Modelling Areas of Habitat Significance for Vertebrate Fauna and Vascular Flora in the Southern CRA Region

A project undertaken as part of the NSW Comprehensive Regional Assessments

February 2000

MODELLING AREAS OF HABITAT SIGNIFICANCE FOR VERTEBRATE FAUNA AND VASCULAR FLORA IN THE SOUTHERN CRA REGION

NEW SOUTH WALES NATIONAL PARKS AND WILDLIFE SERVICE

A project undertaken for
the Joint Commonwealth NSW Regional Forest Agreement Steering Committee
as part of the

NSW Comprehensive Regional Assessments

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EXECUTIVE SUMMARY

This report has been prepared for the joint Commonwealth/State Steering Committee, which oversees the comprehensive regional assessments of forests in New South Wales.

The comprehensive regional assessments (CRAs) provide the scientific basis on which the State and Commonwealth governments will sign regional forest agreements (RFAs) for the major forests of New South Wales. These agreements will determine the future of the State's forests, providing a balance between conservation and ecologically sustainable use of forest resources.

The Southern modelling project was undertaken to produce valid fauna and flora models to predict the range of, and quality habitat for, priority fauna and flora species of the area. These models would then be used for the determination of species area target, and to provide digital information for other project areas for use in satisfying JANIS criteria relating to centres of endemism, significant refugia, and areas of high biodiversity.

The majority of the data used for flora modelling was part of the data collected and validated within the Southern CRA Threatened Plants Project. Data was also collected from CRA systematic surveys and external sources. All flora survey data was designated as incidental data. The validated data set was intersected with environmental variables to derive minimum and maximum values, which were used in creating Biophysical Envelope Models (BEMs).

After the flora models were reviewed by experts during several Response to Disturbance workshops, they were all rejected due to concerns about setting targets for predicted habitat rather than known locations.

External fauna survey data, collected during the Southern CRA fauna data audit process, and data collected on the Southern CRA summer/autumn 97/98 and 98/99 surveys, were collated and validated in preparation for the fauna modelling process. Abiotic and biotic environmental GIS layers for the Southern CRA area were obtained. Various biotic and abiotic indices were calculated by contracted experts and contextual variables derived. All fauna species survey data were designated as presence-absence (from systematic surveys) or presence-only (from incidental surveys) and survey method and effort covariates assigned to the presence-absence data. Experts conducted data validation for species of particular conservation and forest-dependency significance. These 'priority' species were selected through a consultative process involving relevant agencies, experts and the Environmental and Heritage Technical Committee.

Using the modelling program S-PLUS, the completed fauna dataset and GIS layers, predictive distribution models were fitted for each priority species and their distributions extrapolated across the entire Southern CRA area. For each fauna model, statistics were derived indicating the degree of fit of the model to the data and the significance of each predictor (variable) used in the model.

Models and maps for priority fauna species were evaluated by expert modellers and ecologists and revisions to the models were made as necessary. The probability classes for each species' modelled distribution were grouped by the experts to reflect areas considered to be core, intermediate or marginal habitat. A number of species did not produce viable models due to lack of data or poor quality data. In these cases, 'expert' models were created using Boolean overlays of appropriate environmental variables, based on expert knowledge.

The final modeled distributions were used in the CRA Response to Disturbance project expert workshops, where species equity targets were calculated, and target areas delineated on the model maps. The resultant maps from these workshops were used for the Conservation Requirements and Integration phases of the Southern CRA.

1. INTRODUCTION

1.1 BACKGROUND

In 1992 the Commonwealth, State and Territory governments agreed to the National Forest Policy Statement. Arising from that agreement, Comprehensive Regional Assessments (CRAs) are being conducted throughout Australia to assess the values of forested regions, with the aim of establishing a comprehensive, adequate and representative reserve system.

The Southern CRA region is the fourth area to be assessed in New South Wales, after the Eden, Upper North East and Lower North East regions.

1.2 STUDY AREA

The Southern CRA region, comprising 5,550,000 hectares, extends southwards along the coast from Nowra to the Eden study area at Bermagui (figure 1.a). The southern boundary abuts the northern and western boundaries of the Eden study area and then follows the NSW/Victorian state border westwards and along the Upper River Murray almost to Albury. The western boundary follows various Local Government Area (LGA) boundaries northeastwards to just north of Oberon in the southern Blue Mountains.

The vegetation of the area is highly varied due to the wide altitudinal and geographic range. Coastal and mountainous areas predominantly comprise of wet and dry sclerophyll forests, with small patches of rainforest in gullies. Coastal and plateau heathlands also occur along the coast and small patches of alpine heathlands are found at highest altitudes in the mountainous areas. Dry sclerophyll forests, grassy woodlands and open native grasslands, dominate the tablelands and western slopes.

Mean annual temperatures of the region range from 2^{o}C near Mount Kosciusko to 16^{o}C along the coastal plains north of Ulladulla.

The Southern study area comprises 3,098,938 hectares of vegetated areas and 3,074,018 hectares of cleared land. Much of the forested area is contained in State Forest land (699,827 ha) or National Parks (1,164,404 ha) (figure 1.b).

1.3 PROJECT OBJECTIVES

The aim of the Southern fauna and flora modelling project was to produce models to predict the distribution of habitat for vertebrate fauna and flora species of the area. These models were required to satisfy JANIS Biodiversity Criteria number five relating to the protection of high quality fauna habitat, centres of endemism, natural refugia and areas of high diversity.

Figure 1.a

Figure 1.b

2. METHODOLOGY

2.1 INTRODUCTION

The principle objective of the modelling project was to identify areas of habitat significance in the Southern CRA region. This was principally done by spatially extending (or interpolating) fauna and flora survey results throughout the whole study area, based on modeled relationships between species and remotely mapped environmental attributes. The models were produced on an individual species basis to enable definition and evaluation of explicit conservation goals for each species. This also enabled weighting of species according to vulnerability and conservation need, and allowed consideration of specific needs for individual species. These elements were crucial for the Response to Disturbance and Conservation Requirements phases of the CRA process.

The methodology and results of the data audit and survey phases of the Southern CRA project, which generated data used in the current modelling project, are described in detail in NSW NPWS, 1998c.

2.2 PRIORITY SPECIES

Through the Response to Disturbance project, in which a series of workshops and expert consultation was held, a list of priority fauna and flora species was compiled. The process for deriving the priority species list is outlined in the Response to Disturbance project report (Environment Australia, 1999). Although data for all fauna and flora species were collected and collated in the data audit and survey phases of the project, the priority species were targeted in the collation and validation of existing data, the design of the new field surveys, and the derivation of models.

2.2.1 Fauna priority species

The 64 priority fauna species for Southern CRA area, listed in table 2.a, include all threatened and forest-dependent vertebrate fauna species for the area, and some species considered vulnerable to forest disturbance (26 mammals, 24 birds, 7 reptiles and 7 amphibians). Forest dependency was defined as where a species depends on forests for some part of their lifecycle. ‘Forests’ were defined to be >5m in height and >10% crown coverage. The species were sorted by functional groups (i.e arboreal mammals; nocturnal birds; ground mammals; bats; reptiles; and amphibians) for the purposes of data validation and model processing.

2.2.2 Flora priority species

The Response to Disturbance project identified 162 species as priority flora for detailed assessment in the Southern CRA (refer to Response to Disturbance Report). From this priority list, botanists, Doug Binns and Phil Gilmour shortlisted 30 species which would be suitable for investigating habitat modelling for the following reasons; a) sufficient number of records (>5), b) is likely to inhabitat a predictable environmental envelope, c) currently threatened and worth investing limited resources on.

Initially 30 flora species were considered as reasonable candidates for modelling. Due to delays in the arrival of critical data layers, only a few preliminary models were available for review at the time of the first workshop. After reviewing some of these preliminary models, experts had concerns regarding a) the process of applying targets to potential rather than actual habitat models (see Response to Disturbance Report for details) and, b) about the quality and usefulness of many of the models. As a result, nine species (see table 2.b) were identified for which further attempts at modelling were made.

The larger priority flora species list and justifications for compiling the flora and fauna lists are detailed in the Rare Plants report and the Response to Disturbance report (Environment Australia 1999).

TABLE 2.A: PRIORITY SPECIES USED IN THE SOUTHERN FAUNA MODELLING

Functional group	Species	Common Name	TSC Act[1]	ESP Act[2]
Nocturnal Birds	*Ninox connivens*	Barking Owl	V	
Nocturnal Birds	*Burhinus grallarius*	Bush Stone-curlew	E	
Nocturnal Birds	*Tyto novaehollandiae*	Masked Owl	V	
Nocturnal Birds	*Ninox strenua*	Powerful Owl	V	
Nocturnal Birds	*Tyto tenebricosa*	Sooty Owl	V	
Arboreal Mammals	*Phascogale tapoatafa*	Brush-tailed Phascogale	V	
Arboreal Mammals	*Cercartetus nanus*	Eastern Pygmy Possum		
Arboreal Mammals	*Petauroides volans*	Greater Glider		
Arboreal Mammals	*Phascolarctus cinereus*	Koala	V	
Arboreal Mammals	*Petaurus norfolcensis*	Squirrel Glider	V	
Arboreal Mammals	*Petaurus australis*	Yellow-bellied Glider	V	
Ground Mammals	*Mastacomys fuscus*	Broad-toothed Rat	V	
Ground Mammals	*Petrogale penicillata*	Brush-tailed Rock Wallaby	V	V
Ground Mammals	*Perameles nasuta*	Long-nosed Bandicoot		
Ground Mammals	*Potorous tridactylus*	Long-nosed Potoroo	V	
Ground Mammals	*Pseudomys fumeus*	Smoky Mouse	E	
Ground Mammals	*Isoodon obesulus*	Southern Brown Bandicoot	E	
Ground Mammals	*Dasyurus maculatus*	Tiger Quoll	V	
Ground Mammals	*Sminthopsis leucopus*	White-footed Dunnart	V	
Bats	*Miniopterus shreibersii*	Common Bent-wing Bat	V	
Bats	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	V	
Bats	*Rhinolophus megaphyllus*	Eastern Horeshoe Bat		
Bats	*Mormopterus norfolkensis*	Eastern Little Mastiff-bat	V	
Bats	*Kerivoula papuensis*	Golden-tipped Bat	V	
Bats	*Scoteanax rueppellii*	Greater Broad-nosed Bat	V	
Bats	*Pteropus poliocephalus*	Grey-headed Flying Fox		
Bats	*Myotis adversus*	Large-footed Myotis	V	
Bats	*Chalinolobus dwyeri*	Large Pied Bat	V	
Bats	*Pteropus scapulatus*	Little Red Flying Fox		
Bats	*Mormopterus sp. 1*	Unamed Mastiff Bat		
Bats	*Saccolaimus flaviventris*	Yellow-bellied Sheath-tail Bat	V	
Diurnal Birds	*Melithreptus gularis*	Black-chinned Honeyeater		
Diurnal Birds	*Climacteris picumnus*	Brown Treecreeper		
Diurnal Birds	*Falcunculus frontalis*	Crested Shrike Tit		
Diurnal Birds	*Eurystomus orientalis*	Dollarbird		
Diurnal Birds	*Dasyornis brachypterus*	Eastern Bristlebird	V	
Diurnal Birds	*Calyptorhynchus lathami*	Glossy Black Cockatoo	V	
Diurnal Birds	*Melanodryas cucullata*	Hooded Robin		
Diurnal Birds	*Pachycaphala olivacea*	Olive Whistler	V	
Diurnal Birds	*Grantiella picta*	Painted Honeyeater		
Diurnal Birds	*Petroica rodinogaster*	Pink Robin	V	
Diurnal Birds	*Climacteris erythrops*	Red-browed Treecreeper		
Diurnal Birds	*Xanthomyza phrygia*	Regent Honeyeater	E	E
Diurnal Birds	*Cinclosoma punctatum*	Spotted Quail-thrush		
Diurnal Birds	*Lophoictinia isura*	Square-tailed kite	V	
Diurnal Birds	*Polytelis swainsonii*	Superb Parrot	V	
Diurnal Birds	*Lathamus discolor*	Swift Parrot	V	V
Diurnal Birds	*Neophema pulchella*	Turquoise Parrot	V	
Diurnal Birds	*Calyptorhyncus funereus*	Yellow-tailed black Cockatoo		
Diurnal Birds	*Sericornis citreogularis*	Yellow-throated Scrub Wren		

Functional group	Species	Common Name	TSC Act[1]	ESP Act[2]
Amphibians	*Litoria booroolongensis*	Booroolong Frog	E	
Amphibians	*Pseudophryne bibronii*	Brown Toadlet		
Amphibians	*Helioporus australiacus*	Giant Burrowing Frog	V	
Amphibians	*Litoria littlejohni*	Heath Frog		
Amphibians	*Pseudophryne pengilleyi*	Northern Corroboree Frog	V	
Amphibians	*Pseudophryne australis*	Red-crowned Toadlet	V	
Amphibians	*Mixophyes balbus*	Stuttering Barred Frog	V	
Reptiles	*Hoplocephalus bungaroides*	Broad-headed Snake	E	E
Reptiles	*Acanthophis antarticus*	Common Death Adder		
Reptiles	*Morelia spilota variegata*	Carpet Python		
Reptiles	*Morelia spilota spilota*	Diamond Python		
Reptiles	*Varanus rosenbergii*	Heath Monitor	V	
Reptiles	*Nannoscincus maccoyi*	Maccoy's Skink		
Reptiles	*Pseudomia spenceri*	Spencer's Skink		

[1] *Threatened Species Conservation Act 1996* (NSW) E = endangered; V = vulnerable
[2] *Endangered Species Protection Act 1992* (Cwlth) E = endangered; V = vulnerable

TABLE 2.B: FINAL PRIORITY SPECIES USED IN THE SOUTHERN FLORA MODELLING

Species	Comments	TSC Act[1]	ESP Act[2]	ROTAP
Ammobium craspedioides	Located in woodland and open forest from Yass to Tumut	V	V	2V
Diuris aequalis	Occurs within montane forest, along the Dividing range and from Braidwood to Kanagara i.e mostly private land tenures,	V	V	3V
Eucalyptus kartzoffiana	Located in Araluen Valley and possibly within the upper Deua rivers	V	V	2Vci
Eucalyptus langleyi	Occurs within Mallee shrubland on sandstone near Nowra and in Yerriyong State Forest	V	V	2V
Genoplesium vernalis	Found within open forest along the coast north of Batemans Bay, the species is also nationally listed as endangered		E	
Leptospermum thompsonii	Mostly found in open forest and the edge of swamps in Monga State Forest and Clyde Mt	V	V	2V
Melaleuca biconvexa	Occurs in damp places, often riparian	V		
Triplarina nowraensis	Threatened by development it is found in heath and open forest on sandstone, near Nowra	E1	E	
Zieria baeuerlenii	Located in open forest and woodland within Bomaderry Creek and Nowra	E1	E	2E

[1] *Threatened Species Conservation Act 1996* (NSW) E = endangered; V = vulnerable
[2] *Endangered Species Protection Act 1992* (Cwlth) E = endangered; V = vulnerable
ROTAP = Rare or Threatened Australian Plant

2.3 DATA SOURCES

The data used in the fauna and flora modelling project were collated from three sources: systematic survey data from previous survey work; new survey data collected as part of the Southern CRA project; and non-systematic data.

The systematic data collated from previous survey work included survey data from completed studies that were collected using documented field sampling techniques at a series of precise site locations. Such data needed to include presence and absence records for species and have a well defined survey method and effort that was preferably compatible to that of the CRA surveys. Data from previous surveys were particularly sought for the priority species and where large data gaps were identified (see NSW NPWS, 1998c).

2.3.1 Fauna data sources

The new fauna survey data collected as part of the Southern CRA project were collected throughout the Southern area using an environmentally stratified sampling regime, based on three environmental variables (lithology, temperature and rainfall). Specified field techniques were used for sampling each functional group of fauna species at precisely located sites (see NSW NPWS, 1998c). These survey data were the major source of presence/absence data for the fauna species modelling, having consistent method and effort across the area.

The non-systematic fauna data included simple locality records for species from a variety of sources. These data could only be classified as presence-only, opportunistic or presence-only due to there being no systematic sampling methodology or survey design and thus no species absence records. However, such records could still be used separately for modelling, and were useful for species where there was insufficient systematic data. This was often the case for rare or cryptic species which need to be surveyed using targeted non-systematic (or often more specialised) methods to increase chance of detection without wasted survey effort in inappropriate areas.

The primary source of presence-only data was the Atlas of NSW Wildlife (NSW NPWS, 1998a), but some opportunistic data were also collected on the CRA systematic surveys. Data from many external sources were also classified as presence-only due to a lack of quantifiable or systematic survey methodology.

The sources of all fauna data used in the Southern modelling are listed in appendix 1, which includes whether data were classified as presence/absence or presence-only for modelling. Further details on the methods of classifying the data in this way are given in section 2.5.1. The data audit and survey report (NSW NPWS, 1998c) contains more information on the data audit process and sources of records.

2.3.2 Flora data sources

Data used for flora modelling was a subset of the data collected and validated as part of the Southern CRA Rare Plants Project as well as CRA systematic flora surveys and data from other government agencies and independent botanists. New priority species data was collected in the Rare Plants project, targeting areas of previous and historic records (NSW NPWS, 1998c). Most of the flora data used for modelling was classified as non-systematic as many threatened plants require specialised or targeted survey to avoid inappropriate sampling outside a usually limited range. Sources of data used for flora modelling are detailed in the Threatened Plants report (NSW NPWS, 2000).

2.4 DATA MANAGEMENT

Data management procedures for the data audit process and new survey data are described in full in NSW NPWS, 1998c. Collated fauna data were initially stored in a flat file in MS EXCEL due to the unavailability of an appropriate relational database. After the data validation and cleaning process (see below) data was transferred into a basic database in MS ACCESS, for manipulation and preparation for modelling.

A separate file was established in MS EXCEL to store all information about the sources of the raw data. Such information included details on the survey design, methodology and effort, which were later used to classify the data and derive co-variates for the modelling (see section 2.5.1). Collated flora data was stored and manipulated in MS EXCEL flat files. A full relational database was deemed unnecessary due to the simple nature of the data.

2.4.1 Data Validation

Data collected for the priority flora and fauna species in the data audit and survey phases of the Southern CRA project underwent a rigorous validation process. Recognised scientific experts from NPWS, State Forests NSW and private consultants validated individual records of flora and fauna species within their particular field of expertise (see Acknowledgements section).

The validation process involved checking the validity of point locations (against known geographical spread of a species) and species identification (using location, observer expertise and observation method). Thus some records were rejected because:

- they were located outside the known distribution of the species, and were in an inappropriate habitat or area, or the accuracy of the identification was questionable;
- the species identification was questionable due to:
  - observer inexperience;
  - the record being from hair analysis which was designated ‘probable’ or ‘possible’;
  - the record being from a predator scat, and either would have been difficult to accurately identify or may not indicate the true location of the species; or
  - having an inappropriate method of observation for that species.

Once the validated fauna data were imported into MS ACCESS, duplicate records were identified and rejected. Many such duplicates were encountered when data had been received directly from a data source but had also been earlier entered into the Atlas of NSW Wildlife. In such circumstances, the record from the raw data source was retained as the accompanying survey information enabled the record to be accurately designated as presence/absence.

