VERTEBRATE FAUNA SURVEY, ANALYSIS AND MODELLING PROJECTS

NSW WESTERN REGIONAL ASSESSMENTS

SEPTEMBER 2002

Brigalow Belt South

Stage 2

Resource and Conservation Assessment Council

VERTEBRATE FAUNA SURVEY, ANALYSIS AND MODELLING PROJECTS

NSW WESTERN REGIONAL ASSESSMENTS

BRIGALOW BELT SOUTH BIOREGION (STAGE 2)

NSW National Parks and Wildlife Service

Projects undertaken for the
Resource and Conservation Assessment Council
NSW Western Regional Assessments
Project numbers WRA 23 and WRA 27

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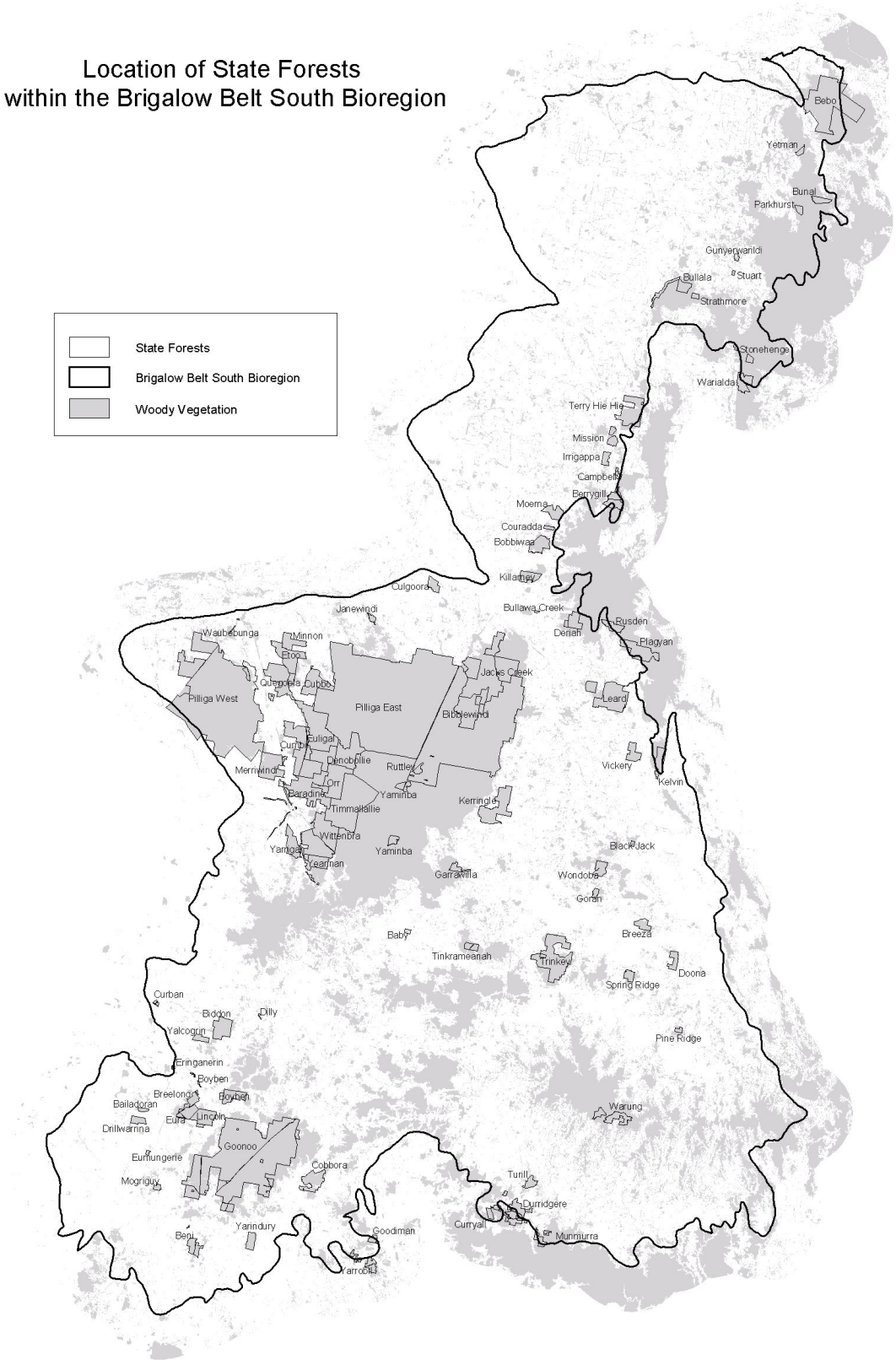


PROJECT SUMMARY

This report describes two projects undertaken for the Resource and Conservation Assessment Council (RACAC) as part of the regional assessments of Western New South Wales. The Resource and Conservation Assessment Council advises the State Government on broad-based land use planning and allocation issues. An essential process for the western regional assessments is to identify geographic gaps in data information and the best ways in which to proceed with data gathering and evaluation.

Project objective/s

RACAC approved two projects to collect and assess data about the vertebrate fauna of the Brigalow Belt South Bioregion (BBSB). These were the *Vertebrate fauna survey (Stage 2) project*, and the *Vertebrate fauna survey data analysis and preliminary species/assemblage distribution and habitat modelling project*. Both these projects were closely linked and essentially formed two parts of the same task. This task was to provide accurate information about the distribution and habitat use of vertebrates in the New South Wales portion of the BBSB. The key objective of the fauna survey project was the collection of field data about the distribution and abundance of vertebrates within the forest and woodland vegetation of the bioregion, with emphasis on filling known gaps in the data previously available. The key objective of the fauna analysis project was to compile and apply analysis techniques to the data collected during the survey project with the aim of identifying areas of high conservation value within the bioregion.

Methods

Standardised systematic methods were used to collect data for vertebrate species from 108 two-hectare plots selected in woody vegetation throughout the bioregion. Specific methods used at each site were: timed diurnal bird census, Elliott trapping, harp trapping, site based spotlighting, habitat search, ultrasonic (Anabat) detection, nocturnal call-playback and a spotlight transect associated with the site. The majority of the methods used were comparable to those used for the survey conducted during the preliminary (Stage 1) and other surveys conducted in adjacent bioregions.

Key results and products

The key results from these projects are a greatly improved knowledge of vertebrate species composition and distribution across all tenures within the bioregion.
Key products are:

- systematically collected fauna data, filling known gaps;
- a database of all known reliable vertebrate fauna records;
- classification analysis results, identifying faunal assemblages on a bioregional scale;
- predictive models for 30 species of conservation concern; and
- profiles for 37 species of conservation concern that were recorded during the survey.

1. INTRODUCTION

1.1 PROJECT DESCRIPTIONS

The Resource and Conservation Assessment Council (RACAC) approved two projects to collect and assess data about the vertebrate fauna of the Brigalow Belt South bioregion. These projects will assist with meeting current conservation requirements and implementing policies concerning the conservation of biodiversity, ecological processes, native ecosystems, genetic diversity and the safeguarding of endangered and vulnerable species. The *Vertebrate fauna survey (Stage 2) project* (referred hereafter as the fauna survey project) and the *Vertebrate fauna survey data analysis and preliminary species/assemblage distribution and habitat modelling project* (referred hereafter as the fauna analysis project).

Both these projects were closely linked and essentially formed two parts of the same task. The fauna survey project involved the collection of field data which was then used in the fauna analysis project to assess the distribution of vertebrate species within the forest and woodland areas of the bioregion.

1.2 REPORT OUTLINE

This report follows a basic outline;

- ***Chapter one*** provides an introduction to the projects, the study area, and the key people involved in the project.
- ***Chapter two*** provides a background from which the projects have developed.
- ***Chapter three*** provides specific details on the survey project including, methods, aims, limitations and results.
- ***Chapter four*** provides specific details on the analysis project including, methods, aims, limitations and results.
- ***Chapter five*** discusses the results of both projects and how the project objectives have been met.
- ***Chapter six*** lists the recommendations made throughout this report.
- ***Chapter seven*** contains a glossary of terms used in this report.

1.3 FAUNA SURVEY PROJECT

1.3.1 Overview

The fauna survey project had five components. The main component was the systematic survey which was managed by New South Wales National Parks and Wildlife Service (NPWS) and conducted by a joint survey team of NPWS and State Forests of New South Wales (SFNSW) ecologists.

The systematic survey was undertaken over two, three-month periods; the summer/autumn season from February to April 2001 and the spring/summer season from September to December 2001. A total of 108 sites were surveyed for vertebrate fauna species using a series of standardised systematic techniques designed to sample the full range of fauna diversity at each site. Additional data were also collected opportunistically throughout the bioregion whilst conducting survey activities.

Survey sites were selected to fill known gaps in the available data and with the aim of collecting data for the Brigalow Belt South bioregion assessment. Sites were selected only from within areas of forest or woodland vegetation. Survey sites were located on a variety of land tenures including state forest, travelling stock reserve, private property, council reserve, nature reserve and national park.

The additional four components of the project were "targeted fauna projects" funded under the project proposal and managed by State Forests of New South Wales. These projects were to specifically research management issues of four individual species, *Hoplocephalus bitorquatus* (pale-headed snake), the squirrel glider (*Petaurus norfolcensis*), the eastern pygmy possum (*Cercartetus nanus*) and the glossy black cockatoo (*Calyptorhynchus lathami*). The outcomes of these sub-projects are reported elsewhere.

1.3.2 Systematic survey project objectives

The overall objective of this project was to undertake systematic scientific surveys of the vertebrate fauna within the Brigalow Belt South bioregion of New South Wales. The aim of these surveys was to contribute data to the biodiversity assessment component of the regional assessment of the Brigalow Belt South bioregion and to collect data suitable for use in conservation and resource assessment, planning and management.

Specific objectives for this project were to:

- build onto data collected from previous surveys of the bioregion;
- provide new data, using targeted surveys, about the distribution and, if possible, abundance of vertebrate fauna in the bioregion, for use in verifying future habitat mapping, and in species and habitat modelling;
- collect information about vertebrate fauna and their habitat to fill as many gaps in knowledge as possible, focussing on threatened, regionally significant and forest dependant species;
- collate information about the known and predicted regional distribution of each species to provide a regional context for the project;
- assist in the identification of High Conservation Values;
- assist the identification of a Comprehensive, Adequate and Representative Protected Area Network including reserves;

- assist in developing conservation protocols as part of Ecologically Sustainable Forest Management (ESFM);
- provide a basis for identifying ecosystems from vegetation mapping;
- provide information on the geographic variation within and between mapped vegetation types; and
- provide information about biodiversity for regional planning bodies such as regional vegetation management committees and catchment management boards.

These objectives were to be met through the increased knowledge of faunal diversity and habitat requirements within all land tenures of the bioregion gained from survey data.

1.3.3Targeted fauna survey project objectives

The four targeted fauna survey projects targeted the pale-headed snake, squirrel glider, eastern pygmy possum and glossy black cockatoo with the aim of addressing management issues for these four species. Specific objectives for these projects are listed below.

Details of the surveyors, survey methodology, results and discussion for these four projects are presented in separate reports produced by RACAC.

Objectives of targeted project 1. Pale-headed snake

- To identify and if possible "model" the habitat in which the snake is likely to occur.
- To test the efficacy of the habitat description and model across the landscape.
- To investigate the behavioural ecology of individuals through radio-tracking to obtain information about habitat use.

Objectives of targeted project 2. Squirrel glider

- To identify and if possible "model" the habitat in which the squirrel gliders are likely to occur.
- To test the efficacy of the habitat description and model across the landscape.
- To investigate the behavioural ecology of individuals to obtain information about habitat use (including tree species used and home range).
- To use the squirrel glider and other arboreal animals likely to be detected during survey as surrogates to investigate hollow use and availability.

Objectives of targeted project 3. Eastern pygmy possum

- to identify and if possible "model" the habitat in which eastern pygmy possums are likely to occur.
- To test the efficacy of the habitat description and model across the landscape.
- To investigate the behavioural ecology of individuals to obtain information about habitat use.

Objectives of targeted project 4. Glossy black cockatoo

- To locate glossy black cockatoo habitat across the bioregion.

1.4 THE FAUNA DATA ANALYSIS PROJECT

1.4.1 Overview

The vertebrate fauna survey data analysis and preliminary species/assemblage distribution and habitat modelling project ran for six months from January 2002 until June 2002.
The key goal of the project was to analyse the systematic vertebrate fauna survey data collected during the Brigalow Belt South Stage 1, Stage 2 and other surveys and if possible identify faunal assemblages, distributions, habitat requirements and areas of habitat significance for vertebrate fauna in the Brigalow Belt South bioregion. The project would also add important information to the biodiversity assessment component of Western Regional Assessment process in the Brigalow Belt South bioregion. Prior to commencing the project there was insufficient information about the distribution, habitat requirements and preferences of fauna throughout the bioregion to formulate recommendations for conservation. This project attempts to use information collected from the Brigalow Belt South Stage 1 and 2 fauna surveys including targeted survey data and additional data sources to identify major habitat types used by selected priority species and faunal assemblages. It also aims to extrapolate this information across areas not previously surveyed. Where sufficient data existed predictive models were developed to identify high quality habitat and habitat significance for some priority vertebrate species within the bioregion.

1.4.2 Project Objectives

The main objectives of this project were to develop the raw data collected during systematic and targeted vertebrate fauna surveys into a useful and practical format to provide information about linkages of faunal assemblages to vegetation communities, suitable for use in conservation and resource assessment, planning and management.

Specific objectives for this project were to:

- collate, refine and validate the data collected from previous vertebrate fauna surveys of the bioregion into a single database;
- produce lists of species expected to occur in identified vegetation communities throughout the bioregion by analysis of data using expert opinion.;
- develop profiles identifying habitat requirements, ecological community and home range information for a limited number of species of concern at the bioregional scale, based on vertebrate fauna survey data and expert advice;
- trial the development of predictive models for certain priority species of concern within the bioregion, to assess the feasibility of developing species models in data poor areas;
- publish the results of fauna survey work undertaken in the Stage 2 fauna surveys and subsequent data analysis in a report;
- assist in the identification of high conservation value areas;
- assist in the identification of a Comprehensive, Adequate and Representative reserve system. (CAR);
- assist in developing conservation protocols as part of Ecologically Sustainable Forest Management (ESFM) and Ecologically Sustainable Land Management (ESLM); and
- provide information about biodiversity for regional planning bodies such as Regional Vegetation Management Committees (RVMCs) and Catchment Management Boards (CMBs).

1.5 DATA MANAGEMENT

1.5.1 Nomenclature

The nomenclature used in this report follows these rules: bats and reptiles are referred to by scientific name firstly and common name, if applicable secondly, all other species are referred to by common name followed by scientific name.

1.5.2 The vertebrate fauna survey database

All fauna data collected during this project have been entered onto the appropriate wildlife databases after data checking. All species records and site location details were checked against field data books and were plotted against topographic maps on GIS. Fauna data were entered onto the BBS fauna database in the NSW NPWS Western Directorate Office, and records from this project will then be extracted (if approval from land managers is obtained) and added to the NSW NPWS Wildlife Atlas.

Slides, prints and scanned images of site photographs are held at the NSW NPWS Western Regional Assessments Office, Dubbo. Original field data sheets are kept at the NSW NPWS Regional Assessments Office, Dubbo, with copies in the NSW NPWS Western Directorate Office.

Fauna specimens collected during the project have been lodged with The Australian Museum, Sydney (Appendix 3).

The data collected during this survey were compiled onto a single Microsoft Access database, BBS fauna database. This database contains all known species records from the study area on the 15th February 2002 from the NPWS Wildlife Atlas, the Stage 1 and Stage 2, Darling Riverine Plains and Nandewar biodiversity surveys. The database also contains records from Queensland Parks and Wildlife Service, CSIRO, the Australian Museum, Birds Australia, RAOU, and Australian Bird and Bat Banding Scheme.

Some of these data have been used under specific licence conditions between NPWS and the owners. Some of these data are not permitted to be released.
Data collected for RACAC during the Stage 2 survey will be available following the release of this report.
Other data that do not contain licence conditions prohibiting their distribution may be available through;

Robert Mezzatesta
NPWS Geographic Information Systems Group,
Level 5, 43 Bridge Street,
PO Box 1967
Hurstville NSW 2220
Phone, (02) 9585 6695

All data on this database were screened for suspect and incorrect records as described in section 4.1.2.

1.6 STUDY AREA

1.6.1 Description of the study area

The Brigalow Belt South (BBS) bioregion extends from southern Queensland into the north of New South Wales, covering an area of 279 496 km^2. It is the sixth largest of the 80 bioregions in Australia. The bioregional boundary was defined by Thackway and Cresswell, (1995), on the basis of Jurassic and younger deposits of the Great Artesian Basin and Cainozoic deposits and elevated Tertiary basalt flows.

This assessment deals only with the New South Wales portion of the bioregion, which covers 52 409 km^2 which is 18.7% of the total bioregion area and 6.5% of the state. Morgan and Terrey (1992) described the BBS as the Northern Sandstones, dominated by the Mesozoic sediments that comprise the south-eastern extremity of the Great Artesian Basin. These north-west dipping beds form a generally undulating landscape with some low hills and a few higher areas overlain by Tertiary lava flows. Sandstone dominated areas, due to their lower fertility soils and hence low suitability to agriculture, have the bulk of the remaining native forest – the two main contiguous blocks being the Pilliga and Goonoo forest areas. The steeper basaltic areas are dominated by native forest also due to their low suitability for agriculture. The more gently undulating areas and alluvial areas have been widely cleared due to their high levels of agricultural capability. This is especially evident in the Northern Outwash and Liverpool Plains provinces described by Morgan and Terrey (1992), (Map 1).

The bioregion covers a large longitudinal and latitudinal climatic range, and lies within an ecological gradient or ecotone between dry inland bioregions and wetter coastal bioregions. Consequently the area is environmentally heterogeneous, and potentially rich in biodiversity. NSW Biodiversity Strategy (in prep).

1.6.2 Bioregion buffer

The bioregions were developed at a national scale (1: 4 million) and consequently, the study area includes a 15 kilometre buffer surrounding the defined boundary to account for potential inaccuracies due to changes in scale (Map1). This buffer extends into the Darling Riverine plains, Southwest slopes, Sydney basin and Nandewar bioregions. Data collected from within the 15-kilometre buffer has been used in analysis and all outputs from this project extend to the boundary of the buffer.

Consideration of areas within the buffer ensured that the immediate landscape surrounding the bioregion was considered when data was analysed.

1.6.3 Bioregion provinces

Morgan and Terrey (1992) subdivided the bioregion into seven provinces (Map 1), each having a distinctive suite and pattern of landforms, soils and vegetation. The provinces were identified by their dominant geomorphological patterns as outlined in Table A.

Map 1 - Brigalow Belt South Bioregion (NSW) showing major towns, roads, provinces and woody vegetation

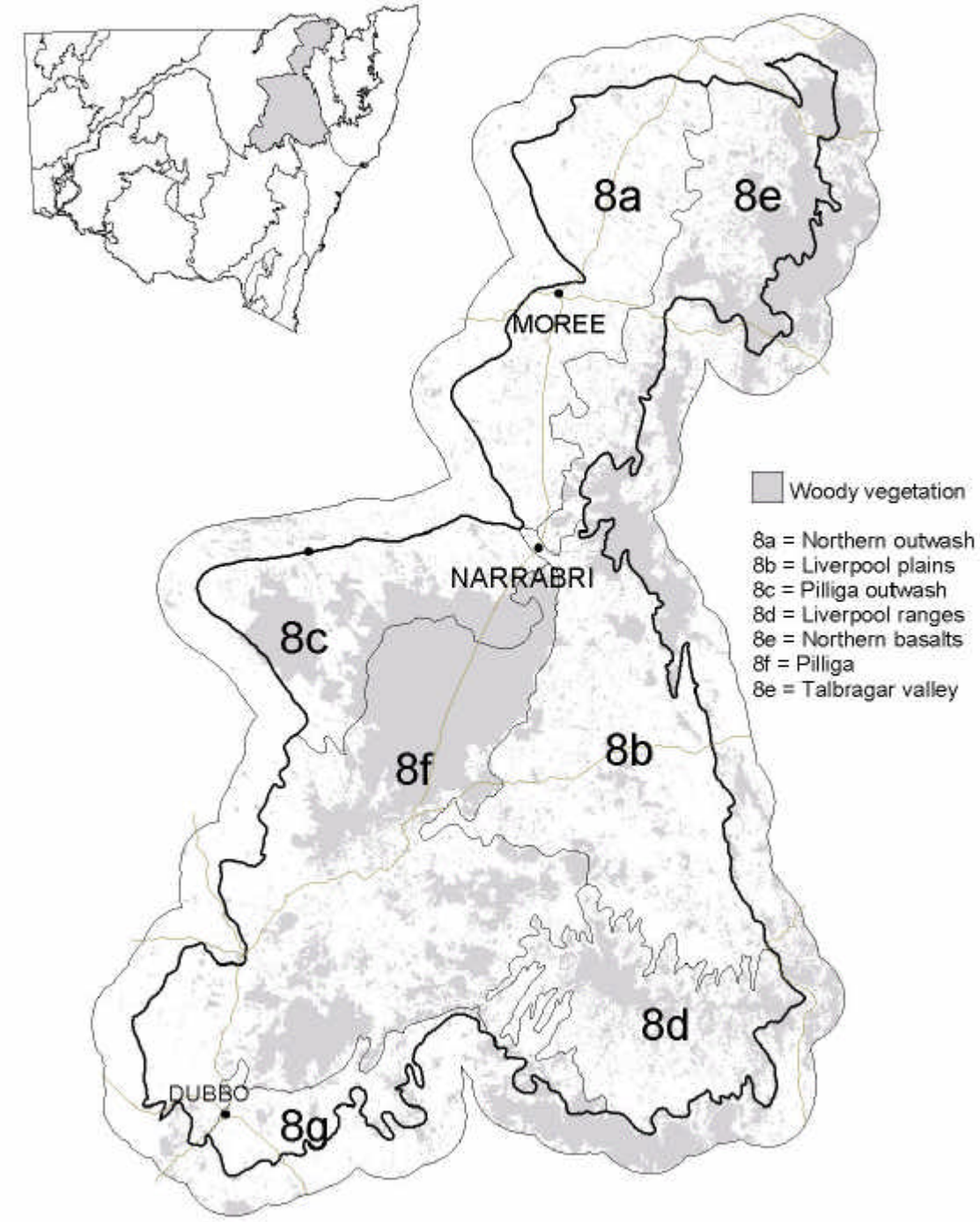


TABLE A – PROVINCES OF THE BRIGALOW BELT SOUTH BIOREGION (NEW SOUTH WALES)

(Morgan and Terrey,1992).

Geology/Lithology	Landform/Soils	Province
Alluvials and colluvials dominant	Gently sloping fans, grey clays	1. Northern Outwash
	Plains, black earths	2. Liverpool Plains
	Plains, deep sandy texture -contrast soils	3. Pilliga Outwash
Basalt dominant	High ranges	4. Liverpool Range
	Undulating, sandstone in valleys	5. Northern Basalt
Mesozoic sediments dominant	Coarse sediments, sandy soils	6. Pilliga
	Fine to medium sediments, red loams	7. Talbragar Valley

Provinces within the BBS and their associated vegetation are described and summarised below (RACD, 2000a; Morgan and Terrey, 1992).

Northern Outwash
This province contains low red rises and a series of alluvial fans between Narrabri and the Queensland border on the western side of the bioregion. Tributaries draining the sandstone and basalt areas to the east have formed the fans. The coarser red soils may be intake areas for the Great Artesian Basin. Grasslands and open woodlands dominate the native vegetation. These continue to be cleared extensively and developed for cropping.

Liverpool Plains
This province lies between Narrabri and Quirindi in the central eastern portion of the bioregion and is made up of extensive black soil plains and low sedimentary and volcanic hills. The grasslands and open woodlands on the alluvial plains and foot slopes of the hills have been mainly cleared and are used for cropping. The southern parts of this province and the eastern parts of the Pilliga Province make up the Oxley Geological Basin. Unusual areas within the Liverpool Plains province include an area of rugged Permian volcanics near Boggabri. This is a restricted geological formation with vegetation cover similar to that in the sedimentary areas.

Pilliga Outwash
This is a gently undulating plain of deep sandy soils formed by outwash from the sandstone hills to the east. Some of the more productive soils around the margins of this province have been cleared for agriculture but most of the elevated areas remain covered by remnant native forests, predominantly found on coarser soils.

Liverpool Range
This province is in the southeast of the bioregion and encompasses the basalt plateau and slopes of the Liverpool Ranges. The higher rainfall of the plateau supports tall eucalypt forests that have been partly cleared and harvested for timber. The slopes on the southern side, within the Hunter River catchment have been cleared extensively and developed for pasture, but on the northern slopes the forests are mostly still present. The Liverpool Range province is the primary catchment for the aquifers of the Oxley Geological Basin and is where the headwaters of the Namoi and Hunter Rivers are formed.

Northern Basalts
Lying between Narrabri and Yetman in the north east of the bioregion, this province has a gently undulating landscape resulting from erosion of the basalt layer to expose the underlying sandstone. The soils are rich and have been heavily cultivated. Almost no native vegetation remains except along waterways, and some small remnants on stony basalt hills and sandstone.

Pilliga
This is the largest of the seven provinces within this bioregion, stretching from Dubbo to Narrabri. It contains extensive sandstone hills with areas of higher basalt peaks and has predominantly sandy soils. Large areas of the forest have been cleared, large areas of native forest also remain, especially on lands with rockier and shallower soils.

Talbragar Valley
This is the smallest of the seven provinces and includes the Talbragar River valley and land to the southern border of the bioregion. The finer sediments of this province provide rich soils from which most native vegetation has been cleared for cultivation and grazing. Native vegetation remains only on the rocky sandstone hills formed by the inliers of the coarse Pilliga Sandstone.

1.6.4 Fauna of the study area

The current level of knowledge of the pre-European and present diversity of native mammals is summarised by Date and Paull (2000), and RACD (2000b). The vertebrate fauna of the study area is highly diverse with 533 species recorded in the region since 1972 (BBS fauna database). The fauna is characterised by a combination of species having both coastal and inland origins with a minor tropical element. The arboreal mammals are of a coastal origin, while the terrestrial species are generally of an inland origin. There is some endemism, for example Pilliga mouse *(Pseudomys pilligaensis).* The reptile and frog fauna is mostly of inland origins, though with strong coastal elements and some endemism, for example *Oedura monilis* (ocellated velvet gecko). The bird fauna is also comprised of roughly equal numbers of species that have coastal and inland origins (RACD, 2000b). Several microchiropteran bat species reach the western and eastern limits of their northern New South Wales distribution in the bioregion. Additional survey effort in this project from the poorly surveyed northern areas of the bioregion also revealed a small torresian influence, with findings of new species previously known from tropical savanna areas, most notably the delicate mouse (*Pseudomys delicatulus)* and *Oedura rhombifer* (zig zag gecko).

The bioregion also appears to hold core habitat for *Nyctophilus timoriensis* (Greater long-eared bat) within New South Wales (RACD, 2000b).

As part of the fauna analysis project the NPWS compiled a database of all vertebrate species previously recorded from the bioregion and included the results from the present survey (BBS fauna database) The sources for this (BBS fauna database) included databases from the NPWS Wildlife Atlas, CSIRO records, Australian Museum records, and information from other studies done in the bioregion. During compilation NPWS staff audited the records and excluded obvious errors, misidentifications and suspect sightings. Following the audit a total of 533 species were recorded on this (BBS fauna database) database. Table B shows an overview of the vertebrate fauna known from within the bioregion compiled on this BBS fauna database, including numbers listed as vulnerable or endangered under the *Threatened Species Conservation Act NSW (1995).* A full list of species recorded in the bioregion is provided in Appendix 4.

TABLE B – NUMBER OF SPECIES RECORDED WITHIN THE BRIGALOW BELT BIOREGION SINCE 1972.

Group	Number of species	Number of records	Number of threatened species
Birds	322	120261	33
Reptiles	106	13717	5
Bats	23	4213	9
Frogs	30	1721	1
Other mammals	34	4580	10
Introduced species	18	4139	0
Total	533	148631	58

The Warrumbungles population of brush-tailed rock-wallaby *(Petrogale penicillata*) which is located within the study area is listed as an endangered population under the *Threatened Species Conservation Act 1995.*

Knowledge of species present in the study area prior to European occupation is poor, and a significant number of mammal species are believed to have become extinct. The species believed to be extinct in the study area are shown in Table C. This list is probably incomplete as mammal remains in quaternary owl pellets, collected in the Stage 1 survey, have revealed a significant number of species not previously known to have occurred in the bioregion. Many more small mammal remains were collected from owl pellets in this survey, these have not yet been identified (Henk Godthelp pers.comm.).

TABLE C – SPECIES BELIEVED EXTINCT IN THE STUDY AREA

Common Name	Scientific Name	Source (Date)
Bilby	*Macrotis lagotis*	AM (1788), WLA (1932,1908,1899)
Western Quoll	*Dasyurus geoffroii*	WLA (1840)
Western-barred Bandicoot	*Perameles bougainville*	WLA (1841)
Brush-tailed Bettong	*Bettongia penicillata*	WLA (1863)
Burrowing Bettong	*Bettongia lesueur*	WLA (1985)
Eastern Hare-wallaby	*Lagorchestes leporides*	WLA (1863)
Bridled Nailtail Wallaby	*Onychogalea fraenata*	WLA (1840)
White-footed Rabbit-rat	*Conilurus albipes*	WLA (1840)
Greater Stick-nest Rat	*Leporillus conditor*	WLA (1995), BBS stage 2 (2002)
Gold's Mouse	*Pseudomys gouldii*	WLA (1840, 1850)
Plains Rat	*Pseudomys australis*	WLA (1932)
Red-tailed Phascogale	*Phascogale calura*	Henk Godthelp (pers.com.)
Hopping Mouse	*Notomys mitchelli?*	Henk Godthelp (pers. com.)
Eastern Chestnut Mouse	*Pseudomys gracilicaudatus*	Henk Godthelp (pers.com.)

1.7 PROJECT TEAM

1.7.1 Technical working group

The activities of the systematic and targeted fauna projects were overseen by a technical working group comprised of three ecologists nominated by the stakeholder agencies and an independent ecologist nominated by the group. Members of the technical working group and their affiliations are listed in Table D.

TABLE D – MEMBERS OF THE FAUNA PROJECTS TECHNICAL WORKING GROUP

Ecologist	Affiliation
Michael Pennay	Project manager, NSW National Parks and Wildlife Service
Darren Shelly	Department of Land and Water Conservation
David Goldney	Independent (Charles Sturt University)
Jim Shields	State Forests of NSW
Murray Ellis	NSW National Parks and Wildlife Service

Scope, objectives and responsibilities of the technical working group
The key objective of the technical working group was to assist the project manager by providing technical advice and focus for the project to ensure objectives and outcomes were met within the agreed time frame. The technical working group also helped ensure communication, coordination and integration of the project with other Resource and Conservation Assessment Council (RACAC), agency and government programs.
The technical working group met at various stages of the survey and analysis projects to discuss the development of the projects and to address technical issues such as methods and techniques used and to make recommendations on the future direction of the projects.

Key tasks of the technical working group included the approving the survey methodology, recommending analysis methodology and reviewing the data and reports produced from the projects.

All decisions were adopted on the basis of consensus, except where consensus could not be reached, in which case a majority vote was used.

1.7.2 Fauna survey team

The fauna survey team contained a number of field ecologists with expertise in the survey and identification of vertebrate fauna in western NSW. The surveys were conducted consecutively in teams of four and two, surveying eight and four sites respectively. Teams were organised to ensure that adequate expertise was available to identify all species groups at each survey, ecologists were rotated between the four and two person teams. The four-person team was a joint agency team comprised of two NPWS and two SFNSW employees, the two-person team consisted solely of NPWS staff. On some surveys volunteers attended all or parts of the survey to assist with general activities, they did not undertake any tasks requiring the identification of species. Survey team members, and their employers are listed in table E.

TABLE E – MEMBERS OF THE FAUNA SURVEY TEAM

Survey team member		Employer
Michael Pennay	(Team leader)	NSW National Parks and Wildlife Service
Carl Gosper	(Team leader)	NSW National Parks and Wildlife Service
Rebecca Drury	(Team leader)	NSW National Parks and Wildlife Service
Chris Turbill		NSW National Parks and Wildlife Service
Alex Dudley		NSW National Parks and Wildlife Service
David Read	(Spring surveys)	State Forests of NSW
Wayne Longmore	(Autumn surveys)	State Forests of NSW

In addition to an ecologist who attended all surveys in a season, SFNSW supplied employees who each assisted one survey. These employees were; Alan Douch, Mike Crowley, Pete Mostyn, Justin Williams, Pat Tap, David Taylor, Ken McCray, Mick Wilson and Bill Dowling.

