CASINO MANAGEMENT AREA EIS

SUPPORTING DOCUMENT No. 6

TERRESTRIAL FAUNA OF THE GRAFTON AND CASINO STATE FOREST MANAGEMENT AREAS - DESCRIPTION AND ASSESSMENT OF FORESTRY IMPACTS
NORTHERN REGION
STATE FORESTS OF NEW SOUTH WALES

by

A.P. Smith, S.P. Andrews and D.M. Moore

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for
State Forests of New South Wales

February 1994

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Published by State Forests of New South Wales
Building 2, 423 Pennant Hills Road, Pennant Hills NSW 2120, Australia.

Bibliography
ISBN 0 7310 6705 3

Available from State Forests of New South Wales Northern Regional Office Coffs Harbour, Phone (066) 528 900 or the Casino District Office, Phone (066) 624 499.

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ACKNOWLEDGMENTS

This study was carried out by the following staff and subconsultants to Austeco Pty. Ltd.

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Subconsultants engaged by Austeco Pty. Ltd.:

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Dr. R. Coles	Bat Call Analysis
Mr. P. Glass	Bat Surveys

Predator scats and hair samples were identified by B. Triggs, and museum specimens were identified by R. Sadlier and L. Gibson (Australian Museum) and G. Ingram and G. Czechura (Queensland Museum). Endangered fauna records were provided by the National Parks and Wildlife Service of NSW, particularly by H. Hines and S. Ferrier. Unpublished reports from the National Parks and Wildlife Service (NPWS) were made available by S. Walker. Road kill records of large mammals were provided by G. Clancy. This report benefited from scientific reviews of an earlier draft by NPWS and State Forests.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

Chapter 2

Chapter 3

Chapter 4

1. PROJECT SCOPE AND OBJECTIVES

Project Scope and Objectives

This report describes the results of fauna surveys carried out in State Forests of the Grafton and Casino Forest Management Areas in north-east New South Wales. The surveys were commissioned by State Forests of New South Wales (SFNSW) to provide background information for preparation of Environmental Impact Statements (EIS) and Fauna Impact Statements (FIS) for forestry operations in the Grafton and Casino Forest Management Areas. Specific aims of the surveys included the following:

a) description of the terrestrial vertebrate fauna (birds, mammals, reptiles and amphibians) of the region;

b) identification of fauna species and habitats of particular conservation significance;

c) identification of fauna habitats of significance, including areas of representative habitats in good condition, which could be considered for reservation;

d) assessment of the significance of the terrestrial fauna in the survey area in a national, state, regional (NE-NSW) and local context;

e) to consider and report on the likely impacts of the proposed forestry operations and associated practices on fauna, with particular reference to old-growth forest.

f) discussion of possible options for ameliorating impacts of forestry operations on fauna.

Surveys commenced in late 1991 and were initially scheduled for completion in mid 1992. Survey methods and design were specified by State Forests of NSW and based on a modified version of standard procedures outlined in version 1.1 of the Forestry Commission of NSW (now SFNSW) survey protocol (York et al., 1991). Impact assessment was determined by literature review and statistical analysis of fauna survey results after the methods of York et al.(1991) and Smith et al. (1992). A number of significant developments in the legislation pertaining to SFNSW EIS's occurred during and after completion of fauna surveys, which had a major impact on the scope of work required. These included: the passing of the Endangered Fauna Interim Protection (EFIP) Act 1991 and the Timber Industry Protection Act 1992; the specification of a series of requirements to be taken into account in preparation of an FIS, by the Director of the NSW National Parks and Wildlife Service; and changes to the NSW list of vulnerable and endangered species (as listed on Schedule 12 of the EFIP Act). These requirements were accommodated, as far as practicable, by supplementary fauna surveys and more rigorous data analysis. This report is not intended to satisfy the full statutory requirements for preparation of EIS and FIS for the Forest Management Areas encompassed within the survey region. It is intended that any additional requirements not covered by this report will be addressed in subsequent documents, including the EISs and FISs for the Grafton and Casino Management Areas. Since this report was prepared before details of proposed forestry activities in these areas had been finalised, some fauna impacts identified and mitigation options recommended here may not be relevant to subsequent EISs and FISs prepared for forestry operations in the Grafton and Casino Management Areas. Impact assessments described here are broad in scope to encompass a wide range of possible forest management operations. Where adverse impacts were considered likely, if previous management practices continued or if foreseeable new management practices were introduced, a range of mitigation options were proposed. The final choice of a preferred option, if any, from the range of options suggested is justified as part of the EIS process, which takes into account hydrological, soil conservation, and other socio-economic matters in addition to fauna impacts.

2. DESCRIPTION OF THE STUDY AREA

Location

The Study Area is located between 28°35'S and 30°10'S and 152°15'E and 153°20'E. It includes the reserve network and all State Forests of the Grafton Management Area in the south and the Casino Management Area to the north. The larger part of the area is encompassed by the Clarence - Moreton Basin, between the sea and the eastern escarpment of the Northern Tablelands. The Richmond Range runs through the Casino Management Area, separating the Richmond River Basin from that of the Clarence River. West of the Clarence River, the Ewingar and Washpool State Forests occupy the eastern edge of the New England Tablelands. The Richmond Range follows the route of Tertiary basalt flow that formed within a valley, but which is now elevated due to the erosion of the surrounding landscape. The climate ranges from Subtropical to Warm Temperate at higher elevations. Maximum rainfall occurs during the summer and autumn, the driest part of the year being late winter to early spring. Rainfall is greatest at higher elevations in the west of the area, and the coast range.

The Natural Environment

The Major Forest Ecosystems

The vegetation communities and forest types in the area are discussed in detail in a separate report (Moore and Floyd, 1994). For the purposes of faunal analysis, we recognise three broad habitat types: Rainforest, Moist Hardwood forest and Dry Hardwood forest.

Rainforest

Rainforest is well represented within the Study Area. Approximately 6,000 ha of Rainforest occurs within the State Forests of the Grafton Management Area, and approximately 9,941 ha in the Casino Management Area. Rainforests are confined to the most fertile and moist sites, and are characterised by closed canopy, relatively open understorey and a ground cover of deep litter, decaying logs and in some cases, ferns. They provide habitat for a wide range of species that are adapted to moist, shaded environments. Three broad types (Subtropical, Warm Temperate and Dry Rainforest) are present. While Subtropical and Warm Temperate Rainforest are floristically diverse, Dry Rainforest, which consists mostly of Hoop Pine (*Araucaria cunninghamii*), typically has a low species diversity.

Moist Hardwood Forest

Moist Hardwood forests (including Moist Blackbutt forest) are characterised by an overstorey of tall eucalypts and an understorey of mesic shrubs and ferns. In frequently burnt areas, the shrubby understorey may be replaced by grasses. Moist Hardwood forest occurs in sheltered locations on fertile soils, and is most widespread in the elevated topography to the west of the Study Area. The fauna includes components of both the Rainforest and Dry Hardwood forests. Approximately 13,500 ha (not including Moist Blackbutt) of Moist Hardwood forest occurs in the State Forests of the Grafton Management Area, and 24,391 ha in the Casino Management Area.

Dry Hardwood Forests

Dry Hardwood forests are highly variable in form and composition, ranging from forests of tall well-spaced trees over a grassy understorey, to low trees with a sclerophyllous shrubby understorey. The poorer sediments of the Richmond and Clarence Basin are dominated by Dry Hardwood forests. These forests tend to be multi-aged in structure, and include a high proportion of fire tolerant plant species. Dry Hardwood can be floristically diverse and support a higher diversity of nectarivorous (nectar feeding) fauna than Moist Hardwood Forests. It is the most widespread of the habitat types in the area, covering approximately 100,000 ha within the State Forests of the Grafton Management Area, and 75,399 ha in the Casino Management Area. Spotted Gum (*Eucalyptus maculata*) is the dominant tree species throughout much of the region.

Biogeographic Subregions

The Study Area is broadly delimited by the Border Ranges to the north, the Northern Tablelands to the west, the Bellinger River to the south and the Pacific Ocean to the east. This area can be subdivided into the following subregions on the basis of climate, geology, physiography and vegetation types.

The River Basins

This subregion includes the low elevation areas (< 150m) of the Clarence and Richmond River Valleys. Although this is the largest region, it has been extensively cleared and supports less than 50% of the State Forest within the Study Area. The topography is flat to undulating. The geology consists principally of siliceous Jurassic and Cretaceous sediments that produce yellow podsolic soils, that are poorly structured and generally low in plant nutrients. The timber producing forests are primarily of a dry Spotted Gum type, subject to frequent fire. Glenugie peak in the south of the Study Area, which supports an anomalous stand of Dry Rainforest, is the eroded remnant of a Tertiary dolerite intrusion, that has been dedicated as a Flora Reserve.

The Coast Range Subregion

The Coast Range follows a major fault line that runs parallel with the coast. A wide variety of forest types occur on this landform including swamps, low quality eucalypt forest and small patches of Rainforest. Candole, Pine Brush, Woodford, Tabbimoble and Double Duke State Forests are on the Coast Range. The area receives greater precipitation than the lowlands, and with the earlier onset of summer rainfall, the climate of the Coast Range is more similar to that of the elevated forests west of the Clarence River Basin. The soils are generally better structured and more fertile than those of the Clarence and Richmond Basins.

The Central Subregion

The Central subregion includes Dalmorton, Grange, and Nymboida State Forests. The area is in a slight rain shadow. The low relief fails to draw rain from cold fronts during the winter months as occurs with the Coast Range and the more elevated terrain to the west.

Grange State Forest is the most isolated of the State Forests in the Grafton Management Area. It occupies the Grange Landform, a small tableland of moderately dissected topography, that ranges in elevation from 250m above sea level in the east up to 600m in the west. The Grange landform is surrounded on three sides by the Clarence and Mann Rivers, the confluence of which is immediately to the north.

The Nymboida and Ramornie State Forests occupy the Buccarumbi Range Landform, between the Orara and Nymboida Rivers. This landform rises to 790m at Mt. Gundahl in the north, but the topography is mainly between 200 and 400m in elevation. This landform is extensively dissected with undulating topography. The Nymboida and Ramornie State Forests are continuous with Dalmorton State Forest and Nymboida National Park.

Dalmorton State Forest occupies the catchment of Cunglebung Creek. The steep outer perimeter of the catchment has an elevation generally in the order of 700m, but rises to 1020m at Mt. Munningyundo in the north-eastern corner of the landform. The lower parts of the drainage basin have a gentle topography, down to 300m in elevation.

The South-Western Subregion

The south-western subregion covers the Tablelands Plateau (800 - 1100m) and its eastern fall, west of the Nymboida and Clarence Rivers. Clouds Creek, Sheas Nob, Boundary Creek and Marara State Forests occur within this zone. The rainfall is high due to the elevated topography. The geology is variable, but consists mostly of Silurian sediments and metamorphics. The soils are mostly friable red acidic podsols that are quite stable and resistant to erosion. Variable topography within this region includes extensive tracts of undulating terrain and fertile soil that support high quality forest.

The Cangai Subregion

The Cangai Landform in the north-western corner of the Grafton Study Area, supports Cangai State Forest. It is dominated by Cangai Ridge; a small plateau of gently undulating topography, at approximately 900m elevation, surrounded on all sides by precipitous slopes. The ridge consists of Permian Granite surrounded by Silurian metamorphics. The geology gives rise to friable red earths which support high quality forests.

The Washpool Ewingar Subregion

The Ewingar subregion includes Ewingar and Washpool State Forests on the edge of the New England Tablelands. The topography is gentle to steep, at elevations in the order of 800m. The climate tends to warm temperate, in contrast to the sub-tropical climate in the rest of the Casino Study Area. The geology is complex as Ordovician and Silurian sediments have been metamorphosed by the intrusion of granites and volcanics during the Permian and Devonian eras. The granitic rock weathers rapidly, giving rise to deep and fertile soils, which erode readily. Soils derived from the metamorphic rocks are less fertile, but also less susceptible to erosion. The forests of this subregion bear a strong resemblance to those of the South West Subregion, due to the similar topography and climate. Like the forests of the South West subregion, these forests form part of a belt of forest on the eastern escarpment of the New England Fold Belt.

The North Richmond Range Subregion

The North Richmond Range subregion includes Richmond Range, Mt. Pikapene and Cherry Tree State Forests. This subregion receives more rainfall than the State Forests further south due to its higher elevation. Large tracts of Rainforest and Moist Hardwood occupy the basalt soils on the plateaus and drainage lines. Dry forests of Spotted Gum, Grey Gum (*E. propinqua)* and Grey Ironbark (*E. paniculata)* occupy the less fertile, exposed slopes.

The South Richmond Range Subregion

South of Mount Pikapene, the Richmond Range curves eastwards towards the coast, through Mount Belmore, Mount Marsh, Banyabba and Gibberagee State Forests. The elevation is lower than further north and the soils are less fertile. Moist Hardwood forest occurs only in sheltered situations.

The Cultural Environment

Before the arrival of Europeans, the coastal and estuarine regions of the Study Area are thought to have been one of the most densely populated areas in Australia. The mild climate and rich estuaries provided abundant food for local aboriginal populations. Cedar cutters first moved into the Clarence and Richmond Valleys in about 1835. Graziers and other agriculturalists began settling during the early 1840s. These settlers and their descendants soon cleared the arable land in the river valleys. The population of the area grew rapidly between 1850 and 1870 after gold was discovered in the Clarence Valley. Settlements flourished in areas such as Bulldog Rock and Ewingar that are now uninhabited. The Crown Lands Alienation Act of 1861 (the Robertson Act) further encouraged settlement in arable areas by allowing the "Conditional Purchase" of land. The conditions associated with the acquisition of land included clearing and development of the land. The slopes and valleys were gradually cleared of timber for pasture and crops, with only the steeper slopes and isolated ranges retaining the natural forest cover. These remaining forests were mostly dedicated as State Forest between 1914 and the 1920s. Since 1972, major extensions have been added to the State Forests, most notably in the Dalmorton area. In 1982, over 25,000 ha of State Forest was revoked and dedicated as part of the Washpool National Park.

Throughout this century, the population of the area has continued to grow, and to become more concentrated within the major towns, particularly Grafton. At present the area has one of the fastest growing populations in Australia, due to tourism and its attractiveness as an area for retirement.

Timber Harvesting

There is little information about the details of the early timber industry. Initially, Red Cedar (*Toona australis*) and Hoop Pine formed the basis of the industry in the area. Timber harvesting commenced in the Casino Management Area prior to 1850, and in the Grafton District, during the 1860s. Six timber mills were operating in the Casino Management Area by 1900. Although commercial operations were largely confined to forests close to Casino and Grafton, it is likely that much of the forest was harvested for building material by miners, agriculturalists and other early settlers. Extensive sleeper cutting operations occurred in the Casino area during the early 1900's. The harvesting of Hoop Pine reached its peak in the 1920s and 1930s. Subsequently, the availability of mature Hoop Pine declined to the extent that harvesting of this species had virtually ceased by the 1980s. The hardwood industry began in the early 1900s but expanded rapidly after the 1930s. In the Grafton Management Area the hardwood industry commenced in the coastal forests close to Grafton. By the 1920s, hardwood was harvested in parts of Clouds Creek and Boundary Creek State Forests. This was extended into Nymboida State Forest during the 1930s, Grange State Forest in the 1940s, Cangai in the 1950s and Dalmorton and Washpool State Forests in the 1960s. Similarly, the hardwood industry spread from forests in the vicinity of Casino into more inaccessible areas.

The history of the timber industry in this area is characterised by a trend from selective harvesting of the most valuable timber towards a policy of "maximum utilisation". Initially, large defect-free stems of durable species such as Tallowwood (*Eucalyptus microcorys*) were selectively harvested. However, this did not promote regeneration and the value of the timber within the forests was rapidly reduced. Consequently, silvicultural treatments were initiated in the more accessible forests of the Casino Management Area in 1920, to remove defective and over-mature trees, and encourage regeneration. The success of these treatments has been variable, depending upon factors such as grazing, fire and seedling scorch. In recent decades, supervision of harvesting has been increased to encourage maximum utilisation and effective regeneration. In Moist Hardwood forests, regeneration is encouraged after harvesting by the practice of burning slash. New practices were introduced in Rainforest harvesting in 1963, to ensure 50% canopy retention and the maintenance of Rainforest structure. Recently general purpose timber harvesting in Rainforest has been totally suspended. These changes in harvesting practices are reflected in a disparity between forest harvested more than 30 years ago, dominated by over-mature and defective trees, and forest harvested more recently dominated by younger rapidly growing trees.

Apiculture

The majority of Hardwood forest types within the Study Area are considered suitable for apiculture, and apiarists hold Occupation Permits for most accessible areas of State Forests. As new areas are made accessible by roading, these are quickly occupied. In the Grafton Management Area, 294 sites were leased by apiarists in 1987 (FCNSW, 1987). The ecological impact of apiculture is not known, but it has been suggested that domesticated bees compete with native nectivorous fauna and may have adverse impacts on the native flora (NPWS, 1989).

Grazing

Grazing under annual Occupation Permits and leases granted under the provisions of the Crown Lands and Consolidation Act, covers most of the accessible areas of forest in the State Forests of the Study Area. In the Grafton Management Area in 1988, there were 39 annual Occupation Permits and 37 other leases of various tenure. The carrying capacity of these leases is estimated at 4,627 head of cattle, with an average grazing period of 9 months per year (FCNSW, 1987). The direct effects of cattle grazing are not well understood; however, it is clear that the most significant effects of current grazing policy are due less to the cattle, than to the propensity of graziers to burn forest to promote feed for cattle. The tick-fence, which forms part of the strategy to exclude certain species of tick from central NSW, runs through the Casino Management Area.

Previous Fauna Surveys in the Study Area

A chronology of previous fauna surveys in the Study Area is given in Tables 2.1 and 2.2. Although there have been many studies of fauna in the region these have tended to be highly localised or to focus on a limited range of special interest species. Information provided by these studies is useful for compiling species lists but has little value for habitat description and impact assessment. Areas sampled are not representative of the full range of habitats and tenures found in the region. Few fauna records have been accurately located to have sufficient latent value for analysis of habitat and land use associations, and many records are now more than a decade old, so may not take account of recent changes in fauna distribution and abundance.

Table 2.1. Chronology of Previous Fauna Surveys in the State Forests of the Grafton Management Area.

Date of Survey	Location SF	Surveyed Fauna	Source
1968-72,1975-81	Clouds Creek, Candole	Mammals	Barnett, J. L. et al., 1976
1978	Cangai	Arboreal mammals	Mackowski et al.. FCNSW Unpubl.
1979	Candole and Pinebrush	Arboreal mammals	Watts et al., FCNSW Unpubl.
1980	Gibraltar Range Washpool Forests	Mammals	Pulsford I.F., 1982
1981	Candole	Arboreal marsupials Small mammals Birds	Smith, A. P. Unpubl.
1981	Dalmorton	Arboreal mammals	Watts, G. Unpubl
1978-91	Bellinger Valley north to Qld.	Possums, Potoroids Macropods, Dasyurids	Clancy, G.P Unpubl.
1980-82	Washpool-Gibraltar Region	Birds	Osborne, W.S. 1982
1982	Washpool (now WNP)	Arboreal Mammals	Watts et al., FCNSW Unpubl.
1987-88	Tweed Volcano Region	Birds	Debus, S. Unpubl.
1987-90	NE NSW	Birds	Debus, S. 1992
1988-90	Clouds Creek	Reptiles	Manning, A. Unpubl.
1989-90	Mt Marsh, Dalmorton	Terrestrial Vertebrates	Hines, H.B. Unpubl.
1990	Cangai	Terrestrial Vertebrates	Greenup, N.
1990-91	Richmond-Tweed Region	Owls	Ford et al., 1991
1991	Grafton Management Area	Birds, Owls, Bats Arboreal mammals	Kavanagh, R. Unpubl.
1991	Boundary Creek	Birds	Horton, G.W. Unpubl.
1991	Dalmorton, Clouds Creek, Billilimbra Boundary Creek	Mouse	Read, D. Unpubl.
1991	Washpool, Billilimbra	Vertebrates	Gilmore, A. M.& Associates. Unpubl.
1991	Washpool, Bunjalung	Terrestrial Vertebrates	NPWS Atlas
1991	Grafton Management Area	Birds, mammals	Kavanagh, R. Unpubl.
Records up to 1991	North Coast Forest	Vertebrates	NPWS Unpubl.
1991	Hunter River to Qld/NSW border	Mammals	Australian Museum Unpubl.
1991	North Coast and Ranges	Reptiles Amphibians	Australian Museum Unpubl.
1991	North-east NSW	Koalas	Kavanagah, R. Unpubl.
1993	North-east NSW	Terrestrial Vertebrates	NPWS Unpubl.

Table 2.2. Chronology of Previous Surveys in the State Forests of the Casino Management Area.

Date of Survey	Location SF	Surveyed Fauna	Source
1980	Gibraltar Range Washpool Forests	Mammals	Pulsford I.F., 1982
1978-91	Bellinger Valley north to Qld.	Possums, Potoroids Macropods dasyurids	Clancy, G.P Unpubl.
1980-82	Washpool-Gibraltar Region	Birds	Osborne, W.S. 1982
1983	Richmond Range	Terrestrial Vertebrates	Mason, B. Unpubl.
1984	Cambridge Plateau	Terrestrial Vertebrates	Smith, A. and Preen A. Unpubl.
1984	Nullum Blackbutt Plateau	Birds, nocturnal Arboreal mammals	Milledge, D. Unpubl.
1984-85	Mid-north coastal NSW	Bats	Parnaby, H. E, 1986
1987-88	Tweed Volcano Region	Birds	Debus, S. Unpubl.
1987-90	NE NSW	Birds	Debus, S. 1992
1988-89	North east NSW	Birds	Date, Ford and Recher, 1989
1989	Richmond Range	Mammals	Barker, J. Unpubl.
1989	Focal Peak Region	Mammals, Reptiles Amphibians	Smith, A. P. et al., 1989
1989-90	Mt Marsh, Dalmorton	Terrestrial Vertebrates	Hines, H.B. Unpubl.
1990	Cangai, Dalmorton	Terrestrial Vertebrates	Greenup, N. Unpubl.
1990	Billilimbra	Mammals, Reptiles Owls, Amphibians	Phillips, S. Unpubl.
1990	Bungabee, Nullum Mebbin, Mooball Whian Whian	Owls	Debus, S. Unpubl.
1990-91	Billilimbra	Bats	Cogger, H. G. Unpubl.
1990-91	Richmond-Tweed Region	Owls	Ford et al., 1991
1991	Dalmorton, Clouds Creek, Billilimbra Boundary Creek	Mouse	Read, D. Unpubl.
1991	Washpool Billilimbra	Vertebrates	Gilmore, A. M.& Associates. Unpubl.
1991 records up to	Washpool, Bunjalung	Terrestrial Vertebrates	NPWS Atlas
1991	North Coast Forest	Vertebrates	NPWS Unpubl.
1991	Hunter River to Qld/NSW border	Mammals	Australian Museum Unpubl.
1991	North Coast and Ranges	Reptiles Amphibians	Australian Museum Unpubl.
1993	North-east NSW	Terrestrial Vertebrates	NPWS Unpubl.

3. METHODS

Impact Assessment Methods

The aim of impact assessment is to predict potential changes in the abundance and distribution of the native fauna resulting from timber harvesting and associated management activities (fire, apiary, grazing, roading). The fundamental ecological assumption underlying impact assessment is that logging and associated activities cause, to a greater or lesser extent, an initial decline in biodiversity followed by a longer period of recovery, which eventually leads to either restoration of the original community or to a different assemblage of species. The processes that drive these changes can be formulated as models which provide a basis for predicting impacts at specified times in the future. Impact assessment is a predictive, hypothesis generating process, and always involves an element of uncertainty. This uncertainty can be minimised by an appropriate choice of models, and through the testing of models by monitoring and further research.

Models commonly used to predict logging impacts can be classified into the following types:

Monitoring Models

These are based on results of long term monitoring, and the measurement of species abundance (and/or health and performance) before and after timber harvesting. They provide information on changes in biodiversity with time since logging, which can be used to predict if and when biodiversity recovers from logging disturbance. No long term fauna monitoring programs were in operation in the Study Area at the time of survey.

Survey Models

These models are based on comparisons of flora and fauna abundance and diversity in previously logged and unlogged sites. This approach is necessary when the time and resources available for impact assessment are limited. The results of survey models are less reliable than monitoring models and, in some cases, they may need to be validated by monitoring programs. A limitation of this approach is that field surveys generally detect fewer rare species than common species. Consequently, it is often impossible to formulate impact models for those species that are of greatest concern with respect to conservation.

a) Comparison of logged and unlogged sites.

In this method (described in York et al., 1991) mean fauna diversity in representative unlogged and logged sites are compared, using Analysis of Variance (AOV) and related statistical procedures. Logged sites may be characterised by different stages of recovery (different times since logging) or different levels of initial logging disturbance (logging intensity). A stratified random sampling design is used to ensure that the biodiversity measured at the sites is representative of the average unlogged and logged states. The technique can not prove that there is no effect of logging as, even if no differences between logged and unlogged sites can be demonstrated with a specific data set, such differences might become apparent if a larger or more stratified data set were analysed. However, the technique may unequivocally demonstrate that there are differences between logged and unlogged sites. Even where such a difference is demonstrated, a causal relationship between logging and biodiversity is not proved as there may be differences between logged and unlogged sites that are related to both logging and biodiversity but which are not caused by timber harvesting. In the Study Area, timber harvesting has proceeded from low-land forests close to the major centres, to progressively steeper, less accessible areas. Also highly productive forests are generally logged before lower quality forests. Thus, forests with a long history of timber harvesting tend to be ecologically dissimilar to unlogged forests, and the biodiversity of logged and unlogged sites may have been different even before logging took place. Of the 12 sites stratified as unlogged and sampled in this survey only three were of high site quality and all of these sites occurred in the vicinity of Washpool State Forest. The remaining sites were predominantly of low quality and all but two in Blackbutt Forests appeared to have been previously logged. This design may introduce bias to comparisons of unlogged and logged habitats, tending to under-estimate the effects of logging.

Another difficulty with this impact prediction procedure results from fine scale environmental variation within the forests. Many factors such as soil fertility, topography and moisture regime which may or may not be correlated to logging, strongly influence biodiversity. Even at one site, weather, season and other factors may influence the results of fauna and flora survey. Variation due to these factors may obscure associations between biodiversity and other variables such as logging. While the statistical procedures used are designed to distinguish this "random" variation from "systematic" correlations with other variables, such associations become less distinct as the variation within the data increases. Non systematic variation in the data causes the effects of logging to be underestimated, particularly when the number of survey sites is small and surveys conducted under variable conditions.

The survey design used in this study reduced this problem to some extent by the use of relatively long survey transects (500m). Such transects sample a variety of microhabitats including different aspects, slopes and topographic situations.

Another source of error in this type of impact prediction model results from the history of timber harvesting in the area. Timber harvesting practices have changed considerably, due to changes in market forces and harvesting technologies. Mature and old-growth stands of preferred timber species have declined, although harvesting of preferred species continues in regrowth forests, and markets have adapted to accommodate previously unmerchantable species such as Brush Box and stems with higher defect levels. Timber stand improvement (TSI) was once practiced to improve the timber production of forests by the culling of over-mature and defective stems and encouragement of the regeneration of commercial species. Recently however, there has been a decline in funds available for this practice and silvicultural improvement in stands now relies on integrated harvesting practices and better utilisation of forest timber resources. Because of the silvicultural changes and the diminishing extent of old-growth forest with time, impact prediction models based on historic records may not accurately estimate the impact of future activities.

b) Post-logging succession.

This method measures biodiversity in a range of sites logged at increasingly distant times in the past. The results are used to model patterns of post logging succession and recovery using linear modelling and other statistical procedures. Models are solved to predict if and when fauna diversity and abundance will recover after logging. The method is most appropriate for investigation of intensive logging operations in moist, productive forest. It is less suitable where logging is of variable intensity because the effects of variation in logging intensity may obscure successional patterns. This study sampled across a successional gradient in forests logged at variable (low to high) intensity.

This method has the same limitations and assumptions as the preceding method. It is based on the assumption that all sites had a similar biodiversity before logging and that all sites have or will undergo the same patterns of successional change after logging disturbance. It is also assumed that all sites were logged at similar intensity. As discussed above, these assumptions may be violated by the data used in this study.

c) Multivariate analysis.

This method analyses changes in biodiversity across a wide range of logging disturbance gradients or categories (including logging intensity and succession) and natural environmental gradients (eg. slope, aspect, soil fertility, vegetation structure and floristics) simultaneously using Principal Components Analysis (PCA), multiple regression and other statistical methods. Copious analyses can be performed using different permutations of variables and statistical techniques. Because a number of variables which influence biodiversity may be included in an analysis simultaneously, it is not assumed that all sites had the same biodiversity prior to logging. It is also possible to include variables such as, number of logging cycles, logging intensity and the time since logging, in an analysis thus avoiding the assumption that all logging operations have had an identical effect on the present faunal community. In practice however, the number of variables that can be usefully incorporated into an analysis is limited by the number of sites surveyed.

The most difficult aspect of multivariate analysis is the interpretation of results and identification of causal associations between land use and biodiversity. Multivariate analyses tend to generate a large number of statistically significant associations between environmental variables and biodiversity. The interpretation of these associations is fraught with difficulties. Association does not necessarily imply causation. Problems can arise when environmental and cultural variables are confounded or intercorrelated. For example, a negative correlation between fire and the occurrence of a species, does not necessarily imply that the species has declined as a result of burning, it may simply be that the species occupies habitats such as rainforests or wet gullies which are not flammable. These problems can be overcome by a variety of methods including the following:

a) selection of appropriate environmental and cultural variables for analysis based on the known or predicted ecological requirements of species ;

b) measurement of the variation in biodiversity explained by environmental and cultural variables (eg. r^2 values in regression analysis);

c) examination and interpretation of correlations between environmental predictor variables by correlation analysis, PCA, and analysis of variance;

d) interpretation of statistically significant associations in the light of ecological knowledge.

Auto-ecological Models

Auto-ecological methods are used to predict the likely impact of logging on fauna by identifying the resource requirements of species (eg. food, shelter, water) and measuring or predicting the effects of logging on the availability of these resources. This technique is applied when insufficient data are available for statistical analysis but where good ecological information is available on species' habitat and resource requirements. For the purpose of this analysis species are often classified into 'guilds' or groups of species with similar resource requirements (eg. all tree hollow dependent species).

There are four common limitations to the auto-ecological method. Firstly, knowledge about species essential resource requirements is limited, particularly for rare and endangered species, and even when resource requirements are known they may vary from region to region. Secondly, there is a general lack of knowledge of the form of association between resource abundance and fauna abundance (eg. what is the relationship between tree hollow numbers and fauna abundance?). Thirdly, there is little quantitative data on the effects of logging on the availability of essential resources. For the purpose of this study, it was assumed that resource availability is reduced in proportion to harvesting intensity, unless data were available to demonstrate otherwise. Finally, there is no objective measure associated with auto-ecological predictions with which to assess their reliability. To minimise the risk of bias, predictions should be supported by one or more experts on the ecology of the species or group.

Expert Opinion

This method is based on prediction of timber harvesting impacts on the presumed resource requirements of species and/or guilds. It is invoked when no detailed autoecological studies have been conducted to determine the actual resource requirements of a species in logged and/or natural habitats. The method involves prediction of a species' likely resource requirements using indirect means such as extrapolation from morphological and physiological specialisations indicating adaptation to particular habitats, or from the known requirements of closely related species that inhabit similar environments. This method is most commonly applied to poorly known endangered species.

The Reliability of Impact Assessment Models

Statistical procedures provide an objective estimate of the uncertainty associated with predictive models. Most statistical procedures provide some measure of the goodness of fit of predictive models or an indication of the uncertainty associated with predictions, but these are accurate only if all the assumptions of the analyses are met. However, there have been surprisingly few previous statistically validated studies of harvesting impacts on biodiversity, and there have been no scientifically and statistically validated monitoring programs to test the predictions of models over a full logging cycle or even over the life of an EIS. No long term fauna impact monitoring programs are in place in the industry in NSW and there have been no audits of previous impact predictions.

Until recently, most logging impact assessment was determined by literature review and relied heavily upon the results of a few scientific and descriptive studies often carried out in areas remote from the proposed development. This approach assumes that species habitat requirements, response to logging, and logging practices exhibit little regional variation. At present, there is little data with which to assess the reliability of these assumptions.

For the purpose of this study, impact assessment methods were ranked in decreasing order of perceived reliability, according to the type of model use and the region of study:

1: long term monitoring and measurement of densities before and after harvesting in the Study Area;

2: measured and statistically validated differences between logged and unlogged habitats in the Study Area (this study);

3: measured and statistically validated differences between logged and unlogged habitats in other locations (previous studies);

4: impacts of logging on the known habitat and ecological resource requirements of the species determined by autoecological study;

5: impacts of logging on the likely habitat and ecological resource requirements of the species determined by expert ecological opinion

6: expert ecological opinion on the possible effects of timber harvesting on the possible habitat and ecological requirements of the species.

Impact Assessment Methods - This Study

This study used statistical methods for impact modelling wherever possible and aimed to statistically quantify the uncertainty associated with fauna impact models. The results of the models are interpreted in the light of existing ecological knowledge. Survey data were generally found to be adequate for predicting the impacts of logging and associated activities on biodiversity for the major taxonomic groups and most guilds. At the species level, reliable impact prediction was only possible for the more common species. Impacts on rare and endangered species were based primarily on expert opinion and the findings of a few auto-ecological studies. The general procedure adopted was as follows:

1. Literature Review:
   Review of impacts in similar landscapes elsewhere in Australia, review of auto-ecological studies of endangered species occurring in the Study Area, review of previous impact models developed elsewhere in Australia, consultation with relevant experts.

2. Biological Survey:
   Quantitative, standardised measurement of fauna distribution and abundance in different natural and cultural (wood production) environments.

3. Environmental Survey:
   Quantitative measurement of natural and cultural environmental variables.

4. Impact Modelling:
   Analysis of associations between faunal distributions and abundance and natural and cultural environmental variables led to the formulation of predictive models. Succession models were developed to predict recovery times and identify species which prefer older forest. Cultural variables were ranked according to the magnitude and importance of the impact upon biodiversity and species populations.

5. Impact Prediction:
   Predictive models were used to estimate the likely magnitude of changes in species biodiversity under alternative management practices in each of the major habitat types, to the extent possible within constraints imposed by survey design

6. Impact Mitigation:
   A series of options are proposed for mitigation of adverse impacts of timber harvesting and associated practices likely to occur under current management proposals. These options are intended to minimise fauna impacts while permitting some level of harvesting activity. Acceptance, rejection or modification of these options is a matter for consideration in the EIS, taking into account non-fauna values.

7. Monitoring and Review:
   Options for further research and monitoring to test and monitor predictions and improve understanding where inadequacies in current knowledge are identified.

Biological Survey Methods

The fauna and flora surveys in the Study Area followed a modified version of the State Forests fauna survey protocols (York et al., 1991). Details of fauna survey techniques specific to each major group are given in subsequent chapters. The method of survey design, measurement of environmental and logging variables, and methods of data

Sampling Design

Survey sites were stratified by State Forests according to the following four major forest types and logging classes:

1) Rainforest;
2) Moist Hardwood;
3) Blackbutt Forest;
4) Dry Hardwood Forest;

1) unlogged;
2) logged pre1960;
3) logged 1960-70;
4) logged 1970-80;
5) logged 1980-90.

Survey sites were located and installed by State Forests. The aim was to locate a minimum of four replicates in each combination of strata with the exception of Rainforest. Rainforest was relatively under sampled because no general purpose logging is proposed in this forest type. At the time of survey unlogged forests were considered by SFNSW to be synonymous with Old-growth forests, and this survey design was initially intended to provide a statistical basis for evaluation of forestry impacts on Old-growth fauna values. It was subsequently recognized that some sites classified as unlogged for the purpose of this study lacked large ecologically mature trees and included forests which had regenerated after ringbarking and early agricultural disturbance, so Old-growth was redefined to include only those unlogged forests which are ecologically mature and have been subjected to negligible disturbance (R. Williams SFNSW). Of the 12 sites originally stratified by SFNSW as unlogged, only five did not appear to have been previously logged or cleared. No survey sites were located in that portion of Dalmorton State Forest ultimately classified as Old-growth by SFNSW. Consequently Old-growth was relatively under sampled in all forest types and the original sample design proved inadequate for assessing impacts on Old-growth fauna using AOV procedures. Impacts on old-growth were therefore determined by primarily by literature review and by auto-ecological modelling, but with some extrapolation using post-logging succession and logging intensity models where possible. No surveys were conducted in PMP zones excluded from logging for reasons of steepness and inaccessibility. Thus no objective basis was available for assessing the adequacy of these areas as conservation reserves within the Forest Estate. Many of the less commercial dry and swamp sclerophyll forests types may also have been relatively under sampled by this design. The location of survey sites in each strata is given in Appendix A. This design proved less than ideal for all three survey methods of impact modelling but was, to some extent, unavoidable due to scarcity of unlogged habitat in the Study Area and the prevalence of low to moderate intensity harvesting and confounding between time since logging and logging intensity.

Site Layout

Each site consists of a 500m transect divided into five 100m 'units'. The start of each unit, and the central 'point' in each unit were flagged with tape. Photographs were taken at each site for reference during data analysis and interpretation.

Environmental Survey

Information on a range of environmental attributes was collected at each survey site to allow the analysis of associations between faunal distributions, and cultural and natural environmental factors. Environmental attributes were derived from maps, databases, and compartment and fire history records held by the State Forests offices at Grafton and Casino. Other variables including forest age structure, tree hollows and ground cover were recorded at each site. The cultural and natural environmental variables used in impact assessment analyses are summarised in Table 3.1.

Table 3.1. List of Environmental Variables used in Analysis of Fauna Habitat Associations and Response to Logging and Associated Land Use, Showing Methods of Measurement.

Natural Variables

Rainfall	Mean annual rainfall (mm) was predicted from AMGs using a climate surface model provided by NPWS.
Aspect	Measured as a continuous variable from 0-180 (from north to south) and as categorical variables: north, north-east, east, south, south-east, south-west, west, north-west and flat.
SlopeA	Measured in degrees as a continuous variable and as degree categorical variables: 0-2, 2-<5, 5-<10, 10-<20, 20-<45, >45.
TopoA	Topographic position of transect units were defined in the categories of 'Top', 'Saddle', 'Upper', 'Mid', 'Lower', 'Flat', or 'Other'.
Geology	Site geological information was obtained by observation and reference to 1:250,000 geology maps.
Habitat	Tree community floristic classification of overstorey data into 'Moist Hardwood', 'Dry Hardwood' and 'Rainforest' as described in Moore and Floyd (1994).
Ovrstr1-3	New gradients derived by ordination of quantitative floristic data using SSH ordination procedure (Moore and Floyd, 1994).
AgeA	Estimation of the tree community age structure described by categorical variables: 'Juvenile', 'Mature', Senescent', 'Old-growth', 'Mixed Age', 'Regrowth'.
Can-CovA	Projected canopy cover in the categories (%) 0, 1-5, 5-20, 20-50, 50-80, 80-99, 100.
Can-HtA	The average height of trees measured in metres as a categorical variable: <10, 10-20, 20-30, 30-40, 40-50, 50-60, >60.
U-type	Floristic classification of understorey data into 'Rainforest ferns', 'Rainforest vines', 'Moist grass', 'Moist ferns', 'Herbs', 'Lantana', 'Swamp Sedges', 'Bracken', 'Dry grass', 'Heath' as described in Chapter 3.
UndrstryA	Site understorey type was described as 'Swampy', 'Mesic', 'Xeric', 'Grassy' or 'Other'.
UndrStr1-3	New gradients derived by ordination of quantitative floristic data using SSH ordination procedure.
ShrbsA	Measure of shrubs as a percentage of ground cover using the categories: 0, 1-5, 5-20, 20-50, 50-80, 80-99, 100.
Gr-HrbsA	Measure of grasses and herbs as a percentage of ground cover using categories: 0, 1-5, 5-20, 20-50, 50-80, 80-99, 100.
LitterA	Measure of litter as a percentage of ground cover using the categories: 0, 1-5, 5-20, 20-50, 50-80, 80-99, 100.
Bare-SA	Measure of bare soil as a percentage of ground cover using the categories: 0, 1-5, 5-20, 20-50, 50-80, 80-99, 100.
R-coverA	Measure of surface rock as a percentage of ground cover using categorical variables: 0, 1-5, 5-20, 20-50, 50-80, 80-99, 100.
Water	Measure of surface water as a percentage of ground cover using categories: 0, 1-5, 5-20, 20-50, 50-80, 80-99, 100.
Stumps	The number of tree stumps in a 50x100m strip measured as a categorical variable: 0, 1-<5, 5-<10, 10-<20, >20.
Hollows	The number of hollow-bearing trees in a 50x100m strip measured as a categorical variable: 0, 1-<5, 5-<10, 10-<20, 20-<50, >50.
Fall-T	The length of fallen timber in a 50x100m strip measured as a categorical variable: 0, <5, 5-<20, 20-<50, 50-<100, >100.

Cultural Variables

Fire-Int	Fire intensity was estimated from State Forests records.
Since-FF	Time (in years) since last fire was determined from State Forests records and estimated on site (Sinc-FAF), and was assigned the following categories: 2-5, 5-<10, >10.
Burn-Ht-	The maximum height of fire scars in metres according to the following categories: 'Unburnt'; 0-<1, 1-<2, 2-<5, 5-<10, >10
Fire-frq	The time interval (in years) between fires was determined from State Forests records and checked on site.
Log-Int	Logging intensity was estimated from State Forests records and assigned the categories: 'none', 'light', 'moderate' or 'heavy'. (after State Forests Flora Survey Protocol Proformas, York et al 1991)
Sinc-LFF	The year of the most recent timber harvesting operation was estimated from site inspection (Sinc-LAF) and State Forests records, and was represented as the number of years since logging: 1-10, 10-50, >50.
Cycles	The number of previous harvesting cycles were obtained from FCNSW records.
Regen	Whether or not the site was burnt after harvesting to promote regrowth.
Culled	Removal of defective trees recorded as "culled" or "not-culled".
Grazed	The number of years that the site had been grazed, determined from State Forests records.
Graz-int	The intensity of grazing, estimated from abundance of scats on site and from State Forests records, was measured as categorical variables: 'None', 'Low', 'High'.
Roaded	Time since the site was first roaded (major road).
Baitfreq	The frequency of 1080 baits used in the area determined from records.
Bait-type	The type of bait used measured as categorical variables: (meat, carrot etc.)
Bee-hive	The distance to the nearest beehive was determined from records.
Bee-frq	The frequency of use of beehives by apiarists was determined from records.

Data Analysis and Predictive Modelling

The data obtained by field survey were transferred from field data sheets into computer databases. These data included the results of habitat searches, spotlighting, bird survey, trapping, pitfalls, hair tubes, scats and signs and opportunistic sightings. The data for each species were then combined to produce a matrix containing measures of abundance of each species at each site. These data were combined with a matrix containing the cultural and natural environmental variables at each site. In this form, the data were transferred to statistical packages such as STATVIEW and SYSTAT for statistical analysis and modelling.

Measures of Biodiversity

Biodiversity is a term that refers both to the number of species, and the abundance of species at a location. There are many different ways of calculating biodiversity, but in general, biodiversity indices rank highly when there are more species present, when the average density of individual species present is higher, and when individual species densities are evenly distributed. We avoided the use of complex biodiversity indices which take into account both species numbers and species abundances because these are difficult to interpret ecologically. Instead we evaluated impacts on the following indices:

1. Species Richness:
   the total number of species in a specified taxon (eg. mammals) or guild (eg. arboreal mammals) detected by all methods at each site;

2. Total Abundance:
   the total number of individuals of all species in the taxon detected at each site using standard survey methods;

3. Species Abundance:
   the number of individuals of a species detected per unit standard survey effort (eg. total of birds recorded per 10 unit counts);

4. Species Frequency:
   the proportion of sites surveyed in a particular strata (eg. Rainforest sites) at which the species was found to be present during a unit of standard survey effort at each site.

Caution should be exercised in the interpretation of relationships between Total Abundance and environmental variables where only a few species contribute disproportionally to the total count. Caution must also be exercised when intepreting Species Richness and Total Abundance indices, as large changes in species composition may go undetected if the number of displaced species is balanced by an influx of a similar number of different species following disturbance.

Statistical Analysis and Modelling

Measures of faunal abundance for each major taxon (birds, mammals, reptiles and amphibians), were analysed to determine whether these varied with respect to measured cultural and natural environmental variables, and to determine the nature of any significant relationships. Statistical modelling procedures used included the following:

1 Analysis of Variance (AOV);
2 Simple and Multiple Regression;
3 Chi-square analysis.

Analysis of Variance

This technique was used to compare mean species abundance and, in two or more categories of an environmental or cultural variable (eg. for forest type: Rainforest, Moist Hardwood and Dry Hardwood), to determine whether the means and their associated variation differs more than would be expected by chance. The probability of a difference in the means occurring by chance is indicated by the P value resulting from the analysis. In this study, a P value of less than 0.05 was assumed to indicate that mean abundances differed significantly between categories (eg. that bird species richness differed significantly between forest types). This technique can be extended to examine differences between nested categories (2-way AOV), for example between logging treatments (logged/unlogged) within forest type. This procedure is recommended in the Forestry Commission's protocol version 1.0 (York et. al. 1991) and was used in this study to identify differences between species richness and abundance in major strata identified by the Commission (forest type and logging history). Results are only reported where significant effects were found.

The AOV procedure has a number of limitations for impact modelling including the following:

a) It assumes that survey sites differ only with respect to the variable being tested (eg. logging history) and that all other environmental variables are constant between replicates and treatments. This assumption rarely holds, and when violated may lead to spurious results due to confounding between logging treatment and other unmeasured variables (eg. logging intensity).

b) It estimates the effects of past logging averaged over the time since previous logging events. This information cannot be used to predict future logging impacts where logging practices have, or are predicted to, change. This problem was overcome in this study by developing succession models under different logging intensities using regression techniques.

Regression Analysis

Regression analysis determines whether there is a linear relationship between species richness or abundance and continuous environmental variables such as logging intensity or time since logging. A linear relationship is one in which species richness or abundance increases (or decreases) in direct proportion to increases or decreases in the value of environmental "predictor" variables. The probability of such a linear relationship occurring by chance alone is indicated by a P value. In this study, linear relationships were assumed significant when $P < 0.05$. The proportion of the variation in species richness or abundance that is explained by the model is indicated by an r-squared value associated with the model. An r-squared value of 1.0 would indicate that there is a perfect correlation between species richness or abundance with the predictor variable. However, in ecological systems, many variables influence the distribution and abundance of species and even within an area of uniform habitat animals are not evenly distributed, thus it is unusual for r-squared values to approach 1.0. Multiple linear regression are used to analyse the effects of two or more continuous variables on fauna species richness or abundance when their effects are additive. The r-squared and P values reported for multiple regression models provide the same information as they do for simple linear models.

Regression models have a number of limitations for impact prediction including the following:

a) they can only be applied to continuous environmental variables.

b) they can only be applied when the form of the relationship between abundance variables and environmental variables is linear. This problem can sometimes be overcome when relationships are non linear by transformation of the environmental variables to a different scale of measurement.

c) a significant linear relationship between abundance measures and environmental variables does not imply causality. Relationships may be caused by confounding with other variables. This problem was overcome in this study by examination of correlations between all measured variables and by classification of confounded (correlated) variables into independent groups (gradients) using Principal Components Analysis. All significant relationships were interpreted with caution unless a rational ecological explanation could be put forward to explain the association.

Chi-squared Analysis

Chi-square tests were used to determine whether a species occurred more frequently in a particular habitat type than would be the case if there were no systematic differences between the habitats. For example "Does a species occur more frequently than expected by chance in a logged forest relative to an unlogged forest, or a Rainforest relative to Dry Hardwood or Moist Hardwood?" The number of times that a species is recorded to be present in a particular category of forest is compared with the expected number assuming that there is an equal probability of the species occurring in all categories. The probability of a species occurring more often than expected in one or more classes is indicated by a P value, which is interpreted in the same manner as P values for AOV and regression. Chi-square analyses yielded a large number of significant results, many of which are due to confounding between environmental categories tested. Unlike regression analysis there is no simple method for identifying confounding between environmental categories using Chi-square. Thus, the results of such analyses should be interpreted with caution. Chi-square analysis is a suitable technique to use when the number of records of a species is small relative to sample size, or when survey methods yield presence-absence rather than quantitative data. It was only used where the data did not allow quantitative analysis.

Impact Prediction

Models that relate biodiversity to land management practices in each of the major habitat types can be used to predict the magnitude of regional changes in biodiversity under alternative management practices. However, this would require information on the area of habitat affected by different proposals. Statistical impact models derived from survey data measure changes in fauna diversity in logged coupes, and not in surrounding unlogged forest retained for various purposes such as erosion control, wildlife corridors, reserves, steepness and inaccessibility. Ideally, surveys and impact models should address fauna changes in these areas as well as logged coupes. However, such an assessment was beyond the scope of this study.

The procedure recommended for assessing regional impacts using data collected in this study is as follows:

a) estimation of the percentage change in local biodiversity between disturbed (including logged, burnt and grazed) and undisturbed sites, as predicted by the impact models, over the time span of the proposal;

b) measurement of the area to be affected by each development and the area to be unaffected;

c) estimation of the percentage change in biodiversity over the entire region during the time span of the proposal.

This procedure assumes that the ability of species to recolonise modified habitats after future logging and development will be no less than their ability to recover after previous logging as predicted by the impact models. This assumption is likely to be satisfied in forest logged at low intensity. In forest logged at high intensity (>50% removal of stems >40cm dbh) there is a possibility that the area of refuge habitat, available to facilitate recolonisation by fauna after logging, will be less than that during previous logging operations. The risk that recovery after future logging will be less than that after previous logging in intensively logged forest can be reduced by the dedication of refuge areas and the adoption of alternative coupe harvesting such that adjacent compartments are logged no less than 10 years apart. It is unlikely, however, within the Study Area, that a compartment which has been logged at high intensity would have its' entire area logged at this intensity (R. Fussell, pers. comm.) therefore few areas are considered likely to require alternative compartment harvesting.

Limitations of Impact Assessment Methods

The procedures described above have the following shortcomings:

1) insufficient records were obtained for the statistical analysis of most rare species.

2) abnormally dry conditions prevailed prior to, and during the survey. This is likely to have reduced the abundance and detection of some species, especially amphibians.

3) some historical land uses, such as fire history, are poorly documented and difficult to measure with accuracy in the field. This may have introduced some variation into the impact models.

4) point based measurements of environmental variables are not appropriate for analysing the habitat of species with large home ranges, such as large forest owls, predatory mammals, and some bat species. Reliable analysis and assessment of survey records for these species will await the development of a GIS (Geographic Information System) capability within the Commission. GIS permit the averaging of environmental variables in a specified radius around sample points which can be adjusted to reflect species home range sizes.

5) predicted impacts of forest management practices are based on the measured response of fauna to previous management activities. To the extent that forest management practices have changed with time, extrapolation of the results to predict the impacts of present and future practices may not be reliable. The effects of an increase in harvesting intensity with time can be predicted from models relating biodiversity to logging intensity. However, there are currently no data with which to assess the impact of changing patterns and scales of logging impacts.

6) the extent or total area affected by logging has increased with time, so that broad scale effects of land use practices may be increasing.

7) the sample design for formulation of impact models measured impacts at the coupe scale only, and did not take into account regional or cumulative impacts.

8) the effects of Old-growth logging on fauna could not be reliably predicted from comparisons of logged and unlogged habitats because of a relative shortage of unlogged forest in the study region in general, and at survey sites in particular.

These short-comings do not invalidate the main conclusions of the study, which are based on more than one line of evidence, interpreted in the light of ecological knowledge and compared with the results of similar studies. Where a high level of uncertainty surrounds the results of an analysis these results are either disregarded or the uncertainty is presented with the results. The most serious shortfalls in information for faunal management have been identified and used to recommend programs for further research and monitoring.

4. IMPACTS ON BIRDS

Introduction

Birds of the Study Area

The boundaries of the Grafton and Casino Forest Management Areas (the Study Area) encompass a diverse range of forest ecosystems in north-east NSW. This region extends from the moist, high elevation escarpment forests on the eastern edge of the New England Tablelands through the drainage basins of the Richmond, Nymboida, Mann, Orara and lower Clarence Rivers to the drier, low elevation forests of the Coast Range. This topographic and edaphic diversity coupled with location of the region on the boundary of two major biogeographic regions has contributed to an exceptional fauna diversity and conservation significance. Torrensian (subtropical) faunal elements are represented at low elevations in the north-east and the mid elevation rainforests along the escarpment of the Great Divide while Bassian elements intrude to the south and along the high elevation tablelands habitats to the west. No bird species are endemic to the Study Area, however, this region provides habitat for a number of species with ranges restricted to NE-NSW and SE-Qld. including the following:

Alberts Lyrebird
Marbled Frogmouth (southern population)
Rufous Scrub-bird
Pale-yellow Robin
Southern Logrunner
Regent Bowerbird
Paradise Riflebird
Fig Parrot (southern subspecies).

As the Study Area occurs in a zone of overlap of two major biogeographic regions it supports many species populations at or close to their geographic limits. Species of special interest at their northern limits include the Olive Whistler, the Chestnut-Rumped Hylacola, and the Southern Emu-Wren. The Red Goshawk, Bush Hen, Marbled Frogmouth, and White-eared Monarch are species of special significance near the southern most parts of their range.

Previous Surveys in the Study Area

The avifauna of the Study Area have been well surveyed at the regional scale, but coverage has been patchy and survey methodologies have been largely subjective, focusing on compilation of species lists and detection of rare or special interest taxa. Communities of the tablelands forests to the west have been described by Smith et al. (1992). Birds of the escarpment in Washpool and Gibraltar National Parks have been described by Osborne (1982), birds of Coastal Byron Shire to the north-east have been surveyed by Milledge (1986), and the avifauna of private lands in the Orara and Bucca Valleys to the south of Grafton were surveyed by Smith et al. (1990). Birds of State Forests in the Murwillumbah region have been surveyed by the FCNSW (unpublished). Rare and endangered species which have been the subject of specialist surveys and ecological studies in the region include rainforest pigeons (Broadbent and Clark, 1976; Morris et al. 1981; Date and Recher, 1990; Gosper, 1992), large forest owls (Ford, Debus and Recher, 1991; Kavanagh unpublished), the Regent Honeyeater (Smith 1987; Gosper 1992), the Red Goshawk (Debus 1988; 1991; 1992), the Eastern Bristlebird (Holmes 1988), and the Rufous Scrub-bird (Ferrier 1985). A list of all bird species known and or considered likely to occur in the Study Area was compiled from published and unpublished reports, RAOU records and results of surveys reported here (Appendix C). A total of 138 forest bird species were recorded in the Study Area during this survey, and on the basis of published geographic ranges and habitat preferences, up to 55 additional species are expected to occur infrequently in the region (Appendix C).