A second check of the fauna data was also run on the ‘observation type’ field (mostly contained in records from the Atlas and CRA surveys) to reject types that could give inaccurate species identification or imprecise geographical and thus environmental location of the species. The observation types that were rejected were (terminology from the Atlas of NSW Wildlife): road, cat, dog, or fox kill; tracks/scratchings; ‘in scat’; ‘in raptor/owl pellet’; fossil/sub-fossil remains; miscellaneous; and ‘not located’.

Fauna records were excluded from the modelling process if they were in Atlas Quarantine, had a poor ‘reliability type’ (as per Atlas of NSW Wildlife), or were pre 1970. Records with an ‘accuracy of geographic location’ code of four or more (i.e. +/- 10 and 100km) (see table 2.c) were also rejected.

2.4.2 Fauna Database

The collated fauna validated data were imported into a ‘presence table’ and an ‘absence table’, in MS ACCESS which contained the fields required for modelling. The ‘presence table’ contained all the details specific to each observation, such as the date, observer, type of observation and the reliability of the observation. The ‘absence table’ contained all absence data for presence/absence surveys, thereby indicating that a survey was conducted but no observation was recorded in the ‘presence table’. For each record there is information on the method used, date and observer.

Information on the species, survey and site for the observation or record is contained in the ‘species table’, ‘surveys table’ and ‘sites table’. These tables are linked to the presence and absence tables by the corresponding ‘species code’, ‘survey id’ and ‘site id’ fields. Smaller tables, such as the ‘methods by functional groups table’ and ‘effort link table’ were constructed to enable the assignment of effort covariate values to unique combinations of ‘survey’, ‘methods’ and ‘functional groups’ values. The ‘functional groups table’ and ‘method table’ were created to provide the necessary links between these tables. The fields in all of the above MS ACCESS tables are listed and explained in table 2.c.

TABLE 2.C: FIELDS CONTAINED IN THE SOUTHERN FAUNA MODELLING DATABASE

Presence Table

Field Name	Description
Site ID	Uniquely identifies each site for each survey. Used to link with the Sites table.
Species code	Numeric identifier for each species from Atlas of NSW Wildlife. Used to link with the Species table.
Number	Number of individuals observed (if unknown default is 1)
Start date	Start date of survey or date of observation
Finish date	Finish date of survey
Season	Numeric identifier representing two seasons: 1 = 1 September to 31 March 2 = 1 April to 31 August
Survey	Text identifier for distinct surveys. Used to link with Surveys table.
Observation type	Type of observation of the species e.g. trapped, observed, heard etc Categories and codes are as those used in the Atlas of NSW Wildlife
Reliability type	Numeric code for reliability of species identification as those used in the Atlas of NSW Wildlife.
Accuracy index	Numeric code for precision of geographic location from the Atlas of NSW Wildlife.
Observer name	Surname of observer
Observer initial	Initials of observer
Duplicates	Identifies duplicate records
Quarantine Status	Quarantine status of Atlas records
Reject	Identifies rejected records
Reject Reason	Provides reason for the rejection of the record

Absence Table

Field Name	Description
Site ID	Uniquely identifies each site for each survey. Used to link with the Sites table.
Method ID	Text code used to identify method of survey.
Season	Numeric identifier representing two seasons: 1 = 1 September to 31 March 2 = 1 April to 31 August
Survey	Text identifier for distinct surveys. Used to link with Surveys table.
Start date	Start date of survey or date of observation
Finish date	Finish date of survey
Observer	Surname of observer
Reject	Identifies rejected records

Surveys Table

Field Name	Description
Source	Identifies the source of the data
Survey	Text identifier for unique surveys. Used to link with Effort Link, Presence's and Absences tables.
Start date	Start date of survey or date of observation
Finish date	Finish date of survey
Method ID	Text code used to identify method of survey. Note: for presence-only surveys the default code is always 'IS' (presence-only sighting). Used to link with Method table.
Model	Identifies the type of data: F = presence/absence data (formal) I = presence-only data (presence-only)
Reject	Identifies rejected surveys for modelling purposes

Sites Table

Field Name	Description
Site ID	Uniquely identifies all sites for each survey within the database (i.e. sites with presences & sites with absences). Used to link with the Presences and Absences tables.
Easting	Australian Map Grid easting (converted to zone 55)
Northing	Australian Map Grid northing (converted to zone 55)
Modelling Site ID	Identifies Site ID that was used in modelling. Two or more Site ID's may have the same Modelling Site ID as different surveys may have used the same site location

Species Table

Field Name	Description
Scientific name	Scientific name (genus, species)
Common name	Preferred common name of species
Species code	Unique numeric identifier for each species as used in the Atlas of NSW Wildlife. Used to link with the Presences table.
Functional group	Functional group the species belongs to. These functional groups were defined for use in the fauna modelling process. The functional groups group species that are likely to be caught or detected using similar methods.
Old Functional group	Functional group used in Eden CRA
Priority species	Identifies species regarded as being of high priority for modelling and conservation consideration
Not Modelled	Identifies species that would not be considered for modelling in the CRA process (e.g feral and marine species)

Method Table

Field Name	Description
Method ID	Text code used to identify method of survey. Used to link with Survey table.
Technique Code-BSS	Text code used in BSS to identify method of survey
Technique ID	Numeric code to identify each method in modelling
Technique Description	Description of each method

Functional Groups Table

Field Name	Description
Functional Group	Functional group the species belongs to. These functional groups were defined for use in the fauna modelling process. The functional groups group species that are likely to be caught or detected using similar methods. Used to provide a link between Species and Methods by Functional Groups tables.
Modelled	Identifies groups which were modelled in the CRA process

Methods by Functional Groups Table

Field Name	Description
Functional Group	Functional group the species belongs to. These functional groups were defined for use in the fauna modelling process. The functional groups group species that are likely to be caught or detected using similar methods. Used to link to Functional Groups and Effort Link tables.
Method ID	Text code used to identify method of survey. Used to link to Effort Link table. The combination of the two fields within the table provides a valid method to detect the functional group for presence/absence surveys

Effort Link Table

Field Name	Description
Survey	Text identifier for distinct surveys. Used to link with Presences and Surveys tables.
Method ID	Text code used to identify method of survey. Note: for presence-only surveys the default code is always ‘IS’ (presence-only sighting). Used to link to Methods by Functional Groups table.
Functional Group	Functional group the species belongs to. These functional groups were defined for use in the fauna modelling process. The functional groups group species that are likely to be caught or detected using similar methods. Used to link to Methods by Functional Groups table.
Effort	Index of survey effort used in the CRA modelling process: 3 = High Effort 2 = Medium Effort 1 = Low Effort

2.5 PREPARATION OF BIOLOGICAL DATA FOR FAUNA MODELLING

2.5.1 Derivation of method, effort and season covariates

Due to variation in survey method, effort and season between and within the various external sources of systematic data and the CRA surveys, covariates were derived that would enable detection of any effect this variation may be having on the detectability of species. The covariates were derived in consultation with scientific experts and only used for presence/absence modelling as method, effort and season are not considered in presence-only modelling.

Before deriving the covariates, all data were classified as either formal (presence/absence) or incidental (presence-only) as different modelling techniques were to be performed on each. As evident in appendix 1, many external data could not be classified as presence/absence due to systematic survey methods not being used, either in the selection of sites or in the survey techniques employed at the sites. Other data did not have enough supporting information to determine accurately the methods and effort employed. These data were therefore classified as presence-only for analysis purposes.

The method covariates were derived separately for each functional group and based on the survey techniques used for detecting species in each. Certain functional groups were split further (some to species level) as they either required specialist survey methods, or the general survey techniques for the larger functional group were not adequate, and could produce false absences. These were small and medium ground mammals, tiger quoll, heath monitor and koala. The method covariates derived were:-

Medium Ground mammals:
1. hair tube
2. cage trap

Small Ground mammals:
1. elliott trap
2. hair tube
3. pitfall trap

Bats:
1. harp trapping
2. Anabat (ultrasonic recording)
3. mist netting
4. trip lines

Arboreal mammals:
1. walking spotlighting transects
2. call playback
3. walking spotlighting and call playback

Nocturnal birds:
1. walking spotlighting transects
2. call playback
3. walking spotlighting and call playback

Diurnal birds:
1. observation census

Reptiles:
1. visual habitat search

Amphibians:
1. nocturnal streamside search
2. visual search
3. pitfall trap
4. vehicle spotlighting

Heath Monitor:
1. habitat search
2. cage trap

Tiger Quoll:
1. habitat search
2. cage trap (vegetarian bait only)
3. cage trap (meat bait only)
4. sand plot

Koala:
1. targeted walking spotlighting transects
2. targeted call playback

Effort covariates were derived for each unique functional group as listed above. Each functional group was allocated one of three possible rankings:

1. Low Effort
2. Medium Effort
3. High Effort

This relative ranking was dependent upon the trapping/observtion effort (i.e number of trapping nights; search times; search areas), the number of visits to the area; the number and experience of surveyers; and the appropriatness of the survey technique(s) used.

The season covariate was derived to take into account the effect of season in the detection or capture of animals. It was decided to keep this covariate simple so as not to over complicate modelling. In consultation with scientific experts it was decieded to have two seasons:

1. 1 Sept to 31 March
2. 1 April to 31 August

These covariates were assigned to the presence/absence records in the MS ACCESS database. In the modelling process, method and season were used as factor covariates while effort was used as a continuous covariate to determine whether they produced any effect on the results.

2.5.2 Exporting data from MS Access

The fauna species modelling was performed by functional group (eleven groupings) and by data type (either presence-only or presence/absence). This separation of data gave 22 potential modelling categories. For each modelling category, data needed to be extracted from the MS ACCESS database into two tables to be used by S-PLUS (StatSci, 1993) and ARCVIEW Spatial Analyst (ESRI, 1996) to generate the final models:

- a ‘species seen’ table detailing each species within the functional group;
- a ‘species data’ table detailing species/site characteristics.

The ‘species seen’ table contained a record for each species recorded for the functional group / data type in the database. Each record detailed the common and scientific name, the species code and a unique record identifier.

The ‘species data’ table contains a record for each site that contains a presence or absence record for the functional group. It is in a crosstab format giving site characteristics versus species code with an abundance figure for each site/species combination. For each record there is a sitecode, an easting, a northing, method covariate value, effort covariate value, season covariate value, and an abundance value for each species in the functional group. For presence/absence modelling a ‘0’ value is an absence and any other value is a presence for the site/species combination. For presence-only modelling non zero values are presences and ‘0’ values are ignored. Also with presence-only modelling the method, effort and season covariates are irrelavent and were held to constant values.

2.6 PREPARATION OF ENVIRONMENTAL DATA FOR FAUNA MODELLING

The fauna modelling project relied on the development of adequate environmental layers that are representative of the environmental variables known to influence species' distribution. A workshop was convened with experts familiar with the environmental needs of the species being modelled and experienced in the process of statistical modelling. From this workshop, various indices and variables were chosen to be used in the modelling and the appropriate experts nominated to undertake their derivation. The effectiveness of variables used in the Eden, Upper North East and Lower North East CRA modelling projects was also considered.

The variables used for modelling can be divided into two categories; habitat indices and abiotic variables. The separate variables for each of these categories and their scales and sources are listed in table 2.d and discussed in more detail below.

2.6.1 Habitat indices

The expert workshop participants decided on a number of fauna habitat indices to be used for fauna modelling process. The first set of these indices involve a proximity to a certain feature type. These proximity features are clearing, bare rock, swamp and heath, disturbance and rainforest. The second set involve derived values (0-9) for various habitat features. These features are habitat disturbance, tree hollows, nectar, pollen, decorticating bark, fine litter, vegetation community complexity, and growth stage. The habitat indices were represented spatially using canopy structure and canopy floristic GIS layers derived from the Aerial Photography Interpretation (API) project.

Vegetation community complexity, growth stage, proximity to rainforest, proximity to rock, proximity to swamp and heath, proximity to clearing and habitat disturbance indices were derived directly from the API special features or canopy structure GIS layers.

For tree hollows, nectar, pollen, decorticating bark and fine litter indices a new API GIS layer was derived (API Structure & Floristic layer), which gave coded values for each spatial combination of canopy structure values and canopy floristics values. External experts were then given a list of all possible floristic/structure combinations. They used their knowledge of the canopy species and the index they were to derive, to assign values of 0 to 9 for each floristic/structure combination. The value assigned indicates the relative value the API floristic/structure combination has for the index in question. These values were then attributed to the API Structure & Floristic GIS layer.

There were limitations with the spatial precision of the underlying API layers and fauna sighting records. This imprecision, combined with the mobility of most of the fauna species being modelled, makes it important not only to consider the index values at any one point, but also the values in the immediate vicinity to a point. To take into account this consideration it was decieded to apply an inverse distance weighting (IDW) to the raw index GIS layers (ie those that contained the expert derived values of 0 to 9). The IDW averaged, with squared inverse distance weighting, the values of the raw index within a 500 meter radius. Therefore the raw index values closest to a point had the greatest influence on that points final derived value with values further than 500 meters away having no influence at all. This IDW regime was applied to the growth stage, nectar, pollen, tree hollow, decorticating bark and fine litter indices. The IDW was not applied to the vegetation community complexity indices as they, by definition, already take into account the surrounding area's characteristics.

This IDW was also used to derive the proximity habitat variables (proximity to rainforest, heath and swamp, disturbance, clearing and rock). The raw spatial layers for these indices contained a value of one where the feature in question occourred and a value of zero were they didn't occour. The IDW was used with a predefined radius to calculate the proximity to a point of each of the raw indices.

The IDW tended to leave a skewed distribution of values with a few very high values. Each of the habitat indices that had used IDW were logged (base ten) to reduce this skew and then multiplied by 100 to give a final integer value.

TABLE 2.D: VARIABLES USED FOR SOUTHERN FAUNA MODELLING

VARIABLE	Grid size	GIS DATA LAYER USED	DERIVED BY
Habitat indices			
tree hollows	100m	API[1] canopy structure & canopy floristic layers[2.]	Phil Gibbons, Centre for Resources & Environmental Studies (CRES), Australian National University
nectar	100m	API[1] canopy structure & canopy floristic layers[2.]	Wayne Braithwaite, Consultant
nectar (apiarist)	100m	API[1] canopy structure & canopy floristic layers[2.]	Greg Roberts, apiarist
pollen	100m	API[1] canopy structure & canopy floristic layers[2.]	Greg Roberts, apiarist
decorticating bark	100m	API[1] canopy structure & canopy floristic layers[2.]	Wayne Braithwaite, Consultant
fine litter	100m	API[1] canopy structure & canopy floristic layers[2.]	Phil Gilmore, Consultant
vegetation community complexity	100m	API[1] canopy structure & canopy floristic layers[2.]	NSW NPWS
growth stage (500m)	100m	API canopy structure layer[2]	NSW NPWS
growth stage (1km)	100m	API canopy structure layer[2]	NSW NPWS
growth stage (2km)	100m	API canopy structure layer[2]	NSW NPWS
Proximity to clearing (1km)	100m	API special features layer[2]	NSW NPWS
Proximity to clearing (2km)	100m	API special features layer[2]	NSW NPWS
Proximity to rock (2km)	100m	API special features layer[2]	NSW NPWS
Proximity to rock (5km)	100m	API special features layer[2]	NSW NPWS
Proximity to swamp & heath	100m	API special features layer[2]	NSW NPWS
Proximity to disturbance	100m	API canopy structure layer[2]	NSW NPWS
Proximity to rainforest (250m)	100m	API special features layer[2]	NSW NPWS
Proximity to rainforest (1km)	100m	API special features layer[2]	NSW NPWS
Proximity to rainforest (2km)	100m	API special features layer[2]	NSW NPWS
Abiotic variables			
digital elevation model (DEM)	25m	Land Information Centre (LIC), DLWC	Land Information Centre, DLWC
mean annual rainfall	100m	ESOCLIM	GISD, NSW NPWS
minimum temperature of coldest period	100m	ESOCLIM	GISD, NSW NPWS
maximum temperature of warmest period	100m	ESOCLIM	GISD, NSW NPWS
rainfall of driest quarter	25m	ESOCLIM	GISD, NSW NPWS
rainfall of wettest quarter	25m	ESOCLIM	GISD, NSW NPWS
rainfall seasonality	25m	ESOCLIM	GISD, NSW NPWS
rainfall seasonality (temp)	25m	ESOCLIM	GISD, NSW NPWS
ruggedness 1km	25m	LIC DEM	GISD, NSW NPWS
ruggedness 500m	25m	LIC DEM	GISD, NSW NPWS
ruggedness 250m	25m	LIC DEM	GISD, NSW NPWS
solar radiation	25m	LIC DEM / ESOCLIM	GISD, NSW NPWS
terrain position	25m	LIC DEM	GISD, NSW NPWS
topographic position 1km	25m	LIC DEM	GISD, NSW NPWS
topographic position 500m	25m	LIC DEM	GISD, NSW NPWS
topographic position 250m	25m	LIC DEM	GISD, NSW NPWS
wetness index	100m	LIC DEM	GISD, NSW NPWS

[1] API = Aerial Photography Interpretation [2] NSW NPWS (in prep)

Tree hollow index

The tree hollow index reflects the amount of hollows found in a particular vegetation type. Values were assigned to the API structure and floristic layer by Phil Gibbons from the Centre for Resource and Environmental Studies (CRES), Australian National Universtiy. The values were assigned based on his knowledge of the hollow characteristics of the tree species and growth stages involved (Gibbons 1999).

Nectar index

Two nectar indices were derived by two different sources; Wayne Braithwaite, an environmental consultant and Greg Roberts, the apiary industry's representative on the Southern Regional Forest forum. The scores reflect the sources' perceptions of relative values for nectar production for the vegetation types in the API structure and floristic layer.

Pollen index

The pollen index was compiled by Greg Roberts, the apiary industry's representative on the Southern Regional Forest forum, and applied to the API structure and floristic layer. The scores reflect the apiarist's perceptions of relative values of pollen production for the vegetation types.

Decorticating bark index

The decorticating bark index is an indication of the propensity of bark for peeling. Values, assigned to the API structure and floristic layer, were derived by Wayne Braithwaite (environmental consultant).

Fine litter index

The fine litter index is an indication of the amount of fine litter produced. Values that were applied to the API structure and floristic layer were derived by Alexander Gilmore (environmental consultant) and were correlated with canopy biomass increments (Gilmore 1999).

Vegetation community complexity index

The vegetation community complexity index is a measure of the number of canopy types (defined within the API canopy floristic layer) within a set radius of any particular point. Radii used were 500 metres, one kilometre and two kilometres, giving three final vegtation community complexity indices. The derivation of these indices was performed using a focal statistics procedure in ArcView Spatial Analyst. The expression used to derive these layers was ([agrid]).focalstats(#GRID_STATYPE_VARIETY,Nbrhood.MakeCircle(X,true),false) where [agrid] it the API canopy floristics layer and X is the radius in meters.

Growth stage indices

The growth stage indices were designed to take into account habitat value (primarily hollow abundance) for fauna species. A simple numerical ranking of the growth stage codes from the API canopy structure layer in terms of increasing fauna value was defined. The ranking of these codes is shown in table 2.e. The IDW was applied using three radii: 500 meters, one kilometre, and two kilometres, to give three final indices.

TABLE 2.E: GROWTH STAGE INDICES GROWTH STAGE RANKINGS

Growth stage code[1]	Growth index
tA	7
tB	6
sA	5
sB	4
tC	3
sC	2
e	1
non eucalypt	0

[1]Growth stage codes are from the API (NPWS in prep.)

Clearing within one and two kilometres

Proximity to clearing within one and two kilometres were derived from cleared land as mapped by the Southern CRA API project. The IDW was applied using a radius of one and two kilometres to give two final indices.

