FAUNA ASSESSMENT IN TIMBER HARVESTING COUPES IN WESTERN AUSTRALIA

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EXECUTIVE SUMMARY

Fauna Assessments in Timber Harvesting Coupes in Western Australia.

The Forest Fauna Distribution Information System-FDIS.

Western Australia's State Forests contain one of the least altered faunas of any of the major ecosystems in Australia that makes the forests an important conservation reserve. Our forest fauna has lived through 150 years of wood harvesting and the evidence suggests that the present harvesting system poses no major problems for them.

There is nevertheless a group of "sensitive" species, whose conservation status is either threatened on a State- wide basis or which have been given "Priority" listing, that deserve particular attention. Planned disturbances such as timber harvesting and regeneration needs to take especial care to ensure that the future of these species is ensured.

Forest fauna has for some time now been protected by a variety of means including, legislation, a comprehensive reserve system, road river and stream corridors as well as the reservation of special areas, critical habitat such as old growth forest and critical habitat elements such as logs and hollow trees. There has also been ongoing research on forest fauna since 1970 and biodiversity will soon be monitored in more detail by the Intensive Monitoring System currently in the planning stages.

Fauna assessments in timber harvesting coupes is an adjunct to these safeguards and the Forest Fauna Distribution Information System [FDIS] has been developed specifically to ensure the continued survival of fauna in areas of forest subject to commercial harvesting and regeneration.

FDIS is a computerized system for predicting the occurrence of vertebrate species in forest blocks where harvest coupes are planned. It allows targeting of "sensitive " species for further investigation only where this is necessary thereby reducing field-surveys to a minimum. As a predictive system FDIS has a number of advantages over the coupe field-survey method that is used in many other places.

These advantages include;

1. Improved targeting of rare species whose presence is often difficult to detect in the field,
2. Eliminating errors caused by differences in seasonal activity of different species, eliminating errors inherent in surveying small areas such as a coupe,
3. Significant cost savings by marked reduction in field-surveys,
4. Enhanced capacity for improvement by having a system that can be continually upgraded and validated as fauna distribution records improve.

Commenced in 1996 FDIS developed from a system of field inspections of forest blocks containing proposed harvesting coupes by forest fauna experts. The likelihood of the presence of fauna species in the block was assessed in the field by using a list of the 297 vertebrate forest species in conjunction with the major vegetation associations found to be present within the block and scoring each species on a scale of 0-3. Species were allocated scores using standard texts for each of the groups of animals together with the accumulated knowledge and experience of fauna distribution [more than 30 years] of the experts.

The system was later refined using the RFA Vegetation Complexes map as a basis for the fauna predictions. Over a period of 2 years various combinations of the more than 300 Vegetation Complexes were assessed against fauna distributions. Using trial and error it was found that a combination of the major forest formations together with moisture and temperature gradients, both dictated largely by latitude and distance from the sea, gave the most reliable Vegetation Complexes combinations, [Fauna Habitats], for predicting fauna distribution.

A Fauna Habitats/Vertebrate species table, {50 habitats/297 species}, comprising a total of 14850 possible combinations forms the basis of predictions which can now be made readily on the computer for any area within the forest. This eliminates the need for field visits to each and every coupe each year. The system has also been validated using those more recent WA Museum and CALM fauna records, which were accurate to within 0.02' latitude and longitude [equivalent to 300 / 300m2]. For mammals 94.1% of predictions were in agreement, for reptiles agreement was 97.3% and frogs 85.1%.

The sample sizes used in the validations, excepting for mammals, was small however due to very few of the fauna records meeting the accuracy criteria and further validation is needed. This may be done simply by carrying out biological surveys, one or two a year over the next few years in selected areas of the forest where information is most limited.

Using the computerized FDIS system fauna in coupes may now be checked and planned for prior to harvesting by simply creating a list of species predicted to occur in the block in which the coupe is planned and checking for any "sensitive" species. A dossier with information on "sensitive" species is then checked to determine if any further action needs to be taken. The package will also contain tables with extra information on the primary and secondary habitat of each species as well as a table with information on hollow users. Tables indicating predicted longer-term effects of disturbance, including wood harvesting and regeneration as well as wildfire and prescribed fire are also being included.

FDIS is now fully operational and will be used to assess timber harvesting coupes planned for the coming year during which process it is expected that any further "bugs" will be ironed out.

Fauna Assessment in Timber Harvesting Coupes

1. Introduction

Western Australia's State Forests contain one of the least altered faunas of any of the major ecosystems in Australia. Since the arrival of Europeans the record of extinctions, especially mammals in woodlands, mallee, mulga and the spinifex deserts has been without parallel.

Only the tropics in the far north and the forests of the south retain their pre-european fauna still largely intact.

Last century forest exploitation and timber cutting were subject to few regulations and timber cutting was unregulated and often heavy and extensive in some areas of forest.

Following the establishment of a Forests Department and the passing of the Forest Act in 1918 the situation changed dramatically and since that time timber harvesting has been subject to increased regulation. State Forests are now managed on a multiple use basis, many areas have been reserved from cutting and the production forests are managed in a manner consistent with the conservation of all forest values (CALM 1992).

Management of fauna in the production forest areas is an integral part of the multiple use concept and knowledge of the fauna in harvesting coupes prior to cutting is a vital component of this.

The purpose of this manual is primarily to document the recently developed technique for predicting the vertebrate fauna in harvest coupes prior to cutting. It also details information on species so that decisions about management may be made prior to cutting if there is a perceived need to alter standard harvest and regeneration techniques.

A brief overview is provided of characteristics of forest fauna, which are important in a management context. Current conservation measures relating to forest fauna are also listed.

2. Forest Fauna

A number of factors are important with respect to timber harvesting and forest fauna, including; the forest as a fauna reserve, factors affecting fauna distribution, disturbance and the types of fauna present in the forest.

2.1 South West forests as a fauna reserve

To some extent the present forest estate may be regarded as a remnant, albeit, a large one. The importance of the forest as a reserve relates very largely to the following features:

a) Large size – Kitchener et al (1980) demonstrate the importance of size for conservation reserves.

b) Comparative intactness – although continuity is broken in places by farms, townships, water supply dams and other permanently changed areas, the forests still form a relatively complete entity.

c) Uniqueness – the south west forests comprise a series of unique ecosystems found nowhere else on earth (see Christensen 1992 and Dell et al 1989).

d) Relictual fauna – the forests contain many species with Gondwanan affinities for example the small fish *Lepidogalaxias salamandroides* and the spider *Moggridgea tingle* (See Christensen 1992).

e) High degree of endemism – the fauna of the south west forests have a very high degree of endemism (See Christensen 1992).

f) Refuge – the forests are a refuge for several species which have become extinct elsewhere on the mainland – eg the Numbat *Myrmecobius fasciatus*

2.2 Distribution of fauna within the forest

2.2.1 Habitat diversity

Fauna are not distributed evenly throughout the forest, species and numbers differing according to the types of habitat present (Harris 1984). Species diversity therefore depends largely on habitat diversity i.e. the number of different habitats present in a given area, (see Kitchener ET al 1980). Vegetation a major component of most habitats as well as also being an expression of other habitat characteristics such as edaphic factors, topography, moisture and temperature, is therefore an excellent indicator of fauna species presence.

2.2.2 Structural and floristic diversity

Within any given forest habitat the greater the structural diversity, the greater we expect the diversity of fauna to be. Thus forest composed of uneven aged trees comprising an upper and lower canopy may be expected to contain more species than an even aged forest. Forest edges around small clearings, scrub and ground layers all add to the structural diversity. Non living things such as litter, logs, rocks and caves also contribute to structural diversity.

Floristic diversity is also an important factor in species diversity since some species may only feed upon the flowers or leaves of certain species. Insectivorous birds for example may feed upon certain insects that occur only on a limited range of plant species.

Floristics may also be important for nesting. Only certain tree species form large hollows suitable for the large Cockatoos for example. Woylies (*Bettongia penicillata*) use grasses, stringy bark from jarrah or the elongated leaves of the snotty-gobble (*Persoonia longifolia*) all of which they can bundle and carry in their tails, to make their nests.

2.3 Disturbance

Disturbance, whether natural or induced by humans, is an important factor that may contribute to diversity by altering, temporarily or permanently, both the structure and floristics of a habitat.

2.3.1 Fire

Fire is a natural disturbance agent which may be initiated either by natural causes eg lightning or by humans, either deliberately as in the case of prescription burning or accidentally.

The cause of ignition matters little; it is the season, frequency and intensity of fire, the fire regime, which determines the effect on the fauna in any habitat.

Fire events generally initiate a succession in the understorey, a change in community structure and composition of both flora and fauna, followed by a return, generally fairly rapid, to the original state. Occasionally following very intense fires, the overstorey may be affected to a greater or lesser extent, (Braithwaite 1995). This in turn may affect particularly birds and arboreal mammals. Some species such as the Southern brown bandicoot (*Isoodon obesulus*) and the Bush rat (*Rattus fuscipes*) (Christensen & Kimber 1975) are early succession species peaking in numbers during the first few years following fire. Other species such as the Mardo (*Antechinus flavipes*) are late successional species preferring the deep litter accumulating after a decade or more without fire (Sawle 1979).

2.3.2 Timber harvesting

Opening up the forest during timber harvesting and regeneration operations is a human disturbance. Similar disturbances however did take place prior to colonisation, on a local scale as a result of occasional very high wind events, or on a more extensive scale as a result of intense fires.

Disturbance caused by timber harvesting whether on a very local level such as in selection cutting or more extensive such as clear felling is always followed by regeneration and like disturbance caused by fire the effect is temporary in nature.

Also like fire the effect varies with intensity and frequency although not season of harvesting.

The forest regenerates according to a predictable structural succession. Fauna returns likewise in a predictable succession the details of which

depend upon the intensity of cutting whether it was clearfelling or selection cutting.

Frequency of cutting, especially in the case of clear felling has the most potential to cause permanent or long term changes if cycles are too short to allow mature stages of forests to develop.

2.4 Types of fauna

2.4.1 Degree of specialization

One last fauna characteristic that is important in a forest management context is the degree to which a species is a specialist, a trait often associated with restricted distribution, or a generalist more usually widespread.

Many animals have comparatively broad habitat requirements such as for example the Grey Kangaroo (*Macropus fuliginosus*) which may be found equally in jarrah or karri forest, woodlands or open scrub and heathland. The Western Rosella (*Platycercus icterotis*) occurs in karri and jarrah forest, woodlands, open heath and farmlands with scattered remnant trees.

Other species much fewer in number occur in a very limited range of habitats e.g. the Sunset Frog (*Spicospina flammocaerulea*) which occurs only in a few peat swamps in the southern flats or the Tammar Wallaby (*Macropus eugenii*) which lives in thickets of *Melaleuca, Gastrolobium* or *Allocasuarina* when these are at a certain successional stage (Christensen & Maisey 1987).

Other species are somewhere in between, being reasonably well distributed across a number of habitats.

Many forest species, especially mammals and birds are widespread outside the forests occurring for example in Mallee and even in the spinifex deserts. Some of these species like the Woylie (*Bettongia penicillata*) and the Chuditch (*Dasyurus geoffroii*) are now largely restricted to the forest having become extinct in the more open habitats as a result of fox predation.

2.4.2 Sensitive species

Sensitive species, in the context of this manual are species regarded as being sensitive to disturbance by timber harvesting and regeneration. These are species that may be disrupted by harvesting and regeneration for an extended period of time because of their low numbers and restricted distribution or particular habitat requirements. Such species include animals with a naturally restricted distribution eg. Nornalup Frog (*Geocrinea lutea*) or a restricted distribution due to human induced causes such as fox predation eg. The Western Ringtail Possum (*Pseudocheirus occidentale*) and animals whose habitat requirements could be disrupted for an extended period, eg large hollow nesters such as the Red-tailed Black Cockatoo (*Calyptorhynchus magnificus naso*) may also be affected.

3. Conservation of Fauna in Western Australian forest area

Conservation of fauna within Western Australian forests is achieved by means of a number of different mechanisms. All of these mechanisms act together to ensure conservation of fauna across the forest estate.

3.1 Legislation

All native fauna are protected under the Wildlife Conservation Act 1950 and CALM is responsible for implementation of the Act. A higher level of protection is provided for fauna if the Minister declares the fauna is likely to become extinct or is rare or is otherwise in need of special protection. In Western Australia "threatened species" is taken to mean an animal taxa declared under this Act as likely to become extinct or rare, whereas taxa declared otherwise in need of special protection are generally known as "specially protected".

All fauna species which occur on the Commonwealth Endangered Species Act Schedule 1 are on the gazetted lists under the Western Australian Wildlife Conservation Act. The converse is not true, however, as the Western Australian list contains taxa rare in Western Australia but present in other states, hence not on the Commonwealth list.

As a consequence of the general protection of all fauna in the Act a license is required to take fauna.

To take in relation to fauna includes, "to kill or capture or to disturb or molest any fauna by any means or to use any method whatsoever to hurt or kill any fauna whether this results in killing or capturing or not"

The destruction or modification of habitat is not specifically covered in the definition "to take". The fauna provisions, unlike the flora provisions of the Act do not explicitly bind the Crown. However, the Crown is bound by the intent of the act.