Survey Methods

Survey Design

Forest birds were surveyed at the 77 stratified sites and the procedure for censuring the birds follows closely the protocol outlined in York et. al. (1991). Each survey site consists of a transect 500m in length containing 5 central survey "points" 100m apart. During a census, birds were recorded at each point of the transect for 10 minutes. Birds detected within 50m of the point were counted and assigned to distance categories (0-5m, 5-10m, 10-20m, 20-30m, 30-50m) on a data sheet. Species that were detected further than 50m from the central point were recorded but not counted. Surveys were performed between dawn and 11.00 am. The temperature, weather conditions, and time of day were also recorded at each census. A minimum of two counts were made on each site on two different days by two different observers, and the time of census was varied over the two days (ie. early morning or late morning). The procedure resulted in a minimum of 10 counts which were added together to give a total count for each survey site. The fact that 10 bird counts were recorded for each transect, reduced much of the variation in bird numbers due to factors such as micro-habitat, weather, time of day and the unpredictable movement of birds through the forest. The survey procedure was designed to produce quantitative data that can be used to compare the relative abundance of birds at different sites, in different environments and with different management histories.

Three rare species, the Olive Whistler, Eastern Bristlebird and Rufous Scrub-bird, were censused at sites of apparently suitable habitat by call playback. The recorded call from each species was broadcast on a 22 watt cassette player in an attempt to illicit a response from nearby birds. Similarly, the calls of Masked, Sooty and Powerful Owls were broadcast at night in order to detect the presence of these nocturnal species. Species that were observed outside the measured census periods were recorded as opportunistic records, as were observations of rare or special interest species at any location within the study area.

Data Analysis

Statistical procedures were used to analyse associations between bird species richness, total abundance and species abundance, with measured environmental and cultural variables. The aims of the analyses were to determine the preferences of species for different habitats, and to test hypotheses about the effect of human activities, such as timber harvesting, on bird communities. Total abundance was calculated as the total number of birds recorded at each site within 50m of the survey points during the standard census periods. It should be noted that this is not a quantitative measure of the size of bird populations, or of their density, it is simply an index of the *relative* abundance of birds at each site. This index enabled the comparison of the abundance of birds at different sites, in different environments, and under different management regimes. Similarly, species richness is a variable that represents the *relative* diversity of birds at each site. It was calculated as the total number of species recorded at each site (excluding opportunistic records). In addition the species abundance and the total number of birds of a particular species recorded at each site, could be analysed for species recorded with sufficient frequency.

Multiple and linear regression analyses were used to identify associations between bird abundance and continuous or quantitative variables. Analysis of variance was used to analyse associations with categorical environmental variables. Species frequencies and the presence or absence of a species at each site, were analysed with respect to categorical environmental variables by Chi-square and Log-likelihood Chi-square analysis. The results of statistical analyses are interpreted in an ecological context and compared with expected findings based on literature review and expert ecological opinion.

Scope and Limitations of Bird Surveys

The emphasis of surveys was placed on detecting the effects of logging. Rainforests, swamp and riparian forests and wetlands and other habitats largely protected from direct logging impacts by virtue of steepness, reservation, protection in buffer strips (riparian habitat) or other reasons, were relatively under sampled.

Some of the 500m transects cover considerable variation with respect to vegetation, topography and fire history. Where variables were measured at each point along a transect, the average value or the most frequently recorded category, was assigned to each transect for analysis. Only the first point on each transect was sampled during the vegetation survey. The site variables and vegetation descriptions obtained from this point were applied to the whole transect, except in the case of some wildlife habitat values (tree hollows, fallen logs) which were measured on all units and averaged prior to analysis. These factors, and others, introduce variation into the data which may, to a greater or lesser extent, obscure relationships between site variables and the distributions of birds. Where effects are strong however, statistical procedures can be used to distinguish systematic patterns of association from other sources of variation.

The use of point count survey methods for comparison of bird numbers between forest sites and land use treatments assumes that there is no difference in detectability between forests of different structure. However, Smith et al. (1992) showed that detectability declines by up to 90% within 50m of the survey point, and that detectability declines most rapidly in forests with dense understoreys. The significance of these findings is that mean bird abundance (based on total counts to 50m) in structurally complex forests will be underestimated relative to that of more open forests. This effect cannot be readily compensated for when comparing forests of different structure, whether this difference be due to forest type, logging history or fire regime. A general rule, supported by the results of this study and others, is that birds are more abundant in dense vegetation than in open vegetation. Consequently, in most cases differences in the abundance and diversity of birds between recently logged (<5yr) and unlogged forests will be underestimated rather than over estimated. Where greater abundances of avifauna are recorded in dense forests, the differences may be under estimated by more than 100%.

Bird Communities and Habitats

High mobility, seasonal migration and nomadism make it difficult to classify forest birds into distinct community groups. Previous studies have found that differences in species composition are most pronounced along forest type, moisture, productivity and successional gradients. Marked differences are generally apparent between rainforest and eucalypt forests due to the presence of unique fleshy fruit resources, and a deep layer of forest litter in rainforest. With the exception of frugivores and graminivores, many other rainforest birds also occur in moist eucalypt forests, especially those which forage in the moist litter and/or shrub layer. In north-east NSW, moist eucalypt forests often support a rainforest understorey in the absence of fire, and consequently avifauna diversity is exceptionally high, incorporating elements of both rainforest and sclerophyll forest avifaunas. Shields et al. (1985) found that in the mid north coast of NSW, rainforest and wet sclerophyll (Moist Hardwood) forest avifaunas had greater affinity with one another than with dry forest avifauna. The distinctions between the avifauna of each habitat type were not pronounced; primarily this reflected an increased occurrence of "open forest" (woodland) avifauna in drier forests. Similarly, in the Washpool Region Osborne (1982) found the greatest community distinction to occur between moist forest (Rainforest and Moist Hardwood) and Dry Hardwood sites. Differences between wet and dry sclerophyll forests are most likely to result from variation in understorey type, particularly the replacement of mesic shrubs with xeric shrubs, heath and/or grassland. Understorey type is not always predictably associated with landform, climate and geology but is strongly influenced by cultural disturbance including grazing, fire and logging.

Species Richness

Species Richness was calculated as the total number of species recorded within 50m of the survey points at each site. This variable is not a quantitative measure of the number of species, but is merely an index that enables the diversity of birds to be compared between different sites, environments and management regimes. Analysis of variance was used to compare the species richness of different types of habitat, both overstorey and understorey. The results are shown in Table 4.1 and Table 4.2. An assumption of the analysis is that the variance in species richness is the same for each habitat type or understorey type. This assumption was tested using Bartlett's test of homogeneity of variance and was not refuted.

Table 4.1. The Mean Total Abundance and Species Richness for Each Habitat Type. The Significance of the Difference Between the Means is Calculated by Analysis Of Variance.

Habitat Type	Total Abundance	Species Richness
Rainforest	129.57	24.85
Moist Hardwood	93.77	22.36
Dry Hardwood	65.30	15.37
Probability	**0.003**	**0.000**

Table 4.2. The Mean Total Abundance and Species Richness for Each of the Ground Cover Types. The Significance of the Difference Between the Means is Calculated by Analysis of Variance.

Understorey	Total Abundance*	Species Richness
Rainforest Ferns	133.90	25.80
Moist Grass	117.00	17.00
Moist Ferns	112.75	24.13
Rainforest Vines	109.75	26.25
Herbs	109.00	27.50
Lantana	91.50	19.00
Swamp Sedges	73.50	14.50
Bracken	63.50	17.44
Dry Grass	57.37	15.81
Heath	55.67	11.33
Probability	**0.000**	**0.000**

*classes not homogenous according to Bartlett's test of homogeneity.

Species Richness is greatest in Rainforest and Moist Hardwood Forest with dense, mesic understoreys of herbs, rainforest vines and ferns. Species richness was analysed with respect to a range of measured environmental variables. Significant associations were found with Overstorey Type ($r^2=0.347$, $P<0.003$), Understorey Type ($r^2=0.384$, $P<0.0001$), Percentage Shrub Cover ($r^2 = 0.28$; Probability < 0.03), Fire frequency ($r^2=0.309$, $P=0.000$), Years since fire ($r^2=0.407$, $P=0.000$) and Fire Intensity ($r^2=0.158$, $P=0.000$).

2-way AOVwas used to determine whether effects of logging on species richness could be demonstrated within the major habitat types. Because the seven rainforest sites had all been logged, it was necessary to eliminate these from the analysis. The results, shown in Table 4.3, do not demonstrate an effect of logging on species richness that is independent of habitat type. The third row in the Analysis of Variance table (LOGGED*HABITAT) indicates a significant association between species richness and an *interaction* between logging history and habitat. This indicates that species richness is correlated to logging history, but only by virtue of the correlation between logging and habitat; only three of the 30 Moist Hardwood sites were unlogged compared to 5 of the 25 Dry Hardwood sites.

Table 4.3. Analysis of Variance of Bird Species Richness with Respect to Logging History and Habitat Type.

DEPENDANT VARIABLE: Species Richness
N:70.
SQUARED MULTIPLE R: .366

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
LOGGED	5.486	1	5.486	0.210	0.648
HABITAT	724.880	1	724.880	27.797	0.000
LOGGED*HABITAT	132.083	1	132.083	5.065	0.028
ERROR	1721.093	66	26.077		

We are unable to conclude that logging alters the species richness of the forests, though it is not proved that there is no such effect because of limitations in sample design (see Chapter 2), however, if there is an effect it is likely to be of low magnitude. Further, these results do not preclude the possibility that logging substantially alters the species composition of the forest without changing the species richness, this question is addressed below. Table 4.4 gives the mean species richness for all combinations of habitat and logging history. Logged Dry Hardwood forest is shown to have a higher mean species richness than Unlogged Dry Hardwood, this may reflect the generally lower fertility of Unlogged Dry Hardwood forests compared to those that have been logged.

Table 4.4. Mean Species Richness for Each Combination of Habitat Type and Logging History.

Logging History	Dry Hardwood	Moist Hardwood	Rainforest	Mean
Logged	16.56	21.89	24.86	19.98
Unlogged	13.40	26.67	-	15.61
Mean	15.38	22.37	24.86	18.96

Bird Abundance

Table 4.1 shows the results of the AOV procedures used to analyse patterns of total abundances (the total number of birds of all species recorded within 50m of the survey points in each survey site) with respect to habitat. Table 4.2 gives the results of the same analysis applied to understorey type. The assumption that the variance is the same for all groups was tested using Bartlett's statistic (SYSTAT, 1989) and was found to be violated with respect to Understorey type. The probability estimate for this analysis may be inaccurate, but a cursory examination of the data shows that it is unlikely that there are no significant differences between the Understorey Types. Habitat Type and Understorey Type are both strongly associated with the abundance of birds, and the pattern is similar to that of species richness. Birds are most abundant in Moist Forest with a Rainforest understorey, and least abundant in Dry Hardwood forests with a heath understorey.

Because the detectability of birds is much lower in moist forests with a well developed understorey, the actual magnitude of the differences in Total Abundance between moist, open forests and dry, closed forests will be underestimated.

Analysis of Guilds

Bird species were assigned to one or more of the following guilds on the basis of known feeding and nesting behaviour:

1. Foliage foragers
2. Canopy foragers
3. Shrub foragers
4. Ground foragers
5. Nectar feeders
6. Hollow nesters

The classification system used to assign species to these guilds is shown in Appendix C.

Analysis of variance was used to investigate associations between site variables and the species richness and total abundance of each of these guilds. In many cases, univariate analysis of variance indicated significant responses that could be attributed to confounding between variables such as, Habitat Type and Understorey Type. To overcome this difficulty, multivariate analyses of variance were employed to test for effects that are independent of vegetation structure.

Foliage Foragers

Thirty species were included in this guild, which includes those that forage in the foliage of either the forest canopy or the shrub layer. The species richness of foliage foragers was analysed with respect to the variables listed in Table 4.5.

Table 4.5. The Fourteen Variables used to Analyse Patterns of Association with the Guild of Foliage Foraging Species.

1. Habitat type
2. Understorey type
3. % Canopy cover
4. Canopy height
5. % Shrub cover
6. % Grass/Herb cover
7. % Litter cover
8. Grazing intensity
9. Years since logged
10. Logging intensity
11. Logging cycles
12. (Distance to) Gully
13. Fire frequency
14. Fire intensity

Significant effects, independent of Habitat and Understorey type were found for Fire Frequency (r^2=0.756, P=0.000; Table 4.6 and 4.7), Years Since Last Fire (r^2=0.774, P=0.033), and Logging Cycles (r^2=0.844, P=0.028; Tables 4.8 and 4.9). Similar results were found for total abundance of foliage foraging birds. There is a clear negative relationship between the species richness of foliage foraging birds and fire frequency. This effect is most likely due to suppression of the shrubby understorey and midstorey by frequent fire and, possibly, also to increased direct and indirect mortality after fire. Canopy height is an indicator of site productivity, a factor generally associated with avifaunal abundance and diversity. Interpretation of the association with the number of logging cycles is less clear. The accessible, lower altitude forests of the Clarence and Richmond Basins have been logged more frequently than the steeper forests of the slopes and ranges. This result may simply reflect differences in the avifaunal assemblages of these contrasting environments.

Table 4.6. Analysis of Variance of Species Richness of Foliage Foraging Birds with Respect to Habitat Type, Understorey Type and Fire Frequency.

ANALYSIS OF VARIANCE

DEPENDANT VARIABLE: Foliage foragers - Species Richness
N: 77
MULTIPLE R-SQUARED: 0.756

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
HABITAT	64.214	2	32.107	8.260	0.001
UNDERSTOREY	44.756	2	22.378	5.757	0.005
FIRE FREQUENCY	71.515	1	71.515	18.398	0.000
ERROR	275.982	71	3.887		

Table 4.7. Mean Species Richness of Foliage Foraging Birds of Each Combination of Habitat Type, Understorey Type and Fire Frequency Category.

Fire	Dry Hardwood			Moist Hardwood			Rainforest
Frequency	Grassy	Xeric	Mesic	Grassy	Xeric	Mesic	Mesic
2-5 years	11.35	6.00	18.50	24.33	15.00	26.00	41.00
5-10 years	22.00	9.00	27.00	-	20.83	39.33	36.00
>10 years	-	-	-	-	-	52.80	58.40

Table 4.8. Analysis of Variance of Species Richness of Foliage Foraging Birds with Respect to Habitat Type.

ANALYSIS OF VARIANCE
DEPENDANT VARIABLE: Foliage foragers - Species Richness
N:77
MULTIPLE R-SQUARED : 0.712

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
HABITAT	148.927	2	74.464	16.287	0.000
UNDERSTOREY	109.058	2	54.529	1.927	0.000
LOGGING CYCLES	22.881	1	22.881	5.005	0.028
ERROR	324.616	71	4.572		

Table 4.9. Mean Species Richness of Foliage Foraging Birds for Each Combination of Habitat Type, Understorey Type and the Number of Logging Cycles.

	Dry Hardwood			Moist Hardwood			Rainforest	
Logging Cycles	Grassy	Xeric	Mesic	Grassy	Xeric	Mesic	Mesic	Mean
0	6.25	9.00	6.00	7.00	10.00	9.00	-	7.00
1	7.40	7.25	-	3.00	9.60	7.22	6.00	7.70
2	8.40	8.67	11.00	6.00	12.00	10.50	7.67	8.79
3	-	13.00	-	-	12.00	8.80	-	10.67

Canopy Foraging Species

Eighteen species were included in this guild. Species richness and total abundance of canopy foraging species were analysed with respect to the variables listed in Table 4.5.

Canopy foraging species show the same patterns of association as species richness and total abundance for the whole avifauna. Only the variables associated with fire regime (Fire frequency, Time since fire and Fire intensity) can be demonstrated to influence the abundance and diversity of this guild independently of the variables Habitat and Understorey type. Significant effects for Fire Frequency (r^2=0.678, P=0.000) are shown in Table 4.10 and 4.11 which clearly indicates a negative relationship between the species richness of canopy foraging birds and fire frequency. None of the variables associated with logging were found to be significant.

Table 4.10. Analysis of Variance of Species Richness of Canopy Foraging Birds with Respect to Habitat Type, Understorey Type and Fire Frequency.

ANALYSIS OF VARIANCE
DEPENDANT VARIABLE: Canopy foragers - Species Richness
N: 77.
MULTIPLE R-SQUARED: 0.678

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
HABITAT	15.532	2	7.766	3.889	0.025
UNDRSTRY	21.428	2	10.714	5.365	0.007
FIREFREQUENCY	33.491	1	33.491	16.772	0.000
ERROR	141.782	71	1.997		

Table 4.11. Mean Species Richness of Canopy Foraging Birds for each combination of Habitat Type, Understorey Type and Fire Frequency Category.

Fire Frequency	Dry Hardwood		Moist Hardwood			Rainforest	Mean
	Grassy	Xeric	Grassy	Mesic	Xeric	Mesic	
2 - 5 years	2.10	1.50	1.50	4.40	2.75	-	2.49
5 - 10 years	4.50	2.00	5.50	5.75	3.00	5.00	4.54
> 10 years	-	-	-	7.30	-	6.40	7.00

Shrub Foraging Species

This guild, which includes 12 species, shows the same patterns of association as the canopy foraging guild, and the total avifauna with strong correlations to Habitat, Understorey type and fire regime. Negative associations with species richness of this guild and fire frequency are evident in Tables 4.12 and 4.13. No other variables were found to be significantly correlated independently of Habitat and Understorey type.

Table 4.12. Analysis of Variance of Species Richness of Shrub Foraging Birds with Respect to Habitat Type, Understorey Type and Fire Frequency.

ANALYSIS OF VARIANCE

DEPENDANT VARIABLE: Shrub foragers - Species Richness
N: 77.
MULTIPLE R-SQUARED: 0.641

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
UNDRSTRY	4.274	2	2.137	1.820	0.049
HABITAT	23.187	1	23.187	19.753	0.000
FIRE FREQUENCY	7.063	1	7.063	6.017	0.017
ERROR	84.514	72	1.174		

Table 4.13. Mean Species Richness of Shrub Foraging Birds of Each Combination of Habitat Type, Understorey Type and Fire Frequency Category.

Fire Frequency	Dry Hardwood		Moist Hardwood			Rainforest	Mean
	Grassy	Xeric	Grassy	Mesic	Xeric	Mesic	
2 - 5 years	1.48	1.00	2.50	3.80	2.00	-	2.15
5 - 10 years	2.00	3.00	3.50	4.25	3.00	4.00	3.29
> 10 years	-	-	-	4.30	-	6.00	5.15

Ground Feeding Species

Twenty seven species were classified as ground feeders. Associations were investigated between the diversity and abundance of ground feeding species and each of the site variables listed above. Significant associations, independent of both habitat and understorey type, were found for Litter cover (r^2 = 0.610, P=0.004; Table 4.14), Grass/herb cover (r^2 = 0.763, P=0.050; Table 4.15) and Fire frequency (r^2 = 0.785, P=0.002; Table 4.16 and 4.17). The results indicate a preference for infrequently burnt forest with deep litter and a negative correlation to Grass-Herb cover. Grazing intensity was found to be negatively associated with ground feeding birds when either Habitat or Understorey type were included in the analysis, but was not significant when both variables were included (r^2=0.563, P=0.062). It is likely that with a larger data set, grazing intensity would be significant, if only because most ground feeding birds forage in deep forest litter, while herbivores prefer a grassy understorey.

Table 4.14. Analysis of Variance of Species Richness of Ground Feeding Birds with Respect to Habitat Type, Understorey Type and Percentage Cover of Forest Litter.

ANALYSIS OF VARIANCE
DEPENDANT VARIABLE: Ground Feeding Birds - Species Richness
N:77
MULTIPLE R-SQUARED : 0.610

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
HABITAT	15.267	2	7.633	8.076	0.001
UNDERSTOREY	9.370	2	4.685	4.956	0.010
LITTERA	8.369	1	8.369	8.854	0.004
ERROR	67.112	71	0.945		

Table 4.15. Analysis of Variance of Species Richness of Ground Feeding Birds with Respect to Habitat Type, Understorey Type and Percentage Cover of Grasses and Herbs.

ANALYSIS OF VARIANCE
DEPENDANT VARIABLE: Ground Feeding Birds - Species Richness
SQUARED MULTIPLE R: 0.582
N 77

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
HABITAT	15.726	2	7.863	7.776	0.001
UNDRSTRY	11.389	2	5.694	5.631	0.005
GRHRBSA	3.684	1	3.684	3.643	0.050
ERROR	71.797	71	1.011		

Table 4.16. Analysis of Variance of Species Richness of Ground Feeding Birds with Respect to Habitat Type, Understorey Type and Percentage Cover of Grasses and Herbs.

ANALYSIS OF VARIANCE
DEPENDANT VARIABLE: Ground Feeding Birds - Species Richness
N: 77
SQUARED MULTIPLE R: 0.617

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
HABITAT	11.036	2	5.518	5.945	0.004
UNDERSTOREY	5.562	2	2.781	2.996	0.051
FIRE_FREQUENCY	9.581	1	9.581	10.323	0.002
ERROR	65.900	71	0.928		

Table 4.17. Mean Species Richness of Ground Feeding Birds of Each Combination of Habitat Type, Understorey Type and Fire Frequency Category.

	Dry Hardwood		Moist Hardwood			Rainforest	
Fire Frequency	Grassy	Xeric	Grassy	Mesic	Xeric	Mesic	**Mean**
2 - 5 years	0.13	0.00	0.00	1.40	0.25	-	0.35
5 - 10 years	1.00	0.00	0.50	1.50	0.67	4.00	1.27
> 10 years	-	-	-	2.60	-	3.80	3.20

Nectar Feeding Species

Twenty two nectivarivorous species were recorded during the survey, with an average of 4.4 species and 30.1 individuals recorded at each survey site. The species richness and total abundance of nectar feeding birds were calculated for each site, and used to investigate the effect of site variables. Analysis of variance was used to test associations between the diversity and abundance of nectiferous birds and the following variables:

1. Habitat Type
2. Understorey type
3. Bee frequency
4. (Distance to) Beehive
5. Fire frequency
6. Years since fire
7. Logging cycles
8. Logging intensity
9. Grazing Intensity

The only significant association found was for Logging cycles, a lower mean diversity of nectiferous species in unlogged forest is suggested (r^2=0.055, P=0.040). This result may reflect confounding between more frequent logging in dry coastal and basin forests and the occurrence of more floristically diverse forests suitable for nectarivores.

Hollow Dependant Species

Fourteen species were classified as hollow dependant. Analysis of variance was used to test for associations between the species richness and total abundance of hollow dependant species and the following variables:

1. Habitat type
2. Understorey type
3. Years since logged
4. Logging intensity
5. Logging cycles
6. TSI treatment
7. Regeneration Treatment
8. Age structure
9. (Distance to) Gully
10. Fire frequency
11. Fire intensity

Only the variables related to fire regime were significantly correlated to the diversity and abundance of hollow dependant species. These associations merely reflect the effect of fire in reducing the foraging substrate of hollow using forest birds. No significant association was found between the total abundance or species richness of hollow dependant birds, with the number of hollows recorded on each transect. This result does not prove that hollows are not a limiting factor on populations of these birds. Many hollow dependant species including Owls, Parrots, Rosellas and Cockatoos travel long distances, and the number of hollows measured at each site may have little relevance to the availability of hollows over a larger area.

Species Habitat Preferences

Associations between individual bird species and habitat were examined to identify which species contribute most to diversity differences between forest types. The preferred habitats of species found to be significantly associated with overstorey type are listed in Table 4.18

Dry Hardwood Forest Birds

Only five bird species were found to be significantly more abundant in Dry Hardwood Forests than Moist Hardwood or Rainforest. All species which significantly preferred Dry Hardwood forest also occurred in Moist Hardwood Forests, but not in Rainforest. A further 15 bird species were found to occur only in Dry Hardwood Forest, but the number of recordings (<5 records) did not permit these to be included in any statistical analysis of habitat associations. Of these, only the Brown Songlark is known to have a specific preference for open spaces and grasslands. Nine species (Australian Magpie, Brown Treecreeper, Eastern Rosella, Horsfields Bronze Cuckoo, Peaceful Dove, Rainbow Bee-Eater, Spotted Quail-Thrush, White-Throated Gerygone, Yellow-Tufted Honeyeater) are reported to prefer open woodland/forest with the Spotted Quail-Thrush preferring stony ridges within this habitat type. A few other species were recorded only in Dry Forest including the White-Throated Needletail, the nomadic Little Bronze Cuckoo, the Satin Flycatcher (which prefers thick forest gullies), and the New Holland Honeyeater which prefers open forest, woodlands and heathy understoreys.

Table 4.18 Preferred Habitats of Bird Species Significantly Associated (Chi-Square $P<0.05$) with Major Vegetation Formations.

Dry Hardwood	Moist Hardwood	Rainforest
CICADA BIRD	BLACK FACED MONARCH	BLACK FACED MONARCH
LEADEN FLYCATCHER	BROWN CUCKOO DOVE	BROWN GERYGONE
LITTLE LORIKEET	BROWN GERYGONE	CRIMSON ROSELLA
NOISY FRIARBIRD	BROWN THORNBILL	GOLDEN WHISTLER
RED-BACKED FAIRY WREN	CRIMSON ROSELLA	GREEN CATBIRD
	EASTERN SPINEBILL	KING PARROT
	EASTERN WHIPBIRD	LARGE-BILLED SCRUB-WREN
	EASTERN YELLOW ROBIN	LEWIN'S HONEYEATER
	GOLDEN WHISTLER	RUFOUS FANTAIL
	GREY FANTAIL	YELLOW-THROATED SCRUB-WREN
	LEWIN'S HONEYEATER	
	RUFOUS FANTAIL	
	SATIN BOWERBIRD	
	STRIATED THORNBILL	
	WHITE-BROW SCRUB-WREN	
	YELLOW-THROATED SCRUB-WREN	

Moist Hardwood Forest Birds

More species were found to be significantly associated with Moist Hardwood than either Rainforest or Dry Hardwood forest. A number of these species (Yellow-Throated Scrub-Wren, Rufous Fantail, Lewin's Honeyeater, Blackfaced Monarch, Brown Gerygone, Crimson Rosella and the Golden Whistler) equally preferred Rainforest and Moist Hardwood (Table 4.18). Species that were not recorded with sufficient frequency to be statistically analysed, but which were observed only in Moist Hardwood include the Brown Goshawk; Collared Sparrow Hawk; Figbird; Forest Kingfisher; Painted Button-Quail; Pied Butcherbird; Pale Yellow Robin; Rose-Crowned Fruit Dove; Southern Boobook; Tawny Frogmouth; Wompoo Fruit Dove Wedge-Tail Eagle; and Yellow-Tailed Black Cockatoo.

Rainforest Birds

Osborne (1982) found that the high elevation rainforests in the Washpool and Gibraltar Range areas are an important habitat for fruit-eating birds and a number of uncommon and rare species including the Grey Goshawk, Pacific Baza, Paradise Riflebird, Noisy Pitta, and Rufous Scrub Bird. In south-east NSW, Shields et. al. (1985) found the Spectacled Flycatcher and Pale Yellow Robin to occur only in rainforest, and further south Smith (1985) identified the Large-Billed Scrub Wren to be the most rainforest dependent species, all other species also occurred in eucalypt forests. In this study, the King Parrot, Large-Billed Scrub-Wren and the Green Catbird were found to be significantly more abundant in Rainforest than Moist or Dry Hardwood Forests. Seven other species; including the Australian Ground Thrush, which prefers damp gullies, and the Grey Goshawk also occurred only in the rainforest, but were detected too infrequently for statistical analysis.

Impact Assessment and Mitigation

The Relative Impact of Cultural Disturbance

General patterns of association between cultural developments, including logging, burning, grazing, roading, apiculture, 1080 baiting and other measured cultural variables were determined by identifying the number of bird species significantly affected by each measured cultural variable. The results are summarised in Table 4.19.

Table 4.19. The Number of Bird Species Significantly Associated with Measured Cultural Variables, Ranked in Order of Importance.

Variable	Significant Associations
Understorey	34
Fire Intensity	33
Habitat type	33
Understorey class	31
Sincefire (FCNSW)	30
Canopy height	26
Fire frequency	26
% Litter Cover	25
Burn height	24
Soil type	24
Geology	23
% Canopy cover	19
Regeneration treatment	19
Grazing Intensity	18
% Grass/Herb cover	18
Bee frequency	15
Soil type	14
Years Grazed	11
Harvest Cycles	11
Logging Intensity	11
Years Since Logging	10
Distance to Old-growth	9
TSI Treatment	7
Distance to Beehive	7
Hollows	7
Aspect	6
% Bare soil	5
Topographic Position	4
No. of Stumps	4
Fallen Timber	3
Slope	3

Bird species showed the greatest association with fire regime and associated variables including understorey type, and least association with logging variables. Grazing and beekeeping are intermediate with respect to the number of significant associations. Logging intensity and other logging disturbance measures affected less than one third of the number of species affected by fire and habitat type. An important feature of these results is the large number of species significantly correlated with fire frequency. The effects of fire regime upon bird communities appears to be considerable; comparable in magnitude to that of natural variables such as forest type.

These results are indicative of general trends only and should be interpreted with some caution because they take no account of confounding effects between variables, and in many cases are derived from small sample sizes. By chance alone 5% of species could be expected to exhibit a significant association with any one measured variable. For this reason variables significantly correlated with 5 or fewer species are not considered to be of any importance.

Logging and Succession

The species composition of avifauna communities is considered to change in a predictable sequence following severe habitat disturbance by fire or intense logging. These changes can be attributed to changes in the floristic composition and structure of vegetation, and are influenced by the size and proximity of undisturbed refuge areas. Previous studies (Loyn, 1985; Kavanagh et al., 1985) have found reductions in bird diversity and an influx of open forest or (open ground feeding) species immediately after logging with recovery approaching that of original mature forest within approximately 10 years. In some cases, a reduction in total abundance and species richness has persisted in advanced regrowth due to the absence, or a reduction in abundance, of a few species which prefer old-growth forest for feeding or nesting. The species that are most likely to be adversely affected by intensive logging (> 75% canopy removal) in the long term are those which nest in tree hollows and forage on separating bark substrates.

The magnitude of changes after logging and the recovery time varies considerably between different forest types, harvesting intensities (the amount of canopy retained), and the incidence of fire and or grazing in regenerating forest. Smith et al. (1992) found no significant effect on canopy avifauna due to low intensity (< 50% canopy removal) logging in Dry Hardwood forests in the Glen Innes Region; however, grazing and burning after harvesting appeared to have a considerable impact on ground and understorey dependent birds. This effect is likely to be most adverse where logging is followed by frequent burning or grazing (Smith et al., 1992). In more productive, moist forest types, logging may be more intense and can remove significant portion of both the overstorey and the understorey. While the understorey may recover relatively rapidly, species which require a mature, uneven-aged or old-growth structure will be disadvantaged in the long term.

In dry sclerophyll forests the shrub layer is reduced for a few years after logging, but may subsequently becomes denser than in undisturbed forest (Moore and Floyd, 1994). These changes can be expected to influence the species composition of the avifauna. Loyn (1985) observed that bird populations are low in the first few years after intensive logging, but include some open forest species which are absent in later years. Understorey birds are most abundant 5-30 years after intensive logging. Some species appear to be confined to mature forest including the Red-browed Treecreeper (tree hollow nesters), Mistletoe Bird, Satin Flycatcher, Varied Sitella, White-naped Honeyeater, and Spotted Pardalote (canopy insect feeders). In wet sclerophyll forest (Mountain Ash) in Victoria a similar pattern was observed, with open country birds (Richard's Pipit, Australian Kestrel, Blue-Winged Parrot) appearing during the first three years after intensive logging and burning, but regeneration is rapid and stands are soon repopulated by understorey and shrub species that are common in old-growth stands. Only the Sooty Owl was found to occur primarily in old-growth forest in Victoria (Loyn, 1985).

Kavanagh et al. (1985) compared bird abundance and diversity in alternate logged and unlogged coupes at Eden. They found fewer bird species and individuals in logged than unlogged forest. This effect is greatest immediately after logging. Species confined to logged forest are mostly open country and non-forest birds (Welcome Swallow, Chestnut-tailed Heath Wren, Willie Wagtail, Jacky Winter). Species found only on unlogged coupes after four years include the Collared Sparrow Hawk, Forest Bronze-wing Pigeon, Wonga Pigeon, King Parrot, Musk Lorikeet, Brush Cuckoo, Restless Flycatcher, Leaden Flycatcher, Red-browed Treecreeper, and Striated Pardalote.

In this study, logging variables were not significantly associated with species richness and total abundance. At the species level, too few records were obtained for analysis of habitat preferences using Analysis of Variance, but a number of habitat associations were suggested by Chi-square analysis. Eleven species were significantly associated with time since logging (these are shown in Table 4.20). The difference between the observed and expected frequency of sightings indicates the extent to which these species are associated with each of the categories. Where a species has positive value with respect to a specific category of logging history, it indicates that more birds of that species were observed in that category than would be expected if the distribution was purely random. This implies that the species have a positive association with that category. Only two species, the Large-Billed Scrub-Wren and the White-Cheeked Honeyeater where found to be positively associated with forests logged more than 50 years previously (including unlogged forest). The Koel, the Scaly-Breasted Lorikeet and the Yellow Throated Scrubwren are positively associated with forests logged less than 10 years previously, and the others are positively associated with forests that have been logged less than 50 years previously. These results should be interpreted with caution because they take no account of the different intensity and effects of logging in moist and dry forest types. The successional changes that occur after timber harvesting cause changes in the structure of the forest, and hence in the detectability of birds, which can lead to spurious habitat associations. Most findings can be explained by greater understory cover after logging.

Table 4.20. Chi-squared Results for Species Significantly Associated with Time Since Logging.

		Observed - Expected			Total
Species	P	1-10yr	10-50yr	>50	Frequency
LARGE-BILLED SCRUB-WREN	0.00	1	-6	5	11
WHITE CHEEKED HONEYEATER	0.04	-1	-2	3	6
SCALY-BREASTED LORIKEET	0.02	3	-2	-1	14
GREY BUTCHERBIRD	0.00	2	-1	-1	5
YELLOW-THROAT SCRUB-WREN	0.03	3	-1	-2	11
KOEL	0.02	3	1	-4	56
PARADISE RIFLEBIRD	0.05	2	2	-4	28
RED-BROW FIRETAIL	0.04	2	3	-4	26
BROWN THORNBILL	0.03	1	3	-4	22
EASTERN SPINEBILL	0.01	2	3	-5	25
BLACK FACED MONARCH	0.02	0	5	-5	48
	Total	11	46	20	

Bird species occurring in the Study Area which have been identified elsewhere as old-growth dependent, or which reach peak abundance in old-growth, on more than one occasion include the Sooty Owl (Loyn, 1985; Milledge et al., 1991), and the Red-browed Treecreeper in previous studies (Loyn, 1985; Kavanagh et al., 1985).

Grazing and Burning

Low intensity fires and grazing were confounded in the Study Area. Both are likely to have similar affects upon the vegetation, causing a decrease in understorey growth and an increase in grass cover. Thirty-four species within the Study Area are significantly associated with understorey vegetation, a further 33 are significantly associated with fire intensity, and 30 with time since fire.

The effects of fire vary with fire intensity, particularly the number of vegetation layers affected, the frequency, season and extent of the fire and previous fire history. The immediate impacts of fire may be minimal, birds have been found to move easily away from fires of low and moderate intensity, but may be killed by suffocation or heat in fires of high intensity (Christensen et al., 1985) or may die of food shortage after fire. Studies in Victoria showed that 18 of 27 banded birds continued to use the same area after a controlled burn (Cowley 1974, in Christensen et al., 1985). Recher et al. (1985) found that fire one year after intensive logging at Eden reduced bird diversity and abundance to a significantly lower level than in logged unburnt forest. The combined effect of fire and logging was greater than either effect alone.

In the longer term, frequent (2-5yr) fire may favour the replacement of shrub and regrowth eucalypt communities with grassland communities. In the Study Area, graziers burn to promote green feed for livestock and SFNSW burns for hazard reduction. Frequent low intensity fires reduce shrub cover and increase grass, while high intensity fires can result in prolific shrub regeneration (Moore and Floyd, 1994). The presence of a shrub understorey has a strong influence on the avifauna assemblages through the provision of food resources, foraging substrate and nesting and roosting sites. Thirty three bird species occurring or likely to occur in the Study Area are dependent on shrub vegetation for nesting, and a further 118 species nest in both shrubs and trees.

Regression analysis was used to investigate relationships between the total abundance and all continuous environmental variables in the Study Area. The results are summarised in Table 4.21. None of the measured variables accounted for more than 25% of the variation in bird abundance. However, the results show clearly that a complex of variables associated with fire regime and understorey structure is strongly correlated with bird abundance. The percentage cover of grass, herbs, litter and bare soil are strongly correlated to fire regime. To a large extent, fire regime is also related to the moisture/productivity gradients within these forests, due to the fact that Moist Hardwood Forests and Rainforest are far less flammable than Dry Hardwood Forests. However, two way analyses of variance demonstrated that part of the effect of fire regime is independent of overstorey or understorey type. Grazing is also significantly associated with species diversity.

Table 4.21. Regression Analysis of Associations between the Number of Birds Recorded at each Site, and the Ordinal Site Variables.

Variable	Constant	Slope	R^2	P
Years Since Fire	65.21	0.582	0.46	0.00
Over Storey 1	82.23	-29.99	0.39	0.00
Fire Frequency	45.49	23.38	0.37	0.00
%Ground cover	146.25	-15.45	0.30	0.01
% Litter cover	3.90	16.34	0.28	0.01
Grazing Intensity	101.28	-20.66	0.28	0.02
% Bare Soil	128.71	-21.69	0.24	0.04

Analyses were also performed to determine the affect of fire interval on the composition of the bird community, associations between individual bird species, Years Since Fire, and bird species significantly correlated to Grazing Intensity (Table 4.22).

Twenty-two species were found to occur significantly more frequently in forests experiencing infrequent fires (fire frequency more than ten years) or unburnt forests. These species are dominated by those commonly associated with Moist Hardwood forests and Rainforest (which are negatively confounded with fire frequency), including the Black Faced Monarch, Brown Gerygone, Rufous Fantail, Eastern Whipbird, Satin Bowerbird, Logrunner, Fruit Pigeons, and Paradise Riflebird. Other species, such as the Golden Whistler, Rufous Fantail, Grey Fantail, White-browed Scrub Wren, Eastern Spinebill, Brown Thornbill, and Green Catbird require a well developed shrub understorey for feeding or nesting. The four species found to be positively associated with frequent fire are predominantly found in dry forests with open understorey including the Black-faced Cuckoo Shrike, Laughing Kookaburra, Noisy Miner, and Grey Butcherbird. Similar results were obtained when associations between each species and the variable representing years since the most recent fire were analysed.

Table 4.22. The Effect of Fire Frequency, on the Species Composition of the Bird Community. (Only Species which show a Significant Result are listed).

		Observed - Expected			Total
Species	P	2-5yr	5-10yr	>10yr	Frequency
Black Faced Monarch	0.00	-12	3	8	25
Brown Gerygone	0.00	-11	2	8	24
Golden Whistler	0.00	-11	2	8	27
Rufous Fantail	0.00	-11	2	8	30
Lewins Honeyeater	0.00	-10	1	9	29
Yellow-Throated Scrub-Wren	0.00	-9	0	8	13
White-Browed Scrub-Wren	0.00	-8	3	5	40
Eastern Whipbird	0.00	-8	2	5	24
Large-Billed Scrub-Wren	0.00	-8	2	5	13
Grey Fantail	0.00	-8	3	4	47
Satin Bowerbird	0.00	-7	2	6	18
Brown Cuckoo Dove	0.00	-7	1	6	12
Crimson Rosella	0.00	-7	1	5	15
Eastern Spinebill	0.00	-7	2	4	21
King Parrot	0.00	-6	0	5	25
Logrunner	0.00	-5	0	4	10
Paradise Riflebird	0.00	-5	1	4	11
Topknot Pigeon	0.00	-4	0	5	7
Silvereye	0.02	-4	1	4	13
Spectacled Monarch	0.00	-4	3	1	6
Green Catbird	0.02	-4	0	4	12
Pale Yellow Robin	0.02	-3	1	2	5
Leaden Flycatcher	0.03	3	2	-4	24
Laughing Kookaburra	0.04	4	-4	0	25
Noisy Friar bird	0.00	6	0	-6	42
Black-Faced Cuckoo-Shrike	0.00	7	-3	-4	22

Patterns of association between birds and grazing are similar to those between birds and fire (Table 4.23). Of the eighteen species found to be significantly associated with grazing intensity, only two species, the Noisy Friar bird and the Rufous Whistler, are more abundant in areas subject to high grazing intensities. Both are associated with dry, open forest and woodland. The other species are all associated with less intensely grazed sites. Because grazing is associated with open forests and grassy understorey types in which detectability is high, these effects are likely to be underestimated. However, the effects of grazing are strongly confounded with habitat type, due to the fact that Moist Hardwood and Rainforest are rarely grazed by cattle.

The combination of frequent fire and grazing in the Study Area is thought to reduce the shrub understorey, reduce the density of eucalypt regeneration and promote the development of a simple grass dominated cover. Fire may also have a direct impact on mortality and fecundity (loss of nest sites). This situation is associated with reduced bird diversity and abundance, and substantial changes in the species composition of the avifauna. Populations of many shrub and understorey dependant species are expected to be reduced as a result of grassland development, and confined to moist gullies protected from fire. Gullies within the Study Area commonly support a mesic understorey which is resistant to fire. These gullies potentially provide important refuge for avifauna populations after fire and logging. These habitats are often protected by filter strips up to 40m wide, but populations in these narrow refuges may be subject to intense population pressure as a result of refugees from adjacent habitat during fire and logging operations. Expanded stream side and other reserves may be necessary to protect moist refugia from intensive logging. The size and location of such refugia will depend upon the scale and spatial pattern of harvesting operations and is a matter for determination in subsequent studies.

Table 4.23. The Eighteen Species Significantly Correlated to Grazing Intensity.

		Observed-Expected			Total
Species	P	None	Low	High	Frequency
Large-Billed Scrub-Wren	0.000	6	-3	-3	14
Yellow-Throat Scrub-Wren	0.000	6	-3	-3	14
Crimson Rosella	0.003	5	-3	-2	16
Lewins Honeyeater	0.018	5	-3	-2	30
White-Brow Scrub-Wren	0.028	5	-4	-2	41
Brown Cuckoo Dove	0.002	5	-4	-2	13
King Parrot	0.017	5	-5	-1	17
Rufous Fantail	0.025	5	-5	0	21
Brown Thornbill	0.006	5	-1	-4	56
Golden Whistler	0.011	5	-1	-4	28
Paradise Riflebird	0.002	5	-3	-2	11
Brown Gerygone	0.007	5	-1	-4	25
Satin Bowerbird	0.015	5	-3	-2	18
Black Faced Monarch	0.022	5	-1	-3	26
Topknot Pigeon	0.028	3	-3	0	7
Shining Bronze Cuckoo	0.029	3	-2	-1	5
Rufous Whistler	0.030	-1	-4	4	23
Noisy Friar bird	0.007	-6	3	3	42

Options for maintaining and enhancing the diversity of shrub and understorey dependent avifauna include:

4.1 Protection of recently logged forests from fire for a minimum period of 12 years.

4.2 Actively managing fuel levels to ensure that a mosaic of fire regimes occurs, with particular emphasis on reducing fire frequency to less than one in 15 years in gullies and unburnt sheltered SE aspects.

4.3 Strict regulation and enforcement of grazier burning and withdrawal of occupation permits if unauthorised burning persists.

Although formulation of fire management plans is a complex process, we consider that up to 60% of the State Forest Estate in the Study Area could be left to burn naturally without endangering human life or public assets. The remaining 40% could be managed for socio-economic reasons including protection from wildfire.

Resources

Tree Hollows

Sixteen species occurring, or likely to occur in the Study Area, depend upon large tree hollows, and a further 11 species depend upon small hollows, for shelter, nesting or protection (Appendix C.). A mean of 16.3 hollow dependant birds were recorded at each site. Many other species use tree hollows in addition to other sites for nesting and roosting. Hollow dependent species include the Owls, Cockatoos, Parrots, Rosellas and Treecreepers. Some details of the specific tree hollow requirements of each species are given by Beruldsen (1980). Parrots tend to prefer deep tree hollows; Owls and

Cockatoos need large hollows; and insectivores prefer open, shallow holes (Ambrose, 1982). The availability of tree hollows in natural forests is primarily determined by tree size and age, although tree species, site quality, tree spacing, and fire history also are important determinants.

The impact of timber harvesting on hollow dependent species, will depend upon the minimum tree hollow requirements (type, spacing and density) of individual species. These are poorly known, but are likely to be a function of average density and home range size. Smith (1985) observed that retained habitat trees in 10-15 year regenerating logged forests at Eden were extensively used by birds. The mean density of retained trees was 5 per ha on ridges and 12 per ha on gullies compared with an original density of 61 per ha on ridges and 40 per ha in gullies in mature forest. Thirty-five percent of bird species in the regenerating forest fed in retained trees and a few species nested in them. Smith (1985) concluded that there would have been fewer species in regrowth forests if no live trees were retained.

The number of trees with hollows on survey sites within the Study Area varied from zero to more than 20 per hectare. At least one sixth of the birds recorded within the Study Area require tree hollows for shelter or nesting for at least part of the year. Tree hollow density has been found to be significantly negatively associated with natural and cultural variables within the Study Area (eg. time since grazing $P< 0.005$, number of logging cycles $P< 0.025$, culling $P< 0.04$, and grazing intensity $P< 0.025$). Even if adequate hollow recruitment commences now, up to two further cycles can be expected before present young trees will develop large hollows. Tree hollows are a vital resource for many birds in providing shelter from climatic extremes and protection during nesting and reproduction. At the time of survey, harvesting plans specifed the retention of a minimum of 3 large mature trees per hectare, preferably in clumps of up to 5 trees.

In this study 7 species were found to be significantly (Chi-Square $P< 0.05$) positively associated with tree hollow numbers. Of these 7 species, only the Red-browed Treecreeper and the King Parrot are hollow dependent. The other four associations, with the Logrunner, Topknot Pigeon, Eastern Yellow Robin and Green Catbird are likely to reflect chance associations or confounding between hollow density and other habitat variables.

Options for conserving populations of hollow dependant species include:

4.4. The maintenance of a minimum of 3 well spaced habitat trees for each hectare of forest in low site quality forest, and 6 well spaced habitat trees per hectare in high site quality forest.
4.5. The selection and retention of trees suitable for rapid hollow development to hasten the recruitment of hollow bearing trees where hollow bearing trees are below the above levels.

Nectar

Introduced Honeybees transported to sites in State Forests harvest nectar which may otherwise be available to nectar feeding birds. The effect of nectar harvesting by bees on native fauna has not been quantitatively determined and likely effects are difficult to predict using ecological models because nectar production varies considerably within and between years. Competition for food, if any is most likely to occur in winter or when natural food resources are in short supply. Honeybees may also compete for tree hollows where these are scarce. In this study fourteen species were significantly (Chi-square, $P< 0.05$) negatively associated with the frequency of use of the nearest commercial beehive site by apiarists. All but three of these associations were with rainforest species suggesting that this result most likely reflects negative confounding between apiary and occurrence of rainforest. Since this study was not designed or carried out at an appropriate time of year to identify apiary impacts of fauna no firm conclusions can be drawn from the results. While apiary remains a potential threat to native fauna a precautionary approach to mitigation of potential impacts is recommended, involving the zoning some areas free of apiary activity through:

4.6 The dedication of areas, with a high diversity of flowering species, within State Forests or adjacent National Parks as control areas in which apiary is to be excluded for the purposes of monitoring and future evaluation of apicultural impacts .

Species of Conservation Significance

Twenty-three species of birds listed as rare, vulnerable, or threatened on Schedule 12 are likely to occur in the Study Area (Appendix G). A further two species that may possibly occur in the Study Area include the Paradise Parrot and the Eastern Bristlebird (NPWS 1993). However, the former species is now presumed to be extinct (Garnett 1992) and the closest extant population of the Eastern Bristlebird is at Mt Burrell, Nightcap National Park (Holmes 1982). The majority of the rare and endangered species likely to occur in the Study Area were not recorded during this survey, however 19 species have been previously recorded within the area (Appendix G).

A dearth of ecological information concerning a number of endangered species places localised, poorly known populations potentially at risk of local or regional extinction after minor disturbances (such as logging of a single coupe). Options for mitigation of this risk include:

4.7 Protection of all known populations of poorly known endangered species with restricted distributions (less than 10 records in the Study Area) from logging disturbance by buffer zones of up to 200m until more is known about their management requirements and sensitivity to logging (see Table 9.1)

Black Bittern (Threatened Schedule 12)

This species inhabits margins of rivers, swamps, tidal creeks and mangroves where it feeds on fish and invertebrates. The Black Bittern has been previously reported in the Study Area (Gosper, 1986; Holmes, 1987a), although not recorded during this survey. Since its habitat is not directly threatened by forestry no mitigation measures are proposed.

Square-tailed Kite (Vulnerable and Rare Schedule 12)

Predominantly a bird of forests and woodlands, which preys upon small birds and nestlings in the forest canopy as well as rabbits and reptiles. It is widely distributed throughout Australia, but breeds only in coastal and sub coastal regions (Debus and Czechura, 1989). This species was not detected during this survey but has previously been reported in Clouds Creek, Bom Bom, Braemar and Ewingar State Forests. Current knowledge of the habitat requirements of this species suggest that it is not likely to be affected by timber harvesting in the long term, although little is known about its requirements and the reasons for its rarity. Direct nest disturbance during logging is likely to significantly adversely affect local breeding birds. An option to ameliorate possible nest disturbance is staff training in the species identification combined with pre-logging surveys to identify any nest sites prior to logging, and protection of any nest sites by a 200m radius disturbance free zone.

Red Goshawk (Threatened Schedule 12).

This species is rare occurring in forests and woodlands in north-eastern and northern Australia. It occurs near the southern extent of its range in the Study Area, and was not recorded during this survey. The Red Goshawk's preferred habitat is tropical open woodland, edges of rainforest and dense riverine vegetation, and it breeds within tall woodland and open forests within 1km of a watercourse or wetland. This species probably occurs at low densities and its home range is thought to be in the range of 50-220 sqkm (Debus and Czechura, 1988). Debus (1988) concluded after an intensive survey of the Red Goshawk in the Tweed Volcano Region, that the species has declined from a probably scarce breeding resident in riverine vegetation to virtual extinction as a breeding species in New South Wales; although there is an unconfirmed breeding record for Bundjalung National Park. Although there is a paucity of recent sightings, sightings of the Red Goshawk has been previously reported in Bom Bom State Forest, Washpool and Yuragir National Parks (Debus, 1991).

Mitigation Options: No mitigation measures proposed

Black-Breasted Button Quail (Threatened Schedule 12).

The Black-Breasted Button Quail is patchily distributed in coastal and sub-coastal areas in eastern Queensland and northern NSW. This species' favoured habitat is the edge of Dry Rainforest, in small grassy clearings, or in tangled vines with thick overhead cover, supplied in some instances by introduced Lantana. The Button Quail is readily detectable by its characteristic feeding scratches in the litter, but has only been recorded at 50 sites and its total population is estimated at <1000 individuals (Brouwer and Garnett, 1990). None of the characteristic litter scratchings made by this species were detected opportunisticly or during field surveys.

Mitigation Options: 4.7

Bush Hen (Vulnerable and Rare Schedule 12)

The Bush Hen is found in eastern Australia up to Asia and New Guinea; a riparian species, inhabiting dense vegetation adjacent to fresh water. It is thought to retreat to wetland refuges in dry conditions. It may be threatened by clearing, grazing and or burning of the shrub understorey, and by introduced predators, but little is known about its sensitivity to disturbance. It reaches the southern limit of its distribution in the Study Area (Morris et al. 1981) and has been reported in the Study area by Gosper (1986) and Holmes (1987a).

Mitigation Options: 4.1, 4.2, 4.3

Bush Thick-knee (Threatened Schedule 12)

This species is rare or uncommon in the Study Area and was not detected during surveys although it has been previously recorded in Doubleduke State Forest and Washpool National Park. It is predominantly a woodland, grassland and wetland bird and so should not be directly affected by forestry, but may be indirectly affected by any activities which increase the risk of fox predation.

Mitigation Options: 4.3, and fox baiting and control in coastal and subcoastal State Forests.

Superb Fruit-Dove (Vulnerable and Rare Schedule 12)

This species is a common inhabitant of rainforests and mangroves in north-eastern Australia, is an uncommon nomad or non-breeding migrant south to the Hunter River, and rare further south, with the occasional birds appearing in Tasmania. Although the species forages and lives in the rainforest, it will also feed in adjacent mangroves and eucalypt forests. Current harvesting proposals pose no significant long term threat to the species, with the possible exception of old-growth Moist Hardwood logging in areas with a well developed rainforest understorey.

Mitigation Options: protection of remaining areas of Old-growth Moist Hardwood with a well developed rainforest understorey.

Rose-crowned Fruit Dove (Vulnerable and Rare Schedule 12).

The eastern race of the Rose-crowned Fruit Dove ranges from Newcastle, NSW northwards to the highlands of Cape York, Qld. This pigeon lives in rainforest where it feeds entirely on fruits from vines, shrubs, large trees and palms. The Rose-crowned Fruit Dove is thought to be not only locally nomadic, following ripening fruits, but also migratory with numbers in north-eastern NSW increasing suddenly during spring and early summer to fall again in April and May. This species was detected at only one site in Richmond Range State Forest during the surveys. It has previously been recorded at a range of sites in the Study Area (Appendix C).