1.7.3 Fauna analysis team

The fauna analysis team consisted of National Parks and Wildlife Service employees acting under the direction of the project manager and the technical working group. Fauna analysis team members and their roles are listed in Table F.

TABLE F – MEMBERS OF THE FAUNA ANALYSIS TEAM

Analysis team member	Role
Michael Pennay	Project management and PATN analysis
Carl Gosper	PATN analysis and co-author of report
Steve Thornton	Statistical modelling and GIS
Jade Freeman	Species profile development
Robyn Molsher	Species profile development
Marc Irvin	Species profile development

2. BACKGROUND

These projects are a part of the second stage (Stage 2) in the brigalow belt south bioregional assessment; and follow on from a preliminary first stage (Stage 1) assessment conducted in 1999 - 2000. Stage 1of the assessment focussed only on the forests of the Pilliga and Goonoo. The stage 1 projects were conducted as a rapid preliminary assessment, with a strong focus on collecting data to assess the feasibility of using the timber resources of these forests to supply charcoal for a proposed silicone smelter in Lithgow. Details of the preliminary survey project and previous fauna studies are included in this chapter.

2.1 PRELIMINARY SURVEY (STAGE 1)

The Stage 1 survey was the most comprehensive fauna survey done in the BBS prior to the Stage 2 project. The Stage 1 project systematically sampled 54 fauna sites on the SFNSW and NPWS estate within the bioregion south of Narrabri (predominantly in Goonoo and Pilliga groups of forests).

2.1.1 Results of the preliminary survey project

Findings from the preliminary survey are detailed in *Preliminary Fauna Survey – Brigalow Belt South Bioregional Assessment (Stage 1) report* (RACD, 2000b). A summary of these findings are presented below;

- Twenty-two threatened species were detected;
- Fourteen forest types were assessed for vertebrate species;
- Twelve species of frog, 39 species of reptiles, 155 species of birds, 17 species of non-flying native mammals, 16 species of bats (a total of 239 native species) and ten introduced species were detected;
- 6 500 new records were collected for the NPWS Atlas of NSW Wildlife database, an increase in records of about 50% on the existing database for the bioregion;
- Two major habitat components were identified as important for maintaining present levels of diversity: large, mature trees and shrubby understoreys.

2.2 OTHER SURVEYS AND RESEARCH

2.2.1 Systematic surveys

Other systematic fauna surveys which have been undertaken within the study area include:

- unpublished systematic owl surveys conducted by Kavanagh and Soderquist in a number of State Forests throughout the bioregion (NPWS Western Directorate, unpublished data);
- survey data from the Darling Riverine Plains biodiversity assessment (Gosper in prep.);
- survey data from the Nandewar bioregional assessment (NPWS , in prep.);
- Coolah Tops vertebrate fauna survey - seven threatened species were recorded, fauna communities were found to differ between the broad landscapes types of plateau forest, slopes woodland, riparian forest and swamp (NPWS, 1998);
- Cypress/Ironbark survey – microhabitat usage, distribution of species assemblages and habitat, and disturbance associations were analysed for each taxonomic group (Date and Paull, 2000);
- Coolah Tops nocturnal birds and arboreal mammal survey – two threatened birds were recorded. Associations between fauna and the major forest communities of Coolah Tops were analysed (Kavanagh, 1995);
- work undertaken by National Parks Association in Pilliga East (RACD in prep.);
- work undertaken by NPWS Coonabarabran area in Pilliga Nature Reserve (NPWS Northern Plains Region unpublished data); and
- work undertaken by Orange Field Naturalists in Cobbora State Forests (RACD 2002).

2.2.2 Other research

The current level of knowledge of the pre-European and present diversity of native mammals is summarised by RACD (2000b) and Paull and Date (1999).

The following published scientific papers also related to the diversity of fauna in different parts of the bioregion:

- Shelly (1998) on The fauna in Goonoo State Forest;
- NPWS assessment of Coolah Tops (1995);
- Bustard's (1967-71) papers on the reptile fauna of the Pilliga forests;
- Fox and Briscoe (1980) and Lim's (1992) studies on the Pilliga Mouse (*Pseudomys pilligaensis)*
- Rabbidge (1987) – a study on the Black-striped Wallabies in the Narrabri district;
- Paull's (1998) study of small mammals in Pilliga East State Forest;
- Parnaby and Hoye's (1997) study of bats in the Pilliga Nature Reserve;
- Cleland (1919) and Chisholm's (1936) work on Pilliga birds;
- Heron's (1973) work on the birds of Goonoo;
- Korn's (1988) work on the Malleefowl of Goonoo;

- NPWS (1997) also conducted a fauna survey in the Goobang and Nangar National Parks. Though outside the Brigalow Belt bioregion, these parks contain similar *Callitris*-ironbark country to this bioregion.

Other sources of unpublished fauna data collected from the bioregion include;

- local fauna and flora lists from Dubbo, Wellington and Orange Field Naturalists, Friends of the Pilliga and the Mudgee Environment Group;
- survey data from Careunga and Brigalow Park Nature Reserves by NPWS, Narrabri;
- University of New England studies of the Pilliga Mouse;
- State Forests of NSW Barradine office sightings list of significant species;
- Databases including; NPWS Atlas of NSW Wildlife, records from the Australian Museum (AM), CSIRO, the Australian Bird and Bat Banding Scheme (ABBBS), and Birds Australia (BA).

3. FAUNA SURVEY

3.1 SURVEY METHODOLOGY

3.1.1 Aims and rationale

The primary objective of the survey was to collect information about the distribution, abundance and habitat use of all vertebrate fauna species from woodland and forested areas within the BBS bioregion. The survey was also required to build onto and supplement data collected during the preliminary BBS (Stage 1) survey.

There are more than 534 vertebrate species recorded in the study area (BBS fauna database) which contains approximately 2 300 000 hectares of woodland and forested vegetation (DLWC woody). Funding was provided to sample 100 sites over two, three-month periods.

Methodology used in this fauna survey followed that adopted for the preliminary (Stage1) survey, although some changes were made to specific techniques (RACD 2000b). The main rationale for following the preliminary survey methodology was to maximise efficiency. For example, using comparable methodologies between Stage 1 and 2 surveys would result in a doubling of the number of comparable sites available for use in any analysis.

A systematic site based sampling method was chosen as it provided the opportunity to sample key areas throughout the bioregion and the potential to extrapolate findings to similar areas not surveyed. The project goals required that the survey techniques be broad and cover all major groups of vertebrate fauna likely to be found in wooded vegetation. The techniques also needed to allow relative efficiency in order to maximise the amount of data collected within the available timeframe. The Stage 1 survey report demonstrated the effectiveness of the techniques for sampling large numbers of vertebrate species in the study area, and contained comments for potential improvements (RACD 2000b). The technical working group was aware that the techniques selected had limitations (see below) in detecting a number vertebrate species, and that some species required specific techniques in order to be more frequently detected. Undertaking specific, targeted, techniques for individual species was considered beyond the scope and resources of the broad bioregional survey project. Some of these species were dealt with in the targeted fauna projects.

3.1.2 Systematic techniques

Each of the following techniques was used wholly within each 100 metre by 200 metre (two hectare) site (Table G).

TABLE G – SYSTEMATIC TECHNIQUES

Target vertebrate group	Technique	Effort
Diurnal birds	Active bird search at dawn, recording all birds seen and heard on site.	1 person 40 minutes (two 20 minute searches on different mornings)
Diurnal reptiles , other animals	Habitat search for active and inactive reptiles. Conducted during the morning, included peeling bark, lifting logs/rocks and searching litter. Any tracks scats or signs of other animals recorded.	1 person 60 minutes (or 2 person 30 minutes)
Microbats	1 harp trap set within the site	3 nights
Microbats	Anabat, ultrasonic call recording from within the site, between dusk and 2 hours after dusk.	30 minute tape recording
Nocturnal reptiles, mammals and birds.	Spotlight search, using 12V, 50W handheld spotlight and binoculars to search for eyeshine from small animals.	1 person 60 minutes on foot
Small mammals	Standard sized 'Elliott' traps baited with peanut butter, rolled oats and mixed fruit. 50 traps were placed along the perimeters of the site 10 metres apart (ie. 10 traps along 100m axis and 20 along each 200m side)	6 nights (300 trapnights)
Nocturnal mammals and birds	Call playback, pre-recorded calls of the following species were broadcast in sequence at natural levels through a speaker at the site. Bush stone curlew, squirrel glider, koala, powerful owl, barking owl and masked owl.	10 minutes listening, 1 minute of call broadcasting and 1 minute listening period was repeated four times for each species listed followed by 10 minutes listening at end of the last species and a 1 minute spotlight scan prior to leaving the site.
Nocturnal mammals and birds	Walking spotlight transect using 12V, 50W handheld spotlight along road adjacent/ near the site.	1000m at slow walking pace (no time set - but approximately 1hr)
Opportunistic records	All animals seen opportunistically whilst conducting the survey.	N/A. Team members were encouraged to record all animals seen in the area.
Site attributes	Structural attributes of the site were recorded, such as number of hollows, ground cover, presence of soil cracks etc. Appendix 5 illustrates all site data collected.	A count of all features within a 10 metre radius at 5 points through the centre of the site.
Floristic data	Full floristic survey of the site.	A botanist visited the site following the survey and recorded all plant species and structural information from a 20 X 20 metre area within the 2 hectare site.

3.1.3 Opportunistic techniques

Opportunistic techniques were used to search specific areas for threatened species. These techniques did not follow any systematic methodology and included car based road transects searches for frogs, cave searches for microbats, ultrasonic recordings of bat roost flyouts, triplining, walking road transects while searching for tracks, scats, signs and birds, and dam searches for frogs. All species detected using these methods were recorded as incidental records.

3.2 SITES

Two types of sites were surveyed; systematic sites and targeted sites.

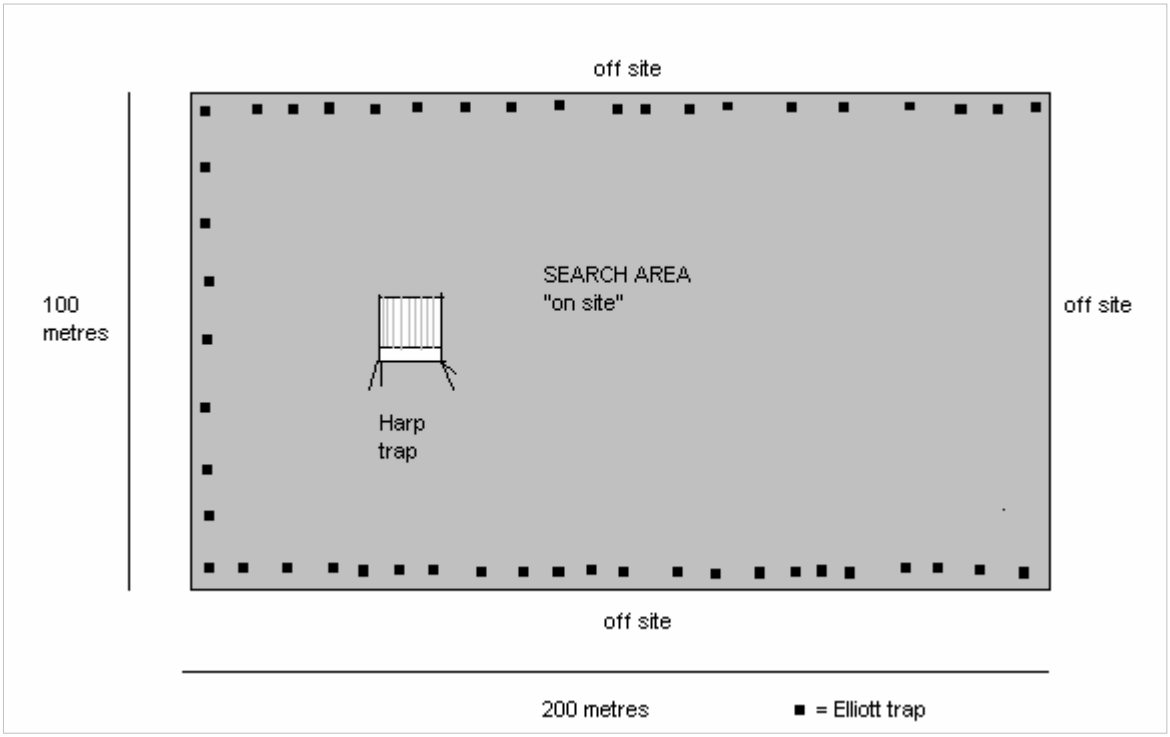
- Systematic sites were the main source of data collection, the same standardised search effort was applied at each systematic site.
- Targeted sites were additional sites where a single standard technique was used to detect specific fauna. Targeted sites were usually selected opportunistically to increase the coverage of habitats surveyed and to include areas that were poorly represented.

3.2.1 Systematic sites

All systematic sites were two hectares (100 metres by 200 metres), set within a single vegetation type where possible. All systematic techniques were conducted within this area and any records from outside the two hectare site were recorded as "off site".

The site was marked with flagging tape and Elliott traps were placed ten metres apart within the perimeter of the site on three sides (figure 1.1). Note, the figure does not accurately show 10 and 20 traps on the boundaries as referred to in table G.

Figure 1.1 Schematic layout of a standard site.



3.2.2 Systematic Site Selection

A target of 100 sites was set at the start of the project. Site selection decisions were made to help meet two objectives:

- to fill known gaps in systematic vertebrate fauna data as identified during the preliminary survey (RACD 2000b); and
- to sample all of the main woody vegetation communities of the study area.

A stratified sampling strategy was used, based on vegetation.. A list of all dominant canopy species mapped within the study area was compiled and used to identify broad woody vegetation communities based on their potential differences as fauna habitat. For example, species known to occur on dry ridges were separated from riparian species. Similar groupings to those found in the preliminary survey were used (RACD 2000b), however additional species and groups were needed to account for the broader coverage area of this survey.

For some groups the broad habitat category was also broken down into a more detailed classification based on different dominant species. A total of 15 broad habitat categories and 24 dominant species categories were used for site selection (Table H).

TABLE H – BROAD VEGETATION CATEGORIES USED FOR SURVEY SITE SELECTION

Broad habitat category	Dominant species category	Code
Mallee	Green mallee	Mallee
Floodplain	Black box +/- river cooba/ coolabah	Floodplain
Redgum-flats	Blakleys, river, or Baradine redgums +/- rough barked apple, yellowbox, river oak	Redgum-flats
Redgum-elevated	Tumbledown or Dwyer's redgum +/- black cypress	Redgum-rises
Ironbark-elevated	Mugga ironbark	Mugga
	Red,blue-leaved, Bayers ironbark +/- brown bloodwood/ black cypress	Broad leafed ironbark
	Narrow-leaved ironbark	Narrow leafed ironbark
Scribbly Gum	Scribbly Gum	Scribbly gum
Stringybark	Red stringybark	Stringybark
Corymbia-angophora	Carbeen +/- white cypress	Carbeen
	Smooth barked apple +/- white cypress	Smooth barked apple
Silver-leaved-Ironbark	Silver leaved ironbark +/- E. doliocarpa	Silver leafed ironbark
Box-open-forest	White box +/- white cypress	White box
	Poplar box +/- white cypress, wilga, silver leafed ironbark etc	Poplar box
	Greybox/pilliga/ fuzzy box +/- yellowbox	Grey box
Cool-wet-sclerophyll	Manna/mountain gum, snow gum	Coolah
Casuarina	Bulloak +/- narrow leafed/silver leafed Ironbark	Bulloak
	Belah +/- poplar box, black box, coolabah	Belah
Acacia	Brigalow +/- poplar box, belah, silver leafed ironbark	Brigalow
	Myall	Myall

Broad habitat category	Dominant species category	Code
Dry-rainforest	Ooline, +/- greybox, white cypress	Ooline
	Dry vine thicket +/- whitebox, silver leafed ironbark, alphitonia	Vine thicket
Cypress	white/black cypress	Cypress
Other	cleared, water, settlement, unmapped, grassland, broom, heathland, barren, rock etc.	Other

Existing survey sites within the study area were used to identify data gaps both geographically and within particular vegetation types.

The number of survey sites required for each province was based on area. Each province was attributed a 'target' number of sites based on its proportionate size within the bioregion. The number of sites already surveyed in that bioregion (Stage 1) was deducted from the 'target' number to give an indication of the number of sites still to be surveyed in each province to ensure reasonable coverage. *Example: Pilliga province consists of 32% of the total area of the bioregion. The anticipated final amount of all sites from both surveys was 228. (32% of 228 = 73, 73 minus the 48 existing sites =25).*

This calculation was used as a guide only to give an indication of the numbers required based on total area. It did not take into consideration vegetation coverage or diversity Provinces differed radically in the extent of coverage and size of woody vegetation patches. Sites were selected from within the woody vegetation, with a minimum patch size of greater than 10ha. Priority was given to vegetation groups which were unsurveyed within the bioregion and then within the province. Logistical parameters such as access and proximity to other sites and to accommodation were also considered. Sites found on private property were given priority over other tenures in an effort to bring the number surveyed on private land as close as possible to the actual proportion of woody vegetation in private property in the bioregion (ca. 35%).

3.2.3 Distribution of Systematic Sites

A total of 108 systematic sites were surveyed. Details of each site are provided in Appendix 6 and Map 2.

All of the identified vegetation types were surveyed five times on average, except for the Floodplain group. This vegetation type was only found in isolated remnants in the far northwest of the bioregion, in patches less than ten hectares, and hence was too small to survey. Survey data from sites in this vegetation type were available from within the 15km buffer in the Darling Riverine Plains bioregion, and a number of targeted sites for bird surveys were also conducted in this vegetation type.

Full systematic survey sites were located in four of the seven provinces of the BBS. The Pilliga Outwash and Liverpool Ranges were not surveyed because both had been intensively surveyed during Stage 1 (RACD 2000b) and the lower northeast CRA survey (RACD 1998). Hence data from these sites was already available for analysis. In addition the Northern Outwash province was not systematically surveyed because the vegetation is so fragmented and isolated that it was not possible to locate any areas of woody vegetation greater than ten hectares where it was logistically possible to conduct a survey. Eleven sites from the Darling Riverine Plains bioregion had been surveyed during other assessments in very similar vegetation within the 15 kilometre buffer surrounding this province and the province was prioritised for targeted survey sites.
A breakdown of the number of systematic sites in each vegetation type and province is detailed in table I.

Systematic sites were surveyed over four tenures, national park/nature reserve, state forest, travelling stock reserve and private property. A breakdown of the number of systematic sites in each tenure and broad vegetation type is detailed in table J.

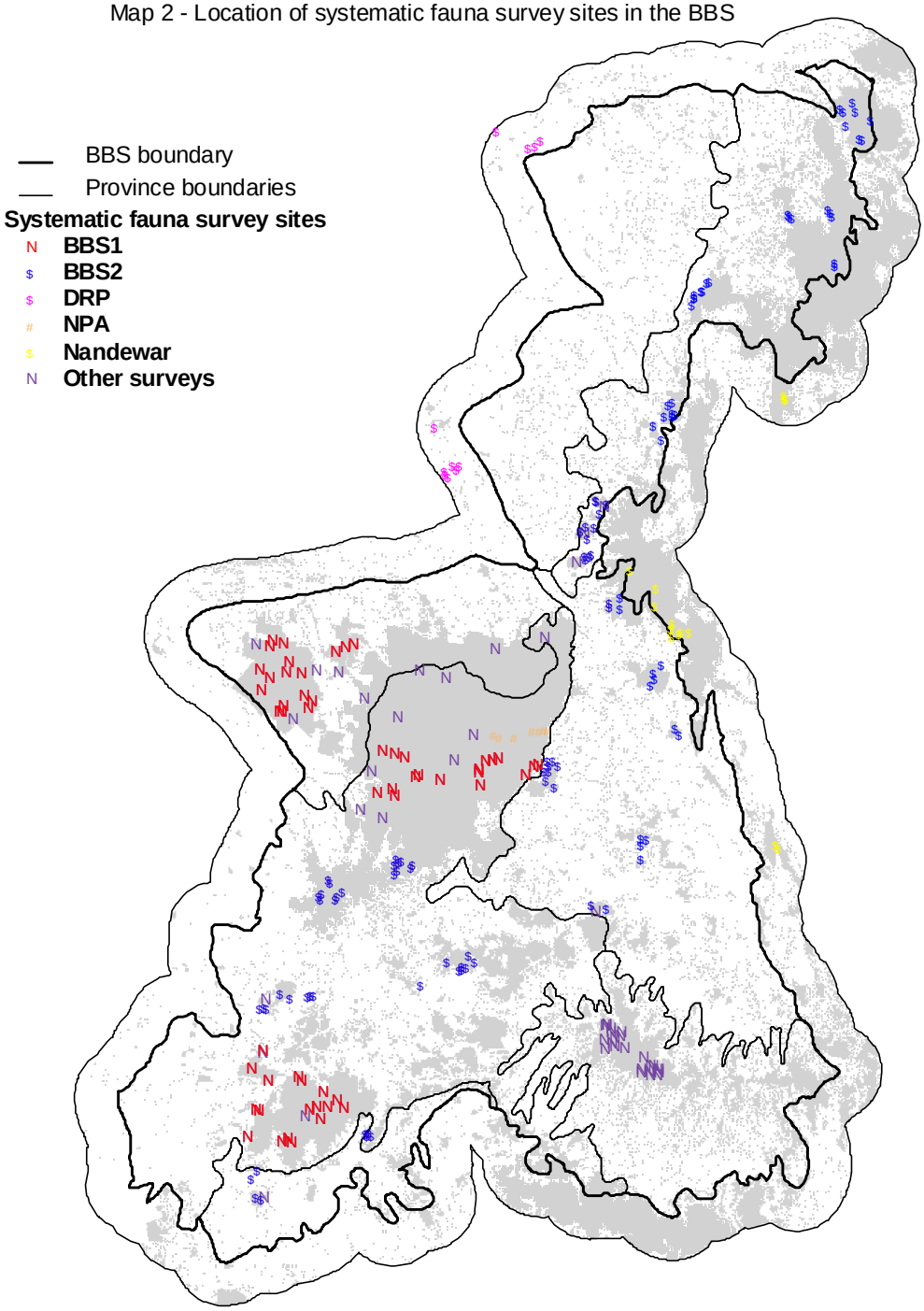
TABLE I – BREAKDOWN OF SYSTEMATIC SITES BY PROVINCE AND VEGETATION TYPE

Vegetation type	Liverpool Plains	Northern Basalts	Pilliga	Talbragar Valley	Grand Total
Belah		2			2
Redgum-flats	3	5	5	1	14
Brigalow	1	1			2
Broad leafed ironbark		3	4		7
Bulloak	1	2			3
Carbeen		1			1
Vine-thicket	1	4			5
Redgum rises			2		2
Grasstree, banksia scrub			1		1
Green mallee	1	1			2
Mallee		1	1		2
Mugga		1		2	3
Myall		1			1
Narrow-leafed ironbark	4		4		8
Ooline		1			1
Grey box	5	1	1		7
Poplar box	2	3			5
Stringybark			6		6
Scribbly gum			6		6
Silver-leafed ironbark	3	4			7
Smooth-barked apple		5			5
White box	6	3	6	1	16
Cypress	1	1			2
Grand Total	**28**	**40**	**36**	**4**	**108**

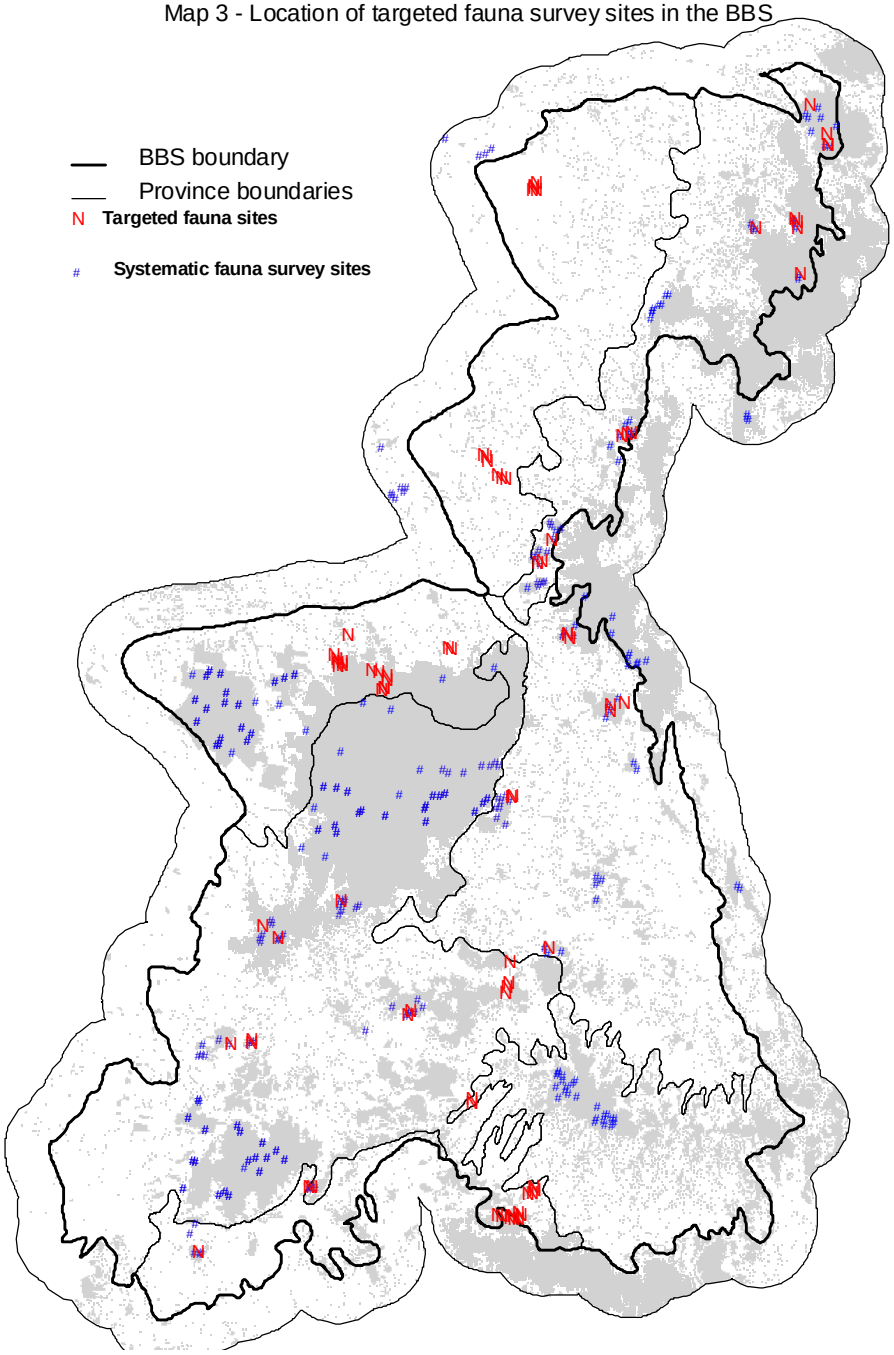
TABLE J – BREAK DOWN OF SYSTEMATIC SITES BY TENURE AND BROAD VEGETATION TYPE

Vegetation type	National park	Private property	State forest	TSR	Grand Total
Belah	1		1		2
Redgum flats	3	4	7		14
Brigalow			2		2
Broad leafed ironbark		2	5		7
Bulloak			3		3
Carbeen			1		1
Vine-thicket	2		2	1	5
Redgum rises		2			2
Grasstree, Banksia scrub		1			1
Green mallee			2		2
Mallee			2		2
Mugga		1	2		3
Myall				1	1
Narrow-leafed ironbark	1	3	4		8
Ooline			1		1
Grey box			7		7
Poplar box			4	1	5
Stringybark	2	4			6
Scribbly gum	4	1	1		6
Silver-leafed ironbark	1		6		7
Smooth-barked apple	2	1	2		5
White box	3	3	10		16
Cypress			2		2
Grand Total	**19**	**22**	**64**	**3**	**108**

Map 2 - Location of systematic fauna survey sites in the BBS



Map 3 - Location of targeted fauna survey sites in the BBS



3.2.4 Targeted Sites

A total of 80 additional sites were surveyed for specific groups of animals using a standard technique. Targeted sites were selected in two ways;

- thirty six targeted sites were selected to increase the coverage of habitats surveyed within the survey area; and
- forty four targeted sites were selected opportunistically by survey team members in other areas of the bioregion with poor survey coverage. These areas were identified by the technical working group.

Details of targeted sites are provided in Table K and Map 3.

TABLE K – NUMBER OF TARGETED SITES BY TECHNIQUE.

Technique	No. targeted sites
Bird census	42
Harp trap	37
Site spotlight	3
Habitat search	1
Elliott trap	1
TOTAL	**84**

3.2.5 Limitations and recommendations

Vegetation classification and mapping
A major limitation in the site selection process was the lack of a bioregion wide vegetation map at the time of planning. The grouping of vegetation types was based on previous work undertaken in the preliminary survey (RACD 2000b) and on survey staff and technical working group knowledge of the bioregion. Future vegetation mapping and analysis, such as that being undertaken by the joint vegetation mapping project (WRA 24) and the targeted flora projects (WRA 24) are likely to provide much more sophisticated and accurate groupings. However, at the time of planning this information was not available, hence the groupings were deliberately broad and used as a guide only. The development of bioregion wide vegetation community classification and mapping may show that some communities were missed during this survey, and any future surveys would benefit from assessing the coverage and sampling intensity of more precisely defined vegetation communities.

Sites on private property
An effort was made during this survey to redress previous survey bias towards public land by prioritising survey sites on private property. Within the bioregion private property accounts for approximately 35% of all woody vegetation patches of greater than10 hectares (DLWC woody). Using this as a guide, a general goal of 35% of sites surveyed was set. While not reached, the 22 private property surveys represent three times as many private land surveys as were undertaken on private property in coastal CRA fauna surveys (RACD 1998).

Significantly, private land surveys provided an excellent opportunity to survey sites in vegetation types occurring less commonly on public land. The majority of sites surveyed were relatively small remnants surrounded by cleared agricultural land. Although numbers of species detected were generally poorer from these remnant sites (ref section 3.2), it was beneficial to sample these as they represent a significant proportion of woody vegetation within the study area.

Resources
Organising sites for survey on private property revealed a number of issues, which if addressed may benefit future surveys. Time was the main factor limiting the number of properties that were eventually surveyed. The survey coordinator needed to spend time contacting various community groups, advertising for interested property owners, communicating with interested landholders, providing information and details of survey activities, and organising visits. Prior to survey, a minimum of one day was required to visit a potential property and assess it for suitability. Approximately 40% of all properties inspected were not useful due to lack of suitable vegetation (mostly the remnants were too small) or for other reasons (outside of the bioregion, fire damage).

As a courtesy to landholders, a report was prepared for each property following survey. It is estimated that while sites on private property amounted to 20% of the total sites surveyed, they amounted to well in excess of 50% of the total time spent organising all survey activities. Any future project requiring large numbers of study sites on private property must have sufficient resources to dedicate a full time position to this task. The success of the biodiversity surveys in the Darling Riverine Plains bioregion, where the majority of sites were on private property, was due to the dedication of a full time community liaison officer by the State Biodiversity Strategy, Gosper (in prep).

Logistical
Properties within the Brigalow Belt were too small to accommodate large numbers of sites. To improve statistical independence, each site was required to be a minimum of one kilometre from any other site, and the maximum number of sites on any single property was six (average = three). To maintain efficiency, sites were surveyed in groups of four (with a team of two) or eight (with a team of four). This meant that in planning the surveys, sites on private properties needed to be within travelling distance of other private or public land suitable for survey. This was not always the case. Future project teams planning to survey on private property may have to make adjustments to the survey design.

Geographic Gaps

Northern Outwash
The Northern Outwash Province is by far the least surveyed area of the bioregion. It is also the most heavily cleared province and it contains only 1.2% of the bioregion's woody vegetation. (DLWC woody). As mentioned in section 3.3.2 suitable survey sites could not be located within this province using the rules set for site selection devised by this project. In an effort to address this, the province was prioritised for targeted bird sites during the survey. This province should be the target of any future fauna survey work, however careful attention should be paid to survey design and the setting of minimum patch sizes for sites.