Rock within two and five kilometres

Proximity to rock within two and five kilometres were derived from rocky areas as mapped by the Southern CRA API project. The IDW was applied using a radius of two and five kilometres to give two final indices.

Swamp and heath within one kilometre

The proximity to swamp and heath within one kilometre was derived from swamp and heath as mapped by the Southern CRA API project. The IDW was applied using a radius of one kilometre.

Disturbance within 500 metres

The value “e” from the canopy structure layer, mapped by the Southern CRA API project was utilised as the index of disturbance. The value represents forest that has less than thirty percent regrowth. The IDW was applied using a radius of 500 metres.

Rainforest within 250 metres, one kilometre and two kilometres

The proximity to rainforest was derived from rainforest as mapped by the Southern CRA API project. Most areas of rainforest were confined to thin strips. The IDW was applied using a radius of 250 metres, one kilometre and two kilometres, to give three final indices.

2.6.2 Abiotic variables

The expert workshop participants also decided on a number of suitable abiotic variables to use in the fauna modelling. The majority of these ‘base’ variables were developed by NPWS GIS staff. Either site variables or contextual variables were used depending on the nature of the feature under consideration. The following variables were developed, and all were used as pedictors in the species modelling:

- digital elevation model (DEM);
- mean annual rainfall;
- mean annual temperature;
- minimum temperature of coldest period;
- maximum temperature of warmest period;
- rainfall of driest quarter;
- rainfall of wettest quarter;

- rainfall seasonality;
- temperature seasonality;
- ruggedness 1 kilometre;
- ruggedness 500 metres;
- ruggedness 250 metres;
- solar radiation index;
- terrain position;
- topographic position 1 kilometre;
- topographic position 500 metres;
- topographic position 250 metres; and
- wetness index.

Digital elevation model (DEM)

The digital elevation model is a 25 metre grid cell coverage with values representing metres above sea level. This layer was supplied by the Land Information Centre (LIC) of the Department of Land and Water Conservation (NSW).

Rainfall and Temperature Variables

These variables were derived using the ESOCLIM component of ANUCLIM, a predictive software package composed of six Fortran programs provided to NPWS by the Centre for Research and Environmental Studies (CRES) at the Australian National University, Canberra. Using rainfall and temperature weather station data provided by the Bureau of Meteorology, Sydney, rainfall and temperature surfaces to be used with the ESOCLIM software were derived.

The climatic surfaces and the DEM were entered into ESOCLIM which output a series of monthly mean estimates of maximum temperature, minimum temperature and rainfall. The rainfall estimates were supplemented by updated rainfall surface data, processed through ESOCLIM by the Bureau of Resource Sciences and provided to NPWS. The mean monthly outputs were then further manipulated to provide the final eight variables. A brief description of these variables are below.

- Mean annual rainfall – average monthly rainfall over the year
- Mean annual temperature - calculation of mean temperature for each month, (maximum + minimum)/2, added together and divided by twelve
- Minimum temperature of coldest period – the coldest temperature at any point, based on minimum temperature
- Rainfall of driest quarter – sum of the driest three months at any point
- Maximum temperature of warmest period – the hottest temperature at any point, based on maximum temperature
- Rainfall of the wettest quarter – sum of the wettest three months at any point
- Rainfall seasonality – coefficient of variance of all twelve months based on rainfall
- Temperature seasonality – coefficient of variance of all twelve months based on maximum temperature

Ruggedness one kilometre, 500 metres and 250 metres

The ruggedness index (NSW NPWS, 1994a, 1994b) assigned to a cell is the value returned from calculating the standard deviation of elevation values within a window of given dimension centred on the cell, i.e:

$$R = STD\{e_1 + e_2 + e_3 + \ldots e_n\}$$

where R is the ruggedness index, STD is the standard deviation and $e_1, e_2, e_3 \ldots e_n$ are the elevations of the cells in the window. It follows that the greater the ruggedness of the terrain the more spread out the elevation values will be and therefore the greater the standard deviation. A rugged terrain therefore can be an area of significant rises and falls in elevation, or a single hillside or part thereof (figure 2.a). Areas that receive low ruggedness values tend to be flat or undulating.

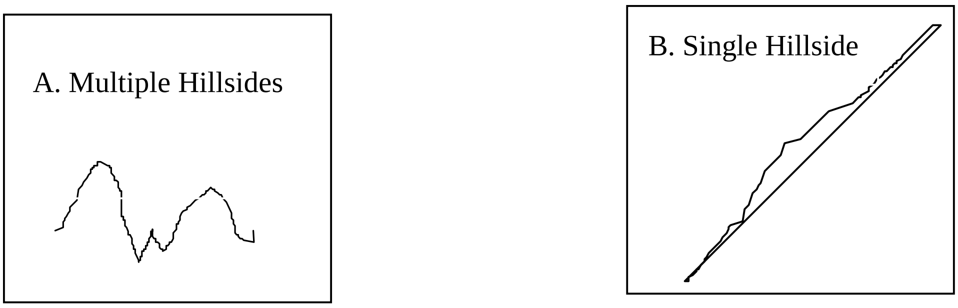
The ruggedness index has been calculated using the ARC/INFO GRID module as follows:

grid: rough_grd = INT(FOCALSTD(dem_grd, rectangle, 10, 10, DATA))

where rough_grd is the roughness grid, FOCALSTD is the GRID function for calculating the standard deviation for the input grid dem_grd using a moving rectangle shaped window of dimensions 10 cells by 10 cells. (The ‘INT’ function converts the output to integer values; ‘DATA’ directs the function to ignore NODATA values).

The example above can be easily modified by changing the size of the window from 10 x 10 cells to other sizes.

FIGURE 2.A: RUGGED TERRAIN



Solar radiation index

The solar radiation index (Nunez, 1980) is 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 as well as scattering by the atmosphere. See figure 2.b for a simple description of the process.

The major components of the method are:

- the DEM - which provides a grid-based model of the terrain;
- sample times - which are the times at which the solar radiation will be sampled. In this case the program was run seven times per day (at two hourly intervals between 7am and 7pm) for one day each month of the year;
- solar azimuth - the angle between the sun and north;
- solar altitude - the angle between the sun and the horizon;
- flat solar radiation - a measure of how much solar radiation reaches the earth’s surface without the influence of terrain;
- hillshade - the process by which the effects of terrain, shade and shadow are calculated for the area;

- diffuse solar radiation - an estimation of the amount of solar radiation that reaches a cell indirectly due to scattering;
- ESOCLIM flat surface radiation - a climatic surface which provides a measure of flat surface radiation based on time of year and average atmospheric conditions.

The process has been implemented using a combination of MS EXCEL and ARCVIEW Spatial Analysis using the Avenue programming language. The list of sample times is inserted into the EXCEL spreadsheet from which the solar altitude and solar azimuth are calculated automatically. These outputs are transferred to a text file which the Avenue code reads as inputs for the calculation of hillshade. The hillshade function is then applied. In parallel the process is applied to a flat shade-free cell. Using the value obtained from the hillshaded flat cell the results from the hillshaded terrain are transformed into appropriate units and a value for diffuse radiation (Nunez, 1980) is added (equation 1). The process is repeated and summed over the sample day (representing a month). The monthly values are then transformed into correction factors by dividing them by the monthly values for a flat shadow-free cell . The correction factors are then applied to the ESOCLIM values for flat solar radiation to derive the final values for solar radiation (equation 2).

EQUATION 1

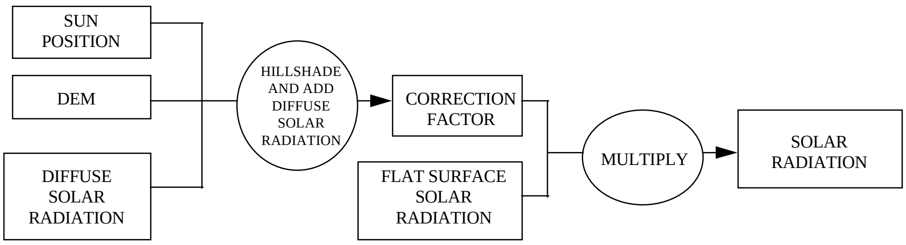
$$S_C = S_H \left(F_N / F_H \right) + S_D$$

EQUATION 2

$$S_R = S_C \cdot F_E$$

where S_C is the correction factor for a given month, S_H is the value for one month calculated using hillshade, F_N is the calculated value for flat surface radiation for that month (Nunez, 1980), F_H is the value for flat surface radiation calculated using hillshade, S_D is the value for diffuse solar radiation (Nunez, 1980), F_E is the ESOCLIM monthly value for flat surface radiation, and S_R is the final value for monthly solar radiation.

FIGURE 2.B: SIMPLIFIED PROCESS FOR THE DERIVATION OF THE SOLAR RADIATION INDEX



Terrain position

Terrain position, as described in detail in Skidmore (1990), is a measure of the position of each grid cell on a continuum between ridge (value = 1) and gully (value = 0). In broad terms the algorithm has three stages. The first two, the identification of ridges and gullies, is purely an analysis of the elevation of each cell in relation to its immediate neighbours. The third step involves an interpolation of midslope positions using Euclidean distance between each cell and their closest ridge and gully (figure 2.c).

The first step is to tag gullies. A cell is defined as a gully if left and right neighbours in one direction are higher in elevation than the cell while with the two orthogonal neighbours one is higher and one is lower. Gully cells are allocated a value of ‘0’.

The second step is to tag ridges. A cell is defined as a ridge if the left and right neighbours in one direction are lower while with the two orthogonal neighbours one is higher and one is lower. Ridge cells are allocated a value of ‘1’. Peaks are also treated as ridges.

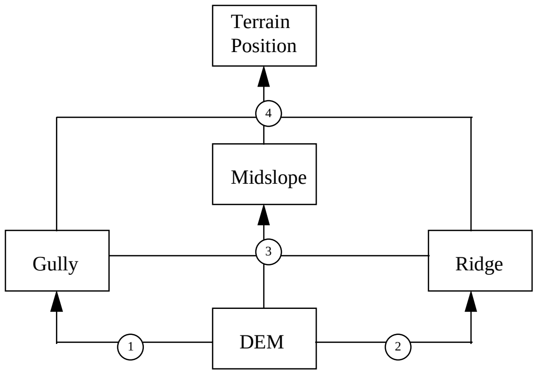
Steps one and two are repeated for all north-south, east-west, northeast-southwest, and northwest-southeast directions. If adjacent cells are equal in elevation to the test cell then the algorithm searches outwards until a cell of different elevation is found.

The third step is the identification of midslopes. After steps one and two, the remaining cells are defined as midslope cells. The Euclidean distance function in Arc/Grid is used to find the distance between each midslope cell and its nearest ridge cell and nearest gully cell. The ratio between the distance to gully (*Dg*) and the sum of the distance to gully (*Dg*) and the distance to ridge (*Dr*) returns the value for midslope i.e.

$$M = \frac{D_g}{D_g + D_R}$$

The algorithm was implemented as an AML program within the ARC/INFO Grid module.

FIGURE 2.C: FLOW CHART ILLUSTRATING THE PROCESS FOR THE DERIVATION OF TERRAIN POSITION



Topographic position one kilometre, 500 metres and 250 metres

The topographic position of a cell (NSW NPWS, 1994a, 1994b) is a measure of the elevation of a cell in relation to the mean elevation value for a window of given dimension centred on the cell i.e.

$$T = e - \bar{e}$$

where '*T*' is the topographic position, 'e' is the elevation at any point and $\bar{e}$ is the mean elevation for the window.

Values can range from positive indicating a cell with above average elevation for the window, to negative indicating a cell with below average elevation for the window. Unlike the Skidmore (1990) method the values are not confined to any range. The method therefore provides a measure of the degree to which the cell's elevation conforms or deviates from its neighbours.

This method has no direct link to the geometry of the DEM as the Skidmore (1990) method has. It does not therefore derive ridges and gullies as such although local high positive values are indicative of ridges and local high negative values of gullies. This method has the advantage of allowing variable resolution by varying the size of the analysis window around each cell.

Since there is likely to be a need for a variety of outputs based on varying window sizes, a prompt for the selection of a window size is provided. Windows of 1000, 500 and 250 metres are likely to be useful.

The algorithm was applied within ARCVIEW Spatial Analyst using the Avenue programming language.

Wetness index

The wetness index produces an indication of the volume of water draining to each part of the landscape as well as the landscape's ability to retain water due to slope. The process (figure 2.d) employs a depressionless digital elevation model (DEM) to derive the flow from each cell to its downslope neighbours based on relative slopes. Multiple iterations allow the flow over the landscape to be simulated and a cumulative value of flow through each cell to be calculated i.e. flow accumulation. With this it is possible to derive the wetness index (Moore *et al.,* 1993) for all cells in the grid as follows:

$$W = \ln(a)/\tan ß$$

where W is the wetness index , *a* is the flow accumulation and tan ß is the slope gradient.

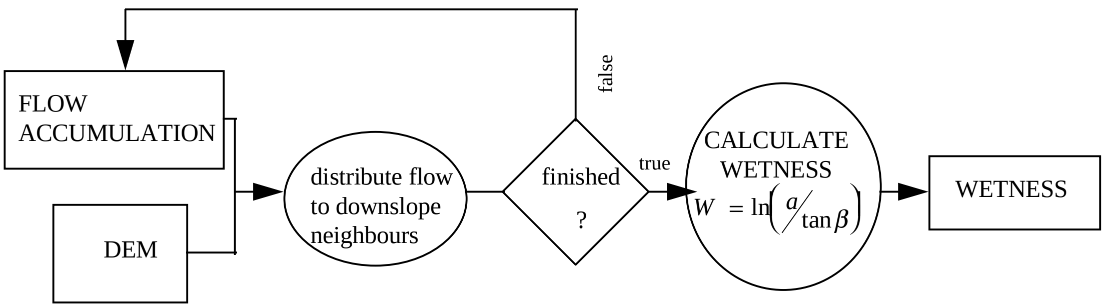
There are two alternative algorithms for the derivation of *a*:

- Single flow direction (SFD), which is based on the methods reported by Jenson and Domingue (1988). With this approach all flow from a cell is allocated to the downslope cell with the greatest drop in elevation. This approach is relatively quick and suits the modelling of stream flow. It also contains a useful method for determining a flow direction in flat areas by progressively searching outwards until a cell of lower elevation is found;
- Multiple flow direction (MFD) (Wolock and McCabe, 1995) where flow is allocated to all downslope cells in proportion to their relative slopes. This process is computationally intensive but greatly increases the quality of the outputs on overland areas. Within well defined channels however, the advantages of MFD over SFD do warrant the extra computational effort required.

In the approach used here, the two approaches have been combined in order to adequately model overland flow with the MFD algorithm and to optimise the efficiency of the program by modelling stream flow with the SFD algorithm. The SFD method is also adopted in flat areas i.e. a flat cell is one where the elevation of all surrounding cells equals the elevation of the cell.

The index was calculated using an AML program within the ARC/INFO Grid module.

FIGURE 2.D: SIMPLIFIED FLOW CHART OF THE PROCESS FOR CALCULATING THE WETNESS INDEX



2.7 PREPARATION OF ENVIRONMENTAL DATA FOR FLORA MODELLING

Flora experts used in the data validation process selected a series of environmental variables to use for the flora modelling. These are listed and described in table 2.f and include some of those derived for fauna modelling but with the edition of Eastern Bushlands Database, Longitude, Latitude, Lithology and Slope.

TABLE 2.F: VARIABLES USED FOR FLORA MODELLING

NAME	CELL RESOLUTION	SOURCE DATA	DESCRIPTION
Digital elevation model (DEM)	100m	Land Information Centre (LIC), DLWC	Elevation based on digital elevation model
Eastern Bushlands Database	30m	NSW NPWS	Species were mapped into broad vegetation types via Satellite Imagery (LANDSAT)
Latitude	2000m	NSW NPWS	Based on Zone 55 northings from the Australian Map Grid (AMG's)
Longitude	1000m	NSW NPWS	Based on Zone 55 eastings from the Australian Map Grid (AMG's)
Lithology	100m	The soil landscape layer produced by DLWC was altered via expert consultation	Lithology is divided into 13 groups based on mineralogy and geomorphology
Topographic position	25m	Derived by GISD, NSW NPWS	An index of position on a slope from ridge to gully
Solar radiation	25m	Data from LIC DEM/ ESOCLIM	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
Mean Annual Rainfall	100m	Data from ESOCLIM	Precipitation of each month added together and divided by twelve
Rainfall of the Driest Quarter	25m	ESOCLIM	Sum of the driest three months at any point
Mean Annual Temperature	100m	Data from ESOCLIM	Calculation of mean temperature for each month (maximum + minimum)/2, added together and divided by twelve to give mean temperature over the year
Minimum temperature in coldest quarter	100m	Data from ESOCLIM	Indicates the coldest temperature at any point, based on minimum temperature
Ruggedness 250m	25m	NSW NPWS	The standard deviation of elevation values within a 250m window around the cell
Slope	100m	LIC DEM	Calculated from DEM within ArcView Spatial Analyst

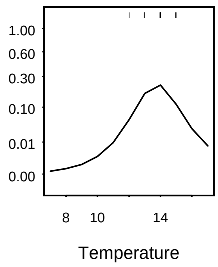
2.8 DERIVATION OF FAUNA SPECIES MODELS

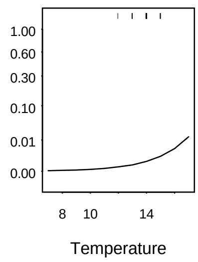
2.8.1 Introduction to modelling methodology

The fundamental aim of the modelling process was to spatially interpolate known occurrences of fauna species from field surveys throughout the study area by finding statistical relationships between the biota and the environmental variables outlined in section 2.6. A module developed by Watson (1996) running under the S-PLUS statistical software (StatSci, 1995) was used with ARCVIEW Spatial Analyst (ESRI, 1996) to conduct the modelling. The values of the environmental variables at each survey site were determined and related to recorded presences and absences (or pseudo-absences for presence-only modelling). This relationship was then statistically analysed to produce a model predicting likelihood of occurrence across the Southern CRA’s study area for each species. Figure 2.f shows the general analysis and modelling pathway used, which is explained in the following pages.

The predictive species modelling package provides the user with a choice between the two most commonly used logistic regression procedures, generalised linear modelling (referred to as GLM) and generalised additive modelling (referred to as GAM) (Watson, 1996). GLM is essentailly an extension of ordinary linear regression, a technique which fits linear (straight line) functions relating a response (dependent) variable to one or more predictor (independent) variables. Two of the basic assumptions of linear regression are that the relationship between response and predictor variables can be approximated by a straight line and that the variance associated with the response is homogenous throughout the full range of the response variables. GLMs overcome these assumptions by allowing a class of models that provide non-linearity and heterogeneous variance in response functions (NSW NPWS, 1994a). GAMs are essentially an extension of GLMs, the major difference being that GAMs use a nonparametric smooth function relating the response to the predictor. The functions are smooth curves estimated from the data using techniques originally developed for smoothing scatter plots. The GAMS derived by this software use cubic splines to fit smooth functions. Hence the principal difference between the two modelling techniques is that GAMs allow the survey data to determine the shape of the response curves, whereas GLMs are constrained by parametric forms, that is, cubic and quadratic polynomial response curves (NSW NPWS, 1994a; Watson, 1996). An example of these differences is shown in figure 2.e.

FIGURE 2.E: COMPARISON OF GAM (A) AND GLM (B) MODELLING OUTPUTS





(A) GAM **(B) GLM**

Exactly the same data was used for both a & b. Note the constraint in the GLM output to a polynomial curve as opposed to the data-fitted GAM curve.