Mitigation Options: protection of remaining areas of Old-growth Moist Hardwood with a well developed rainforest understorey.

Wompoo Fruit Dove (Vulnerable and Rare Schedule 12)

The Wompoo Fruit Dove is found in lowland and adjacent highland rainforest from the Hunter River in NSW (Morris et al. 1981) to Cape York peninsula, where it inhabits dense forest. This species diet includes a wide variety of fruits, and although previously thought to be sedentary this species will move to the higher rainforest sites during spring and summer. Extensive clearing of rainforests for agriculture in the past have greatly reduced the available habitat for this species in the Study Area. Current harvesting proposals pose no significant threat to the species, with the possible exception of old-growth Moist Hardwood logging in areas with a well developed primary rainforest understorey. During this study, 7 individuals were recorded from 4 sites; two sites in each of Clouds Creek and Richmond Range State Forests.

Mitigation Options: protection of remaining areas of Old-growth Moist Hardwood with a well developed rainforest understorey.

Glossy Black Cockatoos (Vulnerable and Rare Schedule 12)

Glossy Black Cockatoos require forest stands containing species of Casuarina, (Blakers et. al., 1984) and large tree hollows for nesting. They may be disadvantaged by land management practices that reduce the Casuarina understorey and to a lesser extent hollow abundance. Casuarina and other understorey species are likely to be reduced immediately after timber harvesting, particularly where head disposal burns have been used to promote eucalypt regeneration. Casuarina regenerates successfully after logging (G. King pers. comm.) so that this habitat component should be restored once regeneration is old enough to produce abundant seed, approximately 10 years. Grazing and/or frequent fire may reduce or eliminate Casuarina regeneration and, and is may have a long term impact on the species in the Study Area if areas subject to frequent control burning are increased. Glossy Black Cockatoos were recorded at seven sites within the Study Area (Appendix G), with the species occurring in both Dry Hardwood and Moist Hardwood forests with Casuarina understorey. Forty-eight Glossy Black Cockatoos were recorded from transect and opportunistic data within the following State Forests: Cangai, Clouds Creek, Dalmorton, Double Duke, Ewingar, Glenugie, Mt Belmore, Ramornie, and Sheas Nob.

Adoption of Mitigation Options 4.1, 4.2, and 4.3 would enhance the conservation of this species in the Study Area.

Double-eyed Fig Parrot (Threatened Schedule 12)

The largest of the 3 isolated racially distinct populations of the Double-eyed Fig Parrot occurs on the central east coast between Gympie in Queensland and the Richmond Range in NSW (Blakers et al., 1984; Holmes, 1987b). The Double-eyed Fig Parrot is likely to occur in the Study Area, and has been previously recorded in Richmond Range State Forest at Cambridge Plateau (Holmes, 1987b); although it was not recorded during this survey. The species' preferred habitat is rainforests at lower altitudes with abundant fruits in the canopy, and tree hollows or hollow branches for nesting. The population found within the Study Area is rare and possibly on the verge of extinction, probably as a result of destruction of its habitat (Blakers et al., 1984).Since pure stands of rainforest will not be logged under the proposal no significant mitigation prescriptions are considered necessary. Since some habitat loss may occur if primary rainforest is felled as an understorey component of Moist Hardwood, any populations encountered in Moist Hardwood should be protected by 200m buffers.

Mitigation Options: 4.7

Paradise Parrot (Presumed Extinct)

This species was formerly recorded in woodlands in the Study Area near Casino (London, 1973) and is now presumed extinct (Garnett, 1992) due to the effects of increased grazing and burning on grass seed resources (Blakers et al. 1984).

Regent Honeyeater (Threatened Schedule 12)

The Regent Honeyeater has a wide range in forests and woodlands of south-east Australia where it is uncommon and declining, particularly in South Australia and south-east Queensland. This species has been reported in Boundary Creek and Clouds Creek State Forests (Smith, 1987) and Royal Camp State Forest (Gosper, 1992). Its preferred habitat is dry, open eucalypt forest and woodland, where it feeds predominantly on nectar and insects. Floriferous eucalypts are considered to be of particular importance to this species (Franklin et al., 1988).

Mitigation Options: 4.6

Current SFNSW policy for protecting possible Regent Honeyeater habitat is as follows:
a) encouragement of the identification and reporting of sightings by staff.
b) protection of nest sites with a 100 metre disturbance free zone.
c) retention of a minimum of 10 Mugga Ironbark per hectare, or all Mugga Ironbark if density is less than this (except in exceptional circumstances) in areas where the species occurs.
d) retention of additional floriferous Yellow and White Box at the discretion of the District Forester.

This procedure needs to be adapted to protect the food trees important to the Regent Honeyeater in the Study Area, which include Spotted Gum and Grey Ironbark (Gosper, 1992) and other regular winter flowering species such as Swamp Mahogany (*E. robusta*). In the interim this policy could be strengthened by conducting pre-logging site inspections targeting this species prior to logging in areas of potential habitat.

Swift Parrot (Vulnerable and Rare Schedule 12)

Sparsely distributed from Tasmania to south-east Queensland this migratory and nomadic species inhabits nectar rich dry forests and woodlands. It has been previously recorded from the Clarence Valley (Hindwood and Sharland, 1964), and is likely to pass through the Study Area in forests with high densities of floriferous species (NPWS, 1993), thus may be adversely affected by any practices which reduce nectar availability.

Mitigation Options: 4.6

Turquoise Parrot (Vulnerable and Rare Schedule 12)

The Turquoise Parrot has a patchy distribution across south-eastern mainland Australia, becoming less common east of the divide (Blakers et al., 1984). This species lives on the edges of woodland, ridges and creeks in farmland (Blakers et al., 1984), where it feeds on grass seeds harvested on the ground. The Turquoise Parrot was not recorded within the Study Area but a population exists adjacent to the Study Area in the Upper Richmond Valley (Morris, 1980). This species nests in hollow eucalypts or stumps, and its food supply may be adversely affected by grazing and burning in low quality dry forests.

Mitigation Options: 4.1, 4.2,4.3, 4.4, 4.5.

Powerful Owl (Vulnerable and Rare Schedule 12)

The Powerful Owl is found between south-western Victoria and eastern Queensland. It is widely dispersed within its range with most of the population living east of the Great Dividing Range. This species, with a home range of between 600-1000 ha, inhabits both wet and dry eucalypt forests preying upon medium-sized arboreal mammals (Common Ringtail and Sugar Glider) and more opportunistically birds and flying foxes. These owls nest in relatively large tree hollows and appear to remain within one large home range all their lives (Garnett, 1992). The Powerful Owl may be threatened by intensive logging practices that could reduce the available nesting sites and prey densities. The Powerful Owl was relatively uncommon in the Management Area, being recorded within two sites in Richmond Range, and one site in each of Dalmorton, Grange and Clouds Creek State Forests during this survey (Appendix G).

Mitigation Options for this species include: 4.4, 4.5, 4.7, and options 4.1,4.2, and 4.3 for protection of hollow trees from fire.

Masked Owl (Vulnerable and Rare Schedule 12)

The southern subspecies of the Masked Owl has a sparse but extensive distribution. It occurs in low densities in forest and woodland in a broad coastal strip around southern and eastern Australia, and wooded watercourses (Garnett, 1992). The Masked Owl is generally considered to inhabit the margins of forests and nest in tree hollows often within tall forest (Schodde and Mason, 1980). This species commonly preys upon small terrestrial mammals and occassionally arboreal mammals and birds. The Masked Owl may be threatened by pesticides where territories are adjacent to agricultural land (G. Czechura), and by a reduction in the availability of nesting sites as a result of clearance of forests for logging or agricultural purposes. During this study, Masked Owls were relatively uncommon in the Management Area, being recorded at two sites in each of Richmond Range and Cangai State Forests, and one site in each of Ewingar and Mount Belmore State Forests.

Mitigation Options for this species include: 4.4, 4.5, 4.7 and options 4.1,4.2, and 4.3 for protection of hollow trees from fire.

Marbled Frogmouth (Vulnerable and Rare Schedule 12)

This species is distributed along the eastern Australian coast. It has two widely separated populations, with the southern population extending from south-east Queensland to Wilson's Peak near Lismore in north-east NSW (Holmes, 1987a). The Marbled

Frogmouth roosts in dense vegetation and prefers rainforest, often along flowing creeks. This species was not detected during this survey; however it has previously been recorded in the Study Area in Richmond Range and Cherry Tree State Forests (Smith et al., 1989). Current harvesting proposals pose no significant long term threat to the species, with the possible exception of old-growth Moist Hardwood logging in areas with a well developed rainforest understorey. Options for mitigation include protection of remaining areas of old-growth Moist Hardwood with a well developed rainforest understorey.

Sooty Owl (Vulnerable and Rare Schedule 12)

The Sooty Owl roosts in large tree hollows and hunts for terrestrial and arboreal mammals in Rainforest and Moist Hardwood Forests. This species is known from a restricted number of localities scattered throughout south-east Australia. Recent surveys using call playback census techniques, have shown it to be more widespread in north-east NSW than was previously supposed (Kavanagh unpublished). During this study, 11 Sooty Owls were recorded in the Rainforest and Moist Hardwood forests of Richmond Range, Cangai, Clouds Creek, Dalmorton, and Mt Belmore State Forests (Appendix G). Reliable analysis of the habitat associations of the Sooty Owl is awaiting access to and/or establishment of a regional GIS environmental database. Access to GIS databases is essential to model the habitat requirements of this species because of its large home range size, and the need to average environmental variables within a defined radius of survey points, a procedure which is impractical to complete manually.

Previous studies have shown Sooty Owls to prefer moist old-growth forest habitats (Loyn, 1985). The ecological reasons for old-growth dependence by this species are unclear, since its prey occurs in open, regrowth and mature forests. On the basis of limited existing information, this species should be expected to decline in the short and long term in logged Moist Hardwood Forests and High Site Quality Dry Hardwood forests with a mesic understorey. In a state and national context this species is rare and restricted.

Mitigation Options for this species include:

Protect or minimise logging disturbance (by > 50% canopy retention) in known home ranges (200-800 ha, Schodde and Mason, 1980) until further information is available. Protection of known nest sites by a disturbance free zone of 200m radius is recommended combined with modified harvesting to ensure permanent retention of approximately 50% of the mature canopy and understorey in all high quality old-growth forests. Detection of nest sites and territories would be facilitated by pre-logging surveys.

Rufous Scrub Bird (Vulnerable and Rare Schedule 12)

This species is a small ground dwelling bird confined to upland forest of north-east NSW and south-east Queensland. Its habitat requirements include extremely dense cover 2-50cm above ground, moderate cover 50 -100cm above ground, a moist microclimate at ground level and abundant leaf litter (Ferrier, 1985). Associations between environmental variables and the frequency of occurrence of Rufous Scrub Birds have been modelled by Ferrier (unpublished) and the predicted range of the species has been mapped using GIS. We did not detect this species, however the main occurrence of potential habitat for this species is in Washpool National Park and it has been recorded in the Bindery Wilderness Nomination Area by Clancy (1985-7) and Holmes (1980). The species formerly occured in Ewingar State Forest (Ramsay, 1919) and areas of potential habitat occur in Billilimbra and Washpool Statte Forests (NPWS, 1993). At a state and national scale the Rufous Scrub Bird is rare and restricted. Lowland populations have become extinct and the species is restricted to 5 isolated upland populations (Ferrier, 1984). Given the rarity of this species, it is recommended that forest management aim to maintain or enhance existing populations within State Forests.

Ferrier (1985) found that selective logging increased habitat suitability in rainforest but reduced suitability in eucalypt forest. Approximately one third of sites surveyed by Ferrier were in eucalypt forest, the rest in rainforest. Preferred habitat in eucalypt forest was associated with an intermediate seral stage of post fire succession. Logging impact is a product of long term habitat changes and short term effects on existing territories. Management should aim to protect existing territories and maintain adequate future habitat. An option to achieve this aim is that (pre-logging) surveys be conducted between August and October in the year prior to any logging within the predicted range of the Rufous Scrub Bird, with the aim of detecting and mapping the home range of any existing residents. Logging, and natural regeneration (no top disposal burn) should be confined to areas more than 300m from the estimated centre of any mapped territories. Known territories may need to be buffered from wild fire by prescribed burning unless existing habitat and topography provides natural protection. This approach should increase habitat availability for Scrub Birds in the long term. SFNSW policy currently excludes timber harvesting from all known Rufous Scrub Bird territories.

<u>Eastern Bristlebird (Vulnerable and Rare Schedule 12)</u>

This species is distributed from eastern Victoria to the Conondale Ranges in Queensland. In north-east NSW this species occurs in open forest or woodland with a tussocky ground cover in close proximity to rainforest. In the southern portion of its range it occurs mainly in tussocky grassland bordering heath. Possible threats to the species include clearing and frequent burning or grazing. No individuals were recorded during this study. The closest known extant population is at Mt. Burrell in Nightcap National Park but apparently suitable areas of habitat occur in Washpool National Park and Washpool and Billilimbra State Forests (NPWS, 1993). More extensive targeted surveys would be desirable to identify any possible additional populations of this species.

Mitigation Options: 4.1, 4.2, 4.3, and 4.7

<u>Albert's Lyrebird (Vulnerable and Rare Schedule 12)</u>

This species is confined to a relatively small area (250km x 100km) of rainforest around old volcanic craters in north-east NSW and south-east Queensland (Blakers et al., 1984). Its preferred habitat includes Subtropical Rainforest, or mixed eucalypt forest, with a mesic understorey often in gullies and lower slopes. Albert's Lyrebird has also been found to inhabit eucalypt forests with *Allocasuarina torulosa* and *Xanthorrhoea spp.* understorey with only small amounts of rainforest in the wetter gullies (Brouwer and Garnett, 1990). It has also been recorded in rainforest logged a number of years previously, such as at Toonumbar in the Urbenville District and Whian Whian State Forest in the Murwillumbah District. There were no recordings of this species in the Study Area during this survey, but it has previously been recorded in Richmond Range State Forest near Mt Brown (NPWS, 1993). No long term impacts on this species are considered likely given its habitat requirements.

<u>White-eared Monarch (Vulnerable and Rare Schedule 12)</u>

This species can be found from Cape York Peninsula to Iluka in north-east NSW where it inhabits eucalypt forests (including regrowth), at the edge of rainforest, along creeks, round clearings, and occasionally mangroves (Blakers et al., 1984). Its primary habitat in NSW is lowland subtropical and littoral rainforest (NPWS, 1993). Its distribution in the Study Area is primarily coastal including the Iluka Nature Reserve and the Blackwall Range (Holmes, 1987a). The White-eared Monarch is found near the southern limit of its range in the Study Area. Although not recorded during this survey, the White-eared

Monarch has been reported at Richmond Range State Forest previously (Mason unpublished). Current harvesting proposals pose no significant threat to the species, with the possible exception of old-growth Moist Hardwood logging in coastal and subcoastal areas with a well developed rainforest understorey. Options for mitigation include protection of remaining areas of old-growth Moist Hardwood with a well developed rainforest understorey.

Olive Whistler (Vulnerable and Rare Schedule 12)

One of the 2 races of this species (*macphersoniana*) occurs within the Study Area north of the Hunter River, NSW to Mistake Mountain and McPherson Ranges in Queensland (Blakers et al., 1984). Within this range, the species usually inhabits upland (above 500m) forest undergrowth in temperate rainforests of Antarctic Beech (*Nothofagus moorei*) feeding mainly on the ground foraging for insects. However, Osborne (1991) recorded the species in Warm Temperate Rainforest in Washpool National Park. This species was not recorded during this survey. There is no evidence that logging impacts are likely to affect this species in the long term unless known populations are inadeventently destroyed by logging or fire.

Mitigation Option 4.7

Yellow-eyed Cuckoo Shrike (Vulnerable and Rare Schedule 12)

The Yellowed-eyed Cuckoo Shrike can be found from Cape York Peninsula to Port Macquarie in NSW (Clancy, 1989), mainly in the canopy of rainforests and their margins, and occasionally in neighbouring eucalypt forests. This species prefers mature forests, feeding on fruit and insects. Although not recorded during this survey, the Yellow-eyed Cuckoo Shrike has been recorded at Richmond Range and Cherry Tree State Forests. Current harvesting proposals pose no significant threat to the species, with the possible exception of old-growth Moist Hardwood logging in areas with a well developed rainforest understorey. Options for mitigation include protection of remaining areas of old-growth Moist Hardwood with a well developed rainforest understorey.

5. IMPACTS ON BATS

Introduction

Insectivorous bats comprise more than one third of the mammal species of north-east New South Wales and one quarter of the mammal fauna of Australia; yet comparatively little is known about their distribution, abundance, habitat requirements and sensitivity to logging and other cultural disturbances. With the exception of recent studies (Richards, 1992; Smith et al., 1992) bats have been largely ignored in previous impact studies. Knowledge of bat ecology and behaviour has been inadequate for making even the most fundamental impact predictions. The principal reason for this has been a lack of suitable, standardised and cost-effective methodology for comparing bat abundance in different natural and cultural environments. Until recently, bats were surveyed primarily by placing mist nets and harp traps on "flyways", natural openings such as roads or creeks which bats use when travelling to and from feeding sites or coming to drink. Capture rates using trapping techniques are notoriously variable, to the extent that capture has been described as being largely a matter of chance (Parnaby, 1986). This variation can be attributed to the effects of temperature and weather conditions; trap height above ground (high flying species are relatively under sampled); proximity to water; proximity to communal roost sites; and perhaps most importantly, to the structure of the vegetation surrounding the trap sites. Capture rates are highest at narrow points along flyways where vegetation funnels the flying bats into the traps, and lowest at randomly located open spaces.

The recent development and use of sonar detectors to record calls made by foraging bats, has made it possible to make more objective comparisons of bat abundance and activity in a wide range of habitats that would otherwise be difficult to survey by trapping (Fenton, 1982; Chrome and Richards, 1988). Sonar detectors record the echolocation pulses emitted by foraging bats. Different species of bats can be distinguished by differences in call frequency, amplitude, duration, and changes in frequency over time (Simmons et al., 1979). The number of calls per unit time can be used as an index of bat density.

The aim of this study was to predict the likely impact of timber harvesting on insectivorous bats in the Study Area, and to suggest options for amelioration of any logging impacts and ensuring the sustainable management of forests for both wood and wildlife values. The procedure involved:

a) a literature review to predict likely logging impacts based on the results of previous surveys and ecological studies of insectivorous bats throughout Australia;

b) field surveys using standardised methods to compare bat diversity in logged and unlogged forests in each of the major logged habitat types in the region (Rainforest, Moist Hardwood forest, Dry Hardwood forest);

c) multivariate statistical modelling to identify species' habitat and land use associations; interpretation of these patterns in terms of species known ecology to predict likely logging impacts.

Review of species known ecology and habitat requirements suggests strong parallels between insectivorous bats and insectivorous birds. Species overlap considerably in diet and broad vegetation preferences (Hall, 1981), but specialise in foraging in specific layers or substrates within the forest (McKenzie and Rolfe, 1986; O'Neil and Taylor, 1986; Chrome and Richards, 1988). There is generally a correlation between flight speed, manoeuvrability, bodysize, wing loading (mass divided by wing area), aspect ratio (wing length squared over wing area) and foraging substrate preference in bats (Norberg and Raynor, 1987). Species with large wing areas and small mass have greater manoeuvrability and slower flight speed, and are found more commonly in structurally denser forests or forest layers. Species with long narrow wings and high aspect ratios are fast flying, preferring open spaces above forests, the spaces below the tree crowns or on forest edges and roads. Large fast flying species also tend to have louder calls for long-range prey detection (Fenton and Thomas, 1980). The few field studies of habitat use by Australian bats (Dwyer, 1965; McKenzie and Rolfe, 1986) confirm these general patterns. By releasing trapped bats with radio-transmitters or lights it is possible to track some individuals to roost sites and observe patterns of foraging and substrate use. In Tasmania, the slowest flying species, *Nyctophilus geoffroyi*, was observed to feed in the understorey close to the vegetation, while *Eptesicus vulternus* and *E. regulus* forage above the understorey vegetation. *E. darlingtoni* and *Chalinolobus morio* have greater flight velocities and forage in mid storey gaps, while *F. timoriensis* and *C. gouldii* prefer open areas beneath the forest canopy (O'Neil and Taylor, 1986).

Previous surveys in the Study Area have been of limited geographic extent and have not used stratified designs to provide for the detailed analysis of habitat preferences. Parnaby (1986) surveyed bats in rainforest habitats in National Parks east of the Divide from Barrington Tops in the south to the Border Ranges in the north. These surveys focused on the use of traps and mist nets at sites such as cave entrances, water holes, and fly ways through dense vegetation to maximise capture rates (Parnaby, 1986). Data generated by these surveys is unsuitable for making comparisons between survey sites to identify species habitat requirements and response to disturbance. However, this method has been extensively used for compiling species lists for different regions and for major habitat types within regions (Parnaby, 1986). With the exception of surveys by Richards (1992) in Wingham State Forest to the south, there has been no previous survey of equivalent scope in State Forests, or in habitats other than rainforest within the Study Area or surrounding region. Existing information on species vegetation preferences, roost sites and foraging substrates are summarised in Appendix F (after Hall, 1981; Parnaby, 1984, 1986; Richards, 1991; Strahan, 1984).

On the basis of this limited information the following general predictions were made:

a) diversity will be determined largely by vegetation structure, with the richest assemblages occurring in high productivity sites with complex multi-layered vegetation;

b) thinning, frequent fire, grazing and other processes which suppress or destroy the shrub understorey cover or reduce the forests' structural complexity may cause an increase in the diversity of high fast flying species and a decrease in the diversity of low closed forest species;

c) intensive timber harvesting of old-growth and/or timber stand improvement (culling of habitat trees) may reduce the relative abundance of hollow dwelling bats by reducing the density of trees with hollows; (TSI has been practiced in the past but is not part of the current proposal).

These hypotheses were evaluated, as far as practicable, by multivariate analysis of asociations between bat diversity and abundance, measured by both sonar detection and harp trapping techniques, and measured natural and cultural environmental variables at surveys sites (see Chapter 3).

Survey Methods

Survey Design

Trapping was conducted at 36 sites (Table 5.1) using Ausbat harp traps set on streams and roads adjacent to or within 300m of transects wherever possible. Where vegetation was not suitable for trapping on or adjacent to transects, traps were placed at the nearest suitable location. For the purpose of habitat analysis and impact assessment only data from traps on or within 300m of transects (25 sites) were statistically analysed. The arrangement of vegetation and other structural features around the trap is thought to influence capture rates at least as strongly as attributes of the immediate area, such as habitat type and land use history. Thus trap site effects may introduce considerable variation and obscure habitat and impact associations, particularly where the number of captures (bat abundance) is used as the dependent variable. To minimize this effect we used measures of species presence/absence per site, rather than just quantitative measures of numbers caught, as the dependent variable in statistical analyses. Caution should be exercised when interpreting habitat associations determined by analyses of trapping data where bat abundance is used as the dependent variable. Specimens captured in traps were identified using Parnaby (1992a). Voucher specimens of species which are difficult to identify were preserved and sent to the Australian Museum for identification.

Sonar surveys were conducted on 35 of the 77 fauna survey transects established in the Study Area. Each survey site consists of five points 100 metres apart, at which sonar signals were recorded for five minutes. For further details of the layout and stratification of the survey sites see Chapter 3. An additional 10 minute recording period was conducted at 33 sites while walking approximately 500m along the access road nearest each transect. This gave a total of 35 minutes sampling at each site. Richards (1992) reports that a 30 minute sonar recording session is adequate to record bat diversity at a site. Eight additional surveys consisting of 4 replicates of previous surveys and 4 new sites in recently logged compartments were also carried out.

Measures of Bat Species Richness and Abundance

The total number of bat species (bat species richness) and the total number of bats (bat abundance) detected at each survey site were calculated separately for sonar surveys and harp trapping. Sonar surveys are thought to bias in favour of loud fast flying species (Richards, 1992) while trapping is thought to bias in favour of some quiet slow flying (Dense Forest) species (Richards, 1992). Analyses of the data did not entirely support these assumptions. Trapping appeared to bias in favour of small bats, while sonar appeared to detect a wide range of both small and large bats, but with a slight bias in favour of large fast flying bats. Since small and large bats may respond to logging in opposite ways, an analysis of bat species richness using both methods combined was considered inappropriate, and results of trapping and sonars were analysed separately. The sonar survey data was used to calculate bat abundance as the average number of bat passes per 5 minutes. Species diversity was calculated as the total number of different species detected per 25 minutes. The Harp Trap data were used to calculate bat abundance as the number of bats caught per trap per night. Species richness was calculated as the number of different species captured per trap per night. Similarly, the relative abundance of each species was derived from the number of individuals detected per 5 minutes, or the number captured per trap per night.

Table 5.1 Location of Bat Sonar and Harp Trapping Survey Sites

	Harp Trap Location		Sonar Transect Location	
State Forest	**Trap Location**	**Transect**	**State Forest**	**Transect**
Washpool NP	creek		Richmond Range	11
Ewingar	road	29	Richmond Range	12a
Double Duke	road, swamp		Richmond Range	12b
Double Duke	swamp		Richmond Range	13
Grange	road	50	Richmond Range	16
Grange	creek	50	Richmond Range	17
Cangai	road/camp	32	Richmond Range	18
Cangai	Mares Run Rd.	34	Richmond Range	19
Dalmorton	road, MHWD	35	Mt Belmore	20
Dalmorton	pond		Mt Belmore	21
Clouds Creek	Muck Creek. Rd.		Mt Belmore	22b
Clouds Creek	Muck Creek Rd		Mt Marsh	23
Clouds Creek		46a	Ewingar	27
Clouds Creek		42	Ewingar	28
Clouds Creek	Kellys Creek Rd		Ewingar	30
Clouds Creek	Kellys Creek Rd		Washpool	31c
Candole	Kangi Flat Rd	56	Washpool	31d
Candole		57	Cangai	32
Candole		58	Cangai	33
Candole		60	Cangai	34
Glenugie	Pheasant Creek		Dalmorton	35
Grange		52a	Dalmorton	36
Clouds Creek	Bridge Highway		Dalmorton	37
Clouds Creek		42	Sheas Nob	42
Clouds Creek		43	Sheas Nob	43
Clouds Creek		47	Sheas Nob	47
Ewingar		27	Grange	51
Ewingar	Ewingar Creek	27	Fortis Creek	53
Richmond Range	Cambridge Pt	18	Fortis Creek	54
Richmond Range	Mt Tryrey Rd	17	Fortis Creek	55a
	Peacock Creek	11	Candole	56
	1km from T11		Candole	57
		12a	Candole	58
Mt. Belmore	Myrtle Creek	21	Candole	60
Mt. Belmore	Myrtle Creek	20	Candole	61
Double Duke			exFortis Creek	
			exMt.Belmore	
			exDalmorton	
			exDalmorton	

Data Analysis: Impact Assessment on Habitat Preferences

Habitat preferences and land use impacts were assessed by the analysis of associations between bat species richness, bat abundance, individual species abundances, and individual species frequencies of occurrence (per site) and measured environmental variables. Associations between quantitative (continuous) variables were analysed by multiple and linear regression. Associations between quantitative dependent variables and qualitative (categorical) environmental variables were measured by analysis of variance. Associations between the frequency of occurrence of individual species (presence-absence at each site) and environmental variables were determined by Chi-square analysis after first converting continuous environmental variables into categories. The data from sonar, harp trapping, and spotlighting surveys were analysed separately.

Results

Comparison of Survey Methods

In this study 15 species out of a total of 22 were detected by sonar, 13 species were detected by trapping, and 1 species was detected by spotlighting. Species detected by the different methods and assigned to different guilds for the purpose of data analysis are listed in Table 5.2. Seven insectivorous species were detected by both methods.

Species of the Study Area

North-eastern New South Wales supports a high diversity of bat species, second only to the Cooktown-Atherton-Chillagoe region of North Queensland (Parnaby, 1984). A total of 21 species of insectivorous bats were detected in the Study Area during this survey. Five other species have been recorded in north-east NSW during previous surveys (Parnaby, 1984, 1986; Osborne, 1982; Baverstock and Chambers, 1992; Unpublished survey by the NSW National Parks and Wildlife Service (S. Gilmore unpublished)) (see Appendix F). Four of these, the Hoary Bat, the Large Pied Bat, the North Queensland Long-eared Bat and the Lesser Long-eared Bat, occur near the margins of their distributions within the Study Area and our failure to detect them may reflect either local absence or low frequency of occurrence in this area. Baverstock and Chambers (1992) reported the North Queensland Long-eared Bat to be locally common in the Murwillumbah region. Only one species with a distribution encompassing the region, the Little Northern Mastiff Bat, was not conclusively identified. The taxonomy of Mastiff bats is confused (Parnaby, 1992b) and they are difficult to identify at the specific level using sonar recordings, so it is possible that this species was detected but not identified.

Five species of fruit bat (Megachiroptera) have been reported in north-eastern NSW (Parnaby, 1986). Only a single species, the Grey-headed Flying Fox, was detected during this survey. This species was commonly observed during spotlight surveys on transects in sub coastal regions when *Angophora* was flowering. Two species, the Black Flying Fox and the Tube-nosed Bat reach their southern limit in the region and are only expected to occur infrequently if at all in the Study Area. The Queensland Blossom Bat has a mainly coastal distribution in areas of heath adjacent to rainforests and sclerophyll forest south to Taree, NSW. It was not detected by spotlighting or trapping during this survey, primarily because its preferred habitat is not included in the timber production forests that formed the focus of this study. It is however, likely to be moderately abundant in coastal heaths and woodlands, and subcoastal forests with a heathy understorey in proximity to rainforest.

Table 5.2. Bats Detected in the Grafton Casino Region During this Survey Showing: Numbers and Frequency of Sites at which Microchiroptera were Detected Electronically (sonar) and by Harp Trapping (trap); and Frequency of Occurrence of Fruit Bats Detected by Spotlighting at Survey Sites.

Common Name	Regional Abundance				
	Trap Spot	Trap % Spot	Sonar	Sonar %	Total
Pteropidae					
Black Flying Fox					
Grey-headed Fruit Bat	3	4			
Little Red Fruit Bat					
Tube Nosed Bat					
Queensland Blossom Bat					
Rhinolophidae					
Eastern Horseshoe Bat	4	3	15	26	19
Emballonuridae					
Yellow-bellied Sheathtail Bat			2	5	2
Molossidae					
White-striped Mastiff Bat			13	18	13
Eastern Little Mastiff Bat			5*	5	5
Little Mastiff Bat			5	10	5
Little Northern Mastiff Bat					
Beccari's Mastiff Bat			4*	8	4
Vespertilionidae					
Gould's Long-eared Bat	13	19	3	8	16
Lesser Long-eared Bat					
North Queensland Long-eared bat					
Common Bent-wing Bat	16	6	4	10	20
Little Bent-wing Bat	5	8			5
Gould's Wattled Bat			29	41	29
Chocolate Wattled Bat	4	11			4
Large Pied Bat					
Hoary Bat					
Large-footed Myotis	2	3			2
Greater Broad-nosed Bat	5	6			5
Eastern Broad-nosed Bat			5	13	5
Golden-tipped Bat	2	6	1	3	3
Greater Pipistrelle			11	18	11
Little Cave Eptesicus	11	14	1	3	12
Little Forest Eptesicus	3	3			3
King River Eptesicus	17	17	22	33	39
Large Forest Eptesicus					
Troughton's Eptesicus	1	3			1

Most bat species occurring within the region are widely distributed. None are endemic to the Study Area, but some species have restricted distributions centred on north-east NSW (*Eptesicus pumilus* and *Mormopterus norfolkensis*). For many other species the area is near the southern or northern extent of their range.

Biodiversity of Bats Detected by Trapping

The statistically measured associations between the abundance and species richness of bats captured in Harp Traps are summarised in Tables 5.3 and 5.4. For continuous variables linear regression analysis was used to measure the strength of associations, while for categorical variables, analysis of variance was used.

Table 5.3 Significant Associations between Bat Species Richness Determined at Harp Trap Sites and Continuous Environmental Variables.

Environmental Variable	Species richness r	Species richness P	Total Abundance (Activity) r	Total Abundance (Activity) P
Fire Intensity (burn ht.)	-0.60	0.002	-	-
Fire Frequency	0.70	0.0001	0.53	0.007
Time Since Fire	0.60	0.002	0.46	0.02
Over storey Community 1	-0.58	0.002	-	-
Shrub Cover	-	-	-0.42	0.006
Aspect	0.41	0.04	-	-

Table 5.4 Significant Associations between Species Richness, Total Abundance and Categorical Environmental Variables Showing Statistical Significance (P values) and Mean Values for each Category.

Environmental Variable		Species Richness	Total Abundance
Forest Type	P=	0.03	
Rainforest		4.0	
Moist Hardwood		1.38	
Dry Hardwood		0.78	
Fire Intensity	P=	0.02	
none		2.63	
light		0.57	
moderate		1.33	
heavy		0.00	
Burn Height	P=	0.02	
none		3.2	
1-2m		1.2	
3-5m		1.11	
6-10m		0.00	
Fire Frequency	P=	0.0005	0.02
high		0.25	0.58
moderate		2.0	4.8
low/absent		2.86	5.7
TSI	P=	0.035	0.05
culled		0.00	0.00
not culled		1.74	3.70

The species richness and abundance of insectivorous bats detected by harp trapping was found to be significantly associated with forest type, fire history and culling. Both the variety and abundance of bats is highest in Rainforest and Moist Hardwood forest and lowest in frequently burnt Dry Hardwood forest. This result is consistent with our initial hypothesis that bat diversity will be greatest in productive, structurally complex forest. Bats were absent from recently and severely burnt forests, and most abundant in areas protected from fire or areas only lightly and infrequently burnt. This pattern can be explained by two related phenomena, the low flammability of Rainforest and the elimination of understorey structure though frequent fire and grazing in Hardwood forests. A 2-way AOV was used to demonstrate that fire frequency has a significant effect on species richness (P= 0.015) within Hardwood forest types alone. Mean species richness was greatest (2.4) in Hardwood forests with no evidence of fire or evidence of very infrequent fire and lowest (0.25) in Hardwood forests subject to frequent (1-3 year) fires.

Bats detected by trapping were not significantly associated with logging intensity or time since logging but, were significantly negatively associated with culling. Most sites had some years to regenerate, and it is likely that dense regrowth developing after logging provided adequate cover for species which require dense to moderate cover. No bats were captured at survey sites in forests in which over mature and defective trees had been removed by culling. This does not necessarily mean that bats will always be absent from all culled areas. The sample size in this study was small, and an increase in sampling effort may reveal occurrences of trapped bat species in culled forests, although at much lower densities than untreated forests. This result is most likely to be due to a combination of the following: reduced availability of tree hollows; more intensive silvicultural management (more frequent control burning and thinning) in culled forests; and the predominant restriction of culling to Dry Hardwood (Blackbutt) forest types (FCNSW, 1987) which have an intrinsically lower variety and abundance of trapped bats. No significant association between the number of tree hollows and the variety or abundance of bats was found, but examination of trends on scatter plots indicated that bats were not captured where hollows occurred at densities of less than two hollow bearing trees per hectare. The present study surveyed too few sites over the range of 0-2 habitat trees per hectare to establish relationships between bat abundance and tree hollow abundance with certainty. Further surveys of bat diversity with a more focused design will be necessary to establish the relationship between tree hollow numbers and bat diversity. Our data indicates however, that the minimum requirement is likely to average more than 2 trees per hectare in the regions surveyed. This is less than minimum habitat tree requirements previously established for arboreal marsupials (Smith and Lindenmayer, 1988, Smith et al., 1992), a result which could be expected if bats occupy smaller hollows than arboreal mammals, travel greater distances from roost sites, and do not occur at densities of more than approximately 2 colonies/ha.

<u>Biodiversity of Bats Detected By Sonar</u>

Associations between the species richness, and abundance of bats detected by sonar and continuous and categorical environmental variables are summarised in Tables 5.5, and 5.6.

Table 5.5 Significant Associations between Bat Species Richness and Bat Abundance, with Continuous Environmental Variables for all Survey Sites (n=35).

Environmental Variable	Species Richness		Total Abundance (Activity)	
	r	P	r	P
Season	0.49	0.001	0.67	0.0001
Fire Intensity (burn ht.)	0.38	0.02	0.41	0.01
Fire Frequency	-0.33	0.04	-0.46	0.004
Grazing (duration of)	0.33	0.04	0.47	0.003
Roading (year of)	0.32	0.05	-	-
Over storey Community 2	0.33	0.04	0.55	0.0004
Shrub Cover	-	-	-0.42	0.006
Aspect	-	-	0.41	0.01

Species richness and abundance of bats detected by sonar were significantly correlated with season, understorey vegetation type, fire history, grazing history, roading history, and aspect. There were no significant associations apparent between logging intensity or frequency and bat species richness. Bat species richness was highest early in the season (February), and in dry forests with an open grassy or dry shrubby understorey and a history of frequent, moderate to high intensity fires. Season explained the greatest variation in the variety and abundance of bats detected by sonar.

Table 5.6 Significant Associations between Species Richness and Bat Abundance, and Categorical Variables showing Mean Values for each Category.

Environmental Variable		Species Richness	Total Abundance
Season	P=	0.001	0.0001
summer		3.33	1.87
autumn		1.15	0.31
Understorey Type	P=	0.030	0.05
mesic		0.94	0.33
xeric		2.00	1.04
grassy		2.80	1.10
Shrub Cover	P=		0.001
1-5%			1.47
6-20%			0.13
21-50%			0.32
51-100%			0.30
Fire Intensity	P=	0.04	0.04
none		1.0	0.2
light		2.09	1.34
moderate		2.92	0.74
heavy		1.0	0.87
Burn Height	P=	0.03	-
none		1.0	-
1-2m		0.5	-
3-5m		2.09	-
6-10m		2.92	
Fire Frequency	P=	-	0.02
1 high		-	1.09
2 medium		-	0.42
3 low		-	0.06

Due to chance confounding between season (month) and some environmental variables (fire frequency and disturbance and other variables) there was a possibility that associations with fire grazing and other variables were spurious due to confounding with season. To overcome this problem, associations were re-analysed for sites surveyed in the autumn months (April -May) only. Results are presented in Table 5.7. Fire frequency, fire intensity, grazing and shrub cover remained significant predictors of bat species richness and abundance within seasons. Roading and aspect were eliminated as predictors of bat biodiversity in autumn.

Table 5.7 Significant Associations Between Bat Species Richness and Bat Abundance and Continuous Environmental Variables for Sites Surveyed During Autumn (n= 26).

Environmental Variable	Species richness		Abundance	
	r	P	r	P
Fire Intensity (burn ht.)	0.38	0.02	0.38	0.027
Fire Frequency	-0.32	0.06	-0.42	0.013
Grazing (duration of)	0.32	0.06	0.41	0.017
Over storey Community 2	-	-	0.50	0.002
Shrub Cover	-	-	-0.38	0.027

The variety and abundance of bats detected by sonar was most strongly correlated with a gradient of increasing fire frequency, reduced shrub cover and a long history of grazing. This result is consistent with predictions that sonar surveys bias in favour of large fast flying bat species which are expected to prefer more open habitat, but could also reflect increased detectability of calling bats in open habitat.

Neither bat species richness nor abundance was significantly correlated with logging intensity, time since logging or any other measure of logging disturbance. This does not prove that logging has no effect on bat abundance or species diversity (see Chapter 3). However, it indicates that any such effects must be small compared to the effects of fire, forest type, and other related variables.

No significant relationship was found between the abundance and diversity of species detected by sonar and the density of hollow bearing trees, indeed bats were recorded on sites on which there were no recorded hollows. This result does not imply that hollows are not required by these bats. Many bat species are fast fliers, capable of travelling long distances from roost sites to forage where there are few or no hollows. Regionally, the availability of hollows may influence populations of these species. More complex spatial analyses which take into account bat home ranges size and movement patterns will be necessary to establish the hollow requirements of these species.

Individual Species Habitat Preferences and Sensitivity to Logging

Associations between the frequency of occurrence of individual bat species and all measured environmental variables were analysed using Chi-square contingency analysis. The results are summarised in Table 5.8.

Associations between the frequency of occurrence of individual species and the measured environmental variables are generally consistent with known habitat requirements. The Chocolate Wattled bat was found to be significantly more abundant in Rainforest and Moist Hardwood forest and occurred only in unburnt and ungrazed forest. In Tasmania this species has been observed to forage in mid storey gaps (O'Neil and Taylor, 1986). Gould's Long-eared Bat was significantly more abundant in Rainforest and Moist Hardwood forest, and unburnt or infrequently burnt forest. The Little Cave Eptesicus was significantly more abundant in forest with a dense canopy cover (>50%), tall canopies (>20m), and occurred in only areas in which there was no evidence of fire. The King River Eptesicus was significantly associated with tall forest with a high shrub cover, infrequent fire, abundant hollows and high logging intensity. The Eastern Horseshoe Bat was significantly more abundant in forests of low (sparse) canopy cover. The White Striped Mastiff bat was significantly more abundant in forest of moderate fire frequency, and forests logged only once. Gould's Wattled Bat was found to be significantly more abundant in frequently burnt forest. The Greater Pipistrelle was significantly associated with frequently burnt forests with grassy or xeric understorey. However, this result was confounded with season and may be spurious. The Large Forest Eptesicus was significantly more abundant in forest logged on two or more occasions, but this result was also confounded with season.

Table 5.8 Summary of Significant Associations between Measured Environmental and Cultural Variables and the Frequency of Occurrence of Insectivorous Bat Species. P values indicate the strength of the relationships.

Trapped Species	
Chocolate Wattled Bat	
forest type	P=0.0027
shrub cover	P=0.08
fire frequency	P= 0.003
grazing intensity	P= 0.0007
Gould's Long-eared Bat	
forest type	P= 0.02
fire frequency	P= 0.05
Little Cave Eptesicus	
canopy cover	P= 0.0006
canopy height	P =0.01
fire frequency	P= 0.02
King River Eptesicus	
canopy height	P= 0.05
fire frequency	P= 0.03
logging intensity	P= 0.05
hollow numbers	P= 0.03
Sonar Species	
Eastern Horseshoe Bat	
canopy cover	P= 0.05
White-striped Mastiff Bat	
fire frequency	P= 0.0001
logging cycles	P= 0.02
Gould's Wattled Bat	
fire frequency	P= 0.02
Greater Pipistrelle	
season	P= 0.01
understorey type	P= 0.02
fire frequency	P= 0.05
Large Forest Eptesicus	
season	P= 0.01
logging cycles	P= 0.006

Impact Assessment and Mitigation

Tree Hollows

Eighteen species of bat, 69% of those likely to occur in the region, are reported to use tree hollows for shelter, hibernation, predator avoidance or reproduction (Appendix F). Seven species may roost under clumps of bark in addition to using natural cavities such as hollows. Little information is available on the size, type and density of tree hollows required by bats. Tideman and Flavel (1987) describe the roosting characteristics of 8 south-east bat species at 77 roost sites. All roosts were close to water, the mean distance being less than 300m. Bats can occupy small hollows when roosting singly but may require large hollows for communal nesting. More than 200 individual bats may roost in a single large hollow tree. Barker (in Parnaby, 1984) reported that bats prefer to roost in large trees in uncut forest rather than in regrowth forest with stems under 40cm dbh, and that regrowth forest with few or no hollows had a lower bat diversity. Lunney et al. (1988) tracked 18 *N. gouldii* to 38 roosts in the Eden region. Only unlogged gullies provided trees suitable for nesting and all roost sites were in trees greater than 80cm dbh. Roost sites were changed almost daily indicating a requirement for more than one hollow for each individual or colony. Taylor and Savva (1988) report that trees greater than 120 cm dbh are preferred as roosts.

- Logging causes a reduction in the number of mature stems (greater than 80cm) and the density of hollows. The effect of hollow reduction upon populations of bats will depend upon many factors including distances travelled from roosts to foraging areas, size of colonies, population densities, the suitability of regrowth forests for foraging and the number of hollows required by a each individual. Colonies vary in size from one to hundreds and the circumstances regulating colony size are poorly understood. Distances travelled from communal roosts to foraging habitats are also poorly known. In the Eden district, *N. gouldii* has been found to confine its activity to within 1 km of the roost, and in the Bega region radio-tracking studies have show that *N. gouldii* travels 1 to 2 km (Parnaby, 1984). In Tasmania, common forest bats were found to move up to 4.8 km from trap sites to roosts (Taylor and Savva, 1988). Little existing information on the spatial distribution and densities of roosting sites is available as a guide to setting minimum prescriptions for tree hollow retention in logged forest. Smith et al. (1992) recommended the retention of 4 hollow bearing trees per ha for the conservation of bats in low site quality forests, as a conservative guide, on the grounds that Ambrose (1982) found that percentage hollow use by bats was approximately equivalent to use by possums and gliders in eucalypt forests in Victoria. However, compared to possums and gliders, bats utilise smaller trees, with smaller cavities and may tolerate greater clustering of roosting sites. Results of this study suggest that separate prescriptions may be necessary for fast flying bats with large home ranges and smaller sedentary bats. Small bats, including *N. gouldii*, are likely to be more sedentary and in this study were absent from sample sites with less than 2 habitat trees per ha. By contrast, fast flying species were present in suitable foraging habitats with infrequent habitat trees. Habitat requirements for this group may be satisfied by clustered old-growth patches, particularly in gullies and along watercourses, up to a 1km or more distant from logged forest.

The number of trees with hollows (habitat trees) retained under current management practice exceeds 2 trees per hectare on average. Current management prescriptions call for retention of an average frequency of one or two trees per hectare depending on size. These should be preferably in clumps of up to five trees scattered throughout the harvesting area (FCNSW, 1987). While it may be desirable to retain habitat trees in clusters in order to protect them from exposure and wind throw, previous research has suggested that clusters of trees should only be counted as providing a single habitat tree for wildlife conservation purposes, because territoriality and competition ensure that hollow dependent fauna are often regularly spaced throughout the environment. The current prescription can be seen as effectively only guaranteeing the maintenance of the equivalent of one habitat tree per 5 hectares in some compartments . This requirement is less than the minimum requirement of two trees per hectare suggested by current knowledge, and consequently the prescription is likely to be inadequate for ensuring the mitigation of logging impacts on hollow dependent bats.

Suggested options for mitigation of logging impacts on bats are:

5.1 Retention of a minimum of 2 evenly or randomly spaced habitat trees per ha of logged forest;

5.2 Protection of all old-growth stems in filter strips from harvesting; (Gully habitat trees being the most critical for bats),

5.3 Active recruitment of habitat trees into forests with less than 2 evenly or randomly spaced habitat trees per ha, due to a history of previous culling or intensive logging.

Note: options 5.1 and 5.3 only apply in forests where the more rigorous prescriptions for aroboreal mammal habitat tree protection do not apply (see chapter 6).

Caves

Six insectivorous bat species, listed below, may depend largely upon caves, rock crevices, mines or large buildings for roosting or reproduction. Caves sites are not considered to be threatened by timber harvesting or associated activities within the Study Area, but protection of any known colonies from recreational disturbance is desirable.

Rhinolophus megaphylus
Myotis adversus
Miniopterus shreibersii
Miniopterus australis
Eptesicus troughtoni

Water

Many bat species regularly drink at water holes in pools or slow moving streams. Access to water is particularly important for species that hibernate in cool, high elevation forests because body water turnover in hibernating bats is higher than energy turnover. and many bats must arouse periodically to drink. Ideally, water sources must be close to hibernation sites so that stored fat is not wasted during flights to and from water. This can be achieved by protection of potential roost sites in large hollow stemmed trees adjacent to large permanent pools. Permanent pools also provide habitat for the endangered Large-footed Myotis which forages over water.

Options for mitigation of potential logging impacts on water resources include:

5.4 Mapping permanent ponds (>5m in length) and protected potential or actual habitat trees adjacent to these pools in 100m wide protection strips of unlogged forest.

Nectar

Nectar and pollen obtained from flowering trees and shrubs in hardwood forests is a potentially important food resource for fruit bats and their allies (*Pteropus alecto, P. poliocephalus, P. scapulatus, Syconycteris australis, Nyctimene robinsoni*). There is little information about the impact of logging and associated activities on nectar and pollen supply. Nectar and pollen production is likely to be reduced by the removal of mature trees during logging operations, and may also be affected by silvicultural practices which alter the floristic composition of the forest. Adverse impacts are most likely to occur where there is a reduction in abundance of trees and shrubs which flower during winter, when nectar is often in short supply, and where there is a reduction in abundance of trees and shrubs which flower frequently (yearly or every 2 years). It is likely that early regrowth regenerating after logging or fire disturbance will carry fewer flowers than old-growth forests. The results of a study in coastal forests by D. Quin (unpublished data) suggest that flowering is more prolific in stems greater than 30cm dbh in some eucalypt species. Relationships between size and flowering in Banksia at the same location indicate no relationship with age, however larger shrubs (>10cm dbh) flowered for longer (6 months) than smaller stems (3 months, D. Quin unpublished data), an important difference in forests with seasonal shortages in nectar supply.

Based on apiary knowledge (Stace, 1992) key areas for nectarivorous bats are likely to include coastal forests with abundant *Melaleuca* and *Banksia*, and inland forests with a high proportion of mature Grey Ironbark and other floriferous species.

Bees may compete for food with nectar feeding bats but their effects are uncertain.

Further research is necessary to establish the relationship between tree and shrub age and nectar production in State Forests. Present data is inadequate to make reliable predictions about the magnitude of logging and apiary impacts on bats or other nectarivorous mammals, however there are reasonable theoretical grounds for predicting that some level of adverse impact is likely. Options for mitigation of possible impacts include:

5.5 The maintenance of floristic diversity, and particularly the abundance of good (winter flowering, frequent flowering and copious flowering) nectar and pollen producing species, within logged coupes by appropriate silviculture;

5.6 Protection of large (>10cm) winter flowering Banksia spp in the shrub understorey from logging and fire damage as far as practicable during harvesting operations;

5.7 The dedication of certain areas within State Forests or adjacent National Parks, with a high diversity of flowering species, as control areas in which apiary is to be excluded for the purpose of monitoring and future evaluation of apicultural impacts;

5.8 Monitoring and further research on the effects of logging and tree age on nectar and pollen production in representative forest types.

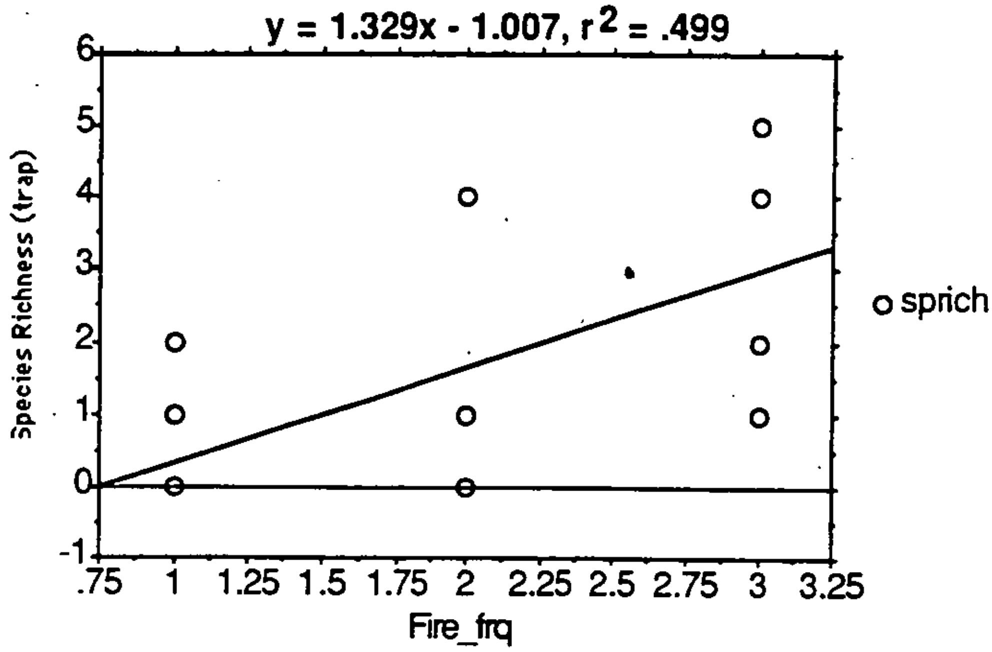
Old-growth and Post-logging Succession

Little is known about the responses of bat populations to succession after logging and fire. Likely impacts can be predicted from species structural requirements and the effects of fire and logging on forest structure. In general, open space foragers are expected to increase and dense forest species to decrease following intensive, post logging grazing and fire. Low intensity logging followed by good understorey regeneration should not adversely affect canopy species. Richards (1991) reported a significantly lower diversity of bat species in Rainforests and Moist Hardwood forests above 500m altitude after logging, but found no effect of logging in Dry Forest types. No significant association between bats and time since logging could be demonstrated for any habitat type. In this study it was found that there was no significant effect of logging or time since logging on species diversity in insectivorous bat communities. However, the survey included few sites that had recently been logged, so that short term effects (< 5 years) would not have been apparent. Two species exhibited significant positive associations with logging. The Large Forest Eptesicus was more abundant in sites logged 2 or 3 times previously, and the King River Eptesicus was more abundant in severely logged than unlogged sites. No species were significantly negatively associated with logging, however few species were captured in sufficient numbers for analysis of logging effects.

Grazing and Burning

Frequent grazing and burning may reduce or eliminate habitat availability for bats which forage in dense shrubby understorey. These are likely to be the smaller slower flying species of bats which are detected by trapping. In this study species detected by trapping decreased with increasing fire frequency and intensity while species detected by sonar increased with increasing fire frequency. Both the species richness and the total abundance of trapped bats was found to be significantly lower in frequently burnt (every 2-5 years) sites. At the species level 4 species, (*Chalinolobus morio, Eptesicus regulus, Nyctophilus gouldii,* and *Eptesicus pumilus*), occurred significantly more frequently in sites which were unburnt or infrequently burnt, and 2 of these species occurred significantly more frequently in areas of high shrub cover associated with the absence of fire.

