi	Genus	sp.(fungi)		
17851	Fungi	Genus	sp.(fungi)		
17852	Hypogymniaceae	Hypogymnia	subphysodes	var.	austerodioides
17853	Hypogymniaceae	Hypogymnia	subphysodes	var.	subphysodes
17854	Cladoniaceae	Cladonia	macilenta		
17855	Cladoniaceae	Thysanothecium	scuttellatum		
17856	Cladoniaceae	Cladonia	scabriuscula		
17857	Cladoniaceae	Cladonia	rigida		
17858	Cladiaceae	Cladia	aggregata		
17859	Cladoniaceae	Cladonia	chlorophaea		
17860	Cladoniaceae	Cladonia	ramulosa		
17861	Cladoniaceae	Cladonia	ramulosa		
17862	Cladoniaceae	Cladonia	krempelhuberi		
17863	Cladoniaceae	Cladonia	sp.		
17864	Parmeliaceae	Pannoparmelia	wilsonii		
17865	Cladoniaceae	Cladonia	tessellata		
17866	Cladoniaceae	Cladonia	cervicornis	var.	verticillata
17867	Cladoniaceae	Cladonia	scabriuscula		
17868	Cladoniaceae	Cladonia	krempelhuberi		
17869	Cladoniaceae	Cladonia	krempelhuberi		
17869A	Cladoniaceae	Cladonia	krempelhuberi		
17870A	Cladoniaceae	Cladonia	krempelhuberi		
17870	Cladoniaceae	Cladonia	krempelhuberi		
17871	Parmeliaceae	Parmotrema	praesorediosum		
17872	Cladoniaceae	Cladonia	krempelhuberi		
17873	Usneaceae	Usnea	subciliata		
17874	Usneaceae	Neuropogon	antarcticus		
17875	Usneaceae	Usnea	scabrida	subsp.	scabrida
17876	Usneaceae	Usnea	rubicunda		
17877	Algae	Genus	sp		
17878	Hypogymniaceae	Menegazzia	platytrema		
17879	Pertusariaceae	Ochrolechia	sp.(twiggy)		
17880	Cladoniaceae	Cladonia	rigida		
17881	Lichen	Genus	sp.(orange powder)		
17882	Teloschistaceae	Caloplaca	ferruginea		
17883	Parmeliaceae	Xanthoparmelia	sp.		
17884	Algae	Genus	sp.		
17885	Phyllopsoraceae	Hypocenomyce	sp.(lead grey)		
17885A	Lichen	Genus	sp.(RJC 14485A)		
17886	Phyllopsoraceae	Hypocenomyce	sp.(lead grey)		
17887	Pertusariaceae	Ochrolechia	sp. G.S.		
17888	Caliciaceae	Calicium	glaucellum		
17889	Cladiaceae	Cladia	schizopora		
17890	Lichen	Genus	sp.(brown warts)		
17891	Caliciaceae	Calicium	glaucellum		
17892	Caliciaceae	Calicium	salicinum		
17893	Graphidaceae	Graphis	sp.(Blackrays RJC		
17894	Cladiaceae	Cladia	schizopora		
17895	Algae	Genus	sp.		
17896	Algae	Genus	sp.		
17896	Algae	Genus	sp.		

APPENDIX 18

Recommended changes to the Silvicultural Guidelines for Jarrah Forest. Report to the Department of Conservation and Land Management by consultant F J Bradshaw

Recommended changes to the Silvicultural Guidelines for Jarrah Forest

F.J. Bradshaw September 2001

These recommendations follow those already made for karri and wandoo on 22 August 2001.

These recommended changes to silvicultural guidelines have been made on the basis of comments and recommendations from staff of the Department of Conservation and Land Management, the Forest Products Commission and my own experience and observations. They have taken account of views expressed by the EPA and of the intent of the Ministerial Conditions and the recommendations of the Burrows committee dealing with Ministerial Condition 11. They also take account of the research findings of the Kingston study.

The recommendations presented here have been discussed with Alan Seymour of the Forest Products Commission, Martin Rayner, Lachlan McCaw and Peter Keppel of the Department of Conservation and Land Management. The opportunity has also been taken to discuss various aspects of jarrah silviculture during a two-day field inspection with Simon Murphy and Dr Rob Campbell of the Centre for Forest Tree Technology, Victoria.

Comments on the various concerns or recommendations that have been made by the EPA, the Burrows committee regarding Ministerial Condition 11, and Dr Christine Sharp are included at the end of these recommendations.

Habitat

Most of the changes required to habitat tree retention which have been recommended as a result of the Kingston study have been incorporated into the draft Silviculture guideline 1/99 and will come through to the new guidelines. Some refinement of the characteristics of preferred habitat trees is required, based on the Kingston study results. Change is required to the senescence scale used in the Guideline (an early research scale) to the present research scale to avoid confusion. Pattern of retention should allow for both small groups and isolated trees with preference for groups in southern forest with heavy post logging debris. The objective of this is to facilitate their protection during the post logging burn. The retention of smaller trees has been recommended to provide 'ladders' for these trees. This can be made more explicit in the silvicultural guidelines.

In addition to the specified hollow log retention rate, it is recommended that all other 'natural' hollow logs be retained. These are relatively rare and are not expected to have any adverse impact on Simcoa operations.

Increase habitat tree retention rate to 6 trees/ha to cater for the presence of both brushtail and ringtail possums. This should be applied to all areas at least until more information becomes available on the original distribution of ringtail possums.

Fire intensity in regeneration release

Review the current prescription for regeneration release burning and specify fuel removal objectives with a view to reducing the intensity of the fire that is being applied to many of these coupes. The object is to reduce the impact on retained trees (particularly habitat trees) and reduce the potential impact on understorey and lignotubers.

Harvesting of dieback and non-protectable forest

I recommend retaining the essential elements of Specification 4/89 (i.e. the retention of 15 m^2/ha of trees with healthy crowns to limit the potential increase in soil moisture) and extend it to the southern region. The exception to this is on sites of low impact where regeneration

release cutting could proceed if the regeneration was of predominantly resistant species. These low impact and resistant sites are still being evaluated but it is expected that they will be based on the vegetation complexes with some refinement. To ensure that there is a consistency of interpretation of these sites, they should be identified on the dieback maps provided prior to harvesting.

Specification 4/89 - Regeneration in forest affected by *Phytophthora cinnamomi*

This specification was originally developed in response to the establishment of the Simcoa dry firewood operation. The intent was to use some of the revenue from this operation to rehabilitate dieback areas from which dry firewood was being extracted. However an examination of dieback sites that followed indicated that most sites were reasonably stocked with marri lignotubers (albeit developing slowly) and other resistant understorey; and that severe disturbance of the site to establish other species was likely to remove more regeneration than it replaced. The exceptions to this were the concreted laterite sites where successful establishment of trees in the short term required massive and expensive disturbance to the site of the type trialed by Alcoa near Jarrahdale, with little likelihood of success.

To my knowledge this specification has never been applied and I recommend that it be excluded from the new guidelines. Should a specific need arise, then a site-specific prescription can be developed as required. Research into the value of fertiliser application to existing lignotuber stock in dieback sites might be a more promising avenue to pursue, with the object of speeding up the development of a cover of resistant trees, at least to woodland density

Cull removal in gaps

I recommend a shift in emphasis from the pushing of cull jarrah to the removal of stems (up to 25 or 30cm dbh) by coppicing. The object of this in gaps is to reduce the loss of some advanced growth that occurs when saplings and small poles are pushed out rather than broken off, and to make use of the faster growth rate and better form of coppice, especially in marri dominant regrowth. It would also reduce unnecessary site disturbance with its impact on understorey species. Gap pushing should be retained as an option, but its use should be more limited. The increased cost is acknowledged but the reduced level of harvest will make it more feasible to achieve coppicing than it has been to date. The existing supplementary guidelines for cull pushing should be incorporated in the new guidelines.

Guidelines for scrub rolling should be included to minimise the loss of saplings and lignotubers prior to harvesting.

Shelterwood treatment

There are several areas relating to shelterwood treatment that should be revised.

Marri dominant regeneration. In the southern jarrah/marri forest in the high rainfall zone on podsolic soils, the lignotuber pool in jarrah forest is frequently dominated by marri, even where the overstorey has a high jarrah component. As a result of this the next generation of forest will inevitably have a high initial marri component regardless of how or when the forest is cut.

The present guideline requires cutting to shelterwood where the proportion of jarrah in the ground coppice pool is less than 20%. The objective is to increase the jarrah component by retaining a seed source of jarrah and promoting establishment of seedlings. However, if seedling jarrah did become established, it would not become part of the next generation because it would be out-competed by more advanced marri. It would remain as part of the lignotuber pool and may become moribund before it ever has the chance to be released. A more positive and effective approach is to harvest such an area to a gap and supplement the

ground coppice regeneration with planted jarrah. Planted jarrah has a good prospect of maintaining a place in the next generation of regrowth and can be favoured in later thinning treatments. A side effect of this change is a reduction in the area cut to shelterwood in the high rainfall southern jarrah forest, and a consequent small reduction in the annual area that is cutover.

Disturbance for regeneration establishment. The present guideline calls for site disturbance:

- In areas with dense root stock understorey (such as ti-tree) where disturbance should am to remove swathes of understorey covering about 30-50% of the area. Removal of understorey and soil disturbance is essential if regeneration is to become established. Those site types that are characterised by a low stocking of jarrah overstorey and a dense understorey of rootstock species are withheld form cutting (Strelein types R, B, F, A, Havel types A, G, J, B and McCutcheon type 6). Most of these are now contained within reserved Diverse Ecotype Zones.

- Where banksia and sheoak are inhibiting regeneration establishment, the guideline calls for 80% of the unmarked banksia and *sheoak* to be pushed (some of these individuals or groups are marked for retention). This is aimed at a deliberate temporary reduction in the abundance of these understorey species in order to establish jarrah regeneration and allow it to develop along with the regeneration of the understorey species. Jarrah will not become established or develop beyond ground coppice under these species, and periodic recruitment to the lignotuber pool after fire does not occur once they (banksia and sheoak) have become dominant. Unlike jarrah, *Banksia grandis* recruitment will continue in the absence of fire. For the most part the dominance of banksia and sheoak is a response to earlier harvesting which was done in the absence of sufficient jarrah ground coppice present to out-compete the understorey. The same requirements for removal of rootstock thickets, banksia and sheoak apply where planting is intended, though the need for soil disturbance is less critical.

  Some sheoak stands are a reflection of natural site selection and development. Where there is an absence of stumps in such stands they should be explicitly excluded from shelterwood treatment.

- Site disturbance to be carried out only under dry soils conditions, with a preference for the use of wheeled machines except in areas of dense ti-tree.

It is therefore recommended that the new guidelines retain the present provisions for removal of competing understorey in the western forest. The recommendations below will reduce the need for site disturbance in the eastern forest.

Use of planted stock. The treatment of shelterwood areas requires site disturbance, followed immediately after by burning in a seed year while the seedbed is still receptive. Successful regeneration in recent years has only been achieved by autumn burns, probably because of reduced invertebrate gathering. Managing the coincidence of burning, seed source and site preparation is extremely difficult, made particularly so because of restrictions on smoke over Perth. By far the best opportunity for regeneration is the first event after harvesting and once this chance is missed it becomes progressively more difficult to achieve as competition becomes more established. There would therefore be advantages in minimising the area cut to shelterwood and the dependence on seed for regeneration.

In the wetter southern forest, recent experience suggests that planting into gaps will result in the rapid development of saplings and it is recommended that this option be provided for where stocking levels are marginally below acceptable levels.

On harsher sites it should be expected that planted stems may need to be regularly burnt off or coppiced to encourage root development and better form and for this reason planting

should only be used under shelterwood until field evidence suggests that they are capable of normal development.

Removal of commercial products from shelterwood areas. The primary purpose of shelterwood is the retention of a seed source and the retention of a forest cover for water, wildlife and aesthetic values during the extended period of regeneration establishment. This is likely to be a minimum period of twenty years between seedling and dynamic ground coppice assuming that satisfactory regeneration is established in the first regeneration event. This is unlikely to occur in the drier forest in particular and several regeneration events may be required to build the lignotuber pool, and in these areas a 50-year establishment period may be more realistic if seedling regeneration is required. This uncertainty in the timing of future yield is serious problem for yield prediction and uncertainty is exacerbated by the increasing restrictions on the extremely limited opportunities for burning for regeneration establishment.

With a retention rate of 6 large habitat trees and 6-8 potential habitat constituting a retained basal area of about 4.5 m^2/ha, it would not be possible on many sites to retain an additional economic volume of sawlogs and at the same time reduce the basal area to a level that would allow seedling regeneration to develop.

It is therefore recommended that in areas that require shelterwood treatment, all of the commercial products be removed in the first operation, retaining non-commercial trees (most of them habitat trees) for seed source and 'shelter'. Commercial trees would need to be retained if they were necessary to retain the necessary basal area or representation of jarrah in the seed source. This approach would reduce the area cutover to shelterwood and reduce the total area cutover; remove the timing constraint on about half of the yield from these stands; increase the certainty of about 25% of the future yield; have no adverse impact on the sustained yield; have no adverse impact on water and wildlife values; reduce the number of entries into the forest but with no increase in harvest intensity. It is unlikely to have any adverse impact on the quality of the seed for regeneration since most of the variation in tree quality is related to past fire damage.

Silvicultural practice in eastern jarrah woodlands

The existing condition of the eastern jarrah woodlands does not readily lend itself to the standard silvicultural practices. Although the same principles apply, their condition and place in the landscape suggests a different approach, especially in relation to stocking standards.

These forests are characterised by widely spaced trees and a uniform cover of low herbaceous understorey. Regeneration is patchy and usually very sparse in lightly cut areas. In areas that have been more heavily cut in the past, regeneration can be prolific in parts mostly from the release of scattered regeneration or from coppice. They contain a relatively high proportion of non-sawlog trees. These areas more or less coincide with the Ecological Vegetation System Vp1, Vp2, Ip3 – Semi arid to peri-arid lateritic uplands with less than about 800mm rainfall or Vegetation Complexes Y5, Y6, D4. Associated slopes of jarrah/wandoo (*EVS* W11, W12 or *VC* Pn, Ck) are similar though usually of poorer quality. These areas have been harvested in the past to varying intensity for sleepers, sawlogs and charcoal logs. Their maximum original density (and current density) is in the order of 15 m^2/ha but can be up to 20 m^2/ ha in some areas.

Under the present standards, a shelterwood operation would be indicated for a high proportion of the area. However in many areas the commercial operation would not remove sufficient density to facilitate seedling regeneration and seedling survival is very low given the competition and the harsh climate. Natural development of these stands suggests that a stocking standard for regeneration that is more compatible with the woodland structure should be adopted and greater attention given to coppicing.

I recommend that the following system be adopted for these areas:

- Cut to remove all marketable trees to a minimum basal area of 6 m^2/ha including suitable habitat trees. In most areas this would result in a very patchy harvest of

individual trees or small groups though in some areas it would be more extensive. A pre-harvest regeneration survey is not required. Following harvesting:

- Survey the area impacted by harvesting and assess regrowth only in areas with <10 m^2/ha remaining. In these areas, adequate stocking is represented by 65% stocked at the rate of 120 spha of saplings and poles to 25cm dbh or 250 spha of ground coppice (specific limits are yet to be confirmed).
- In areas that do not meet the stocking standard, remove competing banksia and sheoak and burn in autumn in a seed year.
- In patches impacted by harvesting and standing at <10 m^2/ha, coppice any poor formed saplings or small poles (to 25cm dbh). The object is to produce 120 spha of good-formed regeneration. Remove culls between 25-50 cm dbh to 6 m^2/ha.
- In areas carrying >10 m^2/ha, no further follow-up treatment is required.
- Coppicing as part of the harvesting contract should be encouraged.

Regeneration survey and stocking standards

The following recommendations are made:

- Attempt to write the instructions for karri and jarrah to be identical wherever possible
- Amend the pre-harvest recording of existing structure to indicate samples within thinnable stands (no regeneration or regeneration count required)
- Amend the post harvest recording to indicate plots within shelterwood areas that are within heavy overstorey and therefore not expected to regenerate.
- Amend recording to incorporate larger stems that can contribute to regeneration.
- Amend recording to be compatible with direct SILREC input.
- Maintain the existing stocking standards except for the variations mentioned above.

Fire damage

Include a section on operational response to damage of regrowth by fire similar to that for karri

2nd order catchments

Include a section outlining a method of managing the retention of 30% of the catchment above 15 m^2/ha to avoid accidental encroachment.

Response to issues raised by the EPA

The following concerns about jarrah silvicultural practice were drawn from Bulletin 912 of the EPA.

Poor regeneration of jarrah on some soil types. Jarrah regenerates from seed, developing through a seedling phase to form lignotubers. Once lignotubers have developed sufficiently they are capable of rapid development into saplings and trees. Most seedlings die in their first year and under most circumstances the lignotuber pool is developed over many regeneration events. Some sites have a very small lignotuber pool. This is due to the excessive competition from other components of the site. These situations relate to a combination of overstorey and understorey competition, soil type, nutrient status and rainfall. Low lignotuber stocking is not confined to any particular soil type. It most commonly occurs in virgin forest, with dense root stock competition on sands or podsols and in lower rainfall areas.