Liverpool Ranges
The Liverpool Ranges province was accorded a low priority when selecting sites due to the relatively high number of systematic surveys that had been conducted there by Kavanagh (1995) and National Parks and Wildlife Service (1998). However, during this project, it became apparent that there are geographic gaps in the data from this province.
Firstly, all of the previous surveys were focussed on the plateau forests of Coolah Tops and Warung State Forest, and there is very little data from outside this area. Some effort was therefore made to redress this by prioritising areas in the province outside of the plateau forest for targeted surveys. Any future surveys should note that the mid to lower elevation areas of this province are poorly surveyed.

Secondly, the data from the earlier surveys is not as comprehensive as that for other areas. While nocturnal and diurnal birds, arboreal mammals and bats have been sampled in similar

ways to other sites throughout the bioregion, trapping was not routinely undertaken. As a result, site based data from the Liverpool Ranges is not fully comparable with other survey results in the bioregion. For this project the data from the Liverpool Ranges could not be used for the site based PATN analysis (see section 4.2.4), although some data were used on a technique by technique basis for other analysis (see section 4.3). To maximise the usefulness of any future survey work in the province, survey teams should endeavour to ensure that sites are sampled for all species groups. This should preferably be carried out in a manner simular to other surveys undertaken in the bioregion.

Fertile flats
Much of the relatively fertile flatter areas in the bioregion have been cleared of woody vegetation as a result of past agricultural practices (NSW Biodiversity Strategy, in prep.). Fertile flats were surveyed during this project, however vegetation groups which occur there (ie. Box woodlands, Brigalow, Carbeen, Myall) proved difficult to locate. They were often the smaller fragments and were more highly disturbed than the more widespread vegetation types in less fertile areas.. Sampling was therefore biased because of low availability. Little can be done to improve this bias, except that analysis should take into account that there may be insufficient acknowledgment of the relative value of these areas.

3.3 RESULTS OF THE FAUNA SURVEY

3.3.1 Introduction
This section provides the results of the 108 systematic and 80 targeted sites surveyed in this project between February 2001 and January 2002.

3.3.2 Species Detected

A total of 326 vertebrate species were recorded during the fauna survey amounting to more than 11 850 records and 19 928 individual animals detected. These records included five endangered species and 22 vulnerable species. A complete table listing all species detected during the survey is provided in Appendix 7.

Birds accounted for the majority of species observed (62%) followed by reptiles (18%) and mammals (16%). Frogs had the lowest diversity of any group making up only (4%) of species detected. Thirty species of frogs are known from the study area (section 1.6.4), however there were no specific techniques used to detect frogs, and dry weather during much of the survey period was not conducive to detecting frogs.

The faunal composition of the bioregion seems to be divided between species which were found at most locations and those, which were very infrequently encountered. Analysis of the frequency of sightings for each species recorded during the survey shows that approximately half of all the species found were either very infrequently encountered or were observed almost everywhere. The largest proportion were found only on a few occasions, 35% (n=111) of all species detected were recorded less than five times. Conversely 12% (n=39) of the species were recorded more than 100 times (Figure 1.2). Section 4.1.4 (table S) reports on both the frequently and infrequently found species of the bioregion.

Figure 1.2 Frequency of sightings for each species found during the survey

This survey detected 77 more species than were detected during the preliminary survey (Table AH). This was likely a reflection of the much wider geographic range surveyed (Map 2). Despite significantly less sampling than other CRA surveys, and being limited to a single bioregion, (the lower north-east boundary crossed five bioregions) the results from this survey emphasise the exceptionally high faunal diversity of the bioregion. More bird fauna species were detected during this survey than in any of the other assessments. The diversity of the bioregion is further emphasised when records from Coolah Tops surveys are considered.

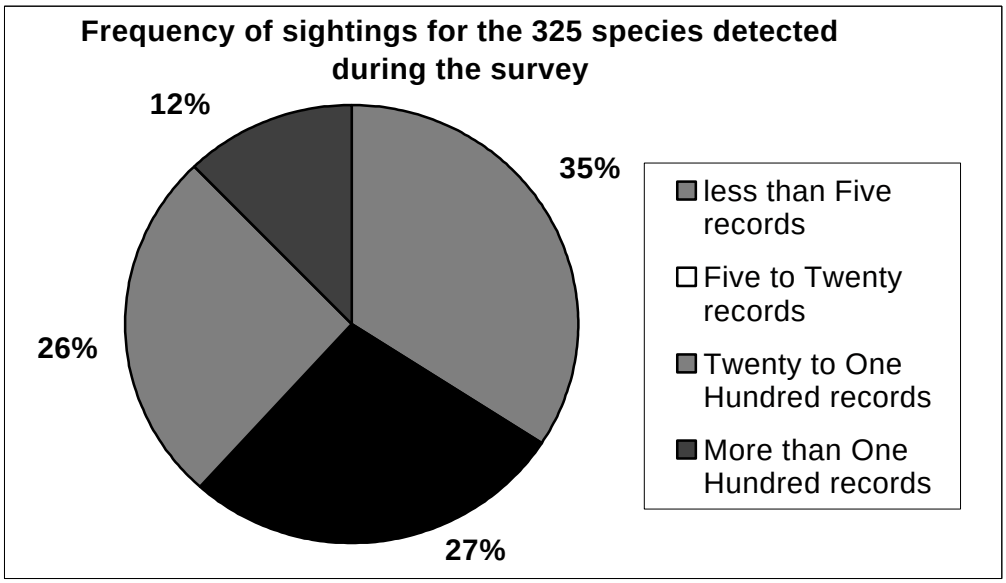


TABLE AH – A COMPARISON OF THE RESULTS OF SPECIES DETECTED IN THIS SURVEY WITH THOSE FOUND IN OTHER REGIONAL ASSESSMENTS (RACD 1998, RACD 2000B).

(Key: TSC: species listed in *NSW Threatened Species Conservation Act NSW 1995)*

Taxa	**Brigalow Belt Stage 2 Survey**		**Brigalow Belt Stage 1 Survey**		**Upper North-east CRA Survey**		**Lower North-east CRA Survey**		**Sydney Basin CRA Survey**	
	Sites	108	Sites	54	Sites	172	Sites	279	Sites	188
	All taxa	TSC	All taxa	TSC	All taxa	TSC	All taxa	TSC	All taxa	TSC
Frogs	13	0	12	0	40	7	40	8	25	4
Reptiles	61	3	39	1	87	4	87	4	47	2
Birds	201	15	155	11	162	12	200	14	164	8
Mammals	29	5	17	5	14	12	40	10	28	5
Bats	20	6	16	5	27	11	33	11	24	8
Totals	**326**	**29**	**249**	**22**	**330**	**46**	**400**	**47**	**288**	**27**

3.3.3 Threatened Species

A total of 27 species listed under the *Threatened Species Conservation Act (NSW) 1995*, including five endangered species, were recorded during surveys (Tables L and M). Three species were detected which are not listed at present but will be nominated following their discovery in New South Wales (Table M). Details of other significant species discovered during this survey, which have not been listed as threatened species, are listed in table N.

TABLE L – NUMBER OF RECORDS FOR ENDANGERED SPECIES FOUND DURING THIS SURVEY

Common Name	*Scientific Name*	No. records
Black-striped Wallaby	*Macropus dorsalis*	3
Malleefowl	*Leipoa ocellata*	2
Squatter Pigeon	*Geophaps scripta*	1
	Anomalopus mackayi	1
Black-necked Stork	*Ephippiorhynchus asiaticus*	1

TABLE M – NUMBER OF RECORDS FOR VULNERABLE SPECIES FOUND DURING THIS SURVEY

Common Name	*Scientific Name*	No. records
Speckled Warbler	*Chthonicola sagittata*	100
Brown Treecreeper*	*Climacteris picumnus*	71
Koala	*Phascolarctos cinereus*	62
Turquoise Parrot	*Neophema pulchella*	42
Grey-crowned Babbler	*Pomatostomus temporalis*	41
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	38
Greater Long-eared Bat	*Nyctophilus timoriensis*	25
Squirrel Glider	*Petaurus norfolcensis*	23
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	22
Little Pied Bat	*Chalinolobus picatus*	22
Painted Honeyeater	*Grantiella picta*	22
Barking Owl	*Ninox connivens*	17
Masked Owl	*Tyto novaehollandiae*	17
Eastern Cave Bat	*Vespadelus troughtoni*	17
Diamond Firetail	*Stagonopleura guttata*	16
Large Pied Bat	*Chalinolobus dwyeri*	10
Hooded Robin	*Melanodryas cucullata*	7
Square-tailed Kite	*Lophoictinia isura*	7
Black-chinned Honeyeater	*Melithreptus gularis*	3
Eastern Pigmy-possum	*Cercartetus nanus*	1
Pale-headed Snake	*Hoplocephalus bitorquatus*	1
Border thick-tailed Gecko	*Underwoodisaurus sphyrurus*	1

* One subspecies of the Brown Treecreeper, (*Climacteris picumnus victoriae*), has been listed as threatened in NSW. This subspecies and *C. p. picumnus* occur in the BBS (Schodde and Mason, 1999), however, they were not identified to subspecies level in the field.

TABLE N – OTHER SIGNIFICANT SPECIES DISCOVERED IN NEW SOUTH WALES DURING THIS SURVEY WHICH HAVE NOT BEEN LISTED AS THREATENED SPECIES.

Common Name	*Scientific Name*	No. records
Delicate mouse	*Pseudomys delicatulus*	3
Zig-zag gecko	*Oedura rhombifer*	2
Hairy nosed mastiff bat*	*"Mormopterus" sp. 6*	1

* This taxon has been recorded once previously in NSW (Ellis 2001), however it has yet to be nominated for listing on the TSC Act.

3.3.4 Significant Findings

A number of major findings were made during the survey. These include the discovery of two new species for the State, extensions of range for some species and a large increase in records and notable absences.

The key findings are outlined below.

Bats

- Capture of and major extension to known range of *Mormopterus species 6*
- Extension to the known range and maternal roosting information for *Chalinolobus dwyeri*
- Extension to the known range and additional information for *Vespadelus troughtoni*
- Addition to the known range of cave dwelling bat *Rhinolophus megaphyllus*
- Significant increase of the records for *Saccolaimus flaviventris* in the study area, more than doubling all previous records.
- Significant captures of *Nyctophilus timoriensis.*

Birds

- Second record of squatter pigeon in NSW in the last decade.
- Record of black-necked stork
- Significant number of masked owl sightings
- Significant number of painted honeyeater records
- Very low number of sightings for black chinned honeyeater
- Very low number of sightings for hooded robin

Other mammals

- Discovery of a new species for the State and major extension to the known range of *Pseudomys delicatulus*
- Large number of squirrel glider records.
- Large number of brush-tailed possum records.
- Confirmation of common wombats in the Warrumbungle/Coonabarabran area, representing the Northwestern limit of this species range.

Reptiles

- Discovery of a new species for the State and major extension to the known range for *Oedura rhombifer*
- Extension to the known range to the west of the Great Dividing Range in NSW for *Diporiphora australis*
- Record for *Anomalopus mackayi*
- Record for *Underwoodisaurus sphyrurus*
- Record for *Hoplocephalus bitorquatus* (pale-headed snake)

3.3.5 Review of techniques

This section discusses the efficacy of some of the techniques and methods used and/or trialed during the survey.

Bird census

The bird census technique was the most successful of all techniques used. It accounted for approximately 60% of all fauna records collected through the systematic techniques, and 37% of all records collected during the survey. The technique also detected the greatest number of species (140 species) and accounted for 43% of all species detected during the survey.

While devising survey methods, the fauna technical working group recommended undertaking two, 20 minute censuses on separate days, rather than a single 20 minute census on one day. It was considered that this would improve significantly the detection of bird species using the site. Independent analysis of the technique carried out in a project in the adjoining Darling Riverine Plains bioregion Gosper (in prep), supports this view i.e. 55% of the bird species were only detected from one of the two surveys.

A simular pattern was observed when this study's results were examined. Analysis of bird census in this project revealed that the number of bird species detected at a site was approximately doubled on average with the inclusion of two 20 minute censuses An average of 49% of species recorded at each site were only detected from one of the two censuses.
It is not known from this study how many censuses would be required to stop finding new species at each site. This requires further investigation.

Small mammal trapping

The number of Elliott trap nights conducted during the survey was 32 700, or 300 trapnights per site. Generally capture rates for small mammals were low (0.92 animals were caught per 100 trapnights), with capture rates for native mammals (0.59 per 100 trapnights) much higher than those recorded in the Darling Riverine Plains bioregion to the west (0.03 per 100 trapnights Gosper, in prep.). Capture rates of mammals in Elliott traps are shown in table O.

TABLE O – CAPTURE RATES OF MAMMALS IN ELLIOTT TRAPS

Species	Number caught	Percentage of total mammal captures	Rate per 100 trap nights
Yellow footed antechinus	169	57%	0.52
House mouse	76	25%	0.23
Common dunnart	21	7%	0.06
Black rat	9	3%	0.02
Pseudomys delicatulus	3	1%	0.009

The yellow footed antechinus was the most frequently captured small mammal followed by the house mouse. While Elliott trapping was specifically targeted at small mammals, 14 other species were also captured in the traps (Table P). The majority could be regarded as infrequent

and unusual captures, although one species, *Egernia striolata* was the third most commonly trapped animal. It was captured in traps 45 times accounting for 46 % of all sightings for this species.

TABLE P – NON MAMMAL CAPTURES IN ELLIOTT TRAPS

Species	Number caught
Egernia striolata	45
Lophognathus burnsii	17
Egernia whitii	9
Demansia psammophis	4
Egernia saxatilis saxatilis	3
Ctenotus robustus	3
Tiliqua scincoides	2
Morethia boulengeri	2
Pogona barbarta	2
Anomalopus leuckartii	1
Diplodactylus Williamsi	1
Amphibolurus nobbi	1
Carlia tetradactyla	1
Ctenotus taeniolatus	1

The decision to use a large number of traps over a six night period was taken because of an anticipated low rate of trapping success in western New South Wales. Similar trapping periods were used during the Western Region Biodiversity Conservation project, and capture rates were found to plateau after six days (Murray Ellis, pers. com.). Work in Goobang National Park found that species detection rates continued to rise after four days (National Parks and Wildlife Service 1997). Studies undertaken by Read (1998) on small mammals on the Darling River revealed a 10 day trapping period was required to detect all species present.

The trapping night on which each small mammal was captured at each site was recorded, (ie. night 1 - 6). Assessment of the average night on which species were caught revealed that captures for all species over the entire survey period peaked on the fourth night, 22% of all small mammal captures were on the fourth night, and then declined on the fifth and sixth night (Figure 3). This pattern was simular for the individual species with the exception of the common dunnart where captures reached a plateau on the fifth and sixth nights.
The number of species detected reached a plateau on the third and fourth nights and began to decline on the remaining nights of trapping. No new species were detected beyond the fourth night (Figure 4), indicating that the six night period was probably sufficient to detect most small mammal species likely to be captured in Elliott traps.

Pitfall traps were not used in this survey as they are very time consuming to set up. A number of small mammal species such as dunnarts and planigales are more frequently captured in pits, as are many frogs and reptiles. It is recommended that pitfall trapping be included in future survey design, to ensure these species are more adequately sampled.

FIGURE 3: PERCENTAGE CONTRIBUTION TO TOTAL SMALL MAMMAL CAPTURES IN ELLIOTT TRAPS FOR EACH NIGHT OF TRAPPING DURING THIS SURVEY

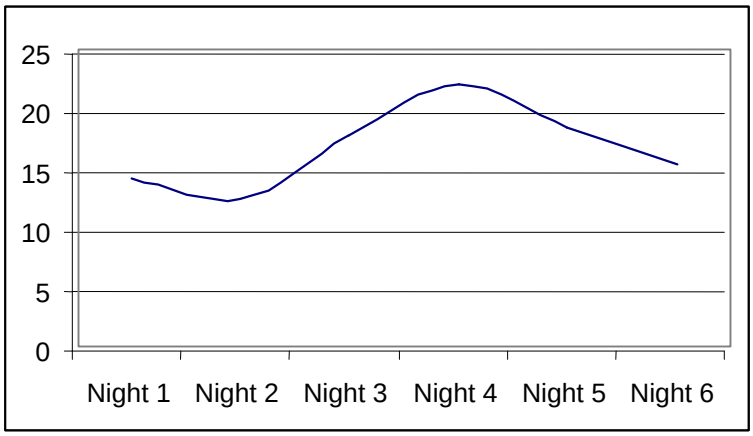
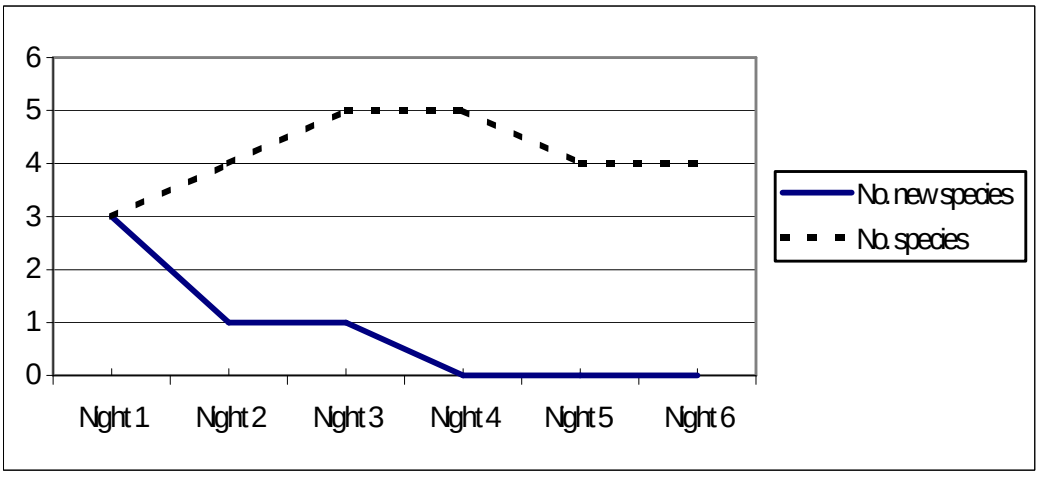


FIGURE 4: NUMBERS OF SMALL MAMMAL SPECIES CAPTURED IN ELLIOTT TRAPS FOR EACH NIGHT OF TRAPPING DURING THIS SURVEY



Spotlight techniques.

This survey trialed a one kilometre spotlight transect technique which was not used during the preliminary (Stage 1) survey. This transect was introduced with an expectation that the one hour site based spotlight may have been insufficient to detect larger, mobile and sparsely distributed animals (Table Q). It was anticipated that a linear transect would increase the number of habitat types searched and hence the chances of detecting such species. While transect data could not be directly linked to the two hectare site, the increased chances of detecting additional species for a regional context was deemed worthwhile.

TABLE Q – COMPARISON BETWEEN RESULTS OF TWO SPOTLIGHT TECHNIQUES USED

	Two hectare site based spotlight		One Kilometre transect	
Group	**No. Species Seen**	**No. Individuals seen**	**No. Species Seen**	**No. Individuals seen**
Diurnal birds	20	30	8	15
Nocturnal Birds	8	68	7	77
Geckos	9	110	7	58
Other Reptiles	7	19	2	2
Macropods	5	17	5	44
Arboreal Mammals	6	109	7	157
Frogs	10	35	10	55
Bats	2	15	2	17
Introduced species	4	9	4	12
Other mammals	1	1	3	2
Total	**72**	**413**	**55**	**439**

The site based spotlighting revealed significantly more species and numbers of reptiles, smaller arboreal mammals such as ringtail possum and feathertail glider were also only detected in site based spotlighting. The road transect revealed a slightly higher number of arboreal mammal species in total and approximately 40 % more individuals seen.

The road transect provided a good opportunity to collect additional data on some species (brushtail possum, squirrel glider, koala). However the information was collected from up to 500 metres away from the site and was difficult to incorporate with the attributes and other data collected within the two hectare site (the transects often passed through different habitats). If future surveys are limited in resources the detailed site based spotlighting would provide best efficiency as more species were detected and the data was more easily incorporated with the site based habitat variables and other data collected.

Anabat

More than 1 500 call sequences were recorded from the 108 systematic sites, 370 of which were too weak or too short to be analysed. Only eight species could be identified positively from the call sequences accounting for only 97 site records for all species. Most bat records were achieved by other means (mostly harp trapping and spotlighting for *S. flaviventris*). Anabat detection accounted for a very low number of unique records.

One species was recorded only by Anabat, *Miniopterus schreibersii*. Nine call sequences were identified as "probable" for this species, all in the Coonabarabran/Warrumbungle area. This would represent the western most point at which this species has been found.

Miniopterus schreibersii is known from the Mt Kaputar and Coolah Tops areas of the bioregion. The cooler peaks and presence of caves in the Warrumbungle area appear consistent with known habitat of this species further east, however further work is required to validate these records.

Table R below provides a list of species which could be identified accurately, and shows the number of records (Ford 2001, 2002)

TABLE R – NUMBER OF RECORDS PER SPECIES FROM ANABAT ANALYSIS

Species	Recording frequency (no. sites at which definitely recorded)
Rhinolophus megaphyllus	2
Saccolaimus flaviventris	16
Tadarida australis	11
Chalinolobus dwyeri	2
Chalinolobus gouldii	29
Chalinolobus picatus	9
Scotorepens balstoni	13
Scotorepens greyi	13
Species which could not be definitely identified *Mormopterus sp.* *Nyctophilus sp* *Vespadelus sp.* *Miniopterus schreibersii*	

Given the effort and cost required to collect and analyse these calls (over 54 hrs of recording and 80 hours of analysis) these results represent very poor value.

The project team for this survey would highly recommend that the Anabat method used during this survey be changed for future surveys. Recording Anabat call sequences onto audio cassette reduces the quality of the recording (Reinhold *et al*. 2001). It is recommended that if ultrasonic detection is used call sequences should be recorded directly into a laptop computer as this greatly improves the recording quality of the call sequences. Of the 1 500 calls recorded onto audio cassette in this project only 6% of could be accurately identified. This is well below the level expected if calls were recorded onto a laptop. In a project where 298 bat calls were recorded directly onto a laptop Pennay (2000) found that 30% of calls were of high enough quality to measure all parameters required for accurate analysis and an additional 33% were of high enough quality for measuring characteristic frequency only.

Some species can not be identified by Anabat recordings (Reinhold *et al*. 2001). In this bioregion the positive identification is problematic for all *Mormopterus* species, all *Nyctophilus* species, all *Vespadelus* species, *Chalinolobus picatus*, *Scotorepens greyii*, *Miniopterus schreibersii* and *Chalinolobus morio*. This is due to the call features of some (*Nyctophilus, M. schreibersii, C. morio*), variation across the species range (*Vespadelus vulturnus*), variation in different environments (*C. picatus, S. greyii*) and an overall lack of reliable reference calls (*Vespadelus troughtoni, baverstocki* and *vulturnus* and all *Mormopterus* species) (Ford, 2001,2002, Reinhold e*t al*. 2001, Law *et al.* in prep).

Saccolaimus flaviventris has been regarded previously as a species reliably identified by Anabat methods because it calls at a relatively distinct characteristic frequency (approx 17-20 khz). During this survey at least three sites *Saccolaimus flaviventris* was spotlighted flying below the canopy in open woodland and recorded on Anabat. When flying below the canopy *S. flaviventris* appears to increase the characteristic frequency at which it calls to just above 20 kilohertz which overlaps with the characteristic frequency of *Mormopterus beccarii* (Pennay unpublished data). *Mormopterus beccarii* has been recorded to the Queensland border. In light of this information extra care should be paid to call identification of both of these species in future surveys. A recommendation from this project is that any future bat surveys collect reference calls from species captured to increase the number of species that can be reliably identified.

4. FAUNA DATA ANALYSIS AND MODELLING

In this project data collected during the fauna survey and from other sources was analysed to identify areas of conservation significance.

Three main approaches were taken:

- A classification analysis (PATN, Belbin, 1994) was undertaken by mapsheet for the entire study area. This analysis provided a broad coverage overview of differences in species composition across the bioregion. This analysis used all available data for the study area including data from this project, data from previous projects and from assorted other sources included in the BBS fauna database.

- A more detailed classification analysis of fauna communities in specific habitats for the systematic site data collected during this survey and the preliminary survey. This analysis used only data collected in Stages 1 and 2 of the Brigalow Belt South fauna survey and data from the Darling Riverine Plains and Nandewar biodiversity surveys collected from within the 15 kilometre buffer.

- Logistic regression analysis of presence/absence data and environmental variables from the systematic sites was undertaken for selected species. This analysis was used to identify environmental variables significant to the species distribution and interpolate spatially the predicted distribution of the species in unsampled areas (distribution modelling). This analysis used only systematic presence/absence data collected in both stages of the Brigalow Belt South fauna survey, data from the Darling Riverine Plains and Nandewar biodiversity surveys, and data from additional systematic surveys such as Kavanagh's Owl survey, Sydney CRA Coolah Tops survey and UNE Phd. Pilliga Mouse survey.

The details of each analysis and the data sources used are provided in each section.

4.1 MAPSHEET FAUNA CLASSIFICATION FOR BBS AND BUFFER

4.1.1 Aims

Mapsheets provide a bioregion-wide, spatially uniform sample which is relatively convenient to use in terms of scale and comparability of coverage. The classification of fauna by mapsheet for the BBS (including buffer) aimed to address the following questions:

- Is there broad variation in the faunal community across the BBS?
- Can the distribution of faunal communities be sensibly be mapped across the bioregion at a mapsheet scale?
- Do provinces have distinct faunal composition?
- Are any particular areas consistently distinct when faunal groups are classified separately?

A major advantage of these analyses over those using site systematic fauna data is the coverage of the whole of the BBS. Using systematic fauna data limits coverage mainly to woody vegetation and the larger blocks of public lands. This assessment methods used for this project produce information relating to the whole of the bioregion, and as such have compared to other methods have an improved chance of identifying bioregion-wide patterns. This analysis provides regional context for local site-based information. In the process of completing these analyses a database of fauna records within the BBS and buffer will be created.

4.1.2 Methods

Data sources
Point location fauna records were extracted per mapsheet from the BBS Fauna database which is a compilation of the following databases;

- The Atlas of NSW Wildlife (last date January 2002) (this included BBS Stage 1 data, Sydney and Lower North Coast CRA data);
- Birds Australia;
- CSIRO;
- Australian Museum;
- Australian Bird and Bat Banding Scheme;
- BBS Stage 2 data; and
- Darling Riverine Plains biodiversity assessment data.

The relevant data were cut to the BBS and the 15 km buffer geographic information system (Arcview) and then entered into a relational database (Access). This database now contains more than 153 000 fauna records and covers 140 mapsheets.

Data verification and screening
The compilation of such a wide variety of datasets leads to several data reliability problems, including inconsistent taxonomy, suspect records, incorrect location of records and historic records. Each of these discrepancies has the potential to affect fauna classification and the identification of patterns in fauna distribution across the bioregion.

- Inconsistent taxonomy - Taxa that have undergone taxonomic revision or changes in nomenclature within the last 30 years were identified by fauna specialists and from inspection of unique, common and scientific name combinations in the database. In some cases these taxa were then merged, for example taxa that were present in the database under multiple names (*e.g.* white-throated nightjar *Eurostopodus mystacalis* and *Caprimulgus mystacalis*), or where subspecies were occasionally, but not always identified (*e.g.* Nobbi dragon *Amphibolurus nobbi, A. n. nobbi* and *A. n. coggeri*). Subspecific taxa that were consistently identified to subspecific level in the database were retained (*e.g. Egernia saxatilis saxatilis* and *E. s. intermedia*). Recent taxonomic changes were followed if reflected by the records in the database (*e.g. Mormopterus* sp. 3 and 4 vs. *M. planiceps*).

- Suspect records and incorrect location - Records from the Wildlife Atlas were screened by reliability code, with all low reliability records (reliability code 6) excluded. The database also contained records of a number of taxa that were, for various reasons, suspect. Fauna specialists identified these taxa and the records were checked, including information on location and detection method. Those records in which the location description did not match the mapped location were excluded. Taxa not known from NSW (*e.g. Ctenotus labillardieri, Varanus kingorum,* Papuan frogmouth *Podargus papuensis*) were excluded, as were those regarded as being extremely unlikely to occur in the BBS and buffer (*e.g.* black-eared miner *Manorina melanotis, Paracrinia haswelli* and long-nosed potoroo *Potorus tridactylus*) or being recent escapees or domestic animals (*e.g.* Cape Barren geese *Cereopsis novaehollandiae*, red junglefowl *Gallus gallus* and domestic cattle). Records not identified to species level were also excluded, as were those of obvious vagrants, such as seabirds. Checking of records was restricted to species whose occurrence anywhere in the BBS was considered suspect. Therefore while this process removed many inaccurate records, some errors may have gone undetected.

- Historic records - As the purpose of the analysis was to examine current patterns of fauna distribution across the bioregion, historic records were excluded. For this project historic records were defined as those pre-1972 (*i.e.* more than30 years old). Undated records unlikely to have been recent (such as of long-extinct mammals) were also excluded, as were species detected through methods unable to be confidently dated (such as bones and cave deposits, *e.g.* greater stick-nest rat (*Leporillus conditor*)).

Final dataset
Following the above exclusions and merging of taxa, a total of approximately 148 000 records of 517 taxa remained in the fauna database for the BBS and buffer. Approximately seven thousand records were excluded.

Data analysis
Fauna records were extracted from the Access database as species per mapsheet, with the records identified above excluded. This converted all fauna records to species presence or absence from each mapsheet. The BBS and buffer is covered by mapsheets ranging in scale from 1:25 000 in the south and east to 1:50 000 in the north and west. Typically, records on the four 1:25 000 mapsheets were merged to make up a 1:50 000 sheet. Exceptions were made if the 1:25 000 sheets contained no fauna records (these were then excluded), or in rare cases where a 1:25 000 sheet included a specific habitat feature expected to support distinct fauna (*e.g.* Mt Kaputar) and the sheet had many fauna records (these were kept separate). Occasionally, on the boundaries of the bioregion where there were less data and all mapsheets

would otherwise have been excluded, adjacent 1:50 000 sheets were merged. Extractions were completed for all vertebrate fauna species (excluding fish) and several groups of fauna separately; terrestrial (non-wetland) birds, reptiles, amphibians, non-flying mammals and bats.

Further mapsheets (1:50 000 and composite 1:50 000) were excluded from particular analyses if they did not contain records of a number of species exceeding a set threshold. These thresholds are somewhat arbitrary, but reflect what was considered a minimum species richness that indicated that the mapsheet had been appropriately sampled for that faunal group. For the faunal group analyses these thresholds were set at ten species of reptiles, seven amphibians, seven bats, eight non-flying mammals and 90 birds. A single measure of species richness was not sufficient to determine if a mapsheet had sufficient data for classification in the all-species analysis. In this case records for each mapsheet were inspected and those lacking good representation of each taxonomic group were excluded. In this process mapsheets consistently lacking sufficient data can be identified.

PATN analysis software (Belbin 1991 & 1994) was used to manipulate data and examine the distribution of fauna by mapsheet. Mapsheets were classified using the *ASO* (Bray-Curtis association measure) and *FUSE* (flexible UPGMA, *B*-value specified on dendrograms) functions, and were plotted with the *DEND* function. Mapsheet groups were identified by inspection of the dendrograms and ordinations (using semi-strong hybrid multi-dimension scaling, *SSH*, 3 dimensions), and groups and subgroups were plotted over the BBS and buffer in Arcview. The species composition of mapsheets groups was examined using the *GDEF* and *GSTA* functions (Belbin 1994). Species were classified using the Two Step association measure (Belbin 1994).

4.1.3 Results

The most frequently recorded species for each faunal group on wildlife databases for the BBS and buffer are shown in Table S. This is a rough indication of the most abundant species across the BBS, but with some unavoidable biases towards some groups. Among the mammals, for example, bats are over-represented in this measure as trapped bats are usually entered into databases individually (with measurements), while macropods are entered as the total number seen at a point. The mapsheets with the greatest number of records were centred on the Warrumbungles; Bugaldie, Tooraweenah, Coonabarabran and Tenandra. This may reflect either or both the high visitation to the Warrumbungles and Coonabarabran area and/or the diversity of landforms and habitats on these mapsheets (from mountain heaths and open forests to woodlands and open habitats on plains).

TABLE S – FAUNA SPECIES WITH THE MOST RECORDS ON WILDLIFE DATABASES IN THE BBS AND BUFFER

Amphibians	Reptiles	Birds	Mammals
Limnodynastes tasmaniensis	*Morethia boulengeri*	Galah	*Vespadelus vulturnus*
Litoria peroni	*Heteronotia binoei*	Australian Magpie	*Antechinus flavipes*
Crinia signifera	*Egernia striolata*	Willie Wagtail	*Chalinolobus gouldi*

The species most widespread geographically (as measured by occurrence on the most mapsheets) were all birds (Table T). The most widespread reptiles and mammals (Table T) were mostly different from those with the most records (Table S).