The following models generated in this study (Figures 5.1a,b) can be used to predict the likely magnitude of changes in bat abundance associated with maintenance of frequent fire by control burning and/or grazier activity:



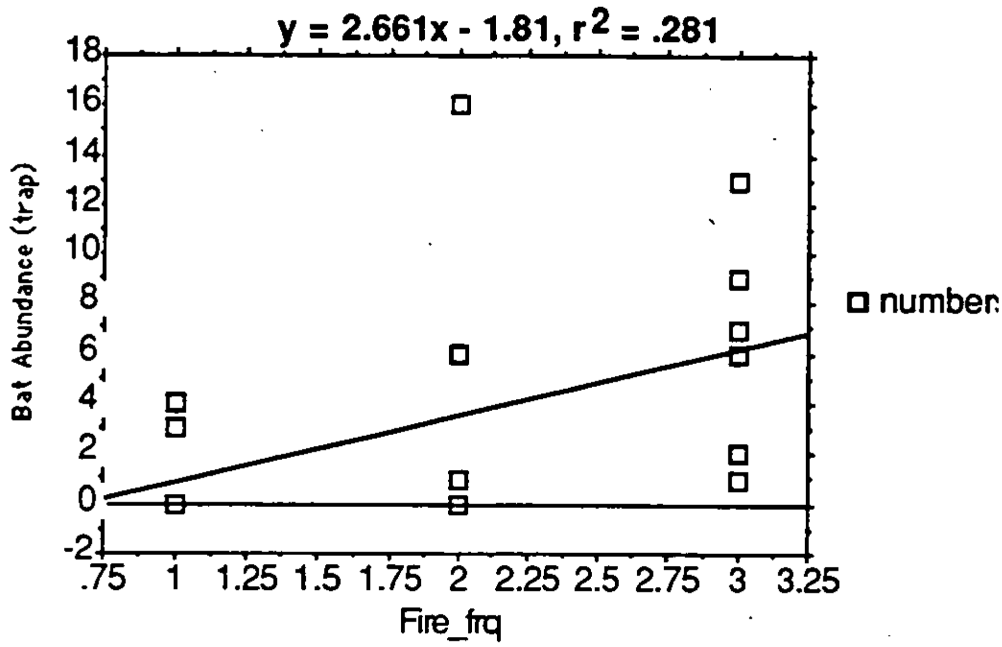
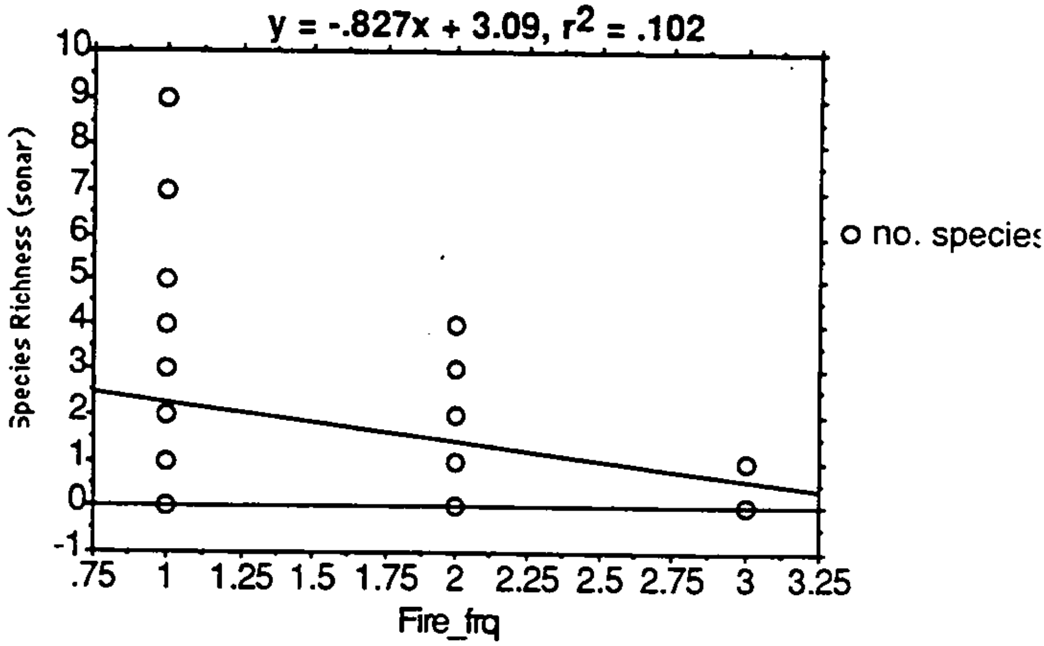


Figure 5.1a Relationship between Fire Frequency (1= every 2-5 years, 2= every 5-10 years, 3= > every 10 years) and the Species Richness and Abundance of Bats detected by Harp Trapping



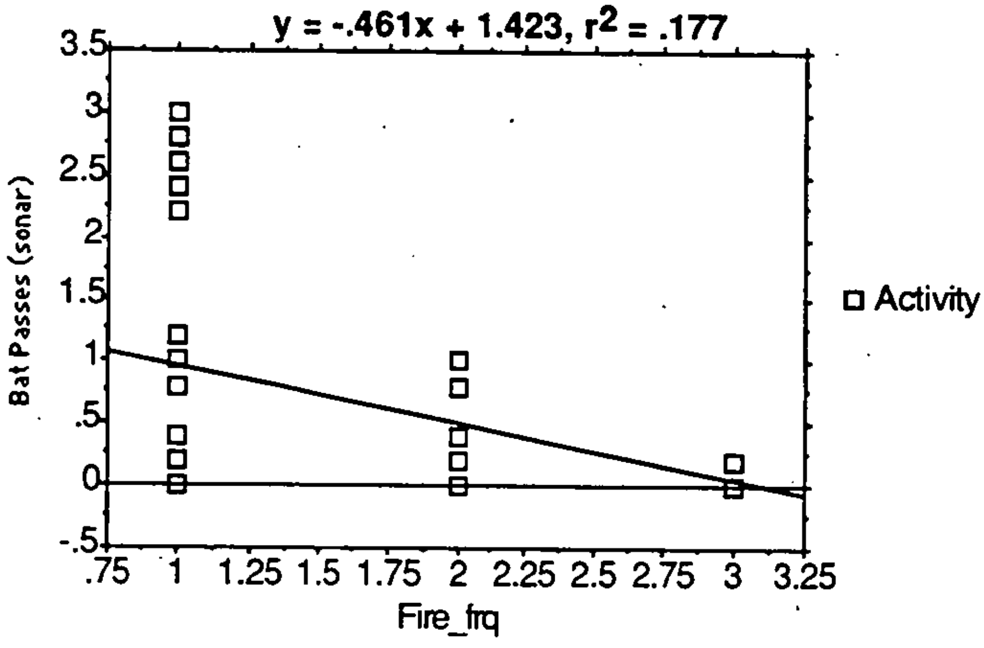


Figure 5.1b Relationship between Fire Frequency (1= every 2-5 years, 2= every 5-10 years, 3= > every 10 years) and the Species Richness and Abundance of Bats detected by Sonar.

Bat Communities Detected by Sonar
Species richness (species per 25 minutes) = 3.09 -0.827(fire frequency class*)
Bat Abundance (passes per 5 minutes) = 1.423 -0.461(fire frequency class*)
*Class 1= every 1-3 years, class 2= every 4-9 years, class 3 = every 10 or more years.

Bat Communities Detected by Trapping
Species richness (species per 25 minutes) = 1.329 -1.007 (fire frequency class*)
Bat Abundance (passes per 5 minutes) = 2.661 -1.81 (fire frequency class*)

Since frequent fire is naturally excluded from rainforest no mitigation measures are necessary for this type. However, overall bat diversity in hardwood forests, particularly in Dry Hardwood, is likely to increase with a reduction in the relative area affected by frequent fire. Options for enhancement of bat diversity in the Study Area include:

5.9 Exclusion of control burning and grazier burning as far as possible from gullies and protected aspects with the potential to develop good understorey cover. Burning should aim to achieve a mosaic of forests with different burning histories and levels of understorey development.

Abundance and Conservation Status

No species considered likely to occur in the region are listed as rare or threatened at the national level (Burbidge and Jenkins, 1984). Fourteen species are listed as Vulnerable and Rare in NSW under Schedule 12. At a regional level the conservation significance of bats in State Forests of the Study Area is considered to be primarily a function of their abundance (rarity), and sensitivity to logging and associated disturbance.

The relative abundance of bats in the study area is summarised in Table 5.2 and discussed by species in the following section. For the purpose of this study we classified species as rare if they were detected at fewer than three 3% of survey sites. Since there has been no other systematic survey of the Study Area, this is the best available information on the distribution and abundance of bats. Five insectivorous bats and 4 fruit bats considered likely to occur in the region were not detected during the study. Only one of these species, the Little Northern Mastiff Bat is considered rare, the other species either occur at the margins of their ranges in the study area and may only be present as vagrants (Hoary Bat, Large Pied Bat, North Queensland Long-eared Bat, Lesser Long-eared Bat), or their habitats were not well sampled (Fruit bats and their allies). The following species are classified as regionally rare:

Yellow-bellied Sheath-tailed Bat
Large-footed Myotis
Little Forest Eptesicus
Troughton's Eptesicus
Greater broad-nosed Bat
Beccari's Mastiff Bat
Eastern Little Mastiff Bat

These species are sufficiently uncommon and regionally rare (and since details of habitat requirements and ecology are few, procedures should necessarily err on the conservative) that options for mitigation of possible logging impacts should include:

5.10 Protection of known roost sites from harvesting disturbance by unlogged buffers of 100m radius;

5.11 Reservation of good examples of high diversity bat communities including these species in regional unlogged reserves and National Parks.

At present no roost site locations are known for these species in the Study Area.

Endangered Species Recovery and Management

Nyctimene robinsoni (Queensland Tube-nosed Bat)

Distribution: Central north-eastern Australia from the north-eastern corner of NSW to Cape York.
Abundance: Not recorded in this study. Rare in NSW, some Australian museum specimens from the Lismore region. Recorded from the Alstonville region by Milledge (1987) which appears to represent the southern known range limit.
Habitat: Found in timbered habitats ranging from rainforest to open forest, woodland and coastal heaths. Feeds on rainforest fruits and nectar of native trees and shrubs. May favour patches of rainforest for shelter.
Habitat Components: Favours the nectar of Banksias found in open woodlands and coastal heaths.
Threats: Reduction in abundance of flowering Banksias.
Impact Mitigation: 5.5, 5.6, 5.7, 5.8,5.9, 5.10.

Pteropus alecto (Black Flying-fox)

Distribution: Coastal northern Australia from north-east NSW to central coastal WA. Its range may be increasing southwards.
Abundance: Not recorded in this study, recorded in the Murwillumbah region (Baverstock and Chambers 1992) locally concentrated in north-east NSW with known roost sites near Lismore (McWilliam 1986).
Habitat: Dry sclerophyll forest, swamp forest and eucalypt woodland. Often camps in mangroves, on mangrove islands in estuaries, and in paperbark swamps and rainforest patches. Has also been recorded roosting in a shallow cave.
Diet: Feeds largely on the blossoms of Eucalypts, Paperbarks and Turpentines, and on native fruits.
Threats: Reduction in abundance of floriferous trees and shrubs (see Stace 1992 for a guide to nectar and pollen value of different species).
Impact Mitigation: 5.5, 5.6, 5.7, 5.8, 5.10.

Syconycteris australis (Queensland Blossom Bat)

Distribution: Coastal north-eastern Australia to Taree in NSW.
Abundance: Not detected in this study, locally common in coastal patches, detected at one site in Murwillumbah, and reported from Iluka Nature Reserve (NPWS 1993).
Habitat: Found in swamp forests, mature shrub heaths, rainforests, and nearby wet sclerophyll forests, where it feeds exclusively on nectar and pollen. Reported to roost in rainforest and/or moist hardwood forest gullies by day and forage for nectar and pollen in swamp forest and heath by night (Baverstock and Chambers 1992, A. Smith unpublished).
Habitat Components: Food plants include paperbarks, bottle brushes, banksias and bananas. Assumed to roost in tree hollows or under large hanging leaves.
Diet: Feeds on nectar and pollen in the canopy and understorey
Threats: Reduction in abundance of floriferous shrubs and trees.
Impact Mitigation: 5.5, 5.6, 5.7, 5.8, 5.11

Chalinolobus dwyeri (Large Pied Bat)

Distribution: Central inland NSW and Qld. in scattered localities along the western slopes, from Copeton north to the Queensland border.
Abundance: Not detected in this survey, reported at 2 sites in Murwillumbah (Baverstock and Chambers 1992). The closest known record is from a rainforest-sclerophyll forest ecotone north of Lismore (Parnaby 1986).
Habitat: Occurs in moderately well-wooded or forested habitats, where it forages below the forest canopy. Thought to inhabit Dry Sclerophyll forest, but caught in Wet Sclerophyll forest adjacent to Rainforest by Parnaby (1984) and rainforest and Moist Hardwood forest by Baverstock and Chambers (1992). Reported to favour moist forests by Richards (1991).
Habitat Components: Roosts in caves, mine tunnels, and the abandoned mud nests of Fairy Martins.
Diet: Forages above the canopy
Threats: Not known
Impact Mitigation Options: 5.10, 5.11

Chalinolobus nigrogriseus (Hoary bat)

Distribution: Northern Australia from the north-eastern corner of NSW to Kimberleys in WA.
Abundance: Not recorded in this study, but reported at Ramornie State Forest and Bundjalung National Park by Milledge et al. (1992).
Habitat: Occurs in a wide range of habitats, from wet sclerophyll forest to open woodland.
Habitat Components: Poorly known. Roosts in tree hollows and rock crevices.
Diet: A variety of insects and other invertebrates, many of which are gleaned from the ground, surfaces of trees, and rocks.
Threats: Not known
Impact Mitigation Options: 5.1, 5.2,5.3, 5.10,5.11

Eptesicus troughtoni (Troughton's Eptesicus)

Distribution: North-eastern Australia from Cape York to north-eastern NSW east of the Divide.
Abundance: Known from few records in NSW, rare in Study Area (trapped at Clouds Creek State Forest but no voucher specimen taken).
Habitat: Considered to occur in wet and dry sclerophyll forest and woodland.
Habitat Components: May depend on caves.
Threats: Not known
Impact Mitigation Options: 5.10, 5.11,

Falsistellus tasmaniensis (Great Pipistrelle)

Distribution: South-eastern and south-western Australia to Qld/NSW border region, along and east of the Divide.
Abundance: Locally common, recorded at 8% of survey sites (42,43,53,57,58,60,61 and Dalmorton State Forest).
Habitat: Found in tall wet sclerophyll forests.
Habitat Components: Roosts in tree hollows, also found in caves and may occupy abandoned buildings. Moist forest dependant.
Diet: Moths, beetles and ants.
Threats: Reduction in tree hollows
Impact Mitigation: 5.1, 5.11

Kerivoula papuensis (Golden-tipped Bat)

Distribution: Eastern coastal and sub-coastal Australia. Has been found in coastal NSW from Bega, near the Victorian border, to the Queensland border. Likely to be limited to warmer low altitude coastal forests within its marginal distribution, given its New Guinea-centred distribution, but occurs above 1000m on the eastern escarpment near Tenterfield (NPWS 1993).
Abundance: Detected at 3 sites in Grafton Casino(27,43,52a) and 3 sites (19%) in Murwillumbah (Baverstock and Chambers 1992), also detected in Ewingar, Richmond Range, Boundary Creek, and Billilimbra State Forests by NPWS (1993).
Habitat: Ranges from temperate coastal Eucalypt forests to tropical rainforest. Prefers thick vegetation near water. Thought to have a diet specialising in orb-weaving spiders.
Habitat Components: Roosts in thick vegetation in rainforest, particularly under palm fronds.
Diet: Gleans insects from trees in upper canopy
Threats: Loss of understorey caused by frequent burning and grazing.
Impact Mitigation: 5.9, 5.11

Miniopterus australis (Little Bent-wing Bat)

Distribution: Coastal and sub coastal north-eastern from Kempsey region in NSW to Cape York.
Abundance: Only 5 nursery sites are currently known in Australia. Scarce in Study Area in this survey (sites 50, 17), recorded in Tabbimobile and Mt Marsh State Forests by NPWS (1993).
Habitat: Occurs in most forest and woodland habitats. Forages beneath the canopy.
Habitat Components: Roosts in caves and tunnels.
Diet: Insects taken on wing beneath the canopy

Threats: Disturbance of over wintering and nursery roosts poses a major threat, as populations can be concentrated in a few small sites and hence will be extremely vulnerable. Disturbance of roosts greatly increases mortality. The tendency for colonies to be dominated by a particular sex and/or age class means that disturbances may also disrupt population structure.
Impact Mitigation: 5.10, 5.11

Miniopterus shreibersii (Common Bent-wing Bat)

Distribution: Coastal and sub coastal eastern and northern Australia from south-east SA to Kimberleys in WA.
Abundance: Regionally common, recorded at 35% of survey sites in the Wingham Forest Study Area by Richards (1992), recorded at 13% of sites in this study (17,32,37,50,54) and 1 site (6%) in Murwillumbah (Baverstock and Chambers 1992).
Habitat: Forages above the tree canopy in wet sclerophyll forest , rainforest and dry sclerophyll forest, favouring valley areas.
Habitat Components: Roosts in caves, old mines, stormwater channels, and buildings. Nursery caves essential for reproduction.
Threats: Disturbance of nursery and roost sites.
Impact Mitigation: 5.10, 5.11.

Myotis adversus (Large-footed Mouse-eared Bat)

Distribution: Coastal and sub-coastal eastern and northern Australia from SE-SA where it is rare, to the Kimberleys in WA. Occurs east of the Divide in NSW.
Abundance: Rare in Study Area, recorded at one site only (Washpool National Park over water). Recorded at 16% of survey sites in Wingham Study Area by Richards (1992) and 1 site in Murwillumbah (Baverstock and Chambers 1992). Reported in Billilimbra and Ramornie SFs by NPWS (1993).
Habitat: Moist Riparian forest habitat above 500m. Largely restricted by the availability of water bodies such as rainforest streams, lakes and reservoirs, where animals often feed on aquatic insects by raking the water surface with their hind claws. Considered rare in southern Australia, but common in the coastal tropics where suitable roost sites are apparently not restricted to caves required in south. Also recorded in several logged sites in the Wingham Study Area. (Richards, D.C., 1991).
Habitat Components: Roosts in caves, mines, tunnels, under bridges and in buildings near water. Animals gather in tightly clustered colonies of 10-15 animals during the breeding season. During the non-breeding season males roost alone. This species becomes torpid during winter, and winter roosts are separate from maternity sites. Also found roosting in dense foliage in the north of its range. The species also requires open, free water bodies for feeding.
Diet: Forages for aquatic insects, over water bodies, in low flight. Also forages in the air for flying insects.
Threats: Disturbance of feeding sites (pools).
Impact Mitigation: Protect roost sites, retain unlogged forest buffers adjacent to **major** creeks and rivers, 5.2, 5.4, 5.10, 5.11.

Scoteanax ruepellii (Greater Broad-nosed Bat)

Distribution: Sub-coastal (tablelands and east of Divide) eastern Australia from southern Cape york to the NSW/Vic. border.
Abundance: Rare in Study Area (Muck Creek and Kellys Creek roads in Clouds Creek State Forest), recorded to be uncommon by Parnaby (1984), reported from Richmond Range, Doubleduke and Ramornie State Forests by NPWS (1993).
Habitat: Moist forest including forest grassland ecotone, and riparian forest. Reported to be wet sclerophyll and rainforest dependant by Parnaby (1984).
Habitat Components: Usually roosts in tree hollows, also found in the roofs of buildings. May be dependant on riparian habitat.
Diet: Hunts above canopy (Richards 1922) along tree-lined watercourses, also thought to prey on small vertebrates.
Threats: Clearing and disturbance of riparian forest, loss of roost sites.
Impact Mitigation: recommendations 5.1,5.2,5.3, 5.9,5.10, 5.11

Saccolaimus (Taphozous) flaviventris (Yellow-bellied Sheathtail-bat)

Distribution: Found in NSW from the east coast through to the central western region. Extends further west in the north of the State.
Abundance: Rare in Study Area (detected at sites 28, 53 in Ewingar and Fortis Creek State Forests respectively). Patchily distributed.
Habitat: Found in wet and dry sclerophyll forests below about 500m elevation, where it forages above the canopy. Also found in mallee and open country, where animals feed closer to the ground.
Habitat Components: Roosts in tree hollows.
Diet: Feeds on insects while flying rapidly above the canopy
Threats: Reduction in tree hollows
Impact Mitigation: 5.1, 5.2

Mormopterus beccarii (Beccari's Mastiff-bat)

Distribution: Northern Australia from the coastal north-eastern corner of NSW to the WA. Qld. border.
Abundance: Regionally rare, recorded by sonar on 2 occasions (sites 42, 61) but calls may have been confused with other *Mormopterus sp.*, requires confirmation.
Habitat: Forages in habitats ranging from closed forests to woodland, but appears to prefer structurally open forest due to poor manoeuvrability.
Habitat Components: Roosts in hollow trees and under the roofs of houses.
Diet: Leafhoppers, chafers, weevils and other beetles (requires open spaces for foraging due to its lack of manoeuvrability).
Threats: None known
Impact Mitigation: 5.1, 5.2, 5.3, 5.11

Mormopterus norfolcensis (Eastern Little Mastiff-bat)

Distribution: Coastal eastern Australia, from approximately Sydney to Fraser island.
Abundance: Patchy, uncommon, restricted and poorly known. Reported to be common in the Washpool National Park by Tideman (1982). Roosting colonies may contain up to 50 animals. Rare (detected by sonar at sites 61.60b but no voucher specimens obtained) in Study Area.
Habitat: Lives in sclerophyll forest and woodland, where it hunts insects above the canopy or in clearings at the forest edge.
Habitat Components: Roosts in tree hollows and under loose bark. Has also been found in the roofs of buildings.
Diet: Hunts insects above the canopy or in forest clearings for leafhoppers, chafers, weevils and other beetles.
Threats: None known
Impact Mitigation: 5.1, 5.2, 5.3, 5.11

Nyctophyllous bifax (North Queensland Long-eared Bat) Vulnerable and Rare (Schedule 12)

Distribution: Northern Australia from northern Western Australia, Northern Territory and north Queensland to about Rockhampton. Coastal from Rockhampton southwards to north-eastern New South Wales, just south of Queensland border (Strahan 1991; Parnaby 1992a).
Abundance: Not recorded during this survey, although previously recorded in Iluka Nature Reserve in the Grafton-Casino region. Reported by Parnaby (1992a) to be common, but localised.
Habitat: Found in a variety of habitats ranging from Rainforest to Dry Sclerophyll Woodland; often found along watercourses (Strahan 1991).
Habitat Components: Roosts in tree hollows and in roofs of buildings.
Diet: Invertebrates from the air and from foliage (Strahan 1991).
Threats: Reduction in tree hollows.
Impact Mitigation: 5.1, 5.2, 5.3, 5.9, 5.10, 5.11.

6. IMPACTS ON NON-FLYING MAMMALS

Introduction

The State Forests of the Grafton, Casino region include some of the most diverse and significant mammal habitats in NSW. Calaby (1966) reported that the Clarence Valley supported a greater range of mammal species than any other region of comparable size in Australia. This region also has considerable conservation significance as a refuge for many mammal species whose ranges have declined elsewhere in Australia (including the Long-nosed Potoroo, Rufous Bettong, Parma Wallaby, Black Striped Wallaby, and Brush-tailed Phascogale). Range decline precedes extinction and there have been more mammalian extinctions in Australia than in any other continent of equivalent size. These extinctions have affected mainly medium sized mammals in the body weight range of 35 grams to 5500 g, referred to as Critical Weight Range or CWR mammals. The reason for these extinctions has not been conclusively established, but Fox predation is considered the main cause. Current evidence indicates that survival of CWR mammals is higher in productive environments with: a dense shrub or ground cover to provide protection from predators; low densities of Foxes and Rabbits, and presence of Tiger Quolls and or Dingos as the dominant natural predators.

Previous mammal surveys in the Study Area have been patchy in geographic coverage (Chapter 2), and scope has largely been limited to collation of distribution records and description of species broad habitats. The Moist and Dry Hardwood State Forests of the escarpment and New England Tablelands to the west of the study area have been comprehensively surveyed and described by Smith et al. (1992) with emphasis on assessment of logging impacts. The mammal communities of the Washpool and Gibraltar National Parks have been described by Osborne (1982) and Pulsford (1982). Mammal communities of the Rainforests and Moist Hardwood forests in National Parks of the Border Ranges to the north and north-west have been surveyed by Smith et al. (1989a,b). Survey of State Forests and private property within the region has been limited. Milledge (1986) surveyed the fauna of Coastal Byron Shire and Smith et al. (1990) surveyed the fauna of private land in the Orara and Bucca Valleys to the south of Grafton. In addition to these general surveys there have been a number of more focused surveys targeting specific localities or species (Koala, Potoroo and Rufous Bettong) throughout the region (see Chapter 2). The least surveyed habitats are the coastal and sub-coastal Hardwood forests and associated heaths and swamp forests. A limited survey of Candole State Forest (Smith, 1982) revealed a high arboreal diversity in an area adjacent to Yuragir National Park.

A list of all mammal species known or considered likely to occur in the Study Area is given in Appendix F. No species of mammal are endemic to the Study Area, but the region covers a significant portion of the range of two geographically restricted species, the Parma Wallaby and the Hastings River Mouse. Candole State Forest appears to be a stronghold for the Squirrel Glider in NSW. Candole and other coastal State Forests to the north, and foothill forests to the west including Dalmorton State Forest, appear to be major population centres for the Yellow-bellied Glider in NSW. Other species occur at their geographic limits, in the region and may represent genetically isolated populations. Such species include the Dusky Antechinus, Eastern Pygmy-possum, Black Striped Wallaby, and New Holland Mouse.

Scope and Methods of Survey

Survey Design

Mammals were surveyed at 77 sites (Appendix A) by a variety of complementary standardised techniques including: spotlighting; scat collection; hair sampling; small mammal trapping; wet pitfall trapping; and predator scat analysis. Details of stratification, sampling, statistical analysis and interpretation methods are given in Chapter 2.

Spotlighting

Large arboreal mammals were surveyed at night by spotlighting along walked and vehicle driven transects. The procedures followed are described in York et. al. (1991). Each of the five 100m units in the survey transects was searched for a minimum of nine minutes. For each animal detected, the right angle distance from the transect, the species of tree occupied, and other information, including forest structure and visibility, were recorded. Temperature, weather conditions, and time of day were also recorded at each census. The results of spotlighting surveys are strongly biased by vegetation structure, due to the greater visibility in open forests compared to denser forests (Smith et al., 1992). For this reason, vegetation structure was included as a variable in all multi-variate habitat analyses. Habitat preferences and effects of logging were determined by comparing total numbers of animals seen to a distance of 20m either side of the transect, after York et. al. (1991).

Trapping

Small mammals were surveyed using aluminium Elliott live traps and wet pitfall traps (see Chapter 7 for description of wet pitfall techniques). Five small traps, baited with a mixture of peanut butter and rolled oats, were set 20m apart along the first unit of each transect for two nights. One large Elliot trap baited with rolled-oats and peanut butter and one large wire mesh cage trap baited with meat were set at each end of the transects for two nights.

Hair Sampling

Hair tubes, alternately baited with sardines and chicken for carnivores, and rolled oats and peanut butter for omnivores, were set on the ground for a minimum of two weeks, one in each unit of each transect. Hair samples were analysed by B. Triggs. Although few mammals could be identified to the specific level using this technique, the procedure provided valuable information on the distribution of Spotted-tailed Quoll.

Scats and Signs

Scats and signs of mammals were recorded during a half man hour search of each transect unit. The procedure proved useful for detecting the presence of macropods and large possums and gliders.

Opportunistic Sightings

Macropods or other mammals that were observed during other censes (ie. bird survey) were recorded as opportunistic data, but were not included in quantitative analyses.

Predator Scats

Roads close to transects were searched for a period of 10 minutes for predator scats. The source and content of the scats were analysed by B. Triggs.

Pitfall Traps

A number of small mammal species were detected in wet pitfall traps set for reptiles. These records were treated as opportunistic data.

Data Analysis

Associations between the relative abundances of mammals and continuous environmental and cultural variables were investigated using regression analysis. Associations with categorical environmental variables were identified by Analysis of Variance. Relationships between species presence-absence data and environmental and cultural variables where analysed by Chi-square and Log-likelihood Chi-square analysis. The results of statistical analyses were interpreted in an ecological context and compared with expected findings based on literature review and expert ecological opinion. For further details see Chapter 3.

Mammal species richness was calculated as the number of mammal species, in the relevant taxon, detected at each site by all methods (scats and signs, spotlighting, trapping, hair sampling, and opportunistic encounters).

Data Interpretation

Impact assessment was based on a combination of:

literature review of logging impacts measured in similar situations elsewhere in Australia;

statistical modelling of associations between measured mammal diversity and abundance, and previous logging and land use in the study area;

ecological interpretation of predictive models to forecast likely impacts under alternative management regimes.

Impact prediction by these methods involves an element of uncertainty which can only be eliminated by long term monitoring. Monitoring procedures are recommended where there is a high level of uncertainty.

Mammal Diversity and Communities

Field surveys, literature review and searches of museum records and data bases revealed that a total of 41 species of native mammal and 10 species of introduced mammals have been recorded in the Study Area (Appendix F). In order to gain a more detailed insight into associations between cultural and natural environmental variables, and mammal diversity and abundance, mammals were classified into three guilds:

1. Arboreal Mammals
   a) Folivores (Brushtail and Ringtail Possums, Greater Glider and Koala)
   b) Nectarivore/insectivores (Petaurid Gliders, Feathertail Glider and Burramyids)
2. Grazers and Browsers
   a) Kangaroos and Wallabies
   b) Domestic stock
3. Terrestrial Carnivore/Omnivores
   a) Insectivores (Potoroids, Bandicoots, Dasyurids, Echidna)
   b) Carnivores (Dasyurids, Dingo, Fox, Cat)
   c) Omnivores (Rodents)

Mammals in these guilds are expected to exhibit broadly similar responses to timber harvesting, land use and natural habitat gradients.

Arboreal Mammals Possums and Gliders

Species of the Study Area

A total of 10 species of arboreal mammals have been reported in the Study Area (Osborne, 1982; Pulsford, 1982; Smith, 1982; Smith et al., 1989a,b; A. Smith unpublished). This group includes five species of arboreal folivores, including the Koala, Greater Glider, Common Ringtail Possum, and Brushtail Possums, and five nectarivore/insectivores including three Petaurid Gliders, the Feathertail Glider and the Eastern Pygmy Possum (Table 6.1).

The relative frequency occurrence of arboreal mammals in the Study Area is summarised in Table 6.1

Table 6.1 Frequency of Occurrence (on survey sites) of Arboreal Mammals Detected in the Study Area.

Species	Number of Sites Occupied	Frequency of Sites (%) Occupied
Koala	3	4
Greater Glider	40	51
Ringtail Possum	17	22
Common Brushtail Possum	16	21
Mountain Brushtail Possum	29	37
Yellow-bellied Glider	12	15
Squirrel Glider	0	0
Sugar Glider	17	22
Feathertail Glider	2	3
Eastern Pygmy-possum	0	0

Four species occurred at less than 5% of survey sites. These species (the Koala, Squirrel Glider, Feathertail Glider, and Eastern Pygmy-possum) are rare in the State Forests of the Study Area. The Feathertail Glider is difficult to detect because of its small size. Most records result from chance encounters. It is not clear at present whether the apparent rarity of this species is real or an artefact of its cryptic behaviour. Only 2 individuals were detected in this study, but on the basis of known ecological requirements this species is likely to occur throughout the eucalypt forests of the Study Area. The Squirrel Glider was not detected in this study, but has been detected in Candole State Forest on at least 4 separate occasions indicating that this area is likely to be a regional stronghold for the species. The Eastern Pygmy Possum has been recorded in a Fox scat in Richmond Range State Forest (A. Smith unpublished) but is otherwise unknown in the Study Area.

Diversity and Habitat Requirements

Arboreal mammal species richness and abundance was greatest in Moist Hardwood forest, but differences between habitat types were not statistically significant. The average number of arboreal mammals detected per transect was 1.7 in Moist Hardwood, 1.4 in Dry Hardwood, and 1.0 in Rainforest. These counts equate roughly to numbers per hectare (in Hardwood forest types) of the larger possums and gliders, which are readily detected by spotlight. The total transect area searched was 2 ha (500m by 40m) and approximately half of all animals present are likely to be missed during spotlight searches due to the effects of forest cover on visibility. Visibility is so low in Rainforest that true densities cannot be readily estimated from transect counts.

Greater Glider abundance was found to decline significantly with decreasing hollow numbers ($r = 0.42$, $P < 0.04$). All arboreal mammals in the Study Area, except Koalas, den in tree hollows. Shortage of nest sites may limit arboreal mammals where the density of hollow bearing trees is less than 2 to 8 trees per hectare (Smith and Lindenmayer, 1988; Smith et al. , 1992). Koalas, which sleep exposed on tree limbs, may require large trees with sufficient branch development for resting. The mean number of arboreal mammals per transect was also significantly lower in culled forest (Mann Whitney U test P< 0.05 mean for culled forest = 0.67 per transect, mean for non-culled = 1.66 per transect). This result can be explained by a reduction in habitat tree (tree hollow) availability in culled forest but may also reflect differences in habitat quality.

Foraging structure can also limit folivore diversity and abundance. Different species are adapted to moving and feeding in different layers in the forest and may be absent from areas which lack appropriate foraging substrate. Gliders favour habitats with relatively open structure, larger species preferring mature forests. In this study, both large gliders, the Greater Glider and the Yellow-bellied Glider, were found to be significantly more abundant in taller (>30m) forests (r=0.32, P< 0.02, Chi-square, P< 0.02).

The guild of arboreal mammals can be further subdivided on the basis of dietary preference, into folivores and nectarivore/insectivores. The folivores are widespread and abundant but exhibit local variation in distribution and abundance in response to factors such as tree species composition, foliage protein and fibre levels, leaf toughness, toxins, forest structure and the availability of shelter sites. Arboreal folivores are expected to be most abundant in areas of high productivity, high soil fertility and moderate climate, where there is adequate shelter and suitable foraging substrate. In this study arboreal folivore species richness was greatest in Moist Hardwood forests and was found to increase significantly with forest canopy cover, an index of site quality (r=0.4, P< 0.002).

Arboreal nectarivore/insectivores feed on a wide variety of plant and insect exudates including the nectar of flowering eucalypts and shrubs, particularly Banksia, the gums of certain Acacias and the sap of specific trees which are incised to induce sap flow. They also feed extensively on insects particularly under the shed bark of eucalypts. The distribution and abundance of nectarivore/insectivores is considered to be related to the abundance of nectar and pollen producing plants (particularly those producing in winter), the abundance of bark shedding eucalypts which harbour insect prey, and occurrence of key sap and gum exudate producing trees (Sap Feed Trees) and shrubs (gum producing Acacias). The most important areas for arboreal nectarivore-insectivores in the Study Area are considered to be Candole State Forest and the mature (unlogged) Grey Gum-Grey Ironbark-Spotted Gum forests of Dalmorton State Forest. The Candole region supports an exceptionally high eucalypt diversity (Smith, 1982), which helps to ensure a year round nectar supply. It also grades into heath and swamp forests with reliable winter flowering Banksia and Ti tree (*Melaleuca quinquinervia*). This area, and similar forests to the north, are known for their significance to the Yellow-bellied Glider (FCNSW, 1987). Unlogged forests in Dalmorton State Forest were also found to support abundant Yellow-bellied Gliders during this study. This can be attributed to the predominance of preferred sap feed trees especially Grey Gum, and mature examples of good nectar and pollen producing Dry Hardwood species.

With the exception of the Yellow-bellied Glider, the nectarivore-insecitvores were too infrequently detected for statistical analysis of habitat preferences and sensitivity to logging. Ecological considerations suggest that this group are most likely to benefit from the same management practices which benefit apiary. These are:

a) management practices that allow a multi-species tree population to occur;

b) the maintenance of the major honey and pollen production species within the forests as sufficiently mature trees to allow maximum honey and pollen production (after Stace, 1992).

Species Habitats and Response to Logging

Greater Glider

Greater Gliders are widespread and common in tall open and open eucalypt forests, but are most abundant in high site quality old-growth eucalypt forests (Kavanagh, 1984) where they feed upon young eucalyptus leaves and flowers. This species is by far the most abundant arboreal folivore in the Study Area occurring at 51% of survey sites. Because they show seasonal variation in their preference for tree species, Greater Gliders favour forest with a diversity of Eucalypt species (Kavanagh, 1984). The relative abundance of Greater Gliders on survey transects was significantly greater at higher elevations ($r = 0.35$, $P < 0.002$); in forest with more abundant tree hollows ($r = 0.42$, $P < 0.04$); forests that are infrequently burnt ($r=0.29$ $P<0.002$) and forests with a tall canopy ($r = 0.28$, $P < 0.02$). These findings are consistent with expectations and can be explained by the occurrence of moist, high productivity forests at mid to higher elevations within the Study Area.

Common Ringtail Possum

Common Ringtail Possums are reported to be most abundant in Rainforest (Osborne, 1982) and Moist Hardwood with a rainforest understorey (Dunning and Smith, 1986) in north-east NSW, but are also found in most types of Eucalypt forest. In this study, the frequency of occurrence of Common Ringtail Possums was found to be significantly correlated to canopy height (Chi-square $P < 0.04$) forest type (Chi-square $P < 0.04$), and shrub cover (Chi-square $P < 0.001$). They are most abundant in tall Rainforests and Moist Hardwood Forests with greater than 50% shrub cover.

Mountain Brushtail Possum

Mountain Brushtail Possums are reported to be most common in Rainforest (Osborne, 1982) and Old-growth Moist Hardwood forest in north-east NSW (Dunning and Smith, 1986). In this study, they were found to be most common in Eucalypt forest with rainforest understorey (Chi-square $P < 0.002$).

Common Brushtail Possum

Common Brushtail Possums occur at moderate to low densities in a wide range of habitats including farmland, but are generally most abundant in dry forest and woodland types where they may feed on herbs and eucalypt leaves. This species was not detected in the Washpool and Gibraltar Range National Parks by Osborne (1982) or Pulsford (1982). We found it to be less common than the Mountain Brushtail Possum, occurring mostly in Dry Hardwood forests and Moist Hardwood forests with a grass understorey (Chi-square $P < 0.009$).

Sugar Glider

Sugar Gliders are widespread and moderately abundant in Eucalypt forests and woodlands, favouring areas with Acacia understorey (Smith, 1982). Osborne (1982) found the greatest number of Sugar Gliders among regrowth Eucalypt and Acacia with some mature Eucalypts still present. In this study, Sugar Gliders were detected mainly by call but despite a relatively high frequency of occurrence no specific habitat associations were apparent.

Squirrel Glider

Squirrel Gliders are closely related to the Sugar Glider and have similar ecological requirements (Strahan, 1983). Due to their larger size, they require more reliable and productive environments, particularly those with an abundant and reliable winter nectar supply. There are few records of the Squirrel Glider in the Study Area (Appendix F), but 4 separate surveys have reported Squirrel Gliders in Candole State Forest suggesting that this area is a regional stronghold for the species. Available information suggests that this species will occur in greatest abundance in floriferous sub-coastal and coastal forests with a high diversity of good nectar and pollen producing Eucalypts and *Banksia integrifolia* in the understorey. The largest known population in the general region occurs in coastal Blackbutt/ heath forest at Limeburners Nature Reserve north Port Macquarie (A. Smith unpublished data).

Feathertail Glider

Feathertail Gliders are widely distributed in eucalypt forests and woodlands where they feed on Eucalypt nectar and pollen. The species is infrequently encountered and difficult to census. Most records result from chance encounters. It is not clear at present whether the apparent rarity of this species is real or an artefact of cryptic behaviour. Only 2 individuals were detected in this study, however on the basis of its known ecological requirements this species is likely to occur throughout the eucalypt forests of the Study Area.

Yellow-bellied Glider

Yellow-bellied Gliders are widespread at low densities in north-east NSW reaching their western known range limit along the boundary of the Study Area. They occur in a wide range of Eucalypt forests but most frequently in Dry Sclerophyll forest (Mackowski, 1986). They have large home ranges (10-100 ha) in which microhabitat preference may vary seasonally according to patterns of flowering, bark shedding and the availability of other food resources (Kavanagh, 1984). This species was detected mainly by call and feeding scars at 12 widely scattered sites. In Dalmorton State Forest abundant feed scars were observed in Grey Gums throughout unlogged mature forest and the species was detected at all sites surveyed.

Kangaroos and Wallabies

Species of the Study Area

Eleven species of Macropods, including the Rufous Bettong, are recorded in the Study Area (Calaby, 1966). The relative abundance of species detected in this study is show in Table 6.2

Table 6.2 Frequency of Occurrence of Macropods at Survey Sites in the Study Area.

Species	Sites	Frequency (%)
Eastern Grey Kangaroo	29	37
Red-necked Wallaby	41	53
Common Wallaroo	0	0
Swamp Wallaby	37	47
Whiptail Wallaby	1	1
Brush-tailed Rock Wallaby	0	0
Black-striped Wallaby	0	0
Parma Wallaby	1	1
Red-necked Pademelon	16	21
Red-legged Pademelon	0	0
Rufous Bettong	1	1

Seven species were detected at less than 5% of sites and are considered regionally rare or localised. The Whiptail Wallaby was detected opportunistically on steep grassy slopes at

3 locations. It reaches the southern limit of its range in northern NSW but is relatively common in south-east Queensland. The Brush-tailed Rock Wallaby is widely distributed on rock faces with northerly aspects along the Upper Clarence (Calaby, 1966). These habitats were not sampled during this survey. The Black-striped Wallaby has been reported at a number of locations in the Study Area (Calaby, 1966) but is regionally scarce. It occurs at its southern range limit in the region and is more abundant in Queensland. The Red-legged Pademelon is predominantly a rainforest species and its apparent rarity may reflect limited sampling of this habitat type. The Common Wallaroo is regionally scarce in the coastal portion of its range (Calaby, 1966) where it is largely confined to steep rocky slopes, a habitat which was not surveyed during this study. It is abundant elsewhere in Australia. The Parma Wallaby was only reported at one site in Washpool National Park. It is patchily distributed along the escarpment to the west of the Study Area (Smith et al., 1992)

Diversity and Habitat Requirements

In general macropods select habitats which provide a combination of dense cover for shelter and refuge, and open areas for feeding. This combination of resources commonly occurs on forest edges, or in vegetation mosaics created by fire, grazing or logging. The larger grazing species (Grey Kangaroo, Red-necked Wallaby, Common Wallaroo, Whiptail Wallaby) tend to occupy drier more open habitats; the smaller species, moister more densely vegetated habitats (Pople, 1989).

Three species, the Red-necked Wallaby, Swamp Wallaby and Grey Kangaroo are common within the Study Area. All 3 benefit from the expansion of grassy understorey in the forests as a result of grazing and frequent burning. The Red-necked Wallaby was found to be significantly associated with Dry Hardwood forest with a grass cover of greater than 50% (Chi-square $P< 0.05$). The Eastern Grey Kangaroo was significantly associated with forest with a grassy understorey (Chi-square $P< 0.04$). The Swamp Wallaby was significantly associated with areas with bracken and grass cover (Chi-square $P< 0.04$).

Smaller macropods are more restricted within the Study Area, apparently preferring the interface between moist forest and grasslands. The interface between regularly burnt open forest and moist closed forest is particularly favoured by the Black-striped Wallaby, Parma Wallaby, Red-necked Pademelon and Long-nosed Potoroo (Johnson, 1980; Southwell, 1987). Red-necked Pademelons rarely move more than 100m from moist forest and may reach pest proportions where agriculture or forestry has created a mosaic of forest and open grassland (Johnson, 1984, in Strahan 1984). The Parma Wallaby has been found to prefer Moist Hardwood and Rainforest with dense understorey and patches of open grass (Read and Fox, 1991; Smith et al., 1992).

In this study the Red-necked Pademelon was found to be significantly associated with unburnt forest (Chi-square $P< 0.007$), rainforest understorey (Chi-square $P< 0.05$) and grass cover of 5-20% (Chi-square $P< 0.04$). The Rufous Bettong was detected at one site in Mount Marsh State Forest, and a number of opportunistic sightings were made in Grange State Forest, Glenugie State Forest and in agricultural landscapes on the border of Washpool/Ewingar State Forests. The species is locally common in grassland with scattered trees at Baryulgil where one road kill and 3 sightings were recorded. The absence of any records of this species from hair sample tubes suggests that it is regionally scarce in State Forests particularly in the east of the Study Area, a distribution pattern consistent with the findings of Schlager (1981). This species prefers open forest habitat where it feeds upon roots and tubers as well as herbs, grass and fungi. At Wallaby Creek in north-east NSW, the Rufous Bettong is reported to occur in a mosaic of grassland and open forest, where it is negatively associated with canopy density, and positively associated with ground vegetation diversity and cattle density (Southwell, 1987). Rufous Bettong have been reported to feed on improved pasture (Calaby, 1966).

Dasyurids, Bandicoots, Rodents, Echidna, and the Potoroo

Species of the Study Area.

The terrestrial carnivore/insectivore/omnivores include a diverse range of species from 5 different orders. The relative abundance of each species detected during this survey is shown in Table 6.3.

Table 6.3. Frequency of Occurrence of Carnivorous, Insectivorous and Omnivorous Mammals in the Study Area.

	Sites (no)	Frequency (%)
Carnivores:		
Spotted-tailed Quoll	3	4
Cat	7	9
Dingo	7	9
Scansorial insectivores:		
Brushtailed Phascogale	0	0
Brown Antechinus	9	12
Yellow-footed Antechinus	1	1
Ground Insectivores		
Dusky Antechinus	0	0
Common Dunnart	2	3
Common Planigale	0	0
Soil insectivores:		
Long-nosed Potoroo	1	1
Echidna	43	56
Northern Brown Bandicoot	2	3
Long-nosed Bandicoot	5	6
Aquatic Insectivore		
Water Rat	0	0
Terrestrial Omnivores: Rodents		
Bush Rat	6	8
Swamp Rat	0	0
Pale Field Rat	0	0
Fawn-footed Melomys	3	4
Grassland Melomys	0	0
Hastings River Mouse	0	0
Eastern Chestnut Mouse	1	1
New Holland Mouse	0	0

The apparent rarity of some species (Swamp Rat, Water Rat, Grassland Melomys, Pale Field Rat, New Holland Mouse, Common Planigale, Common Dunnart) is attributed to a preference for habitats that were not surveyed during this study. The long-nosed Potoroo, Spotted-tailed Quoll, Brush-tailed Phascogale, Yellow-footed Antechinus, Dusky Antechinus, Chestnut Mouse, New Holland Mouse and Hastings River Mouse, are considered rare or localised in the Study Area on the basis of these results and those of previous surveys in the region.

Species richness in this guild increases along a gradient of decreasing moisture in the shrub understorey ($r=0.3$, $P< 0.005$) and increasing fallen timber (large log) cover ($r=0.28$, $P< 0.02$). With the exception of 3 common species with well known habitat requirements (the Echidna, Brown Antechinus and Bush Rat) insufficient records were obtained to analyse the effects of habitat and land use on individual species.

Impact Assessment and Mitigation

Logging and Succession

Few studies have compared mammal communities before and after logging and none have monitored post logging impacts over a full logging cycle. Consequently our understanding of logging impacts on mammal communities is based largely on post disturbance comparisons of mammal diversity between logged and unlogged forests. The results of such studies have shown that fauna communities undergo a successional change with time since logging, which varies in magnitude and recovery time with the intensity of timber harvesting and the proximity of unlogged refuge areas.

An understanding of patterns of successional changes under both intensive and selection logging is necessary to predict impacts, because logging intensity generally varies considerably within forestry districts in time and space, according to market demand for small diameter wood, site quality, and previous management history. Current objectives of harvesting in the Study Area involves maximum economic utilisation and does not include woodchipping of residual roundwood. Thus logging intensity will be high in high quality stands of mature or greater age forests with uniform age structure, such as old-growth Moist Hardwood and intensively treated regrowth Blackbutt, and low in uneven aged stands with a significant proportion of young stems, such as untreated low quality Dry Hardwood.

High intensity logging results in a decline in arboreal mammal richness and abundance followed by a gradual recovery as habitat returns to a stage suitable for recolonisation. The age at which forest becomes suitable for re-colonisation varies between habitats and regions. A number of species have been shown to re-invade logged or burnt habitat in the early stages of succession. Mountain Brushtail Possums recovered 6 years after low intensity logging in Moist Hardwood Forest (M. Howarth and A. Smith unpublished data). Common Ringtail Possums have been reported to reach peak abundance in Moist Hardwood forest 10-25 years after logging in north-east NSW (Dunning and Smith, 1986) but may prefer old-growth elsewhere (Davey and Norton, 1990). Sugar Gliders are reported to reach maximum abundance in Moist Hardwood forests at mid-successional stages in the Eden region (Davey and Norton, 1990). Species which have been shown to reach peak abundance in forests greater than 100 years of age include the Yellow-bellied Glider, Eastern Pygmy-possum, Greater Glider, Sugar Glider, Squirrel Glider and Common Ringtail (Smith et al., 1985; Dunning and Smith, 1986; Davey and Norton, 1990; Milledge et al, 1991). Milledge et al. (1991) found that, in the Victorian Central Highlands where intensive logging is practiced, Greater Gliders and Yellow-bellied Gliders are most abundant in forest greater than 165 years of age. M. Howarth and A. Smith (unpublished data) compared Moist Hardwood forests in the Mt Boss region that had been experimentally logged at a range of intensities. They found that Yellow-bellied Gliders occurred only in unlogged old-growth forest. By contrast, Greater Gliders declined approximately in proportion to the amount of canopy removed. The seral preferences of Feathertail Gliders and Eastern Pygmy-possums have not been studied, but are expected to be strongly influenced by changes in the abundance of flowering eucalypts and understorey shrubs after fire and logging.

Survey design in this study precluded a reliable assessment of the effects of logging intensity and time since logging on arboreal mammals. The majority of survey sites (87%) were uneven-aged in structure following past selection or moderate to low intensity logging. Only 4 of the sites classified as unlogged old-growth were dominated by a predominance of large old stems (>1m dbh), and only 6 sites had a predominantly juvenile age structure resulting from intense logging within the past 10 years. No significant effects of forest type, logging intensity, age structure, or time since logging on species richness and abundance of arboreal mammals were apparent within the Study

Area. This result is considered to reflect the prevalence of moderate to low intensity harvesting throughout the region. This does not mean that logging intensity has no effect, since most of the study region has been logged previously and few unlogged sites were available for comparison.

At the species level, the Mountain Brushtail Possums were recorded most frequently in intensively logged Moist Hardwood forests (Chi-square $P < 0.03$) and Greater Gliders were found to be significantly associated with forest logged at moderate intensity (Chi-square $P < 0.02$). Yellow-bellied Gliders occurred in logged forests (Candole State Forest) but were most abundant in unlogged forest, and were absent from forests logged during the preceding 5 years. No other arboreal mammals were found to exhibit significant associations with either logging intensity or duration in this study.

Survey results should be interpreted with caution because the analysis of spotlighting data is problematic due to variation in detectability (visibility) of animals in forests of different structure. Comparisons cannot be readily made between dense forests such as Rainforest, Moist Hardwood and vigorous young regrowth and open forests such as grazed Dry Hardwood and recently logged forest. Increased visibility in recently logged forest may compensate for decreased fauna populations. Smith et al. (1992) found that total counts of greater gliders were higher in logged than unlogged forests in the Glen Innes region until detectability differences were taken into account, when the reverse trend became apparent. At present it seems most likely that the abundance of arboreal folivores will decline in approximate proportion to logging intensity (as indicated by the % stand basal area removal), and that Yellow-bellied Gliders will decline in greater proportion than expected from canopy removal.

Since most of the Study Area has already been logged, the most severe future impacts are likely to result from the logging of remaining patches of high quality Old-growth forest (Moist Hardwood and high quality Dry Hardwood) and the re-logging of high quality Moist Hardwood sites which were only lightly logged in the past, such as those in Cangai State Forest. The species most likely to be adversely affected during the next 10 years are the Yellow-bellied Glider and the Greater Glider. The former by logging of mature unlogged and Old-growth high site quality (>30m) Spotted Gum, and Grey Ironbark forest in Dalmorton and Mt Marsh SFs and the latter by logging of remaining patches of high quality Moist Hardwood in Dalmorton SF, and Old-growth Moist Hardwood in Washpool and Billilimbra SFs.

Options for mitigation of impacts on arboreal mammals which reach peak abundance in unlogged high quality old-growth forest include.

6.1 Reservation of all remaining areas of unlogged Moist Hardwood and high quality Dry Hardwood from logging.

6.2 Reduced logging intensity of high quality Dry Hardwood forests to retain 50% of the stems >40cm dbh in order to maintain a permanent uneven aged structure.

6.3 Marking and retention of all feed trees of the Yellow-bellied Gliders (this represents continuation of current practice)

6.4 Reservation of Moist Hardwood forests in Cangai State Forest from future logging to permit restoration of old-growth structure.

Tree Hollows

All species of arboreal mammals, with the exception of the Koala, den in tree hollows. In some regions of Australia the Common Ringtail Possum is known to construct free nests in dense vegetation, however this habit has not been observed in the Study Area where Common Ringtail Possums are considered most likely to rely upon tree hollows for shelter and nesting. Hollows provide animals with shelter from climatic extremes and protection from predators during nesting, reproduction and hibernation. There have been few studies on hollow selection by arboreal mammals, but size, depth, orientation, aspect, insulation, cover and many other features may be important. Most animals choose hollows with entrances approximating their body size. Large deep hollows are preferred by the larger species of possums and gliders (see Ambrose, 1982). The availability of tree hollows in natural forests is determined by many factors including tree species, site quality, tree spacing, and fire history. The size and age distributions of the trees are apparently the most important factors. Most eucalypts do not develop hollows until more than 100 years of age (Ambrose, 1982). Large hollows do not develop in Blackbutt *(Eucalyptus pilularis)* until approximately 200 years of age (Mackowski, 1984).