On these sites it is necessary to take steps to establish regeneration, before it can be released to grow into saplings. This is the purpose of shelterwood harvesting which has been explained in detail in the response to the Codd report. It does not represent a failure of regeneration, but a different technique for a particular situation. Shelterwood is both appropriate and conservative and ensures that the overstorey is not removed till the regeneration has reached an appropriate stage of development. The present guideline provides for the exclusion from harvesting of those areas where excessive disturbance is required to establish regeneration. The guidelines provide for monitoring its development. Shelterwood is the most commonly used silvicultural system in temperate hardwood forests around the world

Marri dominance in the regeneration. Jarrah reaches its best and purest development on the well-drained laterite in the high rainfall area. This is most common in the forests north of the Blackwood River. This landform continues south but is confined mainly to the area on either side of the Donnelly River. The majority of the remaining southern forest occurs on podsols and much of it is on the transition zone between jarrah and karri. These forests are typically mixed forests with varying proportions of jarrah and marri. In these forests it is the norm for the lignotuber pool to be predominantly marri as a natural phenomena. Under these circumstances it is inevitable that the sapling regeneration will be predominantly marri, regardless of the timing or the intensity of harvest. Under natural conditions the shift towards jarrah is almost certainly in response to the greater fire sensitivity of marri. Under managed conditions the opportunity exists to shift the balance towards jarrah by thinning, if it is necessary or if it is desirable. However it is unrealistic to expect these jarrah/marri forests to have the same yield of jarrah as pure jarrah forests. The natural dynamics of these stands must be accepted and appropriate adjustments made to the yield expectations.

Debris remaining after logging. Apart from the maintenance of sufficient woody debris for wildlife values it is desirable to minimise the debris left by logging. While small diameter material is removed by the post logging fire, large material remains more or less intact. Any improvement in utilisation will improve this situation but by far the greatest impact is made by the presence of a residue using industry. Debris as a result of culling can be minimised by notching standing trees, though this can have an adverse short-term aesthetic impact. Post harvest culling is restricted to <12 m^2/ha to prevent excessive debris or waste of potentially useful wood fibre. Although the EPA has recommended that additional resources be applied to culling in these areas, I would recommend that the above limit be retained in the guidelines and that these trees be left standing until a residue using industry can be established. EPA endorsement of the value of residue using industries would be useful in this context.

Lack of post harvest treatment. To my knowledge there has been no difficulty in recent years in funding the necessary post harvest treatment though there has been considerable difficulty in achieving the necessary silvicultural burning because of concerns over smoke

over Perth. The recommendations made above will alleviate some of this problem by reducing the area of jarrah requiring burning in a seed year. Post harvest silvicultural treatment is reported in the Annual Reports of the Department of Conservation and Land Management.

Stump coppice in regeneration areas. Stump coppice is not included in the assessment of adequacy of regeneration. Most large-stump coppice will fall off the stumps in a few years. That which survives can make a useful contribution. A greater use of coppice from small stumps is recommended as an important contribution to regeneration because of its rapid growth rate, good form and assured survival. This is the source of much of the pole stands originating from the 1930's.

Frost damage and form. Frost is known to cause forking in regeneration and there is a clear relationship between frost occurrence and position in the landscape. In frost susceptible areas frost damage to jarrah will occur beneath a full canopy and there is no practical method of frost prevention. A study of form and gap size in jarrah has found no clear relationship. While very small gaps (in the order of one tree height) may produce better form, these gaps are too small for other management reasons. In any regeneration, maintaining sufficient trees from which to select 150 crop trees per hectare is the most practical means of overcoming issues relating to form.

Prescriptions be more specifically formulated and applied to take account of variations in conditions such as soil, landform, forest types, forest ecosystems, slope, and climate. Jarrah silvicultural practice provides for the removal of trees by partial harvest for thinning, shelterwood, selective and single tree selection; it provides for near-complete removal of trees to create gaps ranging from 0.2 to 10 ha; retention of habitat trees; retention of unharvested areas, both permanently or temporarily. To that extent the prescription is generic but this is inevitable since it covers the full range of possible harvest methods and intensities. The application of any one or combination of these methods and their intensity, however, varies according to stand structure, VLM zone, salt sensitivity and regeneration potential. Stand structure and regeneration potential are themselves a reflection of the combination of past treatment, fire history, soil, landform and climate. Silvicultural treatment related to salt sensitivity is derived from a combination of climate, landform and past disturbance. The guidelines provide for application of different treatment to a minimum resolution of 0.2 ha.

The outcome of this combination of influences is a wide variety of harvest method and intensity, added to which is a variety of post harvest treatment. The diversity of structure that results from current practice is greater that produced at any time in the past 130 years.

Most of the critical conservation issues are dealt with by resolution at the either the broad reserve scale or at the finer scale of reservation within State forest, such as the reservation of all stream zones and Diverse Ecotype zones.

Experience has shown that while forest condition, and hence treatment required, varies in a general way according to soil, landform and climate it does so at a much finer scale than any of these and that many of the critical differences can only be detected by direct observation in the field.

Since 1999 a complete map coverage of the southwest forests has been available for Vegetation Complexes and Ecological Vegetation Systems. These maps are based on the mapping of landform and climate and the attribution of vegetation to various combinations of those categories. They do not map vegetation directly but infer it from landform and climate, and as such the coincidence mapped forest type and these categories is relatively weak. While they provide a valuable insight into vegetation trends and the probability of certain conditions occurring they do not provide sufficient resolution for detailed silvicultural decision making. Categories derived from these maps are proposed in the current recommendations above, for identifying the 'eastern' forest for application of a modified suite of prescriptions, but they not used to indicate specific action.

Site types (Havel, Strelein, McCutcheon) are a further refinement of vegetation mapping but because they can only be mapped by field survey, there are no broad scale maps available. They combine the influence of soil, landform and climate but they do not incorporate the added influence of past treatment and fire history. As such they provide useful insight into the probable condition of the forest, but not usually sufficient to suggest specific action. They are however important in certain situations. Current guidelines refer to their likely influence on regeneration status; and proposed changes (above) recommend their use to inform the treatment of *Phytophthora cinnamomi* infected forest.

Soil type maps of appropriate resolution do not exist for the forest areas. While soil obviously influences forest condition, in field application it is easier to observe the actual forest condition which integrates all of the influences, rather than infer what it might be from soil mapping.

Similar comments apply to both karri and wandoo, for which different prescriptions exist.

The EPA has not indicated what changes need to be made with respect to any of the above parameters.

Response to issues raised by Dr Christine Sharp

These issues relate to matters raised in her discussion paper of ecologically sustainable forest management. Most of her comments appear to apply to the jarrah forest.

Change water quality protective measures. There are no specific issues cited here but these prescriptions have been developed in co-operation with the Water Authority. They have been by the Burrows committee which has recommended no change.

Don't accept local extinctions. At the present time there are no specific conservation objectives that provide a guide to this issue, specifically at what scale are flora and fauna populations to be maintained. I am not aware of any intent to accept 'local extinctions' in the long term. However as a principle it is not possible to prevent 'local extinctions' of some species in the short if that is interpreted as being the absence of a species at a local area for a period of time. This is a normal successional process e.g. both species richness and species diversity in understorey flora reduces from about five years post burning in jarrah forest and would qualify in the narrowest sense as 'local extinction'. These are issues that relate equally to reserved forests and to production forests.

Develop guidelines for the maintenance of biodiversity. I agree that this is an essential exercise but it must be preceded by the development of objectives for conservation at the whole of forest scale and at the 'landscape' scale. Prescriptions will remain controversial and unresolved in the absence of clear objectives.

Goals for production forest should stipulate percentage of mature trees and accurate structural goals to prevent 'juvenalisation' and homogenisation. Structural goals (including the proportion of mature forest) for the whole of forest have been specified and I believe that they should be developed at the 'landscape' scale. However this cannot be done sensibly till the conservation objectives have been determined. The structural goals should support those objectives. In their absence it is not possible to include local structural goals in this revision of the guidelines. The current guidelines for jarrah ensure structural diversity at the landscape scale though they are not aimed at any specified conservation objective.

The removal of any mature trees inevitably leads to an increased proportion of younger trees which is necessary for sustained yield. In that sense 'juvenalisation' is inevitable to some degree. The acceptable degree depends on the structural goals, which depends on the conservation objectives. The current levels of reservation already places limits on the degree of 'juvenilisation' that can occur. This is an issue influenced by the level of harvest rather than silviculture.

In terms of homogenisation, the current silvicultural prescriptions in use in the jarrah forest have created a greater degree of structural diversity than at any time in the past and especially compared to virgin forest. Overall structural diversity of the karri forest has increased by harvesting, though there is greater homogeneity at the finer scale in production forests. Ironically there has been considerable reduction in landscape diversity in production forests in recent years as a consequence of reduced access to a wider area of forest.

No clearfelling or gaps. The removal of a single tree creates a gap in the canopy of a forest. Cutting that results in small gaps tends to be called selection cutting while larger gaps are called clearfelling but there is no distinct demarcation. The term 'gap creation' was coined some years ago in an attempt to encourage a more specific description of the gap concerned in terms of size rather than the broader ill-defined descriptions such as clearfelling or selection cutting.

The creation of gaps is essential if regeneration is to become established, develop and be manageable thereafter. Presumably the issue is not the creation of gaps *per se* but their size. In 2000, 16% of the jarrah area harvested was cut to a gap, 60% of which was less than 2 ha, the smallest unit of recording. The overall average gap size was 1.1 ha. Reducing the size further is unlikely to serve any conservation benefit but it would reduce the already limited flexibility, increase entries to the forest and increase *Phytophthora cinnamomi* risk.

The continuation of clearfelling in karri has been endorsed by the MAG review, with the recommendation that coupe size be reduced to 40 ha in previous selection cut forest and 20 ha in regrowth forest. This has been incorporated in the recommendations here together with the use of smaller gaps in visually sensitive areas. In 2000, the average coupe size was about 11 ha.

Remove trees across all grades, not just sawlogs. This practice is already followed in both jarrah and karri, using commercial means where possible, or with follow-up non-commercial cull removal in the case of jarrah. Extension of this to the non-commercial removal of trees in stands with more than 12 m^2/ha of culls is not recommended.

More thinning in jarrah and karri. About nine percent of the area of jarrah harvested in 2000 was suited to thinning (16% average over the last decade). About 35,000 ha have been thinned since 1987. Most of this has received routine non-commercial follow-up. Because most of these older regrowth stands contain some commercial products all thinnings are integrated with commercial harvest. To date no areas of young regrowth have been identified as being ready for crown release thinning but each stand is routinely programmed for review as the stands reach 20 years of age. Thinning is regarded as a high priority.

There may be a case to review the opportunity for non-commercial thinning (or partial thinning) in areas with little marketable product and which will not be harvested for many years. However if funds were to be invested in such areas greater security of purpose would need to be provided to justify the investment.

First thinning in karri has been delayed beyond its original planned date, partly because of the reduction in chip intake and the higher priority accorded to removal of chipwood for regeneration. However, timely first thinning is critical to early sawlog supply, especially given the increased reliance on small regrowth for sawlogs. Although outside the scope of the silvicultural guidelines, every encouragement should be given to implementing the thinning program, giving it a higher priority for chipwood removal. Non-commercial thinning in karri as a means of providing employment is not feasible because of access and safety issues of manual falling. Machine thinning is required for stands in that condition.

Response to changes recommended by the Burrows committee on Ministerial Condition 11

These comments relate only to those recommendations that directly concern the guidelines. Recommendations for research are not addressed here.

Regeneration adequacy standards be reviewed to better reflect site differences. Changes have been included in the proposed amendments for the eastern jarrah forest and to account for different components of the regeneration. All of these standards need to be kept under review and changed as necessary.

Incorporate new information on the selection of habitat trees. This has been included in previous draft guidelines and will be carried into the new guideline, along with changes to numbers and the inclusion of balga habitat.

Fox control measures be reviewed. These are included in existing draft guidelines but need to be kept under regular review.

Retain patches of mature forest at the minimum rate of 200 ha per block. The basis for this is not clear other than the presumption that more old habitat characteristics is better than less in terms of wildlife populations. There are no population objectives stated nor does the recommendation discuss the value of mature forest relative to varying levels of habitat tree retention. A recommendation on this aspect is held pending an analysis by Forest Management Branch on the status of mature forest in reserves throughout the forest area.

Better definition of what constitutes severe competition to avoid unnecessary understorey disturbance. Formal precise definition is unlikely to be achievable in a practical sense. The very absence of regeneration is a direct indicator of excessive competition, but the threshold for competition to regeneration is much more difficult to establish and will be extremely variable in both a site and a seasonal sense. The current draft calls for the retention of 20% of the banksia and sheoak to 30cm in shelterwood areas. In areas requiring ti-tree disturbance, 50-70% would be retained. It is also proposed to protect thickets of sheoak that did not previously support jarrah. These provisions should ensure the minimum necessary disturbance to understorey.

F.J. Bradshaw
17 September 2001

SUMMARY OF PROPOSED VARIATION TO JARRAH SILVICULTURAL GUIDELINES

Issue	Proposed variation		Rationale for variation	ESFM criteria
Habitat trees	Number and quality	Increase numbers to 6/ha plus 6-8 potential trees. Closer specification of suitable trees.	Improve habitat for hole nesting species, based on improved knowledge from Kingston study.	Biodiversity
Other habitat	Associated vegetation and balga	Provide for retention of smaller trees as 'ladders' for habitat trees and retain some balga as habitat.	Improve habitat for arboreal mammals in light of new knowledge.	Biodiversity
Fire intensity in regeneration release burning	Reduce fire intensity	Provide more specific objectives and guidelines for regeneration release burning.	Increase survival of habitat trees in areas with heavy fuel loads. Decrease impact on understorey species.	Biodiversity
Harvesting of *Phytophthora cinnamomi* infected forest	Extend retention of overstorey to all harvested forest.	Extend the retention of 15 m^2/ha of overstorey to all infected and non-protectable forest except for low impact sites, where normal harvesting may occur. Define low impact sites and indicate on dieback maps.	Maintain a consistent approach to the conditions believed to be required to reduce dieback impact where it is necessary.	Health and vitality
Regeneration of *Phytophthora cinnamomi* infected forest	Exclude guideline	Dispense with this guideline which provides a generalised approach to rehabilitation and design specific prescription if needed for specific sites.	Guideline never used because most sites are already stocked. Any rehabilitation required needs specific prescription.	Biodiversity
Cull removal	Increase use of coppicing	Maintain option to use machine pushing for cull removal but increase the use of coppicing.	Reduce impact on understorey, make better use of existing established advance growth in the future crop. Increase potential for more jarrah in the regeneration.	Biodiversity Productive capacity
Marri dominant regeneration	Plant jarrah	In areas with less than 20% jarrah in the lignotuber pool, cut to a gap and plant jarrah to a specified level instead of cutting to shelterwood.	Improve prospect of jarrah in next crop and reduce shelterwood harvesting.	Productive capacity
Harvesting impact on understorey	Reduce unnecessary soil disturbance in shelterwood preparation	Maintain requirement for soil disturbance where shelterwood is required but specify where and what is to be done more closely and specify preference for rubber tyred machines.	Reduce unnecessary impact on understorey species.	Biodiversity Soil and water
Reduce need for shelterwood	Plant jarrah	In high rainfall southern forest in sites that are marginally stocked cut to a gap and plant jarrah rather than cut to shelterwood	Improve certainty of stocking and reduce need for complex shelterwood operations; reduce the need for soil disturbance. Based on the results from research plots and operational planting experience.	Biodiversity Productive capacity

Issue	Proposed variation		Rationale	ESFM criteria
More site specific silviculture	Apply different system and regeneration standard to eastern forest	Harvest to 6 m^2/ha, apply a reduced stocking standard and coppice or treat for shelterwood only those areas where harvesting has reduced the density to less than 10 m^2/ha. (NB specific limits yet to be confirmed). Specify the sites for application of this prescription.	Make better use of coppice as regeneration to a standard more appropriate to the lower productivity stands, and confines treatment only to those patches impacted by harvesting. Reduces extensive shelterwood areas and the amount of culling.	Biodiversity
Regeneration surveys	Changes to stocking standards and methodology	Amend to incorporate stocking standards mentioned above. Amend recording method to account for areas where regeneration is not required (thinning etc) and facilitate direct SILREC input.	Incorporate more flexible standards and efficiency	Productive capacity
Status of future forest	Amend SILREC recording	Record harvest objective (as it is done now) as an interim forest condition. Update after treatments have been carried out.	Provides a more accurate and realistic description of the forest as it affects future yield.	Productive capacity
Fire damage	Prescribe response to fire damage of regrowth	Include a prescription in the guideline for the treatment of regrowth that has been damaged by fire, of a similar type to that used in karri.	Clarify the response required so that treatments can be carried out appropriately and in a timely fashion.	Productive capacity
2nd order catchments	Managing retention areas	Include a section outlining a method of planning for the retention of the 30% of second order catchments in salt sensitive areas.	Avoid accidental encroachment on temporary retention areas.	Soil and water

F.J. Bradshaw. 17 September 2001

APPENDIX 19

Forest Structural Goals – Recommendations to the Department of Conservation and Land Management. Report to the Department by consultant F J Bradshaw

Forest Structural Goals

Recommendations to the Department of Conservation and Land Management

F.J. Bradshaw

March 2002

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1. Summary

The purpose of this report is to make recommendations on the applicability of the existing whole-of-forest structural goals, to analyse the impact of the recommendations of the panel reporting on the application of Ministerial Condition 11 (jarrah silviculture) with respect to landscape structural goals, and recommend a mechanism for developing structural goals at the landscape level.

The main conclusions with respect to whole-of-forest goals were that:

- The whole-forest goals for karri is satisfactory but that greater flexibility is required,
- The requirement to 'grow-on-to-senescence' some of the regrowth forest in areas available for timber production is no longer necessary to meet the structural goals,
- The jarrah structural goals should be simplified and include rehabilitated mine sites in the determination of goals,
- Structural goals should be developed for wandoo and tuart forest.

