A PROPOSED INTEGRATED STUDY OF THE EFFECTS OF TIMBER HARVESTING ON THE JARRAH FOREST ECOSYSTEM

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

FOREST ECOLOGY RESEARCH TEAM

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INTRODUCTION

General background

The use of native forests for timber production has given rise to one of the most intense environmental debates experienced in Australia. Conservation groups argue that logging and burning the forest destroys or seriously degrades its natural integrity. On the other hand, forest managers argue that logging is compatible with conservation provided that sufficient areas are reserved and that appropriate measures are taken within production forests to mitigate the effects of logging.

Modern forest management policies are formulated around the concept of "ecologically sustainable development", a concept which has been defined variously in the literature (eg. ESD Working Group Report 1991, RAC Inquiry 1992). According to the ESD Working Group (1991), ecologically sustainable forest use implies:

> "optimising the tangible (material) and intangible (non-material) social and economic benefits which forests can provide to the community with the goals of maintaining the functional basis of forested land, biodiversity, and the options for future generations".

The principles of ecologically sustainable forest use require the development and implementation of policies which maintain ecological processes, maintain biodiversity and optimise benefits to the community. CALM's Forest Policy Statement (CALM 1992a) embodies these principles:

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

In order to implement this policy, CALM recognises the need for basic ongoing research to gain scientific knowledge of forest ecosystem processes and how these are impacted on by forestry operations (CALM 1992a). CALM also recognises the need to monitor the implementation and impact of these operations to gauge the success of its policies in regard to achieving sustainable forest use. Meaningful monitoring procedures can only be designed and implemented with a firm understanding of natural processes and of key ecosystem elements which should be monitored. Without this information, monitoring risks being "token" and a waste of valuable management resources.

It is now clear that CALM will be managing the jarrah forest for wood production and other forest values over the long-term (Minson 1993). This commitment to long-term sustainable harvesting now sets the scene for research to ensure that the silvicultural systems and management practices used are ecologically sustainable. A number of Ministerial Conditions have been imposed on CALM's forest management proposals, and Condition 13 is particularly relevant to this study. It states:

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

In discussing this condition, Meagher *et al.* (1993) recommend to the Minister for the Environment that CALM be instructed to:

> *evaluate the effect of a reduction of tree hollows in multi-purpose forest on populations of animals that use hollows*

and to:

> *monitor the effectiveness of remnant habitat trees for fauna and determine the density and distribution of trees required to sustain populations of the fauna*

The research in this proposal will fulfill these recommendations and enable CALM to revise its silvicultural system (if necessary) to meet the Ministerial Condition.

Facilitation of research within native forests

The CALM Science and Information Division (SID) has a mission which supports that of CALM's purpose to conserve and manage the lands, waters and wildlife of Western Australia for the benefit of present and future generations (Science and Information Division Strategic Plan 1993). The Division's mission is to provide up-to-date and scientifically sound information to uphold effective conservation and sustainable land management practices in Western Australia.

The new structure of Science and Information Division aims to facilitate integration and co-ordination of scientific expertise from the four primary groups which comprise the Division. This structure has also facilitated the establishment of formal links between Science Groups and the various branches within CALM.

The first such committee integrating SID with the operational areas of CALM is concerned with forest management, and is known as the Native Forest Research Committee (NFRC). It is chaired by Jack Bradshaw, Manager of Native Forests, and comprises a core group of relevant members including the Heads of each Science Group, and the managers of operational branches. The NFRC integrates the branches through operations-based research which will address the broader CALM perspective in relation to forests. This committee should also facilitate speedy incorporation of research findings into operations and ensure that operations themselves form a part of the information gathering process.

The NFRC recognized deficiencies in knowledge concerned with timber harvesting operations in jarrah forest and recommended that an integrated research program be established to address this issue. NFRC also foreshadowed funding to meet the cost of this research.

A Forest Ecology Research Team (FERT) was recently established to carry out this integrated program of research. This team comprises staff from four of the six new Sections within the Science and Information Division, viz. Natural Products Section (Neil Burrows (Chair) and Geoff Stoneman), Community Conservation Section (Gordon Friend and Grant Wardell-Johnson), Species Conservation Section (Keith Morris) and Biometrical Services (Matthew Williams). The Forest Ecology Research Team and its objectives exemplify the Science and Information Division's close alignment with the Departmental goals. The Team has the capacity to integrate and co-ordinate a multidisciplinary group of scientists to provide a scientifically objective and independent source of reliable knowledge.

This document provides a brief overview of the literature relating to disturbance in the Jarrah forest ecosysytem, describes the aims, methods and major research topics of such a study, and estimates the human and financial resources needed to carry out the work.

Overview of Jarrah forest disturbance studies

The jarrah (*Eucalyptus marginata*) forest of the south-west of Western Australia is a unique ecosystem occurring on the highly leached soils of the Darling Plateau. The forest originally covered about 5.3 million hectares from Gingin in the north to Albany in the south, with its eastern distribution approximating the 600 mm rainfall isohyet. Clearing for agriculture, mining, service corridors, housing and other uses have reduced the forest to about 3 million hectares.

Timber has been extracted from the forest for the past 160 years. Professional foresters have supervised the industry since the early 1920's. Non-timber values of the forest, including water catchment management, mining, recreation, and conservation, have been receiving much greater emphasis since the 1960's.

To place the proposed work in perspective it is necessary to briefly review the literature regarding the impact of forest management practices on the flora and fauna of jarrah forests. For the purposes of the present document, only the two practices associated with the production of wood will be considered, viz. burning and logging. The reader is referred to Wardell-Johnson and Nichols (1991) for a comprehensive review of Western Australian forest wildlife and habitat management issues, and to Christensen and Abbott (1989) for a review of the impact of fire on the forest ecosysytems of southern Western Australia. Various papers on the impact of forest management in south-western Australia were also published by CALM (1992b).

Fire

With respect to vegetation, early studies concentrated on the regeneration responses of Jarrah to fire (Van Noort 1960, Wallace 1966, Peet and McCormick 1971, Nicholls 1974, Kimber 1978, Abbott and Loneragan 1983) while other studies examined aspects of damage to the trunk and crown of trees (McCaw 1983, Burrows 1987) and impacts on timber values (Peet and Williamson 1968). Detailed work has also been carried out on the role of fire in the dynamics of recruitment in several understorey species such as legumes (Shea *et al.* 1979), *Boronia megastigma* (Christensen and Skinner 1978) and *Banksia grandis* (Abbott 1985a, 1985b, Burrows 1985).

Few studies, however, have examined the broader aspects of the impact of fire on plant communities. Peet (1971) recorded higher cover values and more species in areas burnt under moderate intensity, primarily because of the presence of leguminous fireweed species (eg. *Acacia pulchella*), while Christensen and Kimber (1975) found few changes in the number of species following a series of low intensity fires. Similar results were described by Abbott (1984) and Abbott *et al.* (1984), while Bell and Koch (1980) used multi-variate analyses to reveal that sites factors, rather than fire, were the main determinants of plant species richness and composition.

There is very little information available on the long term effects of frequent fire on plant species richness and composition in the jarrah forest. However these aspects are being examined in a series of plots established in 1970 near Manjimup. (Christensen and Burrows *pers. comms.*) Results to date indicate that the majority of species show no changes in abundance as a result of any of the treatments.

Although invertebrates have received some attention in relation to fire in the Jarrah forest, no concensus on the impact of such disturbance on these organisms has yet been achieved. Early

studies by McNamara (1955) and Springett (1976, 1979) suggested that fire had a significant long-term effect on the litter fauna, with recovery taking longer than the normal prescribed fire interval of 5-7 years. By contrast Bornemissza (1969), Whelan *et al.* (1980), Majer (1980, 1984) and Abbott (1984) found significant short-term effects (both increases and decreases in selected taxa), but found (or predicted) recovery of the invertebrate communities within 2-3 years. Similarly, Abbott *et al.* (1984) found few differences in the litter and soil fauna of regularly burned and long-unburned jarrah forest, and concluded that periodic low intensity fires in these forest types have few permanent effects on such components of the fauna.

Many of these conflicting conclusions have arisen because of variations or shortcomings in experimental design, taxonomic treatment and length of study. Few studies have any prefire data or any long-term post-fire data, and in the majority of cases invertebrates have been identified only to ordinal level, thus potentially masking important changes in species and family composition following fire. In addition, most workers have contemporaneously sampled areas of different fire histories and ascribed faunal differences to the effect of these fires. Given the inherent within-site variability of invertebrate populations (Campbell and Tanton 1981) this assumption of pre-fire homogeneity between control and treatment plots is tenuous.

Studies on the effects of fire on small vertebrates in Jarrah forest show a clear dichotomy in approaches and research effort. No work has been published on reptiles, and only the work of Driscoll *et al.* (*pers. comm.*) on restricted *Geocrinia* spp. (frogs), and Wardell- Johnson in the Walpole-Nornalup National Park are current. Work on birds has focussed at the community level and examined the responses of various guilds in relation to foraging heights (Kimber 1974, Christensen and Kimber 1975, Christensen *et al.* 1985). In general, the effect of fire on individual species was inversely proportional to their foraging height, and the overall impact on the community was largely dependent on fire intensity.

Mammal studies, on the other hand, have primarily concentrated on individual species such as the Woylie *Bettongia penicillata* and Tammar *Macropus eugenii* (Christensen 1980), and the Common Brushtail Possum *Trichosurus vulpecula* and the Western Ringtail Possum *Pseudocheirus occidentalis* (Inions 1985, Inions *et al.* 1989). Only the work of Christensen and Kimber (1975) examines response patterns of small mammals at the community level. They reported that fire reduces populations of many species to low levels, and that post fire recovery proceeds in tandem with the regeneration of the vegetation. Predation can be an important factor influencing the immediate post-fire outcome, but mammal species response patterns and longer-term successional patterns are largely determined by their life history parameters, particularly their requirements for food, shelter and breeding (Friend 1993).

The above overview indicates that carefully designed studies which incorporate pre-fire data and unburnt control sites are clearly needed to clarify the role of fire in the management of the Jarrah forest ecosysytem. As indicated by Christensen and Abbott (1989), these studies need to be long term and focus primarily on key species which are likely to be sensitive to fire. Such work is currently underway near Collie, and is seen as an important adjunct to the studies on timber harvesting proposed here.

Logging

Research on the ecological impacts of logging in the jarrah forest is very sparse. No work has been reported on the effects of logging on mammals, although several potentially sensitive and/or endangered species occur in jarrah forest (eg. Chuditch *Dasyurus geoffroii*, Quenda *Isoodon obesulus*, Mardo *Antechinus flavipes leucogaster*, Western Pigmy Possum *Cercarteus concinnus*, Common Brushtail Possum *Trichosurus vulpecula*, Brush-tailed

Phascogale *Phascogale tapoatafa* and several species of bat). Athough some work has focussed on birds and logging in Karri forest (Wardell-Johnson unpubl.), only two studies have addressed this topic in jarrah (Abbott and Van Heurck 1985, Norwood *et al.* in review). Abbott and Van Heurck (1985) suggested that the jarrah forest bird community has high threshold levels of tolerance to disturbance, and that no species were affected significantly by logging. Norwood *et al.* (in review) studied the response of birds to edge effects created by intensively logged gaps, and compared these sites to the adjacent unlogged forest. Fourteen species were tested for differences in distribution between treatments. Eight, two and one species were more frequently observed in gaps, edges and forest respectively, while the remaining three species showed no significant differences between treatments. Although limited in duration, this work provides important direction for further work of this nature.

The only other faunal study on silvicultural practices in jarrah forest is that by Curry and Humphries (1988) who examined insect communities in *Pinus radiata* plantations and the native forest which they replaced (ie. not logging *per se*). Assessment of the degree of impact was dependent on the level of identification of taxa (as was the case in the fire studies, see above), with ordinal level analyses unable to separate treatments from the background variabilty attributable to season and site. At the family and generic levels of identification several groups such as the Diptera (flies) and Lepidoptera (moths and butterflies) could be highlighted as particularly sensitive to disturbance. These groups, along with spiders (from the work of Curry *et al.* (1985) regarding logging in karri forest) are likely to be useful indicator taxa on which to focus attention in future studies.

It is clear that knowledge on the impact of timber harvesting on fauna and flora in jarrah forest ecosysytems is inadequate. If sound management decisions on silvicultural practices, logging levels and sustainability are to be made, they must be made from a satisfactory knowledge base. There is thus a critical and urgent need for empirical information on the ecological effects of timber harvesting operations on the jarrah forest ecosystem.

Indeed, this is also the case at the national level. Recent forestry reports and national reviews of forestry practices (eg. RAC, ESD, NPAC, NFPS and IGAE) conclude that, Australia-wide, the research base is far from adequate. The RAC Inquiry (1992) concluded that there is insufficient information available to support claims about whether impacts resulting from forest activities are benign or deleterious to the forest environment. Further, the Inquiry stated that current levels of monitoring were inadequate and recommended that systematic, long-term research and monitoring be established as a matter of highest priority. This requirement was also a recommendation of the 1992 EPA report (EPA 1992).

CALM's (1992a) recent review of forest management strategies has been well accepted at the national level. It is clear that some proposals highlighted in the report are intuitively well considered. It is also true, however, that there are a lack of data upon which to demonstrate the value of the approach, or where necessary, to refine it. Empirical data will be necessary to allow sensible decisions to be made regarding optimal multiple use of the jarrah forest in a changing social framework.

THE PROPOSED STUDY

Overall design and methods

The program of research advocated in this plan is designed to investigate the ecological effects of integrated timber harvesting operations in the jarrah forest. The study will integrate the work of scientists with expertise in plant and animal ecology, silviculture and landscape ecology.

The study involves three approaches:

1. Experimentation over a narrow but critical geographical area and range of sites, to concentrate on short-term (1-5 years post-logging) effects.

2. Contemporaneous sampling of sites over their geographic range (retrospective study) to enable a temporal and spatial perspective on experimental results.

3. Contemporaneous sampling of the range of sites occurring in the domain of the experiment to provide a regional and landscape perspective for the experiment.

The experiment is designed to examine short term (1-5 years post logging) phenomena in detail. The overall study design of the experiment is of the BACI (before, after, control, impact) type with potentially several replicates of each of the four treatments. The four treatments are:

1. Control (forest area that will be burnt but not logged during the study period),
2. Shelterwood (in coupes with patches of 5-50ha),
3. Gap with standard 3 habitat trees per ha (in coupes with gaps no larger than 10ha),
4. Gap without retained habitat trees (in coupes with gaps no larger than 10ha).

There will be at least one year of pre-treatment data collection to calibrate study sites. All sites will be burnt at the same time prior to the harvesting treatments. Each coupe (consisting of many gaps or patches) will include three replicates. Further replication necessary for some aspects of the study will be carried out in gaps within a coupe, but in sites at least 200m apart. This design will allow the impacts of the current harvesting operations (gap treatments) as well as both more intensive (no retention of habitat trees) and less intensive (shelterwood) operations to be assessed. The spatial and temporal effectiveness of habitat trees will also be examined. It is recognised that introduced predators have a major impact on native wildlife, particularly following disturbance. Thus the experimental domain comprises a large area which has been regularly baited for fox control over several years prior to the commencement of the study.

The experimental work is planned to occur in open jarrah forest of the medium rainfall zone in Warrup/Kingston Forest Blocks, 25km north east of Manjimup (Fig. 1). These sites are representative of a major focus of timber production in State Forest over the next decade, and include populations of several species of gazetted threatened fauna. The experiment will be carried out within planned operations in the lateritic uplands and sandy terrain of the Bevan landform unit. This landform/soils unit represents the most widespread of the sites from which jarrah timber is harvested. This unit is replaced north of the Blackwood River by the Dwellingup unit and in the Blackwood Plateau by the Kingia unit.

The experimental study will provide results not only on the short-term effects of the treatments, but, because of the multidisciplinary approach and sharing of the individual data sets that this

engenders, also on processes and interactions between various components of the ecosysytem. This synergism will allow much more rapid advances in knowledge and extrapolation of the results beyond the study area.

The second (retrospective) approach involves contemporaneous sampling of sites that are similar in landform/soils attributes to the experimental area, but which include a range of management histories (particularly in relation to timber harvesting and fire). This work is being carried out simultaneously with the experimental work (years 2-5 of the program) to ensure a broad temporal and geographic applicability of the results. Data from the retrospective studies will be valuable as a base-line against other studies in jarrah forest ecosystems, and against a broad range of management activities in the jarrah forest. All retrospective work will be carried out in large permanently located quadrats.