CALM has developed a Policy Statement No. 33 "Conservation of Threatened and Specially Protected Fauna in the Wild". This requires CALM to identify rare and threatened fauna species and also to take action to conserve those species and their habitats. Policy Statement No. 44 entitled "Wildlife Management Programs" requires CALM to develop Wildlife Management Programs for species or groups of species of threatened, specially protected and harvested fauna.

This latter policy distinguishes between a Management Program which deals with taxa which are harvested (eg Kangaroos) and Recovery Plans which deal with threatened taxa. Guidelines on the preparation of Recovery Plans are provided.

Recovery Plans have been completed for a number of species, which occur within State Forest namely the Woylie, Chuditch, Orange-bellied and White-bellied frogs and the Numbat.

CALM has established recovery teams for threatened fauna and the teams have CALM as well as non-CALM representatives.

CALM Policy No. 33 also requires the nomination of an officer in each Region who will be responsible for identifying threatened and specially protected fauna, training staff and providing liaison and advice on threatened and specially protected fauna.

CALM's current Forest Management Plan (LFC 1994) commits to monitoring and a detailed monitoring programme for fauna is currently being set up.

3.2 Protection of forest fauna through the Forest Management Plan System

Forest Management Plans also provide for the protection of fauna in the following ways;

3.2.1 The Reserve System

Establishment of a representative reserve system throughout the forest. Representative areas of the range of Vegetation associations to be found within State forests have been progressively reserved from timber harvesting since the early 1900's. With the latest additions resulting from the Regional Forest Agreement (RFA) process this reserve system will be fully representative of almost all of the Vegetation associations present within the forest. A very few types for example some Blackbutt (*Eucalyptus patens*) associations are under represented because little of these types remains uncleared. Blackbutt forest was particularly sought out by early settlers for farmland clearing because of the fertile soils on which they occur.

Special reservation has also been made in instances where endangered or vulnerable species are known to exist eg. The Perup nature reserve, which was, established principally for six endangered species the Numbat, the Woylie, the tammar, the Western Ringtail Possum the Chuditch and the Southern brown bandicoot. The woylie and tammar have since been removed form the threatened species list as a result of CALM's fauna recovery programme.

Special case reservation is an ongoing commitment and may occur at any time when considered necessary. In the current Forest Management Plan for example reservation has been made of a portion of Witchcliffe Forest Block to enhance the protection of the White-bellied Frog (*Geocrinea alba*).

3.2.2 Special areas

Provision is made for the protection of special areas of conservation significance at the local level. Granite outcrops, unusual and restricted vegetation types, small soaks etc may be excluded from timber harvest with

an uncut buffer at the time of coupe demarcation. Provision has been made in the current management plan to cater for this requirement.

3.2.3 Old growth forest

Mature and over-mature trees, are necessary throughout the forest to cater for species which depend on habitat elements provided by such trees, mainly hollows for refuge and nesting and flaking bark.

So-called "old growth forest" is not a necessity for any known element of the Western Australian vertebrate forest fauna. Old growth trees certainly are but other elements of old growth forest such as deep litter layer, old rotting logs and various nutrient cycling processes may be provided equally in mixed age regenerating forest and are not necessarily always present in old growth. In Western Australia these elements are more a function of fire frequency than of the so-called old growth stage (see Christensen 1992).

The requirement for old growth, mature and over mature trees is nevertheless a critical factor in forest management since these can be all but eliminated over time within timber harvesting areas. A considerable element of the fauna particularly mammals 75% and birds 17% utilise hollow trees or logs. Hollow logs are not likely to be a problem in the first cutting cycle when large old veteran trees are being harvested. Provision needs however to be made for these in future cutting cycles where rotation lengths may be less than optimum for production of trees suitable for providing hollow logs following harvesting.

Provision for old growth trees, not only to be retained during harvest operations but also for their continual production into the future, is a vital part of planning for timber harvesting. Substantial areas of forest with mature and over mature trees may be necessary for some species of fauna whilst others may require only isolated groups to be present within areas of regrowth.

The extensive reserve system caters for the former with extensive areas of forest and woodland reserved throughout the forest linked by a system of wide road and river reserves. The latter requirement is catered for by a system of narrower but much more frequent stream reservations together with a system of habitat tree retention within harvesting coupes. To ensure continuity of a supply of mature trees a portion of the regenerating forest also needs to be retained from harvesting to grow on for a longer rotation, 150 years or more.

3.2.4 Road, river and stream reserves

A network of uncut forest is reserved throughout the production forest along streams, rivers and major roads linking with reserves to form an extensive mosaic of mature trees throughout the forest.

These linear reservations ensure:

a. Linkage of mature forest between major reservations

b. Access to mature trees by fauna residing within regenerated forest coupes.

All reservations including road, river and stream reserves, together with other reservation total no less than 20% in any forest block in the karri where clear felling is practiced.

3.2.5 Retention of critical habitat elements within harvesting coupes

All forest areas harvested for wood products are regenerated. Detailed silvicultural guidelines for both jarrah [CALM 1995a] and karri [CALM 1995b and CALM 1997], which have been developed and field tested over many years, ensure that successful regeneration is achieved consistently.
The jarrah silvicultural guidelines (CALM 1995a), as well as guideline criteria for management of fauna habitat, provide for retention of habitat trees as well as potential habitat trees, Balga [grass trees], den logs and stumps. These provisions ensure that fauna requiring these habitat elements can more quickly re-colonize the regenerating forest.
Cull pushing guidelines - post harvest also provide for the retention of unmarked trees with a diameter of greater than 30 cm. at breast height.

Habitat trees are not retained in karri because young karri will not grow successfully underneath mature trees (CALM 1995b) and isolated tall karri are very prone to wind-blow. As a result species requiring mature habitat elements may take longer to re-colonize karri regeneration not directly adjacent to edges adjoining reserved mature forest. This is compensated for by a very extensive and well designed system of reserves containing mature trees in the karri.

3.2.6 Timber harvesting coupe fauna assessment

A system for predicting vertebrate fauna presence in harvesting coupes has recently been developed and refined. The system may also be used to predict the impact of fire, prescribed or wildfire.

The system relies on fauna predictions that are based upon vegetation complexes. Tables are also available showing predicted responses to timber harvest and regeneration. The system is computer based but field inspection may be necessary and management action may result if certain sensitive species are believed to be present.

All of the above provisions under items 3.2 were designed to cater for the distribution of fauna as well as the critical life history characteristics, of forest animals which were outlined earlier.

3.3 Research on forest fauna

Information on all aspects of forestry, harvesting and regeneration and forest ecology is continually progressing and improving with research and monitoring which is a critical aspect of forest management. Management techniques are continually evolving and changing and the current fauna management and protection system is based on information derived from research and monitoring and management experience.

Biological survey work and research into the effects of forest management operations on fauna has been carried out since the early 1970's.

At first research concentrated on fire effects (see Christensen and Abbott 1989). Information obtained on the effects of disturbance by fire as well as distribution data gathered from biological surveys (Christensen et al 1985) are relevant to the effects of timber harvesting on fauna. Single species studies on threatened species in particular provide data for use in forest management. Aspects of the biology of many threatened forest species has been studied eg the Chuditch (Serena et al 1991), Numbat (Calaby 1960, Christensen et al 1984, Friend 1994) and the Woylie (Christensen 1980) have all been the subject of detailed biological and ecological research. The jarrah forest contains the majority of the Chuditch population and a recovery plan has been published and is being implemented (Orrell and Morris 1994). Research has also been done on other threatened species, Western Ringtail Possum (Inions et al 1989, Jones et al 1994a, 1994b), Tammar Wallaby (Christensen 1980, and Hall 1991), Quokka (*Setonix brachyurus*) (Liddelow pers comm.) and Brush-tailed Phascogale (*Phascogale tapoatafa*) (Christensen pers comm, Rhind 1996), the Mardo (*Antechinus flavipes*) (Sawle 1979), the Red-tailed Black Cockatoo (*Calyptorhynchus magnificus naso*) (Abbott 1998).

Studies have also been undertaken on The White-bellied and the Yellow-bellied (*Geocrinea vitellina*) frogs (Roberts et al 1990, Driscoll et al 1994, Williams 1994).

Small freshwater fishes on the threatened list, the Salamander fish (*Lepidogalaxias salamandroides*), Mud Minnow (*Galaxiella munda*), Black-stripe minnow (*Galaxiella nigrostriatus*) and Balstons perchlet (*Nannatherina Balstoni*) have been studied (Christensen 1982, Jaensch 1992, Pusey 1981, 1989, and 1990, Pusey and Edwards 1990 and Morgan et al 1996).

A large experimental study is currently in progress in the southern jarrah forest at Kingston Block examining silvicultural systems which will achieve broad forest sustainability, that is wood production with wildlife habitat. The Chuditch, Numbat, Ringtail Possum and the Woylie (see Morris et al 1996) in particular are being studied in detail.

One of the major findings of these studies with respect to conservation of forest fauna is that fox predation is the factor largely responsible for the decline of the medium sized mammals that are on the threatened list. Wherever fox control has been carried out in the forest, medium sized mammals have increased dramatically. Project Western Shield a major fox control initiative is resulting in many medium sized mammals re-appearing all over the forest regardless of cutting history, in areas where they have not been seen for decades.

A significant result of this process of biological survey, research, protection and management of endangered and vulnerable fauna has been the recent removal of the Woylie and Tammar Wallaby from the threatened species list.

3.4 Monitoring

Monitoring the effect of timber harvesting is a Ministerial requirement which requires CALM to monitor both the long term effects of harvest and regeneration techniques as well as the effectiveness of current prescriptions for the conservation and protection of forest fauna.

Monitoring the impact of disturbance has been largely carried out through research studies, primarily on 'keystone' species.
CALM's current Forest Management Plan (LFC 1994) commits to monitoring and a detailed monitoring programme Integrated Forest Monitoring System (IFMS)is currently being set up.

4. Timber harvesting coupe fauna assessments

The above review is a brief look at the forest fauna conservation strategy currently being practiced by CALM. Timber harvesting coupe fauna assessment should be seen as just one part of this wider forest fauna conservation strategy. In this context we may now look at timber harvesting coupe fauna assessments in more detail.

4.1 Introduction

Assessment of fauna in timber harvesting coupes prior to harvesting is one of the conservation measures currently operating in State forests in Western Australia (see 3.2.6 above). As the most recent inclusion amongst the conservation measures in timber production forests the technique was first described in Christensen and Liddelow (1997) more recently the technique has been much refined (See Christensen and Liddelow 1998).

The object of the assessment procedure is to identify what fauna is likely to occur within felling coupes prior to any timber harvesting taking place so that measures to protect any species which might need special attention, over and above the current practices, may be taken if considered necessary.

The procedure is an indirect method based on predictions of fauna occurrences in mapped vegetation complexes. As explained in Christensen and Liddelow (1997) this indirect method of assessment is preferred to direct biological survey of each coupe, because of the following biological and practical disadvantages of the direct biological survey method;

a. Where a species occurs in low numbers (which is often the case) they are difficult to record directly by capture or sighting over the short, usually 1-2 weeks, period of biological survey.

b. The activity of many species in particular reptiles and birds is strongly regulated by seasonal factors so that single short biological surveys will not locate all species in an area.

c. Surveys on small areas such as a felling coupe will inevitably underestimate the species present in the area.

d. In order for direct biological survey technique to yield meaningful data the surveys must be well planned, and executed over a reasonable length of time of at least 7-10 days. This is extremely resource demanding as several dozen coupes are usually felled each year.

e. A formal predictive system provides a template on which to build. The system can be continually added to and updated as new knowledge becomes available.

In spite of the superficial attractiveness of direct survey the above deficiencies are considered to severely limit the usefulness of the technique.

Biological surveys in coupes can in fact be counter-productive in that managers may be lulled into a false sense of security thinking that they have a complete list of fauna for a coupe when in fact it will almost certainly be incomplete. Moreover the species missing are most likely to be the less obvious and more uncommon species which are the very ones they should be most interested in.

The indirect technique on the other hand focuses attention on the species sensitive to timber harvest and regeneration in the most practical and cost effective manner. Species predicted to occur in each coupe are listed, each is considered against information on their likely response to harvesting and regeneration and sensitive species are highlighted.

If predictions indicate their probable presence, some sensitive species may require field assessment and confirmation of their presence in some coupes. Some coupes may require no field inspection and usually only a limited number require any special treatment to cater for sensitive species.

The main objective of this section is to describe in detail the technique of timber harvesting coupe fauna assessment, it's development and it's use.

4.2 The Forest Fauna Distribution Information System (FDIS)

4.2.1 Fauna habitat maps

The timber harvesting coupe assessment technique was previously based on field inspections of each forest block which contained coupes proposed for harvesting over the next 12 to 18 months.

On these inspections, lists of all vertebrate species predicted to occur in each of the major habitats (Vegetation associations) were drawn up. A scale of probability, 1 = certain to occur, 2 = probably occurs, 3 = possibly could occur, was applied to each species in each habitat (usually about 5 to 6 in most forest blocks). The presence of a few species, in particular the quokka, was assessed directly by interpreting signs of their presence.
This technique required persons with long field experiences in forest ecology to undertake the inspections, identify and select the habitats and to make the predictions.