Naturally occurring old-growth and mixed aged forests generally contain abundant hollows. The extent to which the number of trees with hollows can be reduced without having a significant impact on arboreal mammal populations has been determined in the moist tall open forests in Victoria (Smith and Lindenmayer, 1988). The number of arboreal mammals (determined by stag watching) was found to be directly proportional to the number of habitat trees up to a density of 4-6 hollows per ha. Because most arboreal mammals are territorial, and habitat trees are not usually shared, maximum population densities occur where habitat trees are evenly spaced throughout the forest. These estimates can be used to predict the tree hollow requirements in other regions provided that some allowance is made for differences in habitat quality and arboreal mammal density. Smith et al. (1992) found no significant relationship between tree hollow density and the abundance of arboreal marsupials in the Glen Innes Region where logging intensity was generally low and habitat tree availability averaged 8 trees/ha. By contrast, in this study Greater Glider abundance was found to decline significantly with decreasing tree hollows. This result is consistent with the longer history of intensive forest management in the Study Area.

The density of trees with hollows (habitat trees) remaining after timber harvesting can be expected to vary with harvesting intensity, Timber Stand Improvement (TSI), silvicultural treatment (utilisation standards) and fire history. The number of hollow bearing trees recorded per survey site varied from 0 to more than 5 per hectare. Analysis of associations between tree hollow density and natural and cultural variables revealed significant negative associations with time since grazing commenced at the site (Grazed)($P< 0.0005$), the number of logging cycles ($P< 0.025$), grazing intensity ($P=0.02$), TSI ($P=0.04$) and vegetation community gradient Overstorey 3 ($P=0.02$, a decreasing moisture and increasing fire frequency gradient). Current management policy does not include the culling of defective trees for both economic and habitat reasons, but neither does it include adequate tree hollow recruitment in previously culled forests. Cessation of culling may not be sufficient to reverse current trends in habitat tree reduction in the immediate future because the length of time required for the formation of tree hollows can exceed several logging rotations (Mackowski, 1984). Further studies of stand structure and dynamics are necessary to clarify the future availability of tree hollows in the Study Area.

Current harvesting plans in the Study Area specify the retention of a minimum of 3 large mature trees per hectare, preferably in clumps of up to 5 trees. This is well below the maximum requirements of hollow dependent arboreal mammals. Retention rates need to be increased to a minimum of 3 clusters or 3 individual trees per hectare for low quality forest and 6 clusters or 6 individual trees per hectare in high site quality forests, because arboreal mammals are territorial and a cluster of habitat trees may only be used by a single animal. In this study Greater Gliders were absent from surveyed sites with less than six tree hollows per hectare.

Options for mitigation of logging impacts on hollows include:

6.5 Retention of a *__minimum__* *of 3 well spaced habitat trees per ha in low site quality forest, and 6 well spaced habitat trees per ha in high site quality forest. Where necessary, Habitat trees should be within a clump of other trees to protect against exposure and wind damage.*

6.6 Habitat tree recruitment in forests with densities of living habitat tree below the above minimums. Recruitment trees should be selected on the basis of suitability for rapid hollow development, and retained to restore habitat tree density to minimum levels as soon as possible.

6.7 Further research and evaluation of logging impacts on habitat tree dynamics, including a quantitative assessment of current forest structure.

<u>Fallen Timber</u>

Large logs provide important refuge areas and feeding sites for small terrestrial mammals (Smith et. al., 1990; Dickman, 1991). Large logs harbour moisture and provide refuge during drought and fire. Large logs are a feature of unlogged, old-growth forests where they provide continuity of ground cover through successive generations of fire disturbance (Scots, 1991). Little attention has been paid to the maintenance of large logs in logged forest ecosystems and no quantitative data is available on log density or dynamics. Logging operations of the type practiced in the Study Area appear to generate a temporary increase in log abundance, particularly after the initial logging cycle. It is presently unclear whether this head log and log residue material performs the same ecological functions as naturally formed logs resulting from the decay and collapse of large old forest trees. Logs generated by harvesting operations may not provide the large cavities for animals that shelter in large hollow logs. At present no adequate quantitative data is available for modelling the long term impacts of logging on the large log resource. In this study, species richness of terrestrial carnivore-insectivore-omnivores was significantly correlated with the amount of Fallen Timber at surveys sites ($r=0.25$, $P<0.03$). Fallen timber abundance is correlated with the abundance of large dead trees with hollows thus, maintenance of the large fallen timber resource will require and depend on effective tree hollow management.

Options for protection of the large log resource from logging impacts include:

6.8 The protection of large fallen logs (>40cm diameter and 5m length) from destruction in regeneration burns as far as practicable;

6.9 Reduction in the proportion of logged forest subject to prescribed and grazier burning to reduce the risk of log removal by burning;

6.10 Maintenance of a minimum stocking of large diameter habitat trees to maintain a supply of natural fallen logs;

6.11 Conduct further research into the dynamics of large log production and decay in representative logged forest types.

Grazing and Burning

Grazing and frequent (1-5 year) low intensity burning tend to occur together and are both associated with decreasing understorey diversity and increasing grass cover. Graziers in the Study Area burn regularly to promote palatable nutritious feed for live-stock. This burning is usually carried out under SFNSW permits and is considered useful as broad area fuel reduction management. The SFNSW burns more frequently for hazard reduction in small key areas. Grazing and frequent burning encourage the development of some grass species, at the expense of shrubs and herbs. Increased grazing and fire frequency is expected to have a negative impact on shrub dependent species and positive impact on grazing species. There are 2 main groups of shrub dependent species, the CWR marsupials which need shrub cover to reduce predation, and arboreal and scansorial (ground and tree frequenting) mammals which feed in the shrub layer or moist litter layer beneath mesic shrubs. A third group, the large grazing macropods, need only scattered or reduced cover from predators, are expected to benefit from increased burning and grazing and a reduction in shrub cover, although loss of nitrogen in the forest (ie through loss of nitrogen fixing shrubs *Acacia* and *Allocasuarina*) has also been found to limit the distribution of wallabies (Turner and Lambert, 1988).

Vertebrate fauna, particularly small mammals, are most abundant in forest with a complex understorey (Catling, 1991). Frequent fire may fragment and simplify such habitat, restricting it to streams and moist gullies, and causing populations of some species to become more isolated and vulnerable. Catling (1991) classified small to medium sized mammals as disadvantaged or advantaged by the simplified forest structure resulting from fire. Hastings Mouse, Eastern Chestnut mouse, Brush-tailed Phascogale and the White-footed Dunnart were considered to benefit from forest simplification while Spotted-tailed Quolls, Southern Brown Bandicoots, Squirrel Gliders, Potoroos, Parma Wallaby, and the Black Striped Wallaby were considered to be disadvantaged. Newsome et al. (1983) report that at Nadgee, predation of Long nosed Potoroos by Dingos was highest 2 years after a severe fire. Similarly in Western Australia, it was observed that of 24 Brush-tailed Bettongs that survived a fire, 11 were subsequently taken by predators. The increased vulnerability of small mammals to predation as a result of fire, has great significance for the conservation of endangered CWR species, as predation by foxes and other carnivores has been implicated in their decline and extinction.

Like domestic stock, the larger grazing macropods, including Grey Kangaroos and Red-necked Wallabies, preferentially graze on grasslands after fire. At Wallaby Creek, Grey Kangaroos moved to recently burnt areas within days of the fire, cattle moved in 2-3 months later, and Red-necked Wallabies after several months (Southwell, 1987). In this study significant increases in the frequency of occurrence of Swamp Wallabies (Chi-square P< 0.04), and Grey Kangaroos (Chi-square P< 0.04) were associated with increased fire frequency. Red-necked Wallabies occurred significantly more frequently in forests with a long history of grazing (Chi-square P< 0.04) and moderate to high levels of cattle grazing (Chi-square P< 0.05).

The smaller CWR macropods, Parma Wallaby and Red-necked Pademelon, which require moist, dense ground cover, were found to be restricted in distribution to tall moist forests with a mesic or rainforest understorey on the western margin of the Study Area. The Red-necked Pademelon only occurred in areas with no evidence of fire (Chi-square P< 0.007). A similar pattern was detected in the Glen Innes region (Smith et al., 1992).

A number of arboreal mammal species depend on the shrub understorey for feeding. In this study, the Mountain Brushtail was found to significantly prefer unburnt and ungrazed understorey (Chi-square P<0.008, and P<0.05). Both the Greater Glider and Yellow-bellied Glider were significantly less frequent in moderately to intensively grazed forest (Chi-square P< 0.03, P< 0.02). No arboreal mammal species were positively associated with frequent grazing or burning.

Control burning in the Study Area is practiced or may be practiced by the SFNSW for the following reasons (after FCNSW, 1992);

a) to protect community assets (villages, recreation areas and arterial roads);
b) to dispose of logging slash;
c) to promote regeneration;
d) to protect plantations and intensively treated stands;
e) to reduce fuel levels in regrowth;
f) to reduce fuel levels in undeveloped areas;
g) to reduce fuel before logging.

The actual level of burning is limited by funding, personnel and weather conditions.

Burning by graziers is carried out predominantly during mustering and whenever the habitat will carry fire. Grazier burning is regulated by SFNSW through the issuing of permits. Where frequent unauthorised burning is known to have occurred on State Forests held under Occupation Permits, or on private or leased land adjacent to State Forests, the owners or occupants of the land have been notified by the SFNSW that it is the Commission's intent to terminate Occupation Permits and take appropriate legal action. SFNSW favours continuation of grazing in the Grafton area as an economic form of fuel reduction (R. Williams pers. comm.). Fuel reduction burning is perceived to be an important tool for reducing the risk of extensive and intensive wildfire. Intensive crown fire is considered to reduce wood value, through the promotion of defect, and wood volume through the impact on growth rates. However, no quantitative data appears to be available to substantiate these beliefs and quantify any economic costs. Similarly, no data appears to be available on the natural frequency and risk of wildfire in the Management Area or on the effect of control and grazier burning on reducing this risk. This is an important area for further research and monitoring as current ecological wisdom predicts that Australian native flora and fauna are adapted to, and able to recover from, infrequent episodes of intense (crown) fire but that biodiversity gradually declines under regimes of frequent, low intensity fire (Catling, 1991). Frequent control burning maybe disadvantageous for timber production. Control fires and even slash burn fires may kill natural eucalypt seedlings and reduce regeneration and stocking. In south-east NSW slash burns do not produce the same level of stocking as wildfire and may lead to poor regeneration (Bridges and Dobbyns, 1991). Slash burn kills seeds in felled crowns and subsequent control burns kill seedlings and small regenerating saplings. SFNSW has signalled its intent to reduce the area of forest subject to frequent burning by graziers and to monitor the extent of future fires in the Grafton Management Area (Moore and Floyd, 1994).

Options for achieving this include:

6.12 Elimination of grazing under Occupation Permits in all leases where burning is not effectively brought under control by SFNSW.

6.13 Reducing frequent and moderate (< 15 years) control burning to strategic locations for hazard reduction, over not more than 50% of the Hardwood forests in the Management Area.

<u>Nectar, Sap and Pollen</u>

Nectar from the flowers of eucalypts, Banksias, and other shrubs provide an important food resource for many arboreal mammal species, particularly Yellow-bellied Gliders, Squirrel Gliders, Feathertail Gliders, Sugar Gliders, and the Eastern Pygmy-possum. When nectar is not available, the sap from certain Eucalypt species provides a critical resource for Gliders. Nectarivore diversity is expected to be greater in forests with a high diversity of nectar producing plants with an even spread of nectar production throughout the year, particularly during winter. Flowering rates and nectar and pollen production have been reported to increase with the size of trees and shrubs of some species (D. Quin unpublished data), particularly Banksia, suggesting that nectarivore diversity is likely to be greatest in mature and old-growth forest. The most important areas for nectar, sap and pollen production in the Study Area are considered to be the mature unlogged Spotted Gum, Grey Ironbark, Grey Gum forests of Dalmorton State Forest and the high Eucalypt diversity Dry Hardwood forests of Candole and Double Duke State Forests, particularly where they border heaths with Banksia and/or swamp forest with *Melaleuca quinquinervia*. Yellow-bellied Gliders were more abundant in unlogged forest in Dalmorton State Forest than elsewhere in the Study Area. Yellow-bellied Gliders were detected on all of the unlogged sites in Dalmorton State Forest and sap feed trees were observed at many other sites during road travel through the region. The suitability of this region for Yellow-bellied Gliders can be attributed to the age and floristic composition of the dominant forest type (Spotted Gum, Grey Ironbark, Grey Gum). Grey gum is a preferred sap feed tree of the Yellow-bellied Glider, Grey Ironbark is considered to be one of the best (most prolific and most frequently flowering) nectar producing species on the north coast (Stace, 1992), and Spotted Gum is also a high quality and large volume nectar producer and probably the highest value pollen producer in the region (Stace, 1992). Options for protection of habitat for gliding possums include:

6.14 Reservation of a significant area (50%) of unlogged old-growth Spotted-gum, Grey Gum, Grey Ironbark forests in Dalmorton State Forest. Approximately 3,151 ha (47%) of this forest type falls in unloggable terrain in Dalmorton State Forest and will not be logged under the current proposal;

6.15 Further surveys to determine whether unloggable areas provide equally suitable habitat for Yellow-bellied Gliders as areas scheduled for logging;

6.16 Further research and monitoring to determine the impact of logging on nectar and pollen production;

6.17 Protection of swamp forests (M. quinquinervia) and forests with an understorey of mature (>10cm diameter) Banksia integrifolia from harvesting;

6.18 Exclusion of apiary from any new logging areas in Dalmorton State Forest to act as control sites for monitoring and future evaluation of possible apicultural impacts.

Dingo and Fox Control

There is strong evidence that small macropods in the Critical Body Weight Range (CWR) of 1500-5500 grams, such as the Parma Wallaby, Black-striped Wallaby and Rufous Bettong, Bandicoots, and Potoroo, have declined in range since European settlement as a result of predation by introduced Foxes and to a lesser extent cats (Johnson et al., 1989). CWR species appear to persist in moist high quality forests (Burbidge et al., 1990) and other areas from which Foxes are absent, and in which other predators such as Dingos and Quolls are abundant. The nature of the relationship between Foxes, Dingos, Quolls, Cats and CWR mammals is poorly understood, but may be critical to the long term future of many small macropods and native mammals. One theory suggests that CWR species persist where Dingos are common and actively exclude Foxes. Although Dingos prey upon many macropod species, it has been found that their principle prey are the larger macropods, especially Swamp Wallaby and to a lesser extent Red-necked Wallaby (Robertshaw and Harden, 1989). It is noteworthy that Foxes appear to be absent and Quolls and Dingos moderately abundant, in the high elevation and escarpment forests to the west of the Study Area where Parma Wallaby, Black-striped Wallaby and Red-necked Pademelon occur. Where Dingos are abundant they may control and exclude Foxes and

Cats, and CWR mammals may escape predation from Dingos in areas with abundant shrub cover.

1080 baiting has been shown to reduce numbers of both Foxes, Dingos and Spotted-tailed Quolls in the Glen Innes Region (P. Fleming pers. comm.) but Foxes and Cats may recover more rapidly and replace Dingos in the ecosystem after control operations. 1080 baits laid for Rabbits and Pigs are considered to pose potential threats to Bandicoot populations (Ashby et. al., 1990).

Options for protection of CWR mammals include:

6.19 Fox control using species specific techniques which do not affect Dingos and Quolls;

6.20 Allowing Dingo numbers to increase (by exclusion of grazing and non-compatible uses and eliminating Dingo control within 1.5km of boundaries with agricultural land) and control of Foxes and Cats;

6.21 Increasing shrub cover by minimising the area subject to frequent fire (see preceding sections) until more is known about the possible ecological consequences of baiting on endangered mammals.

Roading

Roads are commonly used by foxes and it is possible that roading associated with timber harvesting will hasten invasion by foxes and reduce populations of threatened small CWR mammal species. There does not appear to be any evidence to confirm or reject this hypothesis, but we consider it to be of sufficient importance to justify further investigation and monitoring. Recent technological advances in spatial habitat modelling using GIS have provided, hitherto, unavailable opportunities for evaluating the impact of roads on fauna populations. Current policy in the survey region includes natural revegetation of all but major roads after logging.

Options for mitigation of possible impacts include:

6.22 Long term monitoring and further research to evaluate the impact of roading on CWR marsupials and their natural and introduced predators.

Rare, Poorly Known and Sensitive Species

The distribution, ecology, habitat requirements and sensitivity to logging of a number of endangered species with highly restricted distributions is so poorly known that localised populations are potentially at risk of local or regional extinction after minor disturbances such as the logging of a single compartment.

Options for mitigation of this risk include:

6.23 Protection of all known populations of endangered species with restricted distributions (less than 10 known sites in the survey region, species as specified in following sections) from logging disturbance by buffer zones of up to 200m until more is known about their management requirements and sensitivity to logging (see Table 9.1).

Species of Conservation Significance

Squirrel Gliders (Vulnerable and Rare; Schedule 12)

Squirrel Gliders are sparsely distributed from Cape York to Victoria, inhabiting open, dry forest and woodland, and occasionally moist eucalpyt forest and rainforest. Much of the species habitat has been cleared for agriculture. There are few records of the Squirrel Glider in the Study Area (Appendix F), but the species has been reported in Candole State Forest on four separate occasions, suggesting that this is a local stronghold for the species. Present understanding suggests that this species will be most common in floriferous sub-coastal and coastal forests with abundant winter flowering trees and shrubs. The largest concentrated population in the general region occurs in coastal Blackbutt/heath adjoining littoral rainforest at Limeburners Nature Reserve north Port Macquarie (A. Smith unpublished data).

Mitigation Options: 6.5-6.7, 6.16- 6.23.

Yellow-bellied Gliders (Vulnerable and Rare; Schedule 12)

Yellow-bellied Gliders are distributed along and east of the divide from Victoria to north Queensland. They are widespread at low densities in north-east NSW. They occur in a wide range of eucalypt forests but have been reported to be most abundant in Dry Sclerophyll forest with a xeric understorey (Mackowski, 1986). Yellow-bellied Gliders did not occur more frequently than expected in any major forest types but preferred taller forest and were absent from heavily grazed and recently logged sites. Yellow-bellied Gliders have large home ranges (10-100 ha) and may move seasonally according to patterns of flowering, bark shed and availability of other food resources (Kavanagh, 1984). Evidence from elsewhere in Australia indicates that Yellow-bellied Gliders are eliminated from clearfelled and intensively logged forest. The effects of moderate intensity logging remain unknown, but results of the present study suggest at least some population decline, possibly in approximate proportion to mature tree removal. Further quantitative data is required to predict the magnitude of population changes. A local concentration of this species occurs in the unlogged old-growth forests of Dalmorton State Forest and in the lightly logged areas of Candole State Forest.

Mitigation Options: 6.1-6.3, 6.5-7, 6.14-6.18

Koalas (Vulnerable and Rare; Schedule 12)

Koalas are widely distributed at low density, or in patches of local abundance, in a wide range of eucalypt forest and woodlands throughout Eastern Australia. The habitat requirements of the Koala are poorly known, particularly at regional and local scales. At a state wide scale Koala distribution is closely linked with tree species occurring on high nutrient soils along river flats and drainage lines. This habitat has been extensively cultivated and most Koalas are found primarily on or near farmland (Reed and Lunney, 1990). Koalas sleep in the open on sturdy branches, and may therefore be unable to occupy regenerating forests until trees are sufficiently large for climbing and resting (approximately 25cm dbh). In Pine Creek State forest to the south of the Study Area Koalas have been found to prefer high site quality mature and old-growth forests, particularly those dominated by Tallowwood and Brush Box (Austeco unpublished data). Koalas were observed at only 3 sites during this study (Richmond Range and Fortis Creek) but have been recorded at 11 other localities in previous surveys (Appendix F). Insufficient records were obtained to evaluate regional habitat requirements.

Mitigation Options: 6.1, 6.2., 6.23 Protection of known populations by a 200m buffer zone (approximately one home range) (refer to Table 9.1)

Long-nosed Potoroo (Vulnerable and Rare; Schedule 12)

The Long-nosed Potoroo is sparsely distributed in sub-coastal forests and heaths of south-eastern Australia. Only two sightings were recorded in this study, in the dense moist forests of the eastern escarpment in Washpool State Forest and in Candole State Forest. Although this species is rare and difficult to detect it has been previously recorded in the Study Area (Appendix F). The preferred habitat in North-east NSW is high elevation Rainforest and Moist Hardwood, and Heath at lower elevations (Schlager, 1981). This may be a relict pattern reflecting local extinction from fox predation in areas lacking dense ground cover. In Victoria, this species does not venture far from dense cover (Seebeck, 1981). Potential threats to the Long-nosed Potoroo may include the reduction of understorey cover by grazing and burning, and predation by Foxes and Cats. Sensitivity to Fox predation is considered to be the major threat to its survival, both regionally and nationally. Forest management practices which reduce understorey cover and indirectly increase fox numbers could have an adverse impact on this and other CWR marsupials.

Mitigation Options: 6.1, 6.9, 6.12, 6.13, 6.17, 6.19-23.

Parma Wallaby (Vulnerable and Rare; Schedule 12.)

This species range has declined in historic times and it was once considered to be extinct in Australia. It has a restricted distribution in moist forests from Watagan Mountains Gosford to the Richmond Range and Murwillumbah regions in north-east NSW (Smith and Quin, 1993). Little quantitative data is available on the habitat preference or sensitivity to logging of the species but it predominates in areas with a mozaic of moist forests and grass patches where foxes are scarce or absent (Smith et al., 1992). Attempts to re-introduce this species to its former range have failed due to Fox predation. Ecological considerations suggest that, like the Long-nosed Potoroo, the most significant threat to this species is predation by Foxes. In the absence of Foxes, grazing and fire, it is likely that timber harvesting may increase habitat suitability for this species in the long term.

Mitigation Options: 6.1, 6.4, 6.12, 6.13, 6.19-22

Rufous Bettong (Vulnerable and Rare; Schedule 12)

The Rufous Bettong was once widespread and common throughout NSW but has declined since the turn of the century, and is now restricted to the north-east of the State from the border to the Kempsey region. It has been reported in Richmond Range, Ramornie and Boundary Creek State Forests (NPWS, 1993). The upper Clarence Valley is considered to be a stronghold for this species in NSW (NPWS, 1993) where it is commonly associated with Spotted Gum forest (Schlager, 1981). An inhabitant of well grassed open forest and woodland, it shelters in nests constructed of grass. It is likely that its decline is due to predation by the Fox and that the remaining refugia occur in areas where Quolls and Dingos predominate and Foxes and Rabbits are scarce. It is unlikely that timber harvesting adversely affects this species, but practices which may increase fox distribution and abundance such as Dingo baiting and new roading, or which reduce cover (fallen logs) such as frequent burning, may have an adverse impact.

Mitigation Options: 6.8-13, 6.19-22

Red-legged Pademelon (Vulnerable and Rare; Schedule 12).

This macropod occurs in coastal and subocastal Rainforests and associated Moist Hardwood forests of eastern Australia north of Sydney (Strahan, 1984). No individuals were recorded during this study but isolated populations have been reported in the Study

Area (Appendix F). It is dependent on dense Rainforest cover and is thought to be adversely affected by Fox predation and burning and grazing of existing forest cover.

Mitigation Options: 6.1, 6.4, 6.12, 6.13, 6.19, 6.20, 6.21, 6.23 in potential habitat.

Brush-tailed Rock Wallaby (Vulnerable and Rare; Schedule 12)

The Brush-tailed Rock Wallaby is widely distributed along the Great Dividing Range form eastern Victoria to Central Queensland. It prefers rocky scarps with wet and dry eucalypt forests adjacent to grassland. The species has been recorded in the Mann River Wilderness Area, Guy Fawkes River National Park, and north-facing rock faces along the Upper Clarence River within the Study Area. It inhabits steep rocky terrain which is not subject to timber harvesting, but there is a possibility of fire and logging disturbance of shelter in feeding areas adjacent to rocky refuges.The principle threat to this species is considered to be fox predation. Timber harvesting is considered unlikely to have a significant impact on local populations.

Mitigation Options: 6.19-23

Black Striped Wallaby (Threatened; Schedule 12)

This Wallaby is distributed from north-east NSW to Central Queensland. It prefers thick undergrowth in a variety of forest types for shelter and feeds in open forest and grassland edges. It occurs in the north-western portion of the Study Area where it has been reported at Richmond Range State Forest (NPWS, 1993), probably close to its southern limit. It is likely to favour Moist Hardwood forests with dense understorey adjoining grassland. Management practices which reduce the shrub component of the understorey and increase fox numbers are likely to have an adverse impact on local populations.

Mitigation Options: 6.1, 6.8, 6.12, 6.13, 6.19-6.22.

The Brush-tailed Phascogale (Vulnerable and Rare Schedule 12)

This species is patchily distributed throughout south-eastern, northern and south-western Australia (Strahan, 1984). It appears to have a centre of concentration in south-east Queensland and to a lessor extent north-east NSW. It is rarely detected and little is known about its ecology and habitat preference. It has declined in range in historic times for reasons which are unclear, but it falls within the critical weight range and may be threatened by Fox predation. Calaby (1966) did not collect any live specimens in his surveys of the Clarence Valley but reported it to be not uncommon in partially cleared agricultural country on the basis of local accounts. No individuals were detected by trapping in this study.

Mitigation Options: 6.1-6.3, 6.5-6.13, 6.18, 6.19-6.23.

Hastings River Mouse (Vulnerable and Rare Schedule 12)

The Hastings River Mouse is patchily distributed from the Barrington Tops in NSW to Warwick in south-east Qld. It was not detected at any survey sites but has previously been reported in the Billilimbra State Forest (NPWS, 1992), Cunglebung Catchment of Dalmorton State Forest (NPWS, 1991), and Charlie Plain area in Clouds Creek State Forest (Horton, 1991) (Appendix F). The habitat of Hastings River Mouse is reported to be characterised by streams or soaks under tall open forest with dense ground cover including patches of sedges (*Carex, Juncus, Restio*) (King, 1984; D. Read unpublished). Features of its habitat at Billilimbra include: moist grassland with *Lomandra* and heath elements; proximity to drainage lines, Rainforest or Moist Hardwood Forest; sandy infertile soil; and abundant cover or large boulders, large fallen logs and large Oldgrowth tree buts with hollows and cavities. The effects of logging, burning grazing and other forestry activities on this species, and the cause of its general rarity and apparent decline remain unknown. Life history features suggest that it could be attributed to Fox and Cat predation or frequent burning and loss of diversity in the understorey. Known populations are so few that protection of all populations from cultural disturbance can be justified as a precautionary measure. Certainly any populations subject to intentional disturbance should be monitored before and after management to provide much needed information on possible impacts.

Mitigation Options: 6.12, 6.13, 6.19-6.23 In addition protect all riparian habitat with Hastings River Mouse habitat characteristics by an expanded unlogged filter strip 50m either side of streams.

The Spotted-tailed Quoll (Vulnerable and Rare Schedule 12)

The Spotted-tailed Quoll has declined in range since European settlement. It occurs in a wide range of habitats and preys upon a wide variety of small to medium sized arboreal and terrestrial mammals (Boschma, 1991). In north-east NSW it appears to be most abundant in the moist forests of the Washpool and Gibraltar Range regions. It was reported to be locally abundant in the Gibraltar State Forest region where it was detected at six sites by hair tubes and scats and wire cage trapping (Smith et al., 1992). It was widespread but less common (than Dingos and Cats) in the Study Area with only 3 records at survey sites and a local concentration of scats collected in Richmond Range State Forest. NPWS (1993) recorded the species in Doubleduke, Ewingar, Mt Marsh, Richmond Range, Billilimbra and Cangai State Forests. Potential threats to this species include 1080 baiting of Dingos and increased roading of new areas where this leads to an increase in competition from Foxes, and long term reduction in food supply due to habitat degradation by burning and grazing.

Mitigation Options: 6.1, 6.2, 6.4, 6.8-6.13, 6.19-21.

Eastern Chestnut Mouse (Vulnerable and Rare Schedule 12)

This species has a coastal and sub-coastal distribution from Cairns in Qld to central NSW. It prefers heathland but also occurs in forest and swamp forest with a dense (heathy) understorey (NPWS, 1993). Two specimens of this species was detected in this survey, one at a recently burnt site in Double Duke State Forest and one in habitat with a heath understorey in Candole State Forest. It is thought to prefer heath and dry forest habitats at an early successional stage after fire (Strahan, 1984). Consequently, it is not considered likely to be disadvantaged, in the long term, by timber harvesting and infrequent burning within the Study Area, however, burning and grazing which reduces or eliminates the heath understorey in the long term may pose a threat.

Mitigation Options: 6.12-13.

Common Planigale (Vulnerable and Rare Schedule 12):

Two subspecies of the Common Planigale are recognised (Strahan, 1991). *Planigale maculata maculata* is distributed along the east coast of mainland Australia from central New South Wales to Cape York, and on the Top End of the Northern Territory. This species is reported to occupy a range of habitat types including rainforest, wet and dry sclerophyll forests, grasslands, heathlands, marshlands and rocky areas. In general, this species is not found far away from water or moist areas near creeks, swamps and marshes (Denny, 1982). *Planigale maculata* is recorded as far south as Scone in New South Wales and recently in the Urunga Management Area (Austeco in prep), but few records are available from the coast south of the Clarence River (Milledge, 1986). This species has been recorded at Alstonville, Ballina, Byron Bay and Lennox Head and in southern Queensland (Mt. Tamborine) (Milledge, 1986; Gilmore 1987). *Planigale maculata* has been previously recorded in the Upper Richmond and Clarence River Basin (Calaby, 1966) and in Cherry Tree State Forest (Smith, 1989b), although this species was not detected during this survey. Little is known about the species preferred habitat requirements, or responses to timber harvesting operations. Some protection may be afforded in filter strips. Management practices which reduce the extent of understorey shrub cover or ground log cover, promote the movement of feral cats, and disturb vegetation adjacent to water courses may have an adverse impact on local populations.

Mitigation Options: 6.10-13, 6.17, 6.23.

7. IMPACTS ON REPTILES

Introduction

There have been few comprehensive surveys of the forest herpetofauna of the Grafton Casino Study Area. The Moist and Dry Hardwood forests of the escarpment and New England Tablelands to the west of the Study Area have been comprehensively surveyed and described by Smith et al. (1992) with emphasis on the assessment of logging impacts in State Forests. The reptile faunas of the Washpool and Gibraltar National Parks have been surveyed by Osborne (1982) and Barker (1980). Reptile communities of the Rainforests and Moist Hardwood forests in the Border Ranges to the north and north-west have been surveyed by Smith et al. (1989a,b). There have been few surveys of State Forests or private property in the region. Milledge (1986) surveyed the fauna of Coastal Byron Shire and Smith et al. (1990) surveyed the fauna of the Orara and Bucca Valleys to the south of Grafton.

The ecological requirements and basic biology of most reptiles of the Study Area are poorly known. Most of the ecological information available has been surmised from habitat descriptions, species locality records, anecdotal evidence and expert opinion. There have been few studies of habitat preferences for reptiles using systematic surveys and statistical validation. Smith et al. (1989a) surveyed rainforest herpetofauna in the Mount Warning Caldera region, Pugh (1982) studied differences in reptile communities in different habitats in Clouds Creek State Forest, and Smith et al. (1992) examined habitat preferences of forest reptiles in the Glen Innes Forest Management Area.

Reptiles are ectothermic (rely on external sources for body heat), and predominantly insectivorous and carnivorous, consequently their habitat requirements are less directly determined by vegetation characteristics than other taxa which feed directly upon plants. By contrast, reptile distributions are strongly influenced by climate and other factors affecting thermoregulation such as shade (canopy structure), and availability of shelter and basking sites. In a survey of the moist forest herpetofaunas of north-east NSW, for example Smith et al. (1989a,b), found that few species discriminated between Rainforest and Wet Sclerophyll forest, with most species responding to differences in climate and the availability of microhabitat components and foraging substrates. The availability of different substrates, or microhabitats of varying thermal properties is particularly important for most reptiles as behavioural thermoregulation (regulation of body heat) is important in controlling critical body functions such as digestion, foraging activity and reproduction. In contrast to birds and mammals, reptile diversity and abundance is often significantly higher in drier habitat types, particularly where there is a variety of ground substrate microhabitats. Exceptions to this pattern include the larger non-lizard eating snakes from the Boidae, Colubridae and Elapidae Groups. The distribution and abundance of these species within climatically similar areas may depend largely on the abundance of prey species and suitable foraging substrates. Ecologically these reptiles are similar to mammalian carnivores. Species such as the Carpet Python, which preys on small to medium sized birds and mammals, are likely to respond to environmental gradients favouring these animals. Many of the large Elapids are frog eaters and their distribution is likely to be determined by the availability of favourable amphibian habitat. Tree snakes are likely to respond to both increasing understorey structural diversity and the abundance of smaller vertebrates which constitute their prey.

A list of reptile species likely to occur within the Study Area, has been compiled on the basis of broad distribution patterns and known habitat requirements (Cogger, 1986; Swan, 1990; Wilson and Knowles, 1988). This list is presented in Appendix D which also summarises the results of this survey and those of other surveys, as well as Australian Museum and NPWS Fauna Atlas records. Habitat preferences and the conservation status of each species are given where available. As discussed previously, the Study Area falls on the junction of 2 major biogeographic regions and contains a high level of biodiversity. There are 4 species of reptile which are restricted to north-east NSW and south-east Qld., however none are strictly endemic to the Study Area.

The aims of this study are to:

a) describe the reptile communities and endangered reptile fauna of State Forests in the Study Area

b) assess the likely impact of timber harvesting and associated land uses on these communities and species

c) suggest options for mitigation of impacts and implementation of ecologically sustainable forest management operations.

Methods

Survey Methods

Reptile records were obtained during half-person-hour "habitat searches" on each unit of each transect, wet pitfall trapping at the start of each transect, and collation of opportunistic sightings during other activities on survey transects and in the State Forests. Reptile surveys were carried out between November 1991 and early April 1992. Habitat searches were conducted usually by 2 or 3 operators between the hours of 9.00am and 6.00pm on any day, and involved searching substrates such as litter, fallen logs, grass tussocks, rocks and loose bark. None were conducted during cold conditions or in heavy rain. Weather conditions (rainfall, cloud cover), date and time of day were recorded for each survey. Two 20 litre buckets, containing approximately 40mm of 10% formalin solution to narcotise and preserve trapped animals, were dug into the ground at the start of unit 1 of each of the 77 sites (except in swampy sites) and left open for a minimum of two weeks. Specimens collected in pitfall traps and voucher specimens of taxonomically uncertain species were preserved and lodged with the Australian Museum for positive identification.

Habitat searches tend to under sample species which are arboreal, nocturnal, or which reside in immovable or inaccessible refuges while not active (eg. large rock crevices, burrows, termitaria, tree hollows and large logs). Habitat searches are most effective for the detection of species which are diurnal, litter or grass dwellers, and species which utilise easily searched refugia such as small rocks and logs, leaf litter, and shedding bark. Higher order carnivores (eg. most of the large snakes) were detected infrequently, possibly because of the relativity large home range sizes relative to the area searched.

Wet pitfall traps sample only a small area relative to survey effort however, pitfalls complement habitat searches by sampling nocturnal fauna, small species that shelter in inaccessible refuges, and species that are active only under certain weather conditions.

Species Richness and Abundance

Data obtained during reptile searches were used to calculate relative measures of species richness and total abundance. The results of all 5 half-person-hour searches for each site were pooled prior to data analysis. Pitfall data was not subjected to statistical analysis because of the paucity of records and the high variability in weather conditions during the trapping period.

Data Analysis

Habitat preferences and landuse impacts were assessed by the analysis of associations between reptile species richness, total reptile abundance, species abundance, and species frequency of occurrence per site with respect to measured environmental variables. Associations between quantitative variables were analysed by linear regression.. Associations between quantitative dependant variables and qualitative environmental variables were measured by analysis of variance. Associations between the frequency of occurrence of individual species and environmental variables were determined by Chi-squared analysis after first converting continuous environmental variables into categories. (see Chapters 1 and 2 for further explanation).

Data Interpretation

Impact assessment was based on a combination of:

a) literature review of logging impacts measured in similar situations elsewhere in Australia;

b) statistical modelling of associations between measured reptile diversity and abundance and previous logging and other forestry land-uses in the Study Area (eg. logged versus unlogged);

c) ecological interpretation of predictive models to forecast likely impacts under alternative management regimes.

Impact prediction by these methods involves an element of uncertainty which can only be eliminated by long term monitoring. Monitoring procedures are recommended where uncertainty is considered to be high.

Results

Diversity and Communities

A total of 41 species of reptile were detected in the Study Area (Tables 7.4, 7.9, 7.14). The greatest diversity and numbers of reptiles were found in the Southern Richmond Range (18 species) and Coast Range (14 species) subregions in the Study Area, which is probably a reflection of the diversity of dry, open forest habitats and the existence of sandstone escarpments and rocky areas in these areas. The results from statistical analyses of total reptile species richness and environmental variables are summarised in Tables 7.1 and 7.2. Analyses of the effect of weather, time of day and date of survey revealed that none of these variables had any significant effect on the measured species richness of reptiles. Species richness was significantly associated with the ordinal variable Overstorey 3, a gradient of decreasing moisture and increasing fire frequency, and with understorey type, fire and soil depth. The results suggest that reptile diversity is higher in the drier open canopy forest types which typically occur in low site quality areas.

Table 7.1. Significant Associations between Species Richness and Continuous Environmental Variables.

Environmental Variable	Regression r	Probability P
Time Since Fire	-0.335	0.003
Burn Height	0.322	0.004
Overstorey 3	0.290	0.011

Table 7.2. Significant Associations between Total Reptile Abundance and Species Richness and Categorical Environmental Variables.

Environmental Variables	Total Abundance P	Species Richness P
Understorey stratum	0.001	0.027*
Soil Depth	0.006	0.048*
Stumps	0.014	
Fire Intensity	0.014	
% Shrub Cover	0.04	
Time of year	0.002	

*Group variances are not homogeneous according to Bartletts test of homogeneity.

The Total Abundance of reptiles was associated with many environmental variables; the results are summarised in Tables 7.2 and 7.3. These results should be treated with some caution, as the analyses of the effect of weather, time of day and date of survey reveal that total reptile abundance was significantly higher during surveys conducted in January/February (mean=23.4) compared to those carried out in November/December (mean=7.6) or March/April (mean=9.7, P=0.001). The low detectability recorded during November/December most likely reflects the drought conditions experienced during the spring of 1992. Weather and time of day had no significant effect. The index of total reptile abundance is dominated by records of the Grass Skink (*Lampropholis delicata*) which was by far the most frequently detected species (see Table 7.4).

Regression analysis showed that total reptile abundance was positively correlated with grazing and the amount of fallen timber, and negatively correlated with shrub cover and time since fire. Analysis of variance shows that total reptile abundance is higher in: areas of low fire intensity; little shrub cover, shallow soils (compared to both deep and skeletal soils), and grassy and xeric understoreys. Total reptile abundance was lower in sites with no recorded tree stumps. Again these results predominantly reflect the preference of *L. delicata* for drier open forest habitats with moderate to high ground cover.

Table 7.3. Significant Associations between Total Reptile Species Abundance and Continuous Environmental Variables

Environmental Variable	Regression r	Probability P
Years Grazed	0.363	0.001
Time Since Fire	-0.322	0.004
% Shrub Cover	-0.290	0.011
Fallen Timber cover	0.235	0.041

In order to interpret patterns of reptilian diversity in detail, associations between cultural and natural environmental variables and reptile species richness and abundance were examined at the community group and species level. Many of the frequently detected reptile species could be classified as belonging to one of two broad 'community groups', based on known similarities in habitat preference. Species were placed in each 'community group' only where evidence from the literature and expert opinion clearly demonstrated their likely 'group' membership. The groups are -

1. Open Forest "sun seekers" e.g:

Lampropholis spp.	
Carlia spp.	
Ctenotus spp.	
Cryptoblepharus virgatus	Wall Skink
Amphibolurus spp	
Liasis burtonis	Burtons's Legless Lizard
Egernia mcpheei	
Oedura lesueurii	Lesueur's Velvet Gecko
Ctenotus spp.	
Saiphos equalis	Three-toed Skink

2. Closed Forest terrestrial "shade seekers", which favour dense canopies and moist microhabitat e.g:

Saproscincus challengeri	Challenger's Skink
Eulamprus murrayi	Murray's Skink
Egernia major	Land Mullet
Cacophis squamulosis	Golden-crowned Snake
Hypsilurus spinipes	Southern Angle-headed Dragon
Morelia spilota	Carpet Python
Ophioscincus truncatus	
Ceoranoscincus reticulatus	

Other species responded to specialised environmental gradients and could not be classified into the above broad guilds. These species included aquatic, riparian or swamp dwellers, soil and litter dwellers, large carnivores with wide environmental tolerances and apparent habitat generalists. Individual species and their associations with environmental variables were examined by Chi-squared analysis (presence/absence data) and linear regression (quantitative data).

<u>Open Forest Species</u>

Diversity and Abundance.

Fifteen species of "Open Forest Reptile" were detected within the Study Area. The greatest diversity occurred in the Southern Richmond Range (14 species) and Coast Range (9 species) subregions in the Study Area, again probably reflecting the diversity of dry, open forest habitats and the presence of sandstone escarpments and rocky areas in these regions. The relative abundance of the species detected is shown in Table 7.4. Species which were detected at less than 5% of sites can be considered uncommon to scarce in the Study Area. These species include:

Rainbow Skink *Carlia vivax* - regionally scarce but locally abundant, common in the southern Richmond Range sub- region

Wall Skink *Cryptoblepharus virgatus*- likely to be more common in rocky outcrops and woodlands.

Yellow-faced Whip Snake *Demansia psammophis*- difficult to detect when active, may be more common than these results suggest.

Burton's Legless Lizard *Lialis burtonis*- very cryptic species, difficult to detect when active, likely to be more common than these results suggest.

Skink *Egernia mcpheei* - a saxicoline species, probably genuinely uncommon in the Study Area.

Skink *Carlia tetradactyla* - scarce in the region, more common in dry habitats on the western slopes and ranges.

Skink *Lampropholis amicula* - scarce in the region, secretive inhabitant of heaths and Dry Hardwood forests (Wilson and Knowles, 1988), possibly confused during this survey with *L. delicata* from which it is not readily distinguishable whilst active. Previously thought to be distributed from just south of Brisbane and northward, however, Clancy (1992) collected 7 individuals during surveys of the Wingham area. May be more common than these results suggest.

Robust Velvet Gecko *Oedura robusta* - nocturnal and mostly arboreal and, therefore not often detected during herpetological searches, may be more common than these results suggest.

Red-naped Snake *Furina diadema* - likely to be scarce in the region, may be associated with termitaria.

Nobbi Dragon *Amphibolurus nobbi* - scarce in the timber production forests, likely to be common in heaths and woodlands which were not intensively sampled.

Dragon *Diporiphora australis* - a rare species in the Study Area, previously not recorded, taxonomic status uncertain, nearest previous record *(D. australis)* from central coastal Queensland. One specimen was collected in Fortis Creek State Forest and is currently being examined by the Australian Museum.

Other species likely to occur on the basis of known distribution and habitat, but not detected are shown in Appendix D. Many of these species are more common in heath, woodlands or cleared grazing land, or only occur in the Study Area at the edge of their known ranges. Still others are cryptic or burrowing species difficult to detect by systematic survey methods. All should be considered uncommon to rare in the timber production forests of the Study Area.

Table 7.4. Frequency of Occurrence of "Open Forest Reptiles" in the Study Area.

Species	No. of sites	% Occurrence	Total records.
*Lampropholis delicata**	59	77	642
Eulamprus tenuis	20	26	58
Saiphos equalis	16	21	39
Ctenotus taeniolatus	8	10	19
Lampropholis guichenoti	7	9	10
Lygisaurus foliorum	4	5	13
Carlia vivax	3	4	15
Cryptoblepharus virgatus	3	4	5
Demansia psammophis	3	4	3
Lialis burtonis	2	3	2
Egernia mcpheei	2	3	2
Carlia tetradactyla	1	1	2
Lampropholis amicula	1	1	1
Oedura robusta	1	1	1
Furina diadema	1	1	1
Amphibolurus nobbi	0	0	1
Diporiphora spp (near australis)	0	0	1

*see discussion of this species in following text

Significant associations between the diversity of Open Forest Reptiles and environmental variables are summarised in Tables 7.5 and 7.6. The results should be treated with some caution as time of survey was correlated with reptile abundance and was significantly higher during January/February as compared to November/December or March/April. Also, the data for total Open Forest Reptile abundance are biased by the disproportional abundance of the Grass Skink (*L. delicata*) (see Table 7.4).

Species richness was significantly associated with habitat type (preferring Dry Hardwood), soil depth (preferring shallow soils), understorey (preferring xeric and grassy understoreys), and logging intensity (preferring light to none or mod/high). Open Forest Reptile species richness was positively linearly correlated with fire intensity and % grass/herb cover and negatively correlated with time since fire, litter cover and canopy height. The total relative abundance of Open Forest Reptiles was significantly associated with fire intensity (prefer light and intense to none), soil depth (preferring shallow soils), and understorey stratum (avoiding mesic). The total relative abundance of these Forest Reptiles was negatively correlated with time since fire and time between fires. The results indicate a preference for open, dry forest habitats and their typical ecological characteristics.

Table 7.5. Significant Associations between Total 'Open Forest' Reptile Abundance and Species Richness and Categorical Environmental Variables.

Environmental Variables	Total Abundance	Species Richness
Fire intensity	P=0.019	
Soil depth	P=0.014	P=0.01*
Understorey stratum	P=0.001	P<0.001
Habitat		P=0.002
Logging intensity		P=0.009
Time of year	P=0.002	

*Group variance are not homogenous according to Bartletts test of homogeneity.

Table 7.6. Significant Associations between Total 'Open Forest' Reptile Abundance and Species Richness and Continuous Environmental Variables.

Environmental Variable	Regression r	Probability P
TOTAL NUMBERS		
Time since fire	-0.345	0.002
SPECIES RICHNESS		
Time since fire	-0.467	<0.001
Burnheight	0.457	<0.001
%litter cover	-0.371	0.001
%grass/herb cover	0.307	0.007
Canopy height	-0.291	0.010

Individual Species

Four species were sufficiently abundant for the statistical analysis of habitat associations. These were *Eulamprus tenuis*, *L. delicata*, *Saiphos equalis* and *Ctenotus taeniolatus*. The results of Chi-squared analysis of the frequency of occurrence of these species and measured environmental variables are summarised in Table 7.7. The results of linear regression analysis of significant associations between species relative abundance and measured continuous environmental variables are summarised in Table 7.8.

Table 7.7. Significant Associations between Species Frequency of Occurrence and Measured Categorical Environmental Variables.

Variables Environmental	Species	Probability P
Habitat Type		
	Ctenotus taeniolatus	P < 0.001
	Eulamprus tenuis	P = 0.033
Soil Type		
	Ctenotus taeniolatus	P < 0.001
	Lampropholis delicata	P = 0.034
Soil Depth		
	Eulamprus tenuis	P = 0.036
% Shrub Cover		
	Eulamprus tenuis	P = 0.037
% Litter Cover		
	Eulamprus tenuis	P = 0.035
	Saiphos equalis	P = 0.037
	Ctenotus taeniolatus	P = 0.045
Topographical Position		
	Lampropholis delicata	P = 0.006
	Eulamprus tenuis	P = 0.042
Understorey Stratum		
	Ctenotus taeniolatus	P = 0.034
Time Since Fire		
	Eulamprus tenuis	P < 0.001
	Ctenotus taeniolatus	P < 0.001
Fire Intensity		
	Eulamprus tenuis	P = 0.032
Fire Frequency		
	Eulamprus tenuis	P = 0.03

Table 7.8. Significant Associations between Species Relative Abundance and Measured Continuous Environmental Variables.

Species	Regression r	Probability P
Eulamprus tenuis		
% Shrub Cover	-0.267	= 0.019
Time Since Fire	-0.298	= 0.008
Between Fire Interval	-0.296	= 0.009
Burn Height	0.266	= 0.019
Ctenotus taeniolatus		
Over storey 3	-0.465	< 0.001
Exposed Rock	0.367	= 0.001
% Rock Cover	0.357	= 0.001
Logging Cycles	-0.261	= 0.022
Time Since Logging	0.259	= 0.023
Years Grazed	-0.258	= 0.023
Stumps/ha	-0.232	= 0.043
Lampropholis delicata		
Time Since Fire	-0.247	= 0.03
Between Fire Interval	-0.225	= 0.049

Habitat associations of the Grass skink *L. delicata* may be confounded with the requirements of two closely related species *L. guichenoti* and *L. amicula* which are easily confused with *L. delicata* in the field and occasionally sympatric with it. Both of the former species were detected in the Study Area. The majority of records collected during reptile searches were from sightings of active individuals on the ground only. The identity of these individuals was not always determined by collection, though at least one specimen was collected and verified as *L. delicata* on each site. Uncertain specimens and specimens collected by 'wet' pitfall traps were sent to the Australian Museum for verification.

The Grass Skink *L. delicata* was by far the most frequently detected reptile species in the Study Area, found in all broad habitat types. The species is common in suburban areas and appears to survive in many disturbed habitats. Although occurring in a variety of habitat types, it is invariably associated with canopy gaps and sunny patches within habitats with an otherwise closed canopy - for example, it is common along roadsides in closed forests. *L. delicata* was significantly associated with Dry Hardwood forests in the Glen Innes Forest Management Area (Smith et al., 1992). In this study, *L. delicata* was found more frequently than expected in areas with clay soils and less frequently than expected in gullies and along creeks. *L. delicata* was negatively associated with time since fire and fire frequency. From the results of AOV, *L. delicata* was also found to prefer sites with a grassy understorey .

The Bar-sided Skink *Eulamprus tenuis* may well be a composite species requiring taxonomic revision (Wilson and Knowles, 1988), in which case the identification of habitat preference may be clouded by the effects of combining more than one species in any analyses of species abundance or frequency of occurrence and measured environmental variables. However, judging by the number of significant associations between the skink we recorded and consistent environmental variables, it is likely that only one taxa is involved in this study. This species was often detected in tree trunk and stump crevices, and under fallen timber. *E. tenuis* was recorded more frequently than expected in Dry Hardwood habitats, in areas with shallow soils, in sites with a litter cover of 20-50% and in lightly logged areas. It was found less frequently than expected on ridges. *E. tenuis* was positively correlated with burn height, and negatively correlated with shrub cover, time since fire and time between fire. Many of these variables are likely to be confounded. The results indicate that *E. tenuis* prefers sites of moderate to low quality with little shrub cover.

The Three-toed Skink *Saiphos equalis* forages in leaf litter and is often found under rotting logs. In the Glen Innes Area (Smith et al., 1992) found *S. equalis* most commonly in Dry Hardwood habitats. The same trend was found in this study, although a statistically significant correlation could not be demonstrated. *S. equalis* was significantly associated only with litter cover, preferring habitats with a good cover of litter.

The Copper-tailed Skink *Ctenotus taeniolatus* is often associated with low site quality rocky areas, particularly of granite or sandstone (Wilson and Knowles, 1988). In this study, *C.taeniolatus* was found to be significantly associated with broad habitat type (preferring Dry Hardwood forests), soil type, litter, and time since fire, avoiding sites not burnt for many years. *C. taeniolatus* was positively correlated with rock cover and time since logging, and negatively correlated with logging and grazing. The results are consistent with the known habitat preferences of the species, the negative associations with cultural disturbance most likely reflect confounding with sites of low quality. Dry open forests found in rocky sandstone areas are likely to be poorly utilised for timber production and grazing.

Closed Forest Species

We detected 8 species of '"Closed Forest Reptile" within the Study Area. The greatest diversity (7 species) and numbers of this reptile group were found in the Eastern Fall sub-regions (South-western, Ewingar/Washpool and Cangai sub-regions) of the Study Area, where Rainforest and Moist Hardwood forests are most extensive. The relative abundances of the species detected are shown in Table 7.9. Species which were detected at less than 3% of sites can be considered uncommon to scarce in the Study Area. These species include *Ceoranoscincus reticulatus*, *Ophiscincus truncatus*, Pink-tongued Skink *Hemispaeriodon gerrardii* and the Southern Angle-headed Dragon *Hypsilurus spinipes*.

Table 7.9. Frequency of Occurrence of "Closed Forest Reptiles" in the Study Area.

Species	No. of sites	% Frequency Occurrence	Total Records (incl. Opportunistic)
Eulamprus murrayi	8	10	60
Saproscincus challengeri	8	10	16
Morelia spilota	3	4	5
Egernia major	3	4	3
Cacophis squamulosis	2	3	3
Ceoranoscincus reticulatus	1	1	1
Ophioscincus truncatus	1	1	1
Hemispaeriodon gerrardii	1	1	1
Hypsilurus spinipes	1	1	1(nest)

The results from statistical analyses of total "Closed Forest Reptile" abundance and species richness with respect to environmental variables are summarised in Tables 7.10 and 7.11. 'Moist forest' reptile species richness and total abundance were not significantly associated with the date of survey, time of day of survey, or weather conditions at time of survey, but with variables such as fire regime, ground cover and site quality, which are strongly confounded with Habitat type. The results simply reflect the expected association between "Closed Forest" species and Rainforest and Moist Hardwood habitats.

Because of the confounding effect of habitat type on "Closed Forest Reptiles", further analysis on the effects of cultural variables (indices of fire, grazing and logging) on "Closed Forest Reptile" abundance and species richness was conducted within sites containing moist forest types only (ie. only data from sites which were Moist Hardwood and Rainforest). The results are summarised in Table 7.12. They show that within moist habitats, "Closed Forest Reptile" abundance and species richness are negatively correlated to grazing and fire. There were no significant associations with indices of timber harvesting.

Table 7.10. Significant Associations between Total '"Closed Forest Reptile" Abundance and Species Richness and Categorical Environmental Variables.

Environmental Variables	**Total Abundance**	**Species Richness**
Broad habitat	<0.001	<0.001

Table 7.11. Significant Associations between Total "Closed Forest Reptile" Abundance and Species Richness and Continuous Environmental Variables.

Environmental	**Species Richness**		**Total Relative Abundance**	
Variable	**r**	**P**	**r**	**P**
Fire interval	0.689	<0.001	0.621	<0.001
Time since fire	0.569	<0.001	0.479	<0.001
Burn Height	-0.481	<0.001	0.484	<0.001
% grass/herb cover	-0.553	<0.001	-0.408	<0.001
% litter cover	0.531	<0.001	0.384	0.001
Grazing intensity	-0.382	0.001	-0.386	0.001
Canopy height	0.304	0.007	0.307	0.007
Slope	-0.277	0.015	-0.225	0.049

Table 7. 12. Significant Associations between Total "Closed Forest Reptile" Abundance and Species Richness and Categorical Cultural Environmental Variables in Moist Hardwood or Rainforest Habitat Types Only.