The retrospective study is being limited to two soil types (lateritic and sandy) in three equivalent landform units (Dwellingup, Bevan and Kingia) in both the medium and high rainfall zones of the jarrah forest. Eight study sites each with a range of logging and burning history have been chosen (Dwellingup, Jarrahdale, Margaret River, Nannup, Yornup, Kirup, Lockhart and Dixon; Fig2). The layout of quadrats and data collection procedures in the experimental and retrospective studies will allow direct comparison of the results between them. The Dwellingup area will continue to be sampled over the four year period to provide a seasonal and year-to-year control for the other areas.

It is recognised that only a proportion of the study area including the experiment would be logged. Thus a third approach, involving mapping of plant communities in the study area, is being used to place the experiment in a regional perspective. This work will allow an understanding of the variation in habitats and sites within the domain of the experimental work. This will involve relating on-ground quadrat-based vegetation data to extrinsic data sets to provide a broad scale vegetation map of the area.

It is also intended that the aesthetic landscape qualities of both the retrospective study areas and the Kingston experimental sites will be assessed, and that any alternative forest management prescriptions developed will incorporate aesthetic landscape management principles and study findings where possible. Details of this particular project are appended.

Although further aspects of the ecology of the jarrah forest ecosystem could also be examined in this study, it is considered that the most important priorities are being examined within the constraints of a reasonable funding request. Further, the most cost-efficient means of data collection, storage and analysis have been sought through a multidisciplinary approach to the work. Effective delivery of scientifically sound experimental and monitoring results to forest managers and receipt of feedback on costs, management implications and practicality will be the primary considerations in the conduct of the study.

Human Resources

Below are listed the principal CALM personnel involved in the study. The Science and Information Division team are liaising closely with the Southern Forest Region and Manjimup District staff to ensure efficient planning and implementation of the experiment in Kingston and Warrup blocks.

Principal Calm Personnel Involved

NAME	AFFILIATION	EXPERTISE
Neil Burrows	Science & Information Division	Vegetation/fire response
Gordon Friend	Science & Information Division	Vertebrate/invertebrate ecology
Keith Morris	Science & Information Division	Vertebrate ecology
Geoff Stoneman	Science & Information Division	Silviculture
Grant Wardell-Johnson	Science & Information Division	Vegetation/vertebrate ecology
Matthew Williams	Science & Information Division	Experimental design/analysis
Grant Revell	Parks, Recreation, Planning & Tourism Division	Aesthetic landscape assessment
Kevin Vear	Southern Forest Region	Regional management
Alan Lush	Southern Forest Region	Planning
John Lloyd	Manjimup District	District management

In addition, a large number of technical and administrative staff from within CALM will be involved in the work, as well as several Ph.D students. Details are provided in the relevant Project Plans which follow in this document.

Financial resources required

Funding to meet the cost of this research from the Forest Resources program was foreshadowed by the Native Forest Research Committee.

Cost Estimate for first 5 years of Project.
(CALM staff salaries not included)

	Year 1	Year 2	Year 3	Year 4	Year 5
Plant	$35265	$47074	$45314	$41744	$39540
Materials	112815	42683	34697	23575	29071
Travel/ Overtime	23355	28048	26620	26909	27325
Ext. Salaries/ Wages	31570	31570	31570	31570	31570
Total (excl. ext. salaries/wages)	171435	117805	106631	92228	95936

Detailed breakdown of estimated expenditure is provided by the individual Project Plans. These proposals and costings represent the most desirable level of input to research the effects of timber harvesting on the jarrah forest ecosysytem. Less intensive and simpler studies could be carried out for less cost, but would not yield the same level of information and understanding.

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DETAILS OF PROPOSED STUDIES

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project: The effect of timber harvesting on the jarrah forest microclimate.**

2. **Project Leader:** Dr Geoff Stoneman

3. **Aim:**

   To quantify the effect of logging-and-burning on particular aspects of the microclimate, namely air temperature, soil temperature, temperature inside tree hollows, humidity, vapour pressure deficit, global radiation, wind speed and direction, and soil water content.

   To relate these changes in microclimate to changes in flora and fauna following the logging-and-burning treatments.

4. **Background/Justification:**

   Microclimatic conditions of a stand are critical to understanding and predicting biological processes. Microclimatic parameters such as temperature, moisture and solar radiation, drive biological processes and control the distribution of organisms (Geiger 1965; Whittaker 1975; Zobel *et al.* 1976; Waring and Schlesinger 1985; Chapin *et al.* 1987). Soil moisture and temperature largely control litter decomposition rates (O'Connell 1990) and thus litter availability for invertebrate populations. Invertebrate populations are toward the bottom of the food web and therefore influence the fauna which use them as a food source, etc. Solar radiation and vapour pressure deficits directly control rates of photosynthesis and evaporation of water from soil, litter and vegetation. Radiation and vapour pressure deficits also indirectly control the rate of development of understorey vegetation. Emergence, survival and growth of the regenerating overstorey is also dependent on microclimatic conditions (Stoneman 1992).

   Silvicultural treatment of forest can greatly influence physical conditions and biological processes. For example, (i) in Douglas fir forest ecosystems some wildlife species respond positively to edge conditions while other species which require protected forest conditions, respond negatively (Thomas *et al.* 1979; Yahner 1988; Hunter 1990). These responses relate to several factors including microclimate, predation and food resources. (ii) variation in microclimate within a stand relates to variation in density of invertebrates (Nicoli 1986) and so changes in microclimate by silvicultural treatment can be expected to impact invertebrate populations. (iii) microclimatic characteristics of hollows is related to usage of the hollows by the fauna (Scmidt 1979; Calder *et al.* 1983) so changes in microclimate of hollows in response to silvicultural treatments may make these hollows unsuitable even though they may be abundant. This information has also been used to design artificial hollows. The study of the effects of disturbance practices on microclimate has been identified as a priority research area in biological conservation research (Saunders *et al.* 1991).

   It is clearly important if we want to relate the changes in microclimate to changes in flora and fauna, for this to be undertaken as part of a multi-disciplinary study such as the one that this RPP is a part of.

There is very little information on the effects of silvicultural treatment on the microclimate of any forest ecosystem anywhere in the world. I know of only one study where a robust experimental design has been used (Chen *et al.* 1993). This study was part of the research programme associated with new approaches to forest management in the Pacific north-west of the USA. Whilst many studies on the effects of silvicultural treatments have taken some measurements of microclimate, these measurements have been limited in the number of variables measured and in catering for spatial and temporal variation. Advances in technology of weather stations and reduction in their cost has now made quantification of silvicultural effects on microclimate possible.

The study on the effects of silvicultural treatment on flora and fauna that this RPP is a part of would have very limited usefulness if it did not attempt to understand the reasons for changes in flora and fauna. A simple environmental impact type experimental design (BACI: before, after, control, impact) would only tell us what happened in part of one forest block, without any basis on which to extrapolate to other areas of forest. Coupling the base BACI experiment with studies on the effects of the treatments on microclimate and habitat availability (see other relevant RPP's section) provide an excellent basis on which to understand the dynamics of the flora and fauna.

Some other aspects of microclimate that will not be measured in this study have already been studied in jarrah forest eg throughfall of rainfall (Stoneman and Schofield 1989), stemflow (WAWA pers. comm.), soil temperature in relation to soil depth and thinning intensity (Kinal 1993).

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5. Keywords:

silviculture, logging, burning, forest density, microclimate, air temperature, soil temperature, humidity, vapour pressure deficit, wind speed, wind direction, soil water content, fauna, flora, tree hollows

6. Target Users:

Whilst this is an important study by itself, it is probably more important as a provider of microclimatic information to the other studies that this RPP is a part of. Information is important to management of State Forest in the Swan, Central and Southern Forest regions. The study will also provide data regarding the effects of logging-and-burning of relevance to the general public and researchers in other terrestrial ecosystems in WA, the rest of Australia and overseas. Much of the information will be particularly relevant to the dry sclerophyll forest ecosystems of south-eastern Australia.

7. Associated Staff:

Neil Burrows (Como), Gordon Friend, Grant Wardell-Johnson and Keith Morris (Woodvale).

8. Associated Institutions:

None directly in this study.

9. Study Design:

Overall Study Design:

The overall study design is of the BACI (before, after, control, impact) type, with three replicates of each of three treatments. The three treatments are: (i) control (forest area that will be burnt but not be logged in the study period), (ii) shelterwood and (iv) gap. Treatments (ii) and (iii) will each recieve normal burning regimes for these silvicultural operations.

Experimental Design For Study of Microclimate:

Experimental design is of the BACI type with three treatments:
(i) control,
(ii) shelterwood, and
(iii) gap.
There will be three replicate weather stations in each of the three treatments. Each of these stations will continuously measure:
(i) air temperature,
(ii) soil temperature,
(iii) humidity,
(iv) wind speed, and
(v) global radiation.

ANOVA table:
3 treatments x 3 replicate weather stations = 9 = 8 df
df for treatments = 2
df for replicates (error) = 6

Additionally two base stations located in openings in the forest will measure:
(i) rainfall,
(ii) air temperature,
(iii) humidity,
(ii) wind speed and direction, and
(iii) global radiation.
Rainfall data will be used to describe the climate of the study area and to relate to the other microclimate variables eg soil temperature. Wind direction will be used to compare wind speed in the different treatments under different wind directions. Global radiation will be used to compare to that measured in the four treatments. Appendix 2 shows a schematic of the experimental layout. Appendix 3 illustates the layout of instrumentation at each of the 12 study sites.

In addition to the effects of logging-and-burning on microclimate, we will study spatial (horizontal) variation in microclimate in intact jarrah forest, using the maps of stand density from SPP / . Vertical spatial variation will also be examined, particularly humidity near the ground which is very important for germination of seed on the soil surface.

Experimental Design For Study of Soil Water Content:

Experimental design is of the BACI type with three silvicultural treatments:

(i) control,
(ii) shelterwood, and
(iii) gap.
As for the weather stations there will be three replicate sites in each of the three treatments. At each of the 9 sites there will be weekly measurement of soil water content over four depth intervals. At each depth there will be two replicate probes. That is:
9 sites x 4 depths x 2 replicates for each depth = 72 probes.
At one of these 9 sites there will be continuous monitoring of soil water content.

ANOVA table for soil water content (at each depth):
3 treatments x 3 sites = 9 = 8 df
df for treatments = 2
df for error = 6
df for within plots = 9

Soil water content will be measured at the same 9 sites as those with the weather stations and Appendix 2 includes this in the schematic of the layout. Appendix 4 shows an illustration of soil water monitoring at each of the 9 study sites.

Experimental Design For Study of Temperature of Tree Hollows:

Experimental design is of the BACI type with three silvicultural treatments:
(i) control,
(ii) shelterwood, and
(iii) gap.
and two hollow treatments:
(i) hollows in standing trees, and
(ii) hollows in logs on the ground.
There will be three replicates for each of these six treatments.

ANOVA table:
3 silvicultural (S) treatments x 2 hollow (H) treatments x 3 replicates (R) = 18 = 17 df
df for S = 2
df for H = 1
df for R(S) = 6
df for SxH = 2
df for HxR (error) = 6

Appendix 2 shows temperature monitoring in hollows in the schematic of the layout.

10. Costs

All costs have made an allowance for inflation of 5%/yr.

Materials

Study of Microclimate:

The costs for all the necessary instrumentation are detailed below. All instruments are UNIDATA except where indictated:

A. Base station

pluviometer	838
wind speed and direction	843
temperature, humidity and global radiation	658
data logger	780
termination strip	151
enclosure	162
Total	3432
x2	6864

B. Forest stations

temperature, humidity and global radiation	658
cable	28
wind speed	702
soil temperature (x3)	219
data logger	780
termination strip	151
enclosure	162
Total	2700
x 9	24300

C. High quality station (for checking other stations)

Humicap temperature and humidity	780
screen	226
global radiation (LICOR)	335
mounting bracket for LICOR	110
wind speed	702
data logger (Macro)	1430
termination strip	153
enclosure	162
Total	3898

D. Other

software	464
cables	115
portable computer	2000
Total	2579

A + B + C + D	37641

An allowance of 10% (3764) for repairs to instruments in subsequent years will also need to be made.

Study of Soil Water Content:

Time domain reflectometer	15000
probes (72 @ 80)	5760
cables	1000
multiplexer and switch board	2670
Total	24430

An allowance of 10% (2443) for repairs to instruments in subsequent years will also need to be made.

Study of Temperature of Tree Hollows:

thermistors (@73x18)	1752
data logger (x9)	6498
termination strip (x9)	1359
enclosure (x9)	1458
Total	10629

An allowance of 10% (1063) for repairs to instruments in subsequent years will also need to be made.

Plant

Establishment of weather stations - 1000 km x 3 trips = 3000 km @ 0.15 $/km = 450 + (onsite cost of 40 x 3) = 570
Establishment of soil water study - 1000 km @ 0.15 $/km = 150 + (onsite cost of 40) = 190
Establishment of tree hollows study - 1000 km x 2 trips = 2000 km @ 0.15 $/km = 300 + (onsite costs of 40 x 2) = 380
Maintenance of weather stations and hollows - 1000 km x 6 trips per year = 6000 km per year @ 0.15 $/km = 900 + (onsite cost of 22.50 x 6) = 1035
Maintenance of soil water study - 80 km x 52 trips = 4160 km @ 0.15 $/km = 624 + (onsite costs of 416) = 1040

Accomodation

Establishment of weather stations - 4 days x 3 trips x 2 people = 24 days @ 44.35 = 1064
Establishment of soil water study - 4 days @ 44.35 = 177
Establishment of tree hollows study - 4 days x 2 trips x 2 people = 16 days @ 44.35 = 710
Maintenance - 3 days x 6 trips per year = 18 days per year @ 44.35 = 798

Salary

A Level 5 Research Scientist (Temporary) will be required to run this experiment. The cheapest way of employing a RS would be to second a suitable Level 4/3 Technical Assistant from my group. The additional cost of this is $1972 in the first year rising to $7448 (with 5%/yr inflation) in the fifth year.

COST SUMMARY (allowing for 5%/yr inflation)

	Year 1 (93/94)	Year 2 (94/95)	Year 3 (95/96)	Year 4 (96/97)	Year 5 (97/98)
Materials	**72700**	**7633**	**8015**	**8416**	**8837**
Plant	**3215**	**2179**	**2288**	**2402**	**2522**
Accomodation	**2350**	**838**	**880**	**924**	**970**
Total	**78265**	**12074**	**11183**	**11724**	**12329**

11. Proposed date of commencement and proposed completion date.

The experiment will commence in September 1993. There will be two years of pre-treatment data collection, a disturbance period of hopefully less than one year, followed by at least two years of post-treatment data collection. Annual reports will be prepared by the L5 RS in consultation with me.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

RESEARCH PLAN

Cover Sheet 1

1. Title of Project: Changes in stand structure, composition, density, growth and wood yields in response to timber harvesting in jarrah forest.

2. Project Leader: Dr Geoff Stoneman

3. Aim:

I. To map the following attributes of the stand, before and at intervals after the logging-and-burning treatments:
(i) total stand basal area,
(ii) basal area of each of the species recorded and each of the structural components,
(iii) basal area of crop trees and potential crop trees,
(iv) stocking of ground coppice,
(v) amount of coarse woody debris, and
(vi) areas which would be suitable for various silvicultural treatments.

II. To determine the effect of the logging-and-burning treatments on recruitment, growth and survival of all stems > 5 cm dbhob.

III. To determine the effect of the logging-and-burning treatments on the yield of the full range of wood products.

IV. To provide a data-base to enable the modelling of the effect of alternative silvicultural prescriptions (eg the retention of more trees suitable for wildlife habitat, the retention of more coarse woody debris) on the yield of wood products.

4 Background/Justification:

This RPP is part of a larger study investigating the ecological effects of logging-and-burning of jarrah forest. Other studies will determine the effects on (i) microclimate, (ii) fauna - selected large vertebrates, small vertebrates, invertebrates, and (iii) understorey flora. There will also be retrospective studies of the effects of logging and burning on flora and fauna of medium to high rainfall jarrah forest, and a study on the formation, frequency and longevity of hollows in jarrah and marri trees. The effects of the logging-and-burning treatments on the overstorey stand structure, composition and density will have a large impact on the responses of microclimate, fauna and understorey flora to the treatments. The maps of stand structure, composition and density will describe the forest before treatment, aid in the selection of plots for the other studies, describe the overall effects of the logging-and-burning treatments on stand structure, composition and density immediately after the treatments and at intervals thereafter.