TABLE T– MOST WIDESPREAD FAUNA SPECIES IN THE BBS AND BUFFER

Species	Number of mapsheets
Birds	
Willie Wagtail	134 (96%)
Australian Magpie	133
Galah	132
Magpie-lark	131
Pied Butcherbird	130
Laughing Kookaburra	129
Australian Raven	129
Noisy Miner	128
Nankeen Kestrel	127
Superb Fairy-wren	127
Mammals	
Macropus giganteus	74
Trichosurus vulpecula	65
Wallabia bicolor	65
Herpetofauna	
Morethia boulengeri	58
Egernia striolata	53
Litoria latopalmata	53

Data gaps

Some mapsheets and larger areas had consistently low diversity of species in each faunal group, indicating a lack of incidental records and survey effort. The areas on the following mapsheets should be a priority for further survey:

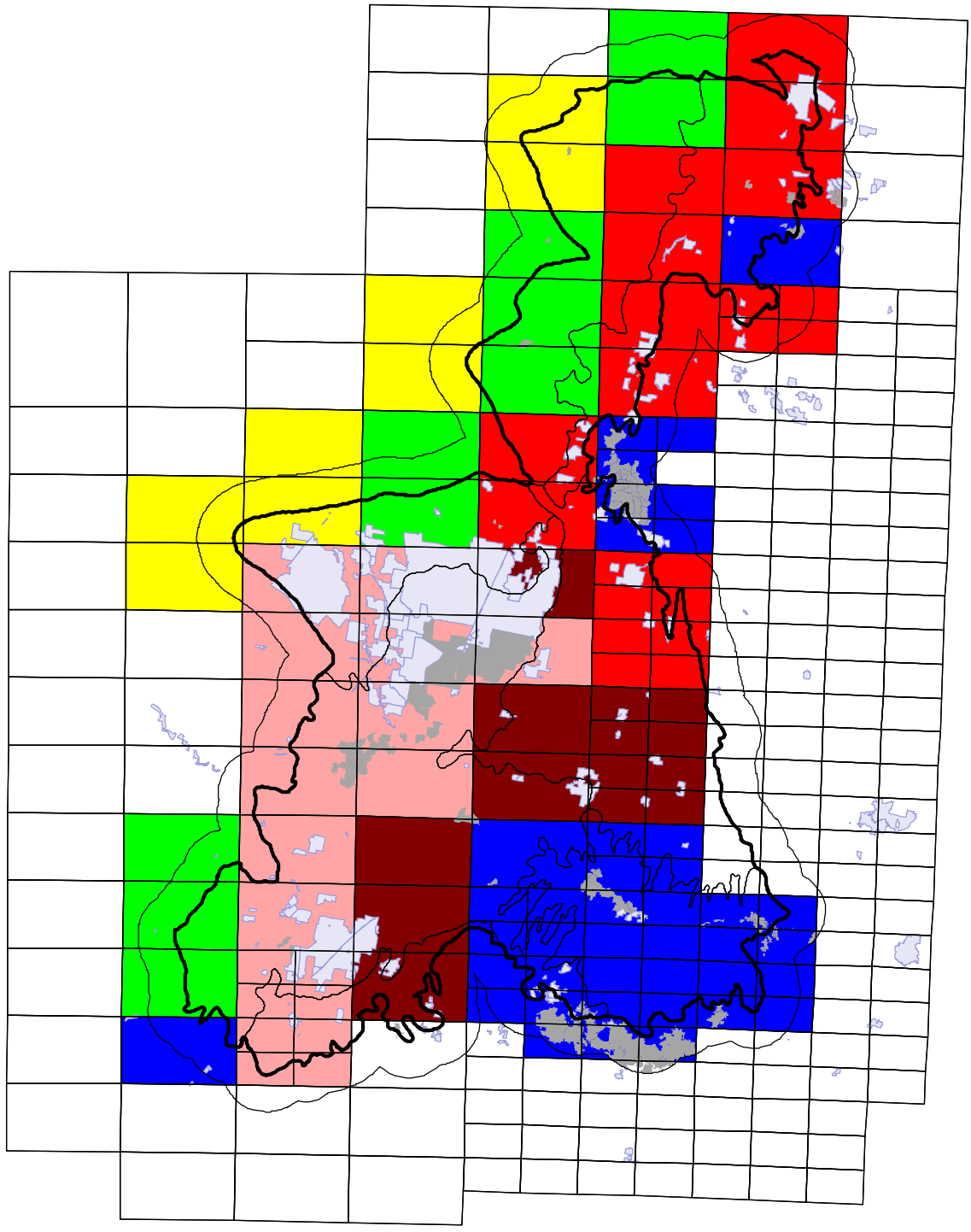
- Eastern BBS and buffer, from Parry (89341S) to Temi (90341S) north to Watermark (89351S) and Piallaway (90354S), also Yarraman (89344N) to Coolanbilla (89353N);
- Gravesend (8938N) (eastern edge);
- Yelarbon (9040N) (far north);
- North Star (8940S) and Croppa Creek (8939N) (central north);
- Pilliga (8637S) and Cuttabri (8737S) (northern Pilliga Scrub);
- Coolah area (88342N&S, 88343N&S) (central south);
- Mullaley (8835N) (centre); and
- Gurley (8838S) (north-west edge).

All species

In the classification of mapsheets by their overall vertebrate species composition (excluding fish), 16 1:25 000 and eight 1:50 000 mapsheets were excluded due to lack of data. These were all on the fringes of the bioregion or only intersecting the buffer, particularly in the east, north of Murrurundi. A number of adjacent mapsheets were merged, however, to achieve adequate representation of all fauna groups.

Four broad groups of mapsheets were recognised in the classification (Figure 1.3). These were also readily distinguishable in the ordination (Figure 1.4, stress = 0.188). This indicates that there is broad variation in the fauna community across the BBS, and that this variation can be divided into four broad groups. Classification by mapsheet for all vertebrate fauna in the BBS is shown on map 4. The species composition of these four faunal communities is provided in Appendix 8.

Map 4 – Classification by mapsheet for all vertebrate fauna in the BBS



Group 1 - Green
Group 2 - Red (with three subgroups, 2a - red; 2b - maroon; 2c - pink)
Group 3 - Blue (with two subgroups)
Group 4 - Yellow

NPWS ungazetted
NPWS estate
State Forest
Bbs provinces
BBS boundary

N
W E
S

0 30 60 Kilometers

Group 4 was the first division in the classification and the most divergent group in the ordination. The remaining groups were less divergent and appear to represent a gradient in composition. This may reflect the east-west gradient from group 3 to 1. As Group 2 covered the bulk of mapsheets in the BBS (Figure 1.3), the internal structuring of this group was investigated further in an attempt to define additional divisions within this large group. It was possible to identify three distinct internal subgroupings (subgroup 2a, 2b and 2c). The lower dissimilarity of internal divisions within Group 2 indicates that the bulk of the BBS is more consistent in fauna composition than the areas around the margins of the bioregion. This is not totally unexpected if bioregional boundaries are also indicators of changes in faunal composition. Areas at the boundary of bioregions may be expected to have a mixing of faunas from the adjoining regions.

The distribution of the four identified groups of mapsheets with similar fauna composition was plotted across the BBS (Map 4). The distribution of the groups appeared ecologically logical and reflects some of the greatest environmental gradients across the bioregion. This suggests that the classification has been successful in identifying bioregion-wide patterns.

Group 1 – Mapsheets classified into this group (11% of all mapsheets) in a thin band along the western margin of the BBS, mainly in the north-west and south-west (Map 4). These areas are mainly flat, along the lower floodplains (for the BBS) of the Macquarie, Namoi, Gwydir and MacIntyre Rivers. Those fauna species more frequently recorded on mapsheets in this group were a number of species inhabiting wetlands (*e.g.* Latham's snipe, glossy ibis, pink-eared duck, *Hydromys chrysogaster*), floodplain habitats (*e.g. Suta suta, Pseudechis guttatus*), open country (*e.g.* Australian pratincole, Australian bustard), western areas (reaching the eastern limits of their distribution in the BBS, *e.g.* little crow, *Sminthopsis macroura, Macropus rufus*) and northern areas (reaching the southern limits of their distribution in the BBS, *e.g. Macropus dorsalis,* Torresian crow). The higher occurrence of wetland species presumably reflects increased wetland habitats on the western margins of the BBS, particularly along the Namoi and Gwydir Rivers. Fauna absent included a number of species typical of more eastern woodlands and open forests, such as brown thornbill, turquoise parrot, *Chalinolobus morio* and *Lygisaurus foliorum*. Species unique to mapsheets in this group were few, but included *Planigale gilesi* and *Chelodina expansa*.

Group 2 – These mapsheets (54% of total mapsheets) were located throughout the centre of the BBS from south to north (Map 4). This area ranges from the relatively flat Liverpool Plains to the Warrumbungle Mountains and foothills of Mt Kaputar, but does not include any of the wetter mountain areas. These mapsheets were characterised by the consistent presence of a range of temperate woodland and open forest taxa, as well as the distinctions identified in the description of other groups. The characteristic taxa included woodland birds (such as painted button-quail, turquoise parrot, white-bellied cuckoo-shrike, white-browed babbler and barking owl), reptiles (*Amphibolurus nobbi, Oedura robusta*), mammals (*Phascolarctos cinereus, Antechinus flavipes, Petaurus brevipes, P. norfolcensis, Nyctophilus timoriensis*) and amphibians (*Limnodynastes terrareginae, L. ornatus*). The unique species from mapsheets in this group included yellow-plumed honeyeater, white-fronted chat, *Pygopus lepidopodus, Diplodactylus intermedius* and *Cercartetus nanus*. To further divide this large portion of the BBS, the internal structuring of this group was investigated and three subgroups recognised:

Subgroup 2a – This subgroup in the south-western portion of Group 2, covering the bulk of the Pilliga Scrub, the Warrumbulges and south through eastern Goonoo and Beni SFs. Differences in the faunal composition of the subgroups was minor. Subgroup 2a more frequently contained a number of species typical of more arid areas (crested bellbird, diamond dove, chestnut-rumped thornbill).

Subgroup 2b – These mapsheets were distributed in the north of the BBS, from the northern border and Bebo SF, south along the eastern fringe of the BBS (Terry Hie Hie) to the Nanedwar foothills, and skirting the Nandewar range (Narrabri, Leard SF). Species more frequent in this subgroup (c.f. other subgroups) typically had northern (brown honeyeater, *Macropus dorsalis*) or eastern (white-browed scrubwren, common koel) affinities.

Subgroup 2c – This subgroup was located mainly to the east of subgroup 2a, from Dunedoo to Binnaway, the Liverpool Plains and north-east Pilliga. Species associated with more eastern, and sometimes rocky areas (*Oedura robusta, Ctenotus taelionatus, Amphibolurus muricatus*), were more frequent in this subgroup.

Group 3 – Mapsheets classified into Group 3 (27% of mapsheets) were distributed in the south of the BBS (mainly along the Liverpool Range and south) and in patches along the east (Mt Kaputar area and near Warialda) (Map 4). These are the moistest locations in the BBS and support patches of wet forest. Consequently, mapsheets in this group commonly lacked many species typical of warmer, western areas that were widespread elsewhere (including white-breasted woodlswallow, chestnut-rumped thornbill, white-winged fairy-wren, *Cryptoblepharus carnabyi* and *Gehyra variegata*). Alternatively, the uniqueness of the wet forest habitats of this group lead to a large number of unique species, such as wonga pigeon, superb lyrebird, powerful owl, *Antechinus stuartii, Falsistrellus tasmaniensis, Vespadelus darlingtoni, Phyllurus platurus, Pseudemoia pagenstecheri* and *Uperoleia laevigata*. Other species more frequently found in this group were Lewin's honeyeater, white-browed scrubwren, *Vombatus ursinus, Eulamprus quoyii, Crinia signifera* and *Limnodynastes dumerilii*, typical of more eastern open forests and woodlands, and *Egernia cunninghamii, Ctenotus taeniolatus* and *Petrogale penicillata*, inhabitants of rocky outcrops.

Group 4 – Group 4 mapsheets (9% of total) were distributed at the north-west extremity of the BBS and buffer (Map 4). These mapsheets were mainly characterised by the low frequency of occurrence of many common bird species (*e.g.* little pied cormorant, sulphur-crested cockatoo, brown goshawk, rock dove, Australian pelican), which reflects poor sampling of these mapsheets rather than a true absence of species. Group 4 mapsheets, if covered by more adequate bird data, are likely to be similar in composition to those of Group 1, having more western, northern, open-country and wetland species than groups 2 and 3. This is indicated on the ordination, where groups 1 and 4 share similar values on SSH1, the axis explaining the most variation. Only *Diplodactylus steindachneri* were found uniquely on a mapsheet in Group 4, although a number of amphibian species (*Cyclorana verrucosa, Litoria alboguttata, L. caerulea, Notaden bennettii*), floodplain species (*Denisonia devisi, Lophognathus burnsii*) and western species (mulga parrot, *Chalinolobus picatus, Heteronotia binoei*) were more frequently found here than in other groups.

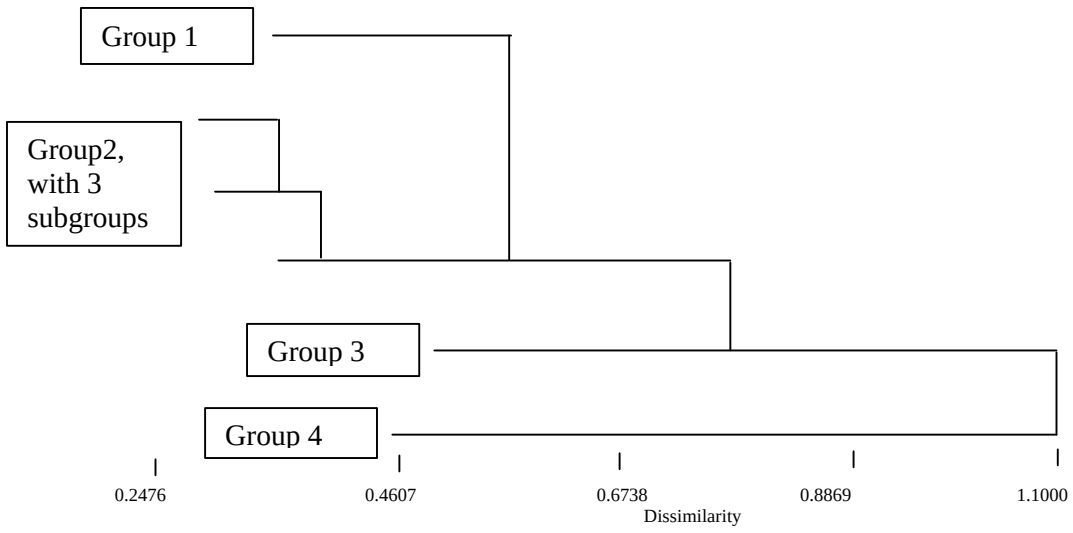


Figure 1.3 Dendrogram of mapsheet groups classified by vertebrate species (excluding fish) composition

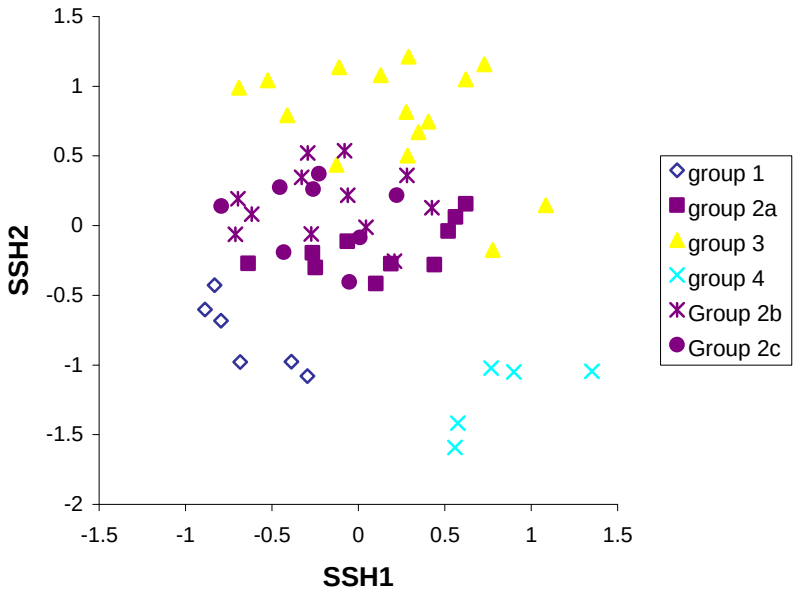


Figure 1.4 Ordination of mapsheets by composition of all vertebrate species (excluding fish), showing the four groups

Stress = 0.188. First two dimensions of a three-dimension ordination shown

Threatened species records by mapsheet group

Many species listed under the *TSC Act* have been recorded from a disproportionally greater number of mapsheets within some groups than others (Table U). Their preference for habitats within mapsheet groups can prove useful when assessing the relative importance of each group for each species, and for suites of threatened species. Group 2 mapsheets, which cover the bulk of the BBS, were the most important for the greatest number of threatened taxa (26). These taxa are considered to be mostly dependent on woody vegetation and included most of the threatened woodland bird species (including the decliners in Reid 1999 and Traill and Duncan 2000) and arboreal mammals.

Group 1 mapsheets were also the important areas for many threatened taxa (22), although in this case most of the species concerned are regarded to inhabit either grasslands or open country (*e.g.* grass owl, Australian bustard, *Smithnopsis macroura*) or wetlands (*e.g.* freckled duck, painted snipe, brolga). Several of these threatened taxa were recorded from proportionally more mapsheets from this group, but because of the small group size this equated to only a single mapsheet (*e.g. Underwoodisaurus sphyrurus, Anomalopus mackayi*). The preference of these species for Group 1 mapsheets should only be regarded as tentative until more records are obtained.

In contrast to Groups 1 and 2, Groups 3 and 4 were the most significant for many fewer threatened species, 15 and seven respectively. With group 4, this is probably a reflection of the poorer data, particularly of birds, from these mapsheet areas. For most of the birds of grasslands, open country and wetlands, Group 4 mapsheets are likely to be as significant as those from Group 1. Group 4 mapsheet areas were the most significant for two bat species widespread in inland NSW, *Chalinolobus picatus* and *saccolaimus flaviventris*. The threatened taxa for which Group 3 mapsheets were the most significant were several woodland birds (many also as widespread in Group 2), several taxa restricted to rocky outcrops and cave systems (*e.g.*

Chalinolobus picatus, Vespadelus troughtoni, Petrogale penicillata) and several inhabiting moister forests (*e.g.* powerful owl and *Dasyurus maculatus*).

For the conservation of threatened taxa dependant on woody vegetation in the BBS, the area covered by Group 2 mapsheets is the most significant (Map 4). Group 1 and Group 3 mapsheets are the next most significant for threatened species dependent on woody vegetation, for species of open woodlands, and woodlands and wetter forests respectively.

TABLE U – DISTRIBUTION OF TSC-LISTED FAUNA AMONG MAPSHEET GROUPS

[1] E – endangered on the *TSC Act 1995*; V – vulnerable on the *TSC Act 1995*

[2] Percentage of mapsheets within each group that each species has been recorded. Bold type indicates species found most often in this group (two groups are in bold if within 5% of each other).

[3] Subgroups of group 2 listed as a, b and c for 2a, 2b and 2c. The letter(s) in upper case indicated the subgroup in which the species is most frequent (among Group 2).

Species known from only a single mapsheet in the study area were omitted.

* Species found from highest proportion of mapsheets within this group, but this equates to only a single mapsheet (or composite mapsheet)

Species	Status [1]	Group 1 [2]	Group 2 [3]				Group 3	Group 4
Litoria booroolongensis	E						**20**	
Underwoodisaurus sphyrurus	V	**17***	**13**		B	c	7	
Anomalopus mackayi	E	**17***	10		B			
Hoplocephalus bitorquatus	V	**50**	33	a	B	c		40
Malleefowl	E		**37**	A		c	13	
Magpie-goose	V		**7**		B			
Freckled Duck	V	**50**	7			C	7	20
Blue-billed Duck	V	**33**	3	A				
Bush Stone-curlew	E	**67**	40	A	b	c	7	20
Australian Bustard	E	**50**	13	A	b		7	
Australasian Bittern	V	**17***	13	a		C	7	**20***
Painted Snipe	V	**33**	3			C		
Plains-wanderer	E		**7**		b	C		
Square-tailed Kite	V	33	**50**	A		c	33	
Black-breasted Buzzard	V	**17***	**13**	A	b	c		
Grey Falcon	V	**17***	**13**	A				
Black-necked Stork	E	**33**	17	a	B			20
Brolga	V	**83**	10	A				40
Squatter Pigeon	E		**7**		B			
Glossy Black-cockatoo	V	67	**80**	A	b	c	**80**	60
Major Mitchell's Cockatoo	V	**17***	10	A		c		**20***
Swift Parrot	E		**10**	A				
Superb Parrot	V	**33**	**30**	A	b		7	
Turquoise Parrot	V		**93**	A	B	c	60	20
Powerful Owl	V						**33**	
Barking Owl	V	17	**70**	A	b	c	40	20
Masked Owl	V	17	**50**	a	B	c	27	
Grass Owl	V	**17***	7		B			
Brown Treecreeper (either subspecies)	part V	**100**	**100**	A	B	C	**100**	**100**
Speckled Warbler	V	50	**100**	A	B	C	**100**	
Regent Honeyeater	E		43	A	b	c	**60**	
Black-chinned Honeyeater	V	17	**57**	a	b	C	**60**	
Painted Honeyeater	V	50	**60**	a	b	C	27	40
Hooded Robin (either subspecies)	part V	67	**100**	A	B	C	**100**	60
Grey-crowned Babbler	V	**100**	**100**	A	B	C	60	**100**
Gilbert's Whistler	V	**17***	10	A				
Diamond Firetail	V	67	**97**	A	b	C	**100**	
Dasyurus maculatus	V		7	a		C	**27**	
Sminthopsis macroura	V	**33**	10	a	B	c		
Phascolarctos cinereus	V	67	**77**	a	B	c	40	20
Petaurus norfolcensis	V	17	**60**	a	B	c	33	

Species	Status [1]	Group 1 [2]	Group 2 [3]				Group 3	Group 4
Cercartetus nanus	V		**17**	A		c		
Macropus dorsalis	E	**50**	30	a	B	c		
Petrogale penicillata	V		10	A			**47**	
Saccolaimus flaviventris	V	33	53	a	B		7	**60**
Chalinolobus picatus	V	17	40	a	B	c	7	**60**
Chalinolobus dwyeri	V		27	A	b	c	**40**	
Falsistrellus tasmaniensis	V						**33**	
Miniopterus schreibersii	V		3		B		**27**	
Nyctophilus timoriensis	V		**67**	A	b	c	40	
Vespadelus troughtoni	V		13	A	b		**20**	
Pseudomys pilligaensis	V	**17***	**17**	A	b			**20***
Total number of species the group is most significant for		**22**	**26**				**15**	**7**

Terrestrial birds

A total of 233 bird species were included in the analysis of the distribution of threatened species of fauna among mapsheet groups. These were the native terrestrial, arboreal and aerial bird species, excluding wetland species. Wetland species were excluded to specifically investigate pattern of distribution of birds of terrestrial habitats, such as forests, woodlands, shrublands and grasslands. Data coverage for this faunal group was good, with only a few mapsheets on the extremities of the bioregion being excluded for lack of records. These were mainly in the north-west of the BBS and buffer.

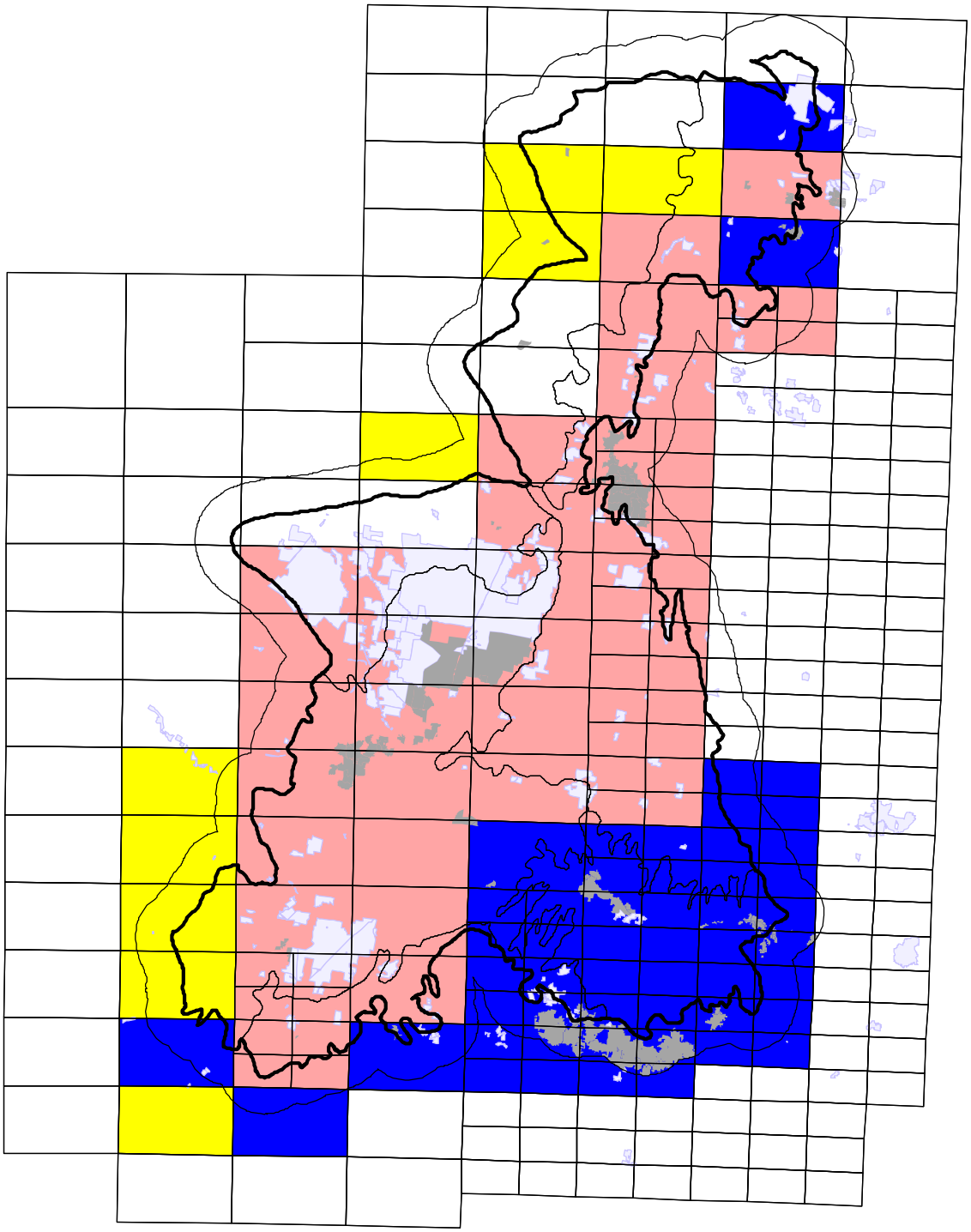
In the classification (Figure 1.5) three groups of mapsheets could be readily identified as supporting similar suites of bird species. These groups were also reasonably distinct on the ordination (Figure 1.6, stress = 0.175). Group 1 was the most distinct in both the classification and ordination, and consisted of areas in the far west and north-west of the BBS and buffer. Groups 2 and 3 were more closely aligned in the ordination and classification, and occurred in the moister portions and throughout the centre of the bioregion respectively. Group 1 was somewhat more similar to Group 3 (Fig 1.6), as would be expected given the distribution of the two mapsheet groups. The avifaunal composition of the mapsheet groups is discussed further below and detailed in Appendix 9.

Group 1 – These mapsheets, at the far west and north of the bioregion and buffer (Map 5), consistently lacked or infrequently contained a number of bird species widespread in the other two groups. These were typically species widespread in the east of the bioregion, but approaching their western limits in Group 1 mapsheets. These species included red-browed finch, musk lorikeet, white-naped honeyeater, striated thornbill, leaden flycatcher and cicadabird. Several other species were missing from mapsheets within this group, although their absence probably reflects the greater habitat modification and fragmentation at the western edge of the BBS. These species include crested bellbird, white-fronted chat and black-eared cuckoo. Although no species were unique to Group 1 mapsheets, species such as budgerigar, blue bonnet, white-winged fairy-wren, masked woodswallow and black-faced woodswallow were much more frequently recorded from mapsheets in this group than from the other mapsheet groups. All of these species are typical of more western areas, and approach the eastern limits of their distribution in the BBS.

Group 2 – The mapsheets with this group were located in the south and east of the BBS, including the Liverpool Range and near Warialda and Yetman in the north (Map 5). The differences between Groups 1 and 2 are described above. Compared to Group 3, Group 2 mapsheets typically had few records for a suite of species more widespread in more western or warmer areas, such as plum-headed finch, apostlebird, yellow-throated miner, Australian ringneck and pale-headed rosella. Species more frequently recorded in this group than in either Group 1 or 3 include brown thornbill, red wattlebird and crimson rosella, all species common in moister forests. There were a number of species unique to mapsheets in this group, including wonga pigeon, superb lyrebird, rockwarbler and powerful owl.

Group 3 –In addition to the differences identified above, mapsheets within this group more frequently contained typical woodland and open forest species such as painted button-quail, turquoise parrot, white-bellied cuckoo-shrike, inland thornbill and painted honeyeater. Unique species were few, but included Australian brush-turkey, pheasant coucal and swift parrot. This group covered the bulk of the BBS.

Map 5 – Classification by mapsheet for all terrestrial birds in the BBS



Group 1 - yellow
Group 2 - blue
Group 3 - pink

NPWS ungazetted
NPWS estate
State Forest
Bbs provinces
BBS boundary

N
W E
S

0 30 60 Kilometers

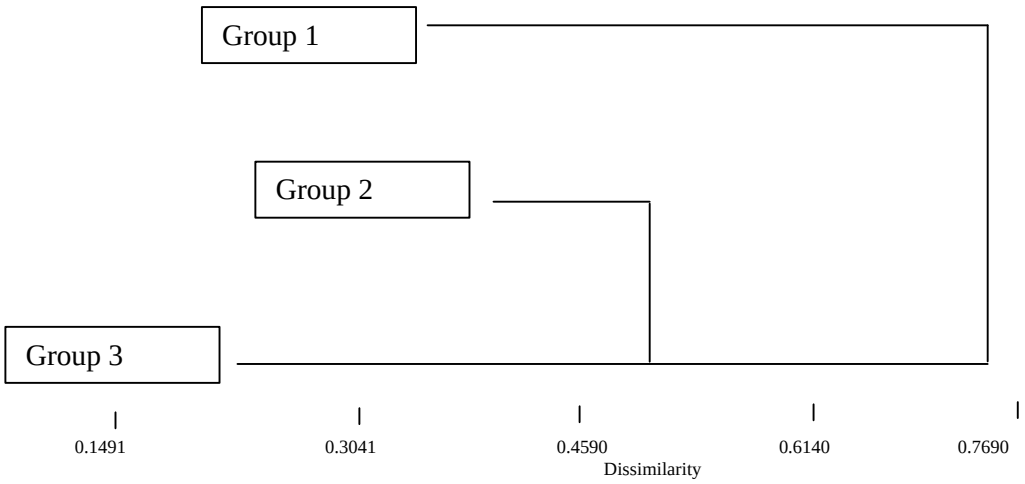


Figure 1.5 Dendrogram of mapsheet groups classified by terrestrial bird species composition

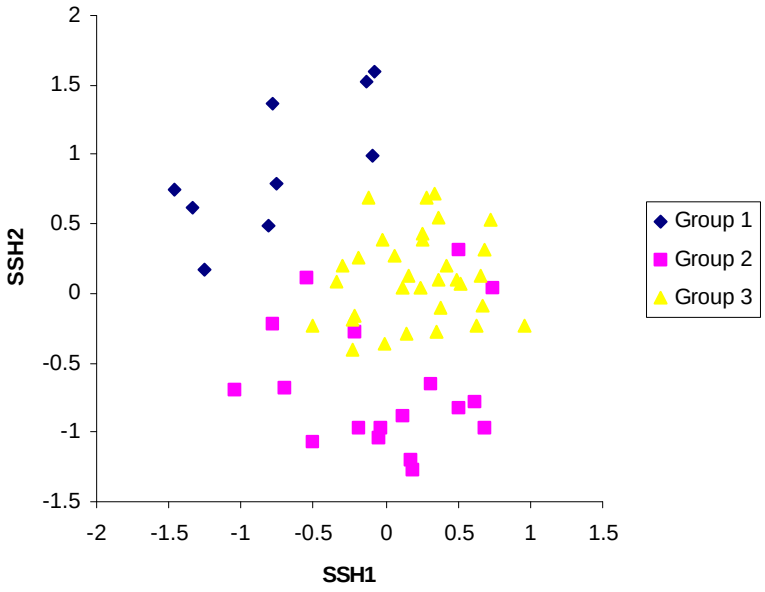


Figure 1.6 Ordination of mapsheets by terrestrial bird composition, showing the three groups

Stress = 0.175. First two dimensions of a three dimensional ordination shown

Threatened terrestrial bird species records by mapsheet group

Most threatened species have been recorded from disproportionally more mapsheets within some groups than others (Table V). Their preference for habitats within mapsheet groups can prove useful for assessing the relative importance of parts of the landscape for each species, and for suites of threatened species. For example, threatened species typically found in open habitats such as open woodlands and grasslands, were recorded from more mapsheets of Group 1 than from other mapsheet Groups. These species include bush stone-curlew, brolga, Australian bustard and grass owl. These mapsheets covered much of the western fringe of the BBS. Powerful owls were the only threatened species more widespread on Group 2 mapsheets than among other groups.