The recommendations of the Panel reporting on the application of Ministerial Condition 11 were analysed by determining the area within each forest block that would need to be deferred from harvesting over the long term to meet their recommended criteria. Various interpretations of the intent of the recommendations are possible with the impact on area available for timber productions varying from nil to more than 87,000 ha with an impact on yield that is likely to be substantially in excess of the 15% of the area available for timber production that that represents. A detailed analysis through IOPS is required to determine the impact on yield.

The report recommends that application of the Panel prescription relating to the maintenance of forest with mature characteristics be deferred until:

- A further examination of objectives has been made, especially as they may vary across the forest estate and on different tenure,
- An examination of alternative landscape units to forest blocks has been made,
- An examination of alternative prescriptions to meet the enunciated objectives has been made,
- An 'expert' system that related structure to fauna values to assist with evaluating the above has been developed.

It is concluded that deferral of the recommendation would not adversely impact on conservation values given that the area of intensive harvesting (gaps) that will take place in the near future will be in the order of 0.2% of the forest estate per annum.

2. Terms of reference

- Examine the whole-of-forest level structural goals contained in the 1994 - 2003 Forest Management Plan for jarrah and karri forest, and advise on their applicability in their current form for the new Forest Management Plan, given the proposed changes to the tenure and management status of these forests;
- Quantify and describe the implications on an area and yield basis of the recommendation from the panel reviewing jarrah silviculture for retaining a minimum of 200 hectares of mature forest within each forest block across the jarrah forest;
- Recommend a mechanism for the development of structural goals at the regional or landscape level that are consistent with the patch level controls implemented at the coupe level through silvicultural guidelines;
- Propose practical performance indicators at the whole-of-forest and landscape level for consideration in monitoring the implementation of the Forest Management Plan; and
- Prepare a written report detailing the findings and advice for the Director of Sustainable Forest Management.

3. Introduction

Structural goals are designed as a step towards ensuring that all stages of forest development, from seedling to maturity, are maintained within the forest at all times. While the emphasis is often placed on protecting the mature stage of development, the maintenance of all other stages is equally important if structure is to be sustained over the long term. Structural goals recognize the dynamic nature of forests by accepting the inevitable and continuous change at the stand or site level while maintaining a degree of stability at the forest level over time.

The assumption is that if the various stages of development are sustained then the other elements of biodiversity and forest values that are related to those stages will also be sustained. It provides a precautionary goal for sustaining important components of biodiversity in the absence of a detailed knowledge of the requirements of every organism.

In forests used for timber production, the achievement of sustained yield, which also depends upon a continuous representation of age classes throughout the forest, is sometimes seen as a means of achieving or a necessary part of achieving biological sustainability. In the past when the yield was aimed at large size logs (and therefore coming from large, old trees) and management intensity was low, there was a closer relationship between the social and industrial objective of sustained yield and the objective of sustaining biological values. However with changing intensity of management and the ability, or even desirability, of utilizing smaller trees for timber production, the use of sustained yield as a surrogate or means of achieving structural goals is cumbersome and inappropriate; nor is it of itself a means of ensuring biological sustainability.

In forests that are reserved from industrial disturbance, the emphasis has been on preservation of existing values, with emphasis on the older development stages that are usually not catered for as well in forests used for timber production. There has usually been little recognition of the dynamic nature of forests, with the inevitable demise of the existing old individuals and the need to ensure that there is a capacity to replace them over time, if not *in situ*. The use of protection from disturbance as a surrogate or means of achieving structural goals is simple but inappropriate over the long term; nor is it of itself a means of ensuring biological sustainability.

Structural goals provide a direct means of addressing the issue of structural diversity as well as a means of combining the structural elements of reserved forest and forest used for timber production as one forest, in the way that it is recognized by organisms rather than by tenure. Although they

impact on one another, sustained yield and structural goals can be developed independently, each aiming to satisfy different objectives (one social, the other biological) without one of them unnecessarily constraining the other. For example mixed rotation lengths are likely to provide greater benefits for both conservation values and for timber production than are longer rotation applied throughout the forest.

Structural goals relevant to forests need to be considered at several levels:

- Whole-of-forest level – where the proportion of some or all of the overstorey development stages (Establishment, Juvenile, Immature, Mature, Senescent) is specified for the forest as a whole. The spatial arrangement or the relationship of one to another is not specified.
- Stand or coupe level – where inter stand or intra stand overstorey structural elements are specified
- Landscape level - an intermediate stage that essentially incorporates a spatial goal to whole-of-forest goals to ensure that the various development stages are represented across the whole forest rather than the possibility of excessive concentrations in certain parts of the forest. The primary issue is determining a meaningful 'landscape' size and composition.
- Understorey goals – for virtually all flora values and most fauna values the condition of the understorey is more important than that of the overstorey. For that reason understorey seral stage goals are also required at the three levels described above. Fire is the primary tool for re-initiating understorey seral stages.

The evolution of specific structural goals has taken place over a long period of time. Landscape goals were first considered in the ERMP for Woodchipping Operations in 1975, stand and coupe level goals were introduced in the jarrah forest from the mid-1980s, and whole-of-forest goals were developed for the 1994 Forest Management Plan. The purpose of this report is to review the existing goals and recommend a process for the development of specific landscape level goals.

A study is currently underway, as a part of the fire management review, to develop structural (or seral) goals for the understorey in the forest.

4. Determining whole-of-forest goals

Whole of forest structural goals aim to specify the proportion of the forest that should be maintained in each age class so that as older trees die they are replaced by successively younger trees. Development stage (e.g. Establishment, Juvenile, Immature, Mature, Senescent) is used instead of age to simplify the number of classes, to facilitate mapping and monitoring, and because other values are more likely to be related to stages than to age *per se*. See section 10.1 for a description of structural development stages for karri and jarrah.

Determining the proportion of each stage that is appropriate is problematic. e.g. there is no point in requiring a proportion of mature forest that is higher than can be replaced as it dies, or does not provide flexibility for variation that may have occurred from time to time. Goals that exactly mimic the condition of virgin stands at the time are not necessarily appropriate since there is no reason to believe that this distribution is typical or consistent; nor would it be achievable if part of the estate is used for timber production purposes even with long rotation lengths. Distribution of virgin age classes also varies according to fire sensitivity of the particular forest type and the extent to which stands are created by stand replacing events or gap phase regeneration. The age distribution of very fire sensitive species tends to follow a negative exponential form; moderately sensitive species that may be both even-aged and uneven-aged tend towards a 'normal' distribution skewed to the left, and that of fire tolerant species more skewed to the right. The exact nature of the distribution will also vary according to the methodology and definition of stand age that is used. Stands managed for timber production will tend to have a flatter distribution up to the chosen rotation age.

The principal purpose of whole-of-forest goals is to provide assurance that the oldest development stages are adequately represented, that regeneration is occurring at a satisfactory level and that there is a reasonable degree of stability over time. Forest structure has implications for wildlife, for timber production, for aesthetics and for carbon sequestration. No one structure is optimum for all of these values or even for the different components within each of these. Arriving at an 'acceptable' distribution is in large part a value judgment, tempered by what is biologically possible. Goals may specify a minimum proportion to be maintained in any or all stages, or a typical level with an allowable variation.

4.1. Karri forest gaols

The karri forest structural goals specified in the 1994 Forest Management Plan were essentially based on a simplified model of mortality and regeneration at the rate of 0.5% per annum up to 200 years. This translated to a development stage proportion of:

Development stage	Percentage required
• Establishment	4%
• Juvenile	8%
• Immature	48%
• Mature/Senescent	40%

Subsequent to the establishment of these goals, a project was undertaken to map development stages in the karri forest (Bradshaw & Rayner 1997a), first for karri-dominated stands and later for the remainder of the area containing karri. This revealed that about half of the present virgin karri-dominated forest was uneven-aged, and that the age distribution ranged from 0 to 400 years in a bell shaped distribution skewed to the left, with a dramatic reduction in the area of stands that were older than 250 years. Modeling of changes in age distribution over the next one hundred years (for

the combined reserved and harvestable forest) indicated that the distribution remained relatively stable with the average in each development stage over the period being 5%, 10%, 45% and 40% (Bradshaw & Rayner 1997b). Despite the different approach to stand ageing and the availability of data on age distribution, the actual and projected representation was similar to the goals. The remainder of the karri forest has since been mapped for development stage but the age projection over time has not been undertaken.

Since that time all of the old growth forest and a substantial proportion of previously harvested forest has been reserved so that the proportion of forest in the mature/senescent category is now higher and will remain higher over time. It would be expected that over time, all of the forest subject to harvesting and a portion of the reserved forest would be in the first three categories, with the remainder in the mature/senescent category. Based on our present understanding of karri structural dynamics, at least 20% of the reserved forest must be in the immature stage or less if the mature phases are to be sustained in those areas, though this percentage will vary depending on the severity of the fires that induce regeneration. This assumes that disturbance by fire will continue to occur though the impact on structure will depend on whether fire management practices encourage frequent low to moderate intensity fires or infrequent intense wildfire.

There appears to be no reason at this stage to alter the present structural goals for karri. However it is apparent that in their present form they are unsuitable as a performance standard because the sum of all categories equals 100%. i.e. if any category (say mature forest) exceeds its limit, then at least one other category must fail to reach its target. This can be overcome by providing for goals with a permissible variation of ± say 20% of each target, or a lower limit that is say 20% less than the 'ideal' figure. Greater variation is acceptable in the sub-mature categories because of the shorter time span that each of them represents.

At 2000, the percentage of karri forest in each development stage (Establishment, Juvenile, Immature, Mature/Senescent) was 9%, 18%, 23% and 50% respectively.

Change to whole-of-forest structure during the life of the new Management Plan will not be significant in terms of the proportion of forest in mature/senescent stages, though more significant changes can be expected in the early shorter-duration stages. This is especially so because of the reduction in harvest levels.

By the end of the new management plan in 2012 representation is expected to be about 1%, 14%, 34% and 51% respectively, though this may vary by a small amount depending on the final agreed level of harvest. Given the large increase in reserved forest, both immature and mature, since the last Management Plan, the requirement to 'grow on to senescence' some of the regrowth in the area available for timber production is no longer required to meet the structural goals. I would recommend that this requirement be removed from the new management plan.

4.1.1. Monitoring the achievement of karri structural goals

Structure at the forest level changes by relatively small increments and significant changes are required to make a major impact on the forest structure. The order of magnitude of these changes in the medium term is relatively easy to predict.

In forest available for timber production, changes in age structure can be predicted with a high degree of reliability on the basis of predicted harvest rate of mature forest, and by incrementing existing regrowth forest, the current age of which is already known. Estimates of wildfire effects can be incorporated on the basis of probability. In reserved forests, regrowth elements can be incremented in the same way as described above, while changes to mature forest can be modeled in the same way that it was for the karri-dominant forest (Bradshaw & Rayner 1997b). Variable estimates of wildfire impact can be incorporated. Significant changes in reserved forests are not likely to be evident in periods of less than 50 years.

I therefore recommend that the whole-of-forest structural condition need only be reported on at the revision of each management plan. At that time a report should be prepared on the current structural condition and the expected condition at the end of the plan period. It should also predict the structural conditions expected over the next one hundred years, at 50 year intervals. A prediction of future condition is likely to provide a more valuable insight into forest condition than the achievement of precise goals at any one time, in the same way as yield flow over time is more valuable than the use of a single sustained yield figure.

The condition at 2001 has been given above. The expected condition in 2012 should be revised when the level of harvest has been finalized. It may not be possible to develop the long term prediction for the Management Plan under preparation, because further sampling of the age of dominant and secondary cohorts is required in mixed karri forest.

4.2. Jarrah forest goals

The goals for the jarrah forest enunciated in the 1994 Forest Management Plan are not based on a direct measure of stand age but on an inferred condition based on the degree of disturbance to which the forest is subjected. The principal reason for this is the difficulty of readily identifying and mapping the development stages of those forests that have a fine scale uneven-aged structure, especially in the separation of trees of the same size but of widely different age. This makes the assumption that reserved forest will contain a representation of all ages in proportions appropriate to their sustainability. Given the fire tolerance of the species and its method of regeneration via a lignotuber pool that is developed over a long period, this is probably a reasonable assumption, if appropriate allowance is made for the expected variation between site types. This assumes however that the areas will continue to be subject to fire disturbance either through controlled burning or wildfires.

For forest subject to disturbance by harvesting, the goal incorporates some element of identifiable structural condition. It implies that no limitations will apply to the extent of open-cut mining, but prompt regeneration is encouraged.

One of the main purposes of maintaining structural goals in the jarrah forest for biological reasons is to ensure that there is an adequate proportion of the forest that contains large trees that contain or have the potential to contain hollows for hollow dependent fauna. This is assumed to be contained in undisturbed forest and in mature forest, but mature elements may also be contained within areas of younger forest with appropriate stand structure.

The goals stated in the present plan are given below together with the position at December 2000 shown in brackets. The definitions of development stage are given at section 10.2 In the existing definition, mature jarrah is defined as beginning at about age 70. There may be value in re-examining this definition. The second figure in brackets indicates the situation if the age of maturity was extended to 120 years.

Condition	Target %	(status at 2000)
• minimal disturbance (large reserves)	- 25%	(38%)
• low disturbance (informal reserves, rare flora sites etc)	- 5%	(9%)
• moderate disturbance (forest used for timber production) – harvest for regeneration <= 1% of the multiple use forest /ann. (0.25% in the last period)		
(the long term goal within the multiple use forest is	*establishment* 5%	(1%, 1%)
	juvenile 15%	(5%, 5%)
	immature 40 %	(4%, 9%)
	mature/ senescent 40%	(90%, 85%)
• high disturbance (mining)	no limits (regenerate as soon as possible)	

Since these goals were developed there has been no new information or developments to indicate that these goals are not satisfactory, although it may be desirable to reconsider the age basis for some of the stages. The area of 'minimal' disturbance has increased substantially with the increase in old growth and other reserves.

However the criteria do seem to be unnecessarily complex.

A recommended alternative to the present goals is to place a more direct emphasis on mature overstorey elements, while retaining the essential intent and levels of the current goals. These would then read:

"70% of the jarrah forest to contain forest with mature overstorey elements (at least 30% to be in the form of reserves that are not disturbed by future harvesting or mining activities)."

Qualifications:

- *To qualify in this context, stands must contain a crown cover >= 10% (i.e. ~15% of maximum crown cover) of mature trees.*
- *Utilities (power lines, dams, other forms of permanent clearing etc are excluded from the area base)*
- *Mine rehabilitation areas are included in the calculation*

This is a higher expectation than in the current goals in terms of mature forest, which equates to 60% rather than 70%. This is considered reasonable given the change from the emphasis on undisturbed forest to mature elements. This has the advantage that it directly accounts for the element of most interest and concern. Furthermore current goals do not take into account the accumulating area of mined forest.

Under this standard, the condition at December 2000 is:

- 47% of the jarrah forest estate is in the form of reserves, and
- 91% consists of the jarrah forest consists of forest with mature characteristics (87% if mature forest defined as >120 years)

4.2.1. Monitoring achievement of jarrah structural goals

The slow change in structural condition of the forest discussed earlier applies equally well to jarrah. I recommend that monitoring of the structural condition of the jarrah forest should be done as follows:

- determine the condition according to the above criteria at the beginning of each plan period using set definitions,
- predict its expected condition at the end of the plan period,
- make a further prediction of its condition over the next one hundred years, at 50 year intervals, preferably for this plan but at least developed during the next plan period.

4.3. Other forest types

While not specifically included in this brief, consideration should be given to the development of structural goals for the two remaining major forest types in the south-west. Consideration could be given to using the same goals for wandoo as for jarrah, or combining jarrah and wandoo as one since at least in the eastern forest, they are intimately mixed.

The tuart forest has a particular requirement for structural goals where the emphasis or issue of concern is quite different to all of the other species. Changes to the condition of the tuart forest, probably because of changes to fire management practices, has created the situation where natural regeneration does not occur except under catastrophic wildfire conditions which current management plans try to prevent. It is therefore unsustainable under present management, a fact that has been highlighted by, but not due to, the current insect attacks to part of the forest. There is therefore a need to develop structural goals that place appropriate emphasis on the establishment stage and establish monitoring processes to ensure the sustainability of these forests. In this forest type lack of disturbance is the cause of the problem, not the solution to it. This also needs to be addressed in the development of understorey goals.

5. Overstorey structural elements at the local level

A variety of steps have been taken over the last 25 years to ensure that important elements of structural complexity are provided for at a stand or local level within the multiple use forest. These have in part been based on specific research results and in part on the precautionary principle. The elements in place today have almost all been adapted and modified over time as better information and understanding of the issues have developed. Some of these, such as the retention of potential habitat in karri, increased habitat trees in jarrah, long-term retention of 'shelterwood' trees, limitations on culling are newly proposed in the revision of the Silvicultural Guidelines and have not yet been implemented. They have been developed to cater for a variety of values and objectives, sometimes complementing, sometimes conflicting with each other. They include various steps taken at local level to protect water quality (turbidity and salinity), aesthetics, wildlife and timber production. They impact on stand and local forest structure. Elements at the stand level inevitably aggregate to the local and then landscape level so that the elements described below do not all neatly fit into separate categories.

The following elements contribute to structural diversity at the local level. Some are permanent while others are temporary. They have only been listed here and further detail of their application can be found in planning protocols, recovery plans, interim management guidelines and silvicultural guidelines.