There is very little data on the effects of these new silvicultural prescriptions on recruitment, tree and stand growth, survival and wood yields. This basic tree growth data is required as a part of the study to determine the yield of wood products and response of the stands over time to the various treatments. This data will aid in later attempts to model the effects on wood yields of any modified silvicultural prescriptions that may be recommended following the larger study.

5 **Keywords:**
stand, structure, composition, density, growth, tree, coppice, recruitment, survival, coarse woody debris, wood yields, silviculture, logging, burning, overstorey, vegetation

6 **Target Users:**
The maps of overstorey vegetation are important to the other studies that this RPP is a part of. All information is important to management of State Forest in the Swan, Central and Southern Forest regions.

7 **Associated Staff:**
Martin Rayner (Manjimup Inventory), Paul Biggs (Bunbury Inventory), Neil Burrows (Como), Keith Morris, Grant Wardell-Jonhson and Gordon Friend (Woodvale).

8 **Associated Institutions:**
None directly in this study.

9 **Study Design:**
I. Mapping of stand structure, composition and density will use a grid system (probably 100 x 100 m) which will be established on each of the study areas. The assessment procedure at each grid intersection point will be:

A. Basal area sweep (wedge prism factor of 2) and record each hit:
(i) species (see Appendix 1 for species codes)
(ii) growth stage
1 - > 1.5 m in height and < 15 cm dbhob
2 - 15 to 45 cm dbhob
3 - 45 to 75 cm dbhob
4 - 75 to 120 cm dbhob
5 - > 120 cm dbhob
(iii) crop tree or potential crop tree (which is defined as at least a codominant with a good crown and at least 3 m of bole free of defects which would preclude its use as a sawlog)
1 - yes
2 - no
B. Stocking of ground coppice (using the Ward {1991} triangular tesselation method).
C. Dominant size classes of the stand
1 - even-aged sapling
2 - even-aged pole
3 - even-aged pile
4 - even-aged tree
5 - mixed with sapling dominant
6 - mixed with pole dominant
7 - mixed with pile dominant
8 - mixed with tree dominant
9 - totally mixed
D. Objectives of future silviculture
1 - To reduce competition to allow seedlings to develop into ground coppice (ie a partial removal of the overstorey to retain a forest cover while the regeneration develops)

2 - To allow ground coppice to develop unimpeded into saplings, poles and trees (ie a complete removal of the overstorey)
3 - To promote growth of the remaining trees (ie a thinning. Regeneration is not wanted at this stage.)
4 - No need for treatment
5 - Stream or other reserved area

Appendices 2 and 3 shows examples of maps produced using this method in two research catchments.

II, III and IV. The methods used to determine the effects on recruitment, growth and survival, wood yields, and modelling the effects of alternative prescriptions on wood yields over time will be determined in consultation with Dr Martin Rayner (Native Forest Management, Manjimup) and Dr Paul Biggs (Native Forest Management, Bunbury).

10. Costs

The following list details the steps required for this SPP to be performed:
A. 1993/94. Year 1. 07-12/93. Establishment of the grid.
B. 1993/94. Year 1. 07-12/93. Measurement of grid.
C. 1993/94. Year 1. 01-06/94. Measure permanent plots.
D. 1994/95. Year 2. 01-06/95. Remeasure permanent plots.
E. 1995/96. Year 3. 01-06/96. Re-establish the grid.
F. 1995/96. Year 3. 01-06/96. Remeasure permanent plots.
G. 1995/96. Year 3. 01-06/96. Remeasure the grid.
H. 1998/99. Year 6. 01-03/99. Remeasure permanent plots.

All costs have made an allowance for inflation of 5%/yr. I have not included the costs for assessing wood products, which will be done by the Inventory section (@$380/plot), as assessment of these plots will be incorporated into their normal programme.

Materials

A. Establishment of the grid (yr 1):	
120 x 1.35 m star pickets @ $4.90	588
800 x 5' wooden stakes @ $60/100	480
B. Measurement of grid (yr 1):	
2 x wedge prisms @ $100	200
C. Measurement of permanent plots (yr 1):	
stainless tape, etc	1000
E. Re-establishment of grid (yr 2):	
800 x 1.5 m steel tubing @ $2/m = 2400 (x 1.1025)	2646

Plant

A. Establishment of the grid (yr 1):	
80 km x 40 trips = 3200 km @ $0.15/km = $480 + (onsite cost of $40 x 8 wks = $320)	800
B. Measurement of grid (yr 1):	
800 pts @ 40 pts/day = 20 days. 80 km x 20 trips = 1600 km @ $0.15/km = 240 + (onsite cost of $40 x 4 = $160)	400
C. Measurement of permanent plots (yr 1):	
48 plots @ 4/day = 12 days. 80 kms x 12 trips = 960 kms @ $0.15/km = 144 + (onsite cost of $40 x 2.4 = $96)	240
D. Remeasurement of permanent plots (yr 2):	
same as C (x 1.05)	252
E. Re-establishment of grid (yr 3):	

same as A (x 1.1025) 882

F. Remeasurment of permanent plots (yr 3):
same as C (x 1.1025) 265

G. Remeasurement of grid (yr 3):
same as B (x 1.1025) 441

H. Remeasurement of permanent plots (yr 6):
same as C (x 1.2763) 306

COST SUMMARY

	Year 1 (93/94)	Year 2 (94/95)	Year 3 (95/96)	Year 4 (96/97)	Year 5 (97/98)	Year 6 (98/99)
Materials	**2268**	**0**	**2646**	**0**	**0**	**0**
Plant	**1440**	**252**	**1588**	**0**	**0**	**306**
Total	**3708**	**252**	**4234**	**0**	**0**	**306**

11 Proposed date of commencement and proposed completion date.

The experiment will commence in September 1993. A grid will be surveyed in over the study areas. Pre-treatment surveys of the areas will follow. When the maps of overstorey vegetation are available, these and the maps of understorey vegetation and soils (Neil Burrows) will be used to determine the study sites. Trees in the permanent plots will be measured twice prior to treatment and at least twice following treatment. Wood products will be assessed prior to treatment. Following re-establishment of the grid after the logging and burning, overstorey vegetation will be surveyed again. Annual reports will be prepared by me. The study will continue until at least 1999.

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DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

RESEARCH PLAN

1. **Title of Project:** Effects of timber harvesting on mortality, regeneration, floristic composition and structure of jarrah forest vegetation.

2. **Project Leader:** N. Burrows

3. **Aim:**

To study the effects of logging and fire on jarrah forest vegetation. Specifically;

a) plant mortality and regeneration/recruitment
b) floristic composition
c) vegetation structure (cover, height and density)

4. **Background/Justification:**

While there is a long association between fire, climate and the jarrah forest, logging is a relatively recent disturbance factor. Although jarrah forests have been commercially logged virtually since European settlement there are no detailed studies of the impact of logging on the forest vegetation.

There is a substantial amount of literature on the effects of fire on components of the jarrah forest ecosystem, especially vegetation, (see review by Abbott and Christensen 1990), but there is a surprising lack of information on the impact of logging and on the combined, synergistic effects of logging and fire. By and large, this situation holds for all Australian commercial forests. Past logging impact research in Australian *Eucalyptus* forests has concentrated on the silviculture and ecology of commercial timber species, of selected fauna, hydrology, soil damage, and nutrient cycling. The most extensive studies of the impact of logging on vegetation have taken place in rainforest.

Vegetation is important in its own right and forms habitat for a diverse suite of fauna. Broadly, logging impacts on vegetation by;

i) physical removal of trees and damage to understorey vegetation, altering the structure, cover and composition of the forest

ii) inducing micro-climatic changes resulting from tree removal and disturbance to the understorey, litter layer and soil.

ii) soil disturbance and physical damage caused by roading, snig tracks and log dumps which affect plant establishment and development.

iii) accumulations of logging debris

The effects of a fire on jarrah forest vegetation are reasonably well understood. In addition, there are ongoing studies to address questions of fire regime effects (e.g. RPPs 12/86, 23/87). However, there have been no studies of the combined effects of fire and logging on vegetation. Logging, as well as causing the impacts reported above, causes a significant re-distribution of fuel. Heavy accumulations of large fuel particles such as non commercial logs and tops, burn more intensely and with longer duration than the predominantly litter fuels of an undisturbed forest. The type of fire resulting from the combustion of logging slash is likely to have a greater physical impact on vegetation and soils.

Logging and burning are major management-induced perturbations to the jarrah forest, impacting on all organisms and on the soil and hydrology. A firm understanding of these impacts is essential for responsible management and utilization of the jarrah forest to achieve production and conservation benefits.

5. **Keywords:**
Jarrah, logging, fire, vegetation, floristics, structure, effects

6. **Target Users:**
Forest operations, research scientists

7. **Associated Staff:**
B. Ward, A. Robinson, G. Liddelow

8. **Associated Institutions:**

9. **Study Design**
The work will be carried out in Kingston and Warrup Forest Blocks, 25 km north-east of Manjimup. Four treatments will be imposed: (i) burning only (control); (ii) shelterwood logging; (iii) gap creation leaving habitat trees; and (iv) gap creation leaving no habitat trees (clearfell). Logged areas will be subjected to the normal prescribed burning carried out for such operation. It is anticipated that logging operations will be carried out in 1995.

A complete plant species list will be prepared for the study area by regular specimen collection visits. Voucher and museum specimens will be made.

Within each large quadrat used for the vertebrate and invertebrate sampling (20 for vertebrates and invertebrates, 40 for birds) four 20 x 20m quadrats will be systematically located (ie. 240 quadrats in the study area). Plots will be permanently marked, labelled and mapped.

Vegetation sampling in each 20m x 20m plot will be stratified as:

1. LOGS, LITTER and SOIL
Variables to be measured: size class distribution, length, hollow dimensions and quantity of logs, cover and depth of litter, soil condition (e.g., degree of compaction, ashbed etc.).

Van Wagner (1968) line transects will be established across the plot diagonals and the species, diameter, length, and hollow dimensions of all logs intercepted will be recorded. Litter cover will be assessed by point samples at 0.5 m intervals along the transects (i.e. 113 points/plot). At each point ground cover will be recorded as either; litter (depth), bare ground undisturbed (not compacted), bare ground disturbed (compacted e.g. snig track),log, live vegetation, ashbed or combinations of these classes.

Data will be analysed by comparison of variable means and variances before and after treatment and comparison of treatments and controls.

2. UNDERSTOREY VEGETATION (0 - 2m)
Variables to be measured: species present and abundance rating, % projected ground cover, scrub density at 20 cm height classes, mean height.

The entire plot will be searched and all species recorded and given an abundance rating (Havel rating system). Cover and height will be sampled using the drop plate technique (Bell and Schneider 1985) along diagonals transects at 0.5 m intervals (113 measurements/plot). Scrub density profile will be estimated using the Levy rod technique (Levy and Madden 1962).

Data will be analysed by comparison of species richness (using various richness indices, raw counts etc.) before and after logging and by comparing changes in species representation and abundance. Structural data will analysed by comparison of means and analysis of variance.

3. MID-CANOPY VEGETATION (2-10m)
This includes lower tree species such as *Banksia, Persoonia, Xylomeleum, Nuytsia, Allocasuarina* etc.

Variables to be measured: Species present and number, cover (%), height.

Cover in the mid-canopy stratum will be measured using a periscope type densiometer with readings taken at 2m intervals along diagonal transects. Height to canopy intercept and canopy top height will be recorded.

Data will be analysed as described above.

4. OVERSTOREY VEGETATION
Variables to be measured: Species, dbhob, height to crown break and top height of all tree species will be measured. Canopy cover will be measured using technique described above.

Data will be analysed by comparing means and analysing variance of measured variables before and after treatment and against controls.

5. SEEDLING REGENERATION
To assess seedling regeneration, about ten 1m x 1m quadrats will be randomly located in each 20 m x 20 m plot. All seedlings in each plot will be identified if possible and counted. The final number of seedling plots will be determined after a pilot survey of variability.

Plots will be assessed before logging and then annually after logging for at least 5 years.

Photographic points will be established.

A weather station will be set up on site.

History of fire and logging at the study site will be compiled.

All details of logging and burning operations will kept.

10. Costs

The following are estimated CRF (non-salary) expenditures:

First Year of Experiment (1993/94):

Materials	**$**
Pegs, quadrats, falgging etc.	1,500
Plant	
Vehicle running	3,340
Travel	
RS travel from Perth	950
TOTAL	**5,790**

COST SUMMARY

	1993/94	94/95	95/96	96/97
Travel	950	1,000	1,100	1,200
Plant	3,340	3,650	3,850	4,000
Materials	1,500	1,000	500	500
TOTAL	5,790	5,650	5,450	5,700

Includes allowance for 5% inflation per year

11. Proposed date of commencement and proposed completion date.

August 1993 - July 1998?

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. Title of Project:

The effects of timber harvesting and associated activities on medium sized mammals in the jarrah forest.

2. Project Leader:

Keith Morris.

3. Aim:

a) To investigate the ecological impacts of logging and associated burning operations on populations of medium-sized mammals inhabiting medium rainfall jarrah forest.

b) To determine what factors contribute to the observed impacts.

c) To use the results of this investigation to develop prescriptions for the appropriate management of timber harvesting operations in the jarrah forest.

4. Background/Justification:

CALM's operations in the jarrah forest are coming under increasing public scrutiny and there are few published accounts of the ecological impact of timber harvesting activities on the jarrah forest fauna. In addition, several of the medium-sized mammals which have declined or become extinct in other parts of Australia still occur in parts of the jarrah forest. A working group has been established within CALM to plan and undertake the research required to understand the ecological impacts of timber harvesting activities on the forest ecosystem and on its ability to maintain all of its processes and components. The threatened medium-sized mammals form an important part of this ecosystem and it is important that any impacts on them are known, what causes them, and that management prescriptions that enhance their conservation are prepared based on sound scientific knowledge.

This project is part of a larger co-ordinated project examining the impacts of timber harvesting on vegetation, invertebrates, small terrestrial vertebrates, bats and birds. The Chuditch Recovery Plan (Orell and Morris 1991) also requires that the effects of timber harvesting on Chuditch be examined and prescriptions prepared to enhance the conservation of this species in the jarrah forest..

The present study will examine the effects of four silvicultural treatments on Chuditch, Woylie, Quenda and Brushtail Possum in medium rainfall jarrah forest. Some information may also be collected for Numbat, Ringtail Possum and Brush Wallaby which are also known to occur in the proposed study area. It is proposed that a similar study will commence in high rainfall jarrah forest when the present study nears completion.

5. Keywords:

Jarrah forest, timber harvesting, medium-sized mammals, ecological impacts.

6. Target Users:

CALM managers in the Swan, Central Forest and Southern Forest Regions. Managers of other dry sclerophyll forest ecosysytems in south east Australia.

7. Associated Staff:

Gordon Friend and Peter Orell, Woodvale.
Mike Dillon, Dwellingup.
Neil Burrows, Geoff Stoneman and Matthew Williams, Como.
Leon Price and Tim Foley, Manjimup District.
John Rooney and Colin Ward, Manjimup SID.

8. Associated Institutions:

None.

9. Study Design:

The work will be undertaken in the Kingston and Warrup forest blocks, 25 kilometres north east of Manjimup. Three silvicultural treatments will be imposed: 1) gap creation with no habitat trees; 2) gap creation with three habitat trees /ha left; 3) shelter wood (thinning). Each will be subject to the normal prescribed burning operation (lignotuber regeneration and tops burns). Unlogged controls will also be established. Three replicates of the treatments and controls will be established.