FIGURE 2.F: GENERAL ANALYSIS AND MODELLING PATHWAY USED IN THE SOUTHERN FAUNA MODELLING

Time constraints meant that only one of these methods could be used. Using advice from modelling experts, and the experiences with both the Eden and Northern CRA, it was decided to use only the GAMs.

The outputs from the modelling process are in two forms;

- A digital map across the Southern CRA study area with values indicating the probability of occurrence of the modelled species (in the case of presence-only modelling this is a relative likelihood scale - see below)
- A postscript file containing information about the model, for example; deviance, model type and degrees of freedom, as well as 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.

A detailed discussion of the theory and mathematical detail of this modelling technique is beyond the scope of this report. Further details are contained in Yee and Mitchell (1991) (detailed theoretical account of GAMs) and Hastie and Tibshirani (1990) or Hastie (1992) (further mathematical detail). Watson (1996) details the modelling software used for this study. Further explanation of the model outputs are contained in section 3.2.1.

Within the GAM process, two types of modelling could be performed:

- presence/absence modelling, which utilises systematic survey data and produces models based on recorded presences of a species in relation to recorded absences. Unlike presence-only models these models produce upper and lower standard error maps and the graphical outputs contain three additional diagnostic plots portraying model discrimination, calibration and refinement (Murphy and Winkler, 1992) (see section 3.2.1 for explanations of these).
- presence-only modelling which uses both systematic and opportunistic sightings but does not use positive absence data. Presence-only data were modelled in relation to 1000 'pseudo-absences' which were randomly chosen from all forested land within the study area. Pseudo-absence points were given a weighting of n/1000 where n = the number of presence records for each species. This manner of weighting facilitated approximation of degrees of freedom, deviances and significance levels appropriate to presence-only modelling. The weightings also enabled predictions to be expressed in terms of an index of relative likelihood of occurrence ranging from 0 to 1 (later converted to a percentage). Unlike presence/absence modelling this is only a *relative* index and not an estimation of the probability of occurrence. Confidence limits could not be applied to these models due to the weightings and approximations involved (NSW NPWS, 1994a).

2.8.2 Species groups, variables and sub-regions

The statistical modelling software required that individual species be placed together in functional groups. The functional groups for Southern modelling were: bats, reptiles, amphibians, ground mammals, arboreal mammals, nocturnal birds, diurnal birds, goannas, tiger quoll and the koala.

Each functional group was run through the modelling as a batch with the user able to specify which species were to be modelled and which environmental variables were to be used. Two basic runs were completed for each functional group: presence/absence and presence-only.

Most of the variables outlined in section 2.6 were used initially for every functional group, but due to time and monetary constraints, further refinement of many models was not possible, although this was originally intended. However for those species where both models were deemed inadequate during the first round of expert model evaluation, attempts were made to improve models by removing certain environmental variables, or incorporating new data where available.

Concern was expressed over the initial use of all habitat indices for every functional group. On occasion, a variable was identified by a model as being significant to a species but it had no true known ecological basis for that relationship. However, it was felt that these variables could remain if the predicted distributions for the species were consistent with where experts felt the species should be occurring. As the habitat indices were essentially a numerical grouping of vegetation types, any correlations found with these indices were really correlations with vegetation types. Furthermore, the index selected may be acting as a surrogate for another variable(s).

Because key data layers, such as Aerial Photographic mapping (API) became progressively available in three stages in the middle part of 1999, the Region was divided into three subregions based broadly on IBRA bioregions and the API data capture areas. Boundaries of the South Coast, Western and Northern Subregions were proposed by NPWS, agreed to by SFNSW and endorsed by the CRA/RFA Steering Committee. The subregions represented discrete areas to be negotiated.

The priority species were modelled seperately for the south coast and tablelands modelling areas. The Tablelands modelling area comprised the Western and Northern sub-regions while the South Coast modelling area included all the South Coast sub-region. Buffer zones were placed around each modelling area in order to include as much site data from the adjoining sub-regions.

2.8.3 Initiation of a run

The first and most important file required for the running of a batch was the 'sites' file. This file contained all the sites for the functional group and the covariate values for each site (a site was defined as any unique combination of location, season, effort and methodology). Cross-tabbed with these site details were columns representing each species within the functional group. The intersection of the rows representing the sites, and the columns representing the species, contained the abundance of the species found at the site. Any positive value represented a presence for the species at that site and zero values represented an absence. These files were extracted from the MS ACCESS database.

The sites file was imported into ARCVIEW Spatial Analyst where it was intersected with all the environmental variables. This step outputted a file called 'envars', the environmental variables file, which contained the value of each variable at each site. Other files coming out of ARCVIEW included 'varfiles' which contained the range of each variable across the study area, and 'outlines', an ASCII file of the coordinates of the study area. The final file was a ‘pseudo-absences’ file which contained 1000 random points across the study area and was required for presence-only modelling. Cleared land was removed at this point to prevent pseudo-absence points occurring on cleared land, as this would have led to certain biases due to survey efforts being concentrated on forested land.

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

The first task within S-PLUS was to establish the ‘variable classes’ data frame. This comprised a matrix with 100 rows and a column for each variable, with the values in each cell determined by the data ranges file (‘varfiles’). The next major task was to test for collinearity between variables. The procedure employed for this task tests for collinearity in three ways: between continuous variables; between continuous and categorical variables; and between categorical variables (Watson, 1996). Once it has decided which variables are collinear, the variables are placed into groups such that:

- a group of collinear variables can contain more than just a pair of variables but if it does, then all the variables within the group must be correlated;
- a variable may have membership of more than one group; and
- any single variable that is not correlated with any other variable is put into a group of its own (Watson, 1996).

Once the variables have been grouped the software moves to the stepwise variable selection procedure. The initial test involves the evaluation of all univariate models. Any variable which does not significantly ($p < 0.15$) reduce the null deviance is discarded permanently. Any variable which reduces the significance less than a variable with which it has found to be correlated with, is permanently discarded. If no univariate models significantly ($p < 0.15$) improve the null fit, then a null model results. Species with fewer than 10 positive observations also result in a null model. After this stage, the forward-backward stepwise selection procedure begins with a pool of non-correlated variables each represented by one term expression. The starting model is the univariate model which achieved the most significant reduction in null deviance (Watson, 1996).

Each of the other variables is added to the starting model. The bivariate model which affords the most significant ($p < 0.15$) reduction in deviance becomes the new interim model. A similar process produces the best trivariate model whereupon backwards stepwise selection is invoked to determine whether a bivariate model comprised of the most recently added variable, and either of the two already included, significantly ($p < 0.20$) reduces the deviance of the trivariate model. If so, the bivariate model becomes the new interim model, otherwise the trivariate model enters a new cycle where a fourth variable is tested for inclusion on the same basis as the previous cycles. After each addition, backward selection is performed to explore whether it is possible to revert to a simpler model. When six variables are chosen or when no variable significantly reduces the deviance of the interim model, further selection ceases (Watson, 1996).

2.8.4 Interpolation of Fauna Species Models

Once the model for a species has been created, the predicted occurrence of that species across the study area is derived. The values in the variable classes dataframe (see above) are assigned prediction values (on the logit scale) (Watson, 1996). These values are imported into ARCVIEW Spatial Analyst and used to spatially interpolate a map of predicted species distribution. At this point the values are converted from a probability scale of 0 - 1 into a percentage value (for data storage and manipulation purposes). The output for presence-absence modelling comprises three maps; a predicted, and upper and lower confidence limit maps with values ranging from 0 - 100. For presence-only modelling a single map is produce with values from 0 - 100 indicating a *relative* likelihood of occurrence across the study area.

The other output from S-PLUS is a postscript file which contains graphs of the functions fitted to each variable used plotting the probability of occurrence across the range of values for that variable. The order in which the variables are displayed is indicative of the level of significance of each variable, that is, the most significant variable is displayed first. In the case of presence/absence modelling three additional graphs relating to model discrimination, calibration and refinement (see section 3.2.1 for explanations) are also produced.

South coast modellimg included data from the Eden CRA as the regions are biogeographically similar, but in many cases after model validation this data was excluded.

2.9 DERIVATION OF FLORA SPECIES MODELS

Statistical modelling of flora species was attempted using S-Plus, however, only limited correlations with one to three environmental variables per species were found. Any correlation found was largely statistically insignificant due to the low number of validated records per species and the fact that the data was unsystematic, hence no true absences were available and pseudo-absences had to be used. Any statistical models generated would have been inaccurate and difficult to fine tune. Therefore, methods using boolean overlays were explored ie overlaying specific value ranges of environmental variables using GIS to produce predictive maps.

The validated flora dataset was intersected with all of the environmental variables (listed in table 2f), using the Species Predict Extension within ArcView. This determined the values of each environmental variable at each point record of a species. These values were then used as maximum and minimum limits in the building of Biophysical Envelope Models (BEMs).

The biophysical envelope modelling approach, which may be concisely described as Boolean Interpolation from Locality Data (BILD), provides a systematic and defensible method for the delineation of minimum potential habitat areas for the threatened vascular plant taxa. The BILD approach is also simple, time-efficient and can produce ecologically meaningful predictive models.

In order to construct a BEM, the ranges between the highest and lowest values for each biophysical variable (for the localities of each species) are overlain using the map calculation facility in ArcView. The resultant map represents the biophysical envelope or potential habitat of the taxon according to the known locality data. This however is subject to the types and accuracy of the biophysical layers available. The resultant map in this instance assumes that because a taxon has been recorded within a particular environment (as defined by the intersection of biophysical layers) it may be expected to occur in an equivalent situation elsewhere, particularly where occurrence is considered over the longer-term. Conversely, it assumes that a taxon is much less likely to occur in areas dissimilar to the defined biophysical envelope.

These assumptions provide the pragmatic basis for phytogeographical modelling but are not necessarily always valid. The BILD approach further assumes that taxon occurrence is much more likely within the value range of the biophysical layers rather than outside them on the presumption that the highest and lowest values represent the two poles of a taxon distribution. While this assumption is also pragmatic it is similarly not always valid in reality. This is particularly so where rare species may only occur in remnant refuges due to external threatening process and not necessarily because of any limitations in environmental variables.

Possible perceived errors or limitations in the models are more likely in the case of a bipolar biophysical distribution and are also more likely to occur where the taxon is only known from a very few related localities rather than from a large number of geographically dispersed records. In this case, the biophyscial envelope represents the state of current knowledge as much as the co-occurrence of a taxon and particular habitat parameters.

The BILD approach provides a direct and objective means of spatial interpolation from locality data. It also allows for the simple refinement of models by either excluding outlying locality data or through more direct adjustment of the biophysical variable ranges or the list of selected layers. BEMs may also be represented entirely as syntax (table 2.g) which provides for very efficient model refinement, storage and documentation.

TABLE 2.G: AN EXAMPLE OF SYNTAX USED TO CALCULATE A BEM

SPECIES: Ammobium craspedioides
COMMON NAME: Yass Daisy

((([Wetnessrp] >= 62) and ([Wetnessrp] <= 237)) and (([Tempminqrp] >= -0.10) and ([Tempminqrp] <= 2.30)) and (([Sloperp] >= 0.20) and ([Sloperp] <= 13.20)) and (([Roughrp] >= 0) and ([Roughrp] <= 20)) and (([Rainminqrp] >= 129.40) and ([Rainminqrp] <= 218.90)) and (([Rad12mrp] >= 14097) and ([Rad12mrp] <= 17896)) and (([Posnskidrp] >= -4) and ([Posnskidrp] <= 98)) and (([Lithologyrp] = 4) or ([Lithologyrp] = 7) or [Lithologyrp] = 8) or ([Lithologyrp] = 9) or ([Lithologyrp] = 10) or ([Lithologyrp] = 13)) and (([Ebdbrp] = 2) or ([Ebdbrp] = 5) or [Ebdbrp] = 6) or ([Ebdbrp] = 7) or ([Ebdbrp] = 17) or ([Ebdbrp] = 26)) and (([Demrp] >= 330) and ([Demrp] <= 923))

2.10 MODEL EVALUATION

2.10.1 Fauna Model Evaluation

Contracted and in-house scientific and modelling experts evaluated the models of the priority species and suggested any changes that could be made to the modelling process, such as including/excluding certain variables. The best model and map were slected for each species, or where no model was considered suitable, an ‘expert’ model was created using boolean overlays of particular variables or vegetation types as suggested by the experts. In this case additional variables to those already used for the modelling were recommended (table 2.h). In some cases not enough was known about a species to be able to construct an expert model, so buffer zones were created around the known point locations of that species.

The probability classes for each species’ modelled distribution were grouped by the experts to reflect areas considered to be core, intermediate and marginal habitat.

As there was no time to run any statistical cross-validation (e.g. jackknifing) or conduct field validation, acceptance of the models was based on the experts’ evaluation. All final agreed models were given a reliability score out of 5 to reflect the confidence that could be placed in the predictions of species habitat. Some models were considered to be only indicative of possible habitat rather than predictive.

The models were then used in the Response to Disturbance project for applying species equity target areas (SETAs) (see report for that project, Environment Australia, 1999). The SETAs delineated spatial areas within which targets were sought. The SETAs actually refined the models even further as some modelled areas were excluded. A final model reliability score was then given for each model with SETAS.

2.10.2 Flora Model Evaluation

The flora boolean models were reviewed by experts at the first Response to Disturbance workshop. The models were tightened by altering the maximum and minimum environmental values or by excluding variables altogether on a species specific basis.

The models were re-presented to experts at the second Response to Disturbance workshop but all were rejected in favour of using point localities or known mapped areas to achieve targets. The models were rejected due to continuing concerns about the process of setting targets for currently unoccupied habitat, particularly for species with few locality records and poor re-colonisation ability or probability.

In order for the models to be usefully applied within C-Plan, they needed to be of a high quality so that there was a reasonable level of confidence that the modelled areas represented potential habitat. However, in regards to these models, experts were concerned about the usefulness of the concept of potential habitat in the context of the current RFA process, believing that the known localities of the priority species should be of higher importance. Furthermore, since many of the calculated area targets could be met in existing known occupied patches, it was decided by experts to use mapped occupied habitat rather than modelled potential habitat. Such maps were compiled from existing reports and expert knowledge and were considered the best maps to be used in C-plan for the RFA negotiation process. These maps were only possible for 2 of the 9 modelling priority species as pre-existing maps were not available and expert knowledge was insufficient to create new maps in the time available. The other 7 species were dealt with in the process by point locations in the Threatened Flora Species project (NSW NPWS, 2000).

TABLE 2.H: ADDITIONAL VARIABLES USED FOR FAUNA MODEL EVALUATION

VARIABLES	DESCRIPTION
Longitude	Based on Zone 55 eastings from the Australian Map Grid (AMG's)
Latitude	Based on Zone 55 northings from the Australian Map Grid (AMG's)
Draft Modelled coastal vegetation map for Southern CRA	The draft vegetation map was modelled using the following layers in this priority order: modelled splits between two adjoining vegetation types; together with the following layers assigned to vegetation groups: the Acid Sulphate Soils layer; the CRAFTI API floristics layer; and the Soils Landscapes layer provided by DLWC. Using an Arcview script these layers were then combined to form a composite map.
API special features	Derived from classifying non-eucalypt species alliances through 1:25000 aerial photography and ground truthing
Lithology	DLWC produced a soil landscape layer using various data such as the CSIRO lithology layers. The soil landscape layer was than categorized into broad lithology layer via expert consultation
Aspect	Derived from the Digital Elevation Model (DEM) in ArcView (GIS)
Stream order	Indicates relative volume of stream/river. Dervied from the DEM by NPWS GISD
Skidmore Index	Measure of the position of each cell on a continuum between ridge and gully
Known roost sites	Known roost sites for bats located throughout the southern and eden CRA regions, collated from NPWS and State Forest Experts
Eastern Bushlands Database	Species were mapped into broad vegetation types via Satellite Imagery (LANDSAT)

Note: Variables listed in table 2d were also available to be used for expert models during fauna model evaluation.

3. RESULTS

3.1 FAUNA SPECIES DATA

After data validation, the total number of sites for which there were data available for modelling was 18,404 (9,682 with presence/absence data and 14,549 with presence-only data). The totals of these for each functional group are shown in table 3.a. The total number of survey sites used in the Southern fauna modelling does not correspond with the total number of presence/absence sites and presence-only sites. This is due to the fact that all the presences in the presence/absence data was also utilised within the presence-only data. Therefor the true number of sites is equal to all the presence-only sites plus the absences used within the presence/absence sites.

TABLE 3.A: TOTAL NUMBER OF SURVEY SITES USED IN THE SOUTHERN FAUNA MODELLING

Functional Group	Number of Presence /absence sites[1]	Number of presence-only sites	Total number of sites
Arboreal mammals	1544	3784	4364
Nocturnal birds	1109	2267	2786
Bats	650	888	1078
Diurnal birds	870	3271	3384
Ground Mammals	1411	1882	2635
Reptiles	471	774	902
Amphibians	500	822	968
Heath Monitor	496	249	535
Koala	1761	449	1130
Tiger Quoll	870	163	622
Total	9682	14549	18404

[1] At each presence/absence site there may be multiple species records. Note: some of these sites are at the same location.

As the model program only uses species with >= 10 records, the total number of priority species with records suitable for presence-only modelling was 69, whilst 32 species had suitable number of records for presence/absence modelling (10,501 records in total) (see table 3.b & 3.c).

3.2 FAUNA SPECIES MODELS

Table 3.b and 3.c show the number of presence/absence and total records for each priority species (all records for a species were used in the presence-only modelling). The tables show:

- the best model selected by the experts for each;
- where that model was later modified by experts; or
- where expert models or buffers were created; or
- where no significant model could be produced.

The model results, statistics and predictive maps for each of the priority species where S-PLUS models were accepted, and those that had expert models derived are shown in Appendix 2. A guide to interpreting the results is provided below. The maps show the final agreed core, intermediate and marginal habitat distributions. The maps for presence/absence modelling show the absences used in the modelling. All maps show all the presences whether used in modelling or not (i.e presence-only sites are shown on presence/absence model maps as well, to indicate the current known distribution of the species).

3.2.1 Guide to interpreting fauna species models

There are two outputs from the modelling process. The first is a map of the study area with values corresponding to a probability of occurrence expressed as a percent (relative probability for presence-only). The second is a postscript file with data relating to the chosen model. There are two components to the postscript file: the table at the top left; and a graphical display of the variables used in the model, and in the case of presence/absence modelling three additional graphs describing the performance of the model.

The table

The table provides a statistical summary of the model. The species common and scientific names are displayed, followed by the number of presence sites for that species and the total sites for the functional group.

The null, residual and explained deviance of the model follows. Deviance is a measure of the closeness of the fit of a model to the data used to derive that model. It measures the deviation between the site data (presence or absence of a species) and the probability of presence as predicted by the model (NSW NPWS, 1994a). Null deviance is a measure of the deviance of the null model before any environmental variables are used as predictors. In this way a measure of the inherent variation or noise in the data is provided.

Residual deviance is the amount of deviance remaining after a model has been fitted (NSW NPWS, 1994a). Deviance explained is the percentage of the null deviance explained by the model. Deviance explained is calculated using the following equation:

$$\frac{100 \text{ x (null deviance - residual deviance)}}{\text{null deviance}}$$

A perfectly fitted model would explain 100% of the deviance. Actual values are usually much lower and in the current case the majority were below 50%. This indicates that much of the variation within the data could not be accounted for by the model which could be due to a variety of reasons including: sampling error resulting from incorrect identification of the species; errors in the biological or environmental data; the influence of unmeasured variables such as microhabitat; imperfect sampling techniques; or the presence of spatial autocorrelation in the distribution of species (NSW NPWS, 1994a).