5.1. Permanent reservation (patches)

- large formal reserves adjacent to multiple use forest
- riparian zones on all streams
- buffers on level 1 travel routes in southern forests
- all areas of 'diverse' ecotypes (woodland, swamps, flats, rock outcrops etc).
- areas of rare flora as required
- additional stream buffer reservation in salt sensitive areas
- patches of mature forest every 400 m (karri forest only)
- 'uneconomic' forest *
- steep slopes
- isolated patches of forest *
- specific patches for VLM purposes

5.2. Within the harvested patch – 'long term' retention

- retain habitat and potential habitat trees in jarrah and mixed forest
- retained potential habitat trees in karri
- retained marri patches and some trees*
- retained culls trees in selectively cut areas*
- retained culls in gaps to varying levels
- shelterwood trees to retain forest values during the regeneration phase (jarrah)
- minimum retention of mature trees in 'eastern' forest

5.3. Temporary retention (patches or individuals)

- patches of forest to limit the size of gaps (TEAS)
- crop trees to grow on
- crop trees and culls in selection cut areas (jarrah)
- minimum levels of retention in dieback areas
- minimum levels of retention in eastern jarrah
- 30% of 2nd order catchments in forest east of the 1100 mm rainfall isohyet
- regrowth that can be protected from fire and harvesting (karri)
- phased harvesting in salt sensitive catchments

5.4. Patch size or spatial arrangement

- Gap/coupe size of 1.15 to 40 ha in karri (recent average 10 ha)
- gap size of 0.2 to 10 ha in jarrah (recent average 1 ha)
- retain TEAS for a minimum of 15 years in jarrah (ranges to more than 60 years under current plans)
- retain TEAS until adjacent areas are regenerated or regeneration is safe to burn (karri).
- vary size of gaps and retained patches according to VLM zone (jarrah)

* some of this may become economic in the long term.

The justification or objectives for retaining some of these elements have not always been well documented, and few apart from those related to timber production have been quantified in terms of their benefit. Because of that it can be difficult to objectively evaluate trade-offs where conflict occurs. Nevertheless, the targets or rules relating to each of these elements are clearly stated, either in planning documents or the Silvicultural Guidelines.

All of the above elements together with the diversity of forest types contribute to structural complexity at the landscape level. This complexity of structure as an outcome of harvesting in recent years is greater than at any time in the past (Bradshaw 1999, CALM 2000).

An anomaly occurs in that none of these structural elements or management constraints apply to mining, despite the fact that bauxite mining has the potential to impact on virtually all of the upland jarrah forest north of Collie. An estimated 100,000 to 150,000 ha of the northern jarrah forest will eventually be maintained in an immature even-aged condition with no mature characteristics, as a consequence of mining.

There has been a substantial reduction of local structural diversity in recent years as a consequence of harvesting moratoria which has caused a concentration of harvesting in dispersed patches of mature forest within regrowth areas.

6. Structural goals at the landscape level

Whole-of-forest structural goals ensure that all stages of forest development are represented somewhere within the forest at all times and this represents a major step towards biological sustainability at the forest level. This is based on the presumption that there is a relationship between these stages and their suitability for certain organisms e.g. the relationship between old trees, the presence of tree hollows and suitability for large hole-nesting species. However it provides no limitation to spatial arrangement of those stages. This allows the possibility of a concentration of development stages in certain parts of the forest at the expense of representation in other parts of the forest. For any given area of reservation, the larger the reserves, the more extreme this issue is likely to become.

If the majority of the forest is to be suitable for most organisms, most of the time, then there is a need to ensure that these stages are spread across the forest at some level i.e. each stage needs to be represented at a 'landscape' level as well as a 'whole-of-forest' level. This raises a number of issues that need to be addressed:

- What is a landscape unit and how should it be differentiated from another?
- What is the size of the landscape unit to which the goals are to be applied?
- What are the minimum requirements for the goals? Logically, variation within each of the landscape units should be less restrictive than at the whole-of-forest level. If they are more restrictive then the whole-of-forest goals become redundant.

These issues cannot be properly resolved until several other issues are considered:

- To what extent should forests used for production be similar to reserved forests and to what extent should they complement them?
- What are the conservation objectives? What are the relative population goals for key species in reserved forest, 'production' forest or the both combined at the landscape level. i.e. there is probably general acceptance that extinction of any species at the landscape level is not acceptable, but should for example brushtail possum numbers be encouraged to the maximum level in all areas if by doing so, timber production levels are seriously compromised in the areas available for that activity, if forest regeneration is prevented or it disadvantages other species. What is an acceptable trade-off?
- Is the objective of retaining mature trees in harvested areas to maintain populations of hollow dependent fauna or to facilitate their movement between other patches of suitable habitat?
- Are patches of intensively harvested and unharvested forest more or less effective for wildlife populations and timber production than a larger area harvested less intensively?
- What is the basis for trade-off between impacts on each of the legitimate land use values within the forest?
- How does forest structure relate to the provision of den/nest sites and food source?
- How does the home range or migration range of critical species influence the size of the landscape unit?
- Should landscape units be based on separate vegetation or landform units, or should it amalgamate physically associated units?

These latter questions are by no means exhaustive but indicate the kind of information that is required to make sound decisions on landscape goals. While whole-of-forest goals may be seen in the sense of a broad precautionary approach, landscape goals need to be much more specific it they are to have any real value. If these issues are not explicitly stated then monitoring is restricted to policing a rule-set or prescription, and not to the achievement of conservation objectives.

To date there has been little discussion on these issues despite the fact that quite specific prescriptions have been developed for application at the local level which have inbuilt inferences about some of these issues. The principal limitation is that most of the necessary wildlife research to date provides static information, and there has been little attention given to dynamic modelling such as population viability analysis. For example data exists on avifauna in karri forest that shows the different use of mature forest and adjacent young regrowth, but little data has been collected which would indicate when this difference diminishes. The Department of Conservation and Land Management already has excellent tools (FMIS, IOPS[1]) to map overstorey structural condition and simulate changes over time at any landscape unit from 0.5 ha to the whole forest. What is lacking is wildlife data to attach to that structural data to allow habitat condition and habitat relationships to be predicted into the future, although an important start has been made in this direction in the Fauna Assessment protocols which have just been developed (Christensen *et al.* 2002).

Despite these limitations, consideration and discussion has begun on prescribing landscape goals based on various landscape units.

6.1. Proposal by the panel reporting on Ministerial Condition 11

A panel was appointed to advise the Department of Conservation and Land Management on its requirement to report to the EPA on the implementation of Ministerial Condition 11.1 (monitoring of the jarrah silvicultural prescription) (Burrows *et al.* 2001). This is referred to as the 'Panel report' for the remainder of this report. In their report they propose a preliminary set of objectives and broad prescription aimed at the landscape level.

They used a series of steps starting with the broad definition of Forman (1995) for a landscape:

"A mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area. Several attributes, including geology, soil types, vegetation types, local faunas, climate and natural disturbance regimes tend to be similar and repeated across the whole area."

They then define conservation objectives for a landscape as follows:

- *Ensure that no species declines to irretrievably low levels as a result of forest management activities.*
- *Ensure adequate reservation of forest landscapes.*
- *Ensure a diverse representation of forest structural habitats and seral stages through time and space with an interlocking mosaic of patches of forest at different stages of development including new growth and old growth stages.*
- *Protect ecologically sensitive areas and niches such as riparian zones, aquatic ecosystems, wetlands, granite outcrops and other non-forested complexes.*
- *Ensure maintenance of water quality.*

This implies that they see structural diversity as an objective in itself, not just the means towards ensuring biological diversity.

[1] FMIS – raster based GIS system (Forest Management Information System)
IOPS- GIS based Integrated Operations Planning System

They then effectively define a size limit to the landscape unit by defining objectives at the 'patch' or block level. A forest 'patch' is defined here as:

A spatial element within a landscape. It could be a (sub) catchment or a mapped management boundary, such as a forest block- it could contain a representation of landforms and ecosystems common to the landscape unit. (Note that this is different to the use of the term 'patch' mentioned in dot point three above which is more consistent with the general use of the term 'patch' in a silvicultural sense)

They define both conservation objectives and prescriptions within each block as:

To take all reasonable measures to:

- *ensure biodiversity (species richness) recovers before the next cutting cycle* (presumably this is intended to mean rotation, rather than cutting cycle)
- *ensure that the capacity of the block to provide the range of habitat elements that it provided before logging is not permanently compromised due to logging and associated activities.*
- *ensure at least 20% (including road and stream reserves) of the forest block retains mature or old growth overstorey structural characteristics.*
- *prevent the introduction and spread of dieback.*
- *minimize the introduction and spread of weeds and other aliens*

In their recommendations, they refer to the retention of a minimum of 200 ha of uncut forest or forest with mature characteristics, rather than the 20% mentioned above. This appears to be based on the assumption that 200 ha of such forest would support a viable population of Western Ringtail Possums as a source of re-colonisation to the remainder of the block. By implication this suggests that the harvested area does not support a population of these species or allow them to move between areas that do.

While this report was written in the context of forest harvesting, presumably a more generalised objective for dot point 3 might read:

- ensure that the capacity of the block to provide the range of habitat elements that it provided originally is not permanently compromised due to management activities such as mining, harvesting or inappropriate fire management.

This would then extend its application to reserved areas and to other major land uses on the same area (i.e. mining).

6.1.1. Impact of proposal

The impact of this proposal on sustained yield of timber depends on what is meant by a forest with mature characteristics and whether it refers to 200 ha within or 20% of the forest block.

It is understood that the requirement for more forest with a higher proportion of mature trees derives from the Kingston study and the observation that gaps supported lower populations of arboreal mammals and the assertion that areas with a higher density of forest should be retained to maintain populations at the block level.

As a consequence of the results of the Kingston study, the draft Silvicultural Guidelines have been amended to provide for six habitat trees per hectare, double the number when the study was initiated. Limitations have also been placed on the intensity of culling. If these guidelines are implemented then all future harvested areas will retain a minimum of 10% crown cover of trees with mature characteristics in the form of habitat trees and potential habitat trees. This equates to about 15% or more of the typical original crown cover of the jarrah forest.

If this level of mature characteristics were regarded as satisfactory to sustain arboreal mammals (not necessarily maintain them at maximum levels), then the impact of the Panel proposal would be negligible, other than the impact of the increase in the retention rate of the habitat trees. This also applies to the karri forest.

If forest with mature characteristics is defined as 'uncut patches of mature or old growth forest' (Burrows *et al.* 2001 p 17), then the requirement would not be met in a number of blocks but the impact on yield has already been accounted for, because all existing old growth has already been reserved.

However, if old growth forest is not intended and 10% crown cover of mature trees is not considered sufficient, and there appears to be no evidence to suggest that it would not be, then the requirements of the Panel report would in most instances have to be seen in the context of further long term deferral from future harvesting at least in the short to medium term when the shortage of mature forest is critical to maintaining wood flows for the longer term. The impact on yield of long-term deferral is effectively the same as reservation. It has been analysed and is discussed below.

All forest blocks south of Mundaring within the three forest regions were analysed. Although the Panel report was confined to the jarrah forest, it did not appear sensible to confine the analysis to jarrah because of the intimate relationship that it has in the mosaic with wandoo and karri. Therefore all native forest (or native vegetation) was included. Forest with mature characteristics for this purpose has been defined as that with >20% crown cover of mature trees (jarrah and wandoo) and that which was defined as mature in the karri ageing project (>25% crown cover of mature trees). The existing density classification for jarrah does not permit the separation of stands less than and over 10% mature canopy cover, though karri could be further subdivided.

Recent proposed additions to CALM managed land for reserves are outside forest blocks at this time and have not been analysed in this report. They are indicated on the attached maps.

Because there is some confusion concerning the intent of the authors, three separate analyses were done, using different definitions and criteria. The statistics of the forest blocks are given in Tables 1 and 2 of Appendix 2. The maps in Appendix 3 show those blocks that meet the various criteria.

Criterion 1. If 200 ha of forest with mature characteristics is reserved in each forest block

	At present	If additional areas are added to meet criteria
No. blocks that satisfy criterion	344	394
No. blocks with 100-200 ha with mature characteristics	19	2
No. blocks with 1-100 ha with mature characteristics	35	2
No. blocks with 0 ha with mature characteristics	0	0

Additional area of mature forest that would need to be deferred or reserved 4,250 ha

Additional areas represent 1% of the forest with mature characteristics that is available for timber production.

Criterion 2. If 20% of the native forest in each block contains mature characteristics

	At present	If additional areas are added to meet criteria
No. blocks that satisfy criterion	244	393
No. blocks with 10-20% ha with mature characteristics	44	4
No. blocks with 1-10% ha with mature characteristics	111	1
No. blocks with 0 % with mature characteristics	0	0

Additional area of mature forest that would need to be deferred or reserved 87,030 ha

Additional areas represent 15 % (karri ~10%) of the forest with mature characteristics that is available for timber production.

Criterion 3. If 20% of the native vegetation in each block is non-forest native vegetation (nf) or contains mature characteristics

	At present	If additional areas are added to meet criteria
No. blocks that satisfy criterion	253	394
No. blocks with 10-20% ha with nf or mature characteristics	57	4
No. blocks with 1-10% ha with nf or mature characteristics	88	0
No. blocks with 0 % with nf or mature characteristics	0	0

Additional area of mature forest that would need to be deferred or reserved 73,080 ha

Additional areas represent 12 % (karri ~10%) of the forest with mature characteristics that is available for timber production.

The impact of Criterion 1 (200 ha retained) represents an incremental reduction in yield in an already constrained environment but it would not have a significant impact. Nevertheless it would have a greater impact than that represented by the reduction in area because it represents a further reduction in flexibility.

The impact of Criterion 2 and 3 are very significant and would have a major impact on the viability of the timber industry. Because of the significance that the relatively small areas of mature forest have on timber availability in the immediate future and the cumulative limitations that already exist on flexibility of operations, it is not appropriate to make a superficial estimate of yield impact in this review. The minimum that is required would be an analysis in FORSHED and KARSCHED. Because the spatial arrangement of these areas are likely to have a significant impact, further analysis through IOPS should also be carried out.

The blocks affected by each scenario are indicated in the attached maps. These maps indicate that Criterion 1 (200 ha) could be accommodated with relatively little impact but that the other two alternatives would have a major impact, not only in the north where it would be expected but also in the south and in the karri forest. This is most apparent when viewed alongside the map showing areas immediately available for harvesting (not included). It is also apparent that the impact is sensitive to the size of the unit selected as the landscape unit.

Criterion 2 and 3 represent a more restrictive, rather than a more flexible, structural goal than the whole-of-forest goals. As such they would make the latter redundant.

None of these data have been examined for their spatial implications with the block. Conflicting views have been expressed about the relative merits of dispersal or aggregation of mature characteristics. Any specific requirements relating to spatial patterns of retained old forest will inevitably require more areas to be retained with a consequent increase in impact. This increase could be substantial but can only be determined after clear requirements are known and with the benefit of detailed spatial analysis through IOPS.

6.2. Alternative landscape units

Irrespective of the structural goals chosen for each landscape unit, there are alternatives to the definition of landscape units. The Panel has suggested the forest block as one possibility. The following is a brief discussion on other units that have been proposed.

6.2.1. Forest Fauna Distribution Types

These types form the basis for the Forest Fauna Distribution Information System in that the likelihood of a range of fauna species occurring are related to these types. The forest is essentially divided into nine broad geomorphological units (Darling Plateau, Blackwood Plateau etc) which are subdivided principally on the basis of upland and lowland. Specific units such as heathlands, swamps and rock outcrops etc. are also identified. There are approximately fifty of these units.

Since one of the main objectives of developing landscape overstorey structural objectives is to provide for the sustention of characteristics of importance to fauna, using these types as a basis for landscape units has some attractions. However these types deliberately separate units within the landscape (e.g. upland from lowland etc). As a consequence they do not conform to the critical definition of a landscape as defined by Forman:

> *A mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometers-wide area.*

It is this mosaic of differences, rather than the identification of sameness that is the inherent value of the landscape unit.

Furthermore the physical size of many of the fauna types is quite large and for the purposes of ensuring that representation of critical elements is dispersed throughout the forest, they represent a rather course grain. A further subdivision to geographically smaller units would be required if landscape units are intended to have some relationship to home range, habitat utilisation and recolonisation. Given the pattern and resolution of the Fauna Distribution types, it would appear that the determination of the size of the subdivision to be a more critical problem than the basis of the subdivision.

6.2.2. Forest ecosystems

Forest ecosystems are based on the subdivision of major overstorey types on the basis of geographical units, groupings of vegetation complex and canopy density. They also recognise particular types such as heathlands, swamps and rock outcrops etc. Twenty-six forest ecosystems are identified.

While ecosystems amalgamate different elements of the landscape better than the Fauna Types above, they do so only to a limited degree and they represent an even courser grain than the Fauna units. They would also require some further geographical subdivision.

6.2.3. Understorey seral units

The development of seral goals for understorey is currently being considered and landscape units similar to that for the overstorey will need to be identified. While these have not yet been resolved it is likely that they will be based on groupings of vegetation complex in a similar way to Fauna types described above and they will have the same shortcomings so far as their suitability for landscape units.

6.2.4. Geographically based units

Geographically based units, however defined, have the primary advantage that they amalgamate mosaics of vegetation (and by association landform) rather than separate them, which is the essential criteria of a landscape.

The forest block is one example of a geographic unit with an average size of about 5,000 ha, but ranging from a few hundred hectares to about 19,000 ha (see Figure 1). The boundaries are located to serve the purpose of defining a locality but have been used for a variety of purposes because they are known and recognisable. They generally do not relate to vegetation or natural landscape features, or in this context to wildlife habitat.