To accommodate the anticipated different movement patterns of the medium-sized mammals, sampling will occur at two levels. At the broader scale, 30 km of line trapping transects will be established through the experimental and control areas using 150 wire cage traps set at 200m intervals. At a finer scale, a 5x3 grid (80m cage trap spacings) will be established in each of the experimental and control replicates (total of 12 cage grids, each with 15 cage traps = 180 traps). These grids will overlay and compliment the pit and Elliott trap grids established by GRF to sample small vertebrates in this study. Trap sites will be marked for repetitive use. Sampling on all grids and line transects will be undertaken simultaneously for four nights, six times over a year before the treatments are imposed. Sampling will continue at the same frequency for four years after treatment. Animals captured will be individually marked, sexed, measured, weighed and released. Some will be fitted with radio-transmitters to determine movement patterns, den and home range requirements. Standardized spotlighting transects will be established in both the treatment and control areas.

Forest structure and habitat parameters will be assessed before and after logging in studies by Neil Burrows and Geoff Stoneman. In particular, the availability of suitable habitat trees and ground logs for possums and chuditch will be assessed.

Fox control will be necessary to reduce fox predation as a contributing factor to fauna abundance. Fox baiting will be implemented throughout Kingston and Warrup blocks prior to the study commencing, using a regime shown elsewhere in the jarrah forest to sufficiently control foxes and allow increases in medium-sized mammals (4.5mg 1080 in dried meat baits, 250m spacings along tracks, every three months).

Pre treatment data on abundance, distribution, and requirements of the medium-sized mammals and relevant habitat parameters will be collected from spring 1993 to summer 1994/5. Logging treatments are programmed to commence in January 1995, and post-treatment data will continue to be collected until January 1999. Comparison of pre- and post-treatment data with the control will provide the basis for assessing impact. Paired T-tests and ANOVA's will be used to compare species diversity, abundance, and movement patterns between treatments. Den site selection and diet will also be compared.

10. Costs:

Funding for this project will be from the Forest Resources Program and from external funds (ANCA - Chuditch Recovery Plan)

1. Establishment and equipment:

Vehicle running (1100km x 2 x 0.20c/km)	$ 440
Travel allowance ($27.35 x 3 x 5days)	$ 410
Dropper posts (250 x $1.50)	$ 400
Cage traps (50 x $30)	$ 1 500
Ear tags	$ 200
Radio-collars	$ 4 000
Overtime	$ 300
TOTAL	$ 7 250

2. Fox baiting/year:

Baits (1000 x 4 x $0.65)	$ 2 600
Vehicle running (250km x 4 x $0.20)	$ 200
Warning signs	$ 2 500
TOTAL	$ 5 300

3. Data collection/year:

Vehicle running (1100km x 2 x 6 trips x $0.20)	$ 2 200
Travel allowance ($27.35 x 3 x 5 days x 6 trips)	$ 2 460
Consumables	$ 300
Volunteer food/accom	$ 500
Overtime	$ 2 000
Flying costs (20hrs x $120/hr)	$ 2 400
TOTAL	$ 9 860

COST SUMMARY:

	93/94	94/95	95/96	96/97	97/98	98/99
Equipment	13,400	7 520	7 750	7 980	8 220	8 460
Vehicle costs	2 840	2 500	2 575	2 650	2 730	2 810
Travel	5 170	4 600	4 740	4 880	5 030	5 180
Spec processing:	-	-	-	-	-	-
Publication Costs	-	-	-	-	-	500
Total	21 410	14 620	15 065	15 510	15 980	16 950
ANCA	5 600	3 400	3 400	8 400	3 360	3 360
AMT REQ	15 810	11 220	11 665	7 110	12 620	13 590

The above does not include salaries, but does allow for 3% inflation per year.

11. Commencement and proposed completion date:

Trap site and grid establishment will occur in September 1993. Pre-treatment sampling would commence soon afterwards and continue until January 1995. Post -treatment sampling will commence in the first six months of 1995 and continue until January 1999. Data analyses will commence in 1998/99 and work prepared for publication.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. Title of Project: Effects of timber harvesting on small vertebrates in medium rainfall jarrah forest.

2. Project Leader: Gordon Friend

3. Aim:

(a) To investigate the effects of logging and the associated burning operations on populations of selected small mammals and reptiles inhabiting medium rainfall jarrah forest.
(b) To compile information on the life history strategies of these small vertebrate species, and examine their population dynamics and habitat preferences.
(c) Use these data to develop predictive models of the impact of logging/burning operations on small vertebrates and formulate general principles for the management of fire and logging in jarrah forest ecosystems.

4. Background/Justification:

The impact of burning and logging on Australia's native terrestrial fauna is the subject of much controversy, but there have been relatively few studies which address this issue. There is an urgent need for experimental studies (in combination with retrospective (space-for time) studies) which examine the immediate and short-term impacts of integrated burning and logging operations on small vertebrates in jarrah forest, focusing particularly on keystone species likely to be sensitive to disturbance. Relevant small vertebrate species include litter-dwelling skinks and those reptiles requiring logs and tree-trunks, and small mammals dependent on hollows in old standing trees or logs (eg. the Mardo *Antechinus flavipes* and the Brush-tailed Phascogale *Phascogale tapoatafa*).

Although habitat trees are now retained as part of standard logging operations in the jarrah forest there are few data enabling decisions to be made regarding species selection, spatial configuration and age or size class of retained trees with respect to their influence on faunal species or community composition. Critics of CALM have focussed on these as key issues in jarrah forest management. If these criticisms are to be addressed, managers require sound data on the influence of coupe design and the retention of trees in logged areas on faunal species.

The present study is designed to investigate the direct and short-term effects of standard logging/burning operations on the above groups of small vertebrates in medium rainfall jarrah forest. The work is part of a large, multidisciplinary project examining the impacts of such operations on medium-sized mammals, birds, bats, invertebrates, vegetation, stand structure and dynamics, and microclimate.

The work will later be integrated with a broader-scale (retrospective) study which will examine relationships between species/community composition of the vertebrate fauna and logging and fire history in medium to high rainfall jarrah forest throughout the south-west. This combined approach will provide data on both the short and long-term impacts of logging and burning, and

ensure a broader geographic applicability of the results from the experimental work. The study will also complement existing work on small vertebrates and fire near Collie (RPP 43/92), and the work being undertaken by a Ph.D. student from Murdoch University (Susan Rhind) on the ecology of *Phascogale tapoatafa*.

5. **Keywords:**

Small vertebrates, disturbance, logging, fire, reptiles, mardo, phascogale, jarrah.

6. **Target Users:**

Managers of state forests in the Swan, Central Forest and Southern Forest regions. The study will also provide data regarding disturbance ecology of relevance to other researchers and the general public. Much of the data will also be relevant to the dry sclerophyll forest ecosystems of south-eastern Australia.

7. **Associated Staff:**

Keith Morris, Grant Wardell-Johnson and Brent Johnson (Woodvale); Neil Burrows, Geoff Stoneman and Matthew Williams (Como); Chris Vellios, Colin Ward and John Rooney (Manjimup).

8. **Associated Institutions:**

Murdoch University (Susan Rhind, Ph.D. student).

9. **Study Design:**

The work will be carried out in Kingston and Warrup Forest Blocks, 25 km north-east of Manjimup. Four treatments will be imposed: (i) burning only (control); (ii) shelterwood logging; (iii) gap creation leaving habitat trees; and (iv) gap creation leaving no habitat trees (clearfell). Each treatment will be replicated three times, and two sampling sites will be established in two of the replicates, but only one in the third (ie. 20 sites total). Logged areas will be subjected to the normal prescribed burning carried out for such operation. It is anticipated that logging operations will be carried out in 1995.

Each sampling site will comprise a core area of 80 x 80 m in which a 5 x 5 grid of pitfall traps will be established with 20 m spacing. Superimposed over this grid will be a larger 5 x 5 grid of small mammal traps (Elliott Type A) with 40 m spacing. Large wire-cage traps will also be placed in a 5 x 3 grid at 80 m spacing as part of the integrated studies on medium-sized mammals (KDM; see Appendix). However only one wire-cage grid will be established in each replicate (ie. 12 grids). Traps will be run for three consecutive nights six times during each year (every second month). Animals captured will be individually marked, measured and released. Spotlighting in the vicinity of each plot will also be carried out during each trapping period.

Although abundance and distributional data will be gathered on a wide range of small vertebrate species and their response to logging operations, the major focus of the work will be on several species of litter-dwelling skinks and two species of small mammals, the Mardo (*Antechinus flavipes*) and the Brush-tailed Phascogale (*Phascogale tapoatafa*). With respect to Phascogales, 20 nest boxes will be set up in one replicate of each of the treatments in an effort to catch and radio collar individuals of this species shortly before the logging operations, and to monitor them during and after the treatment. This work is designed to complement the detailed work being carried out by Susan Rhind (Murdoch University) on the ecology of *P. tapoatafa* in the

Perup Nature Reserve, and the species response to logging in one other block at Kingston (which will be logged in summer 1994/95). It will use some of the techniques already developed by Susan, and will extend her work to enable data to be gathered on further logging sites.

Forest structure and habitat parameters which may be of relevance to small vertebrates, and particularly *P. tapoatafa* and *Antechinus flavipes* (such as the distribution , abundance and size of hollow trees and logs, and leaf litter and understorey vegetation cover), will be quantified on each site before and after logging/burning in integrated studies being carried out by Neil Burrows and Geoff Stoneman. Vegetation floristics and microhabitat parameters (eg. abundance and distribution of woody debris, temperature and humidity regimes) will also be assessed in these related studies.

Analyses will involve examining initial similarity between grids using clustering and ordination techniques. Pre and post-treatment similarity in faunal abundance and composition between areas will be assessed and provide the basis for measuring impact. Pairwise t-tests and ANOVAs will be used to compare species richness and abundance between treatments, with time periods providing additional replication.

10. **Costs:**

Per annum costs detailed below are based on an initial establishment and essential equipment purchase phase and subsequent running of the grids. Costs in subsequent years will be less the establishment and initial equipment purchase costs, except in 1995 when some post-logging replacement and re-establishment of pitfall traps may be required. These costs include 5% per annum for inflation. Plant, travel and overtime estimates assume the essential involvement of two TOs from Manjimup, accommodation (permanent camp, no cook) being available and two four-cylinder vehicles driving ex Manjimup daily.

<u>Establishment and essential equipment</u>

Vehicle running 1300km x 0.20 (ex Perth)	$ 260
1000km x 0.20 (2 vehicles)	$ 200
pro-rata on site	$ 300
Cage traps 50 x $28	$1400
Elliott traps 200 x $18	$3600
Chainsaw	$ 800
Trailer	$ 800
TA 2x27.35 x 10 days + 2x18.40 x 10 days	$ 915
OT (3 TOs)	$ 800

<u>Running grids</u>

Plant costs 1300km x 6 trips x 0.20 (Perth)	$1560
700km x 6 trips x 0.20 (Manji)	$ 840
pro-rata on site	$1100
Bait and trap maintenance	$ 500
TA 6x(2x27.35x4 days + 2x18.40x4 days)	$2290
O/T 15% x 3 x 4 days x 6	$1580
Volunteer food and accommodation	$ 750

TOTAL COSTS 1993/94

TRAVEL	$3955
PLANT	$4260
MATERIALS	$7100
OVERTIME	$2380
GRAND TOTAL	**$17695**

COSTS IN SUBSEQUENT YEARS

	94/95	95/96	96/97	97/98
TRAVEL	2522	2775	2900	3045
PLANT	3850	4235	4450	4670
MATERIALS	4375	4000	4200	4410
OVERTIME	1735	1910	2000	2100
TOTALS	**12482**	**12920**	**13550**	**14225**

The above costs do not include salaries. It is estimated that 0.20 FTE PRS and 1.0 FTE TO will be involved in this project.

11. Proposed date of commencement and proposed completion date:

Site selection and grid establishment would take place during Spring/Summer 1993/94. Sampling would commence thereafter and continue (as described above) for twelve months before logging in 1995 and for three years after logging (ie. until mid 1998). Data analyses would be carried out during 1998/9 and the work prepared for publication.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. Title of Project:

Effects of timber harvesting on terrestrial invertebrates in medium rainfall jarrah forest.

2. Project Leader:

Gordon Friend, PRS

3. Aim:

(a) To investigate the effects of logging and the associated burning operations on the terrestrial invertebrate fauna (particularly spiders, beetles and flies) inhabiting medium rainfall jarrah forest.

(b) To compile information on seasonal abundance, habitat preferences and species composition of the above groups.

(c) Use these data to develop predictive models of the impact of logging/burning operations on terrestrial invertebrate communities and formulate general principles for the management of fire and logging in jarrah forest ecosystems.

4. Background/Justification:

The impact of burning and logging on Australia's native terrestrial fauna is the subject of much controversy, but there have been relatively few studies which address this issue. This is particularly so with respect to invertebrates, which are now recognized as central to ecosystem functioning and biological diversity, yet are usually ignored in ecological research. There is an urgent need for experimental studies (in combination with retrospective (space-for time) studies) which examine the immediate and short-term impacts of integrated burning and logging operations on invertebrate communities in jarrah forest, focusing particularly on key groups likely to be sensitive to disturbance. Earlier work carried out in forests and shrublands has pinpointed spiders (particularly Mygalomorphs), certain beetles (eg *Catasarcus* weevils), cockroaches and flies as potentially sensitive to forest management practices and excellent bio-indicators of environmental conditions.

Although habitat trees are now retained as part of standard logging operations in the jarrah forest there are few data enabling decisions to be made regarding species selection, spatial configuration and age or size class of retained trees with respect to their influence on faunal species or community composition. Critics of CALM have focussed on these as key issues in jarrah forest management. If these criticisms are to be addressed, managers require sound data on the influence of coupe design and the retention of trees in logged areas on faunal species.

The present study is designed to investigate the direct and short-term effects of standard logging/burning operations on the above groups of invertebrates in medium rainfall jarrah forest.

It is part of a large, multidisciplinary project examining the impacts of such operations on small terrestrial vertebrates, medium-sized mammals, bats, birds, vegetation, stand structure and dynamics, and microclimate.

The work will later be integrated with a broader-scale (retrospective) study which will examine relationships between species/community composition of the invertebrate fauna and logging and fire history in medium to high rainfall jarrah forest throughout the south-west. This combined approach will provide data on both the short and long-term impacts of logging and burning, and ensure a broader geographic applicability of the results from the experimental work. The study will also complement existing work on invertebrates and fire in the Perup Nature Reserve (RPP 20/90).

5. **Keywords:** Invertebrates, disturbance, logging, fire, spiders, beetles, cockroaches, flies, jarrah.

6. **Target Users:**

Managers of state forests in the Swan, Central Forest and Southern Forest regions. The study will also provide data regarding disturbance ecology of relevance to other researchers and the general public. Much of the data will also be relevant to the dry sclerophyll forest ecosystems of south-eastern Australia.

7. **Associated Staff:**

Invertebrate ecologist (to be appointed) or Ph.D. student (Murdoch University), Keith Morris and Brent Johnson (Woodvale), Neil Burrows, Geoff Stoneman and Matthew Williams (Como).

8. **Associated Institutions:**

Western Australian Museum, Australian National Insect Collection (CSIRO, Canberra), University of Western Australia (Dr Barbara Main).

9. **Study Design:**

The work will be carried out in Kingston and Warrup Forest Blocks, 25 km north-east of Manjimup. Four treatments will be imposed: (i) burning only (control); (ii) shelterwood logging; (iii) gap creation leaving habitat trees; and (iv) gap creation leaving no habitat trees (clearfell). Each treatment will be replicated three times, and two sampling sites will be established in two of the replicates, but only one in the third (ie. 20 sites total). Logged areas will be subjected to the normal prescribed burning carried out for such operations. It is anticipated that logging operations will be carried out in late 1995.

Each sampling site will comprise a 15 x 15m grid of 16 pitfall traps (cups 90mm diameter and 110mm deep) in a 4 x 4 array at 5m spacing. When operational, traps will be 3/4 filled with Galt's solution (preservative) and left open for 10 days, Traps will then be bulked by four to give four samples per sampling session. Fifty sweeps of the understorey vegetation (<2m) on each grid will be taken on each sampling occasion using a 60cm diameter hoop net. Samples will be taken six times during each year (every second month). Forest structure and habitat parameters which may be of relevance to terrestrial invertebrates will be quantified on each site before and after logging/burning in integrated studies being carried out by Neil Burrows and Geoff Stoneman. Vegetation floristics and microhabitat parameters (eg. abundance and distribution of woody debris, temperature and humidity regimes) will also be assessed in these related studies.

Invertebrate samples will be sorted and collated initially at the Order level, and subsequently spiders (particularly Mygalomorphs), beetles, cockroaches and flies will be identified to family or species level.