In contrast, threatened species most widespread within Group 3 were typically woodland and open forest species, including a number known to have undergone recent declines (Reid 1999, Traill and Duncan 2000), such as black-chinned honeyeater, hooded robin, barking owl and speckled warbler. For most woodland and open forest birds, the area covered by Group 3 appears to be the most significant. This is not unexpected, as Group 3 mapsheets cover the largest portion of the BBS and some of the largest remaining wooded vegetation remnants, such as Goonoo, Pilliga, the Warrumbungles and Mt Kaputar. Group 3 mapsheets were the most important for nearly double the number of threatened species than the next group. Group 3 mapsheet areas should be targeted for conservation of threatened birds reliant on woody vegetation. The Group 1 mapsheet areas appear to be the most significant areas for most open country and grassland species.

TABLE V – DISTRIBUTION OF TSC-LISTED TERRESTRIAL BIRDS AMONG MAPSHEET GROUPS

[1] – E – endangered on the *TSC Act 1995*; V – vulnerable on the *TSC Act 1995*
[2] Percentage of mapsheets within each group that each species has been recorded. Bold type indicates species found most often in this group (two groups are in bold if within 5% of each other).
Species known from only a single mapsheet in the study area were omitted.
[*] Species found from highest proportion of mapsheets within this group, but this equates to only a single mapsheet (or composite mapsheet)

Species	Status[1]	Group 1[2]	Group 2	Group 3
Malleefowl	E		17	**34**
Bush stone-curlew	E	**44**	6	38
Australian Bustard	E	**44**		13
Plains-wanderer	E			**6**
Square-tailed Kite	V	11	33	**53**
Black-breasted Buzzard	V	**11**[*]		**13**
Grey Falcon	V	**11**[*]		**13**
Brolga	V	**67**		13
Squatter Pigeon	E	**11**[*]	**6**[*]	
Glossy Black-cockatoo	V	44	**72**	**72**
Major Mitchell's Cockatoo	V	**11**[*]		**9**
Swift Parrot	E			**9**
Superb Parrot	V	**44**	11	31
Turquoise Parrot	V	33	33	**94**
Powerful Owl	V		**33**	
Barking Owl	V	33	44	**69**
Masked Owl	V	11	22	**47**
Grass Owl	V	**11**[*]		**6**
Brown Treecreeper (either subspecies)	part V	**100**	**100**	**100**
Speckled Warbler	V	33	94	**100**
Regent Honeyeater	E		**44**	**44**
Black-chinned Honeyeater	V	11	44	**63**
Painted Honeyeater	V	33	28	**50**
Pied Honeyeater	V			**3**
Hooded Robin (either subspecies)	part V	67	94	**100**
Grey-crowned Babbler	V	**100**	61	**100**
Gilbert's Whistler	V	**22**		9
Diamond Firetail	V	67	**94**	**94**
Total number of species for which the group is most significant		**11**	**6**	**21**

Reptiles

Mapsheets and composite mapsheets with records of more than 10 species of reptiles were classified into three groups (Figure 1.7). These groups were reasonably distinct in the ordination (Figure 1.8) and for the most part distributed in an ecologically logical way across the bioregion. One hundred and seven reptile species were present in the analysis area, which covered most of the central and western BBS. Sections of the BBS with insufficient reptile records to include in the classification were mainly in the north and central south of the BBS and buffer. Overall, coverage of reptile records was reasonable.

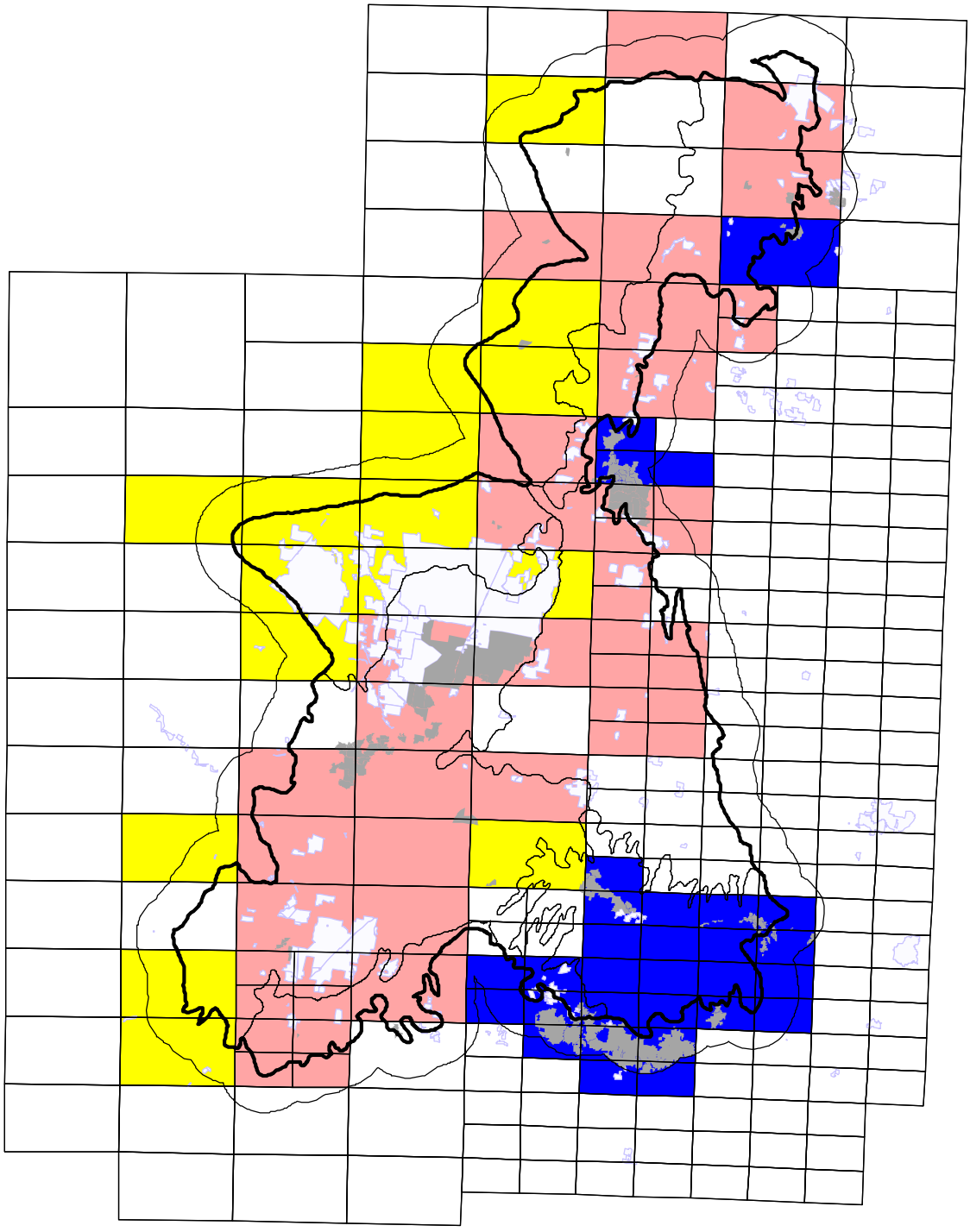
Group three was separated first in the classification, although on the ordination the relationship of sites may be more accurately described as a gradient in composition from Group 1 to 3. This is appropriate as the geographic distribution of the groups has a predominate gradient north-west (Group 1) to south-east (Group 3) (Map 6). The species composition of the mapsheet groups is detailed in Appendix 9.

Group 1 – With the exception of a single outlier, mapsheets classified into this group were located on the western and north-western margins of the BBS, including West Pilliga SF and much of north Pilliga (Map 6). Species more frequently recorded among these mapsheets included several species more typical of inland NSW, such as *Egernia striolata*, *Cryptoblepharus carnabyi* and *Pseudonaja nuchalis*. *Denisonia devisi* was also more often recorded on these mapsheets, reflecting the greater occurrence of cracking clay soils in the area covered by this group. Most commonly absent from maps classified into this group were a range of species more widespread in either more eastern areas (*Amphibolurus muricatus, Eulamprus quoyii, Lygisaurus foliorum* and *Anomalopus leuckartii*), or specifically in rocky habitats (*Ctenotus taeniolatus, Egernia whitii* and *Underwoodisaurus milii*). Only one species was unique to these mapsheets, *Diplodactylus steindachneri.*

Group 2 – This group covered the largest portion of the BBS and buffer, mainly through the centre from south of Dubbo through Goonoo, the Warrumbungles, the foothills of Mt Kaputar and north to Yetman (Map 6). The species more frequently recorded on these mapsheets than those in other groups were a range of species typical in woodlands and open forests, including *Diplodactylus vittatus, Ctenotus robustus, Varanus gouldii, Oedura robusta* and *Lerista bougainvillii*. Cool-climate and rock-dwelling species were less frequently recorded than in Group 3 (see below). Many species were unique to this group, including some restricted in NSW to the north of the BBS and buffer (*Carlia pectoralis* and *Furina dunmalli*) and others more widespread (such as *Underwoodisaurus sphyrurus* and *Pygopus lepidopodus*).

Group 3 – These mapsheets were mostly restricted to the coolest and wettest parts of the BBS and buffer – in the Liverpool Range south to Goulburn River NP, in the Mt Kaputar area and around Arakoola NR (Map 6). A number of reptile species restricted to moister forests were either unique among this group (including *Lampropholis caligula, Saproscincus mustelinus* and *Phyllurus platurus*) or more widespread (*Hemiergis decresiensis*). The rock-dwelling *Egernia whitii, E. cunninghami* and *Ctenotus taeniolatus* were also more widespread in this Group than in Group 2. In contrast, species typical of the warmer western slopes were less widespread, such as *Heteronotia binoei, Gehyra variegata* and *Lerista punctatovittata*.

Map 6 – Classification by mapsheet for all reptile fauna in the BBS



Group 1 - yellow
Group 2 - red
Group 3 - blue

NPWS ungazetted

NPWS estate

State Forest

Bbs provinces

BBS boundary

N
W E
S

0 30 60 Kilometers

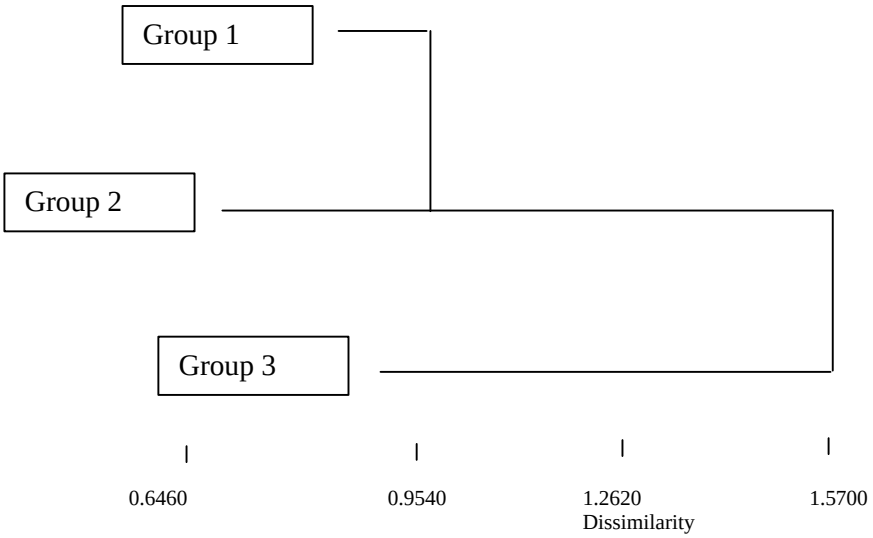


Figure 1.7 Dendrogram of mapsheet groups classified by reptile species composition

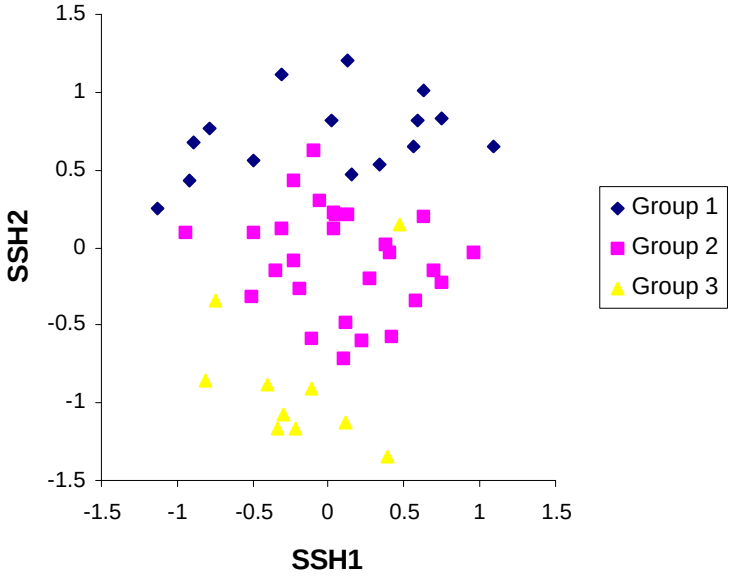


Figure 1.8 Ordination of mapsheets by reptile species composition, showing the three groups

Stress = 0.197. First two dimensions of a three dimension ordination shown.

Threatened species in reptile mapsheet groups

The threatened reptile species (listed on the *TSC Act 1995*) of the BBS have each been recorded on few mapsheets. The species most widely recorded, *Hoplocephalus bitorquatus*, has been recorded from 15 mapsheets. The vulnerable *H. stephensii* and *Aprasia parapulchella*, however, are known from only one, in both cases on the margins of the BBS (these mapsheets classified into Group 3). Records of the more widely distributed threatened reptile species were spread

fairly evenly across mapsheet groups 1 and 2, although not from Group 3. This indicates that the area covered by Group 1 and 2 is the more significant for the conservation of threatened reptile species occurring in the BBS (Table W).

TABLE W – DISTRIBUTION OF TSC-LISTED REPTILES AMONG MAPSHEET GROUPS

[1] – E – endangered on the *TSC Act 1995*; V – vulnerable on the *TSC Act 1995*

[2] Percentage of mapsheets within each group that each species has been recorded. Bold type indicates species found most often in this group (two groups are in bold if within 5% of each other).

Species known from only a single mapsheet in the study area were omitted.

[*] Species found from highest proportion of mapsheets within this group, but this equates to only a single mapsheet (or composite mapsheet).

Species	Status[1]	Group 1[2]	Group 2	Group 3
Underwoodisaurus sphyrurus	V		**22**	
Anomalopus mackayi	E	**7**[*]	**11**	
Hoplocephalus bitorquatus	V	**33**	**33**	
Total number of species for which the group is most significant		**2**	**3**	**0**

Other fauna

Amphibians, non-flying mammals and bats were also classified separately. However, these classifications suffered from a number of constraints that lead to groupings of mapsheets that were difficult to interpret. Lack of data was a particular problem for the bat and amphibian classifications. For both of these only about half of the mapsheets in the BBS and buffer had sufficient data to be useable in the classification, and this data was not evenly distributed. Large blocks of the analysis area had insufficient data from which to identify trends. An additional difficulty with the bat and non-flying mammal data was that specialist equipment is required to detect many species. Therefore, instead of this analysis being a classification of incidental data from across the bioregion supplemented with some systematic survey data, the bat and non-flying mammal classifications were essentially examining those mapsheets with systematic survey data. Analysis of patterns of fauna distribution from systematic site data is most effective using different methods than those used in this case (see section 4.2).

4.1.4 Correlation of classifications with bioregional and province boundaries

The process of categorising mapsheets based on their constituent fauna can be beneficial for identifying biotic patterns and boundaries. Specifically, it is useful for assessing whether the existing breakup of NSW into units of land with similar physical and biological components - bioregions and provinces - reflects the breakup according to fauna composition. Although in these analyses mapsheets have been classified, and hence the scale of the divisions are very coarse, faunal composition would be expected to generally match bioregional and province boundaries.

There is evidence of a change in faunal composition which corresponds with the bioregional boundary between the BBS bioregion and the Darling Riverine Plains (DRP) bioregion, west of the BBS. There is a change in mapsheet group corresponding to the bioregional boundary in the all fauna species analysis, terrestrial birds, and to a lesser extent reptiles. None of the mapsheets of Groups 1 and 4 in the all species analyses are located wholly in the BBS. There is no such change apparent corresponding to the southern and eastern boundary of the BBS. For all species within terrestrial bird and reptile classifications, the whole south-east of the BBS (Liverpool Ranges province) appears to be similar in composition to mapsheets across the south-eastern boundary and elsewhere on the eastern boundary of the BBS.

Investigating the distribution of fauna communities with respect to province boundaries is more difficult, primarily due to the scale at which the analyses were done (Map 4) and the small size of some of the provinces. For example, no 1:50000 mapsheet was wholly located within any of the Talbragar Valley, Pilliga Outwash, Northern Outwash or Northern Basalts provinces. On the basis of the all species classification, terrestrial birds and reptiles, only the Liverpool Plains province seems to support a distinct faunal assemblage in the BBS.

4.1.5 Recommendation

The mapsheets and areas identified in section 4.1.3 as lacking sufficient incidental fauna data should be priorities for further work. This could include, preferably, systematic survey , or other projects to collate existing but currently unavailable incidental data from these areas.

4.2 PATN ANALYSIS OF SYSTEMATIC SITES

4.2.1 Aims

The PATN analysis of systematic site fauna survey data aimed to:

- identify communities of fauna across the BBS and the species that are characteristic of these communities; and
- Correlate environmental, and plant species variables with the fauna classification.

4.2.2 Survey data

Where possible, additional systematic survey data from projects conducted within the BBS and buffer prior to, or concurrently with this project were included in the analyses. Only survey sites with a similar range of survey methodology and survey effort were included. There were minor differences between projects, although these were considered unlikely to heavily influence the analyses. For example, BBS Stage 1 (RACD 2000b) used hair-tubes at systematic sites, however the return from these was extremely low and no additional species were detected with this technique (Murray Ellis, NSW NPWS pers. comm.). Pitfall traps were used in the DRP surveys (Gosper in prep), and although many amphibians were detected using this technique at the DRP survey sites, in the BBS buffer they were mostly detected by other methods. The abundance of amphibians throughout this data set was probably equally related to prevailing weather conditions as to survey methodology. The following data sets were obtained and used:

- west Pilliga, east Pilliga, Pilliga Nature Reserve and Goonoo areas from the preliminary fauna survey (Stage 1) of the BBS bioregional assessment (RACD 2000b);
- sites in the buffer to the west of the BBS conducted as part of the Darling Riverine Plains Biodiversity Assessment Gosper (in prep);
- sites in Pilliga East State Forest conducted by the National Parks Association;
- sites in the buffer to the east of the BBS conducted as part of the Nandewar regional assessment (NSW NPWS Northern Zone unpublished data).

Systematic fauna survey data from the above sources were available from a total of 195 sites.

Systematic fauna data were manipulated by *PATN* software to extract and display patterns in the multivariate data and to examine variation in species composition between sites. Species recorded only flying over or moving through the sites were not included. Prior to detailed

analysis, inconsistencies in the fauna data needed to be addressed. In particular, taxonomic inconsistencies existed among the datasets. For example, cases existed of the same taxa being present in different data sets with different nomenclature (*e.g.* Gilbert's dragon *Lophognathus gilberti* or *L. burnsii*) or different levels of classification had been recorded (*e.g. Suta spectabilis* and *S. s. dwyeri*). In other cases, such as *Cryptoblepharus carnabyi/plagiocephalus*, taxonomic uncertainty rendered species identification problematic and confidence in the accurate identification of the taxon in data sets low. The *MERGE* function in *PATN* (Belbin 1994) was used to combine the presence/absence data for the problematic groups identified by fauna specialists. As such these taxa were taken back to the next level of classification (*i.e. Cryptoblepharus* spp., *Suta spectabilis*) and included in the analysis.

Fauna species were excluded from the analysis if their occurrence at a systematic fauna site appeared to be related to incidental factors and not to the inherent suitability of the site. Wetland vegetation types, for example, were not specifically sampled in this project. Consequently, the occurrence of water bird species at a site, such as being present at a dam, would have unintended consequences on species and site classification. Consequently, bird species tied specifically to aquatic habitats, such as ducks, cormorants and egrets, were not used in the *PATN* classification. These species were identified by fauna specialists and excluded using the *MASK* function. *MASK* was also used to remove records of species that appeared to be spurious (in datasets from other sources), those species not consistently recorded (such as 'wild' dogs) and where identification to species level was not made (*e.g. Tyto* sp.). A total of 270 taxa remained after the merging and masking of data was completed.

Multivariate analysis
Further analysis in *PATN* was undertaken on presence/absence data for all remaining fauna and with all available fauna sites. Presence/absence data for the fauna site classification was analysed in *PATN* by undertaking *ASO* (using the Bray-Curtis association measure), *FUSE* (using the flexible UPGMA fusion strategy, beta-value –0.2) and *DEND* (see Belbin 1991). Site groups were identified from the dendrogram. For each group, the total number of species, mean site richness and number of unique species were calculated. *GSTA* was used to identify the species that occurred frequently in each group of the fauna classification.

The site classifications were further examined through ordination, using semi-strong hybrid multidimensional scaling (*SSH*). Environmental data and floristic composition of the sites were also applied to the site groupings generated in *GDEF*, and then analysed through *GSTA*. Principal axis coordination (*PCC*) was used to fit environmental, flora and fauna species vectors to the ordination of sites.

4.2.3 Environmental attributes

The following environmental variables were generated from available spatial layers for each fauna site (see also section 4.2.5 – Relationship to environmental variables; and table AE for data source):

- Annual mean temperature (Avtemp in table AE)
- Maximum temperature warmest period (mtwp)
- Minimum temperature coldest period (mtcp)
- Annual precipitation (avrain)
- Precipitation driest quarter (precipdq)
- Precipitation wettest quarter (precipwq)
- Annual mean radiation (amrad)
- Highest period radiation (hprad)

- Distance to nearest clearing (cleardis)
- Amount of woody vegetation within a 1km radius of the site (Woody1k)
- Amount of woody vegetation within a 5 km radius of the site (Woody 5k)
- Amount of woody vegetation within a 10km radius of the site (Woody 10k)
- Distance to the nearest stream (greater than order 2) (GIS Unit, State Forests of NSW)
- A topographic index (elevation of the grid cell minus the average elevation of the surrounding 10 grid cells) (Topind10)
- Latitude
- Longitude
- Soil fertility (Soilfert); and
- Soil drainage (Soildrain).

These variables were chosen as they were thought likely to have a high degree of influence on fauna distribution and if coverage of the variable existed over the entire analysis area. They include several broad climatic variables and several landscape features. A spatial vegetation layer was not available at the time of analysis.

For the majority of fauna sites (those of BBS Stage 2 and DRP projects), site-specific environmental data were also available to be used for confirmation of site attributes, where necessary (such as information on hollow availability, vegetation structure *etc*, see survey methodology section). Site floristic composition was also available for most sites, and these were also used as confirmatory attributes in the PATN analysis.

4.2.4 Distribution of systematic survey sites

Within the BBS, the systematic fauna survey sites used in the following analyses were located in four of the six provinces of the bioregion identified in Morgan and Terrey (1992) (Map patn groups). Additional sites were located in the 15 km buffer, in the adjoining DRP and Nandewar bioregions. The distribution of the 195 systematic fauna sites should encompass much of the regional variation in faunal composition within and immediately adjacent to the bioregion. The provinces for which no comparable systematic fauna survey data were available were the Liverpool Plains and Northern Outwash. Systematic surveys have been conducted in these areas, however the methodology was sufficiently different from that of this project to preclude their use. The fauna communities present in these areas were assessed in the mapsheet analysis (section 4.1). All of the DRP biodiversity survey sites in the BBS buffer were adjacent to the Northern Outwash province, and should provide some guide to the fauna communities present in that area.

4.2.5 Faunal communities

The classification of the 195 systematic fauna sites resulted in the identification of four broad faunal communities (Figure 1.9), with some communities having a number of identifiable subcommunities. Throughout the report, the term faunal communities will refer to those generated through classification of sites. Locations with similar faunal composition are grouped and classified as one community. The characteristics of the community can then be identified, its known locations plotted and its conservation status assessed. The term Species groups will refer to those species identified as occurring often in association. Each community and subcommunity has been given a descriptor based on the dominant characters of the component sites (see Table X).

One clear division in the classification (Group 4) (Figure 1.9, Appendix 10) was a depauperate faunal community, mainly recorded in the DRP but also sporadically in the BBS. This community was divergent from the bulk of sites in the BBS and buffer. This community was also the most distinct and isolated in the ordination (Figure 1.10). The remaining groups identified in the classification were less discernible in the ordination. The high stress value (S = 0.27) also suggests that the ordination is a poor representation of the data. This may indicate the difficulty in identifying patterns in fauna survey data from a project of such limited scope – woody vegetation within a single bioregion. The remaining three groups are described below, however their division should be treated with caution.

Distinct characteristics of the three large groups of sites were not readily apparent. There was much overlap between location and vegetation type. For example, red gum vegetation types (*Eucalyptus chloroclada/E. blakelyi/E. camaldulensis*) represented between 9% and 16% of sites in all fauna groups. Consequently a combination of environmental features and fauna and flora composition was necessary to characterise these communities and subcommunities within them. These are listed in Table X and described below.

Group 1 "Northern" – This community is tentatively labelled "northern", as one of the most consistent features of the constituent sites is their location in the northern parts of the bioregion. All of the sites from the Yetman area and most of those south to Narrabri supported this community (map patn groups). Additionally, a number of sites from other areas also supported this community, such as from the Liverpool Plains, Coonabarabran area and Kerringle SF. Dominant vegetation types were diverse, as were soil and landscape characteristics. Fauna species contributing to the separation of this group from others included the more frequent occurrence of several bird species typical of shrubby woodlands (speckled warbler, striped honeyeater and golden whistler) and species associated with warmer areas to the north or east (pale-headed rosella, brown honeyeater and *Cryptoblepharus virgatus*) (Appendix 11). The unique species in this community were also mostly typical of warmer areas (Appendix 11). The average site species richness within this group was moderate (Table Y), although this masks several extreme sites, with two of the four least species-rich sites supporting this community. These were both ridge sites in Bebo SF, with vegetation dominated by *Acacia cheelii* and *E. fibrosa.* This community was represented at 29% of fauna sites. Two subcommunities were recognised:

Mixed – The sites supporting this subcommunity were of mixed characteristics. However, nearly all sites with vegetation dominated by *E. melanophloia* and *Acacia cheelii* supported this subcommunity. This subcommunity also tended to occur in larger blocks of woody vegetation than the northern slopes subcommunity, and in sandy to rocky areas.

Northern Slopes – This subcommunity was reasonably well defined in terms of the environmental conditions in which it occurred. These were in a narrow belt of vegetation along the slopes west of the Nandewar Range, from south of Terry Hie Hie north to near Coolatai. Most dry rainforest sites (ooline *Cadellia pentastylis* and dry vine thicket) were classified here as were a number of box-dominated sites. The box sites included those dominated by *E. albens, E. pilligaensis* and *E. populnea*. These box trees (with *Casuarina cristata*) also occurred often as an emergent canopy above the dry rainforest sites. This subcommunity was mostly recorded from clay soils derived from basalt and in small woody vegetation remnants or on the edge of larger remnants (typically where clay soil types just reached the edge of larger State Forests, which were mostly on sandy soils).

Group 2 "Central sandstone areas" – The bulk of survey sites that supported this faunal community were located within a limited number of large forest blocks; West Pilliga, East Pilliga and Pilliga NR, and Cobbora and Goonoo SFs. Ironbark communities predominated and most sites were in State Forest. Many species were more frequent at sites in this community. These included species typical of open forests, particularly on less fertile soils, such as *Nyctophilus timoriensis, Antechinus flavipes,* inland thornbill, mallee ringneck and white-eared honeyeater. Species typically absent included a number of woodland birds associated with sites of higher soil fertility and more open areas, such as white-plumed honeyeater, willie wagtail and brown treecreeper. Sites with this community were the most species rich on average of all the communities and the most frequently recorded (35%) of all sites. Two subcommunities were identified:

West Pilliga – These sites were predominantly from West Pilliga SF (81%), with a couple also from north-east of Narrabri. Only one site from West Pilliga was not classified into this subcommunity. This indicates that West Pilliga as a whole is relatively distinctive in faunal composition. Species that were particularly distinctive for West Pilliga included grey-crowned babbler, chestnut-rumped thornbill and *Phascolarctos cinereus*. Absent were several species more common in rugged areas, such as buff-rumped thornbill and *Ctenotus robustus*. Vegetation types and soils were mixed, suggesting that the some other aspect/s of being located in West Pilliga was the dominant influence on the classification.

East Pilliga/Goonoo – Most sites with this subcommunity were located in the East Pilliga, Pilliga NR, Goonoo, Cobbora and Gilgandra areas. Ironbark habitat types were predominant (*E. crebra, E. fibrosa* and *E. nubila*) with some red gums and mallee types. Species distinguishing these sites from West Pilliga were the frequently occurring red wattlebird, chestnut-rumped heathwren and buff-rumped thornbill. Several species more widespread in western habitats, such as *Egernia striolata* and *Gehyra variegata*, were mostly absent. Among the species found only in this community were two mallee and shrubby open forest specialists, malleefowl and Gilbert's whistler.

Group 3 "Eastern fauna" Sites within this group (25% of total) covered a diverse range of habitats but were characterised by the occurrence of species associated with eastern or higher areas. The three subcommunities were each relatively well defined, but as a whole community there was little commonality among location, soil type or vegetation. Species frequently recorded across the community included crested shrike-tit, cicadabird, white-throated gerygone and *Pseudocheirus peregrinus*. The greatest number of unique species was found from this community. This probably reflects the occurrence of a number of typically eastern species, such as channel-billed cuckoo, crimson rosella, Lewin's honeyeater and *Bassiana platynota*. Sites with this community were moderately species-rich, although this includes the site with the greatest single count of species, an *E. pilligaensis* site in Leard SF. Three subcommunities were identified:

Box - These sites were overwhelmingly dominated by box vegetation types (mostly *E. albens*, but also some *E. pilligaensis* and *E. populnea*) and located in the central BBS, from Coonabarabran (including the Warrumbungles) to the northern Liverpool Plain. Most of the sites were in small to medium remnants, or occasionally on the edge of large forest patches. Typical species included a number of woodland birds recognised as being in decline in temperate woodlands(Reid 1999, Traill and Duncan 2000), such as brown treecreeper, dusky woodswallow and jacky winter.

Nandewar – Most of these sites were in the Nandewar bioregion, in medium to large blocks of woody vegetation. A number of species with eastern affinities were recorded, and fewer western species (emu, mallee ringneck, inland thornbill).

Ranges –Sites with this subcommunity were spread over two broad areas, Warrumbungles - Pilliga NR and Mt Kaputar - Deriah SF. These areas are the highest in altitude and include the most rugged areas sampled. Vegetation types were mixed, but nearly all of the sites dominated by *E. rossii* and *E. macrorhyncha* supported this subcommunity. Unlike all other subcommunities, sites in this group were predominantly from conservation reserves. Higher elevation species (at least in the BSS) most frequent in this subcommunity include crimson rosella, eastern spinebill, *Egernia saxatilis saxatilis* and *Christinus marmoratus*. Species mostly absent include some of those most widespread through the remainder of the bioregion, such as *Morethia boulengeri* and striped honeyeater.