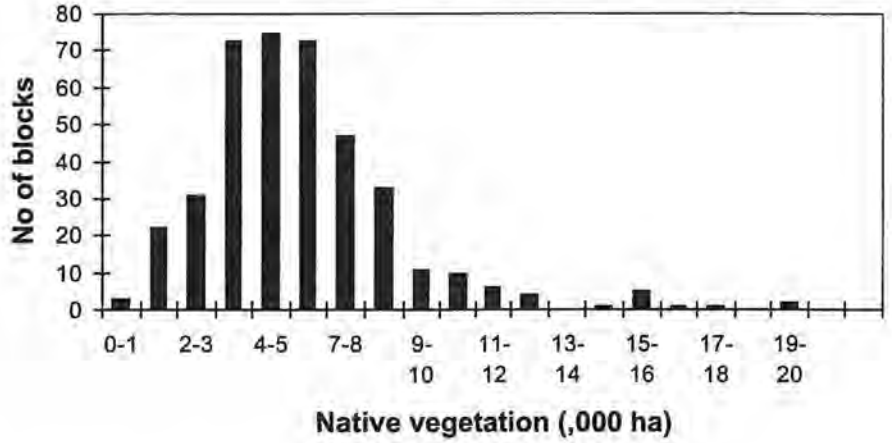

Figure 1. *The areas of forest blocks. The mean size is 5,300 ha*

Rather than the 'arbitrary' definition of a forest block, geographically based landscape units could be based on the subdivision of broader geomorphological units (such as the Darling Plateau, Blackwood Plateau etc) but the size of the units that are finally determined are likely to be such that there may not be a great deal to be gained by this approach.

Geographical subdivision is likely to be the principle means of defining landscape units. It would appear that the most critical elements to be decided in determining an appropriate landscape unit are:

- the size of the unit,
- whether different structural goals are required for units within different broad geomorphological zones, or areas of different species richness,
- the relative merits of having small units with less stringent goals or larger units with more stringent goals in terms of fauna conservation and impact on other values,
- the variation permitted between units.

The Panel prescription for forest block goals does not canvass any of these issues.

6.3. Monitoring landscape goals

The procedure for monitoring of nominated landscape goals cannot be determined until the prescription is finalised. The most rigorous requirement will relate to any spatial requirements that the prescription might contain, although there is limited flexibility in what can be achieved in this direction because it will be largely dictated by what exists.

Regardless of the landscape unit that is finally determined or the goals that are applied within it, the minimum requirement will be to:

- Identify those units where existing reserves do not satisfy the criteria,
- In other units, undertake a check at the time of harvest plan preparation to make sure that the planned activity will not violate the prescription,
- Certify that such a check has been done for all the harvest activities that are approved in the landscape unit.

7. Discussion and recommendations

7.1. Whole-of-forest structural goals

The whole-of-forest structural goals enunciated in the 1994 Forest Management Plan appear to be acceptable in ensuring that all stages of forest development stage are represented within the forest, and that critical elements of it can be sustained. While arguments to change the goals can be mounted, there are good reasons to try to maintain stability of the goals. I am not aware of any compelling arguments to significantly vary the current goals.

Nevertheless, the following changes are recommended to simplify application and to recognize the impact of recent tenure changes. These are:

- Provide for variation in the karri structural goals for the purposes of performance indicators,
- Remove the requirement to "grow on to senescence" areas of regrowth forest in areas available for timber production,
- Include wandoo in the structural goals for the jarrah forest,
- Simplify the jarrah structural goals,
- Develop structural goals for the tuart forest.

The rigid pursuit of specific targets or goals does not seem appropriate or particularly productive. A more valuable approach is the capacity to predict change in structural condition over time and use these trends to decide whether the current management approach is likely to provide a satisfactory outcome over time. The following approach to monitoring is recommended. At the beginning of each plan period:

- Report on the existing structural condition of the forest,
- Predict the condition that will be expected at the end of the period,
- Model the expected condition over the next 100 years (may not be achievable at the beginning of the current plan.)
- Report on the predicted trends and the steps to be taken to address conditions that are perceived to be undesirable,
- These requirements should apply to specific area management plans (eg for the tuart forest) if they are not covered by the Forest Management Plan.

The monitoring of whole-of-forest structural goals will only be relevant so long as landscape goals provide for greater flexibility than whole-of-forest goals.

7.2. Landscape structural goals

The Panel has made the first attempt at defining conservation goals at the landscape level and has recommended a uniform prescription that requires the maintenance of 200 ha (20% ?) of a forest block with mature forest characteristics.

If forest with mature characteristics were defined as 'uncut patches of mature or old growth forest', then many blocks would not meet the requirements of the prescription, especially in the northern forest, but there would be no further impact on yield.

If forest with mature characteristics were defined as having 10% crown cover of mature trees (equivalent to the proposed increase in habitat tree retention), then all future forest harvesting

would maintain those elements. The requirement can be accommodated without significant impact on the level of sustained yield.

If a higher crown cover of mature trees is required, then many blocks would not meet this standard unless additional areas are deferred from harvesting for the long term, effectively having the same impact as reservation. This would have a major impact on timber sustained yields (including karri). While it would have a major effect on the timber industry, the prescription may not be met in the long term in much (the equivalent of about 20-30 forest blocks) of the northern jarrah forest where no restrictions on coupe size, dispersal or retention rates can be applied to bauxite mining without the agreement of the mining companies. The extent of the area potentially subject to bauxite mining is indicated on Maps 7 and 9 of the Comprehensive Regional Assessment (RFA 1998).

If the 'higher crown cover' interpretation is placed on 'mature characteristics' at the level of 20% of the forest block, then I recommend that the Panel prescription not be applied at this point for the following reasons:

- There are no specific conservation objectives enunciated – therefore while the prescription can be policed there is no means of determining whether the conservation objective is being met,
- There is no provision for variation in the prescription to provide for the different habitats or values across the forest estate,
- The arbitrary use of forest block, with variable size and location unrelated to biological values, introduces an element of chance into the achievement of the prescription which may be unrelated to conservation outcomes and which could be minimized by a more considered selection of landscape units,
- The assumption that the retention of 20% of the block is required to achieve an unspecified biodiversity target is untested,
- The significance of a reserve system that already goes well beyond national targets for a comprehensive and representative reserve system does not appear to have been taken into account, nor have the different expectations of reserved forests and multiple use forest been expressed,
- The prescription is least likely to be met in the area where existing reserves are few (the northern jarrah forest) unless mining and other disturbing activities are constrained in the same way as the timber industry,
- A less 'prescription driven' and a more 'objective driven' approach should be pursued to promote an examination of alternative prescriptions,
- Greater rigour should be applied to the development of conservation objectives and to the applications of prescriptions when they have the potential to adversely impact on other legitimate land uses to a significant degree.

I recommend that the development of structural goals at the landscape level be addressed during the plan period, during which time the issues raised in Section 6 can be considered and evaluated more thoroughly. The implications of 'locking in' the Panel recommendation (at the 20% of forest block level) are considerable when the fundamental justification for doing so has not been thoroughly explored. Furthermore the adoption of a rigid prescription of this nature without proper evaluation of the alternatives is unlikely to give the best outcome for either timber production or conservation. Delay in implementing structural goals is unlikely to have a significant adverse effect on conservation values. During the period of the next plan, no more than 2% of the forest estate is expected to be impacted by intensive harvesting to gaps, and all of those areas provide for increased habitat tree retention.

If this prescription is applied then the '400m' rule in karri forest should be revoked as redundant.

7.2.1. Development process for landscape goals

A major impediment to the development of measurable conservation objectives and the development of structural goals has been the lack of information on the dynamic relationship between fauna values and forest condition. There has also been a lack of understanding of the impact of these changes throughout the forest as a whole.

One of the means of progressing these issues would be for the Department of Conservation and Land Management to investigate the development of an 'expert' system based on the relationship between key fauna and stand structure to provide the basis for modeling habitat suitability and population impact. It should be developed upwards from the stand, to the landscape, to the forest; and capable of modeling change over time. Such a system would enable a more objective evaluation of alternative strategies for fauna and timber management at the landscape level leading to more scientifically justified structural goals and prescriptions.

The advantages of developing an expert system are that it:

- allows the use of the best information available without the need to wait for the answers to all questions,
- it explicitly states the assumptions that are made in the decision process,
- it provides a means of focusing attention on important specifics,
- assists in identifying critical gaps in the knowledge base and therefore assists in focusing research priorities,
- allows for sensitivity testing and testing of alternative strategies.

The Department already has the basis for developing such a system. IOPS is an operational resource planning tool that is capable of simulating and spatially representing structural condition at the stand level across the whole of the forest estate, with a spatial resolution of 0.5 ha. It can accommodate spatial data from any GIS source. Much of the critical data is already regularly used within the system. It has the capacity to spatially represent forest structural condition at nominated times in the future on the basis of any simulated disturbance.

The Fauna Distribution System in the process of finalisation relates the probability of fauna species in types that are already used or can be readily input into IOPS. The fauna system also includes relationships to structural development stage. An amalgamation and further development of these two systems would provide the most rapid means of progressing an expert system. To undertake the task would require a team with expertise in fauna, silviculture and resource and spatial analysis. It could draw on and incorporate the expertise and informed opinion of a wide range of scientists and managers.

I recommend that this project be developed early in the plan period so that it can be used to inform decisions on the issues raised in Section 6 above. Landscape goals should be set only after these matters have been more thoroughly quantified and evaluated.

8. Acknowledgments

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10. Appendix 1 Description of stand development stages

10.1. Karri

This description is an extract from Bradshaw and Rayner (1997a).

"Stands of karri develop through several distinct stages from establishment to senescence".

In order to describe the stages in their simplest form we will discuss the development of distinctly even-aged stands and avoid the complexities of site and species mixtures. These descriptions are expanded versions of those previously described by Butcher[2] in (CALM 1992).

Establishment

In a natural forest the establishment stage begins with the death of a tree or a group of trees in the original overstorey of such a size that the space that is vacated is not 're-occupied' by the surrounding trees (Breidhal & Hewett 1995).

If the conditions for establishment are suitable (primarily an exposed mineral soil seed bed and a source of seed) then the 'unoccupied' space will become occupied by seedlings. These seed-bed conditions are most commonly created by fire of varying intensity and as a result the early phases of establishment are characterised by strong inter-specific competition from the understorey species that regenerate at the same time. Rapid growth of the seedlings ensures dominance over the understorey and the establishment stage ends with canopy closure of the saplings at about eight years of age. By this age competition has reduced numbers from perhaps 1,000,000 germinants to 5,000 saplings per hectare and the saplings are about 6-10 metres tall.

Net nutrient demand is highest during this period (O'Connell and Menage 1982).

Juvenile

The juvenile stage begins with crown closure and is characterised by a period of intense intra-specific competition which results in the emergence at the end of this stage of about 400-500 dominant and co-dominant trees from an original 5000 individuals at the start of the period. Current annual volume increment peaks towards the end of this period.

The juvenile stage ends when the stand is about 25-30 years old and the crown shape of the dominant and co-dominant trees has begun to alter from the previous conical form to a more rounded shape. This is due to the retention of branches at the base of the crown as they become too large to be shed cleanly from the bole. The appearance of the stand changes at the end of the period due to the shedding of the lower dead branches causing the stand to take on the more open appearance of the 'pole' stand.

By the end of the juvenile stage and without further fire disturbance the understorey also changes in character. Much of the short lived 'fire weed' species have died and together with the leaf litter and coarser debris, form a partially suspended, well aerated dead litter layer which is still accumulating. There is a sparse mid-layer of green understorey canopy at about 4 metres. Changes in understorey composition over time have been illustrated by Christensen (1972).

Immature

[2] G. Butcher, Department of Conservation and Land Management, Hayman Road, Como, WA

Competition continues throughout the immature stage though at a less rapid rate than in the juvenile stage. Dominants and co-dominants reduce from about 300 to 150 stems per hectare. Small gaps in the canopy resulting from the death of individual trees are quickly re-occupied by the vigorously growing adjacent trees. Net basal area increases till about 50 years of age from which time it fluctuates about a plateau according to the limitations of the site and periodic mortality events (Rayner 1992a).

Height growth continues at a slower rate but the dominants achieve 90% of their final height by the time they are 60-70 years old (Rayner 1992b).

Although bole length continues to increase, the lower dead branches are no longer shed cleanly. The dead branches are now shed by first breaking off several centimetres from the bole and then either rotting away or being overgrown as the bole diameter increases (Jacobs 1955). There is opportunity for the development of hollows to be initiated at this stage where larger branches are involved. The 'shaping' branches become larger and more persistent towards the end of the stage.

This stage ends when individual tree crowns have reached the size above which they are no longer capable of expansion, regardless of the space available. This occurs at about 120 years of age.

In the absence of further fire disturbance the understorey becomes more open. The highly suspended litter of the juvenile stage has broken down, a few long lived individuals of shrub species (such as *Chorilaena quercifolia*) remain, and dry matter (<25 mm) accumulation has stabilised at levels in excess of 50 tonnes per hectare (McCaw unpublished). The situation beyond 65 years is a matter of speculation since this is the longest (documented) unburnt site known to the authors.

Mature

The rapid growth stage ends as the physical limitations of each individual are reached. They can neither occupy more of the site nor increase their crown dimensions; only tree diameter will steadily increase. Intra-specific competition is much reduced and the stand enters a period of relative stability.

The crown has reached its maximum size (about 20-25 metres diameter) and permanent or shaping branches form the outline of the crown. As the extremities of the primary crown become less efficient, epicormic shoots develop within the crown (Jacobs 1955). The branches will periodically break, resulting in replacement through epicormic development without changing crown dimensions (Mackowski 1984). Individuals will slowly decline in vigour, although the growth rate of a dominant tree is largely maintained (Rayner 1992a). Where an individual tree dies, the remaining trees are unable to take up the available growing space, leaving a break in the canopy and allowing regeneration to occur. In many other non-eucalypt forest types this equates to the time when the regeneration of tolerant species will be released and begin to develop (Oliver & Larson 1990).

The majority of hollow development in crowns is probably initiated early in this stage as large shaping branches break and larger branch stubs overgrow. As with jarrah (Inions *et al.* 1989), their development will be accelerated by wildfire.

The end of this stage occurs when the stand is about 200-250 years old.

Senescent

This is the stage of rapid decline in health, vigour and the number of original trees. The trees have a reduced control over the site. The process of crown renewal slows and, as major branch

components are lost, they are replaced by epicormics lower on the branch or bole of the tree. This damage also provides entry points for fungi, which further weaken the tree's structure. In effect, the trees are in decline and will slowly break up. How much of this decline is due simply to the ravages of age and how much to the probability that trees of this age have been subjected to a greater number of damaging events is difficult to determine. However, even relatively young trees may become 'senescent' if severely injured and unable to support their existing structure following such an event.

Previous studies of tree ages (Rayner 1992a) have shown that few living individuals are known to exist beyond 350 years. The age distribution of large living individuals in the forest indicates a rapid decline in numbers between 200 and 280 years, followed by a more gradual reduction till there are only a few rare individuals recorded at 350 years.

Opportunities for regeneration increase as the control of the site by the overstorey diminishes with the increasing death rate of individuals in the stand. In the absence of severe 'stand replacing' disturbance this may result in small patches of regrowth becoming established in small gaps in the canopy if suitable regeneration conditions exist. This may then result in the development of a multi-layered forest. This is the beginning of a new establishment stage overlapping with the senescent stage.

In contrast with some forests, karri has no tolerant climax species waiting to eventually replace it in the absence of disturbance. Furthermore, life-long absence of disturbance from fire is inconceivable in this climate (Underwood 1978). This model is based on the presumption that fire at least of an intensity to create seed bed conditions will occur several times during the natural life span of karri. In the final phase of development there is therefore no late seral phase of alternate species but simply old karri forest which given even modest fire disturbance at that stage will be replaced by a new generation of karri forest."

10.2. Jarrah

This description is an extract from CALM (1992).

"The development stages of jarrah have been described by various authors, (Kessell 1921, Stoate & Helms 1938, Abbott & Loneragan 1984). Jacobs (1955) provides a more general description of the development stages in eucalypts.

Since the jarrah forest is essentially unevenly aged, the development stages refer to individual trees. In any one hectare of forest there could be stands of trees with different proportions of trees at different stages of development.

The development stages described below refer specifically to the jarrah forest, but marri has a similar pattern of development.

Stage 1: Establishment

This stage of development includes the seedling stage (less than one year, usually with cotyledons present); lignotuberous seedling stage (older than one year, cotyledons absent, one stem with a lignotuberous swelling); seedling coppice stage (obvious lignotuber, multiple shoots); and the ground coppice stage (multiple shoots less than 1.5m in height). The establishment stage finishes when the dynamic coppice shoot exceeds 2m. This stage of development can be completed within five years, but may extend over decades depending on the competition from the overstorey and fire regimes.

Stage 2: Juvenile

The juvenile stage is characterised by a crown of small branches, all of which will be shed as the tree gains height. Branches are shed from the base of the crown, and the formation of a clear bole is commenced. This juvenile, or primary crown usually contains about four years of growth and vigorous crowns are conical in shape. This stage ends when the diameter (d.o.b.) reaches 15cm, at an age of between 15-30 years.

Stage 3: Immature

This stage is described by trees between 15 cm and 45 cm in diameter. During this stage a secondary crown develops. The upper crown resembles that of the juvenile stage. The semi-persistent lower branches form leaf-bearing juvenile crown units which give eucalypt crowns their characteristic appearance. The lateral spread of the crown commences during this stage, which concludes at between 40-70 years.

Stage 4: Mature

The mature stage is reached when the diameter reaches 45cm and concludes when it reaches 100 cm.

During this stage, large persistent branches develop. Semi-permanent crown units grow from the main stem and the persistent branches. These persistent branches are also known as the shaping branches. As the primary crown pushes outwards, it may be weighed downwards, although this is less so in jarrah than in other eucalypts. Epicormic shoots may be evident towards the end of the mature stage, and dead branches are common in the crown. This stage of development concludes at between 120 to 250 years.