The environmental predictors and covariates used in the model are presented as tabular data in order of decreasing importance. The degrees of freedom for each variable are displayed followed by two columns, deviance and significance which provide an indication of the importance of each variable to the model. Deviance is measured by calculating the difference between the deviance of the final model with all environmental variables and a model containing all variables except the variable of interest (NSW NPWS, 1994a). This provides a measure of the contribution of each variable to the final model. An approximate significance level for this contribution (i.e. change in deviance) is also provided. This significance level is not always less than 0.05 which is the cut off for inclusion of any one variable during the stepwise selection procedure. This is because a variable selected early in the forward stepwise procedure may cease to make a significant contribution once further variables are added to, and controlled for, in the model (NSW NPWS, 1994a).

TABLE 3.B: SELECTED MODELS AND NUMBER OF RECORDS FOR PRIORITY SPECIES FOR THE SOUTH COAST SUB-REGION

Scientific name	Common name	Functional group[1]	Total number. of records/ Presence-only records[2,3,4]	Presence /Absence Records[3]	Best model selected[5]	Final model reliability[6]
Ninox connivens	Barking Owl	NB	21	<10	nsm	N/A
Burhinus grallarius	Bush Stone-curlew	NB	<10	<10	nsm	N/A
Tyto novaehollandiae	Masked Owl	NB	227	32	P	3.5
Ninox strenua	Powerful Owl	NB	741	52	P	3
Tyto tenebricosa	Sooty Owl	NB	539	35	P *	3.5
Phascogale tapoatafa	Brush-tailed Phascogale	AM	<10	<10	nsm	N/A
Cercartetus nanus	Eastern Pygmy Possum	AM	27	<10	nsm	N/A
Petauroides volans	Greater Glider	AM	1110	535	PA	4
Phascolarctus cinereus	Koala	AM	441 (100)	27	P w/o E *	2.5
Petaurus norfolcensis	Squirrel Glider	AM	38	<10	P	2
Petaurus australis	Yellow-bellied Glider	AM	1375	205	P	4
Petrogale penicillata	Brush-tailed Rock Wallaby	GM	15	<10	EM	5
Perameles nasuta	Long-nosed Bandicoot	GM	192	<10	P w/o E	3
Potorous tridactylus	Long-nosed Potoroo	GM	102	<10	P w/o E	4
Pseudomys fumeus	Smoky Mouse	GM	55	<10	P * / EM	4
Isoodon obesulus	Southern Brown Bandicoot	GM	37	<10	EM	2
Dasyurus maculatus	Tiger Quoll	GM	150	150	P *	3
Sminthopsis leucopus	White-footed Dunnart	GM	89	<10	EM	3
Miniopterus shreibersii	Common Bent-wing Bat	B	62	34	Buffers	4
Falsistrellus tasmaniensis	Eastern False Pipistrelle	B	75 (35)	54	P w/o E	4
Rhinolophus megaphyllus	Eastern Horeshoe Bat	B	73 (50)	48	P w/o E *	3
Mormopterus norfolkensis	Eastern Little Mastiff-bat	B	27	22	P	3
Kerivoula papuensis	Golden-tipped Bat	B	14	<10	EM	3
Scoteanax rueppellii	Greater Broad-nosed Bat	B	53	34	P	3
Pteropus poliocephalus	Grey-headed Flying Fox	B	36	<10	EM	3
Myotis adversus	Large-footed Myotis	B	31	23	nsm	N/A
Chalinolobus dwyeri	Large Pied Bat	B	<10	<10	Buffers	N/A
Pteropus scapulatus	Little Red Flying Fox	B	<10	<10	EM	3
Mormopterus sp. 1	Unamed Mastiff Bat	B	22	21	P	3
Saccolaimus flaviventris	Yellow-bellied Sheath-tail Bat	B	<10	<10	nsm	N/A
Climacteris picumnus	Brown Treecreeper	DB	<10	<10	EM	1
Falcunculus frontalis	Crested Shrike-tit	DB	158 (48)	68	P w/o E *	3.5
Eurystomus orientalis	Dollarbird	DB	48	11	EM	3
Dasyornis brachypterus	Eastern Bristlebird	DB	115	<10	Buffers	N/A
Calyptorhynchus lathami	Glossy Black Cockatoo	DB	464 (278)	32	P w/o E *	3.5
Melanodryas cucullata	Hooded Robin	DB	<10	<10	EM	3.5
Pachycaphala olivacea	Olive Whistler	DB	81	24	P/A *	4
Petroica rodinogaster	Pink Robin	DB	<10	<10	EM	0.5
Climacteris erythrops	Red-browed Treecreeper	DB	195 (74)	115	P w/o E	2
Xanthomyza phrygia	Regent Honeyeater	DB	<10	<10	EM	3
Cinclosoma punctatum	Spotted Quail-thrush	DB	162	36	P/A *	4
Lophoictinia isura	Square-tailed kite	DB	15	<10	EM	1
Lathamus discolor	Swift Parrot	DB	<10	<10	EM	3
Neophema pulchella	Turquoise Parrot	DB	<10	<10	EM	1
Calyptorhyncus funereus	Yellow-tailed black Cockatoo	DB	351 (182)	145	P w/o E	3
Sericornis citreogularis	Yellow-throated Scrub Wren	DB	19	<10	EM	2
Hoplocephalus bungaroides	Broad-headed Snake	R	12	<10	EM *	4
Acanthophis antarticus	Common Death Adder	R	73	<10	Buffers	N/A
Morelia spilota spilota	Diamond Python	R	25 (19)	<10	P w/o E	4
Varanus rosenbergii	Heath Monitor	R	18 (18)	<10	P w/o E *	5
Nannoscincus maccoyi	Maccoy's Skink	R	55 (40)	29	P w/o E	4
Pseudomia spenceri	Spencer's Skink	R	54 (29)	26	P w/o E *	3.5
Heleioporus australiacus	Giant Burrowing Frog	A	39 (23)	<10	P w/o E *	3
Litoria littlejohni	Heath Frog	A	<10	<10	Buffers	N/A
Pseudophryne australis	Red-crowned Toadlet	A	<10	<10	nsm	N/A
Mixophyes balbus	Stuttering Barred Frog	A	17	<10	P *	5 for 1c

Refer to footnotes under Table 3.c.

TABLE 3.C: SELECTED MODELS AND NUMBER OF RECORDS FOR PRIORITY SPECIES FOR THE TABLELANDS SUB-REGION

Scientific name	Common name	Functional group[1]	Total number. of records/ Presence-only records[2,3,4]	Presence /Absence Records[3]	Best model selected[5]	Final model reliability[6]
Ninox connivens	Barking Owl	NB	<10	<10	nsm	N/A
Tyto novaehollandiae	Masked Owl	NB	<10	<10	nsm	N/A
Ninox strenua	Powerful Owl	NB	53	24	P *	4
Tyto tenebricosa	Sooty Owl	NB	<10	<10	EM	2
Phascogale tapoatafa	Brush-tailed Phascogale	AM	<10	<10	nsm	N/A
Cercartetus nanus	Eastern Pygmy Possum	AM	<10	<10	nsm	N/A
Petauroides volans	Greater Glider	AM	290	94	P *	3
Phascolarctus cinereus	Koala	AM	61	<10	P *	1
Petaurus norfolcensis	Squirrel Glider	AM	<10	<10	EM	1.5
Petaurus australis	Yellow-bellied Glider	AM	158	45	P *	4
Mastacomys fuscus	Broad-toothed Rat	GM	128	<10	P	4.2
Petrogale penicillata	Brush-tailed Rock Wallaby	GM	24	<10	EM	3.2
Perameles nasuta	Long-nosed Bandicoot	GM	23	<10	P *	2.5
Pseudomys fumeus	Smoky Mouse	GM	<10	<10	EM	0
Dasyurus maculatus	Tiger Quoll	GM	57	<10	P *	2
Miniopterus shreibersii	Common Bent-wing Bat	B	73	56	Buffers	4
Falsistrellus tasmaniensis	Eastern False Pipistrelle	B	76	66	P	4
Rhinolophus megaphyllus	Eastern Horeshoe Bat	B	103	<10	P *	2.5
Mormopterus norfolkensis	Eastern Little Mastiff-bat	B	64	<10	P *	1.5
Scoteanax rueppellii	Greater Broad-nosed Bat	B	<10	<10	nsm	N/A
Pteropus poliocephalus	Grey-headed Flying Fox	B	<10	<10	EM	3
Myotis adversus	Large-footed Myotis	B	<10	<10	Buffers	1
Chalinolobus dwyeri	Large Pied Bat	B	<10	<10	Buffers	1
Pteropus scapulatus	Little Red Flying Fox	B	<10	<10	EM	3
Saccolaimus flaviventris	Yellow-bellied Sheath-tail Bat	B	<10	<10	nsm	N/A
Melithreptus gularis	Black-chinned Honeyeater	DB	<10	<10	EM	3
Climacteris picumnus	Brown Treecreeper	DB	56	<10	P *	3
Falcunculus frontalis	Crested Shrike-tit	DB	56	<10	EM	4
Eurystomus orientalis	Dollarbird	DB	14	<10	P *	3
Melanodryas cucullata	Hooded Robin	DB	16	<10	EM	4
Pachycaphala olivacea	Olive Whistler	DB	115	<10	P *	4
Grantiella picta	Painted Honeyeater	DB	<10	<10	EM	3
Petroica rodinogaster	Pink Robin	DB	<10	<10	EM	2
Climacteris erythrops	Red-browed Treecreeper	DB	97	16	EM	4
Xanthomyza phrygia	Regent Honeyeater	DB	<10	<10	EM	3.5
Cinclosoma punctatum	Spotted Quail-thrush	DB	77	<10	EM	3.5
Lophoictinia isura	Square-tailed kite	DB	<10	<10	EM	3
Polytelis swainsonii	Superb Parrot	DB	<10	<10	EM	3.5
Lathamus discolor	Swift Parrot	DB	<10	<10	EM	3
Neophema pulchella	Turquoise Parrot	DB	<10	<10	EM	3
Calyptorhyncus funereus	Yellow-tailed black Cockatoo	DB	145	11	P *	3
Litoria booroolongensis	Booroolong Frog	A	<10	<10	EM	3
Pseudophryne bibronii	Brown Toadlet	A	30	<10	P *	2
Pseudophryne pengilleyi	Northern Corroboree Frog	A	131	<10	P *	4.5
Morelia spilota variegata	Carpet Python	R	<10	<10	EM	3
Varanus rosenbergii	Heath Monitor	R	21	<10	P *	4.5
Nannoscincus maccoyi	Maccoy's Skink	R	36	32	PA *	4
Pseudomia spenceri	Spencer's Skink	R	67	27	P	4

[1] AM = Arboreal Mammals; NB = Nocturnal Birds; B = Bats; DB = Diurnal Birds; GM = Ground Mammals; R = Reptiles; A = Amphibians.
[2] Presence-only modelling was conducted using all records.
[3] Shaded boxes indicate less than or equal to ten records and therefore no model produced.
[4] Brackets indicate the number of records utilised in the models were Eden records were excluded from the model.
[5] PA = presence/absence; P = presence-only; w/o E (without Eden) = model based on all records except those within Eden; * = modifications were made to the model during model validation and/or at RTD; EM (Expert Model) = model created by boolean overlays based on expert knowledge of the species; Buffers = buffer zones around known point locations of that species; nsm = no suitable model.
[6] Model reliability ranking indicates experts opinions of the reliability of the model once SETAs were applied, with 1 being low and 5 being high

The graphs

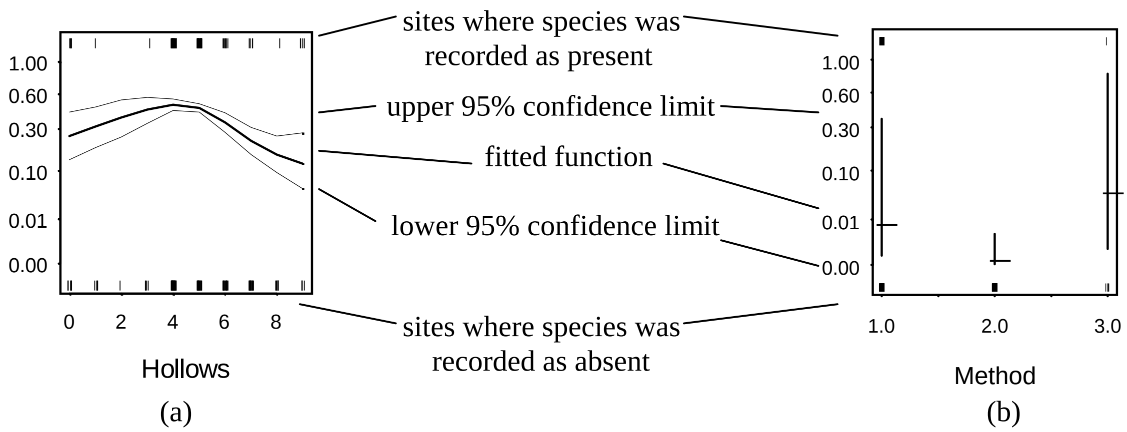
The second component of the postscript file is a graphical output of the environmental variables and covariates used in the model. Each variable that is chosen in the model appears as a graph. As a maximum of six variables can be chosen there is a maximum of six graphs, the minimum number of graphs being one (i.e. a univariate model). Each graph depicts the modelled relationship between the variable (environmental or covariate) and the probability of occurrence for the range of values for each variable. This is plotted on a cube root scale to highlight the variation at the lower end of the probability range, allowing interpretation of environmental relationships of rarer species that would be indiscernible on an untransformed scale (NSW NPWS, 1994a).

Each graph plots the modelled effect of a single variable while controlling for (i.e. holding constant) the effects of all other variables in the model. The effect of each of the other environmental variables is always held at a mean value calculated across all surveyed sites. Examples of the graphs are shown in figure 3.a.

The tick marks across the top of each graph indicate the locations at which the species was recorded as present in relation to the environmental variable or covariate. Each tick represents a single site. The ticks across the bottom of each graph represent those sites at which the species was recorded as absent in the case of presence/absence modelling. For presence-only modelling they represent the 1000 pseudo-absence sites which were chosen randomly from forested land across the study area.

The fitted function relating the occurrence of a species to an environmental variable or covariate is plotted as a solid curve. This curve represents a ‘best estimate’ of the relationship. For presence/absence modelling upper and lower 95% confidence limits for the fitted function are presented as dashed curves. If an environmental variable or covariate is treated as a factor rather than a continous variable then the fitted value for each factor level is plotted as a short horizontal line and the 95% confidence limits are indicated by a vertical line.

FIGURE 3.A: FEATURES OF GRAPHS DEPICTING THE MODELLED RELATIONSHIP BETWEEN LIKELIHOOD OF OCCURRENCE OF A SPECIES AND AN ENVIRONMENTAL PREDICTOR, FOR (A) A CONTINUOUS PREDICTOR AND (B) A FACTOR (CATEGORICAL) PREDICTOR



The graphs should be interpreted with care. In particular the reader should be aware of the following considerations:

- Each graph depicts the effect of only one variable within a multivariate model. This effect is produced by mathematically controlling for the effects of all other variables (i.e. holding each of the other effects at their mean value). This means that the graphs cannot be interpreted in isolation from one another. The effect of a variable in a multivariate model can be very different to the univariate effect of that variable if analysed on its own in the absence of the other variables. The plotted functions depict multivariate, not univariate, effects. It should be noted however that the tickmarks at the top and bottom of each graph reflect the univariate distribution of sites in relation to the environmental variable, without controlling for other variables. This may account for any obvious discrepancy between a fitted function and the distribution of presence versus absence tickmarks; one is controlling for effects of other variables while the other is not.

- The 95% confidence limits need to be considered when assessing the significance of a fitted function. The fitted function is only a best estimate and therefore has associated error. The magnitude of this error varies both within and between functions, depending partly on the density of sampling within different environments and partly on the strength of the species-environment relationships being modelled. The plotted confidence limits provide an indication of the error associated with a fitted function. The confidence limits can be interpreted as follows: at a given value of the environmental variable we are 95% confident that the true value of the function (a probability in the case of presence versus absence models) lies between the upper and lower confidence limits. The significance of a fitted function should be assessed by observing not only the magnitude of change in the fitted function with changing values of the environmental variable, but also the magnitude of the error associated with this change. A highly significant function is one in which there is little or no overlap between the confidence limits for different parts of the function (i.e. the error bands are narrow).

As previously mentioned, for presence versus absence modelling three additional graphs are produced which describe the performance of the model in terms of model discrimination, calibration and refinement respectively. Note that these graphs measure performance of the model in relation to the data used in fitting the model, not independent data.

> 'Discrimination measures the extent to which the proportion of all the positive observations falling in separate classes of predicted probabilities, differs from the proportion of all negative observations falling in those same classes of predicted probabilities. In other words, it is the extent to which the model predicts higher probabilities for the positive observations than it does for the negative observations. Good discrimination is illustrated in the plot by the separation of the line joining the respective proportions of positive observations and negative observations across the defined classes of predicted probabilities.' (Watson, 1996)

> 'Model calibration is a measure of the extent to which the model is either over-predicting or under-predicting. The plot shows, for the survey points occurring in each class of predicted probabilities, the proportion of which returned positive observations. The 95% confidence intervals around these proportions are also provided. In a perfectly calibrated model these proportions would lie along the dotted line. A curve fitted to the proportions is displayed to highlight the regions of the predicted probability range, which are not well calibrated. In those parts of the range where the fitted curve rises above the line of the ideal model, the model is overpredicting and in those parts of the range where the fitted curve falls below that line, the model is underpredicting.' (Watson, 1996)

> 'Refinement is related to discrimination and is evaluated by the use of the receiver operating curve (ROC) (Cox, 1958). The ROC provides a measure of the extent to which the model is correctly predicting the likelihood of a true positive (presence) and a false positive (absence) across the range of the probability scale. It does this by portraying the heterogeneity of prediction, that is, that the model is predicting outcomes which are spreading across the range of the probability scale. The points on the curve are calculated by plotting, for 100 predicted probability thresholds, the proportion of absence records falling below each threshold against the proportion of presence records falling below those thresholds. A well refined model produces a curve which is distant from the dotted 45 degree line. A curve close to the dotted line indicates that the model has little or no predictive reliability.' (Watson, 1996)

The maps

The map shown for each species depicts the predicted distribution of the species based on the best fitted model selected by the experts, or if no statistical model was deemed valid, the expert derived model is shown. The colour scale indicates the likelihood of occurrence of the species. If the model is based on presence/absence data the likelihood is the predicted probability of recording the species in an area. If the model is based on presence-only data then the likelihood is a *relative* index of occurrence. The core, intermediate and marginal designations were set by the experts and are based on higher to lower likelihood, respectively. of occurrence of the species.

The maps also show the SETAs (species equity target areas) as designated in the Response to Disturbance (RTD) workshops (Environment Australia, in press). SETAs are shown as numbers (1, 2, 3 etc) and represent meta-populations (i.e. where recolonisation between populations is not expected within 200 years of a local extinction occurring, and there exists significant geographic barriers to recolonisation e.g. ranges or water bodies). The letters (a, b, c etc) represent sub-SETAs, which were created to ensure that the aerial target (hectares) set for the whole SETA, was sought across the geographic range of the species. Targets were calculated for each SETA, but the proportions to be distributed across sub-SETAs were defined by the experts. When delineating SETAs, some areas of the models were excluded, as experts considered these to be insignificant in the current process i.e. they felt it was more important that areas of known occurrences of the species or critical habitat were focussed on.