The field inspections were largely necessary because no maps with sufficient detail to determine the habitats present in forest blocks were in existence (see Christensen and Liddelow 1997 for details).

More recently new Vegetation Complexes maps have been developed for the whole of State Forest as a part of the Regional Forest Agreement (RFA) process. These maps presented an opportunity to substantially improve on the current harvesting coupe fauna assessment technique by cutting out much of the field assessment.

Using the RFA maps as a basis, new maps of vegetation groupings, fauna habitat maps, which reflect fauna distribution within the forest were developed, and lists of fauna predicted to occur in each were drawn up. These maps and lists can now be used to make harvesting coupe fauna assessments as well as forest block assessments (see Christensen and Liddelow 1998).

The maps and lists were developed over a period of 12 months by mapping and testing groupings of the RFA Vegetation complexes against known fauna distribution. Several attempts were required before satisfactory groupings of vegetation complexes, which adequately reflected fauna distribution, by fauna habitats were achieved.

The RFA Vegetation complexes maps themselves whilst being a major advance in vegetation mapping are not suitable in their present format to use as a basis for a fauna distribution information system.

Firstly, the Vegetation Complexes maps with over 300 vegetation types offer more detail than is necessary or which can easily be coped with in a fauna distribution information system. Thus of some 279 native vertebrate species probably only two species of frog are restricted to one Vegetation Complex only. Many species occur in several complexes and most species occur widely across complexes.

Secondly the RFA maps are too detailed for persons with limited botanical knowledge to be able to identify vegetation complexes with any confidence in the field. For any fauna distribution information system to be of value as a management tool, managers have to be able to recognise the vegetation groupings with confidence in the field. For these reasons the maps needed to be simplified. The process of simplifications took into account the following considerations;

Many species respond to gross changes in overstorey or forest type, to a greater extent than they do to more subtle vegetation complexes. This is partly because of structural elements which affect birds in particular but also because of broad relationships between forest type and geological and edaphic factors. For this reason the major forest associations of the south west as mapped by Bradhsaw, Collins and McNamara (1997) were utilised together with the RFA Vegetation Complexes maps in developing the fauna habitat maps. Many vertebrate fauna, especially frogs and reptiles respond strongly to moisture gradients which in the south west decline sharply from west to east and less sharply from south to north (Christensen et al 1985). This characteristic of moisture gradients is also manifest in differences between valleys and ridges. In addition to moisture gradients there is also a temperature gradient decreasing in the opposite direction from north to south and to a lesser degree from east to west. These moisture and temperature influences need to be taken into account in any attempt at mapping fauna distribution in south west forests.

All of these factors were taken into account in the grouping of Vegetation Complexes to obtain the best combination to reflect fauna distribution throughout the forest areas. It took several attempts to achieve the final result.

In the first attempt Vegetation Complexes from the RFA maps were allocated to 20 groupings based on the major forest associations of Bradshaw et al (1997), plus woodland and sedgeland types and including a north/south and east/west differentiation (see Map 1). Lists of vertebrate fauna were drawn up for each of these 20 types using our knowledge and experience together with reference to publications and standard texts on mammals, birds, reptiles, frogs and fish including; Ehmann 1992, Strahan 1995, Birds; Frith 1976, Blakers et al 1984, Seventy and Whittell 1967, Carnaby 1948, Doust 1993, Keast 1949, Reptiles; Storr et al 1981, 1983, 1986 and 1990, Frogs; Tyler et al 1994, Fishes; Allen 1982 and Morgan et al 1996.

During the course of allocating species to the 20 groupings, a task that took several weeks, it became apparent that this initial grouping of Vegetation Complexes was too coarse. The groupings were too broad to account for many species, in particular those species whose distribution relates strongly to moisture/temperature gradients.

There were also anomalies with some of the Vegetation Complexes which were caused by placing too much emphasis on forest associations rather than more appropriate Vegetation Complexes groupings.

A further map (see Map 2) was produced which overcame some of the problems but it was still too coarse and there were still anomalies, which were considered unacceptable.

The final grouping of vegetation complexes is based on the 12 geological units used in the RFA maps, Vegetation complexes under each geological unit eg Darling plateau, Blackwood etc were allocated to groups based upon major forest associations, eg karri, jarrah, wandoo forest and woodlands, sedgelands etc with further grouping based upon moisture/temperature gradients ie east, west, north, south as well as valleys and ridges.

This final sorting resulted in the 318 RFA Vegetation Complexes being grouped into 51 Fauna habitat groups (See Map 3 and Table 1).

In order to shorten the mammoth task of allocating each of the 279 native vertebrate species, with the correct probability score to 51 habitat types we used the lists which had been prepared for the original 20 groups in Map 1 as follows; One of the lists was allocated provisionally to the most appropriate of the 51 new groupings. We then had printouts of each of the 51 lists made in tabular form and each and every species was checked against each of the 51 groups for correct allocation and probability score.

The final result was a complex table listing the probability of occurrence for each of the 279 native vertebrate species against each of the 51 habitat types, a total of 14229 possible records (see example in Appendix 1).

Each of the 279 species have been allocated a probability of occurrence score in each of the 51 fauna habitat types.

Scoring was done on the considered likelihood of finding a species in a particular vegetation grouping or fauna habitat type, 1 = should occur, 2 = could occur, 3 = possibly could occur. No entry in a box means that it is considered that the species does not occur in that habitat. Conservation status of the species is also given where this is applicable and exotic species are listed separately in the case of mammals and fish and annotated in the case of birds.

Where museum records of sufficient accuracy exist (we obtained these from the RFA fauna database) the box has been allocated an M. similarly records held by CALM Wildlife Section have been allocated W. More detail on any of these records can be obtained by backtracking to the fauna habitat maps, obtaining a map reference for that area and then chasing up the record in either the RFA, Museum or Wildlife data bases.

Only a fraction of the 63,710 records on the RFA vertebrate fauna data base (Museum records) have location data with sufficient precision for them to be used in FDIS.

Thus only records with latitude and longitude readings with a precision of 0.02' or greater were used (the precision is defined for each species in the RFA data base). This level of resolution approximates to a $300m^2$. Records with levels of accuracy below this were not considered acceptable considering the high level of resolution of the Vegetation Complexes. Lesser accuracy would mean that too large a percentage of records could fall into adjacent vegetation complexes which may well be grouped in a different habitat type than the one in which they were actually collected.

(i) Validating the Fauna habitat maps

We also used the RFA fauna data base records which had a precision of 0.02' or greater together with the CALM Wildlife fauna records to validate the predicted occurrences. This was done prior to adding those records to the system.

Unfortunately only 1186 of the 63,710 records in the data base had the required precision of 0.02' and were able to be utilised for this exercise. The much smaller CALM Wildlife fauna database contained 217 mammal records that could be used. The range of species comprising the records however was quite good, 18 mammals, 20 reptiles and 16 frogs.

The sample used for validation is small but the results were pleasing, only 51 (5.9%) of the 871 useable mammal records were not predicted by the FDIS system. The figure for reptiles was 7 (2.7%) of 262 records in error.

Frog records totalled only 107 of which 16 (14.9%) were in error, a high percentage but 8 of the 16 were of one species *Crinea glauerti* in only two vegetation complexes (see Table 2).

Apart from the mammals with 871 records which is a reasonable number, we do not consider the sample an adequate assessment of the FDIS predictive system and further validation should be done.

It is obvious from this exercise that although considerable numbers of fauna records exist for the forest areas (63,710 in the RFA database) only a very small proportion 1186 (1.86%) can be located with a high degree of precision. Being able to place a specimen within a square kilometre grid might have been adequate in the past but now with the comprehensive RFA Vegetation Complexes mapping system in place a higher level of precision is necessary in order to relate records accurately to Vegetation Complexes. This is now possible with GPS and new more accurate Museum records are urgently needed.

4.2.2 Primary and secondary habitat

A table depicting primary and secondary habitat allows species which use the forest as primary habitat to be identified from others which use it as secondary habitat or which primarily use non-forest types such as woodland or heath (Appendix 2). This table from Christensen (1997) was developed from an earlier version by Christensen and Liddelow (1997).

The broad categories used in App 2 are;

Jarrah forest – Associations with an overstorey of jarrah *Eucalyptus marginata* with a crown cover greater than 20 percent.

Karri forest – including jarrah, marri and tingle mixtures.

Riverine forest – Vegetation of various kinds to be found along watercourses permanent or seasonal, typically 50 to 100m in width.

Woodlands – A range of woodlands, (including jarrah 20% cover or less), wandoo, Casuarina Banksia etc.

Flats and heath – Open monocot flats associated with areas of seasonal flooding and heath usually on sandy soils including coastal heath types.

Granite outcrops – granite monadnocks and associated vegetation.

Rivers, lakes and swamps – Permanent streams, rivers, lakes and a range of swamp vegetation permanently inundated or wet for most of the year.

The terms primary and secondary habitat for the purpose of this tabulation are taken to mean:

Primary habitat – habitat primarily used by the species, the species main habitat, significant populations of the species live and breed here.

Secondary habitat – habitat not primarily used by the species, not the species main habitat, population of the species may use it seasonally or may use it for only part of their life cycle eg for feeding only.

4.2.3 Effect of disturbance

(i) Timber Harvesting

In Western Australia the effect of timber harvesting on vertebrate fauna as far as is known is always of a temporary nature. Animals may on occasion be killed directly as a result of felling trees eg a small percentage of possums are killed by felling their nesting trees. Most often however animals die within the first few weeks following falling usually as a result of predation due to the temporary alteration of their habitat. The proportions which are killed depends largely on the level of cutting, a greater proportion of animals survive shelterwood cutting than clearfelling. Many individuals especially birds and other animals living on the edge of coupes manage to re-settle in nearby forest.

As the forest regenerates each species returns as the habitat again becomes suitable. Open country species may invade for the first year or two eg the Australian pipit (*Anthus novaeseelandiae*), scrub species and ground species return within a few years as the scrub develops rapidly , other species return when the new trees develop a closed canopy.

Species that use tree boles such as the Rufous treecreeper (Climacteris rufa) and hollow nesters take longer especially large hollow nesters.
Many hollow nesters utilise the regenerating forest whilst nesting in adjacent uncut forest.

The complete picture for all species is not known in detail but for most species it is possible to make predictions based on the species biology and life history together with field observations. The information presented in Appendix 3 represents a first attempt at assembling all known information on the return of vertebrate species to regenerating forest. With some groups such as the bats there is little information. Many species of birds and mammals in particular are reasonably well known and a fairly accurate picture can be drawn.

The information in Appendix 3 may be used to predict with reasonable accuracy the way in which species will return to a regenerated forest as the trees develop. It can also be utilised to highlight species which may be expected to take longer to return after felling. Such species may be sensitive to harvesting operations if large areas of forest were to be cut on shorter rotations with no forest allowed to grow on to maturity.

It is possible to do calculations with respect to the area available to various species on a forest wide basis using data from Appendix 3 together with Appendix 2 and Appendix 1 and data from the Forest Management Information System (FMIS) relating to forest regeneration stages.

Such calculations may highlight further species that could be sensitive to current timber harvesting and regeneration practices. Such species are likely to be late succession species with limited distribution.

(ii) Fire

In Western Australia timber harvesting is generally associated with fire. The area to be harvested may be burnt some time previous to the operation for protection purposes or the general surrounds may be burned. These fires are usually mild, consuming only the litter layer and the understorey scrub, the overstorey generally remaining intact. Where clearfelling is carried out regeneration burns are usually done to promote vigorous and healthy regeneration. These burns are intense, burning much of the slash, the litter and duff layers and scorching and burning some of the logs and heavier branch material which has been left behind following harvest. As was outlined earlier fire causes temporary disturbance which may affect fauna to a greater or lesser extent depending on the intensity and season of burning.

The predicted effects of fire on fauna, including recovery times are illustrated in Appendix 4. These predictions however relate largely to forest where harvesting has not recently taken place. To interpret them in the context of timber harvesting where the forest has been opened up or where regeneration is taking place following clear felling and burning, reference should also be made to the other Appendices especially Appendix 3. For example, neither of the predicted successions following prescribed burning or wild fire will apply to forest regenerating following recent clear felling. The temporary absence of an overstorey will obviously override any effects of fire.

Interpreting fire effects in the surround of the harvest area may also present difficulties due to edge effects.
The information in Appendix 4 may of course also be used to interpret the effects of prescribed burning operations, wildfires and regeneration burns in conjunction with the notes on the likely effects of disturbance presented in Appendix 7 (see later).

4.2.4 Hollow users

A large portion of forest mammals and considerable numbers of birds use hollow trees for nesting or shelter (Appendix 5).

This group of animals are traditionally of concern where forests are being harvested and regenerated primarily because of the time it takes for a tree to form hollows suitable for use by such animals. Whilst hollows may form in some trees as young as 60 years these hollows are usually small and few in number, also few trees form hollows at this age. Hollows suitable for the large hollow users such as the Brush-tail possum (*Trichosurus vulpecula*) or the Red-tail Black Cockatoo (*Catyptorhynchus magnificus naso*) could take 150 to 200 years to form. Species that utilise fallen trees with hollows, i.e. hollow logs, will not have a problem during the first rotation as these will be in abundance.

However there needs to be provision made for following rotations by ensuring that a portion of the crop is left to mature to an age where felled trees will be large enough to provide hollow logs for these species (See Christensen 1997).