Stage 5: Senescent

The large mature (or senescent) stage describes trees greater than 100 cm in diameter. During this stage the branches of the primary crown break or die and are replaced by branches which develop from dormant buds on the trunk (epicormic branches).

The epicormic branches are never as efficient as the branches of the primary crown. They may live for a few years or decades, then break and be replaced. This process may be repeated many times before eventual death.

Burrows" (1991) analysis of the ages of large jarrah and marri trees indicates that relatively few exceed an age of 360 years."

For the purposes of analysis in this report, establishment was defined as gaps created from 0-4 years ago; Juvenile, gaps 5-20 years ago; Immature, stands first harvested from 20-70 years ago with an upper strata density of <20%; Mature, all other jarrah forest. Separate figures are given for a change in age of the onset of maturity from 70 to 120 years.

11. Appendix 2 Tables

Table 1. Area and percentage of mature forest and native vegetation in formal and informal reserves within each forest block at December 2000. District names have not been updated to reflect recent administrative changes.

Criterion 1		Criterion 2		Criterio 3	
District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
South West Capes - Hamelin	0	Dwellingup - Marradong	1%	Dwellingup - Marradong	1%
Blackwood - Byron	11	Blackwood - Jacobs	1%	Dwellingup - Amphion	2%
Dwellingup - Marradong	20	Mornington - Proprietary	1%	Mundaring - Gordon	2%
Mornington - Proprietary	33	Dwellingup - Bombala	2%	Dwellingup - Curara	2%
Blackwood - Jacobs	35	Dwellingup - White	2%	Dwellingup - Quindanning	3%
Dwellingup - Banksiadale	36	Mundaring - Gordon	2%	Dwellingup - Banksiadale	3%
South West Capes - Punch	37	Mornington - Leach	2%	Dwellingup - White	3%
Dwellingup - Quindanning	47	Dwellingup - Amphion	2%	Blackwood - Jacobs	3%
Dwellingup - Bombala	52	Dwellingup - Banksiadale	2%	South West Capes - Punch	3%
Dwellingup - Amphion	57	Dwellingup - Torrens	2%	Dwellingup - Clinton	4%
Dwellingup - White	59	Dwellingup - Quindanning	2%	Blackwood - Upper Capel	4%
South West Capes - Redgate	71	Dwellingup - O'Neill	2%	Dwellingup - Bombala	4%
Mornington - Centaur	73	Mornington - Shotts	2%	Mundaring - Mundlimup	4%
Mundaring - Gordon	75	South West Capes - Punch	2%	Dwellingup - Taree	4%
Mornington - Shotts	76	Dwellingup - Curara	2%	Blackwood - Byron	4%
Dwellingup - Torrens	77	Mornington - Waterous	3%	Mundaring - Lesley	4%
Blackwood - Tanjanerup	85	Mundaring - Cobiac	3%	South West Capes - Hopkins	4%
Mundaring - Cobiac	88	South West Capes - Hamelin	3%	Mornington - Ernest	4%
Blackwood - Mc Alinden	89	Dwellingup - Taree	3%	Dwellingup - O'Neill	5%
Mundaring - Lesley	100	Mundaring - Mundlimup	3%	Dwellingup - Holyoake	5%
Mundaring - Mundlimup	103	Mundaring - Reservoir	3%	Mornington - Hadfield	5%
South West Capes - Biljedup	104	Mornington - Centaur	3%	Mornington - Waterous	5%
Dwellingup - Kennedy	107	Dwellingup - Kennedy	3%	Dwellingup - Pindalup	5%
South West Capes - Hopkins	108	Blackwood - Munro	3%	Mundaring - Cobiac	5%
Dwellingup - Curara	110	Mundaring - Lesley	3%	Blackwood - Donnybrook	5%
Blackwood - Munro	114	Mornington - Edward	3%	South West Capes - Millbrook	5%
Mundaring - Reservoir	114	Blackwood - Tanjanerup	3%	Mornington - Batalling	5%
Mornington - Waterous	116	Dwellingup - Scott	3%	Mornington - Morgan	5%
Mornington - Edward	117	Dwellingup - Clinton	3%	Blackwood - Munro	5%
Dwellingup - Urbrae	121	Mornington - Driver	3%	South West Capes - Kingia	5%
Mornington - Leach	125	Mornington - Bristol	4%	Blackwood - Woop Woop	6%
Dwellingup - O'Neill	126	Blackwood - Upper Capel	4%	Mornington - Edward	6%
Dwellingup - Taree	127	Dwellingup - Holyoake	4%	Blackwood - Hunt	6%
Blackwood - Donnybrook	131	Mornington - Fleays	4%	Dwellingup - Inglehope	6%
Dwellingup - Clinton	137	Mundaring - Brady	4%	South West Capes - Mc Gregor	6%
Mornington - Western	141	South West Capes - Hopkins	4%	Mornington - Arcadia	6%
Dwellingup - Scott	141	Blackwood - Byron	4%	Blackwood - Towers	6%
Mornington - Boyanup	149	Mundaring - Occidental	4%	Blackwood - Mc Alinden	6%
Mornington - Batalling	152	Dwellingup - Urbrae	4%	Dwellingup - Scott	6%
* Impacts on karri forest					

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
South West Capes - Mc Gregor	152	Mornington - Hoffman	4%	Blackwood - Mc Corkhill	6%
Mundaring - Canning	153	Mornington - Morgan	4%	Mundaring - Reservoir	6%
South West Capes - Happy Valley	162	Blackwood - Mc Alinden	4%	Manjimup - Yardup	6%
Dwellingup - Holyoake	163	Mornington - Nundedine	4%	South West Capes - Happy Valley	6%
Mornington - Morgan	167	Mornington - Godfrey	4%	Mornington - Kent	6%
Dwellingup - Waroona	168	Dwellingup - Cameron	4%	Blackwood - Catterick	6%
South West Capes - Cape Clairault	170	Mornington - Ernest	4%	Dwellingup - Hedges	6%
Manjimup - Diamond 1 *	174	Manjimup - Yardup	4%	Mornington - Fleays	6%
Mornington - Driver	180	Blackwood - Hunt	4%	Mornington - Driver	6%
Blackwood - Upper Capel	183	Dwellingup - Pindalup	4%	Dwellingup - Wearne	6%
South West Capes - Kingia	183	Mornington - Hadfield	4%	Mornington - Hamilton	6%
Mornington - Bristol	189	Dwellingup - Waroona	4%	South West Capes - Maryvale	6%
Mornington - Arcadia	191	Mornington - Western	4%	Dwellingup - Cameron	7%
Dwellingup - Pindalup	196	Mornington - Bowelling	4%	Blackwood - Argyle	7%
Manjimup - Yardup	199	South West Capes - Millbrook	5%	Mundaring - Brady	7%
Mundaring - Churchlands	205	Mornington - Batalling	5%	Mundaring - Occidental	7%
Mornington - Fleays	205	Mornington - Hamilton	5%	Mundaring - Flint	7%
Dwellingup - Samson	211	Blackwood - Woop Woop	5%	Mornington - Shotts	7%
Blackwood - Towers	212	Mundaring - Balmoral	5%	Mundaring - Nockine	7%
Blackwood - Mc Corkhill	222	Blackwood - Donnybrook	5%	Dwellingup - Torrens	7%
Blackwood - Woop Woop	227	South West Capes - Mc Gregor	5%	South West Capes - Quilergup	7%
Mornington - Hadfield	228	Dwellingup - Inglehope	5%	Dwellingup - Saddleback	7%
Dwellingup - Cameron	232	Mundaring - Canning	5%	Mornington - Denham	7%
Mornington - Kent	238	South West Capes - Kingia	5%	Mornington - Hoffman	7%
Mornington - Nundedine	244	Mundaring - Flint	5%	Mundaring - Balmoral	7%
Mundaring - Carinyah	245	Blackwood - Sussex	5%	Mornington - Boyanup	7%
Mundaring - Occidental	246	Mornington - Kent	5%	Mornington - Nundedine	7%
Blackwood - Hunt	248	Dwellingup - Wearne	6%	Blackwood - Sussex	7%
Blackwood - Sussex	248	Dwellingup - Samson	6%	Mornington - Centaur	8%
Mornington - Hoffman	250	Mornington - Arcadia	6%	Dwellingup - Waroona	8%
Dwellingup - Hedges	252	Dwellingup - Myara	6%	Mornington - Yabberup	8%
Mornington - Bowelling	259	Mornington - Cornwall	6%	Mornington - Sherwood	8%
Mornington - Ernest	263	Mundaring - Nockine	6%	Mornington - Cornwall	8%
Dwellingup - Marrinup	263	Blackwood - Towers	6%	Blackwood - Wilga	8%
Mornington - Hamilton	267	Blackwood - Mc Corkhill	6%	Blackwood - Kearney	8%
Mundaring - Brady	267	South West Capes - Happy Valley	6%	Blackwood - Tanjanerup	8%
South West Capes - Molloy	270	Blackwood - Catterick	6%	Dwellingup - Myara	8%
Dwellingup - Holmes	275	Manjimup - Yornup	6%	Mornington - Bristol	8%
Dwellingup - Saddleback	275	Dwellingup - Hedges	6%	Mornington - Hillman	8%
Manjimup - Yornup	279	South West Capes - Maryvale	6%	Manjimup – Lindsay *	9%
South West Capes - Yallingup	281	Blackwood - Argyle	7%	Mornington - Ross	9%
Manjimup - Yerramin	282	Dwellingup - Saddleback	7%	Dwellingup - Marrinup	9%
Pemberton - Lane	285	Mundaring - Churchlands	7%	Mundaring - Carinyah	9%
Dwellingup - Wilson	288	Blackwood - Kearney	7%	Blackwood - Jolly	9%
South West Capes - Millbrook	289	Mornington - Yabberup	7%	South West Capes - Boronia	9%
Manjimup - Mack	291	South West Capes - Quilergup	7%	Mornington - Godfrey	9%
* Impacts on karri forest					

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Dwellingup - Inglehope	294	Manjimup - Yerramin	7%	Mornington - Leach	9%
South West Capes - Maryvale	297	Mornington - Denham	7%	Dwellingup - Wilson	9%
Mundaring - Balmoral	301	Mornington - Boyanup	7%	South West Capes - Abba	9%
Manjimup - Dudijup	303	Blackwood - Wilga	8%	Dwellingup - Urbrae	10%
South West Capes - Ellenbrook	317	South West Capes - Molloy	8%	Dwellingup - Bannister	10%
Dwellingup - Gyngoorda	319	Mundaring - Carinyah	8%	Dwellingup - Hakea	10%
Manjimup - Topanup	324	Manjimup – Lindsay *	8%	Dwellingup - Samson	10%
Dwellingup - Turner	324	South West Capes - Boronia	8%	Dwellingup - Turner	10%
Blackwood - Kearney	325	Blackwood - Jolly	8%	Dwellingup - Lang	10%
Dwellingup - Myara	325	Dwellingup - Wilson	8%	Manjimup - Topanup	10%
Mornington - Darrell	326	Pemberton - Treen Brook *	8%	Dwellingup - Wells	10%
South West Capes - Boronia	333	Mornington - Sherwood	8%	Mundaring - Churchlands	10%
Mornington - Cornwall	341	Mornington - Hillman	8%	Manjimup - Diamond 1 *	10%
Mornington - Sherwood	353	Mornington - Ross	8%	Manjimup - Yeticup	10%
Manjimup - Lindsay	358	Dwellingup - Lang	8%	Blackwood - Harrington	11%
Mornington - Hillman	364	Dwellingup - Marrinup	8%	Dwellingup - Kennedy	11%
Pemberton - Treen Brook	367	Dwellingup - Wells	8%	Mornington - Proprietary	11%
Blackwood - Central	374	Mornington - Arklow	8%	Dwellingup - Gyngoorda	11%
Walpole - Ficifolia	379	South West Capes - Abba	8%	Mundaring - Leona	11%
South West Capes - Quilergup	384	Dwellingup - Bannister	9%	Manjimup – Solai *	12%
Mornington - Arklow	385	Manjimup - Yeticup	9%	Pemberton - Treen Brook *	12%
Manjimup - Mersea	389	Mundaring - Leona	9%	Mornington - Arklow	12%
Blackwood - Jolly	392	Dwellingup - Turner	9%	Manjimup - Yerramin	12%
Manjimup - Coonan	394	Mundaring - Clare	9%	Blackwood - Warner	12%
Mornington - Yabberup	399	Dwellingup - Gyngoorda	9%	Manjimup - Yornup	13%
Blackwood - Sollya	402	Dwellingup - Hakea	9%	Manjimup - Dudijup	13%
Blackwood - Catterick	403	Manjimup - Coonan	10%	Mundaring - Barton	13%
Manjimup - Solai	404	Manjimup - Topanup	10%	Blackwood - Jalbarragup	14%
Mornington - Dardanup	407	Mundaring - Sawyers	10%	Mornington - Darrell	14%
Walpole - Burnside	409	Manjimup - Diamond 1 *	10%	Mornington - Lowden	14%
Mundaring - Nockine	415	Blackwood - Ellis Creek	10%	Blackwood - Ellis Creek	14%
Manjimup - Thorton	419	Manjimup - Dudijup	10%	Mundaring - Sawyers	14%
Mundaring - Gorrie	422	Blackwood - Harrington	11%	Manjimup - Cardac	14%
South West Capes - Leeuwin	424	Mornington - Darrell	11%	Mornington - Western	14%
Mundaring - Flint	436	Mundaring - Barton	11%	Manjimup - Coonan	14%
Mundaring - Clare	436	Manjimup - Mersea	11%	Mundaring - Chandler	14%
Dwellingup - Wells	436	Manjimup – Solai *	11%	Mundaring - Gorrie	14%
Dwellingup - Whittaker	444	Mundaring - Gorrie	12%	Dwellingup - Whittaker	14%
Dwellingup - Hakea	457	Dwellingup - Whittaker	12%	Mornington - Bowelling	16%
Mornington - Denham	458	Blackwood - Warner	12%	Mundaring - Canning	16%
Manjimup - Carter	464	Manjimup – Andrew *	12%	South West Capes - Mowen	16%
Mornington - Godfrey	464	South West Capes - Treeton	12%	Mornington - Mungalup	16%
South West Capes - Abba	468	Manjimup - Carter	12%	Manjimup – Mack *	16%
Manjimup - Yeticup	472	Manjimup - Thorton	12%	South West Capes - Treeton	16%
* Impacts on karri forest					

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Manjimup - Cardac	482	Mundaring - Gibbs	13%	Manjimup - Carter	16%
South West Capes - Witchcliffe	485	Mundaring - Chandler	13%	Mundaring - Clare	17%
Pemberton - Big Brook	488	Blackwood - Jalbarragup	13%	Manjimup – Channybearup *	17%
Mundaring - Barton	494	Blackwood - Gregory	13%	Manjimup - Thorton	17%
Manjimup - Andrew	503	South West Capes - Mowen	13%	Mundaring - Gibbs	17%
Manjimup - Netic	520	Mornington - Lowden	13%	Manjimup – Andrew *	17%
Manjimup - Mooralup	523	Manjimup - Cardac	14%	Blackwood - Sollya	17%
Blackwood - Kerr	535	Mornington - Mungalup	14%	Dwellingup - Holmes	18%
South West Capes - Conto	561	Manjimup – Mack *	14%	Manjimup - Yanmah	18%
Blackwood - Wilga	572	Manjimup - Yanmah	15%	Blackwood - Gregory	18%
Manjimup - Alco	573	Pemberton - Big Brook *	15%	Blackwood - Helms	18%
Mornington - Ross	581	Manjimup – Channybearup *	16%	Pemberton - Kinkin	19%
Mornington - Westralia	592	Blackwood – Sollya	17%	Pemberton - Big Brook *	19%
Dwellingup - Lang	593	Walpole - Burnside	17%	Manjimup - Mersea	19%
Pemberton - Quininup	596	Dwellingup - Holmes	17%	Dwellingup - George	19%
Pemberton - Warren	603	Blackwood - Beaton	18%	Blackwood - Kerr	19%
Manjimup - Yanmah	635	Manjimup - Meribup	18%	Blackwood - Beaton	20%
Mundaring - Leona	639	Blackwood - Helms	18%	Blackwood - Nelson	20%
Blackwood - Ellis Creek	645	Pemberton - Kinkin	18%	Mornington - Clarke	20%
Mornington - Lowden	646	Manjimup - Tone	18%	Blackwood - St John	20%
Blackwood - Jalbarragup	647	Dwellingup - George	19%	Manjimup - Meribup	20%
Blackwood - Argyle	652	Mornington - Clarke	19%	South West Capes - Molloy	21%
Mundaring - Kalamunda	654	Blackwood - Kerr	19%	Manjimup - Tone	22%
South West Capes - Treeton	654	Blackwood - St John	19%	Mornington - Bednall	22%
Pemberton - Diamond 2	662	Blackwood - Nelson	19%	Dwellingup - Tumlo	22%
Blackwood - Gregory	671	Mornington - Bednall	20%	Walpole - Burnside	22%
Blackwood - Warner	744	Mundaring - Ashendon	20%	Manjimup - Netic	22%
Manjimup - Graphite	749	Manjimup - Netic	21%	Manjimup - Mooralup	23%
Blackwood - Helms	758	Mornington - Palmer	21%	Manjimup - Dingup	23%
Mundaring - Zamia	762	Dwellingup - Duncan	21%	Blackwood - Preston	23%
Pemberton - Court	762	Manjimup - Alco	21%	Pemberton - Collins	23%
South West Capes - Bovell	785	Dwellingup - Tumlo	22%	Pemberton - Diamond 2	23%
Pemberton - Malimup	786	Pemberton - Collins	22%	Pemberton - Quininup	24%
Dwellingup - Wearne	799	Manjimup - Mooralup	22%	Blackwood - Barrabup	25%
Manjimup - Channybearup	801	Manjimup - Stoate	23%	Blackwood - Cambray	25%
Blackwood - Harrington	812	Mundaring - Churchman	23%	Pemberton - Lane	25%
Mundaring - Churchman	831	Manjimup - Dingup	23%	Dwellingup - Duncan	25%
Pemberton - Kinkin	838	South West Capes - Chapman	23%	Mundaring - Ashendon	25%
Mundaring - Illawarra	876	Blackwood - Preston	23%	Manjimup - Graphite	25%
Dwellingup - Howse	878	Pemberton - Diamond 2	23%	Manjimup - Lewin	26%
Dwellingup - Teesdale	892	Pemberton - Lane	23%	Mornington - Roseneath	26%
Mundaring - Sawyers	896	Manjimup - Kingston	23%	Manjimup - Stoate	26%
Pemberton - Babbington	899	Blackwood - Redgully	23%	South West Capes - Bovell	26%
* Impacts on karri forest					