Analyses will involve examining initial similarity between grids using clustering and ordination techniques. Pre and post-treatment similarity in faunal abundance and composition between areas will be assessed and provide the basis for measuring impact. Pairwise t-tests and ANOVAs will be used to compare species richness and abundance between treatments, with time periods providing additional replication.

10. **Costs:**

Per annum costs detailed below are based on an initial establishment and essential equipment purchase phase and subsequent running of the grids. Costs in subsequent years will be less the establishment and equipment costs, except in 1995 when some post-logging replacement and re-establishment of pitfall traps may be required. These costs include 5% per annum for inflation. Salary for a full-time invertebrate ecologist @ Level 2/4 Yr 4 are included in these costings, as there is no available expertise within the Department. From the second year (1994/95) on this person would also be involved (half-time) in the retrospective studies (see other RPP). The work would be unable to proceed without the appointment of such a person with considerable experience in invertebrate taxonomy and ecology. Alternatively, this experimental component of the work could be carried out as part of a Ph.D. program (possibly through Murdoch University). For this reason salary costs are treated separately in the costings below.

<u>Establishment</u>

Vehicle running 1000 km x 0.20	$ 200
pro-rata on site	$ 100
Materials (stakes PVC sleeves, cups etc)	$ 300
TA 3 x 45 (camp) x 5 days	$ 680
OT 15% x 5 days	$ 100

<u>Running grids</u>

Chemicals, containers, alcohol	$1000
Plant costs 700km x 6 trips x 0.20*	$ 900
pro-rata on site*	$ 600
TA 6 trips x $27.35x 1.5 days	$ 250
O/T TO assistance 15% x10days	$ 200

* This assumes that setting or pick-up of invertebrate grids is carried out in conjunction with vertebrate trips.

TOTAL COSTS 1993/94

TRAVEL	$ 930
PLANT	$1800
MATERIALS	$1300
OVERTIME	$ 300
SUBTOTAL	**$4330**
SALARY (full-time)	$31570
GRAND TOTAL	**$35900**

COSTS IN SUBSEQUENT YEARS

	94/95	95/96	96/97	97/98	98/99
TRAVEL	250	260	270	285	--
PLANT	1500	1575	1650	1730	--
MATERIALS	1000	1050	1100	1150	--
OVERTIME	200	200	200	200	--
S/TOTALS	**2950**	**3085**	**3220**	**3365**	
SALARY	**15785**	**15785**	**15785**	**15785**	**15785**
TOTALS	**18735**	**18870**	**19005**	**19150**	**15785**

It is estimated that 0.10 FTE PRS and 0.10 FTE TO will be involved in this project, in addition to the appointed invertebrate ecologist.

11. **Proposed date of commencement and proposed completion date:**

Site selection and grid establishment would take place during Spring/Summer 1993/94. Sampling would commence thereafter and continue (as described above) until mid 1998, with logging occurring in 1995. Data analyses would be carried out during 1998/9 by the consultant and the work prepared for publication.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** Characteristics of hollow-bearing jarrah (*Eucalyptus marginata*) and marri (*Eucalyptus calophylla*) trees and coarse woody debris (CWD), their use by selected species of fauna, and the effect of timber harvesting on them.

   Departmental Primary Program: Forests

   Land Tenure: State Forest

   CALM Region(s): Swan, Central and Southern

   CALM District(s):

   Science Group: Sustainable Resources

   Program: Natural Products

2. **Project Leader:** Dr Geoff Stoneman

3. **Aim:**

A. To develop allometric relationships between tree and stand parameters, and the size and abundance of hollows in jarrah and marri trees and CWD.

B. To develop relationships between tree and stand parameters, the size and abundance of hollows in jarrah and marri trees and CWD, and the use of these trees by selected species of fauna.

C. To determine the effects of the logging-and-burning treatments on the abundance of hollow-bearing trees and CWD, and to relate this to the abundance of selected species of fauna.

Hypotheses to be tested are:

A.

Hollow size and frequency (per tree) is independent of tree size, tree age, and tree dominance status.

Hollow size and frequency (per tree) is independent of crown size, crown growth stage and crown condition.

Hollow size and frequency (per tree) is independent of fire evidence/damage and management history.

The size and frequency of hollows in CWD is independent of the amount of log material and logging history.

The size and frequency of hollows in CWD is independent of log type, dimensions, state of decay and evidence of fire.

B.

The use of trees by selected fauna species is independent of tree size, tree age, and tree dominance status.

The use of trees by selected fauna species is independent of crown size, crown growth stage and crown condition.

The use of trees by selected fauna species is independent of fire evidence/damage and management history.

The use of CWD by selected fauna species is independent of the amount of log material and logging history.

The use of CWD on the ground by selected fauna species is independent of log type, dimensions, state of decay and evidence of fire.

C.

The abundance of hollow-bearing trees and CWD is independent of the logging-and-burning treatments.

The abundance of selected species of fauna is independent of the changes in abundance of hollow-bearing trees and CWD caused by the logging-and-burning treatments.

4. Background/Justification:

There has been concern for several decades now on the possible adverse effects of clearing for agriculture, logging and fire on fauna which nest and roost in hollows in trees (Hampton and Seebeck 1970, Cowley 1971, Sanderson 1975, Tyndale-Biscoe and Calaby 1975, McIlroy 1978). Subsequently, a considerable amount of research has been done on the use of tree hollows by selected fauna in eucalypt forest in the eastern states and wheatbelt areas of Western Australia (Calder 1979, Golding 1979, Saunders 1979, Ambrose 1982, Saunders *et al.* 1982, Calder *et al.* 1983, Lindenmayer 1992).

However, there is relatively little known about the development of hollows in trees, and the effects of silvicultural practices on the development and longevity of hollows in trees in Australian forests, and the effect this has on hollow dependent fauna. Mackowski (1984) studied the ontogeny of hollows in *Eucalyptus pilularis.* Trees smaller than 100 cm diameter provided negligible hollows and only trees greater than 120 diameter provided large hollows. From spotlighting studies he showed that the populations of gliders and possums were less in stands with less than 3 hollow trees per hectare. Lindenmayer and others have studied tree hollows in Victoria's montane ash forests and hypothesized about the effects of silvicultural treatments on present and projected populations of the endangered species, Leadbeater Possum, and some other arboreal fauna (Lindenmayer 1991, Lindenmayer 1992, Lindenmayer *et al.* 1990 abcd, Lindenmayer *et al.* 1991abcde).

In State Forest in Western Australia there have been two studies on tree hollows. The first investigated the habitat role that tree hollows provide and the effects of fire on tree hollows in jarrah/marri forest (Inions 1985, Inions *et al.* 1989). The second investigated the formation, frequency and longevity of hollows in jarrah trees and the effects of firewood harvesting on the population of hollows in the forest (Faunt 1992).

Inions (1985, *et al.* 1989) found that the Common Brushtail Possum and the Ringtail Possum used suitable hollows regardless of the tree species, tree condition, height or size of tree. Using very general tree growth data, he estimated that suitable hollows would form in jarrah at about 300 years of age, and in marri at about 200 years. The average age of trees inhabitated by possums was estimated to be as high as 500 years for jarrah and 400 years for marri. He found that possums used about 3 trees per hectare for refuge. Silvicultural prescriptions for retention of habitat trees have been based on this observation. A high intensity fire destroyed 38% of the trees previously used by possums. The fire killed the older and larger trees and reduced the average age of trees containing suitable hollows by about 100 years.

Faunt (1992) counted growth rings on trees with and without hollows and found the age to hollow formation in jarrah was only about 80 years, in contrast to Inion's estimate of 300 years. Hollow formation increased with tree size and age, and fire seemed to be an important precursor to hollow formation. Faunt only investigated hollows in 36 jarrah trees, whereas she indicates (Faunt pers comm 1993) that at least 120 trees would be required to get good estimates of hollow formation in relation to tree size and condition, logging history and fire history. Faunt's study concentrated much more on hollows in logs on the ground. Hollows in this material seemed to increase with the amount of this material on the forest floor, which in turn increased with the incidence of logging. The size and frequency of hollows in logs on the ground increased with log dimensions.

Part A of this RPP is essentially proposed to build on and extend the work done by Faunt (1992). Part B will further develop this work by relating tree, stand and hollow characteristics to use of the trees by selected species of fauna. This will allow estimates to be made of the number and characteristics of trees used by these animals. Part C will partially test the hypotheses developed in part B about the number and characteristics of hollow-bearing trees required by the fauna. These studies will probably show that abundance of hollow-bearing trees decreases following the logging-and-burning treatments, and that populations of the fauna also decrease following these treatments. However, this would not prove that the reduction in abundance of hollow-bearing trees was the causal factor as many other factors will also change due to the logging-and-burning treatments. To test the hypothesis that a critical number of suitable trees per hectare is required to maintain a particular population of animals, it would be necessary to reduce the abundance of these trees by some other artificial means, and determine the impact of this on fauna populations. For example, one-way gates near the base of the trees, which would allow the animals to get down the tree but not to return back up the tree, may be a suitable means. If this approach were to be taken another area would need to be monitored and the population of suitable trees reduced at the same time as the logging-and-burning treatments.

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5. **Keywords:** silviculture, logging, burning, forest density, tree hollows, coarse woody debris, logs, tree size, tree age, crown, understorey, habitat, fauna, conservation

6. **Target Users:**

   Information is important to management of State Forest in the Swan, Central and Southern Forest regions.

7. **Associated Staff:**

   Keith Morris, Gordon Friend and Grant Wardell-Johnson (Woodvale), Neil Burrows (Como).

8. **Associated Institutions:**

   None directly in this study.

9. **Study Design**

A. Relationships between tree and stand parameters and size and abundance of hollows.

   This part of the project is a continuation of the work done by Faunt and will use the same methodology.

Plots:
Plots will be established and all trees > 30 cm dbhob will be assessed for species, dominance class, dbhob, bark depth and bole defects.

Hollows in standing trees:
One tree of each species will be randomly selected from each 10 cm diameter size class and assessed for hollows. Faunt has already assessed some 36 standing jarrah trees and it is anticipated that about 120 trees of each species will be required to develop reasonable relationships. These trees will be photographed and described in terms of crown dominance, crown density, crown size, crown senescence, bole epicormics, fire scarring, and evidence of rot and fire on the stump. The height to all primary branches on the bole will be measured, and diameter and internal rot and termite damage at 1.3 m from where the branch leaves the bole will be recorded. Type, position, orientation and aspect of hollow, cavity dimensions, extent of mudguts, evidence of fire, termites, borers and habitation will be assessed. The tree will be aged by couting growth rings in a section cut from the stump.

Coarse woody debris (CWD):
All coarse woody debris will be assessed for dimension, hollows, shelter, condition and suitability for wood products.
Hollows in CWD:
These will be assessed the same as hollows in standing trees. Faunt has already done a lot of work on hollows in jarrah CWD and it is anticipated that future research will concentrate on marri.

B. Relationships between tree, stand and hollow parameters and the use of these trees by selected species of fauna.

This study will be based in Kingston Block, Manjimup District and will be part of a large inter-disciplinary study. Keith Morris will be using spotlighting and radio-transmitters to identify trees and CWD used by Chudich, Woylie, Quenda, Brush-tailed Possum and to a lesser extent Numbat and Ring-tailed Possum. Gordon Friend will be identifying trees and CWD used by Phascogale, Mardo and lizards, and RPP's by Grant Wardell-Johnson will identify trees used by birds and bats. These trees and CWD will be assessed for bole and crown characteristics as in part A above. Following treemarking of the area and just prior to logging of the area, the trees which will not be retained in the logging will be fallen and assessed for hollow characteristics as in part A above. CWD used by the fauna will be assessed as in part A above. Additional characteristics of the understorey near each tree and CWD will be recorded as this has been found to affect use of trees by some species (Lindenmayer *et al.*, 1991b). Sample size for this work is yet to be determined. Analysis of data from part A above and that of Lindenmayer and co-workers will help to estimate variability, and thus sample size.

C. To determine the effects of the logging-and-burning treatments on the abundance of hollow-bearing trees and CWD, and to relate this to the abundance of selected species of fauna.

This study will also be based in Kingston Block, Manjimup District and will be part of a large inter-disciplinary study. Keith Morris will be using spotlighting and radio-transmitters to identify trees and CWD used by Chudich, Woylie, Quenda, Brush-tailed Possum and to a lesser extent Numbat and Ring-tailed Possum. The relationships between the abundance of hollow-bearing trees and CWD, and the abundance of selected species of fauna, determined in part B above will be tested to see if these relationships are good predictors of the abundance of fauna following the logging-and-burning treatments.

10. Costs
All costs have made an allowance for inflation of 5%/yr.

The following list details the steps required for this RPP to be performed:
A. 01/94 - 06/94. Financial year 1. Part A of RPP. Establish plots, measure and assess trees, CWD, stand and hollows. Fall and dissect trees and CWD.
B. 07/94 - 12/94. Financial year 2. Part B of RPP. Measure and assess trees, CWD, stand and hollows. Fall and dissect trees and CWD.
C. 01/95 - 12/96. Financial years 2 to 4. Part C of RPP. Measure and assess new trees and CWD being used by the fauna. Analyse and write-up data.
D. 01/97 - 12/97. Financial years 4 and 5. Analyse and write-up.

Materials

1993/94: Chainsaw, consumables, etc	2000
1994/95: Consumables, etc	1050
1995/96: Consumables, etc	550
1996/97: Consumables, etc	575
1997/98: Consumables, etc	600

Plant

1993/94: 6 months @ 30,000 km/yr (based on Faunt's study) = 15,000 km x $0.15/km = $2250 + (onsite cost of $40 x 26 wks = $1040)	3290
1994/95: 12 months @ 30,000 km/yr (based on Faunt's study) = 30,000 km x $0.15/km = $4550 + (onsite cost of $40 x 52 wks = $2080) x 1.05	6909
1995/96: 80 km x 100 trips (6 months) = 8,000 km x $0.15/km = $1200 + (onsite cost of $40 x 26 wks = $1040) x 1.1025	2270
1996/97: 3,000 km/yr x $0.15/km = $450 + (onsite cost of $40 x 2 wks = $80) x 1.1576	614
1997/98: 3,000 km/yr x $0.15/km = $450 + (onsite cost of $40 x 2 wks = $80) x 1.2155	644

Accommodation

1993/94: 60ays @ 93.2	5592
1994/95: 40 days @ 93.2 (x 1.05)	3914
1995/96: 20 days @ 93.2 (x 1.1025)	2055
1996/97: 10 days @ 93.2 (x 1.1576)	1079
1997/98: 10 days @ 93.2 (x 1.2155)	1133

COST SUMMARY

	Year 1 (93/94)	Year 2 (94/95)	Year 3 (95/96)	Year 4 (96/97)	Year 5 (97/98)
Materials:	2000	1050	550	575	600
Plant	3290	6909	2270	614	614
Accomodation	5592	3914	2055	1079	1133
Total	10882	11873	4875	2268	2347

11. Proposed date of commencement and proposed completion date.

The project will commence in January 1994, following a complete review, analysis and write-up of data already collected by Faunt. The study will be completed by the end of 1997. Annual reports will be prepared by the L2/4 RS in consultation with me.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** The effects of timber harvesting on birds of the jarrah forest.

2. **Project Leader:** Grant Wardell-Johnson

3. **Aim** To quantify the effect of logging and fire in medium rainfall jarrah forest on the composition of the avifauna. To determine the influence of old-growth marri and jarrah trees (habitat trees and edge effects) on the composition of the avifauna following logging and burning. To determine critical habitat components of marri and jarrah trees. To determine the most appropriate pattern of retained trees.

   To develop general models of the relationships between bird species composition and logging and fire history and formulate general principles for the management of fire and logging in jarrah forest ecosystems.

4. **Background/Justification:** The impact of timber harvesting on Australia's avifauna is the subject of much controversy, yet there have been relatively few detailed studies which address this issue. There is an urgent need for experimental studies (in combination with retrospective-space for time-studies) which examine the immediate and short-term impacts of integrated burning and logging operations on birds in jarrah forest, focusing on key species likely to be sensitive to disturbance. Relevant bird species include hollow nesting (eg. Rufous Treecreeper) and other mature forest dependent species.