Variable	Mean Abundance	Mean Species Richness
Interval between fires	P=0.0039	P=0.0071
1 - 3 years	0.17	0.17
4 - 9 years	0.50	0.33
10 - 30 years	2.63	1.125
30+ & unburnt	8.86	1.571
Grazing intensity	P=0.0164	P=0.0433
medium	0.25	0.25
light	0.60	0.50
none	6.15	1.30

Two species were detected frequently enough to permit analysis of individual species preferences. These were *Eulamprus murrayi* and *Sapropscincus challengeri*. The results of Chi-squared analysis of the frequency of occurrence of these 2 species and categorical environmental variables are summarised in Table 7.13. Significant associations between their relative abundance and measured continuous environmental variables are summarised in Table 7.14.

Table 7.13. Significant Associations between Species Frequency of Occurrence and Measured Environmental Variables as Determined by Chi-squared Analysis..

Variables	Species	Probability
Habitat Type		
	Eulamprus murrayi	P = 0.002
	Saproscincus challengeri	P = 0.002
% Grass, Herb Cover		
	Eulamprus murrayi	P < 0.001
	Saproscincus challengeri	P = 0.009
% Shrub Cover		
	Eulamprus murrayi	P = 0.005
% Litter Cover		
	Eulamprus murrayi	P < 0.001
	Saproscincus challengeri	P < 0.001
% Canopy Cover		
	Saproscincus challengeri	P = 0.003
Understorey		
	Eulamprus murrayi	P < 0.001
Understorey Stratum		
	Eulamprus murrayi	P < 0.001
	Saproscincus challengeri	P < 0.001
Grazing Intensity		
	Eulamprus murrayi	P < 0.001
	Saproscincus challengeri	P < 0.001
Time Since Fire		
	Saproscincus challengeri	P = 0.002
	Eulamprus murrayi	P = 0.027
Fire Intensity		
	Eulamprus murrayi	P = 0.005
	Saproscincus challengeri	P = 0.016
Fire Frequency		
	Eulamprus murrayi	P < 0.001
	Saproscincus challengeri	P < 0.001
Burn Height		
	Saproscincus challengeri	P < 0.001
	Eulamprus murrayi	P = 0.002

Table 7.14. Significant Associations between Species Relative Abundance and Measured Continuous Environmental Variables.

Species	**Regression r**	**Probability P**
Saproscincus challengeri		
% Litter Cover	0.363	= 0.001
% Grass, Herb Cover	-0.347	= 0.002
Canopy Height	0.303	= 0.007
Time Since Fire	0.427	< 0.001
Burn Height	-0.400	< 0.001
Fire Interval	0.552	< 0.001
Eulamprus murrayi		
% Grass, herb Cover	-0.396	= 0.002
% Litter Cover	0.318	= 0.005
Elevation	0.266	= 0.019
Canopy Height	0.255	= 0.025
Time Since Fire	0.411	< 0.001
Burn Height	-0:441	< 0.001
Fire Interval	0.535	< 0.001

The above results demonstrate that *E. murrayi* and *S. challengeri* have very similar habitat preferences, both are found in moist forest habitats of high site quality. They were both detected significantly more frequently in sites that had a high % litter cover, a mesic understorey stratum, no grazing, and no evidence of fire. Their relative abundance were positively linearly correlated with litter cover, canopy height, time since last fire and the interval between fires, and negatively correlated with burn height and grass cover. Slight differences between the 2 species are evident. *S. challengeri* has a strong preference for habitats with an almost complete canopy cover and tolerates some grass/herb cover. *E. murrayi* was not significantly associated with any canopy cover class, strongly preferring a low grass/herb cover, and was detected more frequently than expected in sites which had a rainforest fern understorey. *E. murrayi* was also positively correlated with elevation, while *S. challengeri* showed no such association.

Other Species

Two species of *Calyptotis* (skinks) and the Lace Monitor *Varanus varius* were sufficiently abundant for analysis of habitat associations (Tables 7.16 and 7.17). Most other species of reptile, not classified into "Open Forest" or "Closed Forest" guilds, were detected too infrequently to allow statistical analysis of habitat preference. Table 7.15 summarises the frequency of occurrence and relative abundance of these reptiles. Species detected at less than 5% of survey sites should be considered uncommon to scarce in the Study Area. Many of these species are more common in swamps, riparian areas, woodlands or cleared grazing land, or only occur on the edge of their known ranges. Others are difficult to detect because they favour dense vegetation, or are nocturnal and/or arboreal (eg. tree snakes), or occupy large home ranges (eg. large elapids). Species that should have been detected in reasonable numbers on the basis of habit, detectability, distribution and habitat preference include: Major Skink *Egernia frerei*, Dwarf Crowned Snake*Cacophis kreftii*, Small-eyed Snake*Cryptophis nigrescens*, *Anomalopus verreauxii*, Stephen's Banded Snake *Hopolocephalus stephensii* (not detected), Pale Headed Snake *H. bitorquatus* (not detected) and the Coral Snake *Simoselaps australis* (not detected). These species must be considered genuinely rare in the Study Area.

Table 7.15. Frequency of Occurrence of Other Reptiles in the Study Area

Species	No. of sites	% Frequency Occurrence	Total Records (incl. Opportunistic)
Calyptotis scutirostrum	21	27	247
C. ruficauda	16	21	114
Varanus varius	7	9	18
Hemiaspis signata	4	5	4
Pseudechis porphryiacus	3	4	5
Egernia frerei	3	4	3
Phyllurus sp.	2	3	2
Cryptophis nigrescens	2	3	2
Ramphotyphlops nigrescens	2	3	2
Tropidechis carinatus	2	3	2
Physignathus lesueuri	1	1	6
Anomalopus vereauxii	1	1	1
Eulamprus quoyii	1	1	1
Cacophis kreftii	1	1	1
Boiga irregularis	0	0	1

Table 7.16. Significant Associations between Reptile Species Frequency of Occurrence and Environmental and Cultural Categorical Variables.

Variables Environmental	Species	Probability P
Habitat Type	*Calyptotis ruficauda*	0.007
Soil Type	*Calyptotis scutirostrum*	0.022
% Shrub Cover	*Varanus varius*	0.008
	Calyptotis scutirostrum	0.015
Understorey	*Calyptotis ruficauda*	0.003
Understorey Stratum	*Calyptotis ruficauda*	0.007
Canopy Height	*Calyptotis scutirostrum*	0.011
Years Grazed	*Calyptotis scutirostrum*	<0.001
Grazing Intensity	*Calyptotis scutirostrum*	0.047
Time Since Fire	*Varanus varius*	0.019
	Calyptotis ruficauda	0.047

Table 7.17. Significant Associations between Species Relative Abundance and Measured Continuous Environmental Variables.

Species	Regression r	Probability
Calyptotis scutirostrum		
Understorey 1(Mesic)	0.255	= 0.025
Understorey 2 (Xeric)	-0.244	= 0.036
Elevation	0.242	= 0.034
% Grass, Herb Cover	0.240	= 0.035
Years Grazed	0.396	< 0.001
Calyptotis ruficauda		
Rainfall	0.414	= 0.000
Distance to Old-growth	0.556	= 0.000
Elevation	-0.376	= 0.001
Time Since Fire	-0.246	= 0.03
Burn Height	0.250	= 0.039
Fire Interval	-0.236	= 0.066

Calyptotis scutirostrum was detected more frequently than expected on sites with clay soils, in tall forest and areas with a long history of grazing. It was also found to be positively correlated to grass/herb cover and grazing. The results suggest that this species prefers upland, higher site quality forests with grassy understoreys. It is a crepuscular or nocturnal species favouring moist microhabitats (Wilson and Knowles, 1988).

The analyses suggest that *Calyptotis ruficauda* prefers low elevation, dry forests on sites of low fertility but high rainfall. *C. ruficauda* has been previously reported as having similar habitat requirements to *C. scutirostrum* and being separated geographically (Wilson and Knowles, 1988). The results of this study suggest that these species have quite different habitat preferences even though microhabitat selection appears similar.

The Lace Monitor (*Varanus varius*) is a large carnivorous species which was detected in many of the State Forests of the Study Area. It was however, detected on only 7 sites during systematic survey. From these data, it was found to be significantly correlated to shrub cover and areas that had been burnt 3 to 6 years previously. Due to the small sample size these results should be viewed with caution.

Impact Assessment and Mitigation

Logging and succession

Review of reptile habitat and microhabitat requirements indicates that reptile species assemblages can be expected to change in response to the successional changes in vegetation structure and ground cover initiated by timber harvesting. In the short term timber harvesting opens the forest canopy, increases sunlight penetration to the ground and favours "Open Forest" species. Timber harvesting also increases the short term abundance of fallen timber and ground cover. Where regeneration and top disposal burns are used, "Closed Forest" species may be eliminated in the short term, and replaced by "Open Forest" species. In the medium term, prolific regeneration reduces light penetration and may favour "Closed Forest" species, while in the long term light penetration may again increase as the forest thins. Recovery of reptile communities to pre-disturbance states after logging should occur more rapidly than arboreal mammal communities and bird communities because ground cover and sunlight penetration are more important to reptiles than overstorey composition and the availability of tree hollows. Ground cover resources, with the exception of large fallen timber, are replaced relatively quickly or within a single harvest cycle. The availability of rock shelters is unlikely to be affected by management practices. The resource most susceptible to long term reduction is large log cover, which results from the natural collapse and decay of old-growth stems. This problem is likely to be most severe in forests where harvesting intensity is high and only a small portion of forest stems are able to senesce naturally. Large logs are an important resource for many of the larger reptiles, particularly snakes and egernid skinks. The abundance of large, fallen timber may increase immediately after the first old-growth harvesting cycle, but is expected to decline dramatically in subsequent cycles.

The likely responses and sensitivity of species to timber harvesting practices are becoming evident from recent studies of frequently detected species (Recher et al., 1975; Smith et al., 1992; Smith and Dunning, 1986). Little is known of rare reptiles. Previous surveys of reptiles in Moist Hardwood forests suggest that *L. delicata* and *Eulamprus quoyii* increase immediately after logging (0-8yr) and disappear as the forest matures, while *E. murrayi* decreases after logging and does not reappear until canopy closure up to 15 years after harvesting (FCNSW, 1981). In mixed forest in the Eden region, harvesting was found to favour *Eulamprus tympanum* and *Egernia saxtilis* through the creation of open light conditions with abundant fallen wood cover (Recher et al., 1975). In a study of reptile communities before and after logging in Moist Hardwood forests, Smith and Dunning (1986) found that numbers of *E. murrayi* and *Saproscincus* *challengeri* decreased significantly while *L. delicata* increased significantly after maximum utilisation logging, and only *S. challengeri* decreased after 33% canopy retention logging. Dunning and Smith (1986) found that normal maximum utilisation logging operations in Moist Hardwood forests at Mt Boss reduced canopy cover, large log cover, litter depth, litter cover, and bark cover, and significantly increased bare soil, rock, shrub and small log and debris cover. These effects could be observed 12 months after harvesting. The results from Smith et al. (1992) in forests of the Glen Innes Management Area indicated that *Ctenotus taeniolatus* preferred unlogged forests compared to old-logged (pre-1970) and recently logged forests, and that *Eulamprus murrayi* preferred old-logged forests to unlogged and recently logged forests probably because of the increase in log cover after selection logging combined with enough time for the canopy to close compared with recent logging). Otherwise the study found that timber harvesting alone had little impact on overall reptile abundance and diversity in the forests of the Glen Innes Management Area.

In this study, only *Ctenotus taeniolatus* showed a statistically measurable response to logging, being negatively correlated with the number of logging cycles and positively correlated with time since logging. This species however, prefers low site quality forests on rocky sandstone sites which are unlikely to be well utilised for timber harvesting. Another species *Saproscincus challengeri* has a strong preference for high canopy cover and is an inhabitant of Rainforests and Moist Hardwood forests with a mesic understorey. In Moist Hardwood forests the mesic midstorey is likely to provide the necessary canopy cover, and any impact from logging and post logging management (eg. burning and or grazing), which suppresses the regrowth of this stratum, is likely to disadvantage the species in the long term.

It is clear from the present study, and previous studies of common species, that timber harvesting advantages some species and disadvantages others, and that these effects change in time during of a single harvesting cycle. The only issue of management concern is the maintenance of refuge (shelter) areas to act as recolonisation sources. Options for maintenance of refuge areas include:

7.1 In areas where adjacent compartments are to be subjected to high intensity logging (>75% canopy removal) an alternate compartment logging practice be adopted to allow reptile population recruitment after logging;

7.2 Protection of examples of moist forest with a well developed understorey in filter strips and wildlife corridors, to act as recolonisation sources for moist, shade tolerant species to re-invade compartments after harvesting.

7.3 Permitting natural regeneration (no top disposal burn) in a portion (approximately 33%) of compartments in Moist Hardwood forests, wherever canopy regeneration will not be restricted, to prevent replacement of "Closed Forest" by "Open Forest" species.

Reptile populations generally occur at higher densities than higher vertebrates and persist in smaller reserves. Consequently reserve systems designed for protection of higher vertebrates should be sufficiently large and representative for the protection of the more common reptile species and communities.

Fallen Timber

Large logs provide nesting and feeding sites for small terrestrial carnivore/insectivore omnivores (Smith et al., 1990; Dickman, 1991), the humid environment of rotting timber also provides an important refuge during drought and fire. Large logs are a feature of 'old-growth' forests providing continuity of ground cover through successive generations of fire disturbance (Scots, 1991). Little attention has been paid to the maintenance of this resource in logged forest ecosystems. Logging operations (in areas without woodchip markets) commonly leave abundant fallen timber, but this tends to be green and of small diameter. It is unlikely that this timber fills the ecological role for natural old-growth logs, particularly for the larger reptiles which shelter in hollow logs. In this study, total reptile abundance was found to be significantly correlated with the amount of fallen timber at surveys sites. The forests of the Study Area have had a long history of timber harvesting. We found that natural 'old-growth' large logs (>40cm diameter) were rare, and that large log dependant reptiles (eg. *Egernia major* and *E. frerei)* were also rare.

Options for mitigating the impacts on large logs and large log dependent species include:

7.4 Large fallen old-growth trees be protected as far as practicable from disturbance during logging operations and afterwards from regeneration and prescribed burns.

7.5 Increase recruitment of large fallen 'old-growth' stems by protection of all remaining defective old-growth stems in logged forest from future harvesting and culling.

Grazing and Fire Effects

Many reptiles escape fire by burrowing or sheltering under and inside logs (Christensen et al, 1981; Longmore and Lee, 1981). Burrowing species may be more common during the first few years after fire, litter foraging species increasing later (Caughley, 1985). It is likely that the terrestrial reptile species detected in this survey would be affected by fires in the short term, either directly through mortality or indirectly through effects such as food shortage and increased predation. However, it is considered unlikely that fire effects would directly threaten the long term survival of local populations provided that opportunities for recolonisation remain. The most significant effects of fire are on long term habitat modification such as the suppression of understorey, and the removal of fallen logs.

The most significant potential effect of grazing is the possible reduction of shrub understorey and the effect of this upon arboreal and mesic understorey species. Grazing in the area is also closely associated with frequent burning and both are associated with decreasing understorey shrub cover and increasing grass cover (see Moore and Floyd 1994). This combination is likely to cause a shift in reptile community composition from 'shade seekers' to 'sun loving' species, particularly in moist habitats. The results of this study showed a strong significant association of "Closed Forest" reptile abundance and species richness with sites that were not grazed and which were very infrequently burnt. This suggests that grazing and frequent burning disadvantage these species. One species, *C. scutirostrum*, was found to prefer moist forests that had a long history of grazing and high grass cover. The two "Closed Forest" species *E. murrayi* and *S. challengeri*, which were detected frequently enough for analysis, were both strongly negatively associated with all indices of grazing and burning.

All reptile species which forage in the tree and shrub layer, and which are likely to be disadvantaged by the simplification of understorey through grazing and burning, were rarely detected in the forests of the Study Area. However, it is not clear whether this apparent rarity has resulted from landuse which may have suppressed structural diversity in the understorey of many forests in the Study Area, or is an artefact of poor detectability.

Options available to mitigate against adverse impacts from grazing and frequent burning include:

7.6 Elimination of grazing under Occupation Permits in all leases where burning is not effectively brought under control by SFNSW.

7.7 Reducing frequent and moderate (< 10 years) control burning to strategic locations for hazard reduction, over not more than 50% of the Hardwood forests in the Management Area.

Species of Special Conservation Significance

The majority of species within the Study Area were not reported with sufficient frequency to evaluate their regional conservation status or habitat requirements. The effects of forest land use on all vulnerable, rare, or threatened species should be determined by monitoring and further study.

Options available to improve the knowledge of these species and to mitigate any potential adverse effects of forest management practices:

7.8 The maintenance of a register of any opportunistic sightings of rare, threatened or special interest species with emphasis on accurate location of sightings.

7.9 The protection of all species classified as Rare, poorly known and potentially sensitive from logging disturbance by buffer zones of up to 100m until more is known about the effects of forest management practices on these species. (See Table 9.1)

Table 7.18 lists the species we consider, from the results of our survey and literature review, to be rare, poorly known and potentially sensitive to forest management practices. These species (apart from *D. australis*) also have a core of central distribution in the Study Area

Table 7.17. Rare, Poorly Known and Potentially Sensitive Reptile Species of the Study Area:

Species	Schedule 12 status
Phyllurus cornutus	
Diporiphora australis	
Hypsilurus spinipes	
Ceoranoscincus reticulatus	Vulnerable and Rare
Egernia frerei	
Egernia major	
Hemisphaeridon gerrardii	
Hopolocephalus stephensii	Vulnerable and Rare

Rare, Threatened and/or Potentially Sensitive Species

Carpet Python *Morelia spilota variegata*

This species occurs in a wide variety of habitats however, in north-east NSW it appears to favour wet forests with well developed understorey. Several specimens were detected in Richmond Range State Forest and one in Double Duke State Forest. It is vulnerable to direct mortality during logging operations, but is widespread and moderately abundant in north-east NSW, and is not expected to undergo significant long term population reduction as a result of timber harvesting. Smith et al. (1989a) listed this species as secure in north-east NSW. From the results of this study, it is considered that *M. spilota* is common in the North Richmond Range sub-region and rare in each of the other major sub-regions in the Study Area.

No special mitigation procedures are recommended for this species.

Ceoranoscincus reticulatus (Vulnerable and Rare Schedule 12)

This species is distributed in north-eastern Australia, from Grafton to north of Fraser Island, Queensland, and inland to Ewingar State Forest. It inhabits Rainforest and Wet Sclerophyll forests on rich dark soils. It shelters beneath and in rotting logs and under mats of leaf litter, foraging in these areas as well. Smith et al. (1989a) found it reasonably common in Rainforest of the Border Ranges. One specimen in Ewingar State Forest was detected during this study and it has subsequently been detected in Richmond Range State Forest (NPWS, 1993). *C. reticulatus* may be uncommon to common in the Eastern Fall subregion of the Study Area, and may also occur in the North Richmond Range sub region. It is likely to be rare or absent in the other sub-regions. There is no information on the sensitivity of this species to forestry land use however, it may be adversely affected by canopy disturbance from logging and roading which causes changes to microclimate and moisture regimes (NPWS, 1993).

Options for impact mitigation include mitigation measures 7.2-7.5, 7.8 and 7.9 (50m disturbance free radius).

Dragon *Diporiphora australis*

A rare species not previously recorded in the Study Area, with an uncertain taxonomic status. The nearest previous recording of this species is from central coastal Queensland. One specimen was collected in Fortis Creek State Forest, with its identification confirmed by the Australian Museum, which represents a large range extension into NSW. *Diporiphora australis* is thought to inhabit a wide variety of habitats preferring low shrubs for foraging and sleeping. Impacts of the proposal are unknown. Given the scientific interest of this population, the area around any further sightings should be kept free of disturbance (100m) until more information is available.

The Southern Angle-headed Dragon *Hypsilurus spinipes*

This species has a restricted distribution in moist forests from Gosford to southern Queensland (Webb, 1984). It was classified as restricted but abundant in moist forests of the Focal Peaks region by Smith et al. (1989b). Pugh (1982) subsequently collected many specimens in Rainforest and Moist Hardwood forests of an area in Clouds Creek State Forest. Southern Angle-headed Dragons appear to utilise small diameter mesic understorey shrubs and vines for arboreal activity, and spend most of their foraging time in leaf litter on the ground (Manning and Ehman, 1991). The impact of harvesting on this species is not known, but on the basis of its kown ecology a short term decline may occur in response to timber harvesting. Significant long term decline is not expected, provided habitats with a mesic understorey are not simplified through post logging grazing and burning. This species may occur at high denisties in localised populations where there is suitable habitat. Only one nest of the species in Dalmorton State Forest was detected. The species may be more common than this result suggests. Suitable habitat is most widespread in the Eastern Fall and North Richmond Range sub-regions of the Study Area.

Options for impact mitigation include mitigation measures 7.8.

Major Skink *Egernia frerei*.

This species is distributed from north-eastern NSW to Cape York Queensland. It is known to occur in a wide variety of habitats from vine thickets to woodlands (Wilson and Knowles, 1988), and is thought to be omnivorous. Like many egernids, individuals appear to be dependant on a particular refuge, in this region large hollow logs are often used. Three specimens were detected during this survey, 2 in the Southern Richmond Range sub-region and one in the Central sub-region. Two of which were found in large fallen logs. Forest management practices which reduce large log cover are likely to disadvantage this species.

Options for impact mitigation include mitigation measures 7.4, 7.5, 7.8.

Land Mullet *Egernia major*

This species is distributed in the moist forests of north-east NSW and south-east Queensland. It feeds on fruits, fungi and molluscs in forests with mesic understoreys. Like *E. frerei* , Land Mullets are dependant on large 'home' logs. It may also be dependant upon fruiting shrubs and trees. We detected 3 specimens of *E. major* in the Eastern Fall sub-regions of the Study Area, and the species may occur in wet gully forests in other sub-regions.

Options for impact mitigation include mitigation incude measures 7.4, 7.5 and 7.8.

The Pink-tongued Skink *Hemisphaeridon gerrardii.*

This species inhabits Rainforests and Moist Hardwood forests from central eastern NSW to Cairns in Queensland. It is partially arboreal, has a crepuscular to nocturnal activity pattern and feeds on molluscs (Wilson and Knowles, 1988). We detected one specimen of *H. gerrardii* in Ewingar State Forest. *H. gerrardii* is apparently reliant on moist microhabitats which support terrestrial molluscs and is likely to be sensitive to land use practices which suppress mesic understorey development in Moist Hardwood forests.

Options for impact mitigation include mitigation measures 7.2, 7.3, and 7.8.

The Beech Skink (*Pseudemoia zia*)

The Beech Skink is a rare and restricted species thought to prefer high elevation moist forests including Antarctic Beech forests. Preference for this habitat suggests that it may be adversely affected by logging, burning and grazing, at least in the short term. No data is available to predict possible long term impacts. Most likely to occur in the higher elevation areas of the southern Eastern Fall sub-regions of the Study Area, *P. zia* was not found during this survey.

Options for impact mitigation include measures 7.2 , 7.8 and 7.9.

The Leaf-tailed Gecko *Phyllurus cornutus*

The Leaf-tailed Gecko is distributed in the moist forests of north-east NSW and south-east Queensland. The taxonomy of this genus is uncertain, and a saxicoline (rock inhabiting) form occurring in granite and sandstone areas may represent a distinct, restricted species. Two specimens of the saxicoline form in the Southern Richmond Range sub-region were detected. It is unlikely that timber harvesting will have a significant impact on this form of *P. cornutus*. The effects of harvesting on the wet forest species are not known. Since it is thought to forage on tree trunks and limbs it could be adversely affected by harvesting in the short term. This form of the species was not detected in the Study Area.

Options for impact mitigation include mitigation measures 7.2, and 7.8 .

The White-Crowned Snake *Cacophis harriettae*- Vulnerable and Rare (Schedule 12)

Cacophis harriettae is distributed along the coastal and sub-coastal areas from the Tropic of Capricorn in the north to north-eastern NSW, reaching the southern extent of its distribution at Glenreagh, south of Grafton (Swan, 1990). This nocturnal snake feeds largely on small lizards, sheltering during the day under refuge such as leaf-litter and fallen timber (Cogger, 1992), and is found in Moist Hardwood and heathlands. *C.*

harriettae was not detected during this study but has been reported by Swan (1990) and recorded near the south-west boundary of the Study Area 0.15km SE of the confluence of Stockyard Creek and Chandler Creek by NPWS (1993). Its ecology and sensitivity to forestry is poorly known. The following options were recommended by NPWS (1993).

Options for impact mitigation include mitigation measures: 7.6-7.9 (50 m radius)

The Dwarf Crowned Snake *Cacophis krefftii*

This species has a moderately restricted distribution in moist forests along the central east coast of Australia, and may occur in all major sub-regions of the Study Area. It is a nocturnal or crepuscular skink feeder, foraging in leaf litter and under fallen logs and rocks (Shine, 1980). One specimen was detected in Candole State Forest. Timber harvesting effects on this species are not known, but given its known ecology, no significant long term impacts on regional populations are considered likely.

Options for impact mitigation include 7.8.

Pale-headed Snake *Hopolocephalus bitorquatus* - Vulnerable and Rare (Schedule 12)

Hopolocephalus bitorquatus is patchily distributed along the coast, ranges and western slopes of eastern Australia, from just north of Sydney to Cape York Peninsuia (Cogger, 1992). This nocturnal and partially arboreal snake occurs in a wide range of habitats from Rainforest and Moist Hardwoods to the drier forests on the western slopes. The species has been reported in the Study Area (Swan, 1990), however none of the records of the Australian Museum fall within State Forests. The species was not detected during this study. The few records of *H. bitorquatus* in the literature are probably a reflection of this species rarity. Its sensitivity to forestry practices is not known. The following mitigation option were recommended by NPWS (1993)

Mitigation Options: 7.4-7.9.

Stephen's Banded Snake *Hopolocephalus stephensii* (Vulnerable and Rare Schedule 12)

Stephen's Banded Snake is distributed from central east NSW to south-east Queensland. It is arboreal, inhabits Dry and Moist Hardwood forests and Rainforests, and is known to shelter in tree hollows (Wilson and Knowles, 1988). There are only a small number of records of this species in the literature from the north-east of the state. It was not detected during in this study but has been reported in Richmond Range State Forest and Nymboida National Park (NPWS, 1993). The reasons for its apparent rarity are not known, however it may require tree hollows and shrubby understorey and may be disadvantaged by management practices which reduce these key resources.

Options for impact mitigation include mitigation measures 7.6, 7.7, 7.8, and 7.9 (100m disturbance free radius).

8. IMPACTS ON AMPHIBIANS

Introduction

Amphibians are probably the most poorly known group of vertebrates in Australia. This is clearly shown in Tyler (1992) which presents most of the known information on Australian frog biology and ecology as species by species accounts. There is practically no detailed ecological information for the vast majority of species, and the taxonomy and distribution of several groups is still uncertain. There are also no reliable standardised survey methods available to assess relative abundance or habitat preference of the group. Most surveys rely heavily upon opportunistic records of calls or sightings. This procedure precludes the use of statistical methods for analysing habitat associations. The systematic survey procedures employed in this study are best suited to the analysis of habitat associations of terrestrial species dependent on riparian habitat for breeding.

Previously there had been no comprehensive field survey of amphibians in the Study Area. The amphibian faunas of Moist and Dry Hardwood forests of the escarpment and New England Tablelands to the west of the Study Area have been surveyed and described by Smith et al. (1992). The amphibian faunas of the Washpool and Gibraltar National Parks were surveyed by Barker (1980). Amphibian communities of the Rainforests and Moist Hardwood forests in the Border Ranges to the north and north west were surveyed by Smith et al. (1989a,b). The amphibians of the Murwillumbah Forestry District were surveyed by Manning (1992). There have been few surveys on State Forests or private property within the Study Area. Milledge (1986) surveyed the fauna of coastal Byron Shire and Smith et al. (1990) surveyed the fauna of the Orara and Bucca Valleys to the south of Grafton. With the possible exception of Barker (1980), none of these surveys focused on amphibian habitats.

Survey Methods

Detection Methods

Amphibians were detected by four methods:

Habitat searches

Each unit in the 77 survey sites was searched for one half man hour, and all individuals found active or hidden in refuges, or heard calling in the vicinity, were recorded.

Wet pitfalls

Two 20 litre buckets, containing approximately 40mm of 10% formalin, were dug into the ground at the start of unit 1 of each of the 77 sites (except in swampy sites) and left open for a minimum of two weeks.

Wetland searches

Areas considered prime amphibian habitat such as streams and wetlands were searched opportunistically and visited at night in order to record and identify calls.

Opportunistic sightings

Any frog species located from sightings or calls during other facets of fauna survey were recorded. Most records in this category were obtained during spotlight transects or on roads while travelling in the forests at night. Specimens detected by wet pitfall trapping and voucher specimens of species and morphs of uncertain status were forwarded to the Queensland and Australian Museums for identification.

Scope and Limitation of the Survey

The survey methods have the following limitations:

The principle aim of the study is the assessment of impacts due to timber harvesting and associated activities on the amphibian fauna. Consequently, field survey was focused on dryland habitats directly impacted by logging. Survey of riparian habitats, which are normally protected from logging by filter strips was minimal, aimed only at compiling species lists for different regions. Other habitats such as grasslands and swamps, that are not subject to logging but which often support significant populations of amphibians, were also less intensively sampled than ecosystems associated with timber production.

Habitat searches tend to under sample species which are arboreal, nocturnal, or reside in inaccessible refuges or which are particularly cryptic when inactive. These are characteristics common to many amphibians; most species are active only under favourable conditions of temperature and humidity, and many are nocturnal. Amphibians are most active during and immediately after rain, and this can greatly bias the results of surveys.

Wet pitfall traps sample only a small area, and only detect species which forage in terrestrial habitats. However pitfalls complement habitat searches because nocturnal species, species that shelter in inaccessible places and species that are active only under specific weather conditions are more likely to be collected by this means. In this study, several species were detected primarily by pitfalls (see Table 8.1). The success of wet pitfall traps is greatly influenced by temperature and rainfall (Dunning and Smith, 1986; A. Smith unpublished), rendering the statistical analysis of habitat associations unreliable.

Opportunistic searching of apparently suitable amphibian habitat, particularly in wet warm weather and at night, yields the greatest number of species. This technique does not allow the statistical analysis of habitat preference or impacts of forestry landuse as the data obtained is strongly biased by the selection of survey sites.

Species of the Study Area

The Study Area supports a relatively high diversity of amphibian species due to its location at the junction of two major biogeographic regions. Several species are restricted to north-eastern NSW and south-eastern Queensland, although none are endemic to the region. We compiled a list of amphibian species likely to occur within the Study Area on the basis of broad distribution patterns and known habitat requirements (Cogger, 1986; Tyler, 1992). Appendix E lists these species and summarises the results of our survey, those of other surveys, and records from the Australian Museum and NPWS Fauna Atlas. Habitat preferences, where known, and conservation status are also given.

In this survey, 7 species were recorded during habitat searches yielding a total of 46 specimens for 192.5 person-hours of search time. A further 6 species were collected in wet pitfalls and an additional species 7 were identified opportunistically and by special habitat seaches in streams and other potentially abundant sources of amphibians. A total of 20 species were detected. Only 3 species (Common Froglet *Crinia signifera,* Brown-striped Frog *Limnodynastes peroni* and Red-backed Toadlet *Pseudophryne coriacae)* yielded sufficient records for statistical analysis. Results from wet pitfalls were highly variable with 57 sites recording no amphibians and one site in Double Duke State Forest recording more than 80 individuals (this site was less than 200m from a large ephemeral wetland). The results from wet pitfalls were seriously confounded by weather. In one two-week period, torrential rain filled buckets in several locations rendering them inoperable and requiring re-installation. During another two week period, dry conditions prevailed and few specimens were collected. With the exception of *P. coriacae* no species were recorded with sufficient frequency during systematic surveys, to enable indices of abundance and species richness to be statistically analysed.

The results suggest that few amphibian species occupy habitats subject to logging, and that if forestry activities do impact upon amphibian communities this would most likely be due to indirect effects upon stream flow and water quality. However, in view of the lack of information it would be imprudent to rule out the possibility that some amphibians might experience impacts due to forestry activities.

Table 8.1. Amphibians Detected in the Study Area, Showing Numbers Recorded and Percentage of Sites at which Species were Recorded (transect surveys only).

Species	Habitat Search		Pitfall Trap		Wetland and Opportunistic Sightings
	Number	%sites	Number	%sites	
Adelotus brevis					1
Crinia parinsignifera					1
Crinia signifera	8	5.19			5
Lechriodus fletcheri					2
Limnodynastes ornatus			13	3.90	3
Limnodynastes peroni	6	1.29	50	1.29	2
Limnodynastes tasmaniensis			5	1.29	
Limnodynastes terraereginae			24	2.60	
Litoria caerulea	4	1.29			2
Litoria chloris					2
Litoria dentata	3	2.60			1
Litoria fallax					4
Litoria latopalmata	1	1.29	1	1.29	7
Litoria lesueuri			1	1.29	15
Litoria nasuta			3	2.60	
Litoria peronii					8
Mixophyes fasciolatus					7
Philoria loveridgei	1	1.29			
Pseudophryne coriacea	23	12.99	10	9.09	10
Uperiolia laevigata			3	3.90	1

Amphibian Communities and Habitats

The amphibians of the region are ectothermic (rely on external sources for body heat), predominantly insectivorous, and require free water for reproduction, with the exception of *Assa darlingtoni* and *Philoria spp*. which can breed respectively in moist litter and boggy seepages. The habitat requirements of most species are unlikely to be determined by forest cover or floristics, and are more strongly influenced by climate; distance to water bodies; the hydrological and morphological characteristics of water bodies; stream bank vegetation; and the availability of suitable micro-habitat for aestivation, brumation and shelter. Most species are nocturnal and active only under humid conditions and appropriate temperatures. Micro-habitat selection is important for conserving body water and avoiding predators. Distribution patterns exhibit some broad correlations with vegetation type, but these are most likely due to interrelations between climate and vegetation. Habitat fidelity is generally lower than that of higher vertebrates and many species are found in a broad range of habitat types.

Of the 39 species likely to occur in the Study Area, 36 lay eggs in or near temporary or permanent water bodies and rely upon free water for larval development and metamorphosis. *Assa darlingtoni* rears its young from hatchling to juvenile frog stage in brood pouches on the backs of adult males, and *Philoria spp*. lay eggs in tunnels in wet soil and/or moss where the young develop from egg to young frog within the egg capsule. These species, which do not have an aquatic stage, are confined to moist micro-habitats within wet forests. Of the 36 species that require free water, only a few are dependent on forested habitats and fewer still utilise habitats beyond the riparian zone or beyond areas of temporary inundation. Those species which are widespread within forest are often also common in adjoining woodland and grazing land. Only *Pseudophryne coriacea* and *Lechriodus fletcheri*, which are capable of breeding in very small drainage lines and puddles, are believed to be largely restricted to forest habitats and able to use habitat away from the riparian zone for breeding. *P. coricea* was the only species detected during this survey to display statistically significant habitat relationships. It was found more frequently than expected in sites with a high litter cover (20-50%) (Chi-square P=0.02); in recently burnt sites (Chi-square P=0.03); and in sites with dry rather than mesic understorey strata (Chi-square P=0.04).

Amphibian species of the Study Area can be grouped into the following guilds on the basis of habitat specialisation and requirements for breeding. It should be noted that these classifications are based on extremely limited knowledge, and some species may subsequently be reclassified into different groups on the basis of more complete information .

a) species found throughout moist forests, and which do not require free water for breeding:

Assa darlingtoni
Philoria spp

b) Species found throughout forests and which can breed in temporary (or permanent) ponds:

Adelotus brevis
Crinia signifera
Crinia parinsignifera
Lechriodus fletcheri
Limnodynastes ornatus
Litoria chloris
Pseudophryne coriacae
Uperolia laevigata

c) Species found throughout forests, but which breed in permanent or semi-permanent water bodies, streams, swamps, and dams:

Litoria dentata
Litoria caerulea
Litoria fallax
Litoria gracilenta
Litoria latopalmata
Litoria lesueuri
Litoria peronii
Litoria tyleri
Litoria vereauxii
Mixophyes fasciolatus

d) Species largely confined to riparian habitat or vegetation surrounding permanent or semi-permanent water bodies:

Crinia tinnula
Limnodynastes dumerilii
Limnodynastes fletcheri
Limnodynastes peroni
Limnodynastes tasmaniensis
Limnodynastes terrareginae
Mixophyes balbus
Mixophyes iteratus
Litoria brevipalmata
Litoria nasuta
Litoria olongburensis
Litoria pearsoniana
Litoria phyllochroa
Litoria revelata
Litoria subglandulosa
Litoria aurea

Impact Prediction and Mitigation

Review of published literature failed to locate any previous conclusive studies of forestry impacts on amphibian habitats or communities. There is a dearth of ecological information on the group as a whole, most studies have concentrated on taxonomy and breeding biology. With such little information, it is difficult to assess potential impacts. However, forest managers should be aware of the following points. Amphibian numbers and diversity are greatest in and adjacent to free water. The richest frog faunas found in the Study Area were found in the low-lying parts of Mt. Belmore, Double Duke, Devils Pulpit and Candole State Forests. These areas contain ephemeral swamps and swamp forests of Paperbark and Swamp Mahogany which have had a long history of grazing, grazier burning, Tea-tree harvesting and some logging. No habitats of this type were identified as being in pristine condition during this study, therefore comparisons could not be made and the effects (if any) of these management practices on frogs could not be determined. Some frogs (*Lechriodus fletcheri, Assa darlingtoni, Philoria spp*) within the Study Area are restricted to Rainforest and Moist Hardwood habitats. These species are among those most likely to be disrupted by timber harvesting, burning and grazing, as they are not confined to free water and protected gullies. A stream-side corridor reserve system should help protect the breeding habitat of most amphibian species, except where grazing occurs and where filter strips fail to prevent declines in water quality. Timber harvesting operations have significant effects on water quality including elevated concentrations of dissolved salts, suspended solids and nutrients (Campbell and Doeg, 1989). However, the extent to which riparian species use and depend on upland habitat for purposes other than breeding is not known, so that little advice can be provided on the appropriate design of wildlife corridors for amphibian protection.

Options for mitigation of potential impacts and for redressing the current lack of information on forest amphibians include:

8.1 Amphibian species which breed away from permanent water may be more vulnerable to harvesting-induced changes in micro-habitat, and should be subject to further investigation and monitoring.

8.2 Cultural disturbance, such as grazing and burning, should be discouraged in swamps and ephemeral wetlands, until the effects of these disturbances on important amphibian habitat are more clearly understood.

8.3 A register should be kept of any opportunistic sightings of rare, threatened or special interest species with emphasis on accurate location of sightings.

8.4 All populations of rare and potentially sensitive species should be protected from logging disturbance by up to 50m buffer zone until more is known about the effects of forest management practices on these species. (See Table 9.1).

8.5 Further monitoring and research to determine the sensitivity of amphibians to any changes in water quality associated with forestry operations.

<u>Rare, Threatened and Special Interest Species</u>

Marsupial Frog *Assa darlingtoni* - (Vulnerable and Rare Schedule 12).

Distributed from the McPherson Ranges south to Marengo State Forest and Mount Hyland Nature Reserve (NPWS, 1993), *A. darlingtoni* is found in Beech and Rainforests and adjacent Moist Hardwood forests. Barker (1980) found it to be common at 7 sites in Gibraltar Range and Washpool National Parks. The species was not detected during this survey, but is likely to occur in the wetter forests of the northern Richmond Range and Eastern Fall sub-regions. The species has been recorded previously in Billilimbra and

Washpool State Forests. *A. darlingtoni* is classified as abundant but restricted in the core of its distribution to the north (Smith et al., 1989b). There is no information on the effects of forest management practices on the species, however the species may be sensitive to changes in micro-climate and moisture regimes resulting from canopy disturbance from logging and roading (NPWS, 1993).

Options for impact mitigation include mitigation measures 8.1 and 8.3.

Philoria sp. - (Vulnerable and Rare Schedule 12).

The identity and affiliation of the *Philoria sp.* occurring in the Study Area is uncertain and it may be a new species. Its habitat requirements are likely to be similar to those of other *Philoria* including dependence on moist, mossy, wet soil in seepages and soaks where it reproduces in burrows beside drainage lines. Preferred breeding areas appear to be moist seepages at the headwaters of streams (A. Smith unpublished observations). Water courses of this order are often logged, but the impact of such logging is not known. Excessive clearing and logging may increase light penetration and temperature leading to loss of soil moisture and suitable conditions for persistence. Barker (1980) found *Philoria sp.* to be common at 4 sites in Gibraltar Range and Washpool National Parks. A specimen was detected by call during this survey in Cangai State Forest.

Options for impact mitigation include mitigation measures 8.1, 8.3 and 8.4 (50m disturbance free radius).

Sphagnum Frog *Philoria sphagnicolus* - Vulnerable and Rare (Schedule 12)

This species is endemic to the Northern Tablelands. Known only from a few localities from Gibraltar Range through Dorrigo to the Comboyne Plateau (Anstis, 1981). The habitats of *Philoria sphagnicolus* are known to be similar to those of P. *loveridgei*. This species was not detected by Barker (1980) or during this survey and is not considered likely to occur in the region (NPWS, 1993).

Green and Golden Bell Frog *Litoria aurea* - Threatened (Schedule 12).

L. aurea is found from eastern Victoria and most of eastern NSW, and it reaches its known northern most limit just outside the Study Area to the north of Tyagarah (NPWS, 1993). The species inhabits riparian areas and is largely aquatic. No specimens were recorded during this survey. Direct impacts from forestry land use are unlikely, particularly if riparian habitats are reserved. Little is known of indirect impacts through changes to stream flow and water quality.

Options for impact mitigation include mitigation measures 8.2 -8.5 .

Green-thighed Frog *Litoria brevipalmata* -Vulnerable and Rare (Schedule 12).

Distributed in forests of north-eastern NSW and south-eastern Queensland (known from isolated localities), *L. brevipalmata* is a poorly known species that has apparently declined in recent times. It was not detected during this survey but has been reported at Mobong Falls Forestry Reserve close to the southern boundary of the Study Area (FCNSW, 1992). Logging may affect water quality in streams but no information is available to assess likely impacts of changes in water quality on amphibians.

Options for impact mitigation include mitigation measures 8.1, 8.3, 8.4 (50m disturbance free radius) and 8.5.

Olongburra Frog *Litoria olongburensis* - Vulnerable and Rare (Schedule 12)

A frog of coastal lowland swamps and creeks particularly swamp sclerophyll forests, wet heath and sedgelands (NPWS, 1993). *Litoria olongburensis* is another poorly known species. Although not detected during this survey, *L. olongburensis* has been previously recorded in the Study Area at Broadwater National Park (Australian Museum) and is known to occur near Ballina (Ingram and Corben, 1975). *L. olongburensis* may be susceptible to habitat changes due to fire and grazing in ephemeral swamps and swamp sclerophyll forests

Options for impact mitigation include mitigation measures 8.2- 8.5 .

Peppered Frog *Litoria piperata* - Vulnerable and Rare (Schedule 12)

A Northern Tableland species which has been recorded south-east of Glen Innes (Tyler and Davies, 1985), *L. piperata* inhabits riparian vegetation and is only likely to occur in the higher altitude western extremities of the Study Area. Sensitivity to forestry is unknown, adverses effects of increased siltation resulting from roading, logging, and soii compaction are possible (NPWS, 1993).

Options for impact mitigation include mitigation measure 8.3, 8.4.

Glandular Frog *Litoria subglandulosa* - Vulnerable and Rare (Schedule 12)

This species is a Northern Tableland endemic. *L. subglandulosa* inhabits montane swamps and streams and is likely to occur in the higher altitude, western extremities of the Study Area. Barker (1980) found specimens at 2 sites in Gibraltar Range National Park and it was also found in Gibraltar Range National Park by Smith et al. (1992). Adverse impacts from forestry landuse are unlikely, particularly if riparian areas are adequately reserved, although the species may be sensitive to high sediment loads in streams following soil disturbance and the impacts of cattle grazing in swamps (NPWS, 1993).

Options for impact mitigation include mitigation measures 8.2, 8.3-8.5 (50m disturbance free radius).

Tinkling Froglet *Crinia tinnula* - Vulnerable and Rare (Schedule 12).

C. tinnula is apparently restricted to swamps and swamp forests in north-eastern NSW and south-eastern Queensland. Known to occur near Ballina (Ingram and Corben, 1975). The species was not detected during this study although suitable habitat exists in Double Duke, Tabbimobile and Candole State Forest. The impacts of logging, grazing and tea-tree harvesting on this species are unknown. The swamp forests of the Study Area are important habitat for many amphibian species and further research into landuse impacts on this habitat type is required.

Options for impact mitigation include mitigation measures 8.2, 8.3 and 8.4 (50m disturbance free radius).

Stuttering Frog *Mixophyes balbus* - Vulnerable and Rare (Schedule 12).

This species inhabits riparian rainforest and wet sclerophyll forests and is distributed from northern coastal Victoria to its northern distributional limit in the study area (Corben and Ingram, 1987). The species has been previously recorded in Cangai and Billilimbra State Forests and Washpool National Park (NPWS, 1993), however was not detected during this study. Much of the foraging habitat of the Stuttering Frog should be protected if riparian forests are adequately reserved, however, the species may suffer adverse impacts from increased stream sedimentation following roading or other soil disturbing activities (NPWS, 1993).

Options for impact mitigation include mitigation measures 8.3- 8.5.

Southern Barred Frog *Mixophyes iteratus* - Vulnerable and Rare (Schedule 12).

Distributed in rainforests and moist forests of north-eastern NSW and south-eastern Queensland. *M. iteratus* is a poorly known species which is expected to have habitats similar to other *Mixophyes*. NPWS (1993) consider it to be a specialised riverine frog. The species has been recorded previously in Boundary Creek, Billilimbra and Shea's Knob State Forests and Washpool National Park. The species was not recorded during this study. Impacts from forestry landuse in foraging habitat are unknown, but are unlikely to be severe in breeding habitat if riparian areas are adequately reserved. Impacts from high stream sediment loads due to roading or other soil disturbance are possible (NPWS, 1993)

Options for impact mitigation include mitigation measures 8.3-8.5.

9. IMPACT MITIGATION OPTIONS

The Conservation Significance of the Study Area.

Special Features of the Grafton Management Area

Special features of the Management Area include:

a) A high biodiversity at the State and National levels due to the wide variety of habitat types and ecological gradients represented, ranging from high elevation moist forests to dry subcoastal heaths, and the location of the region in the zone of overlap (Macpherson/Macleay overlap) between Torrensian (tropical) and Bassian (temperate) biogeographic regions.

b) A large number (39) of rare and endangered species, especially mammals in the Critical Weight Range.

c) The occurrence of populations of many species at or close to their geographic range limits, including the only NSW population of the Dragon lizard *Diporiphora australis* in Fortis Creek State Forest.

d) A regionally significant concentration of nectarivorous mammals (Gliders and Flying Foxes) and endangered fauna (including the Squirrel Glider, Brush-tailed Phascogale, Yellow-bellied Glider, Spotted-tailed Quoll, Rufous bettong and Long-nosed Potoroo) in Candole State Forest.

e) Examples of unlogged but loggable Moist Hardwood old-growth in Dalmorton State Forest, which have achieved local significance through previous logging of approximately 97% of the original extent of loggable old-growth Moist Hardwood in the Management Area.

f) Significant populations, in the national and State context, of Yellow-bellied Gliders, particularly in unlogged Spotted Gum forest in the upper reaches of the Cunglebung Catchment in Dalmorton State Forest.

g) The occurrence of locally significant complex mosaics of diverse Rainforest, Moist Hardwood, and Dry Hardwood habitats in Cangai State Forest.

h) The occurrence of a population of the Hastings River Mouse in Clouds Creek State Forest and in unlogged forest in Dalmorton State Forest.

i) The State Forests represent a crucial link in the major north-south corridor of continuous forest cover running along the eastern edge and escarpment of the Northern Tablelands from Washpool National Park to Dorrigo, through Clouds Creek, Sheas Nob, Boundary Creek and Marara State Forests.

Special features of the Casino Management Area

Special features of the Management Area include the following:

a) A high biodiversity at the State and National levels due to: the wide variety of habitat types and ecological gradients represented, ranging from high elevation moist forests to dry subcoastal heaths; and location of the region in the zone of overlap (Macpherson/Macleay overlap) between Torrensian (tropical) and Bassian (temperate) biogeographic regions.

b) A large number (49) of rare and endangered species, especially mammals in the Critical Weight Range.

c) Good examples of north-south moisture gradients under continuous forest cover, from upper Richmond Range State Forest in the north to Mount Marsh State Forest in the south.

d) The provision of major forest corridors incorporating the Billilimbra, Washpool, and Ewingar State Forests on the eastern escarpment of the New England Fold Belt, and Richmond Range, Mount Pikapene, and Cherry Tree State Forests on an extensive north-south tract of forest which branches into an east-west band of forest that extends to the sea, through Mount Belmore, Mount Marsh, Banyabba and Gibberadgee State Forests.

e) The occurrence of near pristine mammal communities in the Moist Hardwood and Warm Temperate Rainforests of Billilimbra, Washpool and Ewingar State Forests.

f) The occurrence of a regionally significant examples of i) dry sandstone escarpment habitat in the southern area of Richmond Range State Forest ii) an extensive patch of Dry Rainforest in Cherry Tree State Forest iii) an ephemeral wetland surrounded by Double Duke State Forest.

g) The occurrence of the most significant known population of the Hastings River Mouse in Australia in Billilimbra State Forest (M. Samson, NPWS pers. comm.).

Options for Mitigation of Impacts

Options for mitigating the impact of landuse practices on the fauna and flora and maintaining special features of Management Areas include:

a) Protection of habitats, species populations or sites of significance in reserves within State Forest;

b) Modification of forest management practices to eliminate or reduce impacts on habitats and species populations;

c) Monitoring to evaluate the effectiveness of mitigation procedures and further research to clarify areas of uncertainty.

Through a careful combination of all three strategies it should be possible to achieve both conservation and economic objectives without excessive reduction in both values.

Options for Reservation

Moist forest ecosystems in the steeper eastern part of the Study Area are well represented within Reserves on a regional basis, including the Guy Fawkes, Nymboida, Gibraltar Range and Washpool National Parks. Further reservation and restoration of high diversity Moist Hardwood forest in Cangai, Washpool and Billilimbra, although desirable from a conservation viewpoint cannot be justified on an area basis as these habitat types are well represented in adjoining reserves. There is a case, however, for the protection of small remaining stands of unlogged Moist Hardwood in Dalmorton State Forest, since this area is geographicly isolated from other major occurences of Moist Hardwood by topgraphic features and river basins. Approximately 320 ha of remnant Moist Hardwood in this area has local significance for maintaining structural habitat diversity and continuity of regrowth and old-growth successional stages.

Smaller, unmapped stands of high quality old-growth forest may well occur within the Study Area. If such stands are identified, for example during prelogging site inspections, the conservation status of each stand should be assessed in relation to the proximity of flora reserves of a similar forest community and other relevant factors before commencement of logging. Where stands represent unique remnants of high quality old-growth forest within a State Forest, there would be strong grounds for incorporating these into the reserve system.

The National Parks on the coast of the Study Area, Yuragir and Bundjalung National Parks contain different types of habitat to those represented within the State Forests. Banyabba Nature Reserve contains habitat representative of the State Forests of the lower Richmond Range. The only subregion that would appear to lack representative Nature Reserves is the Coast Range. An option for the protection of forest ecosystems of the Coast Range is the dedication of a significant portion of northern Candole State Forest (eg. 25%) as a Nature Reserve. Such a reserve would necessarily include previously logged forest that would, in time, regenerate to its unlogged state. Logging intensity appears to have been so low that oldgrowth structure and appearance has been maintained throughout significant portions of Candole State Forest.

Special features of Candole State Forest include the following (after Mackowski pers. comm. 1993, and this study):

a) an exceptionally diverse mosaic of forest types and eucalypt species;

b) a high understorey diversity including the occurrence of heaths and winter flowering Banksia;

c) a high diversity of nectarivorous mammals and endangered CWR mammals;

d) occurrence of littoral rainforest patches in protected gullies providing refugia for some rainforest and mesic forest fauna;

e) a mild climate with less spring drought and mild winter which is thought to be an important factor in maintaining a high nectarivore diversity;

f) close proximity to the adjoining Yuraygir National Park providing a continuous gradient from coastal heath to dry, open forest;

g) a low cattle carrying capacity (one head per 12 ha) due to phosphorus deficiency and toxic plants, which may have been a contributing factor in maintaining high biodiversity.

Management for Impact Mitigation

Options for mitigation of impacts of logging and associated activities on flora and fauna values through modification of management practice have been discussed in the body of the report. A summary of some general issues follows:

Fire

The formulation of appropriate fire regimes is a complex process and requires consideration of issues related to silviculture, hazard reduction, grazing and forest ecology. Ecological considerations were not taken into account in previous Fuel Management Plans for the Area, which was an issue of great concern during the study, given the enormous impact of fire on the ecology of the forests. The predominant fire regime in the hardwood forests of the Study Area consists of low intensity fires at a frequency of less than four years, mostly in the late winter or early spring. The effect of this regime appears to have been to suppress woody shrubs and many species of ferns, leading to the maintenance of large areas of simple grassy understoreys and low levels of forest fauna diversity, particularly in dry hardwood forests. Options for mitigating adverse impact of the fire regime on forest ecosystems include:

1 More precise definition of fire management policy for the Study Area, taking into account the effect of fire regimes on the forest ecosystems, and working to obtain the cooperation of forest graziers in the implementation of fire policy.

2 More active fuel reduction management to maintain a mosaic of different fire regimes with designation of some areas as Low Fire Frequency Zones which are mapped and left unburnt for as long as possible. Although the maintenance of a mosaic of regimes is already an objective of the Fire Management Plans, data from our site-based surveys and general observations from the State Forest estate suggest that large areas are burnt under a similar frequent, low intensity regime. Low Fire Frequency Zones would be protected by a perimeter of forest maintained at low fuel levels, to prevent fire from entering the zone and to prevent wild fires from leaving the zone during the fire season. Such a strategy should include a monitoring and mapping program to more fully determine the ecological and silvicultural effects of different fire regimes.