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Dwellingup - Bannister	914	Pemberton - Quininup	24%	Blackwood - Greenbushes	26%
Pemberton - Collins	951	Blackwood - Cambray	24%	Mornington - Palmer	27%
Mundaring - Boyagarring	955	Manjimup - Graphite	24%	Blackwood - Redgully	27%
Mundaring - Chandler	958	Blackwood - Barrabup	24%	South West Capes - Chapman	27%
Manjimup - Quillben	970	Manjimup - Lewin	24%	Manjimup - Kingston	27%
Manjimup - Gordon	970	Mornington - Roseneath	25%	Pemberton - Warren	27%
Mornington - Bednall	972	Blackwood - Greenbushes	26%	Manjimup - Wheatley	29%
Manjimup - Glenlynn	990	Walpole - Challar	26%	Mundaring - Churchman	29%
South West Capes - Yelverton	1016	South West Capes - Bovell	26%	Blackwood - Mullalyup	30%
Manjimup - Wheatley	1018	Pemberton - Warren	26%	Pemberton - Brockman	30%
Mundaring - Ashendon	1045	Pemberton - Court	28%	Mundaring - Qualen	31%
Blackwood - Dalgarup	1062	Manjimup - Wheatley	28%	Pemberton - Court	31%
Manjimup - Lewin	1065	Mundaring - Qualen	29%	Blackwood - Dalgarup	31%
Blackwood - St John	1065	Pemberton - Brockman	29%	Manjimup - Gordon	31%
Mornington - Mungalup	1081	Mornington - Dardanup	30%	Manjimup - Quillben	31%
Mornington - Clarke	1094	Manjimup - Gordon	30%	Blackwood - Rosa	31%
Walpole - Swarbrick	1114	Blackwood - Mullalyup	30%	Blackwood - Blackwood	32%
Blackwood - Ryall	1114	Blackwood - Blackwood	30%	Walpole - Challar	32%
Blackwood - Nelson	1121	Walpole - Mattaband	30%	Dwellingup - Teesdale	33%
Dwellingup - George	1133	Blackwood - Dalgarup	31%	Mundaring - Flynn	33%
Manjimup - Dingup	1142	Mundaring - Flynn	31%	Walpole - Mattaband	34%
Manjimup - Barlee	1176	Blackwood - Rosa	31%	Mornington - Dardanup	34%
Blackwood - Redgully	1198	Manjimup - Quillben	31%	Mundaring - Talbot	35%
South West Capes - Forest Grove	1213	Pemberton - Poole	32%	Manjimup - Iffley	35%
South West Capes - Chester	1224	Mundaring - Talbot	32%	Manjimup - Barlee	36%
Blackwood - Preston	1233	Mundaring - Kalamunda	33%	Pemberton - Poole	36%
Blackwood - Barrabup	1235	Dwellingup - Teesdale	33%	Manjimup - Easter	36%
Blackwood - Bidella	1241	Manjimup - Barlee	33%	South West Capes - Witchcliffe	37%
Blackwood - Beaton	1247	Manjimup - Iffley	33%	Pemberton - Nairn	37%
South West Capes - Boranup	1275	South West Capes - Rapids	34%	Mundaring - Kalamunda	37%
Blackwood - Hovea	1284	South West Capes - Chester	34%	Dwellingup - Boonerring	37%
Dwellingup - Yarragil	1294	Dwellingup - Boonerring	35%	South West Capes - Rapids	37%
Manjimup - Stoate	1303	South West Capes - Witchcliffe	35%	Manjimup - Alco	37%
Manjimup - Kingston	1311	Pemberton - Nairn	35%	Dwellingup - Yarragil	38%
Pemberton - Broke	1315	South West Capes - Schroeder	35%	Manjimup - Weinup	38%
Walpole - Perillup	1327	Mundaring - Sullivan	35%	Dwellingup - Federal	39%
South West Capes - Mowen	1329	Manjimup - Easter	36%	Mundaring - Serpentine	39%
Blackwood - Bottlebrush	1337	Dwellingup - Federal	36%	Pemberton - Crowea	39%
Walpole - Giants	1347	Blackwood - Canebreak	37%	Pemberton - Sutton	39%
Pemberton - Cleave	1353	Pemberton - Crowea	37%	Blackwood - Canebreak	40%
Blackwood - Cambray	1360	Mundaring - Serpentine	37%	Mundaring - Sullivan	41%
Manjimup - Tone	1372	Manjimup - Weinup	37%	Mundaring - Geddes	41%
Manjimup - Gray	1383	Dwellingup - Yarragil	38%	Manjimup - Warrup	42%

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Dwellingup - Tumlo	1392	Mundaring - Beraking	38%	Manjimup - Gray	42%
Mornington - Roseneath	1395	Mundaring - Geddes	39%	Blackwood - Hovea	43%
Pemberton - Muirillup	1435	Pemberton - Sutton	39%	Mundaring - Randall	43%
Manjimup - Easter	1443	Mundaring - Randall	39%	Mundaring - Karnet	43%
Walpole - Challar	1447	South West Capes - Boranup	39%	Dwellingup - Nanga	43%
Manjimup - Weinup	1471	Walpole - Weld	40%	Mornington - Chalk	43%
Blackwood - Gayndah	1475	Manjimup - Gray	40%	Mundaring - Beraking	44%
Walpole - Willmott	1486	Manjimup - Warrup	40%	Dwellingup - Wandering	44%
Dwellingup - Wandering	1550	Pemberton - Muirillup	41%	South West Capes - Schroeder	45%
Walpole - Mossop	1558	Mundaring - Karnet	41%	Mundaring - Windsor	46%
Mundaring - Karnet	1569	Dwellingup - Wandering	42%	Dwellingup - Howse	47%
Dwellingup - Duncan	1569	Dwellingup - Nanga	42%	Walpole - Weld	48%
Blackwood - Blackwood	1570	Blackwood - Hovea	42%	Pemberton - Dombakup	48%
Blackwood - Greenbushes	1576	Mornington - Chalk	43%	Pemberton - Boorara	48%
Walpole - Mattaband	1576	South West Capes - Leeuwin	43%	Mundaring - Dale	48%
Pemberton - Dordagup	1592	Pemberton - Boorara	43%	Mornington - Westralia	49%
Walpole - Harewood	1616	Mundaring - Windsor	43%	Mundaring - Cooke	50%
Walpole - Nuyts	1624	Mundaring - Dale	44%	Mundaring - Russell	50%
Dwellingup - Nanga	1632	Pemberton - Dombakup	44%	Mornington - Bell	50%
Manjimup - Strickland	1653	Blackwood - Central	46%	Pemberton - Flybrook	50%
Mornington - Palmer	1659	Pemberton - Babbington	47%	Pemberton - Muirillup	52%
Mundaring - Serpentine	1661	Dwellingup - Howse	47%	Walpole - Lochart	53%
Pemberton - Brockman	1669	Pemberton - Flybrook	48%	South West Capes - Chester	54%
Pemberton - Nairn	1685	Mornington - Westralia	48%	Dwellingup - Young	55%
Walpole - Quindinillup	1708	Mundaring - Cooke	48%	Blackwood - Butler	55%
Pemberton - Callcup	1713	Blackwood - Bottlebrush	49%	Blackwood - Bottlebrush	56%
Pemberton - Northcliffe	1731	Mundaring - Russell	50%	Walpole - Mindanup	57%
Manjimup - Gobblecannup	1754	Blackwood - Storry	50%	Dwellingup - Plavins	58%
Dwellingup - Federal	1767	Mornington - Bell	50%	Dwellingup - Keats	58%
Walpole - Keystone	1774	Pemberton - Cleave	50%	Mundaring - Victoria	58%
Manjimup - Iffley	1784	Walpole - Lochart	51%	Blackwood - Central	61%
Mundaring - Gibbs	1810	South West Capes - Conto	52%	Manjimup - Glenlynn	61%
Manjimup - Meribup	1881	Blackwood - Butler	52%	South West Capes - Adelaide	61%
Blackwood - Storry	1881	Walpole - Swarbrick	53%	Pemberton - Cleave	61%
Mundaring - Helena	1888	Pemberton - Northcliffe	54%	Pemberton - Dordagup	61%
Pemberton - Trafalgar	1938	Pemberton - Gardner	54%	Manjimup - Strickland	62%
Walpole - Deep	1955	Walpole - Mindanup	55%	Pemberton - Shannon	62%
Blackwood - Beaufortia	1986	South West Capes - Adelaide	55%	Pemberton - Murtin	62%
Walpole - Pardelup	2045	Walpole - Giants	55%	Walpole - Giants	64%
South West Capes - Chapman	2046	Dwellingup - Young	55%	Blackwood - Storry	65%
Walpole - Spring	2049	Dwellingup - Keats	57%	Pemberton - Northcliffe	65%
Dwellingup - Young	2051	Mundaring - Victoria	57%	Mundaring - Helena	66%
Walpole - Camballup	2079	Dwellingup - Plavins	57%	Walpole - Swarbrick	66%

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Walpole - London	2111	Pemberton - Murtin	59%	Pemberton - Babbington	66%
Mundaring - Beraking	2121	Walpole - Keystone	60%	Dwellingup - Park	67%
Blackwood - Canebreak	2141	Pemberton - Shannon	60%	Mundaring - Gunapin	67%
Walpole - Dawson	2167	Pemberton - Dordagup	60%	South West Capes - Boranup	67%
Dwellingup - Keats	2174	Manjimup - Glenlynn	60%	Dwellingup - Pascoe	67%
Mornington - Lennard	2184	Manjimup - Strickland	61%	Mundaring - Zamia	67%
Pemberton - Maringup	2195	Mundaring - Helena	63%	Mornington - Bennelaking	69%
Pemberton - Chesapeake	2201	Mundaring - Gunapin	63%	Mornington - Gervasse	69%
Blackwood - Rosa	2204	Walpole - Wye	64%	Walpole - Spring	70%
Pemberton - Gardner	2222	Dwellingup - Park	66%	Walpole - Wye	71%
Mundaring - Qualen	2277	Mundaring - Zamia	67%	Blackwood - Bidella	71%
Manjimup - Warrup	2283	Dwellingup - Pascoe	67%	Manjimup - Beavis	71%
Dwellingup - Park	2284	Blackwood - Moonah	67%	Mornington - Goonac	72%
Walpole - Weld	2288	Walpole - Deep	68%	Pemberton - Gardner	72%
Walpole - Inlet	2308	Walpole - Spring	68%	Pemberton - Carey	72%
Blackwood - Mullalyup	2309	Blackwood - Bidella	68%	Blackwood - Moonah	72%
Pemberton - Boorara	2324	Mornington - Bennelaking	69%	Walpole - Keystone	72%
Pemberton - Poole	2331	Mornington - Gervasse	69%	Mornington - Surface	73%
Blackwood - Blythe	2357	Manjimup - Beavis	70%	Mornington - Stockyard	74%
Walpole - Table Hill	2388	Mornington - Surface	71%	Walpole - Deep	75%
Walpole - O'Donnell	2412	Mornington - Goonac	72%	Blackwood - Camballan	75%
Walpole - Lochart	2423	Pemberton - Carey	72%	Mundaring - Illawarra	77%
Dwellingup - Pascoe	2498	Walpole - Mossop	72%	Manjimup - Corbal	77%
Pemberton - Flybrook	2506	Blackwood - Blythe	73%	Blackwood - Blythe	79%
Pemberton - Charley	2511	Pemberton - Maringup	73%	Mornington - Nalyerin	79%
Walpole - Mindanup	2511	Mornington - Stockyard	74%	Manjimup - Walcott	79%
Pemberton - Chudalup	2542	Mundaring - Illawarra	75%	Manjimup - Gobblecannup	79%
Pemberton - Crowea	2593	Manjimup - Boyndaminup	75%	South West Capes - Leeuwin	80%
Pemberton - Shannon	2617	Blackwood - Camballan	75%	Blackwood - Noggerup	80%
Mornington - Bell	2633	Manjimup - Gobblecannup	75%	Manjimup - Boyndaminup	80%
Pemberton - Yeagerup	2642	Manjimup - Corbal	76%	Mornington - Davis	80%
Walpole - Hay	2645	Mornington - Nalyerin	76%	Walpole - Rocky	80%
Walpole - Surprise	2666	Blackwood - Telerah	77%	Blackwood - Telerah	81%
Walpole - Trent	2666	Blackwood - Gayndah	78%	Walpole - Thomson	81%
Manjimup - Bolbelup	2689	Manjimup - Walcott	78%	Pemberton - Westcliffe	81%
Pemberton - Jasper	2689	Walpole - Dawson	79%	Mundaring - Boyagarring	82%
South West Capes - Rapids	2697	Pemberton - Westcliffe	79%	Walpole - Mossop	83%
Manjimup - Winnejup	2699	Walpole - Rocky	80%	South West Capes - Conto	83%
Blackwood - Blackpoint	2764	Blackwood - Noggerup	80%	Mornington - Lennard	83%
Walpole - Romance	2799	Mornington - Davis	80%	Walpole - Dawson	83%
Walpole - Powley	2827	Walpole - Thomson	81%	South West Capes - Whicher	84%
Walpole - Wye	2841	Mundaring - Boyagarring	81%	Mornington - Muja	84%
Mornington - Bennelaking	2841	Pemberton - Trafalgar	81%	Pemberton - Jane	84%

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Dwellingup - Boonerring	2889	Pemberton - Jane	82%	Mornington - Trees	84%
Walpole - Walpole	2914	Mornington - Lennard	82%	Manjimup - Winnejup	86%
Dwellingup - Plavins	2929	Walpole - Burnett	83%	Pemberton - Hawke	87%
Walpole - Frankland	2939	Mornington - Muja	83%	Walpole - Burnett	87%
South West Capes - Schroeder	2982	Mornington - Trees	83%	Pemberton - Trafalgar	87%
Mundaring - Cooke	3019	South West Capes - Whicher	83%	Blackwood - Blackpoint	87%
Walpole - Burnett	3021	Walpole - Inlet	84%	Blackwood - Ryall	88%
Blackwood - Noggerup	3031	Walpole - Walpole	84%	Walpole - Walpole	88%
Pemberton - Dixie	3032	Walpole - Nuyts	85%	Blackwood - Gayndah	88%
Mundaring - Victoria	3040	Blackwood - Blackpoint	85%	Walpole - Frankland	89%
Mundaring - Talbot	3107	Pemberton - Hawke	86%	Pemberton - Maringup	89%
Mundaring - Windsor	3114	Manjimup - Winnejup	86%	Blackwood - Hilliger	89%
Pemberton - Yate	3196	Pemberton - Dixie	86%	Pemberton - O'Sullivan	90%
Manjimup - Poorginup	3225	Blackwood - Hilliger	87%	Walpole - Wattle	91%
Manjimup - Beavis	3255	Walpole - Pardelup	87%	Walpole - Pardelup	91%
Walpole - Thomson	3285	Blackwood - Ryall	88%	Pemberton - Giblett	91%
Walpole - Collis	3313	Walpole - Frankland	88%	Mornington - Yourdamung	92%
Manjimup - Corbal	3405	Pemberton - O'Sullivan	88%	Mundaring - Lupton	92%
Blackwood - Butler	3411	Walpole - Ficifolia	90%	Manjimup - Chitelup	92%
Blackwood - Telerah	3414	Walpole - Ordnance	90%	Walpole - Ordnance	92%
Walpole - Peak	3451	Mornington - Yourdamung	90%	Mornington - Stene	93%
Pemberton - Sutton	3453	Walpole - Wattle	91%	Pemberton - Dixie	93%
Walpole - Clear Hills	3468	Pemberton - Chesapeake	91%	Blackwood - Darradup	94%
Walpole - Northumberland	3471	Pemberton - Giblett	91%	Pemberton - Curtin	94%
Walpole - Rate	3494	Manjimup - Chitelup	92%	Manjimup - Dwalgan	94%
Manjimup - Walcott	3508	Mundaring - Lupton	92%	South West Capes - Bramley	95%
Walpole - Gully	3512	Mornington - Stene	92%	Manjimup - Boyicup	95%
Pemberton - Giblett	3536	Walpole - Harewood	93%	South West Capes - Hamelin	95%
Pemberton - Hawke	3556	Pemberton - Malimup	93%	Walpole - Nuyts	95%
South West Capes - Bramley	3563	Blackwood - Darradup	93%	Walpole - Harewood	96%
Blackwood - Moonah	3597	Pemberton - Curtin	93%	Manjimup - Poorginup	96%
Manjimup - Boyndaminup	3660	Pemberton - Chudalup	94%	Pemberton - Chesapeake	96%
Mornington - Davis	3670	Manjimup - Dwalgan	94%	Manjimup - Moopinup	96%
Pemberton - Dombakup	3672	South West Capes - Cape Clairault	95%	Walpole - Karara	97%
Mundaring - Randall	3686	Manjimup - Boyicup	95%	Walpole - Inlet	97%
Walpole - Soho	3690	South West Capes - Bramley	95%	Manjimup - Yackelup	97%
Mornington - Goonac	3717	Walpole - Karara	96%	Walpole - Sharpe	98%
South West Capes - Adelaide	3736	Manjimup - Poorginup	96%	South West Capes - Forest Grove	98%
Walpole - Mitchell	3749	Manjimup - Moopinup	96%	Blackwood - Hester	98%
Manjimup - Balban	3788	Walpole - Sharpe	97%	Manjimup - Keninup	98%
Walpole - Amarillup	3788	Pemberton - Broke	97%	Pemberton - Charley	98%
Mundaring - Sullivan	3808	Pemberton - Callcup	97%	Walpole - Long	98%
Mornington - Surface	3840	Pemberton - Charley	97%	Manjimup - Chariup	99%