   The retention of habitat trees forms a part of standard logging operations in jarrah forest, yet there are few data allowing a basis for species selection, the spatial configuration of retained trees, or the age or size class of retained trees in respect to their influence on community or species composition. Similarly edge effects on bird communities are critical considerations in the planning of logging operations.

   There have been several brief studies on the effects of logging on birds of the jarrah forest (eg. Serventy pers. comm, Abbott and Van Heurck 1985, Norwood *et al.* in press). but none have been sufficiently detailed to provide guidelines on suitable spatial/temporal configuration of retained habitat trees or to determine the influence of edge effect. Critics of CALM have focussed on these as key issues in jarrah forest management. Managers require direction concerning coupe design and the retention of trees in logging operations.

   The present study is designed to investigate the direct and short-term effects of different intensities of logging/burning operations on the birds of the medium rainfall jarrah forest. It is anticipated that a similar study will be commenced in high rainfall jarrah forest as the present work nears completion.

   The work will be carried out alongside a broader-scale (retrospective) study which is examining relationships between species/community composition of the avifauna and logging and fire history in medium to high rainfall jarrah forest throughout the south-west. This combined approach will provide data on both the short and long-term impacts of logging and burning, and ensure a broader geographic applicability of the results from the experimental work. The study will also

compliment existing work on birds and fire/logging impacts in the karri forest (eg. RPP 22/82 and studies by Ph.D student Penelope Atkinson).

5. **Keywords:** Habitat trees, marri, jarrah, disturbance ecology, birds, edge effects, fire, logging Vegetation structure.

6. **Target users:** Operations (Design), Research (Disturbance Ecology), Public (Perceptions and Information). Managers of State Forests in the Swan, Central Forest and Southern Forest Regions. The study will also provide data regarding disturbance ecology of relevance to other researchers and the general public. Much of the data will also be relevant to the dry sclerophyll forest ecosystems of south-eastern Australia.

7. **Associated staff:** Mike Craig (PhD project), Gordon Friend, Keith Morris, Neil Burrows, Geoff Stoneman, Mathew Williams, Chris Vellios.

8. **Associated Institutions:** UWA (Dr J.D. Roberts, supervisor of Mike Craig).

9. **Study Design:** The work will be carried out in Kingston and Warrup Forest Blocks, 25 km north-east of Manjimup. Four treatments will be imposed: (i) burning only (control); (ii) shelterwood logging; (iii) gap creation leaving habitat trees; and (iv) gap creation leaving no habitat trees (clearfell). Shelterwood treatments would probably occupy 20% of the logging area and be in patches of 5-50 ha. The gap treatment would be limited to 10 ha for any one gap, but in this sort of forest up to 80% of the conventional logging area may be suitable for gap treatment.

   The control area would be in an area of about 400 ha and the other three treatments would all be located within a conventional logging area which in total covered an area of about 400 ha.

   There will be five replicate bird census areas in each of the four treatments each with three census grids (exterior, edge ie straddling treatment, and interior: hence 60 census sites). An area search method as adopted in the RAOU Australian bird count (ABC) will be used to census birds. The alternative point count and transect count methods are not being used because of lower bird densities in jarrah forest compared with structurally similar forests in eastern Australia and because for this study, the area count method allows comparisons with sampling procedures for other components of the biota, site measures at the same sites and the methods proposed for the retrospective study. Each quadrat will be censused for 20 minutes at least three times in each season (ie 180 counts per season). In view of the proximity of the census locations, approximately 10 censuses can be carried out each day (ie 27 days census per season). Recording sheets will be the same as used in the ABC but data will be analysed by project consultant in relation to site factors.

   Birds use of trees, habitat data on trees and site will be recorded to relate species/community composition to management regime. Analyses will involve examining initial similarity between grids using multivariate techniques. Pre and post-treatment similarity in bird composition between areas will be assessed and provide the basis for measuring impact.

   In addition it is hoped to conduct nocturnal censuses. There would be one census per replicate per season which amounts to 60 censuses per season. At a rate of three censuses per night these would take 20 nights to complete and censuses would be conducted in the 2 hours after sunset. Nocturnal censuses may also include playback of species calls though there are many biases associated with this method which would be investigated.

Various site variables will be measured at each replicate so a picture of bird abundances relative to features of the forest can be determined in a pre-logging landscape. By determining natural variations in abundance these results can be used to assess the impact of the various logging treatments on the avifauna.

Several species will be selected for detailed studies of their ecology. Aspects of their ecology to be investigated are nesting foraging and roosting ecology. Both censuses and the single species ecologies will run for the duration of the project (ie. one year pre-logging and one year post-logging for Ph.D and at least two years post-logging).

Single species ecologies will be determined by actively searching for species nests and recording the location of each nest found as well as its success. If required radio-tracking will be used as an aid to locating nests of diurnal species and will almost certainly be needed to locate nests of nocturnal species. Nests will be monitored on a weekly basis to determine fledging success and will be monitored more closely to determine the types of foods bought to the young.

Foraging ecology will be largely determined by observational studies. The site of a foraging bird will be recorded and if possible whether the manoeuvre was successful.

Roosting ecology will be determined through radio tracking . Again the type of roost and its location will be recorded as well as the number and sex of the birds using the roost.

The kinds of variables to be recorded for these investigations include:

i) Width of trunk/branch

ii) Angle of the trunk/branch to the ground

iii) Height of the tree

iv) Height of nest/roost/foraging observation from the ground

v) Species of tree

vi) If the substrate is dead or alive

vii) If on the ground the type of substrates (eg. litter, laterite, sand etc)

viii) Whether the animal is foraging on leaves

ix) Whether the tree is flowering or fruiting

x) Whether the animal is nesting/foraging/roosting in a group or singly and the sex ratio in any group.

Where possible the age and sex of the bird will be determined

Possible species to be included for detailed ecological study include:

i) Long-billed White-tailed black Cockatoo (*Calyptorhychus baudinii*

ii) Red-capped Parrot (*Purpureicephalus spurius*

iii) Western Rosella (*Platycercus icterotis*

iv) Western Yellow Robin (*Eopsaltria griseogularis*

v) Western Thornbill (*Acanthiza inornata*

vi) Rufous Treecreeper (*Climacteris rufa*

vii) Western Spinebill (*Acanthorhynchus superciliosus*)

This list is provisional and final selection will depend on the results from the first years census.

10. Costs:

Year 1	1993/94
Establishment	
Plant 2000 km x .23	$460
Standing charges 470 x 3	$210
15 Radio transmitters @ $100	$1500
Steel pickets 160 x $4.10	$650
Consumables (tape etc)	$200
Assessment (assume 20 counts per day).	
Plant 40 days x 100 km x .23 x 4 seasons	$3680
Standing charges 10 x $70	$700
Total costs for 1993/94	
Materials	$2350
Plant	$5050
TOTAL	**$7 400**

Year 2 (1994/95)

as per assessment costs 1993/94, ie. $4 380 plus 5% ie $4 599.

Year 3 (1995/96)

as per assessment costs 1994/95 + 5% ie $4 829.

Year 4 (1996/97)

as per assessment costs 1995/96 + 5% ie $5 100.

Year 5 (1997/98)

as per assessment costs 1996/97 + 5% ie $5 355.

COST SUMMARY

	1993/94	94/95	95/96	96/97	97/98
Travel					
Plant	5 050	4 599	4 829	5 100	5 355
Materials	2 350				
TOTAL	7 400	4 599	4 829	5 100	5 355

11. Proposed date of commencement and proposed completion date: The experiment will commence in September 1993. There will be 1 year of pre-treatment data collection, a disturbance period of less than one year, followed by at least 2 years of post treatment data collection. Annual reports will be prepared by PhD student in consultation with GWJ.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** The effects of timber harvesting on bats in medium rainfall jarrah forest.

2. **Project Leader:** Grant Wardell-Johnson

3. **Aim:** To quantify the effect of timber harvesting on the composition of the bat fauna. To determine the influence of old-growth marri and jarrah trees and edge effect on the composition of the bat fauna following logging and burning. To determine critical habitat components for forest bats.

   To develop general models of the relationships between bat species composition and logging and fire history and formulate general principles for the management of fire and logging in jarrah forest ecosystems.

4. **Background/Justification:**

   The impact of fire and logging on Australia's mature forest dependent fauna is the subject of much controversy, yet there have been relatively few detailed studies which address the issue of the design of harvesting operations with respect to habitat trees, edge effects and mature dependent species. There is an urgent need for experimental studies (in combination with retrospective-space for time-studies) which examine the immediate and short-term impacts of integrated burning and logging operations Australia's mature forest dependent fauna, particularly forest bats.

   Bats are a major component of the jarrah forest in both absolute terms and species numbers (at least nine species occur there) and while microchiroptera demonstrate remarkable adaptability and endurance, any one species is likely to have extremely tight environmental tolerances. This factor coupled with a low reproductive capacity and frequent dependence upon a small number of roosting sites used by all or most of a population at specific times, suggests that these species present special problems with respect to forest management.

   Because of their requirement for arboreal roosts and their differential use of microhabitats within the forest, bats may be expected to be sensitive to forest operations which affect the structure of their habitat. The impact of logging operations is not only confined to the structural component, but may also include changes in the availability of insects as food.

   The retention of habitat trees forms a part of standard logging operations in jarrah forest, yet there are few data allowing a basis for species selection, the spatial configuration of retained trees, or the age or size class of retained trees in respect to their influence on community or species composition. Similarly edge effects are critical considerations in the planning of logging operations. Critics of CALM have focussed on this as a key issue in jarrah forest management. Managers require direction concerning coupe design and the retention of trees in logging operations. An integrated experimental approach planned to commence in Kingston Forest Block provides scope to address these issues.

   The present study is designed to investigate the direct and short-term effects of various intensities of logging/burning operations on the bats of the medium rainfall jarrah forest. It is anticipated that a similar study will be commenced in high rainfall jarrah forest as the present work nears completion.

   The work will be carried out alongside a broader-scale (retrospective) study which is examining relationships between species/community composition of the bats and logging and fire history in medium to high rainfall jarrah forest throughout the south-west. This combined approach will provide data on both the short and long-term impacts of logging and burning, and ensure a broader geographic applicability of the results from the experimental work.

5. **Keywords:** Habitat trees, marri, jarrah, disturbance ecology, bats, edge effects, fire, logging vegetation structure.

6. **Target users:** Operations (Design), Research (Disturbance Ecology), Public (Perceptions and Information). Managers of State Forests in the Swan, Central Forest and Southern Forest Regions. The study will also provide data regarding disturbance ecology of relevance to other researchers and the general public. Much of the data will also be relevant to the dry sclerophyll forest ecosystems of south-eastern Australia.

7. **Associated Staff:** N/A

8. **Associated Institutions:** UWA (Dr Jamie O'Shea, supervisor to David Hosken).

9. **Study Design:**

   The work will be carried out in Kingston Forest Block, 25 km north-east of Manjimup. The overall study design is of the BACI (before, after, control, impact) type, with potentially several replicates of each of four treatments. The four treatments are:

   i) Control.
   ii) Shelterwood.
   iii) Gap with retained habitat trees.
   iv) Gap without retained habitat trees

   Shelterwood treatments would probably occupy 20% of the logging area and be in patches of 5-50 ha. The gap treatment would be limited to 10 ha for any one gap, but in this sort of forest up to 80% of the conventional logging area may be suitable for gap treatment.

   The control area would be in an area of about 400 ha and the other three treatments would all be located within a conventional logging area which in total covered an area of about 400 ha.

   Field work will include censusing the bat population within the study area, using harp traps, mist nets and bat detectors, and tagging all captured animals; locating roost sites, using radiotelemetry and light-tags; observing animal numbers, sex and behaviour within roosts, using an endoscope or low intensity light camera; estimating home ranges and life history patterns, via radiotelemetry and censusing; observing foraging behaviour, using light tags and bat detectors; collection of faeces for dietary analysis and sampling of insects, using sticky and suction traps.

   These procedures provide data on species and community composition, habitat use by the different species and crucial aspects of the bats biology, enabling the critical resources for species that make up the bat fauna of the jarrah forest to be identified, as well as allowing observations of any changes that occur to this fauna as a result of different fire/logging practices. This will

enable models to be generated which can be used to predict the effects of logging operations on forest bats and enable edge effects and the influence of habitat trees to be determined. These models will be tested following the implimentation of logging operations.

10. Costs:

Year 1 1993/94

Establishment	
Plant 2000 km x .23	$460
Standing charges 470 x 3	$210
Low-intensity light camera	$2 000
Radio transmitters $100 x 20	$2 000
Bat detectors/recorders/interface/software 6 x $1200	$7 200
Consumables (tape etc)	$200
Assessment	
Plant 40 days x 100 km x .23 x 4 seasons	$3 680
Standing charges 10 x $70	$700

Total costs for 1993/94

Materials	$11 400
Plant	$5 050
TOTAL	**$16 450**

Year 2 (1994/95)
as per assessment costs 1993/94 $4 599

Year 3 (1995/96)
as per assessment costs 1993/94 + 5%. $4 829

Year 4 (1996/97)
as per assessment costs 1995/96 + 5%. $5 070

Year 5 (1997/98)
as per assessment costs 1995/96 + 5%. $5 323

COST SUMMARY

	1993/94	94/95	95/96	96/97	97/98
Travel					
Plant	5 050	4 599	4 829	5 070	5 323
Materials	11 400				
TOTAL	16 450	4 599	4 829	5 070	5 323

11. Proposed date of commencement and proposed completion date: The experiment will commence in September 1993. There will be one year of pre-treatment data collection, a disturbance period of less than one year, followed by at least two years of post treatment data collection. Annual reports will be prepared by the PhD student in consultation with GWJ.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** Retrospective study on the effects of timber harvesting on avifauna in lateritic and sandy terrain in three landform units in jarrah forest in the medium to high rainfall areas of the south-west

2. **Project Leader:** Grant Wardell-Johnson

3. **Aim:** To establish a series of permanently located monitoring quadrats for bird census in jarrah forest with a range of management history. To determine the relationship between bird species and community composition, and logging and fire history within sandy and lateritic terrain in three equivalent but geographically separated landform units (Bevan, Dwellingup and Kingia) in jarrah forest in the medium to high rainfall areas of the south-west. To determine the relationship between bird species and community composition, and vegetation structure.

4. **Background/Justification:** There is considerable debate as to the effects of logging and burning on the birds of the jarrah forest. There are few quadrats available in jarrah forest which can serve as long term monitoring sites for bird community and species composition in relation to logging and fire. A retrospective study being established to examine the relationship of vertebrate and vascular plant composition to logging and fire provides this opportunity. The ABC of Australian birds provides a method for comparison throughout Australia and the involvement of volunteers and volunteer co-ordination through the RAOU.

5. **Keywords:** Birds, jarrah forest, disturbance ecology (logging and burning), Vegetation structure.

6. **Target users:** Operations (how to design operations), Research (Community Conservation, Community Resources, Natural Products), Public (perceptions and information).

7. **Associated staff:** Ian Wheeler, Chris Vellios, Mike Craig

8. **Associated Institutions:** UWA (Dr Dale Roberts, supervisor to Mike Craig).

9. **Study Design:** The field work will run over four years (spring 1994 - spring 1995) and include a total of eight areas (see map attached). Twenty 80 m x 80 m permanent quadrats will be established in each area. Two areas will be sampled each year *viz*. Dwellingup and Margaret River in 1994/95, Jarrahdale and Nannup in 1995/96, Kirup and Lockhart in 1996/97 and Yornup and Dixon in 1997/98. In each area sites will include sandy and lateritic soils in three equivalent landform units (plateau elements) with various logging and fire histories (including unlogged and long unburnt sites). This will provide coverage over the major area of the jarrah forest from where timber is harvested and place the experimental studies in context. Sites will be relatively uniform in both logging history and topography and be within a larger area of similar history (minimum size treatment of approx 10 ha). A minimum of two quadrats within each history/site characteristic will be established. Twenty quadrats will be run for two years to provide controls between time periods. About ten quadrats will be run during each week session by two people.

An area search method as adopted in the RAOU Australian bird count (ABC) will be used to census birds. The alternative point count and transect count methods are not being used because of lower bird densities in jarrah forest compared with structurally similar forests in eastern Australia and because for this study, the area count method allows comparisons with sampling procedures for other components of the biota and site measures at the same sites.