3 A thin layer of unburnt litter, preferably of 4 - 6 tonnes per ha should be retained unburnt to avoid destroying the microfauna and flora, and volatilising nutrients. This can be achieved by burning when the lower layers of litter are moist to ensure that the nutrient rich litter and surface soil are not heated to 200ºC.

The Commission proposes to revise current fire management practices in the Grafton District (R. Williams pers. comm.) to take into account ecological considerations. Future strategies will aim to maintain a mosaic of vegetation subject to differing fire frequencies based around four burning cycles (2-3 year, 3-5 year, 6-10 year, and >10 year cycles).The aim of the proposed burning regime is to subject less than 5% of the district to 2-3 year burning, less than 30% to 3-5 year burning, <25% to 6-10 year burning, >25% to >10 year burning and 15% to no burning

<u>Birds</u>

Options for maintaining and achieving the diversity and conservation of avifauna include:

4 Reduction in the extent and frequency of cultural fires in the State Forest Estate Because of the strong 'local cultural' effect (ie frequent burning by graziers to promote fodder) forest grazing may also require phasing out of wherever burning is not effectively brought under control by the Commission.

5 Actively managing fuel levels to ensure a mosaic of fire regimes occurs.

6 The inclusion of sheltered SE-aspects in addition to gullies in the network of unlogged and unburnt refuge areas and corridors.

7 The maintenance of a minimum of 3 well spaced habitat trees for each hectare of forest in low site quality forest, and 6 well spaced habitat trees per hectare in high site quality forest.

8 The selection and retention of trees suitable for rapid hollow development to hasten the recruitment of hollow bearing trees where hollow bearing trees are below the optimum densities.

9 The dedication of certain areas within State Forests or adjacent National Parks, with a high diversity of flowering species, as control areas in which apiary is to be excluded for the purpose of monitoring and future evaluation of apicultural impacts.

10 The Sooty Owl is an endangered species which may be adversely affected by logging operations, as it is reported to be most abundant in moist old-growth forest. Options for the conservation of the Sooty Owl includes 50% canopy retention during logging operations in all high quality moist old-growth forest.

Bats

Options for mitigation of logging and culling impacts on bats include options 2, 4, 5, 7-9, above and, in addition:

11 Protection of all old-growth stems in filter strips from harvesting; (gully habitat trees being the most critical for bats),

12 Mapping permanent ponds (>5m in length) and protected potential or actual habitat trees adjacent to these pools in 100m wide protection strips of unlogged forest.

13 Protection of large winter flowering *Banksia spp* in the shrub understorey from logging and fire damage as far as practicable during harvesting operations;

14 Protection of known roost sites from harvesting disturbance by unlogged buffers of 100m radius, and pre-logging surveys to identify the occurence of roost sites in old-growth;

Non Flying Mammals

Options for mitigation of impacts on arboreal mammals which reach peak abundance in unlogged high quality old-growth forest include, in addition to Options 7-9:

15. Reservation of all remaining areas of unlogged Moist Hardwood and high quality Dry Hardwood from logging.

16. Reduced intensity logging of high quality Dry Hardwood forests to retain 50% of the stems >40cm dbh in order to maintain a permanent uneven aged structure.

17. Marking and retention of all feed trees of Yellow-bellied Gliders (this represents continuation of current practice)

Options for protection of the large log resource from logging impacts include, in addition to Options 1, 2, 4 and 5:

18. The protection of large fallen logs (>40cm diameter and 5m length) from destruction in regeneration burns as far as practicable.

19. Further research and evaluation of logging impacts on habitat tree dynamics, including a quantitative assessment of current forest structure.

Additional options for protection of CWR mammals include:

20. Development of fox control techniques which do not affect Dingos and other predators;

21. Allowing Dingo numbers to increase (by exclusion of grazing and non-compatible uses and eliminating Dingo control within 1.5km of boundaries with agricultural land) and controlling Foxes and Cats;

22. Adopting a scattered mosaic or alternate coupe logging practice to improve population recruitment (of sedentary birds, reptiles, amphibians and small mammals) after logging. Alternate coupes should be logged not less than 10 years apart in Moist Hardwood Forest, and 5 years apart in Dry Hardwood Forest.

Reptiles

Options for maintenance of representative populations of the more common reptile communities include, in addition to Options 2, 4-8, 15, and 18:

23. Permitting natural regeneration (no head disposal burn) in approximately 33% of compartments in Moist Hardwood forests, where ever canopy regeneration will not be restricted, to enhance survival of Closed Forest Species.

Amphibians

Options for mitigation of potential impacts include:

24. Cultural disturbance, such as grazing and burning, should be discouraged in swamps and ephemeral wetlands, until the effects of these disturbances on important amphibian habitat are more clearly understood.

Endangered Species

The following options for impact mitigation apply equally to endangered species of all groups of fauna:

25. All known populations of colonial roosting and nesting sites, and rare and poorly known endangered species with restricted distributions (eg. less than 10 known sites in the Study Area) which are potentially sensitive to forestry, should be protected from logging disturbance by buffer zones of up to 200m as a precautionary measure until management practices have been developed which take their requirements into account and enable them to persist in logged forest. Recommended disturbance free zones for each species is represented in Table 9.1.

Table 9.1. Recommended Disturbance Free Zones for Rare, Restricted and Sensitive Species Requiring Precautionary Protection of Known Populations in the Study Area.The number of known sites refers only to accurately located (within 200m) sites based on results of this survey and the NPWS NE Fauna Survey.

Species	Radius of protected Zone (m)	Number of Known Sites (SFs)	
Rare Species Requiring Nest Site Protection		Grafton	Casino
Square-tailed Kite (nests only)	200	0	0
Powerful Owl (nests only)	200	0	0
Masked Owls (nests only)	200	0	0
Sooty Owl (nests only)	200	0	0
Colonial Bats Requiring Protection (roost sites only)			
Black Flying Fox	100	0	0
Hoary Bat	100	1	0
Little Bent-wing Bat (caves)	100		
Common Bent-wing Bat (caves)	100		
Large Pied Bat	100	0	0
North Queensland Long-eared Bat	100	0	0
Large Footed Mouse-eared Bat	100	2	1
Beccari's Mastif Bat	100	0	0
Yellow-bellied Sheath-tailed Bat	100	1	1
Greater Broad-nosed Bat	100	3	2
Troughton's Eptesicus	100	0	0
Sensitive, Restricted and Poorly Known Species			
Double-eyed Fig Parrot	200	0	1
Eastern Bristlebird	200	0	0
Black-breasted Button Quail	100	0	0
Yellow-eyed Cuckoo Shrike	200	0	0
Olive Whistler	200	1	0
Brush-tailed Phascogale	200	0	1
Squirrel Glider	100	1	0
Eastern Pygmy-possum	100	0	0
Long-nosed Potoroo	100	1	1
Koala	100	9	5
Hastings River Mouse	100	2	1
Golden-tipped Bat	100	3	3
Egernia frerei	50	1	2
Pseudemoia zia	50	0	0
Hopolocephalus stephensii	100	1	1
Ceoranoscincus reticulatus	50	0	2
Diporiphora australis	100	1	0
Philoria spp.	50	1	1
Phyllurus cornutus	40	0	2
Litoria brevipalmata	50	0	0
Litoria aurea	50	0	0
Litoria subglandulosa	50	0	0
Litoria olongburensis	50	0	0
Crinia tinnula	50	0	0
Mixophes balbus	50	1	2
Mixophes iteratus	50	1	0
Cacophis harriettae	100	0	0
Hoplocephalus bitorquatus	100	0	0

Recommendations for Further Research and Monitoring

Options for further research and monitoring include the following:

1. the effects of honey production in State Forests on native fauna;
2. the effects of logging and tree age on nectar and pollen production in representative forest types;
3. the impacts of logging on habitat tree dynamics, including a quantitative assessment of current forest structure;
4. the dynamics of large log production and decay in representative logged forest types;
5. the impact of roading, understorey structure and 1080 baiting on CWR marsupials and their natural and introduced predators;
6. the effects of grazing and fire on fire sensitive habitat components and the fauna dependant upon them;
7. the ecology, habitat requirements and sensitivity of amphibian species to forestry and associated practices;
8. the effects of grazing, burning and tea-tree harvesting on swamp amphibians;
9. establishment of a register of sightings of all endangered, unusual or special interest species by State Forests, staff training in the identification of Schedule 12 species, periodic analysis of the database to review species conservation status and sensitivity to management. Each record in the database should record the following information:

   - specific name
   - Date of sighting or collection
   - The State Forest or general location of the sighting
   - AMG coordinates of the location of the sighting -forestry workers should indicate the location on a 1:25,000 scale map so that it can be located to within 100m
   - The name of the person who reported the data
   - The name of the person who identified the species
   - Whether a specimen was taken
   - Additional comments

   Long term programs such as this are the only inexpensive means of obtaining information on rare species. Data should be analysed regularly to validate past conclusions and clarify future impacts.

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APPENDIX A. THE SURVEY SITES OF THE STUDY AREA.

Site	State Forest	Forest Strata	Logging History	Easting	Northing
4	Doubleduke	Blackbutt	Unlogged Reserve	521580	6775335
5	Doubleduke	Blackbutt	1960-70	522230	6771725
6	Doubleduke	Blackbutt	1960-70	519750	6767315
7	Doubleduke	Non Forest (melaleuca)	Swamp 1980-90	515690	6765925
8	Doubleduke	Blackbutt	1970-80	516575	6766000
9	Devil's Pulpit	Blackbutt	1970-80	515875	6761265
10	Devil's Pulpit	Dry Hardwood	1970	522170	6761780
11	Richmond Range	Moist Hardwood	1960-70	472700	6829445
12A	Richmond Range	Moist Hardwood	Pre 1960	470770	6832090
12B	Richmond Range	Moist Hardwood	Pre 1960	471450	6831560
13	Richmond Range	Moist Hardwood	Pre 1960	470705	6830000
14	Richmond Range	Dry Hardwood	1970-80	477270	6824410
15	Richmond Range	Moist Hardwood	Pre 1960	472595	6821385
16	Richmond Range	Rainforest	1960-70	474125	6816475
17	Richmond Range	Moist Hardwood	1960-70	474035	6813150
18	Richmond Range	Dry Hardwood	1960-70	474475	6812380
19	Richmond Range	Dry Rainforest	Pre 1960	472865	6809105
20	Mount Belmore	Blackbutt	1969/70	476070	6774435
21	Mount Belmore	Blackbutt	Pre 1960	476845	6773750
22A	Mount Belmore	Blackbutt	1960-70	476130	6771880
22B	Mount Belmore	Blackbutt	1980-90	476220	6771720
23	Mount Marsh	Dry Hardwood	Unlogged	481320	6767870
24	Mount Marsh	Blackbutt	Unlogged	482650	6768225
25	Mount Marsh	Blackbutt	Unlogged, old-growth	480100	6764980
26	Mount Marsh	Dry Hardwood	Unlogged	485450	6766050
27	Ewingar	Moist Hardwood	1960-70	445765	6781365
28	Ewingar	Moist Hardwood	1960-70	444085	6779485
29	Ewingar	Moist Hardwood	1960-70	445430	6779975
30	Ewingar	Rainforest	1980-90	446935	6779105
31B	Washpool	Moist Hardwood	Unlogged	442200	6760830
31C	Washpool	Moist Hardwood	Unlogged	443100	6761790
31D	Washpool	Moist Hardwood	Unlogged	442520	6761925
BAN30	Banyabba	Dry Hardwood	Pre 1960	498500	6749335
BAN31	Banyabba	Dry Hardwood	Pre 1960	499530	6749750
BAN32	Banyabba	Dry Hardwood	1970 -80	500550	6749045
WHP33	Mount Marsh	Dry Hardwood	1960-70	485050	6758035
32	Cangai	Rainforest	1980-present	446312	6724087
33	Cangai	Rainforest	1970 -80	448320	6723720
34	Cangai	Moist Hardwood	1970 -80	448750	6724300
35	Dalmorton	Moist Hardwood	1980-present	433570	6715125
36	Dalmorton	Dry Hardwood	Unlogged	435785	6715055
37	Dalmorton	Dry Hardwood	Unlogged	436850	6714540
38	Dalmorton	Dry Hardwood	Unlogged	439450	6715090
39	Dalmorton	Dry Hardwood	1970-80	446435	6700560
40	Dalmorton	Dry Hardwood	1980-present	448385	6700330
CL35	Mount Belmore	Blackbutt	Pre 1960	476685	6777590
CL36	Mount Belmore	Blackbutt	Pre 1960	476150	6777175
BAR37	Mount Belmore	Dry Hardwood	1970-80	473010	6773475
BAR38	Mount Belmore	Dry Hardwood	1980-present	473805	6775480
41	Cloud's Creek	Moist Hardwood	1980-present	469720	6668750
42	Shea's Nob	Moist Hardwood	1970-80	464380	6673850
43	Shea's Nob	Blackbutt	1970-80	463450	6674280
44	Cloud's Creek	Moist Hardwood	1970-80	468180	6671615
45	Cloud's Creek	Rainforest	1970-80	469335	6669045
46A	Cloud's Creek	Moist Hardwood	1970-80	469780	6674975
46B	Cloud's Creek	Moist Hardwood	1970-80	469925	6668125
47	Shea's Nob	Blackbutt	1970-80	463455	6671910
48A	Ramornie	Dry Hardwood	1960-70	458215	6712125
48B	Ramornie	Moist Hardwood	1960-70	461825	6711125
49	Ramornie	Moist Hardwood	1960-70	459635	6712245
50	Grange	Dry Hardwood	1960-70	454945	6735205
51	Grange	Moist Hardwood	1970-80	456250	6736175
52A	Grange	Blackbutt	1970-80	456175	6737425
52B	Grange	Blackbutt	1960-70	456175	6737225
53	Fortis Creek	Blackbutt	Pre 1960	490875	6741998
54	Fortis Creek	Blackbutt	Pre 1960	491350	6740135
55A	Fortis Creek	Blackbutt	1980-present	492300	6735760
55B	Fortis Creek	Dry Hardwood	1980-present	492080	6736390
56	Candole	Dry Hardwood	Pre 1960	518175	6704310
57	Candole	Blackbutt	1980-present	520500	6706600
58	Candole	Blackbutt	1960-70	520525	6707465
59	Candole	Non forest (melaleuca)	1970-80	521650	6713100
60	Candole	Blackbutt	1970-80	522925	6716475
61	Candole	Blackbutt	Unlogged	522330	6717405
62	Glenugie	Rainforest	Pre 1960	506015	6698990
63	Glenugie	Dry Hardwood	1970-80	505340	6699975
64	Glenugie	Dry Hardwood	1970-80	504725	6701335

Possible veg strata = Rainforest, Moist Hardwood, Blackbutt, Dry Hardwood, Non Forest
Possible logging Strata = Unlogged, Pre 1960's, 1960-70, 1970-80, 1980-present, National Park

APPENDIX B. KEY TO THE TABLES.

HABITAT CODE:

1 = Rainforest	2 = Wet Sclerophyll	3 = Dry Sclerophyll
4 = Woodland	5 = Shrubland	6 = Grassland
7 = Littoral Forest	8 = Heath	9 = Swamp
10 = Mangrove	11 = Coastal Scrub	12 = Riparian
13 = Arid Woodland	14 = Urban	15 = Forest-grassland Ecotone
16 = Streamlines	17 = Aquatic	20 = A wide variety of habitats

CONSERVATION STATUS:

National Parks and Wildlife Act (as ammended 1992) Schedule 12

VR = Vulnerable and Rare
T = Threatened

STATE FORESTS AND OTHER LOCALITIES:

GRAFTON

BB = BomBom SF,	**BC** = Boundary Creek SF,	**C** = Candole SF,
Cg = Cangai SF,	**CC** = Clouds Creek SF,	**D** = Dalmorton SF,
Di = Divines SF,	**FC** = Fortis Creek SF,	**G** = Glenugie SF,
Gr = Grange SF,	**M** = Marara SF,	**N** = Nymboida SF,
PB = Pine Brush SF,	**R** = Ramournie SF,	**SN** = Sheas Nob SF,
Wf = Woodford SF.		

WNP = Washpool National Park **NNP** = Nymboida National Park **YNP** = Yuaygir National Park **BWN** = Binderi Wilderness Nomination.

CASINO

B = Banyabba SF,	**Bi** = Billilimbra SF,	**Br** = Braemar SF,
Bu = Bungabee SF,	**Bw** = Bungawalbin SF,	**Ca** = Camira SF,
Cr = Carwan SF,	**CT** = Cherry Tree SF,	**DD** = Double Duke SF,
DP = Devil's Pulpit SF,	**EC** = Eden Creek SF,	**E** = Ellangowan SF,
Ew = Ewingar SF,	**Gi** = Gibberagee SF,	**K** = Keybarbin SF,
MB = Mount Belmore SF,	**MM** = Mount Marsh SF,	**MP** = Mount Pikapene SF,
My = Myrtle SF,	**RR** = Richmond Range SF,	**RC** = Royal Camp SF,
S = Southgate SF,	**Sl** = Sugarloaf SF,	**T** = Tabbimoble SF,
W = Washpool SF,	**Wp** = Whiporie SF.	

BNP = Broadwater National Park **BuNP** = Bundulung National Park **BNR** = Bunyabba Nature Reserve **TNR** = Tuckean Nature Reserve **BNR** = Ballina Nature Reserve **DSNR** = Davis Scrub Nature Reserve **INR** = Iluka Nature Reserve **IPNR** = Inner Pocket Nature Reserve **MPNR** = Middle Pocket Nature Reserve **MNNR** = Mount Neville Nature Reserve **VPNR** = Victoria Park Nature Reserve

BIRD GUILD CODES:

f = Foliage forager (canopy and shrub)	**n** = Nectarivorus
c = Canopy forager	**h** = Hollow-dependent
s = Shrub forager	**g** = Ground foragers
b = Bark forager	

APPENDIX C. THE BIRDS OF THE GRAFTON MANAGEMENT AREA.

Species	Habitat	Special Habitat Components	Guild	Sched. 12 Status	Location in Region Grafton
Black Bittern	20	coastal, floodplains		VR	
Pacific Bazza	2,3				BWN, WNP
Spotted Harrier	4,6				
Square-tailed Kite	3,4			VR	BB, CC
Whistling Kite	3,4				NNP, R
Brown Goshawk	3,4				C, WNP
Collared Sparrowhawk	3,4				BWN, C
Grey Goshawk	2,3				BWN, Cg, WNP
Red Goshawk	4,6,16			T	BB, WNP, YNP
Little Eagle	3,4,5,6,16				C
Wedge-tailed Eagle	2,3,4,6				BWN, C, R, WNP, YNP
Peregrine Falcon	3,4,6	Cliffs			BWN, D, WNP
Brown Falcon	3,4,6				BWN, WNP
Little Falcon	3,4,5,16				R
Australian Kestrel	4,6				
Painted Button-quail	3,4,5,6,8	Debris/low shrubs	g		C, R, WNP
Red-chested Button-quail	4,6				
Bush Thick-knee	4,11,13,16			T	WNP
Black-breasted Button-quail	1,6	Litter		T	
Lewins Rail	9,12	Reeds			BWN
Bush Hen	1,9,12			VR	
Australian Bush Turkey	1,2		g		BWN, D, R, WNP
Wompoo Fruit Dove	1		c	VR	BWN,CC, R, NNP, WNP
Topknot Pigeon	1		c		BWN, WNP
White Headed Pigeon	1				Cg, WNP
Brown Cuckoo-Dove	1		s		BWN, CC, D, R, WNP
Peaceful Dove	2,3,4		g		
Bar Shouldered Dove	2,3,4,5				
Emerald Dove	5		s		R
Superb Fruit Dove	1			VR	
Rose-crowned Fruit Dove	1,2,4,10			VR	
Common Bronzewing	3,4,5				
Crested Pigeon	3,4,6				
Brush Bronzewing	3,4,5,11	Thick understorey			
Wonga Pigeon	1,2,3		g		BWN, D, INR, R,WNP
Glossy Black Cockatoo	2,3,4	Large tree hollows	f,h	VR	BWN, BC,C, CC, Cg, D, G, NNP, R, SN, WNP
Yellow-tailed Black Cockatoo	2,3	Large tree hollows	f,h		BWN, D, WNP
Sulphur-crested Cockatoo	3,4,12	Large tree hollows	g,h		BWN, NNP, R, WNP
Rainbow Lorikeet	2,3,5,8	Large tree hollows	n,f		BC, BWN, C, Cg, D, R, WNP
Scaly-breasted Lorikeet	3,4	Large tree hollows	n,f,h		C
Musk Lorikeet	2,3,4	Large tree hollows	n,c,h		
Little Lorikeet	2,3	Small hollows	n,f,h		BWN, C, Cg, WNP
Double-eyed Fig Parrot	1,16	Small hollows		T	
Australian King Parrot	1,2,3	Large tree hollows	h		BWN, Cg, D, R, WNP
Red-rumped Parrot	4,6	Small hollows			
Turquoise Parrot	4,5,6,8	Small hollows		VR	
Swift Parrot	2,3,4	Small hollows		VR	
Crimson Rosella	2,3,4	Small hollows	h		BC, BWN, D, R, NNP, WNP
Eastern Rosella	4	Small hollows	g		BWN, C, D, R
Pale-headed Rosella	3	Small hollows			
Pallid Cuckoo	2,3,4		g		
Brush Cuckoo	2,3,4				BWN, C, D, R, WNP
Fan-tailed Cuckoo	2,3,4		g		BC, BWN, C, Cg, CC, D, R, WNP
Horsfield's Bronze Cuckoo	2,3,4		f		
Shining (G.) Bronze Cuckoo	4,15		f		BC, BWN, WNP
Common Koel	1,2,3,4		s		BWN, C, D, NNP, R
Channel-billed Cuckoo	2,3		c,s		BWN, NNP, R
Oriental Cuckoo	2,3				
Little Bronze Cuckoo	1,3,4,10		f		
Powerful Owl	2,3	Large tree hollows	c,h	VR	BWN, C,CG,D, NNP,WNP
Southern Boobook	2,3,4	Large tree hollows	c,h		BC, BWN, C, Cg, D, R, WNP
Barking Owl	4	Large tree hollows	h		
Barn Owl	4	Large tree holls,cliffs	h		
Masked Owl	2,3,4	Large tree hollows	g,h	VR	C,D,NNP,R
Sooty Owl	1,2,3	Large tree hollows	c,h	VR	BC, CC, D, NNP,WNP
Tawny Frogmouth	2,3,4		g		BC, BWN, C, Cg, D, R, WNP
Marbled Frogmouth	1			VR	
Australian Owlet Nightjar	2,3,4	Small hollows	h		BC, BWN, C, D, NNP, R, WNP
White-throated Nightjar	2,3,4				BWN, C, NNP, R

APPENDIX C. THE BIRDS OF THE GRAFTON MANAGEMENT AREA.

Species	Habitat	Special Habitat Components	Guild	Sched. 12 Status	Location in Region Grafton
Azure Kingfisher	12				BC, R
Laughing Kookaburra	2,3,4				BWN, C, CC, D, R, WNP
Forest Kingfisher	2,3,12		g		C
Sacred Kingfisher	4	Small hollows	g		BWN, C, D, R, WNP
Red-backed Kingfisher	4,6,16	Earthern banks			
Rainbow Bee-eater	3,4,5	Earthern banks			
Dollarbird	2,3,4,6	Small hollows			
Noisy Pitta	1		g		BWN, D, NNP, WNP
Superb Lyrebird	1,2,3		g		BC, Cg
Australian/Russet Ground Thrush	1,2,3,4		g		BWN, WNP
Rufous Scrub-bird	1,2	Thick undergrowth		VR	
Eastern Bristlebird	4,8,11	Thickets		VR	
Singing Bushlark	4,5,6				
Rufous Songlark	4,5				
Welcome Swallow	20				BC, BWN, C, WNP
Tree Martin	20	Small hollows			Cg
Fairy Martin	20	Cliffs			C
Yellow-eyed Cuckoo-shrike	1,2,3,4			VR	
Black-faced Cuckoo Shrike	20		f		BWN, C, D, R, WNP
White-bellied Cuckoo Shrike	20		f		BWN, C, R, WNP
Cicada Bird	2,3,4,12				BWN, C, D, R, WNP
White Winged Triller	4,5,6				
Varied Triller	2,3				WNP
Rose Robin	1,2,3		f		BWN, C, D, WNP
Flame Robin	3,4,8				
Scarlet Robin	4				BWN, WNP
Hooded Robin	4,5,11				R
Eastern Yellow Robin	2,3,5,8		g		BC, BWN, C, CC, Cg, D, R, WNP
Jacky Winter	4,6,8		g		BWN, C, D, R, WNP
Pale Yellow Robin	1		f		BWN, D
Crested Shrike-tit	2,3,4	Decorticating bark	b		BWN, D, WNP
Olive Whistler	1,2,3,8	Thick undergrowth		VR	WNP
Golden Whistler	2,3,4,8	Shrubs	f		BC, BWN, C, CC, D, WNP
Rufous Whistler	2,3,5	Shrubs	f		BC, BWN, C, CC, D, NNP, R, WNP
Little Shrike-thrush	1,10	Shrubs			
Grey Shrike-thrush	20		g		BC, BWN, C, CC, Cg, D, R, WNP
Black Faced Monarch	1,2,3		c		BC, BWN, CC, D, R, WNP
Spectacled Monarch	1,10		s		BWN, D, R, WNP
White-eared Monarch	1,4,10			VR	
Leaden Flycatcher	1,2,3,10		f		BWN, C, D, R, WNP
Satin Flycatcher	3,4		f		
Restless Flycatcher	3,4,5		f		
Rufous Fantail	1,2,3	Shrubs	s		BWN, CC, D, R, WNP
Grey Fantail	2,3,4	Shrubs	f		BC, BWN, C, CC, Cg, D, R, WNP
Willie Wagtail	4,6	Shrubs			BWN, C, D, NNP, R, WNP
Logrunner	1	Shrubs	g		BWN, Cg, D, WNP
Whipbird	1,2,3,7	Shrubs	g		BC, BWN, C, Cg, D, R, WNP
Spotted Quail Thrush	3		g		BWN, D, R
Grey-crowned Babler	3,4,5				C
Superb Fairy Wren	3,5,8	Shrubs	s		BC, BWN, CC, D, NNP, R, WNP
Variegated Fairy Wren	5,8	Shrubs	s		BWN, C, Cg, D, R, WNP
Red-backed Wren	3,6	grassy	g		BWN, D, WNP
Southern Emu-wren	4,8				BWN
Large-billed Scrub Wren	1,2	Shrubs	s		BWN, D, WNP
Yellow-throated Scrub Wren	1,2,3	Shrubs	g		BC, BWN, Cg, WNP
White-browed Scrub Wren	2,3,5	Shrubs	g		BC, BWN, C, Cg, CC, D, R, WNP
Chestnut-rumped Hylacola	3,4,8	Shrubs			BWN
Speckled Warbler	4,6	Shrubs			
Weebill	4	Shrubs			WNP
Brown Gerygone	1	Shrubs	c		BC, BWN, D, WNP
White-throated Gerygone	2,3,4	Shrubs	c		BWN, D, R
Brown Thornbill	2,3	Shrubs	s		BC, BWN, C, CC, Cg, D, NNP, R, WNP
Buff-rumped Thornbill	2,3,4	Shrubs	g		BWN, D, WNP
Yellow-rumped Thornbill	3,4,6	Shrubs			
Yellow Thornbill	3,4	Shrubs	f		BWN, WNP
Striated Thornbill	3	Shrubs	c		BC, BWN, Cg, D, WNP
Varied Sitella	3,4		b		BWN, C
White-throated Treecreeper	2,3,4	Large tree hollows	b,h		BC, BWN, C, CC, Cg, D, R, WNP
Red-browed Treecreeper	2,3	Large tree hollows	b,h		BC, BWN, Cg, D, WNP

APPENDIX C. THE BIRDS OF THE GRAFTON MANAGEMENT AREA.

Species	Habitat	Special Habitat Components	Guild	Sched. 12 Status	Location in Region Grafton
Brown Treecreeper	2,3,4	Large tree hollows	b		C, R
Red Wattlebird	2,3,5,8		n,f		WNP
Little Wattlebird	3,5,8		n,f		WNP
Striped Honeyeater	4	Shrubs			
Noisy Friarbird	3,4		n,f		BWN, C, D, R, WNP
Little Friarbird	2,3,4		n,f		BWN
Regent Honeyeater	3,4			T	BC,CC
Bell Miner	2,3,4	Shrubs	f		BC, BWN, C, D, R
Noisy Miner	3,4		f		C
Lewins Honeyeater	1,2,3		c,n		BC, BWN, CC, D, R, WNP
Yellow-faced Honeyeater	3,4		n,f		BC, BWN, CC, D, NNP, R, WNP
White-eared Honeyeater	3,4,8	Shrubs	n,f		BWN
Yellow-tufted Honeyeater	3,4		n,c		
Fuscous Honeyeater	2,3,4		n,f		C, R
White-plumed Honeyeater	3,4				C
Brown-headed Honeyeater	3,4,5				
White-throated Honeyeater	2,3				BWN, C
White-naped Honeyeater	3,4		n,f		BC, BWN, C, Cg, WNP
Brown Honeyeater	3,4,8	Shrubs	n		BC, C, NNP, R
New Holland Honeyeater	3,4,8	Shrubs	n,f		BWN, WNP
Black-chinned Honeyeater	3,4		f,n		BC
Blue-faced Honeyeater	3,4		f,n		BWN, C, WNP
Varied Honeyeater	4,10				
White-cheeked Honeyeater	2,3,4,8,11	Shrubs	n,f		
Eastern Spinebill	2,3,4		s,n		BC, BWN, C, Cg, D, WNP
Scarlet Honeyeater	2,3,4		n,c		BWN, C, D, NNP, R, WNP
Mistletoebird	2,3,4		f		BC, BWN, C, NNP, R, WNP
Spotted Pardalote	3,4	Earthern banks	f		BC, BWN, Cg, D, WNP
Striated Pardalote	2,3,4,5	Earthern banks	f		BC, BWN, WNP
Silvereye	3,4		n,f		BWN, C, D, R, WNP
Red-browed Firetail	2,3,8	Shrubs	g		BC, BWN, C, Cg, D, R, WNP
Double-bar Finch	3,4,5,16				
Olive-backed Oriole	3,4		f		BWN, C, D, NNP, R, WNP
Figbird	1,2		f		NNP, R, WNP
Spangled Drongo	2,3,10		c,h		BWN, D, R, WNP
Satin Bowerbird	1,2,3		g		BC, BWN, CC, Cg, D, R, WNP
Regent Bowerbird	1		c		WNP
Green Catbird	1,2	Shrubs	s		BWN, Cg, D, WNP
Paradise Riflebird	1	Shrubs	f		BWN, WNP
White-winged Chough	3,4,5				BWN, D, WNP
Australian Magpie Lark	4,6		g		
White-breasted Woodswallow	2,3,10				C, R,
White-browed Woodswallow	4				BWN, WNP
Masked Woodswallow	3,4,5,8				
Little Woodswallow	3,4				
Dusky Woodswallow	4,6				BWN, C, R
Grey Butcherbird	3,4		g		BWN, C, CC, WNP
Pied Butcherbird	4		g		BWN, C, NNP, R
Autralian Magpie	3,4,15		g		BWN, C, R
Pied Currawong	2,3,4		g		BC, BWN, C, Cg, NNP, R, WNP
Australian Raven	4,6				BWN, CC
Torrensian Crow	4,6				C, NNP, R
Feral Pigeon	introduced				
Spotted Turtle Dove	introduced				
European Goldfinch	introduced				
House Sparrow	introduced				
Common Starling	introduced				

APPENDIX C. THE BIRDS OF THE CASINO MANAGEMENT AREA.

Species	Habitat	Special Habitat Components	Guild	Sched. 12 Status	Location in Region Casino
Black Bittern	20	coastal, floodplains		VR	
Pacific Bazza	2,3				B,Bi,BuNP,IPNR,MPNR
Spotted Harrier	4,6				BuNP
Square-tailed Kite	3,4			VR	Br,Ew
Whistling Kite	3,4				
Brown Goshawk	3,4				Bi,W
Collared Sparrowhawk	3,4				BuNP,MM
Grey Goshawk	2,3				Bi,BuNP,CT,RR,W
Red Goshawk	4,6,16			T	BuNP
Little Eagle	3,4,5,6,16				
Wedge-tailed Eagle	2,3,4,6				Bi,RR,W
Peregrine Falcon	3,4,6	Cliffs			
Brown Falcon	3,4,6				BuNP
Little Falcon	3,4,5,16				
Australian Kestrel	4,6				
Painted Button-quail	3,4,5,6,8	Debris/low shrubs	g		MM,RR
Red-chested Button-quail	4,6				
Bush Thick-knee	4,11,13,16			T	DD
Black-breasted Button-quail	1,6	Litter		T	
Lewins Rail	9,12	Reeds			
Bush Hen	1,9,12			VR	CT,RR
Australian Bush Turkey	1,2		g		Bi,RR,W
Wompoo Fruit Dove	1		c	VR	Bi,CT,RR,VPNR,W
Topknot Pigeon	1		c		Bi,Ew,INR,RR,VPNR,W
White Headed Pigeon	1				Bi,DSNR,INR,VPNR,W
Brown Cuckoo-Dove	1		s		Bi,DSNR,RR,VPNR,W
Peaceful Dove	2,3,4		g		CT,RR
Bar Shouldered Dove	2,3,4,5				
Emerald Dove	5		s		DSNR,INR,RR,VPNR
Superb Fruit Dove	1			VR	RR
Rose-crowned Fruit Dove	1,2,4,10			VR	CT,DSNR,INR,RR,VPNR
Common Bronzewing	3,4,5				
Crested Pigeon	3,4,6				
Brush Bronzewing	3,4,5,11	Thick understorey			
Wonga Pigeon	1,2,3		g		Bi,DD,MM,RR,VPNR,W
Glossy Black Cockatoo	2,3,4	Large tree hollows	f,h	VR	BuNP,DD,Ew,MB,W
Yellow-tailed Black Cockatoo	2,3	Large tree hollows	f,h		Bi,RR,W
Sulphur-crested Cockatoo	3,4,12	Large tree hollows	g,h		Bi,CT,Ew,RR,W
Rainbow Lorikeet	2,3,5,8	Large tree hollows	n,f		Bi,DD,Ew,MM,RR,W
Scaly-breasted Lorikeet	3,4	Large tree hollows	n,f,h		DD,MM
Musk Lorikeet	2,3,4	Large tree hollows	n,c,h		
Little Lorikeet	2,3	Small hollows	n,f,h		Bi,DD,MM,W
Double-eyed Fig Parrot	1,16	Small hollows		T	RR
Australian King Parrot	1,2,3	Large tree hollows	h		Bi,DD,Ew,MM,RR,W
Red-rumped Parrot	4,6	Small hollows			
Turquoise Parrot	4,5,6,8	Small hollows		VR	
Swift Parrot	2,3,4	Small hollows		VR	
Crimson Rosella	2,3,4	Small hollows	h		Bi,DD,Ew,RR,W
Eastern Rosella	4	Small hollows	g		
Pale-headed Rosella	3	Small hollows			
Pallid Cuckoo	2,3,4		g		
Brush Cuckoo	2,3,4				Bi,DD,MM,W
Fan-tailed Cuckoo	2,3,4		g		Bi,DD,Ew,MM,RR,W
Horsfield's Bronze Cuckoo	2,3,4		f		
Shining (G.) Bronze Cuckoo	4,15		f		Bi,MM,RR,W
Common Koel	1,2,3,4		s		BuNP,DD,MM,RR
Channel-billed Cuckoo	2,3		c,s		BUNP,CT,MM,RR,W
Oriental Cuckoo	2,3				
Little Bronze Cuckoo	1,3,4,10		f		
Powerful Owl	2,3	Large tree hollows	c,h	VR	Bu, Bi, Ew,RR, W
Southern Boobook	2,3,4	Large tree hollows	c,h		Bi,DP,Ew,IPNR,MM,RR,W
Barking Owl	4	Large tree hollows	h		DD
Barn Owl	4	Large tree holls,cliffs	h		
Masked Owl	2,3,4	Large tree hollows	g,h	VR	Bu,BuNP,RR
Sooty Owl	1,2,3	Large tree hollows	c,h	VR	Bi,Bu,Ew,MB,RR
Tawny Frogmouth	2,3,4		g		Bi,Bu,BuNP,Ew,MM,RR,W
Marbled Frogmouth	1			VR	CT,RR
Australian Owlet Nightjar	2,3,4	Small hollows	h		Bi,Bu,BuNP,DD,Ew,IPNR,MM,RR,W
White-Throated Nightjar	2,3,4				Bu,BuNP,CT,MM,RR

APPENDIX C. THE BIRDS OF THE CASINO MANAGEMENT AREA.

Species	Habitat	Special Habitat Components	Guild	Sched. 12 Status	Location in Region Casino
Azure Kingfisher	12				
Laughing Kookaburra	2,3,4				Bi,BuNP,DD,MM,RR,W
Forest Kingfisher	2,3,12		g		
Sacred Kingfisher	4	Small hollows	g		Bi,MM,W
Red-backed Kingfisher	4,6,16	Earthern banks			
Rainbow Bee-eater	3,4,5	Earthern banks			
Dollarbird	2,3,4,6	Small hollows			DD
Noisy Pitta	1		g		Bi,RR,W
Albert's Lyrebird	1			VR	RR
Superb Lyrebird	1,2,3		g		Bi,Ew,RR,W
Australian/Russet Ground Thrush	1,2,3,4		g		Bi,MM,RR,W
Rufous Scrub-bird	1,2	Thick undergrowth		VR	
Eastern Bristlebird	4,8,11	Thickets		VR	
Singing Bushlark	4,5,6				
Rufous Songlark	4,5				
Welcome Swallow	20				W
Tree Martin	20	Small hollows			
Fairy Martin	20	Cliffs			
Yellow-eyed Cuckoo-Shrike	1,2,3,4			VR	CT,RR
Black-faced Cuckoo Shrike	20		f		Bi,BuNP,DD,Ew,MM,RR
White-bellied Cuckoo Shrike	20		f		DD,MM
Cicada Bird	2,3,4,12				Bi,BuNP,DD,MM,RR
White Winged Triller	4,5,6				BuNP,DD
Varied Triller	2,3				Bi,W
Rose Robin	1,2,3		f		Bi,Ew,RR,W
Flame Robin	3,4,8				
Scarlet Robin	4				
Hooded Robin	4,5,11				
Eastern Yellow Robin	2,3,5,8		g		Bi,CT,MM,RR,W
Jacky Winter	4,6,8		g		DD,MM,RR
Pale Yellow Robin	1		f		Bi,RR,W
Crested Shrike-tit	2,3,4	Decorticating bark	b		Bi,CT,RR
Olive Whistler	1,2,3,8	Thick undergrowth		VR	
Golden Whistler	2,3,4,8	Shrubs	f		Bi,CT,Ew,RR,W
Rufous Whistler	2,3,5	Shrubs	f		Bi,BuNP,DD,MM,RR,W
Little Shrike-thrush	1,10	Shrubs			DD,RR
Grey Shrike-thrush	20		g		Bi,BuNP,CT,DD,Ew,MM,RR,W
Black Faced Monarch	1,2,3		c		Bi,CT,RR,W
Spectacled Monarch	1,10		s		CT,RR
White-eared Monarch	1,4,10			VR	INR,RR
Leaden Flycatcher	1,2,3,10		f		Bi,BuNP,DD,MM,RR,W
Satin Flycatcher	3,4		f		RR
Restless Flycatcher	3,4,5		f		
Rufous Fantail	1,2,3	Shrubs	s		Bi,CT,MM,RR,W
Grey Fantail	2,3,4	Shrubs	f		Bi,BuNP,DD,Ew,MM,RR,W
Willie Wagtail	4,6	Shrubs			MM,RR
Logrunner	1	Shrubs	g		Bi,RR,W
Whipbird	1,2,3,7	Shrubs	g		Bi,CT,DD,Ew,MM,RR,W
Spotted Quail Thrush	3		g		MM
Grey-crowned Babler	3,4,5				
Superb Fairy Wren	3,5,8	Shrubs	s		RR
Variegated Fairy Wren	5,8	Shrubs	s		Bi,BuNP,DD,MM,RR,W
Red-backed Wren	3,6	grassy	g		BuNP,MM
Southern Emu-wren	4,8				
Large-billed Scrub Wren	1,2	Shrubs	s		Bi,CT,MM,RR,W
Yellow-throated Scrub Wren	1,2,3	Shrubs	g		Bi,RR,W
White-browed Scrub Wren	2,3,5	Shrubs	g		Bi,MM,RR,W
Chestnut-rumped Hylacola	3,4,8	Shrubs			
Speckled Warbler	4,6	Shrubs			
Weebill	4	Shrubs			
Brown Gerygone	1	Shrubs	c		B,CT,RR,W
White-throated Gerygone	2,3,4	Shrubs	c		BuNP,DD,RR
Brown Thornbill	2,3	Shrubs	s		Bi,BuNP,DD,MM,RR,W
Buff-rumped Thornbill	2,3,4	Shrubs	g		Bi,MM
Yellow-rumped Thornbill	3,4,6	Shrubs			
Yellow Thornbill	3,4	Shrubs	f		Bi,RR
Striated Thornbill	3	Shrubs	c		Bi,MM,RR,W
Varied Sitella	3,4		b		Bi,BuNP,DD,RR
White-throated Treecreeper	2,3,4	Large tree hollows	b,h		Bi,BuNP,DD,Ew,MM,RR,W

APPENDIX C. THE BIRDS OF THE CASINO MANAGEMENT AREA.

Species	Habitat	Special Habitat Components	Guild	Sched. 12 Status	Location in Region Casino
Red-browed Treecreeper	2,3	Large tree hollows	b,h		Bi,RR,W
Brown Treecreeper	2,3,4	Large tree hollows	b		RR
Red Wattlebird	2,3,5,8		n,f		Bi
Little Wattlebird	3,5,8		n,f		DD,MM
Striped Honeyeater	4	Shrubs			
Noisy Friarbird	3,4		n,f		Bi,BuNP,DD,MM,RR,W
Little Friarbird	2,3,4		n,f		BuNP,DD
Regent Honeyeater	3,4			T	RC
Bell Miner	2,3,4	Shrubs	f		RR,W
Noisy Miner	3,4		f		BuNP,MM
Lewins Honeyeater	1,2,3		c,n		Bi,CT,DD,Ew,MM,RR,W
Yellow-faced Honeyeater	3,4		n,f		BI,BuNP,DD,MM,RR,W
White-eared Honeyeater	3,4,8	Shrubs	n,f		
Yellow-tufted Honeyeater	3,4		n,c		
Fuscous Honeyeater	2,3,4		n,f		DD,MM
White-plumed Honeyeater	3,4				
Brown-headed Honeyeater	3,4,5				
White-throated Honeyeater	2,3				
White-naped Honeyeater	3,4		n,f		Bi,Ew,RR,W
Brown Honeyeater	3,4,8	Shrubs	n		
New Holland Honeyeater	3,4,8	Shrubs	n,f		Bi
Black-chinned Honeyeater	3,4		f,n		DD
Blue-faced Honeyeater	3,4		f,n		BuNP,DD
Varied Honeyeater	4,10				
White-cheeked Honeyeater	2,3,4,8,11	Shrubs	n,f		DD
Eastern Spinebill	2,3,4		s,n		Bi,MM,RR,W
Scarlet Honeyeater	2,3,4		n,c		Bi,BuNP,CT,DD,MM,RR,W
Mistletoebird	2,3,4		f		Bi,BuNP,DD,MM,RR,W
Spotted Pardalote	3,4	Earthern banks	f		Bi,MM,W
Striated Pardalote	2,3,4,5	Earthern banks	f		BuNP,DD
Silvereye	3,4		n,f		Bi,CT,RR,W
Red-browed Firetail	2,3,8	Shrubs	g		Bi,DD,Ew,MM,RR
Double-bar Finch	3,4,5,16				
Olive-backed Oriole	3,4		f		Bi,BuNP,CT,DD,MM,RR,W
Figbird	1,2		f		CT
Spangled Drongo	2,3,10		c,h		Bi,MM,RR,W
Satin Bowerbird	1,2,3		g		Bi,Ew,MM,RR,W
Regent Bowerbird	1		c		RR
Green Catbird	1,2	Shrubs	s		Bi,Ew,RR,W
Paradise Riflebird	1	Shrubs	f		Bi,RR,W
White-winged Chough	3,4,5				
Australian Magpie Lark	4,6		g		
White-breasted Woodswallow	2,3,10				
White-browed Woodswallow	4				
Masked Woodswallow	3,4,5,8				
Little Woodswallow	3,4				
Dusky Woodswallow	4,6				MM,RR
Grey Butcherbird	3,4		g		BuNP,DD,MM
Pied Butcherbird	4		g		BuNP,RR
Autralian Magpie	3,4,15		g		RR
Pied Currawong	2,3,4		g		Bi,DD,Ew,MM,RR,W
Australian Raven	4,6				DD,RR,W
Torrensian Crow	4,6				
Feral Pigeon	introduced				
Spotted Turtle Dove	introduced				
European Goldfinch	introduced				
House Sparrow	introduced				
Common Starling	introduced				

APPENDIX D. THE REPTILES OF THE GRAFTON MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat components	Sched. 12 Status	Location in the Region Grafton
CHELIDAE					
Long-necked Turtle	*Chelodina longicollis*	9,12,16,17			
Saw-shelled Turtle	*Elseya latisternum*	12,16,17	rivers		
Short-necked Turtle	*Emydura signata*	12,16,17	rivers		BWN,R
GEKKONIDAE					
Wood Gecko	*Diplodactylus vittatus*	2,3,4,5,6,7,8	rocks/small logs		
Lesuer's Velvet Gecko	*Oedura lesueurii*	3,8	rock crevices		
Robust Velvet Gecko	*Oedura robusta*	3,4	arboreal/small hollows		
Southern Spotted Velvet Gecko	*Oedura tryoni*	3,4	rock crevices		
Leaf-tailed Gecko	*Phyllurus platurus*	2,3,4	sandstone caves,overhangs		
Leaf-tailed Gecko	*Phyllurus cornutus*	1,2	arboreal/tree hollows/crevices		W,WNP
Thick-tailed Gecko	*Underwoodisaurus mili*	2,3,4,5,8	rocks/logs/stumps/burrows		
PYGOPODIDAE					
	Delma plebia	3,4	rocks/logs/debris		
	Delma tincta	20	rocks/logs/debris		
Burton's Legless Lizard	*Lialis burtonis*	20	rocks/logs/litter		BWN,C,R
Common Scaly-foot	*Pygopus lepidopodus*	2,3,4,5,7,8,11,13	dense grasses/shrubs		BWN
VARANIDAE					
Sand Monitor	*Varanus gouldii*	20	burrows/dense veg.		
Lace Monitor	*Varanus varius*	1,2,3,4,7,15	tree hollows		BWN,C,CC,Cg,D,FC,G,Gr,R
AGAMIDAE					
Jacky Lizard	*Amphibolurus muricatus*	3,4,5,8,11,15	low hollows/logs/bark		WNP
Nobby Lizard	*Amphibolurus nobbi*	3,4,15	rocks/logs/dense veg.		D,R,SN
	Diporiphora australis	2,3,4,11			FC
Southern Angle-Headed Dragon	*Hypsilurus spinipes*	1,2	dense veg/thickets		
Eastern Water Dragon	*Physignathus lesueurii*	12,16	burrows/crevices/hollows		BC,BWN,C,FC,R,WNP
Eastern Bearded Dragon	*Pogona barbata*	3,4,15	low veg./logs/hollows		C,R
SCINCIDAE					
Verreaux's Skink	*Anomalopus verreauxii*	3,4,6,15	in soil/logs/rocks/litter		SN
	Calyptotis ruficauda	2,3	logs/rocks-moist		C,R
	Calyptotis scutirostrum	1,2	logs/rocks-moist		BWN,CC,D,Gr,R,SN,WNP
Southern Rainbow Skink	*Carlia tetradactyla*	3,4	rocks/logs		C
Tussock Rainbow Skink	*Carlia vivax*	3,4	debri/litter		BWN,FC
	Coeranoscincus reticulatus	1,2	rotting logs/litter	VR	
Wall Lizard	*Cryptoblepharus virgatus*	3,4,14	crevices/bark		BWN,Cg,FC,R
	Ctenotus eurydice	3,4	rocks/burrows		
Striped Skink	*Ctenotus robustus*	3,4,6,15	rocks/logs/burrows		BWN
Copper-tailed Skink	*Ctenotus taeniolatus*	3,4	rocks/burrows		BWN,FC,R
Cunningham's Skink	*Egernia cunninghami*	3,4,6,15	crevices-granite		BWN,WNP
Major Skink	*Egernia frerei*	1,2,3,4	hollow logs/rocks		C,CC,Gr,R
Land Mullet	*Egernia major*	1,2	hollow logs/thickets		BWN,CC,Gr
	Egernia mcpheei	2,3,4	rock/crevices/hol logs		BWN,FC,Gr
White's Skink	*Egernia whitii*	3,4,8	rocks/logs/burrows		BWN,WNP
	Eulamprus murrayi	1,2	hollow logs		BWN,CC,Cg,D,SN,WNP
Eastern Water Skink	*Eulamprus quoyii*	2,3,4,12,16	rocks/logs		BC,BWN,D,FC,WNP
Barred-sided Skink	*Eulamprus tenuis*	3,4	crevices/logs/stumps		BWN,BB,C,CC,D,FC,Gr,N,R,SN,WNP
	Eulamprus martini	3,4	crevices/logs/stumps		BWN,R
Red-throated Skink	*Pseudemoia platynota*	3,4,6,15	rocks/logs/debris		BWN,WNP
Beech Skink	*Pseudemoia zia*	1	litter/rocks/logs		
Pink-tongued Lizard	*Hemisphaeriodon gerrardii*	1,2	hol. logs/litter/crevices		
	Lampropholis caligula	2,3,4	litter /grass		D
Grass Skink	*Lampropholis delicata*	2,3,4,6,14,15	rocks/logs/debris		BC,BWN,C,CC,Cg,D,FC,G,Gr,RR,SN,WNP
Garden Skink	*Lampropholis guichenoti*	3,4	rocks/logs/debris		BWN,CC,D,NNP,R,SN
	Lygisaurus foliorum	3,4	litter/grass/bark		BB,BWN,C,FC
	Ophioscincus truncatus	1,2	logs/litter/soil		CC,R
	Morethia boulengeri	3,4,5	dense veg./rocks/litter		
Three-toed Skink	*Saiphos equalis*	1,2,3	soil-litter/rocks/logs		BWN,C,CC,D,Gr,R,SN,WNP
	Saproscincus challengeri	1,2	rocks/logs/debris		BWN,CC,Cg,WNP
Weasel Skink	*Saproscincus mustelina*	2,3,14	rocks/logs/debris		
Blue-tongued Lizard	*Tiliqua scincoides*	20	holls/logs/debris/low veg		CC,R
TYPHLOPIDAE					
Blind Snake	*Ramphotyphlops nigrescens*	2,3,4	soil-logs/rocks		BWN,Gr,WNP
Blind Snake	*Ramphotyphlops proximus*	3,4	soil-rocks/logs/debris		

APPENDIX D. THE REPTILES OF THE GRAFTON MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat components	Sched. 12 Status	Location in the Region Grafton
Blind Snake	*Ramphotyphlops wiedii*	4, semi-arid	soil-rocks/logs/debris		
BOIDAE					
Eastern Childrens Python	*Liasis maculosus*	3,4	crevices/hollows/logs		
Diamond Python	*Morelia spilota ssp spilota*	1,2,3	arboreal/hollows		
Carpet Python	*Morelia spilota ssp variegata*	1,2,3,4 rocky	arboreal/hollows		BWN,WNP D,WNP
COLUBRIDAE					
Brown Tree Snake	*Boiga irregularis*	1,3,4	arboreal/hollows/thickets		
Green Tree Snake	*Denrelaphis punctulata*	1,2,3	arboreal/hollows/thickets		Cg,WNP
Freshwater Snake	*Tropidonophis mairii*	9,12,16			
ELAPIDAE					
Common Death Adder	*Acanthopsis antarticus*	3,4,8	litter		
White-naped Snake	*Cacophis harriettae*	2,3,8	logs/litter	VR	
Kreft's dwarf Snake	*Cacophis krefftii*	1,2	logs/litter		C
Golden-crowned Snake	*Cacophis squamulosus*	1,2,3	rocks/logs/litter		
Small-eyed Snake	*Cryptophis nigrescens*	1,2,3,8	rocks/logs/debri		
Yellow-faced Whip Snake	*Demansia psammophis*	2,3,4,8	rocks/logs		C,WNP
Red-naped Snake	*Furina diadema*	3,4,6	rocks/logs/termitaria		
Marsh Snake	*Hemiaspis signata*	1,2,3,9,12	rocks/logs/litter		
Pale-headed Snake	*Hoplocephalus bitorquatus*	1,2,3	bark/hol:limbs	VR	
Stephen's Banded Snake	*Hoplocephalus stephensii*	1,2,3	bark/hol.limbs/crevices	VR	NNP
Eastern Tiger Snake	*Notechis scutatus*	2,3,9,12	rocks/hol.logs/burrows		WNP
Taipan	*Oxyuranus scutellatus*	3,4,6	rocks/hol.logs/burrows		
Blue-bellied Black Snake	*Pseudechis guttatus*	3,4	logs/burrows		
Red-bellied Black Snake	*Pseudechis porphyriacus*	3,4,9,12	rocks/hol.logs/burrows		WNP
Eastern Brown Snake	*Pseudonaja textilis*	3,4,6	rocks/logs/debri		
Coral Snake	*Simoselaps australis*	4,6	soil-rocks/logs/litter		
Rough-scaled Snake	*Tropidechis carinatus*	1,2,12	logs/debri/dense veg.		WNP
Bandy Bandy	*Vermicella annulata*	2,3,4	soil-rocks/logs/litter		

Location data from Barker (1980), Osborne (1982), Manning (1992), NSW NPWS surveys (in progress) and the results of this study.