Group 4 – "Depauperate" Sites classified as supporting this fauna community were distributed sparsely throughout the BBS and also in the DRP, and formed 11% of survey sites. Most vegetation types were represented, although none were particularly frequent. The community was found in all survey sites in the DRP, and unlike all other communities, was predominantly recorded from sites on private tenure. Travelling stock reserves were also frequent locations at which this fauna community was recorded. The characteristic of this community was its occurrence in small patches of remnant vegetation, thin strips along roads or watercourses, or within several hundred metres of the edge of medium-sized forest blocks. The Depauperate community was the least species rich per site on average (Table Y) and the most divergent from the other groups in classification and ordination. The species lacking in this community mostly were birds of open forests and woodlands, such as rufous whistler, yellow-faced honeyeater, yellow thornbill and grey fantail. Many of the bird species regarded as being decline in temperate woodlands (Reid 1999, Traill and Duncan 2000) were more infrequently recorded in this community. These declines are thought to be due to the removal and fragmentation of native vegetation and the correlated impacts of predation by and competition with successful species, eucalypt dieback, grazing and wood harvesting (Reid 1999). Alternatively, a number of species were more frequently recorded in this fauna community. These were mainly species tolerant to or exploiters of habitat disturbance (noisy miner, Australian magpie and Australian raven), typical of open country (blue bonnet and cockatiel) or of clay-soil plains (*Pseudechis guttatus* and several frog species). The latter group was mainly recorded in the DRP survey, as clay-soil plains were poorly sampled in BBS 1 and 2. There were a large number of unique species, most of which were frogs or open-country birds. No subcommunities were identified, although some sites within this community were quite divergent on the ordination compared to the other sites with the community. This may be a consequence of this community being characterised to a large extent by species that are absent, rather than by species which are recorded as being present. It is unlikely that this community would have existed in its current composition prior to human-induced landscape changes. The constituent sites would have been distributed through the other communities, or the DRP group forming a distinct community on the north-western fringe of the BBS.

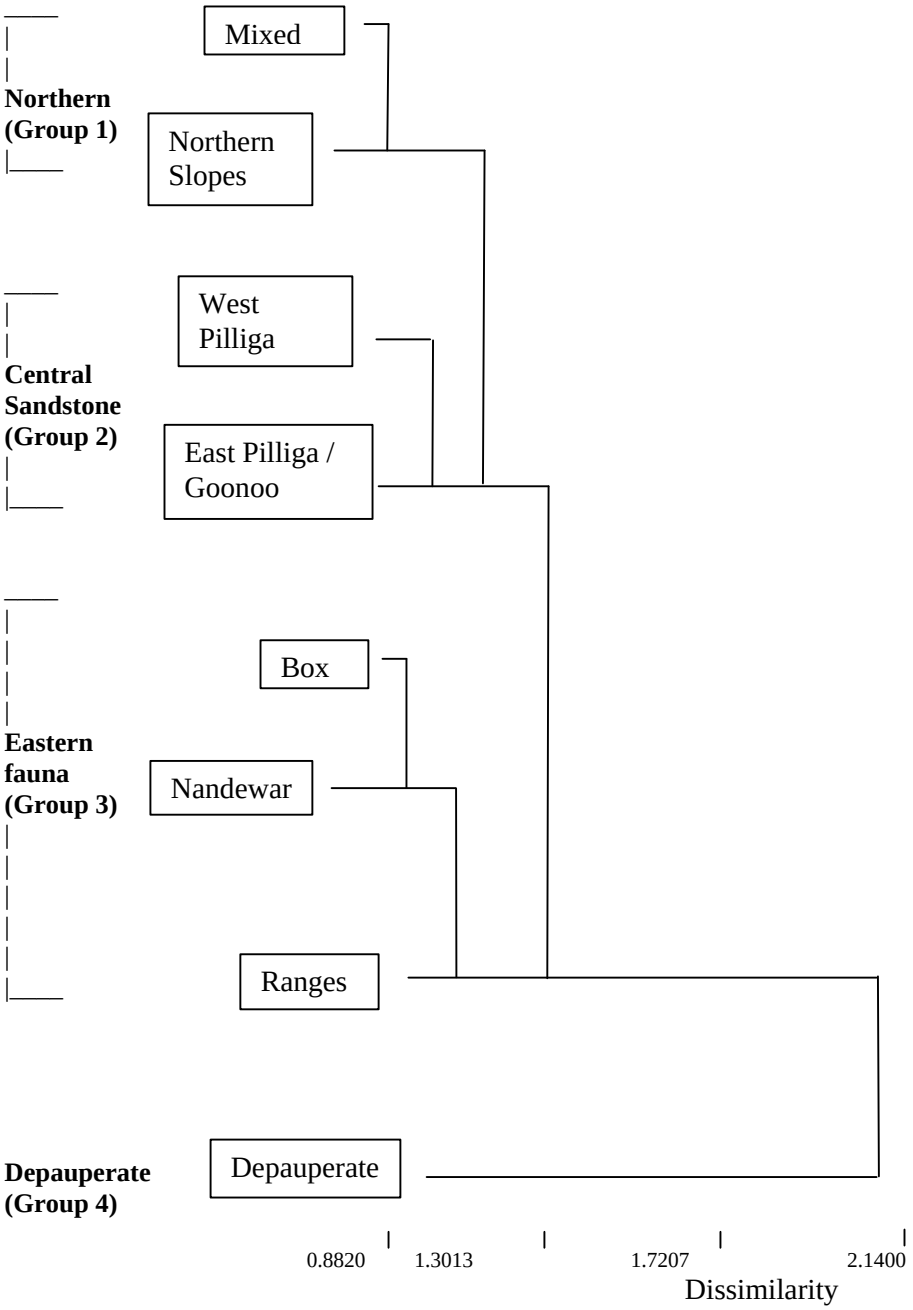


Figure 1.9 Dendrogram of fauna communities identified in *PATN* analysis of fauna composition of systematic survey sites

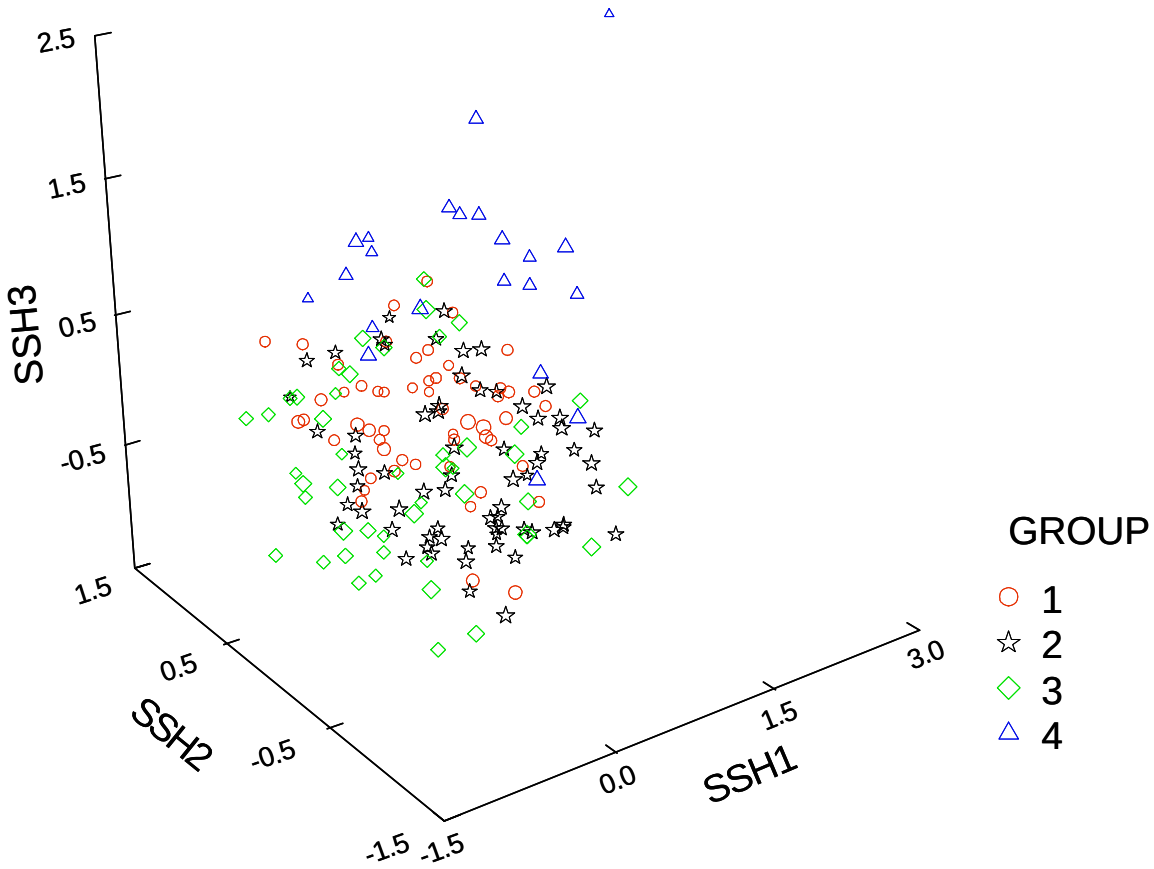


Figure 1.10 Ordination of all fauna survey sites by their vertebrate species composition (presence/absence), showing the four site groups (communities)

Three dimensional ordination; stress = 0.27. Group 1 = Northern; 2 = Central sandstone areas; 3 = Eastern fauna; 4 = Depauperate

In principal axis correlation, the optimal location and orientation of individual fauna species can be placed relative to the same axes as the sites ordination (Figure 1.11). Although the correlations were not strong (those with r>0.35 are plotted), this gives an indication of the species contributing most to the separation of sites along these axes. The most striking differentiation is the orientation of open country and broadly disturbance tolerant species towards the top of the ordination, and forest and woodland species towards the bottom. This corresponds to the directions of the Depauperate fauna community and the Eastern and Central Sandstone communities respectively. Most of the species orientated to the top right were particularly, or exclusively, widespread in the DRP. These species included a number of amphibians, reflecting the wet conditions at the time of the DRP surveys (Gosper, in prep) and open county birds, such as apostlebird and crested pigeon. Species in the top left of the ordination, such as noisy miner and galah, are more widespread. These species still are associated with open habitats and are tolerant of disturbance,. Golden whistler, pale-headed rosella and *Gehyra dubia* are orientated behind the other species (indicated by the smaller font size on Figure 1.11), and were mainly found at Northern fauna community sites (also in the background of the ordination in Figure 1.10). The bottom half of the ordination contains species mostly widespread in all fauna communities except for within Depauperate, although with a trend from more frequent occurrence in Central Sandstone sites on the right to Eastern fauna sites on the left.

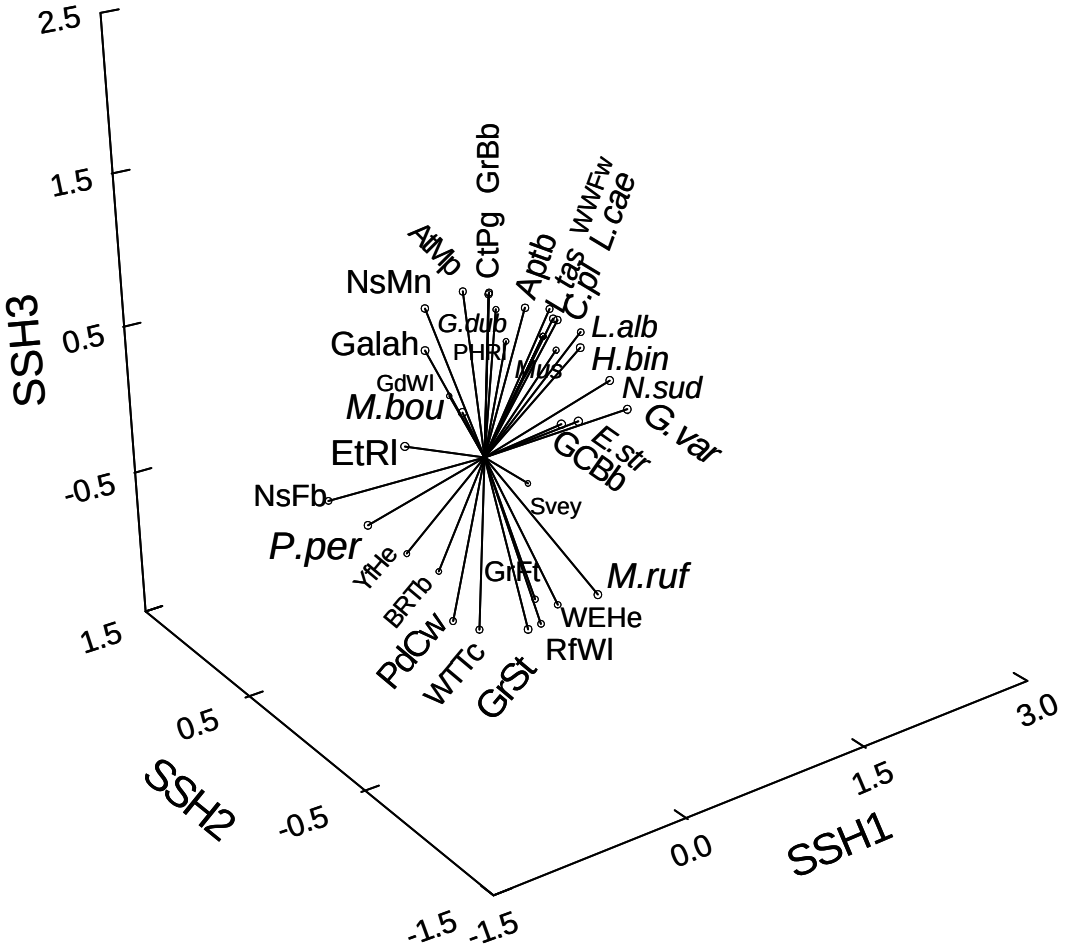


Figure 1.11 Direction of vertebrate species vectors within the ordination of sites by vertebrate species composition (see Figure 1.10)

Vectors shown in three dimensions. Only species with a correlation coefficient r>0.35 are shown. Codes: NsFb – noisy friarbird; *P. per – Pseudocheirus peregrinus*; YfHe – yellow-faced honeyeater; BRTb – buff-rumped thornbill; PdCw – pied currawong; WTTc – white-throated treecreeper; GrSt – grey shrike-thrush; GrFt – grey fantail; RfWl – rufous whistler; WEHe – white-eared honeyeater; *M.ruf – Macropus rufogriseus*; Svey – silvereye; GCBb – grey-crowned babbler; *E.str – Egernia striolata*; *G.var – Gehyra variegata*; *N.sud – Neobatrachus sudelli*; *H.bin – Heteronotia binoei; L.alb – Litoria alboguttata; Mus – Mus musculus; C.pl – Cyclorana platycephala; L.cae – Litoria caerulea; L.tas – Limnodynastes tasmaniensis;* WWFw – white-winged fairy-wren; Aptb – apostlebird; PHRl – pale-headed rosella; CtPg – crested pigeon; GrBb – grey butcherbird; *G.dub – Gehyra dubia*; AtMp – Australian magpie; NsMn – noisy miner; GdWl – golden whistler; *M.bou – Morethia boulengeri;* EtRl – eastern Rosella.

TABLE X – CHARACTERISTICS OF FAUNA GROUPS (COMMUNITIES) AND SUBGROUPS (SUBCOMMUNITIES) DERIVED FROM *PATN* ANALYSIS OF SYSTEMATIC SITE SURVEY DATA

The characteristics are general or uniform features across the sites within each subgroup, except where they are noted as being mixed. Species present and absent identify some of those species that are present in relatively high proportion of sites within the subgroup, or absent from most sites within the subgroup but widespread in many other subgroups. These lists are not exhaustive and can be further examined in Appendix 11.

Fauna group	**Northern (1)**		**Central sandstone areas (2)**		**Eastern fauna (3)**			**Depauperate (4)**
Subgroup	**Mixed**	**Northern Slopes**	**West Pilliga**	**East Pilliga/Goonoo**	**Box**	**Nandewar**	**Ranges**	
Location	Predominantly in the north of the BBS (Yetman-Warialda, Pallamallawa-Narrabri), some Coona-Kerringle, Liverpool Plains	Thin band from Terry Hie Hie north to Planchonella Hill NR	Nearly all from west Pilliga, few sites north-east of Narrabri	Nearly all from East Pilliga, Pilliga NR, Goonoo, Cobbora and Gilgandra areas.	Central BBS, from Coona through East Pilliga and Kerringle to Liverpool Plains	All in Nandewar except for one site in Deriah SF (east edge of BBS). Nandewar sites in Warialda and Playgan SFs	Most sites in the Coon-Pilliga NR area, some in Kaputar area (Deriah SF and Mt Kaputar NP), scattered sites elsewhere.	All sites from DRP - BBS sites scattered across bioregion
Vegetation community	Mixed – contains most *E. melanophloia* & *Acacia cheelii* sites	DRF sites (ooline, dry vine thicket) and box (*E. albens, E. populnea, E. pilligaensis*)	Mixed – *E. crebra, E. populnea, E. pilligaensis*, red gum and *Casuarina cristata*	Mostly ironbark – *E. crebra, E. fibrosa* & *E. nubila*, some red gum & most of the mallee/broombush sites	Box (mostly *E. albens*, some *E. pilligaensis, E. populnea*), few other types	Part unknown, but some *E. albens, E. crebra, E. fibrosa* & *E. dealbata*	Most of the *E. rossii* & *E. macrorhyncha* sites, some red gum, *E. albens*.	Mixed
Soils	Mostly sandy to rocky, rarely clay	Mostly clays, some rocky	Mixed	Mostly sandy to rocky	Mostly clays	Unknown	Mostly sandy to rocky	Mostly clays, some sands
Landscape	Small to large SFs and reserves, mostly in large patches of woody vegetation	Smaller SFs and reserves (isolated), some on edge of larger remnants	Large block of woody vegetation in west Pilliga	Mostly in large blocks of woody vegetation	Mostly small to medium remnants, some edge of larger blocks	Mostly in medium to large blocks of woody vegetation	Mostly large blocks of woody vegetation	Small patches of remnant vegetation, thin strips or on edge of medium-sized blocks
Tenure	Mostly SF, few	Mostly SF	Nearly all SF	Mostly SF, some	Mostly SF,	Nearly all SF,	NP/NR the largest	Mostly private,

Fauna group	**Northern (1)**		**Central sandstone areas (2)**		**Eastern fauna (3)**			**Depauperate (4)**
Subgroup	**Mixed**	**Northern Slopes**	**West Pilliga**	**East Pilliga/Goonoo**	**Box**	**Nandewar**	**Ranges**	
	NP/NR, private and TSR	and NR		NR and private	some NR and private	some crown land	tenure category, some SF and private	few SF and TSR
Species present	golden whistler, speckled warbler, striated pardalote, *Cryptoblepharus virgatus*	pale-headed rosella, brown honeyeater, golden whistler, double-bar finch	grey-crowned babbler, chestnut-rumped thornbill, *Phascolarctos cinereus, Gehyra variegata*	*Nyctophilus timoriensis, Macropus rufogriseus*, red wattlebird, chestnut-rumped heathwren, inland thornbill, glossy black cockatoo	fuscous honeyeater, white-bellied cuckoo-shrike, brown treecreeper, dusky woodswallow	*Chalinolobus morio, Anomalopus leuckartii*	crimson rosella, eastern spinebill, fan-tailed cuckoo, *Pseudocheirus peregrinus*	noisy miner, crested pigeon, Australian magpie, apostlebird, *Limnodynastes tasmaniensis*
Species absent	grey-crowned babbler, mallee ringneck, galah	*Nyctophilus timoriensis*, white-winged chough, Common Bronzewing	Australian magpie, buff-rumped thornbill, *Ctenotus robustus*	*Gehyra dubia, Egernia striolata,* white-plumed honeyeater	buff-rumped thornbill, white-eared honeyeater, *Scotorepens balstoni*	emu, mallee ringneck, inland thornbill, *Diplodactylus williamsi*	Striped honeyeater, grey butcherbird, *Morethia boulengeri*	yellow-faced honeyeater, yellow thornbill, white-eared honeyeater, white-throated gerygone
Unique species	*Anomalopus mackayi, Oedura rhombifer, Macropus dorsalis, Vespadelus troughtoni*	spangled drongo	barking owl	malleefowl, Gilbert's whistler, spotted nightjar	masked woodswallow	*Eulamprus quoyii, Limnodynastes dumerilii,* common koel	Australian brush-turkey, *Egernia saxatilis saxatilis, Christinus marmoratus*	blue bonnet, *Cyclorana platycephala, Denisonia devisi*

4.2.6 Distribution of threatened species among faunal communities

Twenty-six species listed as threatened on the *TSC Act 1995* were recorded at systematic fauna survey sites and included in the *PATN* analysis. Additional threatened species were detected and many additional records were collected opportunistically during the project. Threatened species were distributed in all fauna communities identified, although several threatened species were recorded only from sites within one community. Greater detail about the records of individual threatened species is contained in the Species Profiles appendix of this report (Appendix 2).

The Central Sandstones fauna community was the community from which the greatest number of threatened species, those threatened species widespread within the community (>25% of its sites) and unique threatened species were recorded. This community contains the largest number of sites (69) and therefore would be expected to have more threatened species records than other smaller communities. However, there seem to be factors other than site numbers influencing the relatively high number of threatened species recorded. This community appears to be particularly important for two declining woodland birds (speckled warbler and grey-crowned babbler); in addition to *Phascolarctos cinereus*, glossy black cockatoo and *Nyctophilus timoriensis* (Table Y). RACD (2000b) identifies the BBS as an important stronghold for *N. timoriensis* in NSW, and this analysis indicates that the Central Sandstone community, which is mostly found in the Pilliga and Goonoo areas, is the most significant for the species in the entire BBS bioregion.

The Northern fauna community contained a moderate number of threatened species, widespread threatened species and unique threatened species (Table Y). Of particular interest is the extremely high proportion of sites (71%) at which the speckled warbler was recorded. This would indicate that the north-eastern fringe of the BBS, north-east of Narrabri (where the bulk of sites with this community were located), is particularly important for this species.

The Eastern fauna community contained no threatened species unique to that community. It contained only moderate numbers of threatened species and few widespread threatened species. This community appears to be particularly important for two woodland birds, brown treecreeper and speckled warbler. Brown treecreepers were most widespread in the box subcommunity, indicating the importance of appropriate management of woodlands and open forest of *E. albens* and *E. pilligaensis* for this species.

The Depauperate community contained a moderate number of threatened species and only one species, the grey-crowned babbler was widespread. Currently this species appears to be persisting in open forests and woodlands where other woodland-dependent bird species have disappeared. Remnant woodlands, especially those in the centre and west of the bioregion and into the DRP (Gosper in prep), are critical for this species. Many of these woodlands are under private management or in crown reserves, such as TSRs.

Threatened species recorded infrequently would not have contributed substantially to community classification. Many of these species have been included in the individual species analysis (Section 4.3.8) and the Species Profiles (Appendix 2).

TABLE Y – SPECIES COMPOSITION OF THE FAUNAL COMMUNITIES DERIVED FROM THE CLASSIFICATION OF SITES BY THE PRESENCE/ABSENCE OF VERTEBRATE FAUNA

Communities were derived from PATN analysis of presence/absence data. Four communities were based on *FUSE* of *B*-value of -0.2. Only species listed on the *Threatened Species Conservation Act 1995* are included in this table. Table shows frequency of species at sites in each community. Species are in the same order as the dendrogram for species classification. Numbers in bold = species widespread in community (present in over 25% of constituent sites), number in italics = unique to community. Community 1 = Northern; 2 = Central Sandstone; 3 = Eastern fauna; 4 = Depauperate. Total vertebrate fauna composition of communities is included in Appendix 8.
* brown treecreeper has been included, although only one of the two subspecies occurring in the BBS is listed as threatened. Subspecies were not distinguished in the field.

Fauna community		**1**	**2**	**3**	**4**
Number of sites		56	69	48	22
Mean species richness (all fauna)		34.9	40.0	35.1	29.5
Number of unique species (all fauna)		10	14	17	19
Common Name	**Species**				
Greater Long-eared Bat	*Nyctophilus timoriensis*	7	**41**	21	5
Speckled Warbler	*Chthonicola sagittata*	**71**	**42**	**27**	9
Grey-crowned Babbler	*Pomatostomus temporalis*	7	**30**	8	**41**
Pilliga Mouse	*Pseudomys pilligaensis*	4	16		
Glossy Black-cockatoo	*Calyptorhynchus lathami*	5	**26**	2	14
Koala	*Phascolarctos cinereus*	7	**29**	15	
Squirrel Glider	*Petaurus norfolcensis*	4	6	8	5
Turquoise Parrot	*Neophema pulchella*	9	12	17	
Brown Treecreeper*	*Climacteris picumnus*	13	6	**54**	9
Malleefowl	*Leipoa ocellata*		*1*		
Square-tailed Kite	*Lophoictinia isura*		*1*		
Gilbert's Whistler	*Pachycephala inornata*		*1*		
	Anomalopus mackayi	*2*			
Black-striped Wallaby	*Macropus dorsalis*	*4*			
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	5	1	10	
Little Pied Bat	*Chalinolobus picatus*	4	3	2	
Diamond Firetail	*Stagonopleura guttata*	2	3	2	5
Barking Owl	*Ninox connivens*		*3*		
Pale-headed Snake	*Hoplocephalus bitorquatus*		3		9
Masked Owl	*Tyto novaehollandiae*	4	1	2	5
Eastern Pigmy-possum	*Cercartetus nanus*		*6*		
Painted Honeyeater	*Grantiella picta*	11	1	2	
	Vespadelus troughtoni	*4*			
Hooded Robin	*Melanodryas cucullata*		1	2	5
Black-chinned Honeyeater	*Melithreptus gularis*	2		4	
Large Pied Bat	*Chalinolobus dwyeri*		1	6	
Number of threatened species		18	22	16	10
Number of widespread threatened species		1	5	2	1
Number of unique threatened species		3	5		

4.2.7 Relationship to environmental variables

A range of environmental, habitat structural and survey-specific variables were applied to the communities to determine those most strongly associated with the site classification. The extent to which the variable discriminated between the communities was assessed by the Kruskal-Wallis statistic (Table Z).

The most highly significant variables affecting species presence were:

- Location (longitude and latitude);
- Some survey methodology variables (pitfall, hair-tube and Elliott trap-nights);
- Climatic (rainfall, temperature and radiation);
- Measures of land clearance and fragmentation (amount of woody vegetation nearby, distance to clearing);
- Tenure;
- Soil drainage and fertility; and
- The site-specific habitat variables of; trees and stags (tall, standing dead trees) in the 10-50cm dbh size class, and extent of bare ground covered.

Several other site-specific habitat variables also were strongly discriminating between faunal communities, although at a lower level of significance. Many of the variables were correlated, which complicates interpreting their significance.

TABLE Z – ABILITY OF ENVIRONMENTAL, HABITAT STRUCTURAL AND METHODOLOGICAL VARIABLES TO DISCRIMINATE BETWEEN FAUNAL COMMUNITIES

Variable listed in decreasing order of the Kruskal-Wallis statistic. Variables in non-bold font are related to another variable with a higher Kruskal-Wallis statistic. The correlation of the environmental, habitat structural and methodological variable with the ordination of sites by vertebrate species composition (Figures 1.10 and 1.12) is shown (r).
* Neither pitfall traps of hair-tubes were used in this project. However, they were used in other survey projects (section 4.2.2) and were hence included as a possible confirmatory variable in the analysis.

p<0.001	**r**	**p<0.01**	**r**	**p<0.05**	**r**	**Not significant**	**r**
Decimal longitude	0.39	Disturbance	0.27	Tree cover	0.34	Herp search effort	0.23
*Pitfall trap-nights	0.63	Distance to stream	0.23	Trees >50cm dbh	0.21	Number of logs	0.11
Annual rainfall	0.53			Number of hollows	0.26	Litter cover	0.32
Precipitation wettest quarter	0.41					Topographic index	0.23
Woody vegetation within radius 10km	0.52					Shrub cover	0.27
Woody within 5km	0.54					Ground vegetation cover	0.24
Elliott trap-nights	0.63					Nocturnal search effort	0.11
*Hair-tube trap-nights	0.39					Stags >50cm dbh	0.18
Bird census duration	0.44					Cryptogamic cover	0.12
Distance to clearing	0.27					Anabat period	0.15
Minimum temp. coldest period	0.66					Opportunistic records	0.06
Highest period radiation	0.61					Playback effort	
Woody within 1km	0.62						
Mean annual temperature	0.65						
Decimal latitude	0.51						
Annual mean radiation	0.60						
Precipitation driest quarter	0.59						
Number of birds censuses	0.40						
Tenure	0.33						
Maximum temp. warmest period	0.61						
Soil Drainage	0.42						
Harp trap-nights	0.34						
Soil fertility	0.51						
Cover of bare ground	0.30						
Stags 10-50cm dbh	0.31						
Trees 10-50cm dbh	0.31						

The distribution of the environmental variables among the fauna communities provides some guide as to the character of those communities This is relevant, particularly, when identifying which features of the environment may be influencing or determining the communities' separation. Longitude and latitude are presumably surrogates for a range of climatic patterns and land use variables across the BBS. The "Northern" group are the most easterly and northerly on average, reflecting the occurrence of most of the sites north-east of Narrabri in this community. The Central sandstone areas were the most southerly and westerly, reflecting the survey sites in Goonoo and West Pilliga. The survey methodology variables identified as highly significant are likely to be spurious, reflecting survey project differences rather than the impact of the methodologies themselves. Pitfall trap effort was highest in the Depauperate community. This is because all sites in the DRP biodiversity assessment (the only survey project in which pitfall traps were used) were classified into this faunal community. However, the distinctiveness of the Depauperate community is largely due to the absence of many species of woodland birds widespread elsewhere and the frequent occurrence of many open country species. The detection of these species was independent of pitfall trapping effort, but as a consequence of survey project methodology. Similarly, the significance of Elliott trap-nights is due to the lower standard effort at the DRP sites (compared with BBS 1 and 2), which again has no influence on the detection of birds, the main difference between Depauperate community and the other communities.

The three main climatic variables, measures of temperature, precipitation and radiation, all follow the same pattern. Rainfall variables (annual rainfall, precipitation in the driest and wettest quarter) are highest for the "Eastern fauna" community and lowest at the Depauperate community. All temperature variables (minimum temperature coldest period, mean annual temperature, and maximum temperature warmest period) identify the Eastern fauna community as being the coolest on average, and the Depauperate community being the warmest. Highest period radiation is also lowest among the Eastern fauna community sites, suggesting more frequent occurrence on southerly aspects. Each of these variables indicates the Eastern fauna community as occurring in wetter and cooler areas. This is supported by the fauna characteristic of these sites, with species typical of cooler (such as higher elevations, *e.g.* crimson rosella, *Crinia signifera*) and wetter (*e.g.* eastern spinebill, *Chalinolobus morio*) areas. The Depauperate community appears to occur in warmer and drier areas, and this is supported by the frequent occurrence of northern (*e.g.* pale-headed rosella, *Litoria alboguttata*) and western (*e.g. Cyclorana platycephala,* crested pigeon) species.

Human-induced landscape changes are also associated with particular faunal communities. The amount of surrounding woody vegetation (at scales of one, five and ten km), distance to the nearest clearing, and a composite disturbance measure were each important. The distance to clearing and amount of surrounding woody vegetation were all substantially lower for the Depauperate community that the other communities. Among the other communities, sites of the Central Sandstone community were typically in the least cleared and fragmented. The composite disturbance measure was also greatest on average at Depauperate community sites.

These differences appear to be having a direct effect on the fauna composition of sites classified as having the Depauperate community. Most of the bird species identified by Reid (1999) as declining in the NSW sheep-wheat belt were recorded less frequently at sites of the Depauperate community. Rufous whistlers, for example, were recorded at over 80% of survey sites in all other communities, but at only 9% of sites of the Depauperate community. Likewise, eastern yellow robins were found at over 70% of sites in each other groups, but at only 18% of sites in the Depauperate group. Land clearance and habitat fragmentation are regarded as the main factors influencing these declines (Reid 1999). An obvious exception to this pattern was the occurrence of the grey-crowned babbler, which was most widespread among sites of the Depauperate community. Reid (1999) and Gosper (in prep), however, recognise that the current status of the grey-crowned babbler in northern NSW differs from that in southern Australia. Many other bird species of woodlands and open forests not yet

regarded as being in widespread decline were also recorded substantially less frequently among the Depauperate community, such as yellow thornbill, white-eared honeyeater, noisy friarbird and silvereye.