Hollow tree nesters are catered for by leaving habitat trees and by the system of reserved forest as well as road river and stream reserves. Present indications suggest that these provisions are sufficient for most species.

The requirements of some groups such as owls and bats are not well known and research is ongoing or being planned for these species. Hollow users are listed in Appendix 5.

4.2.5 Species sensitive to harvesting

In this group we include all species listed in Specially Protected Fauna Notice 17 December 1999.

Declared Threatened Fauna (EX = presumed extinct, CR = critically endangered, EN = endangered, VU = vulnerable).

Conservation Dependent Fauna

Other Specially Protected Fauna.

Priority Fauna (P)

These species are currently listed under the above groupings in Appendix 6.

Information on the biology of each of the 50 species, such as is known, together with notes on the likely effect of disturbance is presented in Appendix 7.

The fact that a species is listed in Appendix 6 does not necessarily mean that there is a problem with that species with respect to timber harvesting and regeneration.

Some species on the list do not even occur within the forest types subject to timber harvest and regeneration, eg Freckled duck (*Strictonetta naevosa*), White bellied frog (*Geocrinea alba*) or Sunset Frog (*Spicospina flammocaerulea*). Other species are known to inhabit regenerating forest eg Quenda (*Isoodon obesulus*) and Woylie (*Bettongia penicillata*).

The fact that these species are scheduled however means that care needs to be exercised and whenever they are found to be present each needs to be accounted for by checking the information on them which is supplied in Appendix 7.

4.2.6 Species of concern

Listing of forest species along with their characteristics allows us to target those which are most likely to be of concern. Only a relatively small proportion of the RFA Vegetation Complexes are being or will be subject to timber harvesting and regeneration. The vast majority are outside of production forest. Listing fauna in the Vegetation Complexes which occur in production forest demonstrates that whilst all of the 279 native species are represented in habitats which occur outside of the production forest region only 62.4% of all species occur in the types subject to timber harvesting.

Thus almost 40% of all species which occur within the forest area will never be exposed to the direct effects of timber harvest and regeneration and are unlikely to be affected to any great extent (see Table 3).

For the species that occur within production forest we can select those species which have production forest (karri and jarrah) as a primary habitat. If we then examine these against the list of Sensitive species, hollow users and those species which return to the forest during the later stages of regeneration (Stage 3) i.e. e.g.: between 50 to 60 years to 120 to 150 years after harvest, we can see which are the most likely species to be affected by timber harvest and regeneration (Appendix 8). Those species that score 4 are the species we should be most aware of and they should be the species targeted for research and monitoring.

Table 1.

FOREST FAUNA HABITATS LISTED WITH COMPONENT VEGETATION COMPLEXES

No.	Vegetation Groups - Fauna Habitat		RFA Vegetation Complexes	Data File
1	Darling Plateau	Jarrah uplands North	D1,D2	Darling
2		Jarrah Uplands East	BEs,Bo1s,CO2,D3,D4,MT2,WG	
3		Jarrah Uplands South	BE1,BE2,BEy1,CO1,COd,COy1,CRd,HR,Kp,Ks,Ky,MT1,QP,QT,TP,	
4		Jarrah Uplands South East	BAf,BAg,BEy2,COp1,COp2,COy2,Lg,Lp,Ls,Ly,Mm,MTp1,MTp2,MTy2,PN,PP,Pu,	
5		Karri Uplands	BEb,COb,CP,CRb,CRy,Kb,Kg,MTb,MTy1	
6		Wandoo Uplands	BE3,Bo1,Dk1,DM1,DM2,DMg,Fa1,KU1,KU2,MH,SD,Y5	
7		Powder Bark Uplands	Y6	
8		Scarp	DB3,DS,GA,WS2,WSv	
9		Depression/Swamps North		
10		Depression/Swamps South	CL1,CT,KP,KR,YR	
11		Depressions/Swamps East	CL2,G,KUw,QU,QUs,QUw,,S,SK,	
12		Depressions/Swamps South East	CA,CM,MO,Nu,QN,SC,	
13		Jarrah Valleys North	He1,Lo,My1,Yg1,Yg2	
14		Jarrah Valleys East	BO,CB,WL	
15		Jarrah Valleys South	BL,BLf,BT,BTf,CC1,GR,ML,PM2,QW,QWf,SP,ST,YN2	
16		Jarrah Valleys South East	S2,S5,S6,st,V5,Va2,Va3,Wg,YE	
17		Karri Valleys	DO,LF,PM1,S1,V1,Vh2,Vh3,WA,WH1,YN1	
18		Wandoo Valleys	BR,CC2,Ck,CP1,CP2,Dk2,Dk3,Dk4,Dk5,Dk5f,Fa2,Fa3,Fa4,Fa5,GW,He2,LK1,LK2,Mi,My2,NW1,NW2,NWf1,NWf2,NWg1,NWg2,Pn,WH2,WH3,Wi,YEf	
19		Powder Bark Valleys	Bi,No	
20		Granite Outcrops	Ce	
21		**Estuaries and Open Water**	Bwy,L,Lake,WATER	
22	Collie Plain	Uplands		Darling
23		Depressions/Swamps	MJ,	
24	Dandaragan Plateau	Uplands	Bwy,L,Lake,WATER	Coastal
25		Valleys	Mh,Wn,	
26	Swan Coastal Plain	Uplands	AB,Ad,Co,FoGu	Coastal
27		Valleys	Adw,AF,Af,Aw,Br,Lw,Qw,SW,Yn	
28	Southern Plains	Jarrah	HA,HK,Q,	Redmond
29		Karri	A,V4,	
30		Heath/Sedgeland	BU,BW,BWp,KO,OW,Pi,S3,S4,Wp	
31	South Coast Dunes	South Coast Dunes	D,D5,Dd,Dd5,DE5,Dr,Drd,E,Gg,Mc,Mf,Mp,Mr,Ms,Mu,My,	Coastal
21		**Estuaries and Open Water**	Bwy,L,Lake,WATER	
32	Blackwood Plateau	Jarrah Uplands	B,Bd,BN,CSs,JN,KI,N,Nd,T,Td,TL,WC,WCv,Y,Yd	Blackwood
33		Karri Uplands	Bf	
34		Depressions/Swamps	Bw,CE,Nw,	
35		Valleys	Ba,BD,BK,DP,JL,LY,PR,RO,SS,Tw,Yf,Yw	
36	Margaret River Plateau	Jarrah Uplands	C1,C2,Cd,Cr,Hd,M,Wd,Wr	Blackwood
37		Karri Uplands	H,	
38		Jarrah Valleys	Cw2,Mv,Ww2	
39		Karri Valleys	Cw1,Hw,W1,W2,Ww1	
40	Leeuwin Naturaliste Coast	Jarrah		Blackwood
41		Karri	G2,G3,Gk,Gv,	

42		Coastal Heath	GE,Ge,KB,KbE,KE,FEf,Kf,Kr,WE,We,WEw	
43	Scott Coastal Plain	Uplands	Sd,Sd2,	Coastal
44		Valleys/Swamps	CV,JA,Sw,Swd,Swi,	
21		**Estuaries and Open Water**	Bwy,L,Lake,WATER	
45	Redmond	Uplands	Dc1,Ds,MI,R,TR1,TR2,	Redmond
46		Valleys	Bu,Dc2,F,f,S7,S8,t,V7,V8	
47	Unicup	Jarrah Uplands	FH1,UC3,	Redmond
48		Wandoo Uplands	FH2,GD2,YA	
49		Jarrah Valleys	UC2,	
50		Wandoo Valleys	FH3,FH4,GD4,JP2,UC1,	
51		Shrubland	FH5,GD1,UC4,	

Table 2

Validation of FDIS predictions using RFA and CALM Wildlife fauna data base (precision > 0.02' latitude and longitude)

		FDIS in agreement			FDIS in error		
Data base groups	**No of useable records**	**No of species**	**No of records**	**%**	**No of species**	**No of records**	**%**
Mammals							
RFA	654	18	610	93.3	2	44	6.7
Wildlife	217	4	210	96.7	1	7	3.2
Total	**871**	**18**	**820**	**94.1**	**3**	**51**	**5.9**
Reptiles							
RFA	262	20	255	97.3	7	7	2.7
Frogs							
RFA	107	16	91	85.1	5	16	14.9

Table 3

Fauna occurrence in production and non-production forest fauna habitats

	Production Forest habitats		Non-production forest habitats		All forest
	Total	**%**	**Total**	**%**	**Total**
Mammals (Native)	28	93.3	30	100	30
(Intro)	8	100	8	100	8
Birds (Native)	93	58.1	160	100	160
(Intro)	3	100	3	100	3
Skinks	15	71.4	21	100	21
Geckos	3	50	6	100	6
Pygopods	3	50	6	100	6
Dragons	4	100	4	100	4
Turtles	-	-	1	100	1
Snakes	7	53.8	16	100	16
Reptiles (Total)	32	59.3	54	100	54
Frogs	16	69.6	23	100	23
Fish (Native)	5	41.7	12	100	12
(Intro)	1	20	5	100	5
TOTAL	**186**	**63.1**	**295**	**100**	**295**
TOTAL NATIVE	**174**	**62.4**	**279**	**100**	**279**

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References

ABBOTT, I. (1998). Conservation of the forest red-tailed black cockatoo, a hollow-dependent species, in the eucalypt forests of Western Australia. *Forest Ecology and Management.* **109**: 175-185.

ALLEN, G.R., (1982). A field guide to Inland Fishes of Western Australia. *Western Australian Museum.*

BLAKERS, M., DAVIES, S.J.J.F., REILLY, P.N (1984). The Atlas of Australian Birds. *Melbourne University Press.*

BRADSHAW, F.J., COLLINS, P.M. and McNAMARA, P.J. (1997). Forest mapping in the South West of Western Australia. *Department of Conservation and Land Management.*

BRAITHWAITE, R.W. (1995). Southern Brown Bandicoot (*Isoodon* obesulus) In: The mammals of Australia, R. Strahan ED 176-177. *Published Reid Books, Chatswood New South Wales.*

CALABY, J.H. (1960). Observations on the banded anteater *Myrmecobius f. fasciatus* Waterhouse (Marsupialia), with particular reference to its food habits. *Proceedings of the Zoological Society (London)* **135:** 183-207.

CONSERVATION AND LAND MANAGEMENT [CALM] (1992). Management Strategies for the South-West Forests of Western Australia: A Review.

CONSERVATION AND LAND MANAGEMENT [CALM] (1995a). Silvicultural guidelines 1/95: Silvicultural Practice in the Jarrah Forest.

CONSERVATION AND LAND MANAGEMENT [CALM] (1995b). Silvicultural guidelines 2/95. Silvicultural Practice in the Karri Forest.

CONSERVATION AND LAND MANAGEMENT [CALM] {1997} Silvicultural guideline 3/97. Establishment guidelines for karri forest regeneration following harvesting.

CONSERVATION AND LAND MANAGEMENT [CALM] [Undated] Cull pushing guidelines - post harvest.

CONSERVATION AND LAND MANAGEMENT [CALM] [Undated] Criteria for management of fauna habitat [jarrah].

CARNABY, I.C. (1948). Variations in the White-tailed Black Cockatoos. *Western Australian Nat.* **1** 136-138.

CHRISTENSEN P.E. and KIMBER, P.C. (1975) Effects of prescribed burning on the flora and fauna of south-west Australian forests. *Proc. Ecol. Soc. Of Australia* **9,** 95-106

CHRISTENSEN, P.E. (1980). Biology of *Bettongia penicillata* Gray 1837 and *Macropus eugenii* Desmarest 1804 in relation to fire. *Western Australian Forest Department*, Bulletin 91.

CHRISTENSEN, P. (1982). The distribution of *Lepidogalaxias salamandroides* and other small freshwater fishes in the lower south-west of Western Australia. *Journal of the Royal Society of Western Australia* **65** (4), 131-141.

CHRISTENSEN, P., MAISEY, K. and PERRY, D.H. (1984). Radiotracking the numbat, (*Myrmecobius fasciatus*), in the Perup Forest of Western Australia. *Australian Wildlife Research* **11**, 275-288.

CHRISTENSEN, P., ANNELS, A., LIDDELOW, G. and SKINNER, P. (1985). Vertebrate fauna of the southern forests of Western Australia. A survey. *Forests Department of Western Australia,* Bulletin 94.

CHRISTENSEN, P and MAISEY, K. (1987). The use of fire as a management tool in fauna conservation reserves. In: *Nature Conservation: The Role of Remnants of Native Vegetation.* Eds D.A. Saunders, G.W. Arnold, A.A. Burbidge and A.J.M. Hopkins. Surrey Beatty and Sons, Chipping Norton, N.S.W. pp. 15-28.

CHRISTENSEN, P. and ABBOTT, I. (1989). Impact of fire in the eucalypt forest ecosystems of southern Western Australia: a critical review. *Australian Forestry* **52**, 103-121.

CHRISTENSEN, P.E.S. (1992). *The Karri Forest.* Ed. M. Lewis. Department of Conservation and Land Management.

CHRISTENSEN, P. and LIDDELOW, G. (1997). *Forest Fauna Coupe Assessment.* Department of Conservation and Land Management.