Each quadrat will be censused for 20 minutes at least three times in each season (depending on the number of censusers and the necessity for calibration). Co-ordinator will census birds at least once at all sites each season. Recording sheets will be the same as used in the ABC but data will be analysed by project consultant in relation to site and management history.

A predictive model of bird community composition in relation to management history and site characteristics will be developed. The study will involve two years of quadrat establishment/recording and one year of analysis and writeup.

10. **Costs:**

COST SUMMARY

	1993/94	94/95	95/96	96/97	97/98
Plant		7 650	8 053	8 455	8 878
Materials		500	525	551	579
TOTAL		8 170	8 578	9 006	9 457

11. **Proposed date of commencement and proposed completion date:** field checking for suitable sites will commence 7/93 Completion by 12/97. Annual progress reports will be prepared by consultant.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** Retrospective study on the effects of timber harvesting on terrestrial vertebrate fauna in lateritic and sandy terrain in three landform units in jarrah forest in the medium to high rainfall areas of the south west.

2. **Project Leaders:** Grant Wardell-Johnson/Gordon Friend

3. **Aim:** To determine relationship between species/community composition of terrestrial vertebrate fauna and logging and fire history within sandy and lateritic terrain in three equivalent but geographically separated landform units (Bevan, Dwellingup and Kingia) in jarrah forest in the medium to high rainfall areas of the south west. To determine relationship between species/community composition and stand structure.

4. **Background/Justification:** There is considerable debate regarding the effects of logging and burning on terrestrial vertebrate fauna of the jarrah forest. Data are sketchy on the subject. A detailed experiment is being set up to examine impacts within an area of medium rainfall in jarrah forest near Manjimup during 1993 with a similar study in the high rainfall area later (see proposed RPP by Gordon Friend).

   This study is being carried out simultaneously to ensure a broader geographic applicability of the results from those experiments. The study is being limited to two soil types in three landform units (Dwellingup, Bevan and Kingia) in the medium to high rainfall zone of the jarrah forest.

5. **Keywords:** Terrestrial vertebrates, vascular plants, disturbance (logging/burning), Vegetation structure.

6. **Target users:** Operations (how to design operations), Research (Community Resources, Community Conservation, Natural Products), Public (perception and information).

7. **Associated staff:** David Pearson, Geoff Stoneman, Brent Johnson, Chris Vellios, Ian Wheeler, Tony Annels, District staff and volunteers.

8. **Associated Institutions:** N/A

9. **Study Design:** The field work will run over four years (spring 1994 - spring 1995) and include a total of eight areas (see map attached). Twenty 80 m x 80 m permanent quadrats will be established in each area. Two areas will be sampled each year *viz*. Dwellingup and Margaret River in 1994/95, Jarrahdale and Nannup in 1995/96, Kirup and Lockhart in 1996/97 and Yornup and Dixon in 1997/98. In each area sites will include sandy and lateritic soils in three equivalent landform units (plateau elements) with various logging and fire histories (including unlogged and long unburnt sites). This will provide coverage over the major area of the jarrah forest from where timber is harvested and place the experimental studies in context. Sites will be relatively uniform in both logging history and topography and be within a larger area of similar history (minimum size treatment of approx 10 ha). A minimum of two quadrats within each history/site characteristic will be established. Twenty quadrats will be run for two years to

provide controls between time periods. About ten quadrats will be run during each week session by two people.

In each quadrat, ten pitfall traps each with seven metre drift fence, ten elliot traps and five wire cage traps will be run for three nights in each of four seasons over one year. Quadrat and trap layout design is attached as appendix one. Searching for one person hour and spotlighting in the surrounds of each plot will also be carried out seasonally during trapping periods. A record of total catchings/detections will be kept. Specimens will be lodged of all small vertebrates at the WA Museum. Overall design and detailed trapping design will ensure compliance with existing and planned experimental studies (Batalling, Kingston) while allowing for broad relevance in the jarrah forest.

Site factors such as slope, aspect, detailed logging and fire history, diameter at breast height of all trees > 10 cm dbhob and detailed measures of course woody debris will be recorded. Species composition and abundance will be related to disturbance history and site factors such as the abundance of course woody debris enabling the experiment at Kingston to be placed in context. A predictive model of vertebrate presence in relation to site characteristics will be developed.

The study will involve one year of site selection (funding applied for in vascular plant application), four years of quadrat establishment/recording and one year of analysis and writeup.

Five stand structure/age classes will be nominally included as treatments although it is recognized that there have been considerable variation in logging treatment from decade to decade and from site to site.

10. **Costs:**

Per annum costs detailed below are based on an initial establishment phase and subsequent running of the grids. These costs include 5% per annum for inflation. It is assumed (and costed as such) that the retrospective study on vascular plants will cover costs in year one of site location.

Year 1 - 1993/94:
Costs of site selection borne by vascular plant study

Year 2 - 1994/95:

Assumptions 1. 2 areas x 2 soils x 5 ages/structural classes x 2 replicates = 40 plots. 2. Run 10 quadrats per trip (including search and spotlight). 3. 4 seasons x 2 x 2 areas = 16 trips per year.

Establishment

Vehicle running 600 km x 0.20 x 2	$240.00
on site90 x 2	$180.00
40 plots x 10 pits ie 400 x $11	$4400.00
40 plots x 1/2 x 10 elliots ie 200 x $18	$3600.00
40 plots x ½ x 5 cages ie 100 x $28	$2800.00
Steel pickets (40 x 4 x $4.15)	$664.00
Equipment hire (Kango hammer)	$400.00
TA 2 x 27.35 x 5 x 2	$560.00
Volunteer food and accom.	$320.00

OT 15% x 5 days x 2	$200.00

Running costs

4 samples P.A. @ 10 plots per trip x 2 areas = 16 visits.

Vehicle running 600km x 16 x 0.20	$1920.00
Pro rata visit	$800.00
TA 2 x 27 35 x 4 days 8 x 2	$3600.00
Consumables:	
(calico bags, taper, plastic bags, perserving gear)	$250.00
Volunteer food and accom.	$800.00
OT 30% x 5 days x 8 x 2	$3000.00

Total Costs 1994/95:

Plant	$3140.00
Materials	$13234.00
Travel/Accom	$4160.00
OT	$3200.00
TOTAL	**$23 734**

Year 3. 1995/96

Establishment costs will not include elliott and cage traps.

Vehicle running 600 km x 0.20 x 2	$240.00
On site $90 x 2	$180.00
Steel pickets (40 x 4 x $4.15)	$664.00
40 plots x 10 points x $11	$4400.00
Equipment here (Kango hammer)	$800.00
TA 2 x 27.35 x 5 x 2	$547.00
Volunteer food and accom	$240.00
OT 15% x 5 days x 2	$200.00

Running costs as year 2

Total costs year 3 (1995/96)

Plant	$3190.00
Materials	$6104.00
Travel/accom	$4147.00
OT	$3400.00
TOTAL	**$16 841.00**

Year 4 1996/97

Establishment costs will not include traps

Plant	$3350.00
Material	$1978.00
Travel/accom	$4900.00
O/T	$3570.00

TOTAL	**$13798.00**

Year 5 1997/98

Plant	$3520.00
Material	$2070.00
Travel/accom	$5145.00
O/T	$3750.00
TOTAL	**$14485.00**

COST SUMMARY

	94/95	95/96	96/97	97/98
Travel	4 160	4 147	4 900	5 145
Plant	3 140	3 190	3 350	3 520
Materials	13 234	6 104	1 978	2 070
Overtime	3 200	3 400	3 570	3 750
TOTAL	23 734	16 841	13 798	14 485

Work will be written up during 1998/99.

11. **Proposed date of commencement and proposed completion date:** Field checking for suitable sites will commence late 1993. Completion by 12/97. Annual progress reports would be prepared by staff.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** Retrospective study on the effects of timber harvesting on vascular flora in lateritic and sandy terrain in three landform units in jarrah forest in the medium to high rainfall areas of the south west.

2. **Project Leader:** Grant Wardell-Johnson

3. **Aim:** To determine relationships between species/community composition of vascular plantsand logging and burning history in lateritic and sandy terrain in three landform units (Bevan, Dwellingup and Kingia) in jarrah forest in the medium to high rainfall areas of the south-west. To determine relationship between vegetation structure and floristics in these sites.

4. **Background/Justification:** There is considerable debate regarding the effects of logging and burning on vascular plants of the jarrah forest. Data are sketchy on the subject. A detailed experiment is being established to examine impacts within an area of medium rainfall in jarrah forest near Manjimup during 1993 with a similar study in the high rainfall area later (see proposed SPP submitted by Neil Burrows).

   A retrospective study is also being set up to examine impacts on vertebrate communities over a broad geographic range. The study is being limited to two soil types in three landform units (Dwellingup, Bevan and Kingia) in the medium to high rainfall zone of the jarrah forest. This study is being carried out simultaneously to ensure a broader geographic applicability of the results from those experiments. This will also limit the range of vegetation types being examined.

5. **Keywords:** Vascular plants, disturbance (logging and burning), Vegetation structure.

6. **Target users:** Operations (how to design operations), Research (Community Conservation, Community Resources, Natural Products), Public (perceptions and information).

7. **Associated staff:** Neil Burrows, Tony Annels, Chris Vellios, Ian Wheeler

8. **Associated Institutions:** N/A

9. **Study Design:** The field work will run over four years (spring 1994 - spring 1995) and include a total of eight areas (see map attached). Twenty 80 m x 80 m permanent quadrats will be established in each area. Two areas will be sampled each year *viz*. Dwellingup and Margaret River in 1994/95, Jarrahdale and Nannup in 1995/96, Kirup and Lockhart in 1996/97 and Yornup and Dixon in 1997/98. In each area sites will include sandy and lateritic soils in three equivalent landform units (plateau elements) with various logging and fire histories (including unlogged and long unburnt sites). This will provide coverage over the major area of the jarrah forest from where timber is harvested and place the experimental studies in context. Sites will be relatively uniform in both logging history and topography and be within a larger area of similar history (minimum size treatment of approx 10 ha). A minimum of two quadrats within each history/site characteristic will be established. Twenty quadrats will be run for two years to

provide controls between time periods. About ten quadrats will be run during each week session by two people.

Within each 80 m x 80 m quadrat, four 20 m x 20 m subplots will be established for measures of course woody debris and the size class distribution of overstorey plants. All vascular plants will also be recorded at these sites on a minimum of two visits on a 1-10 cover scale (as per biogeographical studies and Kingston experiment). Soil samples will also be obtained from a minimum of two quadrats within each history/site combination. A 10 m x 10 m subplot will be established in each 20 m x 20 m plot (see appendix 1 for design) to determine if species area curves vary with logging history. Thus 560 20 m x 20 m plots and associated subplots will be assessed over a four year period.

A predictive model of vascular plant abundance and plant community patterns in relation to logging/fire history will be developed.

The study will involve one year of site selection and site history data collection, four years of quadrat establishment and assessment, and one year of analysis and writeup.

10. **Costs:**

Per annum costs detailed below are based on an initial establishment phase and subsequent assessment of the quadrats. These costs include 5% per annum for inflation.

Total costs 1993/94 (re-establishment)

Travel	$1080
Plant	$2760
Materials	$300
Grand Total:	**$4140**

Year 2 - 1994/95:

Assumptions 1. quadrat establishment borne by vertebrate survey
2. 6 subplots assessed per day with three people ie each area of 20 quadrats (80 subplots) assessed over a three week period in both spring and autumn

Assessment costs 1994/95

Vehicle running 600km x .20 x 2 visits x 2 (return) x 2 areas	$1104
Standing charges $90 x 1.5 periods x 2 areas x 2 visits	$540
Steel droppers (40 x 24 x $1.10)	$1056
Herbarium samples $5 materials x 300 specimens	$1500
Soil analysis $5 per sample x 180 samples x 2 analysis	$1400
Travel allowance $27 x 3 weeks x 2 visits x 2 areas x 3 people	$972
Overtime 30% x 4 days x 6 weeks x 3 people	$2160

Total costs year 1994/95

Plant	**$1726**
Materials	**$4721**
TA	**$1021**
OT	**$2269**

TOTAL **$9736**

COST SUMMARY

	94/95	95/96	96/97	97/98
Travel	1 021	1 072	1 126	1 182
Plant	1 726	1 812	1 903	1 998
Materials	4 721	4 957	5 205	5 465
Overtime	2 268	2 381	2 500	2 625
TOTAL	9 736	10 222	10 734	11 270

Work will be written up during 1998/99.

11. **Proposed date of commencement and proposed completion date**

Field checking for suitable sites will be commence 7/93
Completion by 6/97.
Annual progress reports to be prepared by staff.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** Retrospective study of the effects of timber harvesting on terrestrial invertebrates in jarrah forest in the medium to high rainfall areas of the south-west.

2. **Project Leader:** Gordon Friend

3. **Aim:**

(a) To determine relationships between species/community composition of the terrestrial invertebrate fauna and logging and fire history within lateritic terrain in the Dwellingup and Bevan landform units in jarrah forest in the medium to high rainfall areas of the south-west.

(b) Use these data to develop general models of the relationships between invertebrate species/community composition and logging and fire history and formulate general principles for the management of fire and logging in jarrah forest ecosystems.

4. **Background/Justification:**

The impact of burning and logging on Australia's native terrestrial fauna is the subject of much controversy, but there have been relatively few studies which address this issue. This is particularly so with respect to invertebrates. There is an urgent need for studies which examine long-term trends in invertebrate community composition, focusing particularly on keystone groups or species and those likely to be sensitive to disturbance. Earlier work carried out in forests and shrublands has pinpointed spiders (particularly Mygalomorphs), certain beetles (eg *Catasarcus* weevils), cockroaches and flies as potentially sensitive to forest management practices and excellent bio-indicators of environmental conditions.

A detailed experiment is being set up to examine the impacts of logging on vertebrate and invertebrate fauna in one area near Manjimup. The present study is being carried out simultaneously to ensure a broader geographic applicability of the results from that experiment. The study is based on space-for-time substitution (retrospective approach) and is limited to one soil type and landform unit in the medium to high rainfall zone of the jarrah forest.

5. **Keywords:** Terrestrial invertebrates, disturbance, logging, fire, spiders, beetles, flies, jarrah.

6. **Target Users:**

Managers of state forests in the Swan, Central Forest and Southern Forest regions. The study will also provide data regarding biogeographic patterns and disturbance ecology of relevance to other researchers and the general public. Much of the data will also be relevant to the dry sclerophyll forest ecosystems of south-eastern Australia.

7. **Associated Staff:**

Invertebrate ecologist (to be appointed), Grant Wardell-Johnson and Brent Johnson (Woodvale), Matthew Williams (Como).

8. **Associated Institutions:**

Western Australian Museum, Australian National Insect Collection (CSIRO), University of Western Australia (Dr Barbara Main)

9. **Study Design:**

The field work will run over four years (spring 1994 - spring 1998) and include a total of eight areas, as in the integrated retrospective studies on small vertebrates and floristics (see other RPPs). Two areas will be sampled in each year: Dwellingup and Margaret River in1994/95, Jarrahdale and Nannup in 1995/96, Kirup and Lockhart in 1996/97, and Yornup and Dixon in 1997/98 (see map attached). Site selection will be undertaken during 1993/94 as part of the other retrospective studies on small vertebrates and floristics (see other RPP with G. Wardell-Johnson). Data analysis and writing up will take place in 1998/99.

In each area four sites of differing ages since logging will be selected and replicated, giving a total of 8 sampling sites. Ages represented will include 0-2 years, 5-10 years, 25-50 years and 60+ years/virgin (unlogged) forest. These sites will be sampled four times per year (ie. seasonally) using pitfall trap grids. Each 15 x 15m grid comprises 16 traps (cups 90mm diameter and 110mm deep) in a 4 x 4 array at 5m spacing. When operational, traps will be 3/4 filled with Galt's solution (preservative) and left open for 10 days. Traps will then be bulked by four to give four samples per trap session. Fifty sweeps of the understorey vegetation (<2m) on each grid will be taken on each sampling occasion using a 60cm diameter hoop net. Vegetation floristics and microhabitat parameters (eg. leaf litter cover and distribution, understorey vegetation cover, abundance and distribution of woody debris, temperature and humidity regimes) will also be assessed on the grids.

Invertebrate samples will be sorted and collated initially at the Order level, and subsequently spiders (particularly Mygalomorphs), beetles, cockroaches and flies will be identified to family or species level. These invertebrate groups have proven to be useful indicators of disturbance in previous studies.