3.3 FLORA SPECIES MODELS

As discussed previously, the final flora ‘models’ were merely mapped known occupied habitat for two species, due to the difficulties experienced in trying to create statistical models or boolean overlays for rare species that occupy very few remnant locations. Due to the very detailed nature of these maps, they are not published in this report. Instead figure 3.b shows the general locations of the species’ mapped areas.

Figure 3.b

4. CONCLUSIONS

4.1 ACHIEVEMENTS OF THE SOUTHERN CRA MODELLING PROJECT

The Southern CRA fauna and flora modelling project has exemplified the important role that predictive modelling can have in regional conservation evaluation and planning. Field survey data, which is often limited or disjunct in geographical spread, has been spatially extended by such modelling techniques to produce predicted species distributions.

The project has resulted in a comprehensive digital database containing validated vertebrate fauna and vascular flora species distribution data from across and around the Southern CRA region. From this database, predictive models and interpolated distribution maps for priority fauna species of the area have been provided for other phases of the CRA process and stakeholder use.

The project has clarified the known and predicted distributions of many threatened and forest-dependent fauna species, enabling specific conservation prescriptions and management recommendations to be made for each (see the Southern Conservation Requirements report).

The digital survey database and models now provide a valuable information base for future use in regional and state-wide conservation planning and management.

4.2 FUTURE DIRECTIONS

The modelling project has highlighted some significant areas or species where there still exist gaps in quality data. As discussed throughout the report, a large number of the priority fauna species were lacking enough valid systematic records to enable presence-absence modelling. Although there were generally more presence-only records for each, some species still had insufficient records for valid modelling of any type. Such species tended to be those that are cryptic or difficult to survey. The lack of flora records was even more evident, which resulted in limited modelling. In the future, it is recommend that further effort is put into systematic targeted surveying of these priority species to enable better presence-absence modelling.

It would be desirable for future surveys to collect accurate abundance data wherever practical, as the technology and ability to model abundance data continues to improve. If this is not possible, sampling effort should at least be intense enough to ensure that sufficient true presence-absence data are collected.

From the Southern modelling process, a number of recommendations for future modelling projects have arisen:

- For any species that is to be modelled, there needs to be adequate numbers of records once the data is split into systematic and presence-only, and allowing for the process of rejecting records falling outside the chosen domain e.g. excluding cleared/non-forested areas.
- A detailed, valid and extensive vegetation map is important, as the derivation of many variables are dependent on it.
- The precision of site data and most spatially mapped data needs to be improved to at least 50m if possible, although this is often limited by the quality of external data being used.
- There needs to be sufficient time in the modelling process to allow adequate evaluation and re-processing of models i.e. for adjusting variables, layers and domains used. Additional time is needed for application of statistical cross-validation techniques (e.g. jackknifing) and field validation.

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APPENDICES

APPENDIX 1: SOURCES OF PRIORITY FAUNA DATA USED IN THE SOUTHERN FAUNA MODELLING

Source	Total Of Easting	AMPHIBIANS		ARBOREAL MAMMALS		BATS		BIRDS		NOCTURNAL BIRDS		REPTILES		GROUND MAMMALS	
		Presence /Absence	Presence Only	Presence /Absence	Presence Only	Presence /Absence	Presence Only	Presence /Absence	Presence Only	Presence /Absence	Presence Only	Presence /Absence	Presence Only	Presence /Absence	Presence Only
ACT Parks	152	0	5	0	52	0	13	0	0	0	1	0	42	0	39
Allen	23	0	0	0	23	0	0	0	0	0	0	0	0	0	0
Australian National University (ANU)	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0
ANWC	225	0	23	0	8	0	6	0	101	0	10	0	39	0	38
Atlas of NSW Wildlife (NPWS)	6411	0	275	0	1673	0	260	0	2247	0	654	0	679	0	623
Australian Museum	210	0	32	0	9	0	13	0	12	0	4	0	131	0	9
Brogo Bush Heritage Block Survey (Nick Graham-Higgs & Associates)	8	0	0	0	0	0	0	2	2	1	1	0	1	0	1
Broome (NPWS)	101	0	0	0	0	0	0	0	0	0	0	0	50	0	51
Canberra University	3	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Claridge (ANU)	62	0	0	0	0	0	0	0	0	0	0	0	31	0	31
Southern CRA Survey (NPWS)	1933	23	34	164	267	272	276	148	346	68	114	56	102	13	50
Central CRA Survey (NPWS)	65	1	1	2	3	14	14	9	14	2	2	1	2	0	0
CSIRO Division of Wildlife and Ecology	1048	0	0	335	428	0	0	119	125	0	1	0	18	3	19
South West Slopes survey (Charles Sturt University)	32	0	0	6	6	0	0	10	10	0	0	0	0	0	0
Daly (independent researcher)	97	0	27	16	22	2	3	0	6	1	2	0	15	0	3
Eurobodalla National Parks survey (Charles Sturt University)	55	3	3	3	6	0	5	0	7	2	3	3	9	5	6
Neave (ANU)	80	0	0	0	0	0	0	40	40	0	0	0	0	0	0
Lindenmeyer (ANU)	17	0	0	5	5	0	0	2	2	0	3	0	0	0	0
Lunney (NPWS)	149	0	0	0	41	0	30	0	0	0	0	0	40	0	38
Mills (ANU)	104	0	0	0	0	52	52	0	0	0	0	0	0	0	0

Nowra District surveys (NPWS)	4	0	0	0	2	0	0	0	2	0	0	0	0	0	0
National Parks Association	44	2	4	4	15	0	0	3	5	4	4	1	2	0	0
Queanbeyan District surveys (NPWS)	103	0	5	2	12	0	10	7	46	1	4	0	11	1	4
Rehwinkel	14	0	0	0	5	0	0	0	0	0	9	0	0	0	0
Reside&Martin	43	0	0	0	0	0	0	0	0	0	0	0	19	0	24
Smith (NPWS)	80	0	0	0	0	0	0	40	40	0	0	0	0	0	0
State Forests of NSW	4401	1	192	188	1723	32	87	138	564	68	1101	25	128	8	146
Walter	8	0	0	0	0	0	0	0	0	0	0	0	4	0	4
Wise & Spencer (Charles Sturt University)	6	0	0	0	0	3	3	0	0	0	0	0	0	0	0
TOTALS	15481	30	601	725	4300	375	772	518	3572	147	1916	86	1323	30	1086

APPENDIX 2: SOUTHERN FAUNA MODELLING RESULTS

MANY INSERTS FOR THE FOLLOWING SPECIES MODELS ARE ONLY AVAILABLE IN A HARDCOPY FORMAT.
PLEASE CONTACT NPWS TO OBTAIN INSERTS WHERE MISSING.

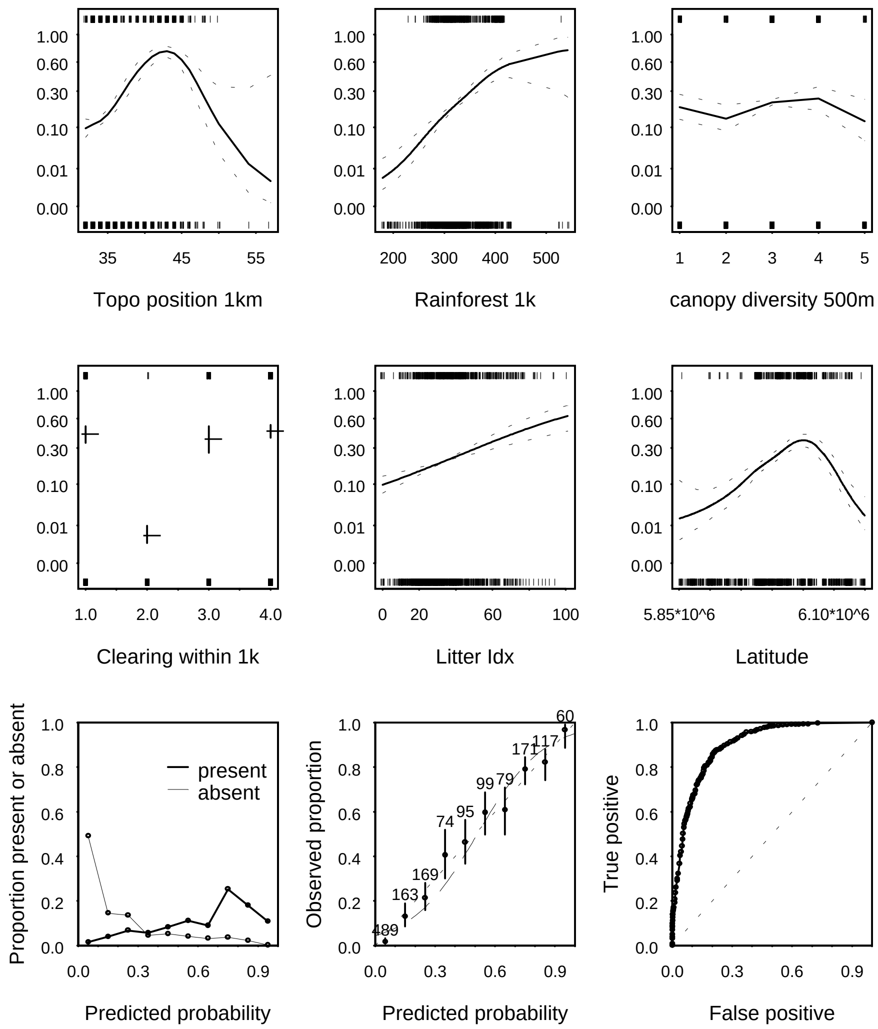
MODEL RESULTS FOR PETAUROIDES VOLANS (GREATER GLIDER) FOR THE SOUTH COAST SUB-REGION

Petauroides volans

Greater Glider

Presence sites 535 Total sites 1516
Null deviance 1968.45 on 1515 df
Residual dev. 1162.29 on 1496 df
Deviance explained 40.95 %
Model type: GAM

Predictors	DF	Dev	Sig
Topop1k	3.8	115.11	0.000
Rfor1k	3.1	179.49	0.000
Gibb500m	1	97.55	0.000
Clear1k	4	284.6	0.000
Litter500	3.8	47.21	0.000
Latitude	4	18.11	0.201



SOUTH COAST GREATER GLIDER MODEL TO BE INSERTED HERE

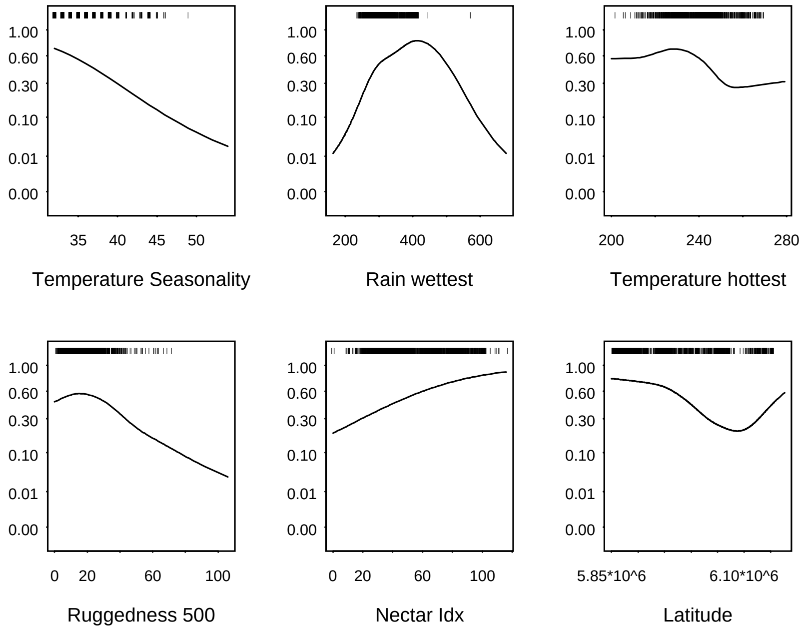
MODEL RESULTS FOR *PETAURUS AUSTRALIS* (YELOW-BELLIED GLIDER) FOR SOUTH COAST SUB-REGION

Petaurus australis

Yellow-bellied Glider

All records 1375 Total pseudo sites 2372
Null deviance 3812.31 on 2371 df
Residual dev. 2314.59 on 2354 df
Deviance explained 39.29 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempseas	1	685.96	0.000
Rainwet	3.9	164.52	0.000
Temphot	3.8	347.86	0.000
Rgh500	3	115.43	0.000
Nectar500	1	82.48	0.000
Latitude	4	25.14	0.201



SOUTH COAST YELLOW-BELLIED GLIDER MODEL TO BE INSERTED HERE

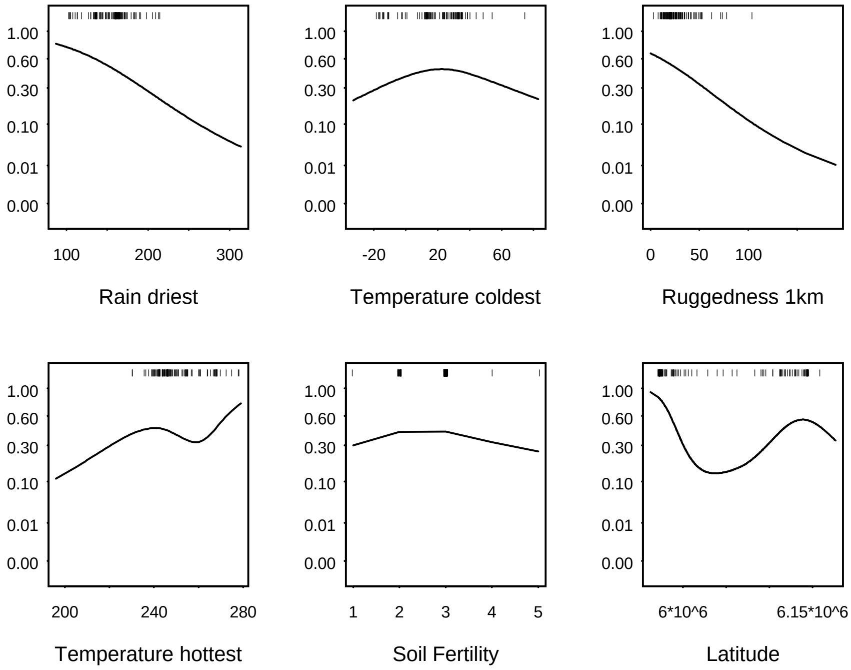
MODEL RESULTS FOR *PHASCOLARCTOS CINEREUS* (KOALA) FOR SOUTH COAST SUB-REGION

Phascolarctos cinereus

Koala

All records 100   Total pseudo sites 1100
Null deviance 277.26 on 1099 df
Residual dev. 174.61 on 1086 df
Deviance explained 37.02 %
Model type: GAM

Predictors	DF	Dev	Sig
Raindry	1	16.63	0.000
Tempcold	2	28.19	0.000
Rgh1000	1	12.43	0.000
Temphot	2.9	12.47	0.005
Fertility	2	6.02	0.047
Latitude	4	16.47	0.000



SOUTH COAST KOALA MODEL TO BE INSERTED HERE

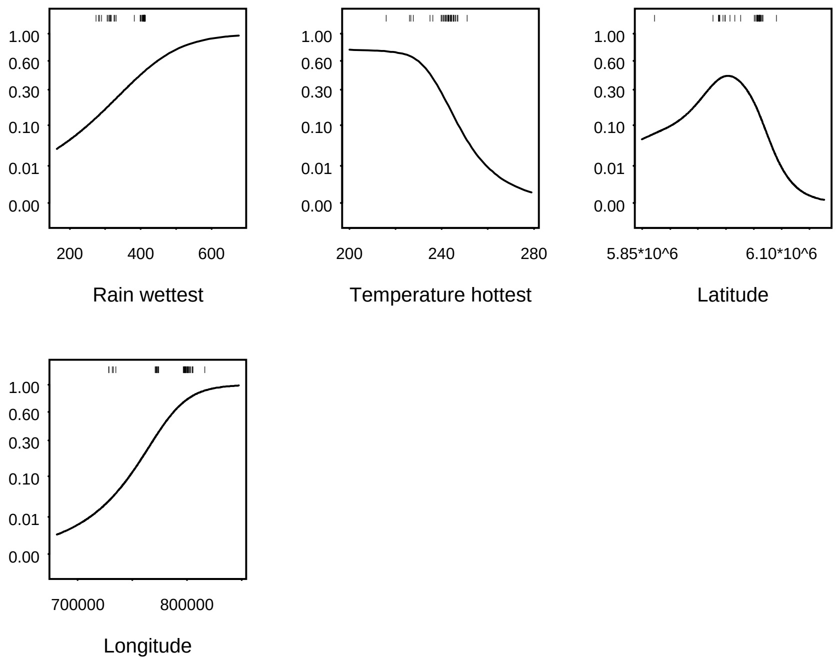
MODEL RESULTS FOR *PETAURUS NORFOLCENSIS* (SQUIRREL GLIDER) FOR SOUTH COAST SUB-REGION

Petaurus norfolcensis

Squirrel Glider

All records 38 Total pseudo sites 1035
Null deviance 105.36 on 1034 df
Residual dev. 43.61 on 1027 df
Deviance explained 58.61 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainwet	1	40.04	0.000
Temphot	2	12.99	0.011
Latitude	3	1236.54	0.000
Longitude	1	4.48	0.033



SOUTH COAST SQUIRREL GLIDER MODEL TO BE INSERTED HERE

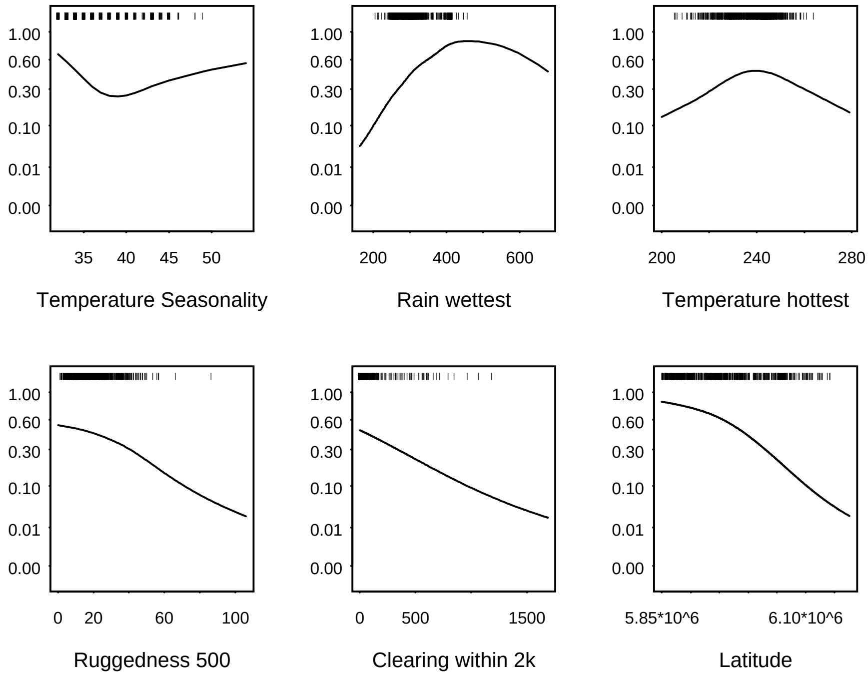
MODEL RESULTS FOR *NINOX STRENUA* (POWERFUL OWL) FOR SOUTH COAST SUB-REGION

Ninox strenua

Powerful Owl

All records 741 Total pseudo sites 1738
Null deviance 2054.49 on 1737 df
Residual dev. 1348.02 on 1722 df
Deviance explained 34.39 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempseas	3	252.61	0.000
Rainwet	3.8	112.05	0.000
Temphot	2.8	193.69	0.000
Rgh500	1.1	34.27	0.000
Clear2k	4	35.89	0.000
Latitude	2	22.61	0.201