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Walpole - Karara	3848	Manjimup - Yackelup	97%	Manjimup - Camelar	99%
Pemberton - Carey	3857	Walpole - Pingerup	97%	Pemberton - Chudalup	99%
Walpole - Wattle	3912	South West Capes - Forest Grove	98%	Walpole - Hiker	99%
Walpole - Denbarker	4023	Blackwood - Hester	98%	Walpole - Pingerup	99%
Walpole - Styx	4029	Walpole - Long	98%	Walpole - Mitchell	99%
Pemberton - Westcliffe	4034	Manjimup - Keninup	98%	South West Capes - Cape Clairault	99%
Walpole - Long	4060	Walpole - Mitchell	98%	Walpole - Ficifolia	99%
Pemberton - Murtin	4067	Walpole - O'Donnell	98%	Walpole - Johnston	99%
Walpole - Sharpe	4078	Manjimup - Chariup	98%	Pemberton - Callcup	99%
Walpole - Johnston	4099	Walpole - Hiker	99%	Walpole - O'Donnell	99%
Walpole - Roe	4114	South West Capes - Ellenbrook	99%	Walpole - Collis	99%
Mundaring - Geddes	4128	Manjimup - Camelar	99%	Walpole - Crossing	99%
Manjimup - Moopinup	4199	Walpole - Collis	99%	Walpole - Styx	99%
Mornington - Stockyard	4221	Walpole - Thames	99%	Walpole - Soho	99%
Mornington - Chalk	4269	Walpole - Styx	99%	Pemberton - Broke	99%
Mundaring - Gunapin	4273	Walpole - Johnston	99%	Manjimup - Talling	99%
Walpole - Ordnance	4278	Walpole - Soho	99%	Walpole - Thames	99%
Walpole - Thames	4314	Walpole - Crossing	99%	Blackwood - Ballan	100%
Manjimup - Dwalgan	4343	Manjimup - Talling	99%	Pemberton - Malimup	100%
Mornington - Gervasse	4388	Blackwood - Ballan	99%	Walpole - Trent	100%
Mornington - Muja	4413	Walpole - Trent	100%	Walpole - Roe	100%
Walpole - Denmark	4414	Walpole - Gully	100%	South West Capes - Ellenbrook	100%
Mornington - Yourdamung	4447	Walpole - Northumberland	100%	Walpole - Gully	100%
South West Capes - Whicher	4536	Walpole - Roe	100%	Walpole - Northumberland	100%
Mornington - Trees	4545	Pemberton - Jasper	100%	Pemberton - Jasper	100%
Walpole - Hiker	4596	Walpole - Surprise	100%	Walpole - Surprise	100%
Pemberton - Curtin	4615	Blackwood - Milyeannup	100%	Blackwood - Milyeannup	100%
Mundaring - Russell	4726	Manjimup - Yendicup	100%	Manjimup - Yendicup	100%
Pemberton - O'Sullivan	4778	Manjimup - Balban	100%	Manjimup - Balban	100%
Blackwood - Ballan	4950	Blackwood - Beaufortia	100%	Blackwood - Beaufortia	100%
Blackwood - Darradup	5035	Blackwood - Layman	100%	Blackwood - Layman	100%
Pemberton - Jane	5277	South West Capes - Biljedup	100%	South West Capes - Biljedup	100%
Mundaring - Dale	5282	South West Capes - Redgate	100%	South West Capes - Redgate	100%
Blackwood - Milyeannup	5290	South West Capes - Yallingup	100%	South West Capes - Yallingup	100%
Manjimup - Camelar	5314	South West Capes - Yelverton	100%	South West Capes - Yelverton	100%
Walpole - Rocky	5320	Manjimup - Bolbelup	100%	Manjimup - Bolbelup	100
Manjimup - Yendicup	5337	Pemberton - Yate	100%	Walpole - Amarillup	100%
Blackwood - Hilliger	5426	Pemberton - Yeagerup	100%	Walpole - Camballup	100%
Mornington - Stene	5459	Walpole - Amarillup	100%	Walpole - Clear Hills	100%
Walpole - Crossing	5469	Walpole - Camballup	100%	Walpole - Denbarker	100%
Manjimup - Boyicup	5498	Walpole - Clear Hills	100%	Walpole - Denmark	100%
Manjimup - Talling	5615	Walpole - Denbarker	100%	Walpole - Hay	100%
Manjimup - Yackelup	5624	Walpole - Denmark	100%	Walpole - London	100%

Table 1 continued

District & Forest Block (ordered by area)	Area (ha)	District & Forest block (ordered by % of forest)	%	District & Forest Block (ordered by % of native vegetation)	%
Mundaring - Flynn	5636	Walpole - Hay	100%	Walpole - Peak	100%
Blackwood - Hester	5640	Walpole - London	100%	Walpole - Perillup	100%
Walpole - Pingerup	5746	Walpole - Peak	100%	Walpole - Powley	100%
Blackwood - Camballan	6180	Walpole - Perillup	100%	Walpole - Quindinillup	100%
Blackwood - Layman	6231	Walpole - Powley	100%	Walpole - Rate	100%
Manjimup - Keninup	6389	Walpole - Quindinillup	100%	Walpole - Romance	100%
Manjimup - Chitelup	6396	Walpole - Rate	100%	Walpole - Sheepwash	100%
Mornington - Nalyerin	6614	Walpole - Romance	100%	Walpole - Table Hill	100%
Manjimup - Chariup	7551	Walpole - Sheepwash	100%	Walpole - Willmott	100%
Mundaring - Lupton	8660	Walpole - Table Hill	100%	Pemberton - Yate	100%
Walpole - Sheepwash	8926	Walpole - Willmott	100%	Pemberton - Yeagerup	100%

Table 2. Additional area of forest with mature characteristics required to be maintained to meet criteria of the Panel. There is insufficient additional forest in shaded blocks to meet criteria. Bold type indicates that reservation may impact on karri.

Criterion2			Criterion 3		
District	**Forest Block**	**Additional ha**	**District**	**Forest Block**	**Additional ha**
Dwellingup	Wearne	2086	Dwellingup	Wearne	1980
Mornington	Godfrey	1751	Blackwood	Argyle	1341
Blackwood	Argyle	1348	Mornington	Godfrey	1273
Mornington	Leach	1218	Dwellingup	Bannister	1107
Dwellingup	Bannister	1212	Mundaring	Flint	1089
Mundaring	Flint	1185	Mornington	Ernest	968
Mundaring	Brady	1115	Dwellingup	O'Neill	962
Dwellingup	O'Neill	1085	South West Capes	Millbrook	960
Mundaring	Gibbs	1074	Mundaring	Nockine	950
Mundaring	Nockine	1022	Mundaring	Brady	948
Mundaring	Occidental	983	Blackwood	Catterick	901
Mornington	Ernest	982	Blackwood	Wilga	883
South West Capes	Millbrook	978	Mundaring	Occidental	838
Mornington	Hoffman	965	Blackwood	Hunt	837
Mundaring	Balmoral	947	Mornington	Ross	821
Blackwood	Wilga	923	Mornington	Denham	820
Mornington	Nundedine	921	Dwellingup	Curara	810
Blackwood	Hunt	907	Mundaring	Balmoral	810
Blackwood	Catterick	906	Blackwood	Upper Capel	807
Mornington	Bowelling	893	Mornington	Hadfield	805
Mundaring	Sawyers	883	Dwellingup	Inglehope	801
Mornington	Hamilton	880	Mornington	Hoffman	796
Mornington	Fleays	877	Mornington	Hamilton	792
Mornington	Driver	877	Mornington	Leach	789
Dwellingup	Cameron	875	Mundaring	Gordon	772
Dwellingup	Lang	874	Mornington	Fleays	763
Mornington	Bristol	866	Dwellingup	Cameron	762
Mornington	Ross	857	Mornington	Nundedine	757
Mornington	Cornwall	846	Dwellingup	Lang	751
Mornington	Denham	830	Mornington	Driver	742
Dwellingup	Inglehope	824	Mornington	Cornwall	724
Mornington	Hadfield	819	South West Capes	Quilergup	715
Dwellingup	Myara	813	Mornington	Yabberup	712
Dwellingup	Curara	810	Dwellingup	Pindalup	695
Blackwood	Upper Capel	809	Dwellingup	Taree	693
Mundaring	Gordon	786	Blackwood	Woop Woop	686
Mundaring	Leona	778	Mornington	Waterous	686
Mornington	Waterous	762	Dwellingup	Holyoake	685
Mornington	Yabberup	750	Dwellingup	Myara	684
Manjimup	Yardup	732	Blackwood	Harrington	680
Dwellingup	Taree	730	Dwellingup	Clinton	666
Dwellingup	Torrens	726	Manjimup	Yardup	659
Blackwood	Woop Woop	720	Mornington	Bristol	646
South West Capes	Quilergup	719	Mundaring	Leona	640
Dwellingup	Pindalup	715	South West Capes	Maryvale	620
Dwellingup	Holyoake	715	Mornington	Morgan	606
Dwellingup	Scott	693	Mornington	Kent	606
Blackwood	Harrington	691	Dwellingup	White	601
Dwellingup	Clinton	671	Dwellingup	Scott	599
Blackwood	Sussex	671	South West Capes	Abba	590
Mundaring	Reservoir	650	Blackwood	Sussex	590
South West Capes	Mowen	648	Mundaring	Sawyers	583
Mornington	Morgan	636	Blackwood	Kearney	569
South West Capes	Abba	635	Mundaring	Mundlimup	563
Dwellingup	Wells	635	Dwellingup	Bombala	555
Mornington	Kent	634	Dwellingup	Hedges	445
Blackwood	Kearney	632	Blackwood	Jolly	551
Dwellingup	White	630	Mundaring	Reservoir	550

Table 2 continued

Criterion 2			Criterion 3		
District	**Forest Block**	**Additional ha**	**District**	**Forest Block**	**Additional ha**
South West Capes	Maryvale	621	Dwellingup	Amphion	549
Manjimup	Yornup	619	Dwellingup	Torrens	549
Dwellingup	Bombala	618	Blackwood	Munro	543
Blackwood	Jolly	601	Blackwood	Jacobs	542
Blackwood	Munro	600	Dwellingup	Saddleback	533
Mornington	Edward	597	Dwellingup	Wells	530
Dwellingup	Waroona	596	Mornington	Edward	526
Mornington	Shotts	596	Mornington	Sherwood	525
Manjimup	Yeticup	592	**Manjimup**	**Lindsay**	**525**
Blackwood	Ellis Creek	591	Mornington	Hillman	523
Mundaring	Mundlimup	589	Blackwood	Mc Corkhill	517
Blackwood	Jacobs	586	Manjimup	Yeticup	515
Dwellingup	Kennedy	577	Blackwood	Towers	510
Mundaring	Cobiac	559	Mundaring	Cobiac	501
Pemberton	**Treen Brook**	**248**	South West Capes	Kingia	500
Dwellingup	Saddleback	556	Mornington	Batalling	500
Dwellingup	Amphion	555	Dwellingup	Hakea	327
Dwellingup	Hedges	445	Mundaring	Lesley	488
Mundaring	Chandler	553	Dwellingup	Waroona	487
Manjimup	**Lindsay**	**552**	Blackwood	Warner	480
Mornington	Hillman	540	Mornington	Arcadia	480
Dwellingup	Samson	540	South West Capes	Boronia	470
Mornington	Arklow	539	Mundaring	Gibbs	463
Manjimup	Yerramin	528	Mornington	Shotts	462
Mornington	Sherwood	525	Mundaring	Chandler	461
Blackwood	Mc Corkhill	520	South West Capes	Hopkins	433
Mundaring	Lesley	518	South West Capes	Mc Gregor	431
South West Capes	Boronia	513	Dwellingup	Quindanning	424
Blackwood	Towers	510	South West Capes	Mowen	410
Mornington	Batalling	509	Blackwood	Donnybrook	406
Dwellingup	Hakea	327	Blackwood	Ellis Creek	405
South West Capes	Kingia	503	Dwellingup	Samson	401
Mornington	Western	500	**Pemberton**	**Treen Brook**	**248**
Mundaring	Clare	493	Dwellingup	Wilson	398
Mornington	Arcadia	486	Mornington	Arklow	391
Blackwood	Warner	484	Dwellingup	Marradong	372
Mornington	Proprietary	483	South West Capes	Happy Valley	366
Dwellingup	Urbrae	481	Dwellingup	Marrinup	363
South West Capes	Mc Gregor	451	Dwellingup	Turner	360
South West Capes	Hopkins	444	Mundaring	Carinyah	358
Dwellingup	Wilson	439	Manjimup	Yornup	351
Dwellingup	Quindanning	436	Manjimup	Yerramin	335
South West Capes	Molloy	435	Dwellingup	Kennedy	334
Mundaring	Canning	428	Dwellingup	Banksiadale	264
Manjimup	Coonan	428	Dwellingup	Urbrae	333
Mornington	Mungalup	427	Manjimup	Topanup	329
Blackwood	Tanjanerup	424	Blackwood	Jalbarragup	324
South West Capes	Treeton	409	Blackwood	Tanjanerup	314
Blackwood	Donnybrook	406	Dwellingup	Gyngoorda	309
Mundaring	Churchlands	402	Mornington	Centaur	307
Mornington	Centaur	400	Blackwood	Mc Alinden	306
Mundaring	Carinyah	394	Mornington	Lowden	305
Dwellingup	Turner	386	Mundaring	Churchlands	302
Dwellingup	Marrinup	384	Mundaring	Barton	295
Mundaring	Barton	378	Mornington	Mungalup	295
Dwellingup	Marradong	374	**Manjimup**	**Solai**	**294**
South West Capes	Happy Valley	368	Mornington	Bowelling	287
Dwellingup	Gyngoorda	360	South West Capes	Punch	267
Blackwood	Jalbarragup	355	Manjimup	Coonan	263
Blackwood	Gregory	347	Mornington	Boyanup	262
Dwellingup	Banksiadale	264	Mornington	Proprietary	256
Manjimup	Topanup	342	Manjimup	Cardac	222
Blackwood	Mc Alinden	339	Mornington	Western	221

Table 2 continued

Criterion 2			Criterion 3		
District	**Forest Block**	**Additional ha**	**District**	**Forest Block**	**Additional ha**
Manjimup	**Andrew**	**326**	Manjimup	Dudijup	214
Mornington	Lowden	314	Dwellingup	Whittaker	210
Manjimup	**Solai**	**302**	Mundaring	Gorrie	207
Mundaring	Gorrie	300	South West Capes	Treeton	202
Dwellingup	Whittaker	296	Mornington	Darrell	196
Manjimup	Mersea	293	Mundaring	Clare	171
Manjimup	Carter	284	**Manjimup**	**Channybearup**	**161**
South West Capes	Punch	283	**Manjimup**	**Diamond 1**	**161**
Manjimup	Dudijup	275	Manjimup	Carter	140
Mornington	Darrell	273	Mundaring	Canning	140
Mornington	Boyanup	266	**Manjimup**	**Andrew**	**133**
Manjimup	Thorton	256	Blackwood	Gregory	112
Manjimup	Meribup	249	Manjimup	Thorton	109
Manjimup	Cardac	223	Manjimup	Yanmah	99
Manjimup	Yanmah	202	Manjimup	Mack	75
Manjimup	**Channybearup**	**192**	Blackwood	Sollya	70
Blackwood	Beaton	169	Blackwood	Helms	67
Manjimup	**Diamond 1**	**162**	Dwellingup	George	67
Pemberton	**Big Brook**	**153**	Pemberton	Kinkin	63
Manjimup	Tone	144	Manjimup	Mersea	44
Manjimup	**Mack**	**111**	Blackwood	Byron	43
Pemberton	Kinkin	95	Pemberton	Big Brook	42
Blackwood	Helms	91	Dwellingup	Holmes	40
Blackwood	Sollya	83	Blackwood	Kerr	27
Walpole	Burnside	78			
Dwellingup	George	78			
Mornington	Clarke	69			
Blackwood	St John	46			
Blackwood	Byron	43			
Dwellingup	Holmes	43			
Blackwood	Nelson	30			
Blackwood	Kerr	27			
South West Capes	Hamelin	0			

12. Appendix 3 Maps of forest blocks meeting various criteria

Map 1 Criterion 1. Existing reservation status - 200 ha of the native forest in each block with mature elements

Map 2 Criterion 2. Existing reservation status – 20% of the native forest in each block with mature elements

Map 3 Criterion 3. Existing reservation status – 20% of the native vegetation in each forest block is native non-forest of is forest with mature elements