Analyses will involve examining initial similarity between grids using clustering and ordination techniques. Similarity in faunal abundance and composition between areas of differing logging history will be assessed and provide the basis for developing relationships between time since disturbance and invertebrate species/community composition.

10. **Costs:**

Per annum costs detailed below are based on an initial establishment phase and subsequent running of the grids. These costs include 5% per annum for inflation. Salary for a half-time invertebrate ecologist @ Level 2/4 Yr 4 are included in these costings; this person would also be involved (half-time) in the Kingston logging studies (see other project proposals). The work would be unable to proceed without the appointment of such a person with considerable experience in invertebrate taxonomy and ecology.

Establishment

Vehicle running 1000km x 0.20	$ 200
pro-rata on site	$ 100
Materials (stakes, PVC sleeves, cups etc.)	$ 250
T/A 3 x 27.35 x 5 days	$ 440
O/T 15% x 5 days x 2 TO	$ 200

Running grids

Chemicals, containers, alcohol	$1000
Plant costs 1000km x 8 trips x 0.20	$1600
pro-rata on site	$ 400
T/A 8 trips x $100 (hotel) x 2 days	$1600
O/T TO assistance	$ 100

TOTAL COSTS 1994/95

TRAVEL	$2040
PLANT	$2300
MATERIALS	$1250
OVERTIME	$ 300
SALARY (half-time)	$15785
GRAND TOTAL	**$21675**

COSTS IN SUBSEQUENT YEARS

	95/96	96/97	97/98	98/99
TRAVEL	1600	1680	1760	--
PLANT	2000	2100	2200	--
MATERIALS	1000	1050	1100	--
OVERTIME	100	100	100	--
S/TOTALS	**4700**	**4930**	**5160**	
SALARY	**15785**	**15785**	**15785**	**15785**
TOTALS	**20485**	**20715**	**20945**	**15785**

It is estimated that 0.10 FTE PRS and 0.10 FTE TO will be involved in this project, in addition to the appointed invertebrate ecologist.

11. **Proposed date of commencement and proposed completion date:**

Site selection would be carried out as part of the floristic and small vertebrate work as described in the other relevant RPPs. Grid establishment and sampling would commence in spring 1994 and continue (as described above) until mid 1998. Annual progress reports would be prepared by the

consultant. Data analyses would be carried out during 1998/99 by the consultant and the work prepared for publication.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SCIENCE AND INFORMATION DIVISION

SCIENCE PROJECT PLAN

1. **Title of Project:** Landscape assessment of vegetation communities in Kingston/Warrup Forest Blocks in south-western Australia.

2. **Project Leader:** Grant Wardell-Johnson

3. **Aim:** To correlate site-based floristic and structural data with TM imagery in a forest landscape. To provide a floristic/structural vegetation map of the Kingston/Warrup Forest using TM imagery and community resources databases. To place timber harvesting experimental sites in geographic perspective.

4. **Background/Justification:** A major program of research on the impact of timber harvesting is planned in the Kingston/Warrup area of State Forest, 25 km north-east of Manjimup. Because not all vegetation types will be logged, it is important to place experimental sites in context. Classification of field validated (structural/dominant species) TM imagery has been effective in the nearby Perup Reserve but has not been correlated with community resourses databases. There is a need to determine the most appropriate tool for broadscale mapping of vegetation.

5. **Keywords:** Thematic mapper imagery, Vegetation mapping

6. **Target users:** Operations (location of vegetation communities in the landscape), Research (Community Conservation, Community Resources, Natural Products), Public (perceptions and information).

7. **Associated staff:** Tony Annels, Ian Wheeler, Chris Vellios

8. **Associated Institutions:** DOLA (RSAC),CSIRO (G. Behn).

9. **Study Design:** Approximately 140 20m x 20m permanent quadrats will be established in the complete range of percieved vegetation types in all landform soils units (6 according to Tille pers comm 1993) of the area defined by Perup, Corbalup, Fred, Westbourne, Tweed, Gommes and Carbunup Brook roads and South-Western Highway. This area includes the proposed Kingston /Warrup harvesting study and includes all or some of eight Forest Blocks on the Manjimup 1:50 000 CALM map sheet. All sites will be accurately located using GPS units. TM imagery of the area will be classified, validated and related to floristic and structural data sets leading to the production of a vegetation map of the area.

10. Costs:

Year 1 1993/94:

Establishment and field assessment costs

Vehicle running 2000 km x .23 x 3 visits	$1380.00
Standing charges $70 x 12	$840.00
Steel pickets (140 x $4.19)	$581.00
Steel droppers (140 x 4 x $1.10)	$616.00
Herbarium samples $5 materials x 300 specimens	$1500.00
Soil analysis $5 per sample x 140 samples x 2 analysis	$1400.00
Travel allowance $27 x 2 weeks x 3 visits	$648.00

Total costs 1993/94

Plant	**$2220.00**
Materials	**$4097.00**
TA	**$648.00**

Year 2 - 1994/95:

Vehicle running 2000 km x .23 x 3 visits	$1380.00
Standing charges $70 x 12	$840.00
Purchase of TM imagery	$2000.00
Processing costs	$1800.00

Total Costs 1994/95:

Plant	**$2220.00**
Materials	**$3800.00**

Year 3 1995/96

Vehicle running 2000 km x .23 x 3 visits	$1380.00
Standing charges $70 x 12	$840.00
Production costs	$1000.00.

Total Costs 1995/96:

Plant	**$2220.00**
Materials	**$1000.00**

COST SUMMARY

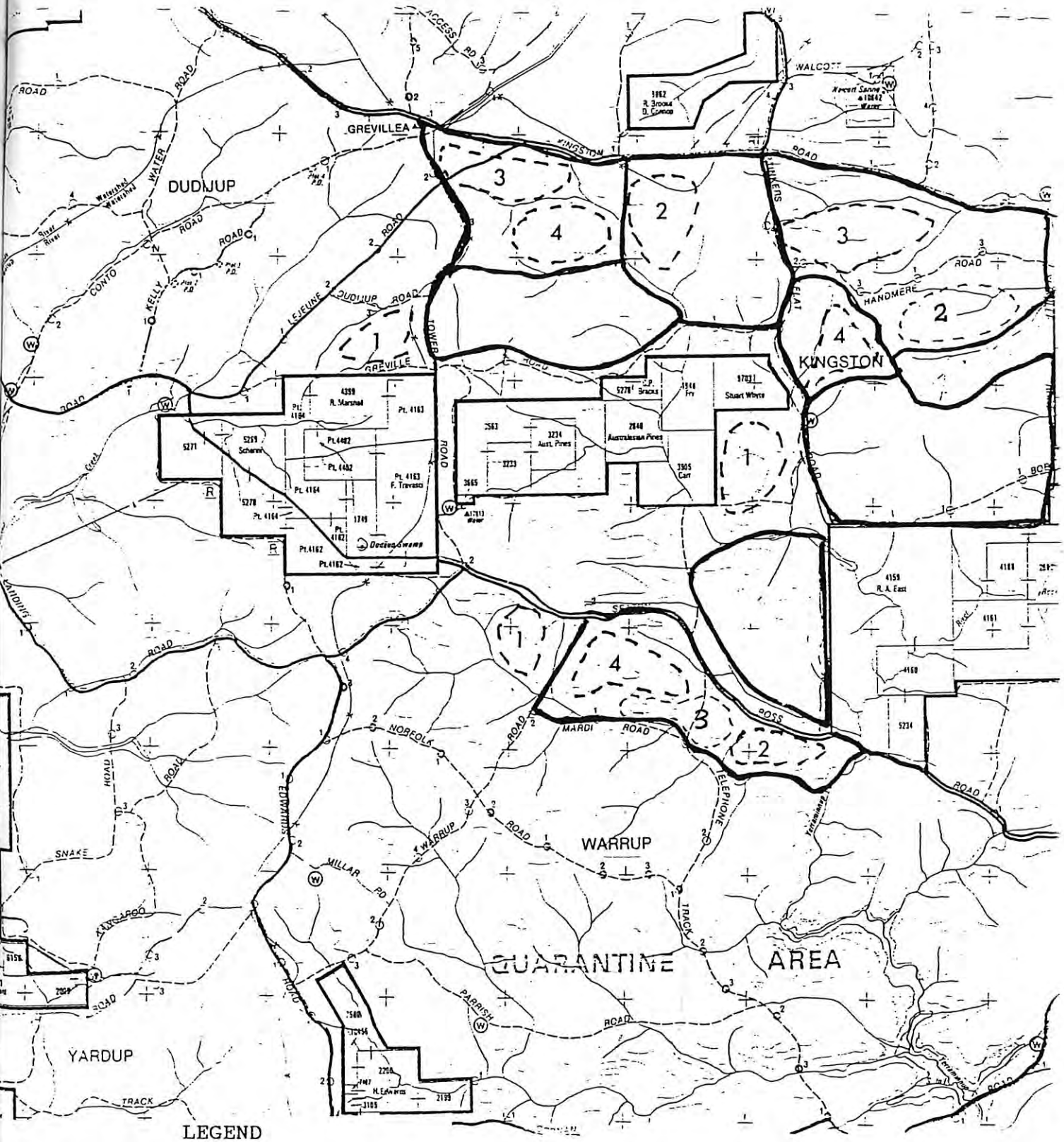
	1993/94	94/95	95/96
Travel	648		
Plant	2 220	2 220	2 220
Materials	4 097	3 800	1 000
TOTAL	6 965	6 020	3 220

Work will be written up during 1997/98.

11. Proposed date of commencement and proposed completion date: Field checking for suitable sites will commence 9/93

Completion by 12/97.

FIGURE 1: Kingston Block Experimental Design

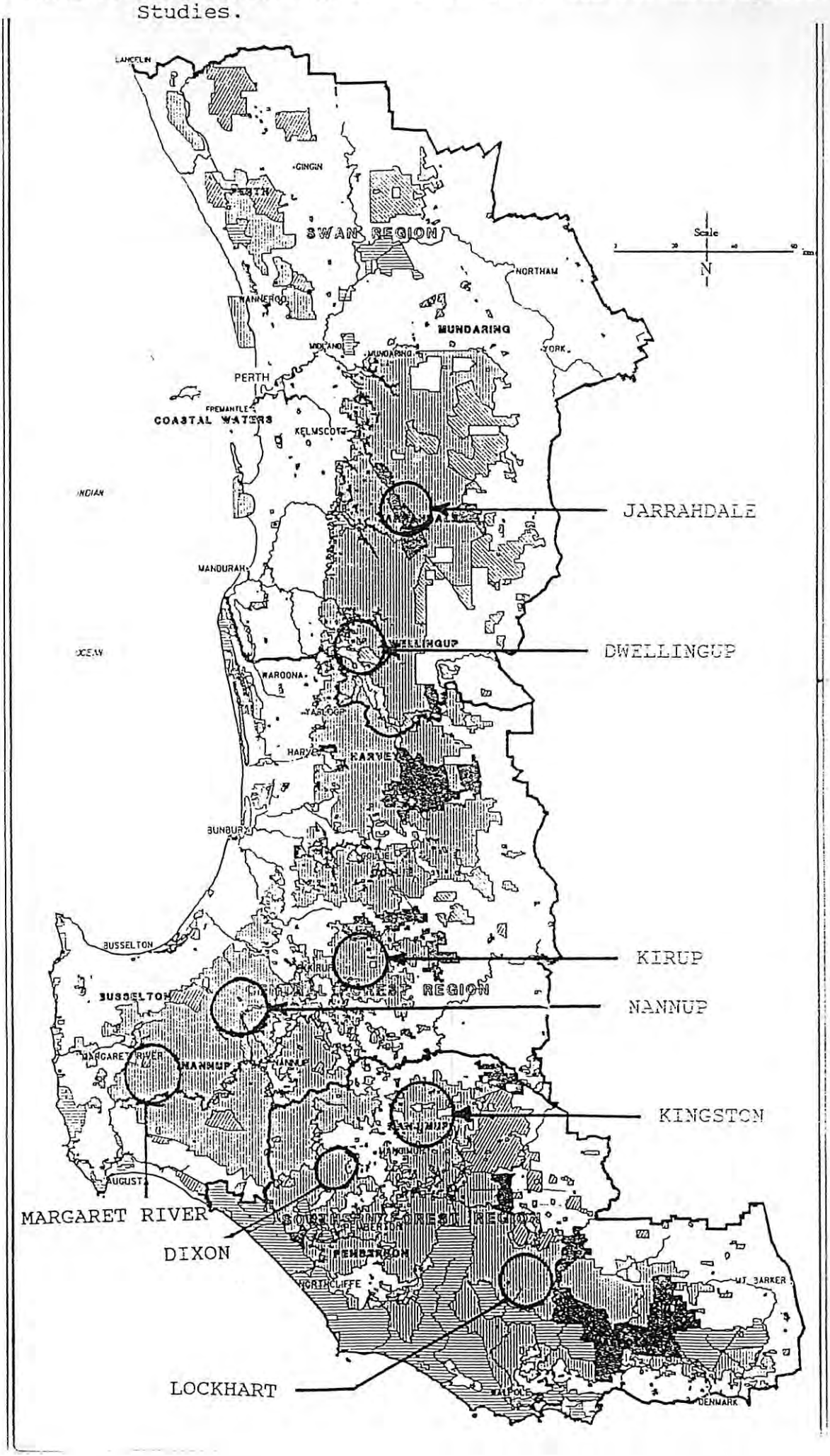


LEGEND

1 CONTROL
2 SHELTERWOOD
3 GAP (3 HABITAT TREES)
4 GAP (NO HABITAT TREES)

COUP BOUNDARY
COMPARTMENT BOUNDARY

FIGURE 2: Distribution of Jarrah Forest Areas For Retrospective Studies.



ATTACHMENT 1

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

PARKS, RECREATION, PLANNING AND TOURISM DIVISION

RESEARCH PROJECT PLAN

1. **Title of Project:** Aesthetic Landscape Assessment of Jarrah Forest In South-Western Australia.

2. **Project Leader:** Grant Revell.

3. **Aim:** To develop predictive aesthetic landscape assessment modeling between jarrah forest landscape attributes, forest management prescriptions and public preference data.

4. **Background/Justification:** A major program of research on the impact of timber harvesting is planned in a number of State Forest block areas, south-west of Western Australia. Study areas have been chosen to represent the landscape character types throughout the region. There is a need to understand the social ecological values of forest landscape aesthetics, and in particular the landscape character type and forest management correlation's with community preferences.

5. **Keywords:** Aesthetic landscape assessment, landscape character type, community preferences.

6. **Target Users:** CALM operations (interpretation of landscape management prescriptions), Research (community and nature conservation, integrated forest management), and Community (social ecological values, public information and community development).

7. **Associated Staff:** Alan Hordacre, Phil Durell.

8. **Associated Institutions/Organisations:** University Of Western Australia, Australian Heritage Commission, Alcoa.

9. **Study Design:** An aesthetic landscape attribute inventory will be carried out for all jarrah forest study areas. A broad range of communities will be sought to complete off and on-site preference checklist surveys of representative forest scene units, including varying forest management treatments. Predicative modeling principles will be developed, together with qualitative data GIS mapping.

10. **Budget:**

- **Year 1 1993/94:**

Establishment and Field Assessment Costs

Plant (Vehicle running @ 23c/km)	$ 1,600.00
Materials (Photographic, graphic supplies & GIS mapping)	$ 6,000.00
Travel Allowance (@ $93 per night max)	$ 1,400.00
TOTAL	**$ 9,000.00**

• **Year 2**

1994/95:

Preference Surveys & Data Evaluation Costs

Plant		$ 1,000.00
Materials		$ 1,200.00
Travel Allowance		$ 500.00
	TOTAL	**$ 2,700.00**

• **Year 3 1995/96:**

Preference Surveys, Data Evaluation And Mapping Costs

Plant		$ 1,000.00
Materials		$ 1,800.00
Travel Allowance		$ 500.00
	TOTAL	**$ 3,300.00**

11. **Study Schedule:** field reconnaissance for suitable forest landscape units will commence at time of project funding approval.

12. **Other Relevant RPP's:** 1/93 - Lochart 4.

13. **Cross Links to other RPP's in the same program and other programs:** Part of a major *integrated* research program of disturbance oriented research being commenced in the jarrah forest.

Grant Revell
September 1993