Ministerial Condition 11: Panel Report Part 1

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October 2001

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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.
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- 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
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- 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).

Lachlan McCaw
Project Leader, ESFM
Science Division
Department of Conservation & Land Management
Manjimup

10 July 2001

Short-term impacts of logging on understorey vegetation in a jarrah forest

N.D. Burrows, B. Ward and R. Cranfield
Science Division, Kensington and Manjimup

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
Science Division, Dwellingup

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

J. Kinal
Science Division, Dwellingup

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

J. Kinal
Science Division, Dwellingup

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

Ian Abbott[a], Tom Burbidge[a], Karin Strehlow[b], Amanda Mellican[a], Allan Wills[a]

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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

G.L.Liddelow
Science Division, Manjimup

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
Science Division, Manjimup

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

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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.

4. 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.