APPENDIX D. THE REPTILES OF THE CASINO MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat components	Sched. 12 Status	Location in Region Casino
CHELIDAE					
Long-necked Turtle	*Chelodina longicollis*	9,12,16,17			BuNP
Saw-shelled Turtle	*Elseya latisternum*	12,16,17	rivers		
Short-necked Turtle	*Emydura signata*	12,16,17	rivers		
GEKKONIDAE					
Wood Gecko	*Diplodactylus vittatus*	2,3,4,5,6,7,8	rocks/small logs		
Lesuer's Velvet Gecko	*Oedura lesueurii*	3,8	rock crevices		
Robust Velvet Gecko	*Oedura robusta*	3,4	arboreal/small hollows		
Southern Spotted Velvet Gecko	*Oedura tryoni*	3,4	rock crevices		
Leaf-tailed Gecko	*Phyllurus platurus*	2,3,4	sandstone caves,overhangs		Bi,MB,MM
Leaf-tailed Gecko	*Phyllurus cornutus*	1,2	arb./tree hols and crevices		Bi
Thick-tailed Gecko	*Underwoodisaurus mili*	2,3,4,5,8	rocks/logs/stumps/burrows		
PYGOPODIDAE					
	Delma plebia	3,4	rocks/logs/debris		
	Delma tincta	20	rocks/logs/debris		
Burton's Legless Lizard	*Lialis burtonis*	20	rocks/logs/litter		DP,MB,W
Common Scaly-foot	*Pygopus lepidopodus*	2,3,4,5,7,8,11,13	dense grasses/shrubs		
VARANIDAE					
Sand Monitor	*Varanus gouldii*	20	burrows/dense veg.		
Lace Monitor	*Varanus varius*	1,2,3,4,7,15	tree hollows		B,Bi,DD,DP,MB,MM,RR,W
AGAMIDAE					
Jacky Lizard	*Amphibolurus muricatus*	3,4,5,8,11,15	low hollows/logs/bark		
Nobby Lizard	*Amphibolurus nobbi*	3,4,15	rocks/logs/dense veg.		BNP,CT
	Diporiphora australis	2,3,4,11			
Southern Angle-headed Dragon	*Hypsilurus spinipes*	1,2	dense veg/thickets		RR
Eastern Water Dragon	*Physignathus lesueurii*	12,16	burrows/crevices/hollows		B,Bi,MM,RR,W
Eastern Bearded Dragon	*Pogona barbata*	3,4,15	low veg./logs/hollows		
SCINCIDAE					
Verreaux's Skink	*Anomalopus verreauxii*	3,4,6,15	in soil/logs/rocks/litter		CT,E,MM
	Calyptotis ruficauda	2,3	logs/rocks-moist		DD,DP,MB,MM,RR
	Calyptotis scutirostrum	1,2	logs/rocks-moist		Bi,CT,Ew,MM,RR,W
Southern Rainbow Skink	*Carlia tetradactyla*	3,4	rocks/logs		
Tussock Rainbow Skink	*Carlia vivax*	3,4	debris/litter		MB,MM
Burrowing Skink	*Coeranoscincus reticulatus*	1,2	rotting logs/litter	VR	Ew,RR
Wall Lizard	*Cryptoblepharus virgatus*	3,4,14	crevices/bark		DD,DP,MB,MM
	Ctenotus eurydice	3,4	rocks/burrows		W
Striped Skink	*Ctenotus robustus*	3,4,6,15	rocks/logs/burrows		N
Copper-tailed Skink	*Ctenotus taeniolatus*	3,4	rocks/burrows		B,MB,MM
Cunningham's Skink	*Egernia cunninghami*	3,4,6,15	crevices-granite		
Major Skink	*Egernia frerei*	1,2,3,4	hollow logs/rocks		CT,Ew,MB,MM
Land Mullet	*Egernia major*	1,2	hollow logs/thickets		Bi,CT,Ew,RR
	Egernia mcpheei	2,3,4	rock crevices/hollow logs		B,MM,RR
Tree Skink	*Egernia striolata*	1,2,3,4	hollow logs/bark/rock crevices		
White's Skink	*Egernia whitii*	3,4,8	rocks/logs/burrows		
	Eulamprus murrayi	1,2	hollow logs		Bi,Ew,RR,W
Eastern Water Skink	*Eulamprus quoyii*	2,3,4,12,16	rocks/logs		B,BuNP,MB,MM,W
Barred-sided Skink	*Eulamprus tenuis*	3,4	crevices/logs/stumps		B,Bi,Ca,MB,MM,RR
	Eulamprus martini	3,4	crevices/logs/stumps		
Red-throated Skink	*Pseudemoia platynota*	3,4,6,15	rocks/logs/litter		
Beech Skink	*Pseudemoia zia*	1	rocks/logs		Bi
Pink-tongued Lizard	*Hemisphaeriodon gerrardii*	1,2	hol. logs/litter/crevices		Bi,Ew
Grass Skink	*Lampropholis delicata*	2,3,4,6,14,15	rocks/logs/debris		B,Bi,Ca,CT,DD,DP,Ew,MB,MM,RR,W
Garden Skink	*Lampropholis guichenoti*	3,4	rocks/logs/debris		B,DD,DP,RR,W
	Lygisaurus foliorum	3,4	litter/grass/bark		MM
	Ophioscincus truncatus	1,2	logs/litter/soil		
Three-toed Skink	*Saiphos equalis*	1,2,3	soil-litter/rocks/logs		CT,DD,Ew,MB,MM,RR,W
	Saproscincus challengeri	1,2	rocks/logs/debris		Bi,Ew,RR,W
Weasel Skink	*Saproscincus mustelina*	2,3,14	rocks/logs/debris		
Blue-tongued Lizard	*Tiliqua scincoides*	20	hol. logs/debris/low veg.		
TYPHLOPIDAE					
Blind Snake	*Ramphotyphlops nigrescens*	2,3,4	soil-logs/rocks		Ew,RR
Blind Snake	*Ramphotyphlops proximus*	3,4	soil-rocks/logs/debris		

APPENDIX D. THE REPTILES OF THE CASINO MANAGEMENT AREA

Common Name	Scientific Name	Habitat	Habitat components	Sched. 12 Status	Location in Region Casino
Blind Snake	*Ramphotyphlops nigrescens*	2,3,4	soil-logs/rocks		Ew,RR
Blind Snake	*Ramphotyphlops proximus*	3,4	soil-rocks/logs/debris		
Blind Snake	*Ramphotyphlops wiedii*	4, semi-arid	soil-rocks/logs/debris		
BOIDAE					
Eastern Childrens Python	*Liasis maculosus*	3,4	crevices/hollows/logs		
Diamond Python	*Morelia spilota ssp spilota*	1,2,3	arboreal/hollows		
Carpet Python	*Morelia spilota ssp variegata*	1,2,3,4 rocky	arboreal/hollows		Bi,CT,RR,W
COLUBRIDAE					
Brown Tree Snake	*Boiga irregularis*	1,3,4	arboreal/hollows/thickets		
Green Tree Snake	*Denrelaphis punctulata*	1,2,3	arboreal/hollows/thickets		
Freshwater Snake	*Tropidonophis mairii*	9,12,16			
ELAPIDAE					
Common Death Adder	*Acanthopsis antarticus*	3,4,8	litter		
White-naped Snake	*Cacophis harrietae*	2,3,8	logs/litter	VR	
Kreft's dwarf Snake	*Cacophis krefftii*	1,2	logs/litter		
Golden-crowned Snake	*Cacophis squamulosus*	1,2,3	rocks/logs/litter		
Small-eyed Snake	*Cryptophis nigrescens*	1,2,3,8	rocks/logs/debris		RR
Yellow-faced Whip Snake	*Demansia psammophis*	2,3,4,8	rocks/logs		C
Red-naped Snake	*Furina diadema*	3,4,6	rocks/logs/termitaria		
Marsh Snake	*Hemiaspis signata*	1,2,3,9,12	rocks/logs/litter		DD
Pale-headed Snake	*Hoplocephalus bitorquatus*	1,2,3	bark/hol.limbs	VR	
Stephen's Banded Snake	*Hoplocephalus stephensii*	1,2,3	bark/hol.limbs/crevices	VR	RR
Eastern Tiger Snake	*Notechis scutatus*	1,2,3,4,7			
Taipan	*Oxyuranus scutellatus*	3,4,6	rocks/hol.logs/burrows		
Blue-bellied Black Snake	*Pseudechis guttatus*	3,4	logs/burrows		
Red-bellied Black Snake	*Pseudechis porphyriacus*	3,4,9,12	rocks/hol.logs/burrows		RR
Eastern Brown Snake	*Pseudonaja textilis*	3,4,6	rocks/logs/debris		
Coral Snake	*Simoselaps australis*	4,6	soil-rocks/logs/litter		
Rough-scaled Snake	*Tropidechis carinatus*	1,2,12	logs/debris/dense veg.		
Bandy Bandy	*Vermicella annulata*	2,3,4	soil-rocks/logs/litter		

Location data from Barker (1980). Osborne (1982). Manning (1992). NSW NPWS surveys (in progress) and the results of this study.

APPENDIX E. AMPHIBIANS OF THE GRAFTON MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat Components	Sched.12 Status	Location in Region Grafton
MYOBATRACHIDAE			(reproduction)*		
Tusked Frog	*Adelotus brevis*	1,2,6	5		BWN, G, R, SN
Pouched Frog	*Assa darlingtoni*	1,2	pouch	VR	BWN, WNP
Froglet	*Crinia parinsignifera*	20	2,3,4		BC, R
Common Eastern Froglet	*Crinia signifera*	20	1,2,3,4,5		BC, BWN, C, FC, Gr
Wallum Froglet	*Crinia tinnula*	9	3	VR	
Fletcher's Frog	*Lechriodus fletcheri*	1,2	1,5		SN, WNP
Eastern Banjo Frog	*Limnodynastes dumerilli*	9,16	1,2,3		BWN, D
Ornate Burrowing Frog	*Limnodynastes ornatus*	1,2,3,4	4,5		D
Brown-striped Frog	*Limnodynastes peronii*	9,16,17	1,2,3		Cg, D, FC
Spotted Grass Frog	*Limnodynastes tasmaniensis*	20	1,2,3,4		BB, Cg, D, G
	Mixophyes balbus	2	1	VR	Cg, WNP
Giant Barred Frog	*Mixophyes iteratus*	1,2	1	VR	BC, SN, WNP
Great Barred Frog	*Mixophyes fasciolatus*	1,2	1		BC, BWN, D, Gr, NNP, R, SN, WNP
Northern Banjo Frog	*Platyplectron terraereginae*	1,2,3,4	1,2,3		D
	Philoria spp.	1,2	burrows	VR	Cg, WNP
Brown Toadlet	*Pseudophryne bibronii*	2,3,6	4,5		
Red-backed Toadlet	*Pseudophryne coriacea*	2,3	5		BC, BWN, C, CC, D, FC, Gr, R, WNP
Red-groined Toadlet	*Uperoleia laevigata*	1,2	2,4,5		BWN, C, Cg
	Uperoleia fusca	1,2	2,4,5		FC
HYLIDAE					
	Litoria aurea	9,16,17	1,2,3	T	
Green Thighed Frog	*Litoria brevipalmata*	2	4	VR	
Green Tree Frog	*Litoria caerulea*	20	4		D, Gr, R, SN
Red-eyed Tree Frog	*Litoria chloris*	1,2	1		D, Gr
Bleating Tree Frog	*Litoria dentata*	9	3,4		D
Eastern Dwarf Tree Frog	*Litoria fallax*	9,16	1,2,3		BWN, C, D, NNP, R
Freycinet's Frog	*Litoria freycineti*	1,2,3,4,6,11			BB
Dainty Green Tree Frog	*Litoria gracilenta*	20	1,4,5		C, R
	Litoria latopalmata	2,3,4,12,15	2,3,4		BWN, C, Cg, D, G, Gr, R
Lesueur's Frog	*Litoria lesueuri*	20	1,2,3,4		BC, BWN, C, CC, Cg, D, Gr, NNP, R, SN, WNP
Rocket Frog	*Litoria nasuta*	2,3,7,9,15	3,4		C, FC
	Litoria olongburensis	9,16	1,3	VR	
Peron's Tree Frog	*Litoria peronii*	20	1,2,3,4		BWN,C,Cg, D,NNP,R
	Litoria pearsoniana	1,2,12	1,3		WNP
Leaf Green Tree Frog	*Litoria phyllochroa*	9,16,12	1,2		WNP
Desert Tree Frog	*Litoria rubella*	20	1,3,4		
	Litoria subglandulosa	2,12	1,2,3,4	VR	BWN
	Litoria tyleri	20	1,2,3,4		BWN, D
	Litoria verreauxii	2,3,6,9,12,	1,2,3		BWN, Cg
Cane Toad	*Bufo marinus*	20	all	introduced	

* Site for reproduction: 1=permenant streams/rivers, 2=dams, 3=permanent swamps, 4=ephemeral swamps, 5=temporary water

Location data from Barker (1980), Osborne (1982), Manning (1992), NSW NPWS surveys (in progress) and the results of this study.

APPENDIX E. AMPHIBIANS OF THE CASINO MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat Components (reproduction)*	Sched.12 Status	Location in Region Casino
MYOBATRACHIDAE					
Tusked Frog	*Adelotus brevis*	1,2,6	5		MM, MB, RR, W
Pouched Frog	*Assa darlingtoni*	1,2	pouch	VR	Bi, W
Froglet	*Crinia parinsignifera*	20	2,3,4		MB
Common Eastern Froglet	*Crinia signifera*	20	1,2,3,4,5		Bi, BuNP, DD, MB, CT
Wallum Froglet	*Crinia tinnula*	9	3	VR	
Fletcher's Frog	*Lechriodus fletcheri*	1,2	1,5		Bi, CT, Ew, RR, W
Eastern Banjo Frog	*Limnodynastes dumerilli*	9,16	1,2,3		
Ornate Burrowing Frog	*Limnodynastes ornatus*	1,2,3,4	4,5		DD, MB, MM
Brown-striped Frog	*Limnodynastes peronii*	9,16,17	1,2,3		Bi, DD, MB, MNNR
Salmon-striped Frog	*Limnodynastes salmini*	3,4,6	4,5		
Spotted Grass Frog	*Limnodynastes tasmaniensis*	20	1,2,3,4		DD
Stuttering Frog	*Mixophyes balbus*	2	1	VR	Bi
Giant Barred Frog	*Mixophyes iteratus*	1,2	1	VR	Bi
Great Barred Frog	*Mixophyes fasciolatus*	1,2	1		CT, DP, MB, MM, RR
Northern Banjo Frog	*Platyplectron terraereginae*	1,2,3,4	1,2,3		BuNP, DD
	Philoria spp.	1,2	burrows	VR	Bi, RR
Brown Toadlet	*Pseudophryne bibronii*	2,3,6	4,5		MM, RR
Red-backed Toadlet	*Pseudophryne coriacea*	2,3	5		Bi, DD, MB, MM, RR
Red-groined Toadlet	*Uperoleia laevigata*	1,2	2,4,5		DD, MB, MM, MNNR
	Uperoleia fusca	1,2	2,4,5		
	Uperoleia rugosa	1,2,3,4	1,4,5		
HYLIDAE					
	Litoria aurea	9,16,17	1,2,3	T	
Green Thighed Frog	*Litoria brevipalmata*	2	4	VR	
Green Tree Frog	*Litoria caerulea*	20	4		MM
Red-eyed Tree Frog	*Litoria chloris*	1,2	1		CT, RR, W
Bleating Tree Frog	*Litoria dentata*	9	3,4		BuNP, DD
Eastern Dwarf Tree Frog	*Litoria fallax*	9,16	1,2,3		CT, DD, MM, MNNR, RR
Freycinet's Frog	*Litoria freycineti*	1,2,3,4,6,11			MM
Dainty Green Tree Frog	*Litoria gracilenta*	20	1,4,5		DD, RR
	Litoria latopalmata	2,3,4,12,15	2,3,4		BNP, Ew, MB, MM, MNNR, W
Lesueur's Frog	*Litoria lesueuri*	20	1,2,3,4		Bi, CT, Ew, MM, RR, W
Rocket Frog	*Litoria nasuta*	2,3,7,9,15	3,4		DD, MM
	Litoria olongburensis	9,16	1,3	VR	BNP
Peron's Tree Frog	*Litoria peronii*	20	1,2,3,4		Bi, CT,MB,MM,MNNR, RR, W
	Litoria pearsoniana	1,2,12	1,3		RR
Leaf Green Tree Frog	*Litoria phyllochroa*	9,16,12	1,2		
	Litoria piperata	1,2,12,16	1,2	VR	
	Litoria revelata	2,6,7,9	2,3,4		
Desert Tree Frog	*Litoria rubella*	20	1,3,4		
	Litoria subglandulosa	2,12	1,2,3,4	VR	
	Litoria tyleri	20	1,2,3,4		RR
	Litoria verreauxii	2,3,6,9,12,	1,2,3		
Cane Toad	*Bufo marinus*	20	all	introduced	

* Site for reproduction: 1=permenant streams/rivers, 2=dams, 3=permanent swamps, 4=ephemeral swamps, 5=temporary water

Location data from Barker (1980), Osborne (1982), Manning (1992), NSW NPWS surveys (in progress) and the results of this study.

APPENDIX F. THE MAMMALS OF THE CASINO MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat components	Sched. 12 Status	Location in Region Casino
MONOTREMES					
Echnida	*Tachyglossus aculeatus*	20			B, BuNP, CT, DD, DP, MB, MM, RR, W
Platypus	*Ornithorhynchus anatinus*	12,16,17			
PHASCOLARCTIDS					
Koala	*Phascolarctos cinereus*	2,3,4,12	food trees	VR	Bi, BuNP, MM, RR
Common Wombat	*Vombatus ursinus*	2,3 - grassy			
MACROPODS					
Long-nosed Potoroo	*Potorous tridactylus*	2,3,8 (coastal)	thick ground cover	VR	RR,W
Rufous Bettong	*Aepyprymnus rufescens*	2,3,4,15		VR	MM, My, RR
Brush-tailed Rock Wallaby	*Petrogale pencillata*	2,3-rocky slopes	caves, rock cracks	VR	Ew
Red-legged Pademelon	*Thylogale stigmatica*	1,2,15	thick understorey	VR	RR, CT
Red-necked Pademelon	*Thylogale thetis*	1,2,15			Ew, MB, RR, W
Parma Wallaby	*Macropus parma*	1,2,3,15	thick understorey	VR	Bi, Ew,RR,W
Whiptail Wallaby	*Macropus parryi*	2,3,4,15			Br, CT, RR, Wp
Red-necked Wallaby	*Macropus rufogriseus*	2,3,8,15			B, DD, DP, MB, MM, RR, W
Black-stripe Wallaby	*Macropus dorsalis*	3,4	thick understorey	VR	RR
Eastern Grey Kangaroo	*Macropus giganteus*	3,4,5,15			B, DD,DP, Ew, MB, MM, RR, W
Common Wallaroo	*Macropus robustus*	3,4,15	caves, rock overhangs		Bi
Swamp Wallaby	*Wallabia bicolor*	1,2,3,4,8,12	thick undergrowth		B, Bi, DD, DP, Ew, MB, MM, RR, W
POSSUMS AND GLIDERS					
Common Ringtail Possum	*Pseudocheirus peregrinus*	1,2,3,12	hollows		B, Bi, BuNP, CT, Ew, MB, RR, W
Greater Glider	*Petauroides volans*	2,3,4	hollows		B, Bi, Bu, BuNP, CT, DP, Ew, MB, MM, RR, W
Yellow-bellied Glider	*Petaurus australis*	2,12	hollows	VR	Bi, Bu, Ca, CT, DD, DP, Gi, MB, RR, T, W
Sugar Glider	*Petaurus breviceps*	1,2,3,4	hollows		Bu, CT, DD, DP, Ew, MB, RR, W
Squirrel Glider	*Petaurus norfolcensis*	2,3,4	hollows	VR	MM, W
Eastern Pygmy Possum	*Cercartetus nanus*	1,2,3	hollows		RR
Feathertail Glider	*Acrobates pygmaeus*	2,3,4,5,8,11	hollows		CT, Ew, MB, RR, W
Common Brushtail Possum	*Trichosurus vulpecula*	2,3,4,14,15	hollows		B, Bi, DD, DP, Ew, MM, RR
Mountain Brushtail Possum	*Trichosurus caninus*	1,2,3	hollows		Bi, CT, Ew, MM, RR, W
DASYURIDS					
Spotted-tail Quoll	*Dasyurus maculatus*	1,2,3,4	caves, logs	VR	B,Bi, BNP, BuNP, DD,Ew,MM,RR, W
Brush-tailed Phascogale	*Phascogale tapoatafa*	2,3	hollows	VR	BuNP, CT, MM, RR
Yellow-footed Antechinus	*Antechinus flavipes*	1,2,3,4,5,9			B, CT, RR
Brown Antechinus	*Antechinus stuartii*	1,2,3	logs		Bi, Ew, MM, RR, W
Dusky Antechinus	*Antechinus swainsonii*	1,2-high elev.,5	logs		
Common Dunnart	*Sminthopsis murina*	2,3,4,8	logs		RR
Common Planigale	*Planigale maculata*	1,2,3,6,12		VR	BNR,CT
BANDICOOTS					
Northern Brown Bandicoot	*Isoodon macrourus*	2,3,4,6,12	tussocks/logs		Bi, CT, RR
Long-nosed Bandicoot	*Perameles nasuta*	1,2,3,4,14			B, Bi, DD, DP, Ew, MB, MM, RR, W
BATS					
Grey-headed Fruit Bat	*Pteropus poliocephalus*	1,2,3,4,10			B,DD, DP,MB,MM,RR, W
Little Red Fruit Bat	*Pteropus scapulatus*	1,2,3			
Black Flying-fox	*Pteropus alecto*	1,2,10		VR	
Queensland Blossom-bat	*Syconycteris australis*	1,2,7,8,9	rainforest foliage	VR	INR
Eastern Horseshoe Bat	*Rhinolophus megaphyllus*	1,2,11	caves		Bi, CT, Ew, MB, RR, W
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	3,4,5	hollows, caves	VR	Ew
White-striped Mastiff Bat	*Nyctinomus australis*	1,2,3,4,12	hollows, bark	VR	Ew, RR, W
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	3,4	hollows, bark	VR	W
Little Northern Mastiff Bat	*Mormopterus loriae*	1,2,3	hollows, bark		
Beccari's Mastiff-bat	*Mormopterus beccarii*	2,3,4	hollows	VR	
Gould's Long-eared Bat	*Nyctophilus gouldi*	3,4	hollows, bark		CT, Ew, RR
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	20	hollows, bark		CT
North Queensland Long-eared Bat	*Nyctophilus bifax*	1,2,3,4,12	hollows, buildings	VR	INR
Common Bent-wing Bat	*Miniopterus schreibersii*	1,2,3	nursery caves/hollows/bark	VR	B, Bi, RR, W
Little Bent-wing Bat	*Miniopterus australis*	1,2,3	nursery caves/hollows/bark	VR	Br, Bw, INR,MM, T, RR
Large Pied Bat	*Chalinolobus dwyeri*	1,2,3	caves,mines,tunnels	VR	
Gould's Wattled Bat	*Chalinolobus gouldii*	2,3,4,5,13,14	hollows, open water		Bi, RR, W
Chocolate Wattled Bat	*Chalinolobus morio*	2,3,4	hollows, bark		Bi, Ew, MM, RR, W
Hoary Bat	*Chalinolobus nigrogriseus*	1,2,3,4,5	rock crevices, hollows	VR	BuNP
Large-footed Mouse-eared Bat	*Myotis adversus*	1,2	caves,dense veg.,water	VR	Bi,W
Greater Broad-nosed Bat	*Scoteanax rueppellii*	2 gullies	hollows	VR	DD, RR, W
Little Broad-nosed Bat	*Scoteanax greyii*	4,6	hollows, buildings, water		
Eastern Broad-nosed Bat	*Scoteanax orion*	1,2,3,4,14	hollows, buildings, caves		Br, Ew, RR, W
Golden-tipped Bat	*Kerivoula papuensis*	1,2	palm fronds (roosting)	VR	Bi,Br, Ew, RR, W
Greater Pipistrelle	*Falsistellus tasmaniensis*	2 gullies	hollows	VR	Br, Bi, MM, W
King River Bat	*Eptesicus regulus*	2	hollows, buildings		Ew, RR
Large Forest Eptesicus	*Eptesicus darlingtoni*		hollows		Bi, Cg, W
Little Cave Eptesicus	*Eptesicus pumilus*	1 - 13	caves,hollows		Bi, CT, RR, W
Little Forest Eptesicus	*Eptesicus vulturnus*	2,3,4,5,6,13	hollows, buildings		
Troughton's Eptesicus	*Eptesicus troughtoni*		caves	VR	

APPENDIX F. THE MAMMALS OF THE CASINO MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat components	Sched. 12 Status	Location in Region Casino
RODENTS					
Water Rat	*Hydromys chrysogaster*	12,16,17	fresh or brackish water		BuNP
Fawn-footed Melomys	*Melomys cervinipes*	1,2,10			Bi, CT, Ew, MM, RR, W
Grassland Melomys	*Melomys burtoni*	1 grass,6			
Hastings River Mouse	*Pseudomys oralis*	2,3,9,16		T	Bi
Eastern Chestnut Mouse	*Pseudomys gracilicaudatus*	3,5,8,9,11		VR	DD, MP, W
New Holland Mouse	*Pseudomys novaehollandiae*	3,5,8,11			
Bush Rat	*Rattus fuscipes*	1,2,3,4,11			Bi, CT, MM, MB, RR, W
Swamp Rat	*Rattus lutreolus*	8,9,12	dense groundcover		Bi, RR
Pale Field Rat	*Rattus tunneyi*	6	loose friable soil		
Black Rat	*Rattus rattus*	3,6,14	introduced		RR
Brown Rat	*Rattus norvegicus*	11,14	introduced		
House Mouse	*Mus musculus*	3,4,6,14	introduced		CT
FERAL					
Brown hare	*Lepus capensis*	4,6	introduced		
Rabbit	*Oryctolagus cuniculus*	20	introduced		
Dingo	*Canis familiaris dingo*	20	introduced		Bi, Ew, MM, RR, W
Fox	*Vulpes vulpes*	2,3,4,12,14,15	introduced		MM
Feral Cat	*Felis cattus*	20	introduced		MM
Horse	*Equus caballus*	3,4,6,15	introduced		B, DD
Pig	*Sus scrofa*	20	introduced		BuNP
Goat	*Capra hircus*	2,3,4,5,6,13	introduced-thickets, surface water		
Cattle	*Bos taurus*	3,4,6,15	introduced		B, Bi, DD, DP, MB, MM, RR
Sheep	*Ovis aries*	3,4,6,15	introduced		MM, RR

APPENDIX F. MAMMALS OF THE GRAFTON MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat Components	Sched.12 Status	Location in Region Grafton
MONOTREMES					
Echidna	*Tachyglossus aculeatus*	20			BWN,C,CC,D,PC,G,Gr,SN,R,WNP
Platypus	*Ornithorhynchus anatinus*	12,16,17			BWN,CC,WNP
PHASCOLARCTIDS					
Koala	*Phascolarctos cinereus*	2,3,4,12	food trees	VR	BC,BWN,CC,D,PC,G,M,R,SN,WNP
Common Wombat	*Vombatus ursinus*	2,3 - grassy			
MACROPODS					
Long-nosed Potoroo	*Potorous tridactylus*	2,3,8 (coastal)	thick ground cover	VR	BWN,C,CC,Cg,WNP
Rufous Bettong	*Aepyprymnus rufescens*	2,3,4,15		VR	BC,BWN,C,CC,D,G,Gr,R,WNP,YNP
Brush-tailed Rock Wallaby	*Petrogale pencillata*	2,3-rocky slopes	caves, rock cracks	VR	BWN,WNP
Red-legged Pademelon	*Thylogale stigmatica*	1,2,15	thick understorey	VR	CC,Cg,WNP
Red-necked Pademelon	*Thylogale thetis*	1,2,15			BWN,CC,Cg,Gr,NNP,R,SN,WNP
Parma Wallaby	*Macropus parma*	1,2,3,15	thick understorey	VR	BWN,CC,Cg,WNP
Whiptail Wallaby	*Macropus parryi*	2,3,4,15			BB,BWN,C,CC,Cg,G,SN,WNP,YNP
Red-necked Wallaby	*Macropus rufogriseus*	2,3,8,15			BWN,C,CC,Cg,D,PC,G,Gr,NNP,R,WNP
Black-stripe Wallaby	*Macropus dorsalis*	3,4	thick understorey	VR	
Eastern Grey Kangaroo	*Macropus giganteus*	3,4,5,15			BWN,C,CC,D,PC,G,Gr,SN,WNP
Common Wallaroo	*Macropus robustus*	3,4,15	caves, rock overhangs		BWN,CC
Swamp Wallaby	*Wallabia bicolor*	1,2,3,4,8,12	thick undergrowth		BWN,C,CC,D,PC,G,Gr,R,SN,WNP
POSSUMS AND GLIDERS					
Common Ringtail Possum	*Pseudocheirus peregrinus*	1,2,3,12	hollows		BC,BWN,CC,Cg,D,Gr,R,WNP
Greater Glider	*Petauroides volans*	2,3,4	hollows		BC,BWN,C,CC,Cg,D,PC,G,Gr,M,N,SN,R,WNP
Yellow-bellied Glider	*Petaurus australis*	2,12	hollows	VR	BWN,BC,C,CC,D,Di,PC,G,Gr,N,PB,R,SN,WNP,YNP
Sugar Glider	*Petaurus breviceps*	1,2,3,4	hollows		BC,BWN,C,CC,Cg,D,Di,PC,G,Gr,M,N,PB,R,SN,WNP
Squirrel Glider	*Petaurus norfolcensis*	2,3,4	hollows	VR	C,PB,R
Eastern Pygmy Possum	*Cercartetus nanus*	1,2,3	hollows		
Feathertail Glider	*Acrobates pygmaeus*	2,3,4,5,8,11	hollows		BC,BWN,C,CC,PC,G,R
Common Brushtail Possum	*Trichosurus vulpecula*	2,3,4,14,15	hollows		BC,BWN,C,CC,Cg,D,Di,PC,G,Gr,N,NNP,R,WNP
Mountain Brushtail Possum	*Trichosurus caninus*	1,2,3	hollows		BWN,CC,Cg,D,Di,Gr,R,WNP
DASYURIDS					
Spotted-tail Quoll	*Dasyurus maculatus*	1,2,3,4	caves, logs	VR	BWN,CC,Cg,Gr,R,WNP
Brush-tailed Phascogale	*Phascogale tapoatafa*	2,3	hollows	VR	BWN,C,YNP
Yellow-footed Antechinus	*Antechinus flavipes*	1,2,3,4,5,9			C
Brown Antechinus	*Antechinus stuartii*	1,2,3	logs		BWN,CC,Cg,D,R,WNP
Dusky Antechinus	*Antechinus swainsonii*	1,2-high elev.,5	logs		
Common Dunnart	*Sminthopsis murina*	2,3,4,8	logs		D,WNP
Common Planigale	*Planigale maculata*	1,2,3,6,12		VR	
BANDICOOTS					
Northern Brown Bandicoot	*Isoodon macrourus*	2,3,4,6,12	tussocks/logs		CC,D,M,NNP,R,WNP
Long-nosed Bandicoot	*Perameles nasuta*	1,2,3,4,14			BC,BWN,C,CC,Cg,D,Di,PC,G,Gr,N,PB,SN,R,WNP
BATS					
Grey-headed Fruit Bat	*Pteropus poliocephalus*	1,2,3,4,10			C,Cg,PC,G,WNP
Little Red Fruit Bat	*Pteropus scapulatus*	1,2,3			
Black Flying-fox	*Pteropus alecto*	1,2,10		VR	
Queensland Blossum Bat	*Syconycteris australis*	1,2,7,8,9	rainforest foliage	VR	
Eastern Horseshoe Bat	*Rhinolophus megaphyllus*	1,2,11	caves		BWN,C,D,Gr,M,WNP
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*	3,4,5	hollows, caves	VR	PC
White-striped Mastiff Bat	*Nyctinomus australis*	1,2,3,4,12	hollows, bark		BWN,CC,Cg,PC,Gr,SN
Little Mastiff Bat	*Mormopterus planiceps*	1,2,3,	small hollows/crevices		SN
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	3,4	hollows, bark	VR	C,WNP
Little Northern Mastiff Bat	*Mormopterus loriae*	1,2,3	hollows, bark		
Beccari's Mastiff-bat	*Mormopterus beccarii*	2,3,4	hollows	VR	C,SN
Gould's Long-eared Bat	*Nyctophilus gouldi*	3,4	hollows, bark		CC,Cg,D,Gr,SN
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	20	hollows, bark		BC,M
Common Bent-wing Bat	*Miniopterus schreibersii*	1,2,3	nursery caves/hollows/bark	VR	CC,Cg,D,PC,G,Gr,WNP
Little Bent-wing Bat	*Miniopterus australis*	1,2,3	nursery caves/hollows/bark	VR	G,Gr
Large Pied Bat	*Chalinobolus dwyeri*	1,2,3	caves, mines, tunnels	VR	
Gould's Wattled Bat	*Chalinolobus gouldii*	2,3,4,5,13,14	hollows, open water		BC,C,Cg,D,PC,SN,WNP
Chocolate Wattled Bat	*Chalinolobus morio*	2,3,4	hollows, bark		Cg,Gr,R,WNP
Hoary Bat	*Chalinolobus nigrogriseus*	1,2,3,4,5	rock crevices, hollows	VR	R
Large-footed Mouse-eared Bat	*Myotis adversus*	1,2	caves,dense veg.,water	VR	Gr,R,WNP
Greater Broad-nosed Bat	*Scoteanax rueppellii*	2 gullies	hollows	VR	CC,R,WNP
Little Broad-nosed Bat	*Scoteanax greyii*	4,6	hollows, buildings, water		D,Gr
Eastern Broad-nosed Bat	*Scoteanax orion*	1,2,3,4,14	hollows, buildings, caves		C,SN
Golden-tipped Bat	*Kerivoula papuensis*	1,2	palm fronds (roosting)	VR	BC,Gr,SN
Great Pipistrelle	*Falsistrellus tasmaniensis*	2 gullies	hollows	VR	C,PC,SN
King River Bat	*Eptesicus regulus*	2	hollows, buildings		C,CC,D,SN,WNP
Large Forest Eptesicus	*Eptesicus darlingtoni*		hollows		C,CC,SN,W,WNP
Little Cave Eptesicus	*Eptesicus pumilus*	1 - 13	caves,hollows		BC,CC,Cg,Gr,M,R,WNP
Little Forest Eptesicus	*Eptesicus vulturnus*	2,3,4,5,6,13	hollows, buildings		BC,D,Gr,M,WNP
Troughton's Eptesicus	*Eptesicus troughtoni*		caves	VR	CC

APPENDIX F. MAMMALS OF THE GRAFTON MANAGEMENT AREA.

Common Name	Scientific Name	Habitat	Habitat Components	Sched.12 Status	Location in Region Grafton
RODENTS					
Water Rat	*Hydromys chrysogaster*	12,16,17	fresh or brackish water		C,WNP
Fawn-footed Melomys	*Melomys cervinipes*	1,2,10			BC,BWN,C,CC,Cg,WNP
Grassland Melomys	*Melomys burtoni*	1 grass,6			
Hastings River Mouse	*Pseudomys oralis*	2,3,9,16		T	CC,D
Eastern Chestnut Mouse	*Pseudomys gracilicaudatus*	3,5,8,9,11		VR	C
New Holland Mouse	*Pseudomys novaehollandiae*	3,5,8,11			BWN,Cg
Bush Rat	*Rattus fuscipes*	1,2,3,4,11			BWN,CC,Cg,D,R,WNP
Swamp Rat	*Rattus lutreolus*	8,9,12	dense groundcover		BWN,CC,WNP
Pale Field Rat	*Rattus tunneyi*	6	loose friable soil		
Black Rat	*Rattus rattus*	3,6,14	introduced		CC
Brown Rat	*Rattus norvegicus*	11,14	introduced		
House Mouse	*Mus musculus*	3,4,6,14	introduced		CC
FERAL					
Brown hare	*Lepus capensis*	4,6	introduced		BWN
Rabbit	*Oryctolagus cuniculus*	20	introduced		CC
Dingo	*Canis familiaris dingo*	20	introduced		BWN,CC,D,PC,M
Fox	*Vulpes vulpes*	2,3,4,12,14,15	introduced		CC,D,BWN,WNP
Feral Cat	*Felis cattus*	20	introduced		BWN,C,CC,Cg,R,M
Horse	*Equus caballus*	3,4,6,15	introduced		G
Pig	*Sus scrofa*	20	introduced		
Goat	*Capra hircus*	2,3,4,5,6,13	introduced-thickets, surface water		
Cattle	*Bos taurus*	3,4,6,15	introduced		BWN,C,CC,D,PC,G,Gr,R,SN,WNP
Sheep	*Ovis aries*	3,4,6,15	introduced		CC

APPENDIX G. SITE LOCATION, LOCAL AND REGIONAL DISTRIBUTION AND ABUNDANCE AND STATE-WIDE STATE-WIDE STATUS OF THE ENDANGERED SPECIES OF THE GRAFTON MANAGEMENT AREA.

Common Name	Scientific Name	Local : Regional Distribution ¥	Location in Management Area *	Local Abundance Frequency/site	Regional Abundance Frequency/site *#	State-wide Status
BIRDS						
Black Bittern	*Dupetor flavicollis*	0:0		0.00 (Rare)	0.00 (Rare)	VR
Bush Thick Knee	*Burhinus magnirostris*	1:2		0.00 (Rare)	0.00 (Rare)	T
Black-breasted Button Quail	*Turnix melanogaster*	0:0		0.00 (Rare)	0.00 (Rare)	T
Bush Hen	*Gallinula olivacea*	0:2		0.00 (Rare)	0.00 (Rare)	VR
Square-tailed Kite	*Lophoictinia isura*	2:4		0.00 (Rare)	0.00 (Rare)	VR
Red Goshawk	*Erythrotriorchis radiatus*	3:4		0.00 (Rare)	0.00 (Rare)	T
Wompoo Fruit Dove	*Ptilinopus magnificus*	5:10	41,46B	0.05 (Uncommon)	0.05 (Uncommon)	VR
Rose-crowned Fruit Dove	*Ptilinopus regina*	0:5		0.00 (Rare)	0.00 (Rare)	VR
Superb Fruit-Dove	*Ptilinopus superbus*	0:1		0.00 (Rare)	0.00 (Rare)	VR
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	11:16	34,35,36,37,38,40,44,47,48B,62,63	0.30 (Common)	0.21 (Common)	VR
Swift Parrot	*Lathamus discolor*	0:0		0.00 (Rare)	0.00 (Rare)	VR
Double-eyed Fig Parrot	*Psittaculirostris diophthalma coxeni*	0:1		0.00 (Rare)	0.00 (Rare)	T
Turquoise Parrot	*Neophema pulchella*	0:0		0.00 (Rare)	0.00 (Rare)	VR
Powerful Owl	*Ninox strenua*	6:11	46A,52B	0.05 (Uncommon)	0.06 (Uncommon)	VR
Masked Owl	*Tyto novaehollandiae*	4:7	32,33	0.05 (Uncommon)	0.08 (Uncommon)	VR
Sooty Owl	*Tyto tenebricosa*	5:10	36,38,45	0.08 (Uncommon)	0.10 (Uncommon)	VR
Marbled Frogmouth	*Podargus ocellatus*	0:2		0.00 (Rare)	0.00 (Rare)	VR
Olive Whistler	*Pachycephala olivacea*	1:1		0.00 (Rare)	0.00 (Rare)	VR
White-eared Monarch	*Monarcha leucotis*	0:2		0.00 (Rare)	0.00 (Rare)	VR
Rufous Scrub Bird	*Atrichornis rufescens*	0:0		0.00 (Rare)	0.00 (Rare)	VR
Yellow-eyed Cuckoo-Shrike	*Coracina lineata*	0:2		0.00 (Rare)	0.04 (Rare)	VR
Albert's Lyrebird	*Menura alberti*	0:1		0.00 (Rare)	0.00 (Rare)	VR
Regent Honeyeater	*Xanthomyza phrygia*	2:3		0.00 (Rare)	0.00 (Rare)	T
REPTILES						
White Crowned Snake	*Cacophis harriettae*	0:0		0.00 (Rare)	0.00 (Rare)	VR
Stephen's Banded Snake	*Hoplocephalus stephensii*	1:2		0.00 (Rare)	0.00 (Rare)	VR
Pale-headed Snake	*Hoplocephalus bitorquatus*	0:0		0.00 (Rare)	0.00 (Rare)	VR
	Coeranoscincus reticulatus	0:2		0.00 (Rare)	0.00 (Rare)	VR
AMPHIBIANS						
Tinkling Froglet	*Crinia tinnula*	0:0		0.00 (Rare)	0.00 (Rare)	VR
	Litoria aurea	0:0		0.00 (Rare)	0.00 (Rare)	T
Green-thighed Frog	*Litoria brevipalmata*	0:0		0.00 (Rare)	0.00 (Rare)	VR
	Litoria subglandulosa	1:1		0.00 (Rare)	0.00 (Rare)	VR
	Litoria olongburensis	0:1		0.00 (Rare)	0.00 (Rare)	VR
Pouched Frog	*Assa darlingtoni*	2:4		0.00 (Rare)	0.00 (Rare)	VR
Stuttering Frog	*Mixophyes balbus*	2:3		0.00 (Rare)	0.00 (Rare)	VR
Giant Barred Frog	*Mixophyes iteratus*	3:4		0.00 (Rare)	0.00 (Rare)	VR
	Philoria spp.	2:4	34	0.03 (Rare)	0.01 (Rare)	VR
MAMMALS						
Spotted-tailed Quoll	*Dasyurus maculatus*	6:15	34, 52B	0.05 (Uncommon)	0.04 (Rare)	VR
Brush-tailed Phascogale	*Phascogale tapoatafa*	3:7		0.00 (Rare)	0.00 (Rare)	VR
Squirrel Glider	*Petaurus norfolcensis*	3:5		0.00 (Rare)	0.00 (Rare)	VR
Yellow-bellied Glider	*Petaurus australis*	14:26	35,36,37,41,60	0.13 (Uncommon)	0.16 (Common)	VR
Koala	*Phascolarctos cinereus*	10:14	55A	0.03 (Rare)	0.05 (Uncommon)	VR
Rufous Bettong	*Aepyprymnus rufescens*	10:13	48A,56	0.05 (Uncommon)	0.05 (Uncommon)	VR
Long-nosed Potoroo	*Potorous tridactylus*	5:7	59	0.03 (Rare)	0.03 (Rare)	VR
Parma Wallaby	*Macropus parma*	4:8		0.00 (Rare)	0.01 (Rare)	VR
Black-striped Wallaby	*Macropus dorsalis*	0:1		0.00 (Rare)	0.00 (Rare)	T
Brush-tailed Rock Wallaby	*Petrogale penicillata*	2:3		0.00 (Rare)	0.00 (Rare)	VR
Red-legged Pademelon	*Thylogale stigmatica*	3:5		0.00 (Rare)	0.00 (Rare)	VR
Common Planigale	*Planigale maculata*	0:2		0.00 (Rare)	0.00 (Rare)	VR
Eastern Chestnut Mouse	*Pseudomys gracilicaudatus*	1:4	60	0.03 (Rare)	0.03 (Rare)	VR
Hastings River Mouse	*Pseudomys oralis*	2:3		0.00 (Rare)	0.00 (Rare)	T
Queensland Blossom Bat	*Syconycteris australis*	0:1		0.00 (Rare)	0.00 (Rare)	VR
Large-footed Mouse-eared Bat	*Myotis adversus*	3:5	50	0.03 (Rare)	0.01 (Rare)	VR
Beccari's Mastiff-bat	*Mormopterus beccarii*	2:2	42,61	0.05 (Uncommon)	0.03 (Rare)	VR
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	2:3	60,61	0.05 (Uncommon)	0.03 (Rare)	VR
Common Bent-wing Bat	*Miniopterus schreibersii*	8:11	32,37,50,54	0.11 (Uncommon)	0.30 (Common)	VR
Little Bent-wing Bat	*Miniopterus australis*	2:8	50,63	0.05 (Uncommon)	0.06 (Uncommon)	VR
Large Pied Bat	*Chalinolobus dwyeri*	0:0		0.00 (Rare)	0.00 (Rare)	VR
Hoary Bat	*Chalinolobus nigrogriseus*	1:2		0.00 (Rare)	0.00 (Rare)	VR
Yellow-bellied Sheath-tailed Bat	*Saccolaimus flaviventris*	1:2	53	0.03 (Rare)	0.03 (Rare)	VR
Greater Broad-nosed Bat	*Scoteanax rueppellii*	3:6	2 in 44-46B	0.05 (Uncommon)	0.07 (Uncommon)	VR
Golden-tipped Bat	*Kerivoula papuensis*	3:8	43,52B	0.05 (Uncommon)	0.04 (Rare)	VR
Greater Pipistrelle	*Falsistrellus tasmaniensis*	3:7	42,43,53,57,58,60,61	0.19 (Common)	0.10 (Uncommon)	VR
	Eptesicus troughtoni	1:1		0.00 (Rare)	0.00 (Rare)	VR
	Total	145 : 279				

¥ Number of SF, NP and NR records in the Management Area and the total for the Study Area. See Appendices B-F for previous records in the region.

* Sites detected this survey, see Appendix A for Site Location.

*# Detected this survey.

Local and Regional Abundance, Frequency / Site: Rare = < 0.05, Uncommon = 0.05-<0.15, Common = 0.15 or more

APPENDIX G. SITE LOCATION, LOCAL AND REGIONAL DISTRIBUTION AND ABUNDANCE AND STATE-WIDE STATE-WIDE STATUS OF THE ENDANGERED SPECIES OF THE CASINO MANAGEMENT AREA.

Common Name	Scientific Name	Local : Regional Distribution ¥	Location in Management Area *	Local Abundance Frequency/site	Regional Abundance Frequency/site *#	State-wide Status
BIRDS						
Black Bittern	*Dupetor flavicollis*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
Bush Thick Knee	*Burhinus magnirostris*	1 : 2		0.00 (Rare)	0.00 (Rare)	T
Black-breasted Button Quail	*Turnix melanogaster*	0 : 0		0.00 (Rare)	0.00 (Rare)	T
Bush Hen	*Gallinula olivacea*	2 : 2		0.00 (Rare)	0.00 (Rare)	VR
Square-tailed Kite	*Lophoictinia isura*	2 : 4		0.00 (Rare)	0.00 (Rare)	VR
Red Goshawk	*Erythrotriorchis radiatus*	1 : 4		0.00 (Rare)	0.00 (Rare)	T
Wompoo Fruit Dove	*Ptilinopus magnificus*	5 : 10	12A,17	0.05 (Uncommon)	0.05 (Uncommon)	VR
Rose-crowned Fruit Dove	*Ptilinopus regina*	5 : 5	17	0.03 (Rare)	0.01 (Rare)	VR
Superb Fruit- Dove	*Ptilinopus superbus*	1 : 1		0.00 (Rare)	0.00 (Rare)	VR
Glossy Black-Cockatoo	*Calyptorynchus lathami*	5 : 16	7,28,30,CB6,BAR37	0.13 (Common)	0.21 (Common)	VR
Swift Parrot	*Lathamus discolor*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
Double-eyed Fig Parrot	*Psittaculirostris diophthalma*	1 : 1		0.00 (Rare)	0.00 (Rare)	T
Turquoise Parrot	*Neophema pulchella*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
Powerful Owl	*Ninox strenua*	5 : 11	11,17,CL36	0.08 (Uncommon)	0.07 (Uncommon)	VR
Masked Owl	*Tyto novaehollandiae*	3 : 7	11,12B,28,CL36	0.01 (Uncommon)	0.10 (Uncommon)	VR
Sooty Owl	*Tyto tenebricosa*	5 : 10	15,16,17,19,BAR37	0.14 (Uncommon)	0.07 (Uncommon)	VR
Marbled Frogmouth	*Podargus ocellatus*	2 : 2		0.00 (Rare)	0.00 (Rare)	VR
Olive Whistler	*Pachycephala olivacea*	0 : 1		0.00 (Rare)	0.00 (Rare)	VR
White-eared Monarch	*Monarcha leucotis*	2 : 2		0.00 (Rare)	0.00 (Rare)	VR
Rufous Scrub Bird	*Atrichornis rufescens*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
Yellow-eyed Cuckoo-Shrike	*Coracina lineata*	2 : 2		0.00 (Rare)	0.04 (Rare)	VR
Albert's Lyrebird	*Menura alberti*	1 : 1		0.00 (Rare)	0.00 (Rare)	VR
Regent Honeyeater	*Xanthomyza phrygia*	1 : 3		0.00 (Rare)	0.00 (Rare)	T
REPTILES						
White Crowned Snake	*Cacophis harriettae*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
Stephen's Banded Snake	*Hoplocephalus stephensii*	1 : 2		0.00 (Rare)	0.00 (Rare)	VR
Pale-headed Snake	*Hoplocephalus bitorquatus*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
	Coeranoscincus reticulatus	2 : 2		0.03 (Rare)	0.01 (Rare)	VR
AMPHIBIANS						
Tinkling Froglet	*Crinia tinnula*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
	Litoria aurea	0 : 0		0.00 (Rare)	0.00 (Rare)	T
Green-thighed Frog	*Litoria brevipalmata*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
	Litoria piperata	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
	Litoria subglandulosa	0 : 1		0.00 (Rare)	0.00 (Rare)	VR
	Litoria olongburensis	1 : 1		0.00 (Rare)	0.00 (Rare)	VR
Pouched Frog	*Assa darlingtoni*	2 : 4		0.00 (Rare)	0.00 (Rare)	VR
Stuttering Frog	*Mixophyes balbus*	1 : 3		0.00 (Rare)	0.00 (Rare)	VR
Giant Barred Frog	*Mixophyes iteratus*	1 : 4		0.00 (Rare)	0.00 (Rare)	VR
	Philoria spp.	2 : 4		0.03 (Rare)	0.01 (Rare)	VR
MAMMALS						
Spotted-tailed Quoll	*Dasyurus maculatus*	9 : 15	BAN 30	0.03 (Rare)	0.04 (Rare)	VR
Brush-tailed Phascogale	*Phascogale tapoatafa*	4 : 7		0.00 (Rare)	0.00 (Rare)	VR
Squirrel Glider	*Petaurus norfolcensis*	2 : 5		0.00 (Rare)	0.00 (Rare)	VR
Yellow-bellied Glider	*Petaurus australis*	12 : 26	12A,12B,22B,31B,CL35 BAR 37,BAR 38	0.18 (Common)	0.16 (Common)	VR
Koala	*Phascolarctus cinereus*	4 : 14	14,18,26	0.08 (Uncommon)	0.05 (Uncommon)	VR
Rufous Bettong	*Aepyprymnus rufescens*	3 : 13	13,26	0.05 (Uncommon)	0.05 (Uncommon)	VR
Long-nosed Potoroo	*Potorous tridactylus*	2 : 7	31B	0.03 (Rare)	0.01 (Rare)	VR
Parma Wallaby	*Macropus parma*	4 : 8	31C	0.03 (Rare)	0.01 (Rare)	VR
Black-striped Wallaby	*Macropus dorsalis*	1 : 1		0.00 (Rare)	0.00 (Rare)	T
Brush-tailed Rock Wallaby	*Petrogale penicillata*	1 : 3		0.00 (Rare)	0.00 (Rare)	VR
Red-legged Pademelon	*Thylogale stigmatica*	2 : 5		0.00 (Rare)	0.00 (Rare)	VR
Common Planigale	*Planigale maculata*	2 : 2		0.00 (Rare)	0.00 (Rare)	VR
Eastern Chestnut Mouse	*Pseudomys gracilicaudatus*	3 : 4	6	0.03 (Rare)	0.03 (Rare)	VR
Hastings River Mouse	*Pseudomys oralis*	1 : 3		0.00 (Rare)	0.00 (Rare)	T
Queensland Blossom Bat	*Syconycteris australis*	1 : 1		0.00 (Rare)	0.00 (Rare)	VR
Large-footed Mouse-eared Bat	*Myotis adversus*	2 : 5		0.00 (Rare)	0.01 (Rare)	VR
Beccari's Mastiff-bat	*Mormopterus beccarii*	0 : 2		0.00 (Rare)	0.03 (Rare)	VR
Eastern Little Mastiff Bat	*Mormopterus norfolkensis*	1 : 3		0.00 (Rare)	0.03 (Rare)	VR
Common Bent-wing Bat	*Miniopterus schreibersii*	4 : 11	17,18,BAN 32	0.08 (Uncommon)	0.09 (Uncommon)	VR
Little Bent-wing Bat	*Miniopterus australis*	6 : 8	13,17	0.05 (Uncommon)	0.05 (Uncommon)	VR
Large Pied Bat	*Chalinolobus dwyeri*	0 : 0		0.00 (Rare)	0.00 (Rare)	VR
North Queensland Long-eared Bat	*Nyctophilus bifax*	1 : 1		0.00 (Rare)	0.00 (Rare)	VR
Hoary Bat	*Chalinolobus nigrogriseus*	1 : 2		0.00 (Rare)	0.00 (Rare)	VR
Yellow-bellied Sheath-tailed Bat	*Saccolaimus flaviventris*	1 : 2	28	0.03 (Rare)	0.03 (Rare)	VR
Greater Broad-nosed Bat	*Scoteanax rueppellii*	3 : 6		0.00 (Rare)	0.03 (Rare)	VR
Golden-tipped Bat	*Kerivoula papuensis*	5 : 8	27	0.03 (Rare)	0.04 (Rare)	VR
Greater Pipistrelle	*Falsistrellus tasmaniensis*	4 : 7	BAN 31	0.03 (Rare)	0.10 (Uncommon)	VR
	Eptesicus troughtoni	0 : 1		0.00 (Rare)	0.00 (Rare)	VR

Total 142 : 279

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* Sites detected this survey, see Appendix A for Site Location.

* # Detected this survey -

Local and Regional Abundance, Frequency / Site: Rare = < 0.05, Uncommon = 0.05–<0.15, Common = 0.15 or more