SOUTH COAST POWERFUL OWL MODEL TO BE INSERTED HERE

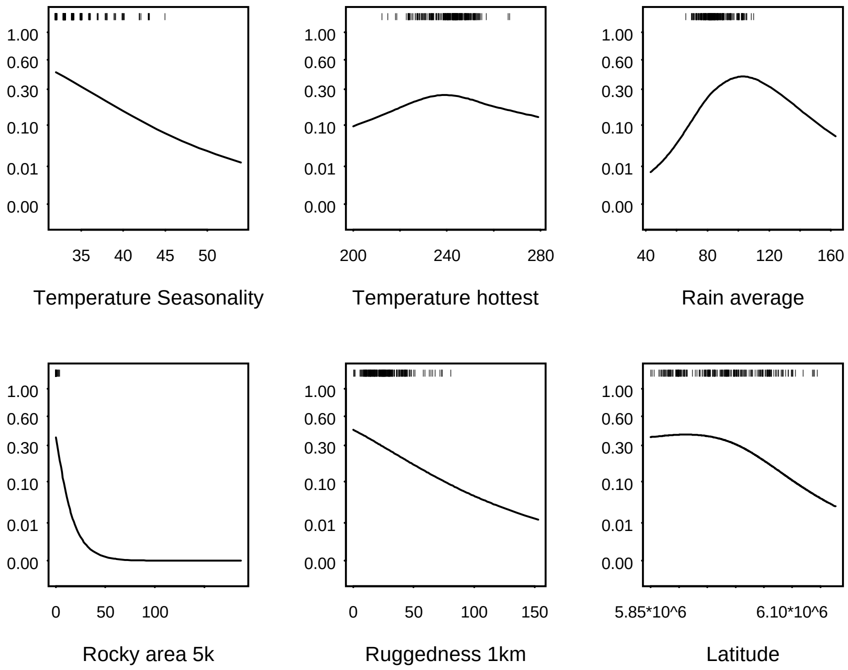
MODEL RESULTS FOR *TYTO NOVAEHOLLANDIAE* (MASKED OWL) FOR SOUTH COAST SUB-REGION

Tyto novaehollandiae

Masked Owl

All records 227 Total pseudo sites 1224
Null deviance 629.38 on 1223 df
Residual dev. 423.94 on 1213 df
Deviance explained 32.64 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempseas	1	104.94	0.000
Temphot	2	44.01	0.000
Rainfav	2.71	2.73	0.004
Rock5k	1.1	17.51	0.000
Rgh1000	1	13.37	0.000
Latitude	2	2.82	0.088



SOUTH COAST MASKED OWL MODEL TO BE INSERTED HERE

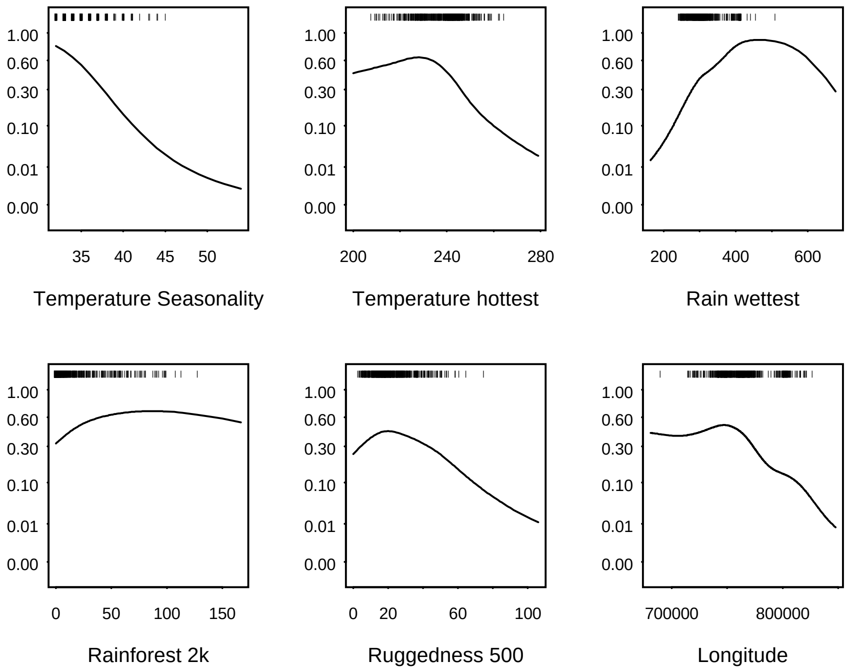
MODEL RESULTS FOR *TYTO TENEBRICOSA* (SOOTY OWL) FOR THE SOUTH COAST SUB-REGION

Tyto tenebricosa

Sooty Owl

All records 539 Total pseudo sites 1536
Null deviance 1494.43 on 1535 df
Residual dev. 871.09 on 1518 df
Deviance explained 41.71 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempseas	1	323.73	0.000
Temphot	2.9	169.07	0.000
Rainwet	3.9	39.04	0.000
Rfor2k	2	28.21	0.000
Rgh500	3	29.91	0.000
Longitude	4	20.85	0.000



SOUTH COAST SOOTY OWL MODEL TO BE INSERTED HERE

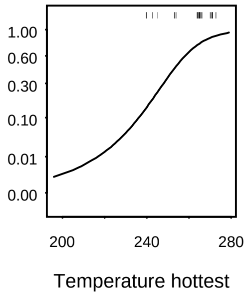
MODEL RESULTS FOR *VARANUS ROSENBERGI* (HEATH MONITOR) FOR THE SOUTH COAST SUB-REGION

Varanus rosenbergi

Heath Monitor

All records 18 Total pseudo sites 1018
Null deviance 49.91 on 1017 df
Residual dev. 36.89 on 1016 df
Deviance explained 26.09 %
Model type: GAM

Predictors	DF	Dev	Sig
Temphot	1	17.89	0.001



SOUTH COAST HEATH MONITOR MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *ACANTHOPIS ANTARCTICUS* (COMMON DEATH ADDER) FOR THE SOUTH COAST SUB-REGION

The model contains a 1km radius buffer around known locations. The original model was rejected by experts, and no expert model was created due to the lack of expert knowledge about the species.

SOUTH COAST COMMON DEATH ADDER MODEL TO BE INSERTED HERE

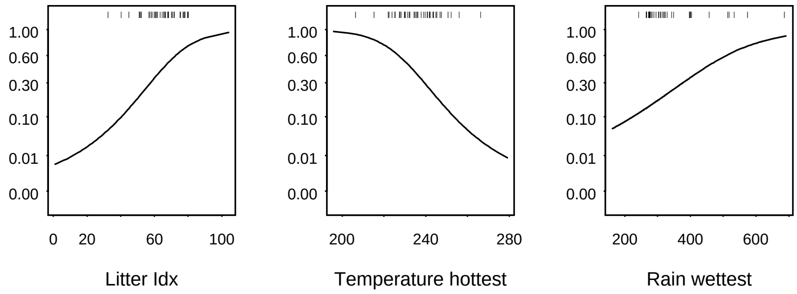
MODEL RESULTS FOR *NANNOSCINCUS MACCOYI* (MCCOYS SKINK) FOR THE SOUTH COAST SUB-REGION

Nannoscincus maccoyi

McCoy's Skink

All records 40 Total pseudo sites 1040
Null deviance 110.9 on 1039 df
Residual dev. 69.46 on 1036 df
Deviance explained 37.37 %
Model type: GAM

Predictors	DF	Dev	Sig
Litter500	1	25.05	0.000
Temphot	1	15.53	0.004
Rainwet	1	10.01	0.038



SOUTH COAST MCCOYS SKINK MODEL TO BE INSERTED HERE

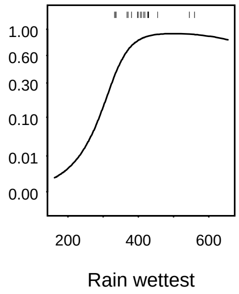
MODEL RESULTS FOR *MORELIA SPILOTA SPILOTA* (DIAMOND PYTHON) FOR THE SOUTH COAST SUB-REGION

Morelia spilota spilota

Diamond Python

All records 19 Total pseudo sites 1019
Null deviance 52.68 on 1018 df
Residual dev. 27.44 on 1016 df
Deviance explained 47.9 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainwet	1.9	27.41	0.000



SOUTH COAST DIAMOND PYHTON MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *HOPLOCEPHALUS BUNGAROIDES* (BROAD-HEADED SNAKE) FOR THE SOUTH COAST SUB-REGION

The original model was rejected as experts felt that the habitat model created by Ross Wellington (NSW NPWS) had greater resolution. Modifications made to Ross Wellington's model include the exclusion of areas around Nowra and Sussex Inlet. Areas west and south of Ulladulla were also lowered to marginal habitat based on expert advice.

SOUTH COAST BROAD-HEADED SNAKE MODEL TO BE INSERTED HERE

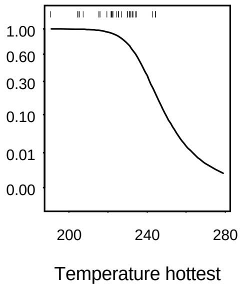
MODEL RESULTS FOR *PSEUDEMOIA SPENCERI* (SPENCERS SKINK) FOR SOUTH COAST SUB-REGION

Pseudemoia spenceri

pseudemoia spenceri

All records 29 Total pseudo sites 1029
Null deviance 80.41 on 1028 df
Residual dev. 41.88 on 1027 df
Deviance explained 47.92 %
Model type: GAM

Predictors	DF	Dev	Sig
Temphot	1	41.63	0.000



SOUTH COAST SPENCERS SKINK MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *LITORIA LITTLEJOHNI* (HEATH FROG) FOR THE SOUTH COAST SUB-REGION

The model contains buffers (250m radius) around validated known locations. The original model was rejected as experts felt there were too few records to make the model reliable. Due to the lack of expert knowledge about the species and the low number of records, no expert model was created for this species.

SOUTH COAST HEATH FROG MODEL TO BE INSERTED HERE

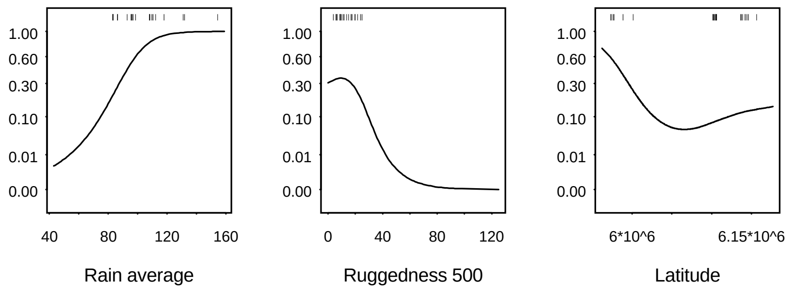
MODEL RESULTS FOR *HELEIOPORUS AUSTRALIACUS* (GIANT BURROWING FROG) FOR THE SOUTH COAST SUB-REGION

Heleioporus australiacus

Giant Burrowing Frog

All records 23 Total pseudo sites 1023
Null deviance 63.77 on 1022 df
Residual dev. 29.37 on 1017 df
Deviance explained 53.94 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	1	22.74	0.000
Rgh500	1.9	9.96	0.041
Latitude	2	7.73	0.021



SOUTH COAST GIANT BURROWING FROG MODEL TO BE INSERTED HERE

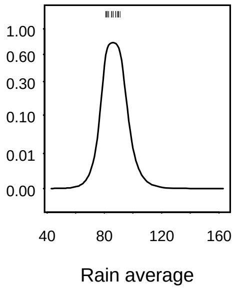
MODEL RESULTS FOR MIXOPHYES BALBUS (STUTTERING BARRED FROG) FOR THE SOUTH COAST SUB-REGION

Mixophyes balbus

mixophyes balbus

All records 17 Total pseudo sites 1014
Null deviance 47.13 on 1013 df
Residual dev. 29.63 on 1010 df
Deviance explained 37.15 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	2.81	9.22	0.001



SOUTH COAST MIXOPHYES BALBUS MODEL TO BE INSERTED HERE

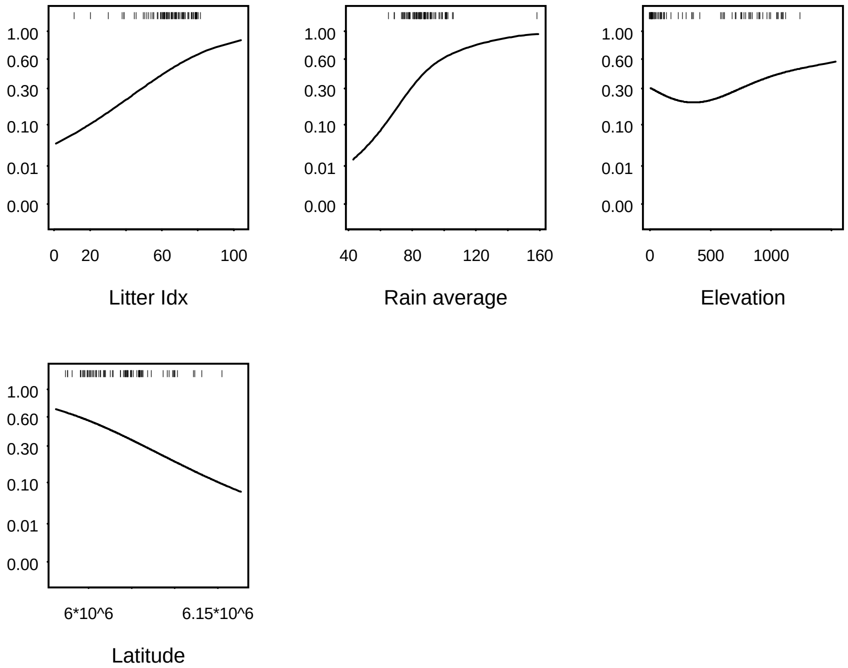
MODEL RESULTS FOR *CLIMACTERIS ERYTHROPS* (RED-BROWED TREECREEPER) FOR THE SOUTH COAST SUB-REGION

Climacteris erythrops

Red-browed Treecreeper

All records 74 Total pseudo sites 1074
Null deviance 205.17 on 1073 df
Residual dev. 143.11 on 1067 df
Deviance explained 30.25 %
Model type: GAM

Predictors	DF	Dev	Sig
Litter500	1	40.11	0.000
Rainfav	2	14.06	0.006
Dem	2	14.57	0.006
Latitude	1	9.31	0.002



SOUTH COAST RED-BROWED TREECREEPER MODEL TO BE INSERTED HERE

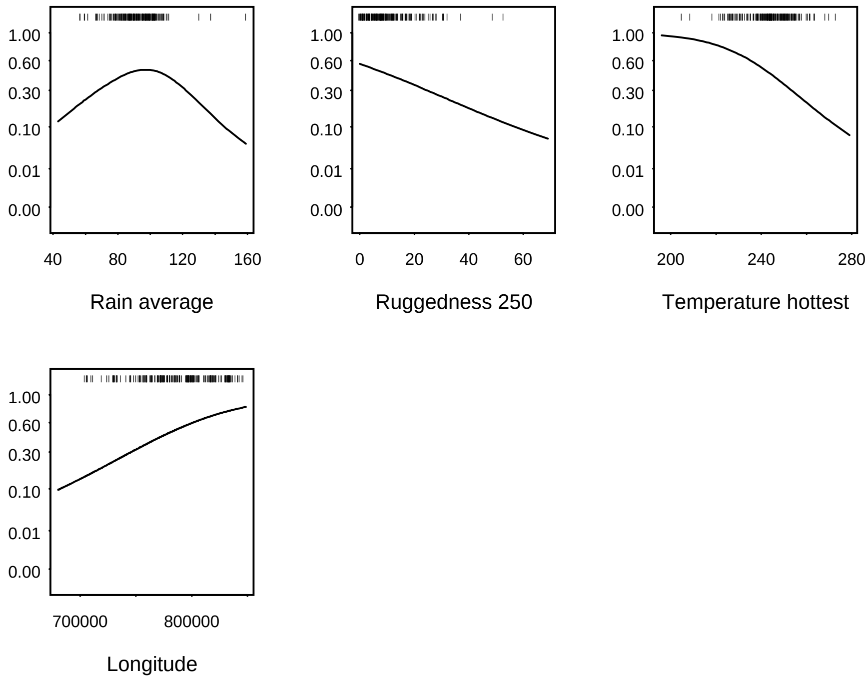
MODEL RESULTS FOR *CALYPTORHYNCHUS FUNEREUS* (YELLOW-TAILED BLACK-COOCKATOO) FOR THE SOUTH COAST SUB-REGION

Calyptorhynchus funereus

Yellow-tailed Black-Cockatoo

All records 182 Total pseudo sites 1182
Null deviance 504.61 on 1181 df
Residual dev. 394.54 on 1175 df
Deviance explained 21.81 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	3	80.41	0.000
Rgh250	1	19.45	0.001
Temphot	1	16.67	0.002
Longitude	1	4.55	0.033



SOUTH COAST YELLOW-TAILED BLACK-COCKATOO MODEL TO BE INSERTED HERE

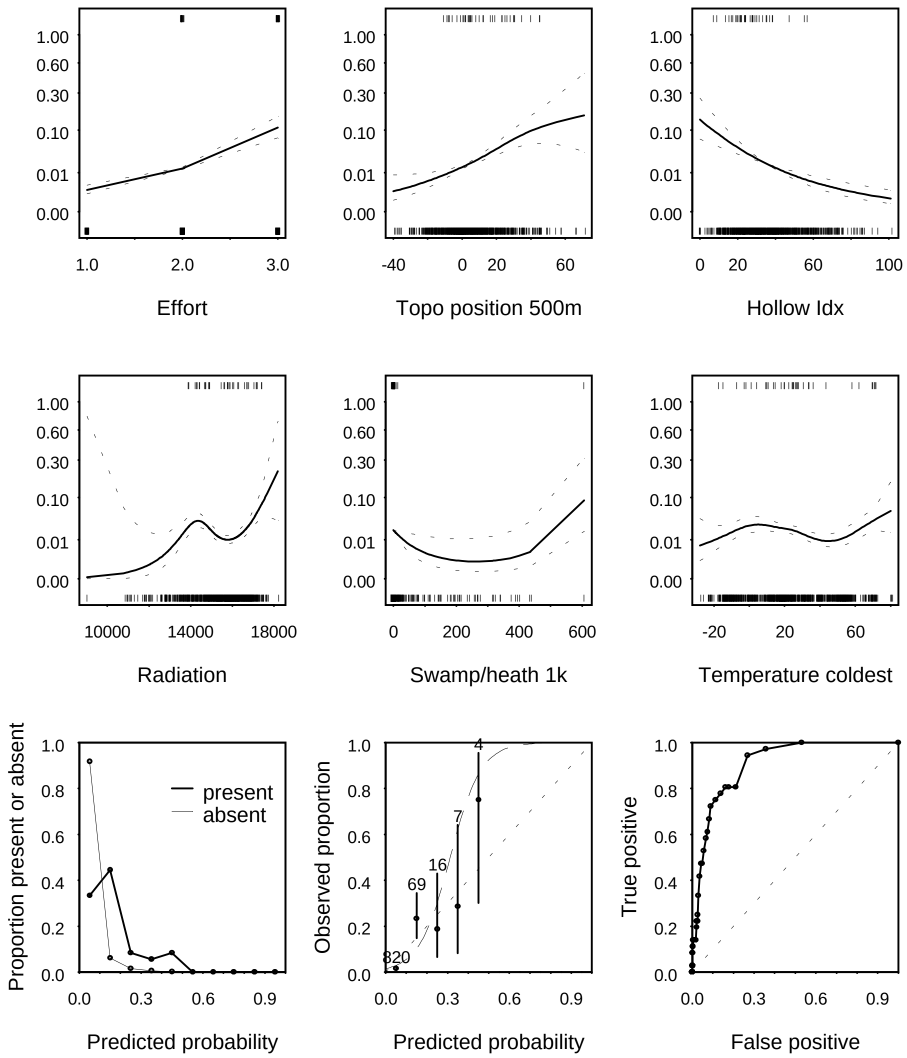
MODEL RESULTS FOR *CINCLOSOMA PUNCTATUM* (SPOTTED QUAIL-THRUSH) FOR THE SOUTH COAST SUB-REGION