CHRISTENSEN, P. (1997). A review of the knowledge of the effects of key disturbances on fauna in the South West Forest Region. *A report prepared for Eau – Australia as part of the Regional Forest Agreement Process.*

CHRISTENSEN, P, and LIDDELOW, G. (1998). Forest Fauna Coupe Assessment. *CALM Report.*

EHMANN, H. (1992). Encyclopedia of Australian Animals. *Collins Angus & Robertson Publishers Pty Ltd.*

DELL, B, HAVEL, J.J. and MALAJCZUK, N. (1989). *The Jarrah Forest, a complex Mediterranean ecosystem.* Kluwer Academic Publishers.

DOUST, G. (1993). Interim Management Guidelines for Mallee Fowl (*Leipoa ocellata*). *Department of Conservation and Land Management, Walpole Western Australia.*

DRISCOLL, D., WARDELL-JOHNSON, G. and ROBERTS, J.D. (1994). Genetic structuring and distribution patterns in rare southwestern Australian frogs: implications for translocation programmes Chapter 15 Pages 85-90 in Reintroduction Biology of Australian and New Zealand Fauna, ed. by M. Serena. *Beatty and Sons, Chipping North* 1994.

FRIEND, J.A. (1994). Western Australian Wildlife Management Program No. 18: Recovery Plan for the Numbat (*Myrmecobius fasciatus*) 1995-2004. *Department of Conservation and Land Management, Como Western Australia.*

FRITH, H.J. (1976). Reader's Digest Complete Book of Australian Birds. *Reader's Digest Services Pty Ltd, Sydney.*

HALL, G.P. (1991). Recovery Plan for the Tammar Wallaby (*Macropus eugenii*). *Department of Conservation and Land Management, Como Western Australia.*

HARRIS, L.D. (1984). The Fragmented Forest: Island biogeography theory and the preservation of biotic diversity. Chapter 5 Animal Community Characteristics. L.D. Harris and C. Maser. *Published University of Chicago Press.*

INIONS, G.B., TANTON, M.T, AND DAVEY, S.M. (1989). Effect of fire on the availability of hollows in trees used by common Brush-tail Possum, *Trichosaurus vulpecala* Kerr 1792, and the Ringtail Possum, *Pseudocheirus peregrinus* Boddaerts, 1785. *Australian Wildlife Research,* 1989, **16**, 449-458.

JAENSCH, R.P. (1992). Fishes in wetlands on the south coast of Western Australia. Unpublished Technical Paper. *Department of Conservation and Land Management Western Australia.*

JONES, B.A., HOW, R.A., KITCHENER, D.J. (1994a). A field study of *Pseudocheirus occidentalis* (Marsupialia: Petauridae). **I**. Distribution and Habitat. *Australian Wildlife Research*, 1994, **21**: 175-187.

JONES, B.A, HOW, R.A., and KITCHENER, D.J. (1994b). A field study of *Pseudocheirus occidentalis* (Marsupialia: Petauridae). **II**. Population Study. *Australian Wildlife Research* , 1994, 189-201.

KEAST, J.A. (1949). The Peregrine or Black-Checked Falcon. *The Australian Museum Magazine* 366-370.

KITCHENER, D.J., CHAPMAN, A, DELL, J and MUIR, B.G. (1980). Lizard assemblage and reserve size and structure in the Western Australian wheatbelt – some implications for conservation. *Biological Conservation* 17, 25-62.

MORGAN, D., GILL, H AND POTTER, I. (1996) The distribution of freshwater fish in the south-western corner of Western Australia. *Waters and Rivers Commission W.A.* Report WRT4

MORRIS, K.D., FRIEND, G.R., JOHNSON, B.W., ORELL, P., WARD, C., ROONEY, J and DILLON, M. (1996). The impact of timber harvesting and associated activities on medium sized mammals in the jarrah forest. Interim Report No. 1. CALM.

ORELL, P., and MORRIS, K. (1994). Chuditch recovery Plan 1991-2001 Western Australian Wildlife Management Program No. 13. *Department of Conservation and Land Management.*

PUSEY, B.U.J. (1981). The life history the Shannon Mud Minnow *Lepidogalaxias salamandroides* with special reference to aestivation. *Hon. Thesis Department of Zoology University of Western Australia.*

PUSEY, B.J. (1989). Aestivation in the teleost fish *Lepidogalaxias salamandroides* Mees. *Journal of Comparative Biochemistry and Physiology* **B92A**. 137-138.

PUSEY, B.J. (1990). Seasonality, aestivation and the life history of the salamander fish *Lepidogalaxias salamandroides* (Pisces: Lepidogalaxiidae). *Environmental biology of Fishes* **29**, 15-26.

PUSEY, B.J. & EDWARD, D.H. (1990). Structure of fish assemblages in waters of southern acid peat flats, south-western Australia. *Australian Journal of Marine and Freshwater Research* **41**, 721-734.

RHIND, S.G. (1996). Habitat tree requirements and the effects of removal during logging on the marsupial Brush-tailed Phascogale (*Phascogale tapoatafa tapoatafa*) in Western Australia. *WA Naturalist* Vol 21 No. 1. p1-22.

ROBERTS, J.D., WARDELL-JOHNSON, G. and BARENDSE, W. (1990). Extended descriptions of *Geocrinea vitellina* and *Geocrinea alba* (Anura: Myobatrachidae) from south-western Australia, with comments on the status of *G. lutea. Rec. Western Australian Museum* 1990 **14** (4): 427-437.

SAWLE, M. (1979) Habitat components of *Antechinus flavipes* (Waterhouse 1838) in the karri forest, south-west of Western Australia. Honours thesis. *Murdoch University*

SERENA, M. SODERQUIST, T.R. and MORRIS, K.D. (1991). Western Australian Wildlife Management Program No. 7: The Chuditch. *Department of Conservation and Land Management, Como Western Australia.*

SERVENTY, D.L. and WHITTELL, H.M. (1967) Birds of Western Australia *Lamb Publications, Perth WA.*

STORR, G.M., SMITH, L.A., JOHNSTONE R.E., (1981). Lizards of Western Australia. **I** Skinks. *University of Western Australia Press with Western Australian Museum.*

STORR, G.M., SMITH, L.A., JOHNSTONE, R.E. (1983). Lizards of Western Australia. **II** Dragons and Monitors. *Western Australian Museum.*

STORR, G.M., SMITH, L.A., JOHNSTONE, R.E. (1986). Snakes of Western Australia. *Western Australian Museum.*

STORR, G.M., SMITH, L.A., JOHNSTONE, R.E. (1990). Lizards of Western Australia. **III** Geckos and Pygopods. *Western Australian Museum.*

STRAHAN, R. (1995). The Mammals of Australia. *Published by Australian Museum/Reed Books.*

TYLER, M.J, SMITH, L.A., JOHNSTONE, R.E. (1994). Frogs of Western Australia. *Western Australian Museum, June 1994.*

WILLIAMS, K. (1994). *Geocrinea* Recovery team annual report. *Department of Conservation and Land Management, Bunbury Western Australia.*

ESTABLIMENT FOREST
JARRAH

ESTABLISHMENT FOREST
KARRI

JUVENILE FOREST
JARRAH

JUVENILE FOREST
KARRI

YOUNG FOREST
JARRAH

YOUNG FOREST
KARRI

MATURE FOREST
JARRAH

MATURE FOREST
KARRI

KARRI VALLEY

JARRAH UPLANDS
SOUTH EAST

WANDOO VALLEY

GRANITE OUTCROPS

HEATH / SEDGELANDS

HEATH / SEDGELANDS

DEPRESSION AND SWAMPS
SOUTH

JARRAH UPLANDS
SOUTH

DEPRESSIONS AND SWAMPS
SOUTH EAST

ESTUARIES AND
OPEN WATER

Appendix 1: Example of output from FDIS Forest Fauna Habitat file.

MAMMALS

Vegetation Group & Number		Darling Plateau																				Collie Plain	
		Jarrah North uplnads	Jarrah east Uplands	Jarrah South uplands	Jarrah Uplands South East	Karri uplands	Wandoo Uplands	Powderbark Uplands	Scarp	Depression / Swamps North	Depression / Swamps South	Depression / Swamps East	Depression / Swamps South East	Jarrah North Valleys	Jarrah east Valleys	Jarrah South Valleys	Jarrah South East Valleys	Karri Valleys	Wandoo Valleys	Powderbark Valleys	Granite Outcrops north	Estuaries & Open water	Uplands	Depresion / Swamps
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
SPECIES	STATUS																							
Western Grey kangaroo *(Macropus fuliginosus)*		1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1
Western Brush Wallaby *(Macropus irma)*	P	1 M	1 M	2	1		1	1	1		1	1	1	1 M	1	2	2		1 M	1	M		1	1
Tammar Wallaby *(Macropus eugenii)*	1		3	M	3		3					3			1				3					
Quokka *(Setonix brachyurus)*	1					2			3					1		2	3	1 M						
Brush-tailed Bettong or Woylie *(Bettongia penicillata)*	P	3 M	2	2	2		1	1	3						1				1	1			3	
Common Brushtail Possum *(Trichosurus vulpecula)*		2 M	1	2	2	2	1	1	2		3	3	3	2	2	2 M	3	2	1	1	2		3	
Western Ringtail Possum *(Pseudocheirus occidentalis)*	1	3 M	2		3		2 M				3	M		3 M	M	2	3	2	2 M					
Western Pygmy possum *(Cercartetus concinnus)*		2 M	2 M	2	2	1	3	3	2		2	2	3	2 M	2	3	2	1	3 M		2 M		1	2
Honey Possum *(Tarsipes rostratus)*			3		3						3	M	1				2		3 M		2 M		1	3
Southern Brown Bandicoot *(Isoodon obesulus)*	1	2 M	2	2	2	2 M	2 M	2 M	2 M		1	1 M	1	1 M	2	1	2	1 M	2 M		2		2	2
Western Quoll or Chuditch *(Dasyurus geoffroii)*	1	1 M	1 M	1 M	1 M	3 M	1 M	1 M	1		1 M	2 M	1	1 M	1 M	2 M	2	M	1 M	1	2 M		1 M	3
Red-tailed Phascogale *(Phascogale calura)*			3		3		2	2							3				3	2				
Brush-tailed Phascogale *(Phascogale tapoatafa)*	P	1 M	1	1	1	2	1	1	1 M		1	2	2	1	1	1	1	2	1	1	2		1	2
Yellow-footed Antechinus or Mardo *(Antechinus flavipes)*		1 M	2	1	2	1	2	2	1		1	1 M	2	1 M	2	1	2	1	2	2	1		2	1
Gilberts Dunnart *(Sminthopsis gilberti)*		1 M	1	1	2		1	1	1		1	1 M		1	1	1	3		1	1	1		1	2

SPECIES STATUS

1	Schedule 1 species
2	Schedule 2 species
4	Schedule 4 species
P	CALM Priority species
S	Sensitive species (Christensen & Liddelow 1997)

SPECIES SCORE - Predicted liklihood of occurence

Score 1	Should occur
Score 2	Could Occur
Score 3	Possibly could occur
M	Museum record (RFA Database)
W	CALM Wildlife Data Base

Appendix 2: Example of output from Forest Fauna Primary and Secondary habitats in major forest ecosystems

KEY	Habitat	
	Primary habitat	
	Secondary habitat	

Status (Conservation Status W.A.)	
Schedule 1 species	1
Schedule 2 species	2
Schedule 4 species	4
CALM priority species	P
Exotic	E

SPECIES	STATUS	Jarrah Forest	Karri Forest	Riverine Forest	Woodland	Flats and Heath	Granite Outcrops	Rivers/Lakes Swamps	Habitat Characteristics in S.W. forest region
MAMMALS									
Bush Rat (Rattus fuscipes)									Dense ground cover
Southern Brown Bandicoot (Isoodon obesulus)	1								Dense ground cover
Yellow-footed Antechinus or Mardo (Antechinus flavipes)									Hollow logs 10 years + unburnt
White-striped Freetail-bat (Nyctinomus australis)									Hollows in trees
Echidna (Tachyglossus aculeatus)	S								
Grey-bellied Dunnart (Sminthopsis griseoventer)									Hollows in dead blackboys
Chocolate Watlled Bat (Chalinolobus morio)									Hollows in trees
King River Eptesicus (Eptesicus regulus)									Tree hollows
Western False Pipistrelle (Falsistrellus mackenziei)	S								Tree hollows, mature trees
Western Grey kangaroo (Macropus fuliginosus)									Open areas
Greater Long-eared Bat (Nyctophilus timoriensis)									Hollow tree and crevices
Lesser Long eared Bat (Nyctophilus geoffroyi)									Tree hollows and crevices
Western Pygmy possum (Cercartetus concinnus)									Tree hollows and crevices

Appendix 3
Example of output from Forest Fauna file – duration of disturbance on population and habitat

Logging:

Mammals

Species	Status	Establishment Forest	Juvenile Forest	Young Forest	Mature Forest	Treatment Effect on Critical Habitat
Western Grey kangaroo (Macropus fuliginosus)						Opening forest encourages Roos and Brushes Following logging
Western Brush Wallaby (Macropus irma)						
Tammar Wallaby 2 & 3 (Macropus eugenii)	1					Temporary effect on thickets
Quokka 1 (Setonix brachyurus)	1					Temporary effect on thickets *
Brush-tailed Bettong or Woylie (Bettongia penicillata)	2					Effect minimal
Common Brushtail Possum (Trichosurus vulpecula)						Reduced number of large hollows **
Western Ringtail Possum (Pseudocheirus occidentalis)	1					Reduced number of large hollows **
Western Pygmy possum (Cercartetus concinnus)						Small hollows reduced
Honey Possum (Tarsipes rostratus)						Habitat not affected
Southern Brown Bandicoot (Isoodon obesulus)	1					Improved habitat initially dense cover
Western Quoll or Chuditch (Dasyurus geoffroii)	1					Logs increase
Brush-tailed Phascogale (Phascogale tapoatafa)	2					Decrease in small hollows
Yellow-footed Antechinus or Mardo 4 (Antechinus flavipes)						Dense regrowth increase litter and logs
Grey-bellied Dunnart (Sminthopsis griseoventer)						Increase logs
Gilberts Dunnart *(Sminthopsis gilberti)*						Open woodland, heath
Numbat 5 (Myrmecobius fasciatus)	1					Forest where Numbat occur not logged
Bush Rat 1 (Rattus fuscipes)						Initial increase in ground cover

*** Fox predation could affect numbers seriously in some areas.**
**** If fox numbers are controlled, Possums may remain stable.**

Species response

	=	Disappears
	=	stable population
	=	declining population
	=	increasing population

Forest Types

Establishment Forest	0-12-15 years
Juvenile Forest	12-15 to 50-60 years
Young Forest	50-60 to 120-150 years
Mature Forest	150+ years

Appendix 4
Example of output from forest Fauna file – Impact of disturbance on population and habitat

Fire:

Mammals

Species	Status	Wildfire			Fuel reduction burns			Treatment effect on habitat
		Early succession	Mid succession	Late succession	Early succession	Mid succession	Late succession	
Western Grey kangaroo (Macropus fuliginosus)								Fire encourages fresh green feed
Western Brush Wallaby (Macropus irma)								Fire encourages fresh green feed
Tammar Wallaby (Macropus eugenii)	1							Intense fire needed to regenerate habitat
Quokka (Setonix brachyurus)	1							Mild fire does not burn swamps
Brush-tailed Bettong or Woylie (Bettongia penicillata)	2							Temporarily alters habitat
Common Brushtail Possum (Trichosurus vulpecula)								Wildfire burns habitat. Trees flush of new crowns.
Western Ringtail Possum (Pseudocheirus occidentalis)	1							Wildfire burns habitat. Trees flush of new crowns.
Western Pygmy possum (Cercartetus concinnus)								Temporarily alters habitat
Honey Possum (Tarsipes rostratus)								Temporarily alters habitat
Southern Brown Bandicoot (Isoodon obesulus)	1							Temporarily alters habitat
Western Quoll or Chuditch (Dasyurus geoffroii)	1							Temporarily alters habitat
Brush-tailed Phascogale (Phascogale tapoatafa)	2							Wildfire temporarily alters habitat
Yellow-footed Antechinus or Mardo (Antechinus flavipes)								Fire destroys litter, needs time to accumulate
Grey-bellied Dunnart (Sminthopsis griseoventer)								Early colonists of burnt areas
Numbat (Myrmecobius fasciatus)	1							May affect logs and termites

Key

Species response

	=	Disappears
	=	stable population
	=	declining population
	=	increasing population

Understorey successional stage

1	early	0 to 2 years
2	mid	2 to 10-15 years
3	late	15 years +

Appendix 5
Example of output from forest fauna file – Forest mammals – Hollow users

SPECIES	FOREST TYPE								STATUS	HOLLOW USE	COMMENTS
	Jarrah	Karri	Tuart	Wandoo Woodland	Banksia Woodland	South Coast Communities	Waterways and Wetlands	Pine Plantations			
Brush-tailed Possum (*Trichosurus vulpecula*)	x	x	x	x	x			x	Locally common	Hollows obligatory	
Western Ringtail (*Pseudocheirus occidentalis*)	x		x	x		x			Uncommon	Hollows obligatory*	*In some areas
South-western Pygmy possum (*Cercartetus concinnus*)	x	x		x	x	x		x	Local in distribution, commoner in north, east and south forest extremities	Hollows usually used	
Honey Possum (*Tarsipes rostratus*)				x	x	x			Local in distribution and common locally	Hollows may be used	
Western native Cat (*Dasyurus geoffroi*)	x	x	x	x	x	x		x	Locally common	Hollows may be used	Logs
Brush-tailed Phascogale (*Phascogale tapoatafa*)	x		x	x					Locally common	Hollows obligatory	
Red-tailed Wambenger (*Phascogale calura*)				x	x				Common	Hollows may be used	Hollow limbs and logs
Mardo (*Antechinus flavipes*)	x	x	?	x	x	x			Common	Hollows usually used	
Grey-bellied Dunnart (*Sminthopsis griseoventer*)	x	x	?	x	x	x			Common	Hollows may be used	Hollow logs
Gilbert's Dunnart (*Sminthopsis gilberti*)	x			x	x				Uncommon	Hollows may be used	Hollow logs
Banded Ant-eater (*Myrmecobius fasciatus*)	x			x					Locally common	Hollows obligatory	Hollow logs
Water Rat (*Hydromys chysogaster*)							x		Local in distribution and common	Hollows may be used	

Appendix 6

SENSITIVE VERTEBRATE FAUNA IN THE SOUTH-WEST FOREST REGION

Specially Protected Fauna Notice 17 December 1999

DECLARED TREATENED FAUNA

SPECIES	VULNERABLE LIFE HISTORY FACTOR	KNOWN OR POTENTIAL RELEVANT THREATENING PROCESSES	SPECIAL MANAGEMENT
MAMMALS			
Chuditch *Dasyurus geoffroii*	Hollow logs	Fire regime/fox	Recovery plan
Numbat *Myrmecobius fasciatus*	Hollow logs	Fire regime/fox	Recovery plan
Western Ringtail Possum *Pseudocheirus occidentalis*	Hollows in trees	Fox	Current research
Quokka *Setonix brachyurous*	Special thickets	Fire regime/fox	
BIRDS			
Mallee Fowl *Leipoa ocellata*	Suitable thickets	Fire regime/fox	
Australiasian Bittern *Botaurus poiciloptilus*	Reed beds	Fire regime	
Baudin's Cockatoo *Calyptorhyncus baudinii*	Hollows in trees	Timber harvesting	
Carnaby's Cockatoo *Calyptorhyncus latirostris*	Hollows in trees	Timber harvesting	
Lewin's Rail *Rallus pectoralis clelandi*	swamps		presumed extinct
Western long-billed corella *Cacatua pastinator pastinator*	Hollows in trees		Outside production forest
FROGS			
White bellied frog *Geocrinea alba*	On farmland in forest regions		Recovery plan
Yellow-bellied frog *Geocrinea vitellina*	Suitable swamps	Fire regime	Recovery plan
Harlequin Frog (Spicospina flammocaerulea) *Myobatrachidae*		Suitable peat swamps	Fire regime

CONSERVATION DEPENDENT FAUNA

Quenda *Isoodon obesulus*		Fire regime/fox	
Tammar wallaby *Macropus eugenii*	Thickets	Fire regime/fox	Special management plan
Woylie *Bettongia penicillata*		Fire regime/fox	Recovery plan

OTHER SPECIALLY PROTECTED FAUNA

BIRDS

Peregrine Falcon *Falco peregrinus*	cliffs	Limited suitable habitat

REPTILES

Ramsay's python *Aspidites ramsayi*		Fox predation
Carpet python *Morelia spilota imbricata*		Fox predation

PRIORITY FAUNA LIST

SPECIES	VULNERABLE LIFE HISTORY FACTOR	KNOWN OR POTENTIAL RELEVANT THREATENING PROCESSES	SPECIAL MANAGEMENT
MAMMALS			
Brush-tailed Phascogale *Phascogale tapoatafa*	Hollows in trees	Cat/fox	Current research
Western Brush Wallaby *Macropus irma*		Fire regime/fox	
Water Rat *Hydromys chrysogaster*	rivers and swamps	fox/cat	
Western False-Pipistrelle *Falsistrellus mackenzei*	Hollow trees	Timber harvesting	
BIRDS			
Freckled duck *Stictonetta naevosa*	Suitable lakes		
Black Bittern *Ixobrychus flavicollis*	Reed beds	Fire regime	
Little Bittern *Ixobrychus minutus*	suitable swamps		
Square-tailed Kite *Lophoictinia isura*			
Bush Stone-Curlew *Burhinus grallarius*		Fox	
Forest Red-tailed Black Cockatoo *Calyptorhynchus magnificus naso*	Large hollows in trees	Timber harvesting	Current research
Barking Owl(SW form) *Ninox connivens*	Hollows in trees/ Low numbers	Timber harvesting	
Masked Owl *Tyto novaehollandiae*	Hollows in trees/ Low numbers	Timber harvesting	
Crested Shrike-tit (s.west subsp.) *Falcunculus frontatus*			
REPTILES			
Ctenotus delli			
FROGS			
Nornalup Frog *Geocrinea lutea*	Very Restricted Habitat		
FISH			
Mud minnow *Galaxiella munda*			
Black-stripe minnow *G. nigrostriatus*	Low numbers		
Balston's Pygmy perch *Nannatherina balstoni*			

Appendix 7
Example of output from forest fauna file

Sensitive Vertebrate Fauna in the south-west Forest Region – Distribution and Sensitivity
Fauna which is rare or likely to become Extinct

NUMBAT *(Myrmecobius fasciatus)*

1. SPECIES PROFILE

Diurnal, the numbat feeds in green areas in Woodland of jarrah and wandoo. It is never far from cover, hollow logs which it uses as bolt-holes to avoid predators as scrub cover. Nests of shredded bark and grasses are constructed in hollow logs occasionally trees or burrows, 1 to 2 metres in length, in winter, are used to sleep in at night. The numbat feeds by searching by scent for underground termite galleries, making small excavations and turning over dead sticks to expose them before using its long slender tongue to extract them.

The numbat is exclusively a termite eater. It concentrates on the specie which are the most abundant in this area in which it is feeding but some species are ignored. Daily activity changes during the year with peaks at midday in winter and morning and late afternoons in summer relating to the activity of termites.

Mating occurs in January, the young are born 14 days later. The young (usually 4) are carried on the teats until July when they are deposited in one of her burrows. Dispersal occurs in December. Numbats are essentially solitary occupying home ranges of 25 to 100 ha. Predators include the Carpet python, several birds of prey and the fox, the latter being the principal predator, regulating population numbers.

1.2 Ability to recover following significant disturbance

Numbats live in the Perup forest which is prescribed burnt on a regular basis. In this forest numbats move about in areas that were selectively harvested for timber and regenerated in the 1970,s and earlier. Radio tracking studies in the Perup have demonstrated high usage of hollow logs that have been left as a result of timber harvesting operations. Studies in Dryandra forest suggest that numbats move out of areas whilst these are being harvested for timber. They soon move back again however once the harvesting operation is over and people and machinery have left the area.
Though not conclusive these studies suggest that numbats are relatively resilient to disturbance.

1.3 Dispersal Mechanisms

Young Numbats disperse from their maternal home ranges to establish their own home ranges during December. Normally they remain in their home ranges for life. Dispersal of over 15km has been recorded.

2. OCCURRENCE

2.1 Known Occurrence Localities

At the time of European settlement, numbat distribution extended from the western parts of New South Wales through South Australia and across parts of the Southern half of Western Australia. Only a few isolated population remain in Western Australia at Dryandra, the Perup and Tutanning Reserve with maybe isolated colonies in the northern jarrah. It has been successfully re-established at Boyigin following fox control.

2.2 Size of Population.

Current estimates put the current numbat population in excess of 1000 animals, but probably less than 2000. The species is on the Declared Threatened Fauna List and the subject of a current recovery plan. Several re-introductions are being planned and Numbats are being bred at the Perth Zoo.

Self-sustaining populations currently occur only at Dryandra forest, in the Perup/Kingston forest and at Boyigin reserve. Numbats are also sighted occasionally in forest blocks to the west of Perup towards Manjimup and Yornup. Smaller populations also exist in several south-west reserves where they have been re-introduced over the last few years.

2.3 Observed Health

Numbats that are captured appear to be largely in good health. A parasitic worm, Acanthocephalan sp. has been implicated in the death of one translocated numbat.

2.4 Regional Importance of Occurrence.

Occurrences in the forested area are very important. The numbat currently only survives in the extreme south-west of its range primarily in forested areas.

3. HABITAT

3.1 General Habitat Requirements.

The numbat occurs in Woodlands, primarily of *Eucalyptus wandoo* and other species as well as open forest of jarrah with an open understorey. It has a requirement for dead woody material which harbours termites (it's diet) and hollow logs for shelter.

3.2 Critical Habitat Components Impacted by Proposed Operations.

Certain fire regimes may impact detrimentally on hollow logs if sufficient new logs are not being recruited. Summer and autumn fires, which may destroy a significant percentage of logs, generally recruit new ones through fallen limbs and trees. Spring fires may destroy a small percentage of logs and rarely recruit new ones. Selective harvesting for timber increases log numbers available for use by the numbat.