Conversely, many of the species identified by Reid (1999) as increasers in the NSW sheep-wheat belt were more frequently or equally most frequently recorded within the Depauperate community. These species include the Australian magpie, Australian raven, magpie-lark, noisy miner, galah and crested pigeon. Artificially high abundance of several of these species has been implicated in the decline of small passerine birds through nest predation (Australian raven and Australian magpie, Major *et al.* 1996) and competition (noisy miner, galah, Clarke *et al.* 1995, Garnett and Crowley 2000).

The composition of the Depauperate fauna community lends weight to the suggestion that land clearance and fragmentation effects have been particularly important in determining community composition, and the distinction of this community from the others identified. However, several of the site-specific habitat variables previously identified as being significant to declining woodland birds, such as shrub cover and number of logs (Seddon *et al.* 2001), were not significantly lower in the Depauperate community sites.

A variety of site-specific habitat features were significantly distributed between faunal communities. Tree cover and trees in the 10-50 cm size class were on average lower in number within the Depauperate community than elsewhere. Recording of trees greater than 50 cm dbh (diameter at breast height) and of total numbers of hollows, indicate that the Eastern fauna and Depauperate community sites have more large trees and hollows, while Northern and Central Sandstone communities have more small trees and less hollows. Sites with the Eastern fauna community also more frequently had loose and falling bark. Trees and stags in the 10-50 cm size class were most abundant in the Northern fauna community.

These habitat structural differences have important implications for fauna. It is of interest, for example, to investigate whether the faunal communities that occur at sites with larger trees and more hollows support more arboreal mammals, as has been found elsewhere (*e.g.* Soderquist and Mac Nally 2000). There is evidence in this study that this is the case for the larger arboreal mammals, *Trichosurus vulpecula* and *Pseudocheirus peregrinus*, which require large hollows (Soderquist and Mac Nally 2000). Both of these species are known historically from throughout the BBS. *Trichosurus vulpecula* and *P. peregrinus* were substantially more frequently detected at sites supporting the Eastern fauna community which has, on average, the most large trees and hollows. In the Depauperate communities and in the Northern and Central Sandstone communities the *Trichosurus vulpecula* and *P. peregrinus* were recorded as being relatively less widespread. There is a relatively high degree of nearby land clearance and fragmentation in these areas. This suggests that the lower number of large trees and hollows in the Northern and Central Sandstone communities may be as deleterious to *T. vulpecula* and *P. peregrinus* as fragmentation of habitat. There is no evidence of a similar effect across the diversity of arboreal mammal species requiring small hollows, such as *Antechinus flavipes, Petaurus brevipes, P. norfolkensis, Cercartetus nanus* and *Acrobates pygmaeus*, some of which were found more frequently in Northern and Central Sandstone communities than elsewhere.

The tenure of the fauna communities with the lowest abundance of hollows and large trees from the structural vegetation measurements taken at survey sites is mainly State Forest (more than 65% of sites within each community). The communities with more large trees and hollows are mainly on private land (Depauperate community) or on a mixture of State Forest, conservation reserve, crown land and private (Eastern fauna community). This distribution of tenure is not independent of other factors, such as soil fertility and rainfall, that may influence the abundance of hollows, large trees and large arboreal mammals. It is suggested that hollows may be limiting for the large arboreal mammals at the sites surveyed in the Central Sandstone and Northern communities. This requires further investigation. RACD (2000b)

came to a similar conclusion regarding the distribution of large arboreal mammals and large and small hollows in State Forests in the Pilliga. State Forests make up a large portion of the sites of the Central Sandstone community.

Tenure was also correlated significantly with the fauna community classification. As noted above, the Depauperate community was predominantly recorded from private property. This indicates that many woodland bird species have been lost from habitat remnants on private property. Similar losses of woodland birds are not apparent from the other fauna communities.

Soil fertility was on average higher from sites of the Depauperate Community. This is not thought to indicate that fertile soil in itself is associated with reduced occurrence of many woodland bird species, rather that soil fertility is correlated with agricultural practices including land clearance, which as have been shown to have substantial impacts on woodland birds.

Each of these environmental attributes was applied in principal axis correlation to investigate which sections of the ordination with which they were most strongly correlated. The most strongly correlated variables ($r>0.5$) are shown in Figure 1.12. These were all identified as being particularly significant in the previous section. Soil fertility, pitfall trapping effort, high radiation and high temperature were all orientated towards Depauperate community sites (see Figure 1.10). Latitude was orientated towards Northern sites, and woody vegetation measures towards Eastern Fauna and Central Sandstone sites (and away from Depauperate sites). The Elliott and rainfall variables were most associated with the direction of Eastern Fauna sites.

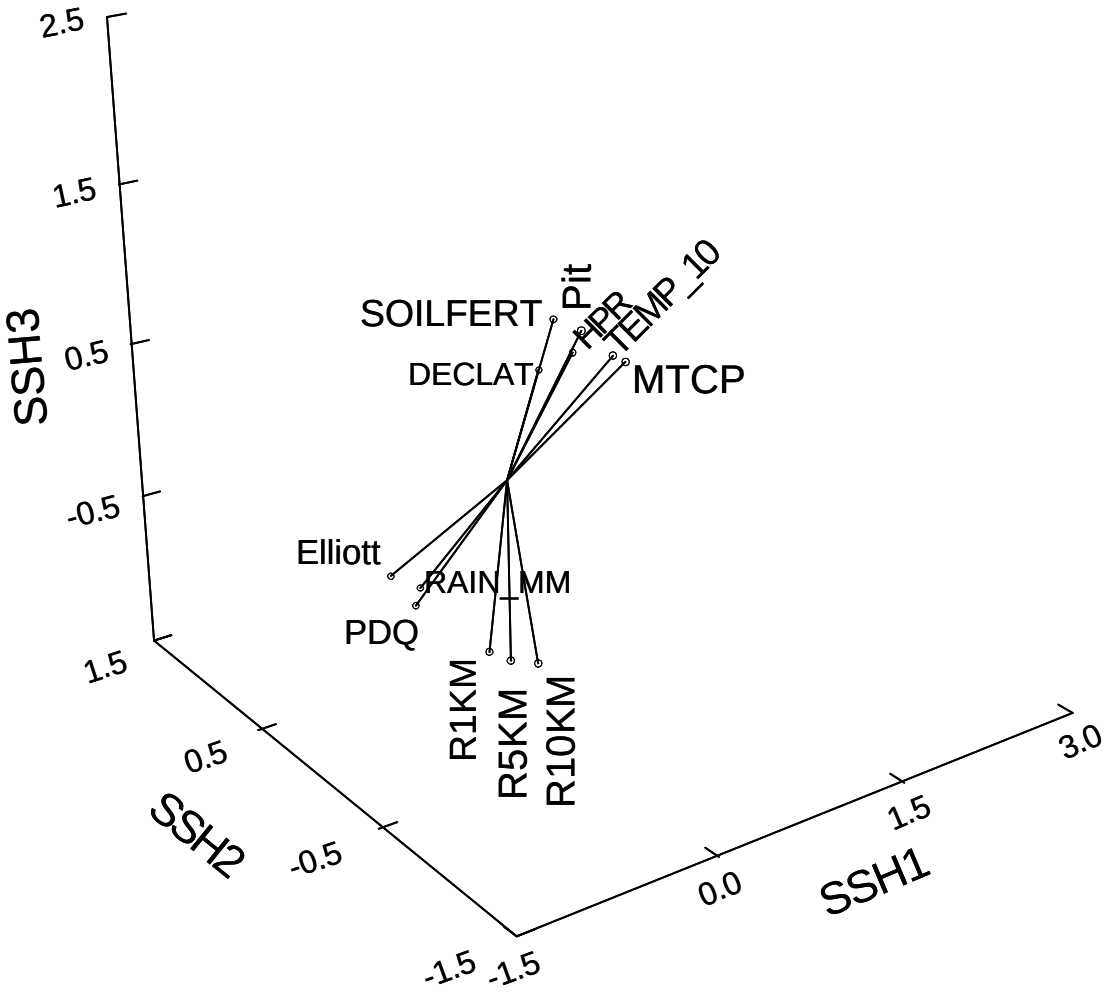


Figure 1.12 Direction of environmental vectors within the ordination of sites by their vertebrate species composition

Vectors shown in three dimensions. Only those variables with a strong correlation with the ordination (r>0.5) are shown. Codes: Elliott = number of Elliott trap nights RAIN_MM = annual precipitation; PDQ = precipitation in the driest quarter; R1KM = amount of woody vegetation within a 1km radius; R5KM = 5km radius; R10KM = 10km radius; MTCP = minimum temperature coolest period; TEMP_10 = annual mean temperature; HPR = highest period radiation; Pit = number of pitfall trap nights; SOILFERT = soil fertility index; DecLat = decimal latitude.

4.2.8 Plant species, vegetation type and faunal site communities

An objective of this project was to identify linkages between faunal communities and vegetation communities, and to feed such information into regional planning bodies/organisations, such as RVCs and CMBs (section 1.3.2) (which typically use vegetation type as a surrogate for biodiversity). Matching fauna species to broad vegetation type was the approach followed in RACD (2000b). In this report, sites were classified by their faunal composition and the environmental variables were identified that most strongly associated with this classification. The vegetation at fauna sites was one of the environmental variables used in correlation with the fauna classification.

Plant species correlations

All plant species recorded at more than five fauna survey sites were applied in Principal axis correlation to identify which were the most strongly correlated in the ordination of sites by their fauna composition (Figure 1.10). Correlations were not high (those >0.34 are plotted in Figure 1.13), and few of the species that dominate communities were among those most strongly correlated. Exceptions were *Callitris endlicheri*, which appears to be orientated towards the Central Sandstone and Eastern fauna communities; and *Geijera parviflora* and *Capparis mitchellii*, which are orientated towards the Depauperate faunal community. The majority of species strongly correlated with vectors in the ordination of fauna composition are understorey shrubs, perennial forbs and grasses, suggesting that these species may provide a stronger guide to fauna community distribution than community dominants. The correlations of all plant species were substantially lower than for either the most strongly correlated environmental attributes or fauna species. This indicates that broad environmental variables and site structural features were more strongly associated with fauna composition than vegetation composition.

Vectors representing the occurrence of the most strongly correlated plant species were broadly in three directions. Firstly, a large group of plant species that were predominantly found on clay soils in the DRP. These were consequently strongly associated with the Depauperate fauna community, including *Chloris truncata, Scleroleana muricata* and *Marselea drummondii*. A second group of two species, *Xanthorrhoea acaulis* and *Persoonia sericea,* were most strongly orientated to the Central Sandstone faunal community. The remaining species were associated mainly with the Eastern fauna community (especially in the direction with *Xanthorrhoea glauca* ssp. *angustifolia*), although some were also associated with the Central Sandstone community (the direction of *Calytrix tetragona*).

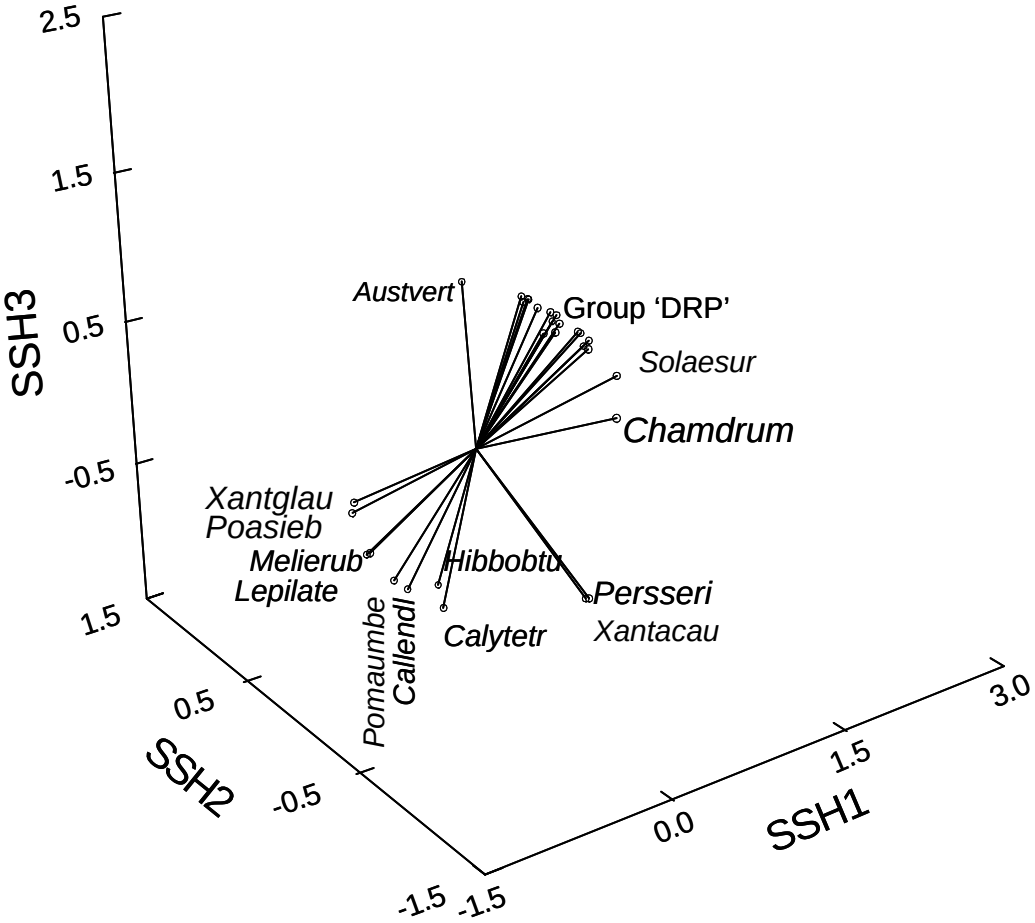


Figure 1.13 Direction of plant species vectors within the ordination of sites by vertebrate species composition (see Figure 1.10)

Vectors are shown in three dimensions. Only plant species with a correlation coefficient r>0.34 are shown. Codes: *Austvert = Austrostipa verticillata;* Group 'DRP' = *Sporobolus caroli, Capparis mitchellii, Geijera parviflora, Hordeum leporinum, Marselea drummondii, Enteropogon acicularis, Einadia nutans* ssp. *nutans, Medicago laciniata, Oxalis perennans, Sclerolaena muricata, Einadia nutans* ssp. *linifolia, Boerhavia dominii, Sida trichopoda, Paspalidium constrictum, Chloris truncata, Malvastrum americanum; Solaesur = Solanum esuriale; Chamdrum = Chamaesyce drummondii; Persseri = Persoonia sericea; Xantacau = Xanthorrhoea acaulis; Hibbobtu = Hibbertia obtusifolia; Calytetr= Calytrix tetragona; Callendl = Callitris endlicheri; Pomaumbe = Pomax umbellata, Lepilate = Lepidosperma laterale; Melierub = Melichrus erubescens; Poasieb = Poa seiberiana; Xantglau = Xanthorrhoea glauca* ssp. *angustifolia.*

Overstorey plant species

Many overstorey species that occur as overstorey plants in vegetation in the BBS were distributed substantially more frequently among sites within one fauna classification group than others (table AA). For example, *E. albens* was present at 41% of sites in fauna group 4, compared to no more than 18% of sites in any other group. This is related to the frequency at which a number of bird species known from box woodlands, such as the declining brown treecreeper and dusky woodswallow, were recorded in the box subcommunity. In contrast, *Allocasuarina leuhmannii* was relatively evenly distributed between the fauna communities. Other overstorey plant species were only recorded at sites within one fauna community;

Acacia cheelii in group 1 (Northern), and *E. nubila* in group 2 (central sandstone). *Acacia cheelii* usually grows in dry sclerophyll forest and scrub on rocky ridges on sandy soils in the eastern and central BBS (Harden 2002). Sandy, shallow and infertile soils are the typical habitat of *Eucalyptus nubila* (Harden 2002).

Overstorey plant species more frequently recorded from sites supporting the Northern fauna community were *Alphitonia excelsa, Acacia cheelii, Angophora leipocarpa, Callitris glaucophylla, Corymbia doiliocarpa, Eucalyptus melanophloia* and *Notalea microcarpa*. *Acacia doratoxylon, Callitris endlicheri, Corymbia trachyphloia, Eucalyptus blakelyi, E. fibrosa, E. nubila, E. sideroxylon* and *Melaleuca uncinata* were substantially more frequent at sites with the central sandstone fauna community. At sites with the Eastern fauna community *Angophora floribunda, Acacia implexa, E. albens, E. crebra, E. macrorhyncha* and *E. rossii* were more frequent, while at sites with the Depauperate community *Alectyron oleiofolius, Capparis mitchellii* and *E. populnea* were more widespread.

TABLE AA – DISTRIBUTION OF OVERSTOREY PLANT SPECIES AMONG FAUNA COMMUNITIES

Communities were derived from PATN analysis of presence/absence data. Four communities were based on *FUSE* of *B*-value of -0.2. Plant species are included if they can become dominant in the upper stratum of woody vegetation and they occurred at greater than five fauna survey sites. Table shows frequency (%) of species at sites in each community: Numbers in bold = species commonly associated with the fauna community (present in over 40% of constituent sites). Numbers in italics = species only recorded within one fauna community. Community 1 = Northern; 2 = Central Sandstones; 3 = Eastern fauna; 4 = Depauperate.

Fauna community	**1**	**2**	**3**	**4**
Number of sites in community	56	69	48	22
Species				
Acacia cheelii	*10*			
Acacia doratoxylon	4	10		5
Acacia implexa	10	2	34	9
Alectryon oleifolius	4			18
Allocasuarina luehmannii	24	22	17	14
Alphitonia excelsa	18	2	7	
Angophora floribunda	4	12	31	9
Angophora leiocarpa	14	3		5
Brachychiton populneus	2	2	7	5
Callitris endlicheri	31	**43**	34	14
Callitris glaucophylla	**73**	**47**	**48**	32
Capparis mitchellii	6	3	3	32
Casuarina cristata	14	8		18
Corymbia dolichocarpa	8			5
Corymbia trachyphloia	2	20	10	
Eucalyptus albens	18	2	**41**	18
Eucalyptus blakelyi	8	22	7	14
Eucalyptus chloroclada	14	15	7	5
Eucalyptus crebra	24	33	**48**	18
Eucalyptus dwyeri		8	10	
Eucalyptus fibrosa	2	12		
Eucalyptus macrorhyncha		3	24	
Eucalyptus melanophloia	29	5		5
Eucalyptus microcarpa	6	5		
Eucalyptus nubila		*12*		
Eucalyptus pilligaensis	2	7	3	5

Fauna community	1	2	3	4
Eucalyptus populnea ssp *bimbil*	12	7	3	18
Eucalyptus rossii	2	3	17	5
Eucalyptus sideroxylon	2	17	7	9
Exocarpos cupressiformis	2	7	10	5
Geijera parviflora	29	22	17	23
Melaleuca uncinata		12	3	5
Notelaea microcarpa	29	5		5
Notelaea microcarpa var *microcarpa*	12	2	21	14

Other plant species

In addition to broad vegetation type and overstorey plant species, other plant species may be associated with fauna site groupings. Floristic surveys were conducted at 83% of the systematic fauna sites used in the analysis. A few plant species were only recorded from sites classified with the one faunal community (that had over five records). These species were rare, and typically were infrequent even within the one group. Examples include *Scleroleana muricata*, found at 45% of the sites only within group 4, *Dampiera lanceolata* var. *lanceolata*, at 12% of sites only within group 2 and *Canthium odoratum*, at 10% of sites only within group 1 (Appendix 13). *Scleroleana muricata* is mainly associated with areas on clay soils and on floodplains – a habitat mainly distributed at the western margins of the BBS and in the adjoining DRP, hence the association of this species to group 4. Plant species present at the majority of fauna sites within a fauna classification group is also of interest in attempting to define the character of each group. Few plant species were present at over 50% of all fauna sites in each group. These included *Callitris glaucophylla* (group 1), *Lomandra filiformis* and *Melichrus urceolatus* (group 2), *Cymbopogon refractus* (group 3), *Einadia nutans* ssp. *nutans* and *Chlorus truncata* (group 4) (Appendix 13). These species may have also been widespread at sites in other fauna groups, but were particularly frequent in one. Again plant species abundant and widespread in the DRP Gosper (in prep) were typical of sites of group 4. These species were found at some sites in the BBS classified into group 4, however, as the DRP sites only made up 45% of the group.

The analysis found plant species composition was not as strong an indicator of faunal community composition over the area considered in this project as other environmental factors. In particular, human-induced landscape changes, such as clearance and fragmentation of habitat. These variables may be masking some of the significance of vegetation composition to fauna. For example, the association of some plant species with faunal group 4, the most depauperate in terms of species richness and composition, may simply reflect landscape habitat management, rather than these plant species being of low conservation value to fauna. These plant species may be associated with the factors linked to land clearance and fragmentation, such as soil fertility and topography. Fauna species susceptible to the impacts of land clearance and fragmentation may have been lost from these areas. More fauna survey work may also be required to establish patterns between vegetation type and faunal composition.

As mentioned in section 4.4 it is anticipated that additional analysis of the fauna data using the vegetation data produced by the Targeted Flora and Joint Vegetation Mapping Projects will eventuate when these data become available for use.

It is hoped this additional analysis will assist in identifying any significant relationships between priority species and vegetation attributes with the inclusion of vegetation and structural data.

4.3 MODELLING OF PRIORITY SPECIES

4.3.1 Aims

The objective of the two previous steps of analysis was to assess faunal communities at different scales over the study area; the principle objective of this next analysis was to identify potential habitat for individual species of conservation concern. This analysis was recommended by the technical working group to obtain specific information on the distribution of key species often poorly represented in the PATN analysis due to their relatively low numbers and co-occurrence with widespread and abundant species.
The modelling was principally done by spatially interpolating fauna survey results throughout the study area, based on modelled relationships between species and remotely mapped environmental attributes.

4.3.2 Priority species

A list of vertebrate species considered regionally significant was developed during the preliminary (stage 1) fauna project. Three criteria were used to develop the list: the species had very few records, was believed to be declining or was at the edge of its distribution in New South Wales within the BBS (RACD, 2000b). This list was reviewed and updated by the technical working group to include newly listed threatened species and additional species detected during this project.

This list of regionally significant species was used for this project to identify species of key interest for additional research and effort in analysis, hence priority in this context refers to the priority for analysis.

Species on this list were ranked in order of priority for analysis based the opinion of the working group. Species listed as threatened or endangered were generally given the highest priority, all other species were given the second highest priority, unless the working group believed they were secure elsewhere in their range in which case they were given a lower priority.

Species where no data from the stage 1 and stage 2 systematic surveys was available and other species not searched for during the survey such as waterbirds, platypus, water-rat were not prioritised. These species were flagged as species of concern and potentially in need of further research, however this project was incapable of assessing the priority.

The full list of priority species is in Table AB and AC.

TABLE AB – SPECIES OF HIGHEST PRIORITY FOR ADDITIONAL ANALYSIS

Species name	Common name	Legal	Reason
Ninox connivens	Barking Owl	V	RARE
Melithreptus gularis	Black-chinned Honeyeater	V	DECLINING
Climacteris picumnus	Brown Treecreeper	V	DECLINING
Stagonopleura guttata	Diamond Firetail	V	DECLINING
Calyptorhynchus lathami	Glossy Black-cockatoo	V	DECLINING
Pomatostomus temporalis	Grey-crowned Babbler	V	DECLINING
Melanodryas cucullata	Hooded Robin	V	DECLINING
Phascolarctos cinereus	Koala	V	RARE

Leipoa ocellata	Malleefowl	E1	DECLINING
Pseudomys pilligaensis	Pilliga Mouse	V	RARE
Xanthomyza phrygia	Regent Honeyeater	E1	RARE
Chthonicola sagittata	Speckled Warbler	V	DECLINING
Petaurus norfolcensis	Squirrel Glider	V	RARE

TABLE AC – OTHER SPECIES IDENTIFIED AS PRIORITY FOR ANALYSIS

Species name	Common name	Legal	Reason
Macropus dorsalis	Black-striped Wallaby	E1	RARE
Burhinus grallarius	Bush Stone-curlew	E1	DECLINING
Hylacola pyrrhopygia	Chestnut-rumped Heathwren	P	RARE
Trichosurus vulpecula	Common Brushtail Possum	P	DECLINING
Pseudocheirus peregrinus	Common Ringtail Possum	P	DECLINING
Macropus robustus	Common Wallaroo	P	RARE
Falcunculus frontatus	Crested Shrike-tit	P	RARE
Vespadelus troughtoni	Eastern Cave Bat	V	RARE
Rhinolophus megaphyllus	Eastern Horseshoe-bat	P	RARE
Cercartetus nanus	Eastern Pigmy-possum	P	RARE
Acrobates pygmaeus	Feathertail Glider	P	RARE
Pachycephala inornata	Gilbert's Whistler	V	EDGE, RARE
Nyctophilus timoriensis	Greater Long-eared Bat	V	RARE
Mormopterus sp 6	Hairy-nosed Mormopterus	IUCN DD*	Unknown
Chalinolobus dwyeri	Large Pied Bat	V	RARE
Chalinolobus picatus	Little Pied Bat	V	EDGE
Tyto novaehollandiae	Masked Owl	V	RARE
Grantiella picta	Painted Honeyeater	V	RARE
Platycercus adscitus	Pale-headed Rosella	P	EDGE
Hoplocephalus bitorquatus	Pale-headed Snake	V	DECLINING
Neochmia modesta	Plum-headed Finch	P	RARE
Aphelocephala leucopsis	Southern Whiteface	P	RARE
Chlamydera maculata	Spotted Bowerbird	P	RARE
Cinclosoma punctatum	Spotted Quail-thrush	P	RARE
Lophoictinia isura	Square-tailed Kite	V	RARE
Geophaps scripta	Squatter Pigeon	E1	EDGE
Anomalopus mackayi	Three-clawed Worm-skink	E1	RARE
Neophema pulchella	Turquoise Parrot	V	RARE
Egernia saxatilis saxatilis	Warrumbungle's Black Rock Skink	P	RARE
Cheramoeca leucosternus	White-backed Swallow	P	RARE
Pomatostomus superciliosus	White-browed Babbler	P	DECLINING
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V	RARE
Manorina flavigula	Yellow-throated Miner	P	DECLINING
Oedura rhombifer	Zig Zag Gecko	?	New for state
Underwoodisaurus sphyrurus		V	RARE

*IUCN "DD" Refers to the International Union for Conservation of Nature classification "Data Deficient" - please refer to the profile for this species in Appendix 2 for more details.

The remaining species of conservation concern are listed in Appendix 14.

4.3.3 Species data sources

The primary data used for the stepwise regression analysis of individual species was collected during the fauna survey project. Systematic site based data from other sources was used to improve the number of records and coverage of sites where the data met the following criteria:

- The data was systematically collected.
- The data was site based.
- The same technique was used (ie. harp trapping, Elliott trapping, call playback of the same species).
- The survey was conducted within the study area.

Some data used was only valid for certain species groups. For example, Milledge (unpubl.) only conducted call playback for three owl species - the masked, barking and powerful owls. As a result, priority species were divided into groups based on techniques used and the additional data was only used for species where that technique was appropriate. Where the technique was the same, but the effort differed, the information was recorded as a variable in the analysis as an effort value ie. number of trapnights or person hours. Table AD, below details the data sources used in this analysis.

TABLE AD – DATA SOURCES USED IN THE ANALYSIS FOR EACH SPECIES GROUP

Systematic Data Source	Bats (*harp trap)*	Owls *(call play)*	Ground Mammals *(Elliott trap)*	Diurnal Birds *(Timed search)*	Nocturnal Mammals *(Spotlight)*
BBS (Stage 2) fauna survey	x	x	x	x	x
BBS (Stage 2) targeted fauna sites	x	N/A	N/A	x	N/A
BBS Preliminary (stage 1) fauna survey	x	x	x	x	x
NPWS Nandewar bioregional survey	x	x	x	x	x
Darling Riverine Plains biodiversity assessment	x	x	x	x	x
Central CRA fauna survey	x	x	N/A	x	x
Milledge's Cypress Ironbark Large Owl Survey	N/A	x	N/A	N/A	N/A
UNE Pilliga mouse survey (Paull, unpubl.)	N/A	N/A	x	N/A	N/A

4.3.4 Data validation

All data used in the analysis was audited by the fauna survey team prior to its inclusion in analysis. A number of checks were undertaken including spatially plotting all records to check for location errors, and the technical working group reviewing species lists and records for suspect identifications. Data from this project, and the preliminary (stage 1) and Darling Riverine Plains surveys were also cross-checked for typographic errors against the original data sheets. The data from the Sydney CRA surveys had previously undergone a rigorous expert review as part of the coastal CRA process (RACD 1998)

4.3.5 Environmental variables used

TABLE AE – ENVIRONMENTAL VARIABLES USED TO ANALYSE FAUNA DATA

Name	Summary	Detail	Source
amrad	annual mean radiation	Produced by modelling the passage of the sun over the digital elevation model (DEM) and calculating the amount of solar radiation that falls on each grid cell by allowing for shade and shadow due to terrain. These are averaged over the year.	head office dataset 25m dem
avrain	annual precipitation	Average precipitation for each month added together	head office dataset 25m dem
Avtemp	Annual mean temp	Calculated average temperature for each month [(maximum + minimum)/2] added together and divided by twelve	head office dataset 25m dem
Cleardis	Distance to cleared land	Euclidean distance to non-woody land as defined by the Department of Land and Water Conservation (DWLC) Woody layer	derived from Woody layer
Ecotone1k	Ecotone within 1k	The boundary between woody and non-woody was converted to a 50m grid. The area of this linear, 50m wide feature within 1 kilometre was calculated for each grid cell	derived from Woody layer
Ecotone5k	Ecotone within 5k	The boundary between woody and non-woody was converted to a 50m grid. The area of this linear, 50m wide feature within 5 kilometres was calculated for each grid cell	derived from Woody layer
Frag	Fragmentation	Area of fragmented woody vegetation where a fragment is defined as woody vegetation at least 1 kilometre from other areas of woody vegetation	derived from Woody layer
hprad	Highest period of radiation	Average radiation values (see "Amrad" for how these values are derived) for the 3 month period of highest values	head office dataset 25m dem
Latitude	Latitude	Based on Zone 55 northings from the Australian Map Grid	V;gis\abiotic models, reorigined and made into integer
Longitude	Longitude	Based on Zone 55 eastings from the Australian Map Grid	V;gis\abiotic models, reorigined and made into integer
mtcp	min temperature coldest period	The coldest temperature based on minimum monthly temperatures	head office dataset 25m dem
mtwp	max tempurature warmest period	The warmest temperature based on minimum monthly temperatures	head office dataset 25m dem
peciipwq	precipitation wettest quarter	Sum of the precipitation of the wettest three months	V;gis\abiotic models and reorigined
precipdq	precipitation driest quarter	Sum of the precipitation of the driest three months	V;gis\abiotic models and reorigined
Rough10	Roughness	Standard deviation of elevation values based on a window radius of 250 metres	V;gis\abiotic models and reorigined
Soildrain	Soil drainage	Six classes (1-6) of soil drainage capacity from DLWC Soil Landscape Reconnaissance Mapping	derived from DLWC soil layer

Name	Summary	Detail	Source
Soilerd	Soil rooting depth	Estimate of soil and substrate depth available for tree roots to penetrate from DLWC Soil Landscape Reconnaissance Mapping	derived from DLWC soil layer
Soilfert	Soil fertility	Five classes (1-5) of soil fertility from DLWC Soil Landscape Reconnaissance Mapping	derived from DLWC soil layer
Soilwhc	Soil water holding capacity	Estimation of a soils capacity to store water for use by plants from DLWC Soil Landscape Reconnaissance Mapping	derived from DLWC soil layer
Stream10k	Streams within 10 km	Index of the length of streams within 10km of each grid cell. Streams used are streams of any stream order as defined by the Streamorder layer derived by State Forests for the BBS.	derived from State Forest BBS Streamorder layer
Stream1k	Stream within 1km	Index of the length of streams within 1km of each grid cell. Streams used are streams of any stream order as defined by the Streamorder layer derived by State Forests for the BBS.	derived from State Forest BBS Streamorder layer
Streamdist	Distance to streams	Euclidean distance of each grid cell to the closest stream. Streams used are streams of stream orders greater than "2" as defined by the Streamorder layer derived by State Forests for the BBS.	derived from State Forest BBS Streamorder layer
Topind10	Topographic index	An index of position on a slope from ridge to gully based on a window radius of 250 metres	V;gis\abiotic models and reorigined
Woody10k	Woody within 10km	The area covered by woody vegetation within a radius of 10 kilometres	derived from Woody layer
Woody1k	Woody within 1km	The area covered by woody vegetation within a radius of 1 kilometre	derived from Woody layer
Woody5k	Woody within 5km	The area covered by woody vegetation within a radius of 5 kilometres	derived from Woody layer

4.3.6 Methodology used to formulate fauna species models

Models were developed by finding statistical relationships between the selected fauna species and the environmental variables outlined in section 4.3.6. A module developed by Watson (1996) running under the S-PLUS statistical software (Statistical Sciences, 1995) was used with ARCVIEW Spatial Analyst (ESRI 1996) to conduct the modelling. The values of the environmental variables at each site were determined and related to recorded presences and absences. This relationship was then statistically analysed using a generalised additive modelling logistic regression procedure to produce a model predicting the likelihood of occurrence across the brigalow belt south bioregion. The models fitted in this study have a binary response (presence vs absence) the link function for logistic regression used in the generalised additive modelling was:

$$P = \frac{e^{y}}{1+e^{y}}$$

Where ‘p’ is the probability of presence and ‘y’ is the predictor resulting from summing the effects of the individual predictors. ‘y’ is specified as:

$$y = a + f_1(x_1) + f_2(x_2) + \ldots$$

where each 'f_1' is a nonparametric smooth function relating to the response to predictor 'x'. The 'f_1' functions are smooth curves estimated from the data using techniques originally developed for smoothing scatterplots.
The variance function used for logistic regression was;

$$Var(p)=p(1-p)$$

The outputs from the modelling processes are in two forms;

- A file containing information about the model, including deviance, degrees of freedom, model discrimination, calibration, refinement, and a graphical plot of each variable found to be significant in indicating the probability of occurrence of the species for the range of values of the variable. The model produces
- A digital map across the study area with values indicating the probability of the modelled species.