Fire may also cause a temporary reduction in available termites. The temporary removal of ground cover by fire may also be a problem with respect to fox predation if there are no adjacent unburnt areas from which recruitment can take place.

3.3 Ability of Habitat Components to Recover.

This depends on the intensity, scale and nature of the disturbance. Generally good if disturbance is localised and not too frequent.

4 OCCURRENCE OF HABITAT

Limited suitable habitat is now available for the numbat and much of it is in the forested area. A large proportion of the numbats prime habitat in the wheatbelt was cleared for farming. Otherwise suitable habitat in mallee and other arid types of vegetation are currently not suitable because of the presence of the European red fox.

5 ADEQUACY OF INFORMATION.

5.1 Adequacy of Information

Several studies have been carried out on numbats, particularly since the 1960's but much of the information remains to be written up and published.

The information that is available is considered adequate for conservation of the species.

5.2 Planned Surveys and Methodology.

No planned surveys. Numbats were surveyed in the 1980's.

5.3 Long Term Monitoring.

Monitoring is being carried out as a part of the Numbat Recovery plan.

5.4 Information Management.

Information is being collected and managed by CALM Science and Wildlife Branch Woodvale.

6 PREDICTED IMPACT OF MITIGATION.

6.1 Conservation Status -Local, Regional, State and National.

Locally and regionally the species may be rare or extinct, though it is common in parts of its range e.g. Dryandra and the Perup. On a state level it is rare and nationally it is now only known from the South-west.

6.2 Impact on conservation status.

Fox control is having a positive effect in many forest areas. Disturbances such as prescribed burning and timber harvesting may impact on the numbat where these practices occur.

6.3 Mitigation of Impact on Critical Habitat Components and Life History Factors.

Wildfire control together with rotational alternating spring and autumn burning and the maintenance of some unburnt areas within the numbats range will minimise any effects of fire.
The majority of the numbats known range is now within reserves and timber harvesting will affect only a minor portion of the numbats habitat. Timber harvesting, where selection cutting is the main method of harvest, could in fact benefit the numbat by increasing the number of refuge logs and wood debris for termites in the short to medium term.
Fox control ameliorates the effects of both fire and timber harvest and it will also allow the numbat to extend its range.

6.4 Relevance of Feral Faunal Management.

Fox control is critical to the numbats survival. Predation by foxes together with clearing of its habitat for farming has resulted in the near extinction of the species.

7 BARRIERS TO MOVEMENT.

Cleared land or dense undergrowth. Re-introduction is addressing the fragmentation of the numbats habitat caused by land clearing.

8 RECCOMMENDED ACTION WHERE DISTURBANCE TAKES PLACE.

8.1 Timber harvesting.

The information available suggests that current standard precautionary measures, including reservation of areas from cutting, scheduling and distribution of cutting coupes habitat logs etc. are sufficient to ensure that numbat populations will not be permanently affected by the disturbance. Western Shield baiting for foxes should be sufficient to ensure protection during and immediately after harvest, provided baiting occurs at least four times a year.

9 REFERENCES.

1. Burbidge, A.A. and Fuller, P.J. {1979}Mammals of the Warburton Region, Western Australia. Records of the Western Australian Museum **8.** pp. 57-73.
2. Burbidge, A.A., Johnson, K.A., Fuller, P.J. and Southgate,P.J. {1988}Aborigional knowledge of the mammals of the central deserts of Australia. Australian Wildlife Research **15.** Pp. 9-39.
3. Christensen, P., Annels, A., Liddelow, G. and Skinner, P. {1985} Family Myrmecobidae. Forests Department, Western Australia, Bulletin In: Vertebrate Fauna in the Southern Forests of Western Australia: a survey **94.** Forests Department, Western Australia, Como. pp. 26-27.
4. Connell, G. W. {1985} Survey of south-west forest and woodland areas for the numbat *Myrmecobius fasciatus*. Department of Conservation and Land Management, Western Australia, Como, W.A. pp. 1-59.
5. Friend., J.A. {1994} Recovery Plan for the Numbat *Myrmecobius fasciatus* 1995-2004. Department of Conservation and Land Management, Western Australia.
6. Friend, J.A. AND Kinnear, J.E. {1983}. Numbat {family Myrmecobidae}. In: Complete Book of Australian Mammals: the National Photographic Index of Australian Wildlife {ed. R. Strahan}. Angus and Robertson, Sydney. Pp. 84-86.

7. Friend, J.A. Thomas, N.D. and Turner,B.G.{1992}. The re-introduction of the numbat *Myrmecobius fasciatus* to Boyagin Nature Reserve. Department of Conservation and Land Management, Western Australia, Como, W.A. pp. 1-39.
8. John Turner and Jim Borthwick {1975-1979} Background paper A52 Volume 1; Preliminary report on the current population status of the numbat. Western Australian Wildlife Authority;,{Perth}. pp. 1-6.
9. Turner, John and Borthwick, Jim {1980}. Status of the numbat *Myrmecobius f. fasciatus* population in Western Australia.: submitted to the Western Australian Wildlife Authority. FEB. 6.pp. 1-19.

21.5.01.

Appendix 8: Example of output from Forest Fauna file - sepcies to be aware of.

MAMMALS

Vegetation Group & Number		PRIMARY HABITAT		SENSITIVE SPECIES	HOLLOW USERS	3rd & 4th STAGES OF REGENERATION	TOTAL
		JARRAH	KARRI				
SPECIES	STATUS						
Western Grey kangaroo *(Macropus fuliginosus)*		Y	Y				2
Western Brush Wallaby *(Macropus irma)*	P	Y					1
Tammar Wallaby *(Macropus eugenii)*	1	Y		Y			2
Quokka *(Setonix brachyurus)*	1	Y	Y	Y			3
Brush-tailed Bettong or Woylie *(Bettongia penicillata)*	P	Y					2
Common Brushtail Possum *(Trichosurus vulpecula)*		Y	Y		Y	Y	4
Western Ringtail Possum *(Pseudocheirus occidentalis)*	1	Y	Y		Y	Y	4
Western Pygmy possum *(Cercartetus concinnus)*		Y	Y		Y		3
Honey Possum *(Tarsipes rostratus)*		Y					1
Southern Brown Bandicoot *(Isoodon obesulus)*	1	Y	Y	Y			3
Western Quoll or Chuditch *(Dasyurus geoffroii)*	1	Y	Y	Y	Y		4
Red-tailed Phascogale *(Phascogale calura)*		Y					1
Brush-tailed Phascogale *(Phascogale tapoatafa)*	P	Y	Y	Y	Y		4
Yellow-footed Antechinus or Mardo *(Antechinus flavipes)*		Y	Y		Y		3
Gilberts Dunnart *(Sminthopsis gilberti)*		Y			Y		2
Grey-bellied Dunnart *(Sminthopsis griseoventer)*		Y	Y		Y		3

Kingston Block

Comparison between FDIS Model and Kingston Study Records

Derived from model		Recorded In Kingston Study	Validated Out
Scientific Name	**Common Name**		
MAMMALS			
Macropus fuliginosus	Western Grey kangaroo	#	
Macropus irma	Western Brush Wallaby	#	
Macropus eugenii	Tammar Wallaby		X
Bettongia penicillata	Brush-tailed Bettong or Woylie	#	
Trichosurus vulpecula	Common Brushtail Possum	#	
Pseudocheirus occidentalis	Western Ringtail Possum	#	
Cercartetus concinnus	Western Pygmy possum		
Tarsipes rostratus	Honey Possum		X
Isoodon obesulus	Southern Brown Bandicoot	#	
Dasyurus geoffroii	Western Quoll or Chuditch	#	
Phascogale calura	Red-tailed Phascogale		X
Phascogale tapoatafa	Brush-tailed Phascogale	#	
Antechinus flavipes	Yellow-footed Antechinus or Mardo		
Sminthopsis gilberti	Gilberts Dunnart	# ?	?
Sminthopsis granulipes	White-tailed Dunnart		X
Sminthopsis griseoventer	Grey-bellied Dunnart	?	
Myrmecobius fasciatus	Numbat	#	
Rattus fuscipes	Bush Rat	#	
Nyctophilus timoriensis	Greater Long-eared Bat		
Nyctophilus geoffroyi	Lesser Long eared Bat		
Nyctophilus gouldii	Gould's Long-eared Bat		
Chalinolobus gouldii	Gould's Wattled Bat		
Chalinolobus morio	Chocolate Watlled Bat		
Eptesicus regulus	King River Eptesicus		
Falsistrellus mackenziei	Western False Pipistrelle		
Nyctinomus australis	White-striped Freetail-bat		
Mormopterus planiceps	Southern Freetail-bat		
Tachyglossus aculeatus	Echidna		
Felus catus	Cat	#	
Canis familiaris dingo	Dingo		X
Capra hircus	Goat		X
Equus caballus	Horse		X
Mus musculus	House Mouse	#	
Rattus rattus	Black Rat	#	
Oryctolagus cuniculus	Rabbit	#	
Vulpes vulpes	Fox	#	
Sus scrofa	Pig		X
BIRDS			
Dromaius novae-hollandiae	Emu	#	
Ardea novaehollandiae	White-faced Heron		X
Nyciticorax caledonicus	Rufous Night Heron		X

Anas superciliosa	Pacific Black Duck		X
Elanus notatus	Black-shouldered Kite		X
Lophoictinia isura	Square-tailed Kite	#	
Haliastur sphenurus	Whistling Kite		
Accipiter fasciatus	Brown Goshawk	#	
Accipiter cirrhocephalus	Collared Sparrowhawk	#	
Aquila audax	Wedge-tailed Eagle	#	
Hieraaetus morphnoides	Little Eagle		
Circus assimilis	Spotted Harrier		X
Circus aeruginosus	Marsh Harrier		X
Falco peregrinus	Peregrine Falcon		X
Falco berigora	Brown Falcon	#	
Falco cenchroides	Australian Kestrel	#	
Leipoa ocellata	Malleefowl		X
Coturnix novaezelandiae	Stubble Quail		
Coturnix australis	Brown Quail	#	
Turnix varia	Painted Button-quail		
Turnix velox	Little Button-quail		X
Porzana pusilla	Baillon's Crake		X
Porzana fluminea	Australian (Spotted) Crake		X
Porzana tabuensis	Spotless Crake		
Porphyrio porhyrio	Purple Swamphen		X
Burchinus magnirostris	Bush Thick-knee		X
Vanellus tricolor	Banded Lapwing		X
Streptopelia chinensis	Spotted Turtle-Dove *		X
Streptopelia senegalensis	Laughing Turtle-Dove *		X
Phaps chalcoptera	Common Bronzewing	#	
Phaps elegans	Brush Bronzewing	#	
Ocyphaps lophotes	Crested Pigeon		X
Calyptorhynchus magnificus	Forest Red-tailed Black Cockatoo	#	
Cacatua pastinator pastinator	Western Long-billed Corella		X
Calyptorhynchus baudinii	Baudin's Cockatoo	#	
Calyptorhynchus latirostris	Carnaby's Cockatoo		?
Cacatua roseicapilla	Galah		X
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	#	
Polytelis anthopeplus	Regent Parrot		X
Melopsittacus undulatus	Budgerigar		X
Purpureicephalus spuruius	Red-capped Parrot	#	
Platycercus icterotis	Western Rosella	#	
Barnardius zonarius	Port Lincoln Ringneck	#	
Neophema elegans	Elegant Parrot	#	
Cuculus pallidus	Pallid Cuckoo	#	
Cuculus pyrrhopphanus	Fan-tailed Cuckoo	#	
Chrysococcyx basalis	Horsefield's Bronze Cuckoo	#	
Chrysococcyx lucidus	Shining Bronze Cuckoo	#	
Ninox novaeseelandiae	Southern Boobook	#	
Tyto alba	Barn Owl		
Tyto novaehollandiae	Masked Owl	#	
Ninox connivens	Barking Owl		X
Podargus strigoides	Tawny Frogmouth	#	
Aegotheles cristatus	Australian Owlet nightjar	#	
Caprimulgus guttatus	Spotted Nightjar		X
Dacelo novaeguineae	Laughing Kookaburra	#	
Halcyon sancta	Sacred Kingfisher		
Merops ornatus	Rainbow Bee-eater	#	
Hirundo neoxena	Welcome Swallow		?