A detailed discussion of the theory and mathematical detail of this modelling technique are contained in Yee and Mitchell (1991), Hastie and Tibshirani (1990) and Hastie (1992).

Data preparation
A sites file was developed for each species group (bats, diurnal birds, owls, small mammals and nocturnal mammals) containing the site's location and the covariate values for each site. Cross-tabulated with these site details were columns representing each species within the group. The intersection of the rows representing the sites, and the columns representing the species, contained either a zero, representing an absence of that species or a one, representing a presence at that site.

The site file was imported into ARCVIEW Spatial Analyst where it was intersected with the environmental variables. This step produced a file called "envars", the environmental variables file which contained the value of each variable at each site. Other files produced were "varfiles" which contains the range of each variable across the study area and "outlines", an ASCII file of the coordinates of the study area.

The above files combined with "sitfiles", a file identifying the covariates used, and a species index file "spcseen", were imported into S-PLUS for analysis.

Testing of variables for collinearity

S-PLUS established the "variable classes" dataframe, comprising of a matrix with 100 rows and a column for each variable, with the values of each cell determined by the data ranges file ("varfiles"). Variables were then tested for collinearity using S-PLUS. The procedure tests for colinearity in three ways: between continuous variables, between continuous and categorical variables, and between categorical variables (Watson 1996). Once collinear variables are identified they were placed into groups such that:

- A group of collinear variables could contain more than just a pair of variables but if it did, then all variables within the group must be correlated
- A variable could have membership of more than one group
- Any single variable that was not correlated with any other variable was placed into a group of its own (Watson, 1996).

Stepwise regression

Following the grouping of variables a stepwise variable selection procedure was performed. The initial test involved the evaluation of each variable on an individual basis. Any variable which did not significantly ($p<0.05$) reduce the null deviance was discarded permanently.

Any variable which reduced the significance less than a variable with which it was found to be correlated with, was permanently discarded. If no variable significantly (p=0.05) improved the null fit, then the model was rejected as a null model. Species with fewer than 10 positive observations also resulted in a null model.

Forward - backward stepwise selection procedure was then applied to the pool of non-correlated variables each represented by one term expression. The starting model was the variable which achieved the most significant reduction in null deviance. Each of the other variables was added to the starting model. The bivariate model which afforded the most significant ($p<0.05$) reduction in deviance became the new interim model. A similar process produced the best trivariate model whereupon backwards stepwise selection was invoked to determine whether a bivariate model comprised of the most recently added variable, and either of the two already included significantly reduced the deviance of the trivariate model. If so, the bivariate model became the new interim model, otherwise the trivariate model entered a new cycle where a fourth variable was tested for inclusion on the same basis as the previous cycles. After each addition, backward selection was performed to explore the possibility of a simpler model. This stepwise procedure continued until six variables were chosen or when no new variable significantly reduced the deviance of the interim model.

Interpolation of models

Once the model for a species was created the predicted occurrence for that species across the study area was derived. The values in the variable classes dataframe (see above) were assigned prediction values on the logit scale (Watson 1996). These values were imported into ARCVIEW Spatial Analyst and used to spatially interpolate a map of predicted species distribution. At this point values were converted from a probability scale of 0 - 1 into percentage values for data storage and manipulation purposes.

The output comprised of three maps - a predicted, an upper and a lower confidence limit map with values ranging from 0 - 100. The other output was a postscript file containing graphs of the functions fitted to each variable used that plotted the probability of occurrence across the range of values for that variable. The variable was displayed in order of significance. Three graphs relating to model discrimination, calibration and refinement were also produced.

4.3.7 Model evaluation

To provide an indication of the model's ability to successfully predict distribution, the predicted probability surfaces for each species were overlayed with known point locations for the species. These point locations came from point records intentionally withheld from the analysis for the purpose of model validation (BBS fauna database). The predicted value at each independent point was calculated as was the mean, standard deviation. To provide an indication of the model's ability to successfully identify suitable habitat, the number and percentage of independent records encompassed by the upper 50% and 90% of the predicted likelihood were assessed. The closeness of the independent percentage to the predicted likelihood may give some indication on the ability of the model to successfully predict distribution. It is important to view this evaluation as a rough guide. The numbers used to test the models were often low, many of the independent records do not have the same georeference accuracy of the models (25m) and the data used to derive the models was collected from different areas than the independent records.

The details of this evaluation are provided for each model in Appendix 1.

4.3.8 Results

Models were made for 30 priority species with more than 10 systematic records within the bioregion. These species and the number of presence sites at which they were recorded are listed in table AF. The model outputs and predictive surfaces for each species is presented in Appendix 1 with a detailed description on how to interpret the results and the results of each model evaluation process described above.

TABLE AF – LIST OF SPECIES FOR WHICH MODELLING WAS ATTEMPTED AND THE NUMBER OF PRESENCE/ABSENCE RECORDS USED

	No. 'presences'	No. 'absences'	Total sites
Diurnal birds			
Glossy Black Cockatoo	27	243	270
Turquoise Parrot	21	249	270
Grey-crowned Babbler	42	228	270
Speckled Warbler	96	174	270
Brown Treecreeper	47	223	270
Painted Honeyeater	12	258	270
Pale-headed Rosella	16	254	270
Crested Shrike-tit	18	252	270
White-browed Babbler	21	249	270
Emu	55	215	270
Jacky Winter	41	229	270
Red-capped Robin	18	252	270
Painted Button-quail	14	256	270
Restless Flycatcher	20	250	270
Arboreal mammals			
Common Brushtail Possum	68	143	211
Koala	31	180	211
Common Ringtail Possum	32	179	211
Squirrel Glider	11	200	211
Feathertail Glider	13	198	211
Bats			
Nyctophilus timorensis	48	202	250
Saccolaimus flaviventris	36	214	250
Chalinolobus picatus	19	231	250
Chalinolobus dwyeri	15	235	250
Miniopterus schreibersii	10	240	250
Small mammals			
Yellow-footed Antechinus	97	155	262
Pilliga Mouse	34	228	262
Common Dunnart	27	235	262
Owls			
Barking Owl	105	711	816

Appendix 1 provides a two- page presentation for each species includes the following components;

- An evaluation of how the model preformed when compared to an independent data set,
- A graphical presentation of the statistical summary tables,
- A predicted distribution map with the independent records and records used to develop the model overlayed.

The quality of the models is variable. Some of the models appear to successfully predict species distributions when compared against independent data, others appear to have limited potential in predicting distribution. It is hoped the inclusion of vegetation data may help refine some models.

One of the objectives of the project was trial the development of predictive models for priority species of concern within the bioregion, to assess the feasibility of developing species models in data poor areas. As a result all of the models produced have been presented in this report to demonstrate the results of this trial.

4.3.9 Limitations

Restricted coverage

Spatial coverage
All of the survey data used in this analysis was collected from woodland vegetation (>10% cover). Other habitats such as grasslands and wetlands were not sampled and are not covered by the scope of this analysis. The coverage of sites is also limited by factors such as fragmentation, (patches smaller than 10 hectares were not sampled) the need to revisit each site over a number of days and nights had logistical and OH&S factors which resulted in sites grouped around survey base areas. This was required to keep driving times late at night and in the very early morning to a reasonable level (preferably 30 minutes or less).

This survey included sites on all tenures however other survey data used in the analysis was primarily focused on public lands and as such there is a bias in the data for larger remnants of woodland associated with public land. As these remnants also tend to represent poorer land capability classes as a result of land use practices it is likely there is a secondary bias towards less productive and less fertile landforms in the data (NSW Biodiversity Strategy, in prep). Sampling density is also relatively low with an average of one site per 8038 hectares of wooded vegetation. This is less than 40% of the density of sites used in the Lower North East CRA fauna analysis (1 site per 3179 ha) and only 5% of the density of sites in the Eden CRA fauna analysis (1 site per 380 ha) (RACD 1998). Table AG details the number of sites and sampling density used for each species group in the modelling.

TABLE AG – NUMBER OF SITES USED AND SAMPLING DENSITY FOR EACH SPECIES GROUP IN THE MODELLING

Species group	No. sites used in modelling	Hectares of woody vegetation per site	Hectares of total bioregion and buffer per site
Diurnal birds	270	8513	28682
Bats	250	9194	30977
Owls	816	2817	9490
Arboreal Mammals	211	10894	36703
Small mammals	262	8773	29558

Temporal
The data represents a very brief snapshot in time, conditions may change for different species over successive years depending on climatic conditions, and these changes are not represented in the analysis. This survey focused on collecting data from the maximum area where systematic vertebrate fauna data had been previously unrecorded. No attempt was made to assess areas previously surveyed to measure changes over time.

Low numbers of records
As mentioned in the introduction this process was intended to provide detailed distribution data on individual species, in particular species of conservation concern. One problem in attempting to model these species is that many of them have very low numbers. The average number of presence records for the 30 species modelled was 36 (Table AF), whilst models may reflect statistically valid patterns the low number of presence records in some cases may make them statistically weaker.

The problem of low numbers of records for certain species may be a result of the species rarity or it may be an artefact of the survey techniques employed and difficulty in detecting the species. In this case low numbers of records is likely to produce a poor quality model (if a model can be produced at all) because the absence of records from sites may not represent true absences but an inability of the technique to reliably detect the species.

This is overcome to some extent by using standardised systematic survey data however it does not overcome the problem of variation in the effectiveness of techniques in different habitats such as harp traps in open woodland and dense forests, or spotlighting in short mallee or tall dense forest.
Section 3.4.5 of this report provides a critical review of some of the techniques used during this survey.

Variables
The environmental variables used in the modelling are susceptible to inaccuracies. eg The digital elevation model is derived from satellite imaging on a 25 metre grid, models based on the digital elevation model and can at best reflect the accuracy of the original model and probably have inaccuracies of their own.

It is almost certain that innumerable species specific variables exist. Predation or food resources, presence of hollows, litter, grazing and fire impact upon species distribution. The aim of this project was to assess vertebrate diversity on a regional level - there was insufficient resources and information to focus on the needs of individual species in detail beyond the targeted fauna projects (section 1.3.3). The analysis was limited to information available at the time of modelling that could be mapped across the whole of the study area. , Unfortunately there was no mapping of many of these variables.

Missing vegetation data
At the initiation of the fauna survey project it was planned that vegetation data would be collected at all systematic fauna sites as a subset of the vegetation sites conducted under the joint vegetation mapping project (WRA 24). The great majority of sites were not surveyed by a botanist until late May 2002 and the data was not available until June 5th 2002, 5 working days prior to the deadline for the first draft of this report. There has been insufficient time to analyse the relationships between fauna and vegetation at the time of preparing this report. The lack of a bioregion wide vegetation map (which is to be produced by the joint vegetation mapping project) at the time of analysis has meant no modelling of fauna could take place using vegetation as a variable. It would be highly recommended that future projects ensure that deadlines are staged so that vegetation data and mapping be completed prior to the deadline for analysis of fauna distributions.

4.4 FUTURE WORK

The technical working group may supervise continued analysis of the fauna data using the vegetation data produced by the Targeted Flora and Joint Vegetation Mapping Projects if these data become available for use within the timespan of this project.
The goal of this analysis will be to refine the species models produced with the inclusion of vegetation and structural data, and to identify any significant relationships between priority species and vegetation attributes.
The results of this additional analysis may be published as an appendix to this report at a later date.

5 OUTCOMES

5.1 PROJECT OBJECTIVES

The outcomes of this project will be assessed in terms of how each of the project objectives mentioned in section 1.2 and 1.3 was met.

5.1.1 Build onto data collected from previous surveys of the bioregion, provide new data on the distribution of vertebrate fauna and collect information on vertebrate fauna and their habitat to fill as many gaps as possible.

This project collected over 11 000 records from more species than ever previously recorded in the bioregion, all from areas where there were known geographic gaps in the systematic survey data. The data was collected in a systematic and well-documented manner, comparable to the preliminary survey. The two datasets can easily be used together, building a much larger and more comprehensive dataset of the vertebrate fauna of the BBS.

The fauna survey project has provided new data on the distribution of vertebrate fauna. Significant new findings were made on the distribution of common species such as *Lygisaurus florium*, the common wombat, ringtail and brushtail possums. Data collected has added greatly to the known distribution of threatened species such as squirrel glider, *Chalinolobus dwyeri*, *Vespadelus troughtoni*, painted honeyeater and other declining woodland birds. New species have been found such as the delicate mouse (*Pseudomys delicatulus), Oedura rhombifer*, *Mormopterus sp6* , *Diporiphora australis*. Other species such as black-chinned honeyeater and hooded robin were not found as frequently as expected highlighting the urgent need for attention.

In an effort to fill as many geographic gaps as possible the survey exceeded the target 100 sites, and managed to include an additional 80 targeted sites in area where it was not feasible to conduct a full week long survey.

5.1.2 Collate, refine and validate the data collected from previous vertebrate fauna surveys of the bioregion into a useable format (a single database)

The fauna data analysis collated all available data from previous surveys and other sources into a single Microsoft Access database. This database has been checked for incorrect, inaccurate and suspect records.

5.1.3 Collate information on the known and predicted regional distribution of each species to provide regional context to the project

The fauna data analysis project collated the known location of all species recorded in the bioregion and undertook classification analysis of these species to provide a map of broad species assemblage distribution. The database compiled during this project provides known distribution of each species and the models developed provide predicted regional distribution for a number of priority species.

5.1.4 Develop lists of species expected to occur in identified vegetation communities throughout the bioregion

This was attempted, however the vegetation communities of the bioregion were not properly identified at the time of analysis. It is hoped that following the release of the joint vegetation mapping project data and maps that lists of species expected and known to occur in identified vegetation communities can be developed prior to August 2002. And that future analysis can identify any significant relationships between priority species and vegetation communities.

5.1.5 Develop species profiles identifying habitat requirements, ecological community and home range information for a limited number of species of concern at the bioregional scale, based on vertebrate fauna survey data and expert advice.

Species profiles have been developed for 37 species of concern identified by the technical working group. These have compiled known information on the habitat requirements, threats and ecological information. They provide detail on the habitat and new information collected during this survey.

5.1.6 Trial the development of predictive models for certain priority species of concern within the bioregion, with a view to assessing the feasibility of developing species models in data poor areas.

Thirty species models were developed for all priority species with more than 10 systematic records (the minimum number required for modelling).

5.1.7 Publish the results of fauna survey work undertaken in stage 2 fauna surveys and subsequent data analysis in a report.

A report has been published.

5.1.8 Assist in the identification of high conservation value areas.

The results of these projects could be used to identify high conservation areas through a number of means

- The known locations of threatened species and species of conservation concern may be mapped to identify areas where these species are known to occur.
- The predictive models developed may serve to identify areas of potential habitat for species of concern.
- Both of these features may be used in conjunction with other features such as vegetation mapping, rare plant locations, cultural heritage values, and unique landforms which may assist in identifying areas of high conservation value.

5.1.9 Assist in the identification of a Comprehensive, Adequate and Representative reserve system.

- The results of these projects could assist in the identification of a Comprehensive, Adequate and Representative reserve system, through the identification of high conservation areas.
- The results of the regional species classification has identified different species assemblages throughout the bioregion, this information could be used to ensure that a reserve system is comprehensive and representative of fauna groups.
- The raw data, faunal assemblages or models may help provide more definition to broad vegetation communities or other environmental variables used to develop a reserve.
- The ecological information collected during the survey may assist in identifying habitat requirements for some species.

5.1.10 Assist in developing conservation protocols as part of Ecologically Sustainable Forest Management (ESFM) and Ecologically Sustainable Land Management (ESLM).

The vertebrate fauna data, profiles, assemblage mapping and models will be available for use in developing conservation protocols.

5.1.11 Provide information on biodiversity into regional planning processes such as regional vegetation management committees and catchment management boards

The vertebrate fauna data, profiles, assemblage mapping and models will be available for use in regional planning processes. The species profiles were written specifically with these potential uses in mind. Additional analysis of fauna data against vegetation data when it becomes available will be particularly useful for these groups.

6 RECOMMENDATIONS

The recommendations made in various sections of this report are presented here in the order they appear in the text.

Chapter 3

Section 3.2.5
It is recommended that:

- Any future fauna surveys in the Brigalow Belt South reassess the current limitation on site selection to woody vegetation patches greater than 10 hectares. This is particularly relevant if highly fragmented areas such as the Northern Outwash province are to be surveyed.
- A review be carried out, when the complete vegetation mapping and classification is available, to reassess the adequacy of the fauna site selection using vegetation groups. The new maps and classifications will allow gaps in information to be identified.
- Sufficient resources be allocated for a full-time community liaison position for any survey where a significant number of sites are planned for private properties.
- A review of the survey design to be used on private properties be carried out to allow for more sites to be surveyed on smaller properties.
- The Northern Outwash province be selected as a priority for future fauna surveys. Survey design for this area needs to be modified to allow for limitations on patch size
- Areas of the Liverpool Ranges province outside of Coolah Tops be selected as a priority for future fauna surveys.
- Future surveys in the Brigalow Belt South Bioregion sample all species groups using comparable methodology to that used in this project.

Section 3.3.5
It is recommended that:

- Research be undertaken to identify the maximum efficiency of the survey techniques used in biodiversity surveys.
- Future fauna surveys in Western NSW conduct a *minimum* of two twenty minute bird censuses on different days at each site.
- Future surveys undertake Elliott trapping for a minimum six-night period.
- Pitfall trapping be included in the design of future surveys to improve sampling for species not detected easily by other methods.

- Site based spotlighting be used as a minimum requirement for any future surveys.
- All future surveys record Anabat directly into a laptop computer rather than onto audio cassettes, and that reference calls for captured species be collected.

Section 4.1.1

- The following mapsheets be considered as priority areas in future survey effort in the BBS bioregion. These areas were found to contain the lowest number vertebrate fauna records of any mapsheet areas for the bioregion.

- Eastern BBS and buffer, from Parry (89341S) to Temi (90341S) north to Watermark (89351S) and Piallaway (90354S), also Yarraman (89344N) to Coolanbilla (89353N);
- Gravesend (8938N) (eastern edge);
- Yelarbon (9040N) (far north);
- North Star (8940S) and Croppa Creek (8939N) (central north);
- Pilliga (8637S) and Cuttabri (8737S) (northern Pilliga Scrub);
- Coolah area (88342N&S, 88343N&S) (central south);
- Mullaley (8835N) (centre); and
- Gurley (8838S) (northwest edge).

Section 4.3.2

- Future survey effort prioritise non-woodland habitats (grassland, shrublands, wetlands) not studied in this project.

Section 4.3.9

It is recommended that:

- Further survey work is undertaken to improve the relative sampling density for the bioregion to bring it closer to the density in coastal regions.
- More detailed analysis is undertaken for each priority species to identify species-specific variables that may improve modelling potential.
- The final dates of linked projects be staged so that essential data generated by each project is available for use by other reliant projects before the final completion date.

7 GLOSSARY

Abundant

Seen in large numbers, frequently seen over a large area.

Access

Microsoft Access, a relational database program.

Anabat

A device for recording the ultrasonic calls microchirpoteran bats use when navigating in the dark. The recorded calls are converted into a computer graph depicting the frequency and timing and these graphs can be sometimes used to identify the species which made the call.

Arboreal

Lives in, or frequently uses trees.

Arcview

A computer program or Geographic Information System (GIS), used primarily for making and interpreting maps and analysing information spatially.

ASO

The function of generating association measures in PATN (see Belbin 1994), *i.e.* how similar two sites are in terms of their species composition.

Assemblage

A group of species that occur together.

Beta value

A variable that is used control how groups move in relation to each other in the clustering process (using flexible UPGMA) (Belbin 1991).

Bioregion

An area based on biophysical, environmental and vegetation attributes (e.g. climate, lithology, landform, flora). Refers to the interim biogeographic regionalisation of Australia by Thackway and Cresswell (1995).

Black box

Eucalyptus largiflorens

Bray-Curtis association measure

A type of association measure within ASO of the PATN analysis (see Belbin 1994).

Broad leafed ironbark

Eucalyptus fibrosa

Buffer

A 15 kilometre buffer around the boundary of the bioregion to allow for possible inaccuracies due to the large scale at which the bioregions were mapped.

Bulloak

Allocasuarina luehmannii

Call parameters

The features of a bat call recorded using Anabat which can be used to interpret the call and possibly identify the species. Some common parameter used are characteristic frequency and slope.

Call playback

A technique where the pre-recorded call of an animal is played in an attempt to elicit a response from the same species.

Call sequence

The computer file of a bat call produced using the Anabat device.

Carbeen

Corymbia tessellaris

Census

A count of all animals seen and heard within a set time period and area (site). Usually for a particular group of animals, ie. all birds seen and heard in a 20 minute period in the site.

Classification

The process of ordering and identifying patterns in site survey data.

Confirmatory variables

Any environmental, methodological or site variables to be used in explanation of the site classification.

Correlation

The degree of relationship between two variables

CRA

Refers to the Comprehensive Regional Assessment process.

Cypress

Species of Callitris pine, either *C. endlicheri* or *C. glaucophylla*

Darling Riverine Plains

The bioregion to the west of the Brigalow Belt South, typified by the floodplains of the Darling River and major tributaries such as the Gwydir and Namoi.

Data

Refers to specific information for fauna such as a precise map reference (location), date, and species seen.

Dendrogram

A diagram of binary fusions grouping a set of objects (in this case, sites).

Depauperate

Comparatively less species-rich and lacking particular species.

Deviance

The measure of how closely a model fits the data used to produce the model.

Digital elevation model

An elevation map (altitude) produced from information collected by satellite.

Dissimilarity

The difference between the association measures of pairs of, in this case, sites (see Belbin 1994).

Distribution

The extent of an area where a species is known to occur.

Diversity

Refers to the number of different species living in a specified area, a highly diverse area has many different species whilst an area with low diversity would have few.

DLWC

Department of Land and Water Conservation

DLWC soils

A soils map produced by DLWC as part of the Brigalow Belt South biodiversity assessment project. WRA project number 21.

DLWC woody

A map of woody vegetation produced by DLWC from satellite images for the Brigalow Belt South biodiversity assessment project.

Dominant vegetation

A simplified term for the main canopy species, usually tree species such as *Eucalyptus*, Angophora, *Acacia* or *Callitris.*

Elliott trap

A small metal box trap with a spring activated door. The traps are baited and when an animal enters the trap the spring mechanism is activated and the door closes.

Environmental attributes

The environmental attributes of an area such as rainfall, temperature, soil type, vegetation etc. In the context of this report environmental attributes refers to the attributes which information was available.

Environmental variables

The environmental attributes which were used in analysis.

Faunal community

Locations with similar composition of fauna species as identified in PATN analysis.

Fragmentation

The change that has occurred when larger blocks of native vegetation have been incompletely cleared leaving multiple smaller blocks separated from each other. The more highly fragmented an area the smaller and more disjunct the blocks.

FUSE

The clustering (grouping) function in PATN (see Belbin 1994)

GAM

Generalised Additive Model, a type predictive model which uses a curve fitted to the data rather than a linear prediction used in linear modelling techniques.

GDEF

A function in PATN to define groups (of in this case, sites) (see Belbin 1994).

GSTA

A function in PATN to determine how well a set of attributes discriminate between a set of groups (Belbin 1994).

Habitat

An area used by a species for any of its living requirements.

Habitat search

A timed search of a site for any active animals or signs of animals, such as footprints, scats or bones. Habitat searches included looking under logs, bark, rocks, in hollows and other areas of potential habitat.

Harp trap

A trap used for catching small bats. The trap consists of a frame strung tightly with fishing line with a canvas bag hung below the frame. The trap is placed in areas bats are likely to fly. Bats have difficulty detecting the fishing line, collide with the trap and fall into the bag where they remain until collected and identified later.

Hollows

Holes formed in trees over time, some species use hollows for shelter and nesting.

Incidental

A record that was collected incidentally (opportunistically) and not during a systematic search. For example an animal seen while driving to a site. "Incidental" refers to records collected off site. On site incidental records are referred to as "opportunistic on site".

Independent record

A record of an animal (ie. location, date, species) that was not used in the analysis.

Interpolation

The process of predicting the occurrence of a species across the study area by applying environmental values found to be significant in the species modelling process.

Kruskal-wallis

A non-parametric statistical test.

Mallee

Eucalyptus viridis, or any small tree growing in a mallee like form (ie. having many small spreading trunks)

Mapsheet

The area covered by a specific topographic map produced by the Central Mapping Authority (usually at a 25 000 or 50 000 scale in the study area). Each mapsheet has a unique name and number.

Mask

A function of the PATN program where features such as species or sites may be excluded from analysis.

Merge

A function of the PATN program where features such as species or sites may be merged to form a single feature in analysis.

Method

The specific technique, time and area used to search for animals.

Microchiropteran bat

A small insect eating bat, generally with poor eyesight and reliant upon using ultrasonic calls to navigate. As opposed to megachiropteran "fruit bats" which are generally large and don’t use ultrasonic calls.

Mugga Ironbark

Eucalyptus sideroxylon.

Myall

Acacia pendula. Also known as Boree.

Nandewar

The adjacent bioregion to the east of the brigalow belt, consisting mostly of the north western slopes of the Great Dividing Range in NSW.

Narrow leafed ironbark

Eucalyptus crebra.

Nocturnal

Active at night.

NPWS

New South Wales National Parks and Wildlife Service.

Ooline

Cadellia pentastylis

Opportunistic

An animal recorded incidentally (refer to "incidental"). Opportunistic records are referred to either as opportunistic off site or on site depending on where the species was found.

Ordination

A technique to condense information of a set of attributes to a limited number of new attributes (PATN function, see Belbin 1994).

PATN

Pattern analysis package (Belbin 1994).

PCC

Principal axis correlation – a multiple linear regression program in PATN to see how well a set of attributes can be fitted to the ordination space (Belbin 1994).

Pilliga / Grey box

Eucalyptus pilligaensis. Little effort was made to differentiate this species from Grey box *Eucalyptus microcarpa* during the fauna survey and names for the two are used interchangeably in this report.

Pitfall trap

A trap used to catch small mammals and reptiles, the trap usually consists of a hole dug in the ground into which unsuspecting animals fall. Pitfall traps are often used in conjunction with "drift fences", small fences used to direct animals towards the pit.

Poplar box

Eucalyptus populnea, also known as Bimble box.

Precipitation

Rainfall, snow, hail.

Predicted probability

The estimated likelihood of finding a species in a given location based on the statistical analysis and modelling procedure.

Presence / absence

Answer to the question - was the species found to be present at the site? Presence absence data ignores the number of records, giving a simple binary (yes / no) presentation to fauna data. If the species was found at a site (eg. regardless of numbers it is a "presence" if it was not recorded it is an "absence").

Priority species

Species identified as priority for analysis by the technical working group. Priority species were derived from a list of species believed to be of conservation concern in the study

area.

Province

A subregion of a bioregion, having relatively unique biophysical, environmental and vegetation attributes (e.g. climate, lithology, landform, flora) within the bioregion. Refers to the interim biogeographic regionalisation of Australia by Thackway and Cresswell (1995).

RACAC

Resources and Conservation Assessment Council.

RACD

Resources and Conservation Division, Planning NSW.

Radiation

Refers to solar radiation (ie. amount of sunlight received).

Remnants

Patches of native vegetation remaining after land clearing.

Rough barked apple

Angophora floribunda.

Scribbly gum

Eucalyptus rossii.

SFNSW

State Forests of New South Wales.

Site

A 100 metre by 200 metre area where surveys were conducted.

Site Attributes

The attributes that were recorded from each site. For example, dominant vegetation, number of hollows, leaf litter,

Smooth barked apple

Angophora leiocarpa.

Spatial

Relating to space/ locations etc. Spatial data refers to data which can be mapped such as locations.

Spatial Analyst

An extension of the Arcview GIS software.

Species rich

A specified area with a relatively high number of species recorded.

Specimen

An animal killed and preserved for museum identification and use.

Splus

A statistical analysis program.

SSH

Semi-strong hybrid multidimensional scaling – an ordination technique in PATN (see Belbin 1994).

Stepwise regression

A statistical analysis procedure used in multivariate analysis, where each variable is tested against others in a step by step procedure.

Stress

A measure of how well initial dissimilarities between objects are represented in the ordination space.

Study area

The study area of this project is the entire Brigalow Belt South bioregion in NSW, and the surrounding 15 kilometre buffer.

Subcommunity

An internal division within the broad communities identified through PATN analysis.

Suspect record

A record of an animal in a database which is suspected of not being correct because of a strange location, date or identification. Suspect records in the BBS database included animals only known from Western Australia, recent records of extinct species, and animals from other areas that are easily confused with a common species.

Systematic site

A site where all standard survey methods were used, ie. the standard method for birds, bats, mammals and reptiles was employed and site attribute data collected.

Targeted fauna survey

Refers to surveys undertaken by State Forests of New South Wales on four target species, squirrel glider, eastern pigmy possum, pale-headed snake and glossy black cockatoo.

Targeted site

A site where a particular species group was targeted, using only the relevant standard method. For example a targeted site for birds would have only a standard bird census conducted at it, a targeted site for bats only harp trapping.

Technical working group

A group of nominated fauna survey experts from DLWC, SFNSW, NPWS and independent expert who provided technical advice and supervision to these projects.

Technique

Refers to the way an animal was detected, such as in a bird census, habitat search or Elliott trap, (see method).

Temporal

Relating to time.

Terrestrial

Ground dwelling.

Threatened species

Species listed as endangered or vulnerable under the *Threatened Species Conservation Act (1995).*

Threats

Factors believed to have caused a species to decline. For example predation by foxes or disease.

Trapnight

A trapnight is one trap open for one night. To calculate trapnights the total number of traps is multiplied by the number of nights they were set for. For example; one trap set for four nights equals four trapnights. Four traps set for one night also equals four trap nights.

UPGMA

A clustering strategy used in PATN (se Belbin 1994).

Validation

The process of checking data before conducting analysis to ensure that correct records have been included and that suspect records and duplicates are excluded from analysis.

Vegetation map

A map of vegetation communities (species that occur together) over a specific area.

Vegetation type

A generalisation of vegetation often found together characterised by the dominant canopy species.

Vertebrate fauna

All animals with a backbone, for example frogs, birds, mammals and reptiles. Fish are also vertebrates however they were not studied in this project.

White box

Eucalyptus albens

Widespread

A species which is found over a large area. Species widespread in this bioregion have been found in most areas surveyed.

Woody vegetation

Areas of native vegetation with woody stems (ie. trees and shrubs) which have a canopy cover of 15% or greater. This includes areas such as open woodland, dense woodland, and forest. A GIS layer of the present cover of woody vegetation developed by DLWC was used in this project.

Yellow box

Eucalyptus melliodora

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