Cecropis nigricans	Tree Martin	#	
Cecropis ariel	Fairy Martin		?
Anthus novaeseelandiae	Richard's Pipit		
Coracina novaeholldaniae	Black-faced Cuckoo shrike	#	
Lalage sueurii	White-winged Triller	#	
Petroica goodenovii	Scarlet Robin	#	
Petroica goodenvovii	Red-capped Robin		X
Melanodryas cucullata	Hooded Robin		X
Eopsaltria georgiana	White-breasted Robin	#	
Eopsaltria griseogularis	Western Yellow Robin	#	
Falcunculus frontatus	Crested Shrike-tit		
Pachycephala pectoralis	Golden Whistler	#	
Pachycephala rufiventris	Rufous Whistler		?
Colluricincla harmonica	Grey Shrike-thrush	#	
Oreoica gutturalis	Crested Bellbird		X
Myiagra inquieta	Restless Flycatcher		
Rhipidura fuliginosa	Grey Fantail	#	
Rhipidura leucophrys	Willie Wagtail	#	
Pomatostomus superciliosus	White-browed Babbler		X
Cinclorhamphus mathewsi	Rufous Songlark		X
Cinclorhamphus cruralis	Brown Songlark		X
Malurus splendens	Spendid Fairy-wren	#	
Malurus pulcherrimus	Blue-breasted Fairy-wren		X
Malurus elegans	Red-winged Fairy-wren	#	
Malurus leucopterus	White-winged Fairy-wren		X
Stipiturus malachurus	Southern Emu-wren		X
Sericornis frontalis	White-browed Scrubwren	#	
Sericornis fuliginosus	Calamanthus		
Smicrornis brevirostris	Weebill		
Gerygone fusca	Western Gerygoyne	#	
Acanthiza apicalis	Inland Thornbill	#	
Acanthiza inornata	Western Thornbill	#	
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	#	
Daphoenositta chrysoptera	Varied Sittella	#	
Climacteris rufa	Rufous Treecreeper	#	
Anthochaera carunculata	Red Wattlebird	#	
Anthochaera chrysoptera	Little Wattlebird	#	
Manorina flavigula	Yellow-throated Miner		X
Lichenostomus virescens	Singing Honeyeater		?
Lichenostomus ornatus	Yellow-plumed Honeyeater		X
Melithreptus brevirostris	Brown-headed Honeyeater	#	
Melithreptus lunatus	White-naped Honeyeater	#	
Lichmera indistincta	Brown Honeyeater	#	
Phylidonyris novaehollandiae	New Holland Honeyeater		
Phylidonyris nigra	White-cheeked Honeyeater		X
Phylidonyris melanops	Tawny-crowned Honeyeater		X
Acanthorhynchus superciliosus	Western Spinebill	#	
Dicaeum hirundinaceum	Mistletoebird		?
Pardalotus punctatus	Spotted Pardalote	#	
Pardalotus striatus	Striated Pardalote	#	
Zosterops lateralis	Silvereye	#	
Emblema oculata	Red-eared Firetail	#	
Grallina cyancoleuca	Australian Magpie-lark	#	
Artamus cinereus	Black-faced Woodswallow		X
Artamus cyanopterus	Dusky Woodswallow	#	
Cracticus torquatus	Grey Butcherbird		X

Gymnorhina tibicen	Australian Magpie	#	
Strepera versicolor	Grey Currawong	#	
Corvus coronoides	Australian Raven	#	
Corvus bennetti	Little Crow		X

REPTILES

Cryptoblepharus plagiocephalus	Wood Skink	#	
Ctenotus delli	Darling Range Ctenotus		X
Ctenotus impar	Odd-striped Ctenotus		
Ctenotus labillardieri	Red-legged Skink	#	
Egernia kingii	King's Skink	#	
Egernia luctuosa	Mourning Skink		
Egernia napoleonis	Smiths Skink	#	
Egernia pulchra	South-western Rock-Skink		?
Hemiergis initialis	South-Western Earless Skink		
Hemiergis peronii	Burrowing Skink	#	
Leiolopisma trilineatum	New Holland Skink	#	
Lerista distinguenda	Orange-tailed Skink		X
Lerista microtis	Slippery Skink	#	
Menetia greyii	Greys Skink	#	
Morethia lineoocellata	Westcoast Skink		
Morethia obscura	Shrubland Skink	#	
Glaphromorphus australis	South-western Mulch Skink		X
Tiliqua rugosa	Bobtail	#	
Crenodactylus ocellatus	Clawless Gecko		X
Diplodactulus granariensis	Wheatbelt Stone Gecko		X
Diplodactylus polyophthalmus	Speckled Stone Gecko	#	X
Oedura reticulata	Reticulated Velvet Gecko		X
Phyllodactylus marmortus	Marbled Gecko	#	
Underwoodisaurus milii	Barking Gecko		X
Aprasia pulchella	Pretty Worm-Lizard		
Aprasia repens	Sedgelands Worm-Lizard	#	X
Delma fraseri	Fraser's Scale-Footed Lizard		
Lialis burtonis	Burton's Snake-Lizard		
Ctenophorus ornatus	Ornate Dragon		X
Pogona minor	Western Bearded Dragon		X
Varanus gouldii	Sand Monitor	#	X
Varanus rosenbergi	Heath Monitor	#	
Ramphotyphlops australis	Blind Snake	#	
Ramphotyphlops pinguis	Rotund Blind Snake		X
Ramphotyphlops waitii	Beaked Blind Snake		X
Morelia spilota	Carpet Python		
Acanthophis antarcticus	Southern Death Adder		X
Notechis scutatus occidentalis	Tiger Snake	#	
Pseudonoaja affins affins	Dugite	#	
Rhinoplocephalus gouldii	Gould's Snake	#	
Rhinoplocephalus nigriceps	Black-Backed Snake		?
Vermicella bertholdi	Jan's Banded Snake		X
Vermicella bimaculata	Black-Naped Snake		X

AMPHIBIANS

Crinia georgiana	Quacking Frog	#	
Geocrinia leai	Lea's Frog		
Heleioporus albopunctatus	Western Spotted Frog		X

Heleioporus barycragus	Western Marsh Frog		X
Heleioporus eyrei	Moaning Frog	#	
Heleioporus inornatus	Plain Frog (Burrowing Frog)	#	
Heleioporus psammophilus	Sand Frog	#	
Limnodynastes dorsalis	Bullfrog (Banjo Frog)	#	
Litoria adelaidensis	Slender Tree Frog		
Litoria moorei	Bell Frog (Green & Gold Frog)	#	
Metacrinia nichollsi	Nicholls' Toadlet	#	
Myobactrachus gouldii	Turtle Frog		X
Neobatrachus pelobatoides	Humming Frog		X
Pseudophryne guentheri	Gunther's Toadlet	#	
Ranidella glauerti	Glauert's Froglet	#	
Ranidella pseudinsignifera	Bleating Froglet	#	
Ranidella subinsignifera	South Coast Froglet		

FISH

Galaxella munda	Mud Minnow		X
Lepidogalaxias salamandroides	Salamander Fish		X
Bostockia porosa	Night Fish		X
Edelia vittata	Western Pygmy Perch		X

Additional records for Kingston, not predicted by model – ID's questionable or species are vagrants

Smithopsis dolichura		# ?	X
Tadorna tadornoides	Australian Shell Duck	#	X
Chenonetta jubata	Maned Duck	#	X
Apus pacificus	Forked Tailed Swift	#	X
Lerista elegans	Elegant Slider	#	X
Varanus gouldii	Sand Monitor	#	X
Diplodactylus polyophthalmus	Speckled Stone Gecko	#	X
Aprasia repens	Sedgelands Worm-Lizard	#	X
Crinia insignifera	Squelching Froglet	#	X

Species predicted but not recorded at Kingston.

Cercartetus concinnus	Western Pygmy possum
Antechinus flavipes	Yellow-footed Antechinus or Mardo
Tachyglossus aculeatus	Echidna
Nine species of bat	No bat recording has been done
Haliastur sphenurus	Whistling Kite
Hieraaetus morphnoides	Little Eagle
Coturnix novaezelandia	Stubble Quail
Turnix varia	Painted Button-quail
Porzana tabuensis	Spotless Crake
Tyto alba	Barn Owl
Halcyon sancta	Sacred Kingfisher
Anthus novaseelandiae	Richard's Pipit
Falcunculus frontatus	Crested Shrike-tit

Myiagra inquieta	Restless Flycatcher
Smicrornis brevirostris	Weebill
Ctenotus impar	Odd-striped Ctenotus
Egernia luctuosa	Mourning Skink
Hemiergis initialis	South-Western Earless Skink
Morethia lineoocellata	Westcoast Skink
Aprasia pulchella	Pretty Worm-Lizard
Delma fraseri	Fraser's Scale-Footed Lizard
Lialis burtonis	Burton's Snake-Lizard
Morelia spilota	Carpet Python
Crinea leai	Lea's Frog
Litoria adelaidensis	Slender Tree Frog
Ranidella subinsignifera	South Coast Froglet

Status: 1 - DECLARED THREATENED FAUNA (Gazetted - Wildlife Conservation Act - December 1999 list)
2 - CONSERVATION DEPENDENT FAUNA (Gazetted - Wildlife Conservation Act - December 1999 list)
4 - OTHER SPECIALLY PROTECTED FAUNA (Gazetted - Wildlife Conservation Act - December 1999 list)
P - CALM PRIORITY LISTED FAUNA
S - Sensitive Species not included on above lists (after Christensen and Liddlelow 1997)

Score - a probability rating on occurrance in a Fauna Habitat Type

1 - High probability of species occurrence in the Fauna Habitat Type
2 - Moderate probability of species occurrence in the Fauna Habitat Type
3 - Species could possibly occur in the Fauna Habitat Type

Origin - records whether Museum RFA (M) data or CALM data (W) confirm a record for the fauna habitat type.

Operation ID: Andrew 1

Common Name	Scientific Name	Status	Score	Origin	Vegetation	Land System	Landscape Unit
Western Brush Wallaby	(Macropus irma)	P	2		3	Darling Plateau	Jarrah Uplands South
Quokka	(Setonix brachyurus)	1	2		5	Darling Plateau	Karri Uplands
Quokka	(Setonix brachyurus)	1	1	M	17	Darling Plateau	Karri Valleys
Brush-tailed Bettong or Woylie	(Bettongia penicillata)	P	2		3	Darling Plateau	Jarrah Uplands South
Western Ringtail Possum	(Pseudocheirus occidentalis)	1	2		17	Darling Plateau	Karri Valleys
Southern Brown Bandicoot	(Isoodon obesulus)	1	2		3	Darling Plateau	Jarrah Uplands South
Southern Brown Bandicoot	(Isoodon obesulus)	1	2	M	5	Darling Plateau	Karri Uplands
Southern Brown Bandicoot	(Isoodon obesulus)	1	1	M	17	Darling Plateau	Karri Valleys
Western Quoll or Chuditch	(Dasyurus geoffroii)	1	1	M	3	Darling Plateau	Jarrah Uplands South
Western Quoll or Chuditch	(Dasyurus geoffroii)	1	3	M	5	Darling Plateau	Karri Uplands
Brush-tailed Phascogale	(Phascogale tapoatafa)	P	1		3	Darling Plateau	Jarrah Uplands South
Brush-tailed Phascogale	(Phascogale tapoatafa)	P	2		5	Darling Plateau	Karri Uplands
Brush-tailed Phascogale	(Phascogale tapoatafa)	P	2		17	Darling Plateau	Karri Valleys
Numbat	(Myrmecobius fasciatus)	1	2	M	3	Darling Plateau	Jarrah Uplands South
Western False Pipistrelle	(Falsistrellus mackenziei)	S	1		3	Darling Plateau	Jarrah Uplands South
Western False Pipistrelle	(Falsistrellus mackenziei)	S	1		5	Darling Plateau	Karri Uplands
Western False Pipistrelle	(Falsistrellus mackenziei)	S	1		17	Darling Plateau	Karri Valleys
Echidna	(Tachyglossus aculeatus)	S	2		3	Darling Plateau	Jarrah Uplands South
Echidna	(Tachyglossus aculeatus)	S	3		5	Darling Plateau	Karri Uplands
Echidna	(Tachyglossus aculeatus)	S	3		17	Darling Plateau	Karri Valleys
Peregrine Falcon	(Falco peregrinus)	4	3		3	Darling Plateau	Jarrah Uplands South
Malleefowl	(Leipoa ocellata)	1	3		5	Darling Plateau	Karri Uplands
Forest Red-tailed Black Cockatoo	(Calyptorhynchus magnificus)	P	1		3	Darling Plateau	Jarrah Uplands South
Forest Red-tailed Black Cockatoo	(Calyptorhynchus magnificus)	P	2		5	Darling Plateau	Karri Uplands
Forest Red-tailed Black Cockatoo	(Calyptorhynchus magnificus)	P	2		17	Darling Plateau	Karri Valleys
Baudin's Cockatoo	(Calyptorhynchus baudinii)	1	1		3	Darling Plateau	Jarrah Uplands South
Baudin's Cockatoo	(Calyptorhynchus baudinii)	1	2		5	Darling Plateau	Karri Uplands
Baudin's Cockatoo	(Calyptorhynchus baudinii)	1	2		17	Darling Plateau	Karri Valleys
Masked Owl	(Tyto novaehollandiae)	P	1	W	3	Darling Plateau	Jarrah Uplands South
Masked Owl	(Tyto novaehollandiae)	P	2		5	Darling Plateau	Karri Uplands
Masked Owl	(Tyto novaehollandiae)	P	1	W	17	Darling Plateau	Karri Valleys
Crested Shrike-tit	(Falcunculus frontatus)	P	3		3	Darling Plateau	Jarrah Uplands South

Operation ID: Andrew 1

Common Name	Scientific Name	Status	Score	Origin	Vegetation	Land System	Landscape Unit
Crested Shrike-tit	(Falcunculus frontatus)	P	1		5	Darling Plateau	Karri Uplands
Crested Shrike-tit	(Falcunculus frontatus)	P	1		17	Darling Plateau	Karri Valleys
Carpet Python	(Morelia spilota)	4	3		3	Darling Plateau	Jarrah Uplands South