Cinclosoma punctatum

Spotted Quail-thrush

Presence sites 36 Total sites 916
Null deviance 303.59 on 915 df
Residual dev. 212.53 on 901 df
Deviance explained 29.99 %
Model type: GAM

Predictors	DF	Dev	Sig
Effort	1	25.92	0.000
Topop500	1.9	19.44	0.001
Holl500m	1	17.52	0.001
Radiatn	3.9	18.96	0.001
Swhe1k	2	9.06	0.042
Tempcold	3.8	9.75	0.039



SOUTH COAST SPOTTED QUAIL-THRUSH MODEL TO BE INSERTED HERE

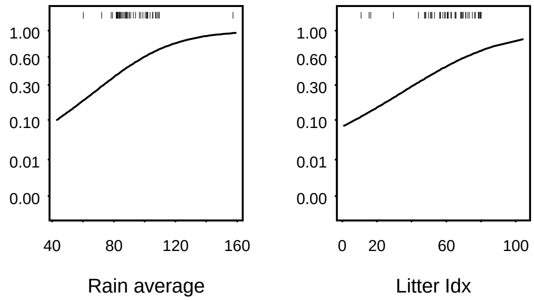
MODEL RESULTS FOR *FALCUNCULUS FRONTATUS* (CRESTED SHRIKE-TIT) FOR THE SOUTH COAST SUB-REGION

Falcunculus frontatus

Crested Shrike-tit

All records 48 Total pseudo sites 1048
Null deviance 133.08 on 1047 df
Residual dev. 109.42 on 1045 df
Deviance explained 17.78 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	1	24.63	0.000
Litter500	1	10.58	0.031



SOUTH COAST CRESTED SHRIKE-TIT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *DASYORNIS BRACHYPTERUS* (EASTERN BRISTLEBIRD) FOR THE SOUTH COAST SUB-REGION

The model contains buffers (hand drawn) around validated known locations. The original model was rejected as experts felt there were too few records to make the model reliable. Due to the lack of expert knowledge about the species, no expert model was created for this species.

SOUTH COAST EASTERN BRISTLEBIRD MODEL TO BE INSERTED HERE

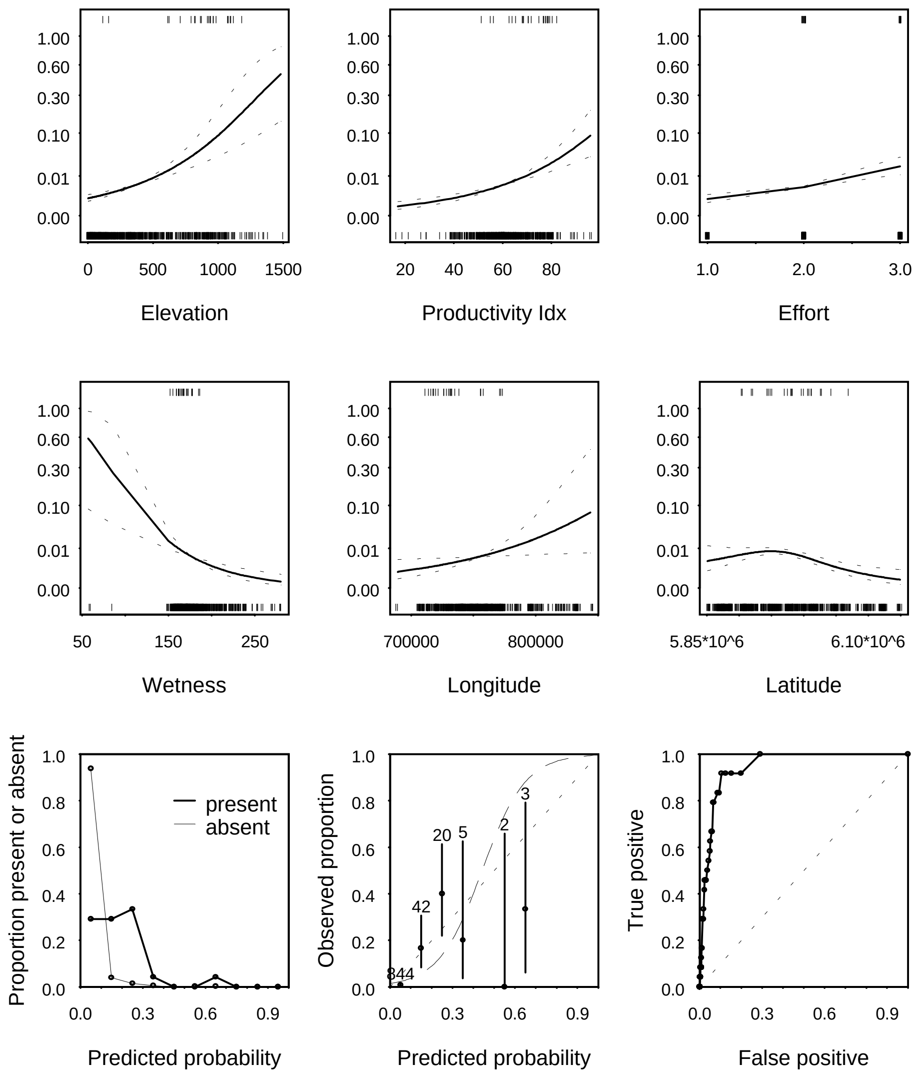
MODEL RESULTS FOR *PACHYCEPHALA OLIVACEA* (OLIVE WHISTLER) FOR THE SOUTH COAST SUB-REGION

Pachycephala olivacea

Olive Whistler

Presence sites 24 Total sites 916
Null deviance 222.18 on 915 df
Residual dev. 141.45 on 908 df
Deviance explained 36.33 %
Model type: GAM

Predictors	DF	Dev	Sig
Dem	1	42.81	0.000
Prod500m	2.9	14.43	0.000
Effort	1	5.31	0.021
Wetness	1	7.51	0.006
Longitude	1	0.41	0.528
Latitude	2	3.01	0.201



SOUTH COAST OLIVE WHISTLER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *EURYSTOMUS ORIENTALIS* (DOLLARBIRD)) FOR THE SOUTH COAST SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on proximity to clearing. All forested areas with high values of the variable 'Clearing within 2km' were classified as core habitat. All cleared areas were excluded from the model.

SOUTH COAST DOLLARBIRD MODEL TO BE INSERTED HERE

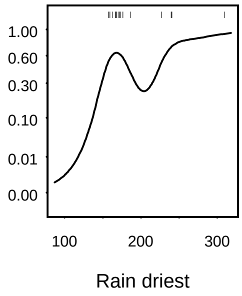
MODEL RESULTS FOR *LOPHOICTINIA ISURA* (SQUARE-TAILED KITE) FOR THE SOUTH COAST SUB-REGION

Lophoictinia isura

Square-tailed Kite

All records 15 Total pseudo sites 1012
Null deviance 41.59 on 1011 df
Residual dev. 31.66 on 1007 df
Deviance explained 23.87 %
Model type: GAM

Predictors	DF	Dev	Sig
Raindry	2.8	9.93	0.041



SOUTH COAST SQUARE-TAILED KITE MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PETROICA RODINOGASTER* (PINK ROBIN) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on the following vegetation types from the Eastern Bushlands Database layer: Allocasurine; degraded grasslands; dry forest systems; exotic forest; integrated logging; moist forest systems; plateaux complex; rainforest system; regrowth forest; rocky complex; severely disturbed vegetation; wattle scrub system; white cypress pine; and woodland systems. These vegetation types were classified as intermediate habitat. No area was classified as core habitat.

SOUTH COAST PINK ROBIN MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *MELANODRYAS CUCULLATA* (HOODED ROBIN) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on the vegetation type 'woodland systems' from the Eastern Bushlands Database (EBDB). This vegetation type was classified as intermediate habitat. No area was classified as core habitat.

SOUTH COAST HOODED ROBIN MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *NEOPHEMA PULCHELLA* (TURQUOISE PARROT) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on the vegetation type 'woodland systems' from the Eastern Bushlands Database (EBDB). This vegetation type was classified as intermediate habitat. No area was classified as core habitat.

SOUTH COAST TURQUOISE PARROT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *LATHAMUS DISCOLOR* (SWIFT PARROT) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on vegetation types with winter flowering eucalypts. Vegetation types used from the draft vegetation map were those that included *E. agglomerata, E. beyer, E. dalrympleana, E. globoidea, E. longifolia, E. maculata, E. ovata, E. pseudoglobulus, E. robusta, E. stellulata and E. tricarpa*. These vegetation types were classified as intermediate habitat. No area was classified as core habitat.

SOUTH COAST SWIFT PARROT MODEL TO BE INSERTED HERE

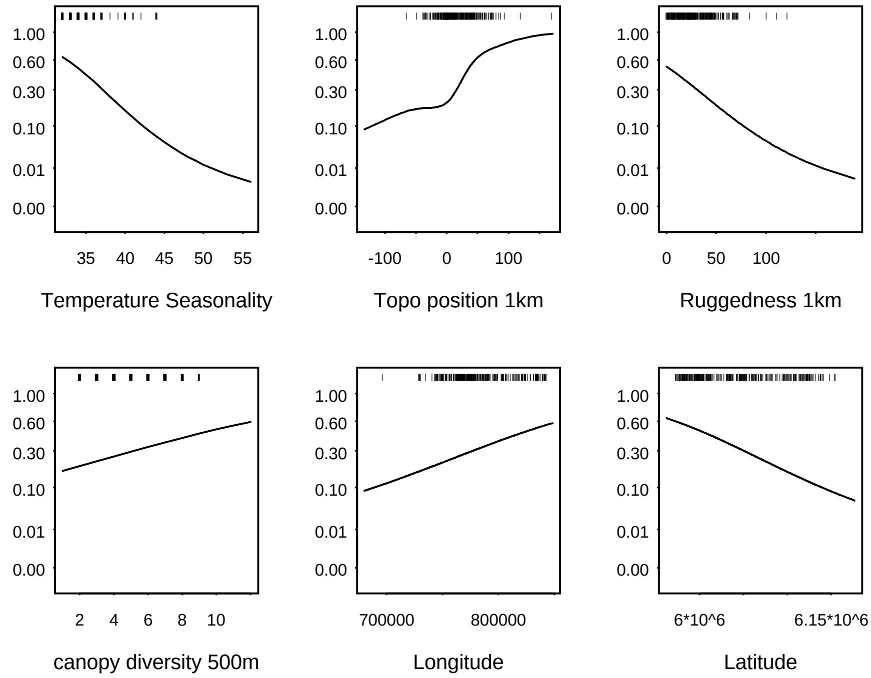
MODEL RESULTS FOR *CALYPTORHYNCHUS LATHAMI* (GLOSSY BLACK-COCKATOO) FOR THE SOUTH COAST SUB-REGION

Calyptorhynchus lathami

Glossy Black-Cockatoo

All records 278   Total pseudo sites 1278
Null deviance 770.78 on 1277 df
Residual dev. 469.86 on 1268 df
Deviance explained 39.04 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempseas	1	208.01	0.000
Topop1k	1	48.02	0.000
Rgh1000	3.9	19.73	0.000
Gibb500m	1	9.07	0.003
Longitude	1	8.25	0.004
Latitude	1	5.74	0.201



SOUTH COAST GLOSSY BLACK-COCKATOO MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *SERICORNIS CITREOGULARIS* (YELLOW-THROATED SCRUBWREN) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on all areas indicated as 'rainforest' within the API special features layer and 'moist forest' within the Eastern Bushlands Database (EBDB). 'Rainforest' was classified as core habitat while 'moist forest' was classified as marginal habitat.

SOUTH COAST YELLOW-THROATED SCRUBWREN MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *XANTHOMYZA PHRYGIA* (REGENT HONEYEATER) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on vegetation types from the draft vegetation map. Vegetation types that included the following tree species: *E. agglomerata, E. beyer, E. dalrympleana, E. globoidea, E. longifolia, E. maculata, E. ovata, E. pseudoglobulus, E. robusta, E. stellulata and E. tricarpa*; were classified as intermediate habitat. No area was classified as core habitat.

SOUTH COAST REGENT HONEYEATER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *CLIMACTERIS PICUMNUS* (BROWN TREECREEPER) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on vegetation types. Numerous vegetation types were utilised from the draft Southern CRA modelled vegetation layer to create core habitat (see vegetation mapping report, NSW NPWS, in press). “Woodland’ areas identified within the Eastern Bushlands Database (EBDB) were classified as intermediate habitat.

SOUTH COAST BROWN TREECREEPER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *SMINTHOPSIS LEUCOPUS* (WHITE-FOOTED DUNNART) FOR THE SOUTH COAST SUB-REGION

An expert model was created for this species. The expert model was based on a combination of the presence-only models calculated with and without Eden records. For the areas south of Bateman's Bay, the presence-only model minus Eden data was used, and for north of Bateman's Bay, the presence-only model with Eden records was used. The experts decided on percentage cut-offs from the model outputs to define core, intermediate and marginal habitat.

SOUTH COAST WHITE-FOOTED DUNNART MODEL TO BE INSERTED HERE

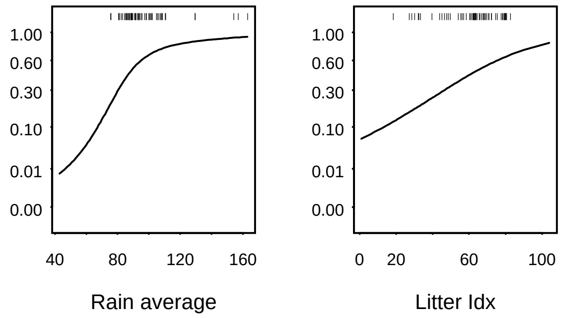
MODEL RESULTS FOR *PERAMELES NASUTA* (LONG-NOSED BANDICOOT) FOR THE SOUTH COAST SUB-REGION

Perameles nasuta

Long-nosed Bandicoot

All records 57 Total pseudo sites 1057
Null deviance 158.04 on 1056 df
Residual dev. 111.95 on 1053 df
Deviance explained 29.16 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	2	42.11	0.000
Litter500	0.9	9.48	0.047



SOUTH COAST LONG-NOSED BANDICOOT MODEL TO BE INSERTED HERE

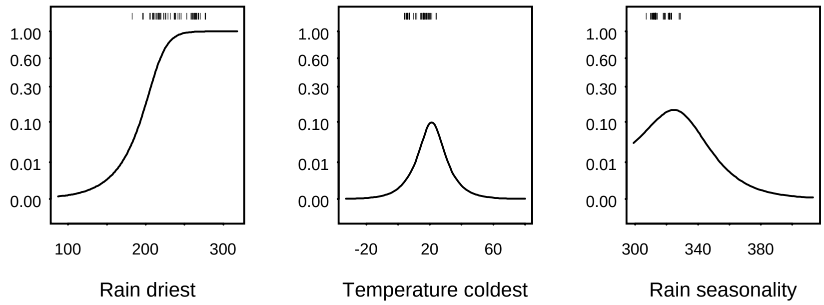
MODEL RESULTS FOR *PSEUDOMYS FUMEUS* (SMOKY MOUSE) FOR THE SOUTH COAST SUB-REGION

Pseudomys fumeus

Smoky Mouse

All records 55 Total pseudo sites 1052
Null deviance 152.49 on 1051 df
Residual dev. 21.16 on 1045 df
Deviance explained 86.12 %
Model type: GAM

Predictors	DF	Dev	Sig
Raindry	1	86.91	0.000
Tempcold	2.83	9.73	0.000
Rainseas	1.81	1.16	0.014



SOUTH COAST SMOKY MOUSE MODEL TO BE INSERTED HERE

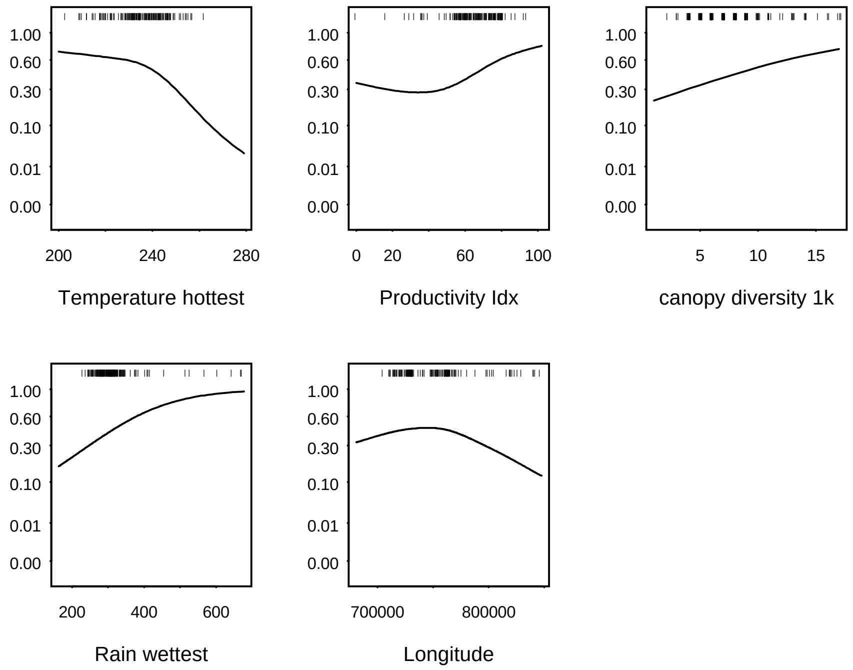
MODEL RESULTS FOR *DASYURUS MACULATUS* (TIGER QUOLL) FOR THE SOUTH COAST SUB-REGION

Dasyurus maculatus

Tiger Quoll

All records 150 Total pseudo sites 1147
Null deviance 415.89 on 1146 df
Residual dev. 324 on 1138 df
Deviance explained 22.1 %
Model type: GAM

Predictors	DF	Dev	Sig
Temphot	2	52.63	0.000
Prod500m	2	27.72	0.000
Gibbon1k	1	10.31	0.033
Rainwet	1	10.42	0.031
Longitude	2	6.51	0.038



SOUTH COAST TIGER QUOLL MODEL TO BE INSERTED HERE

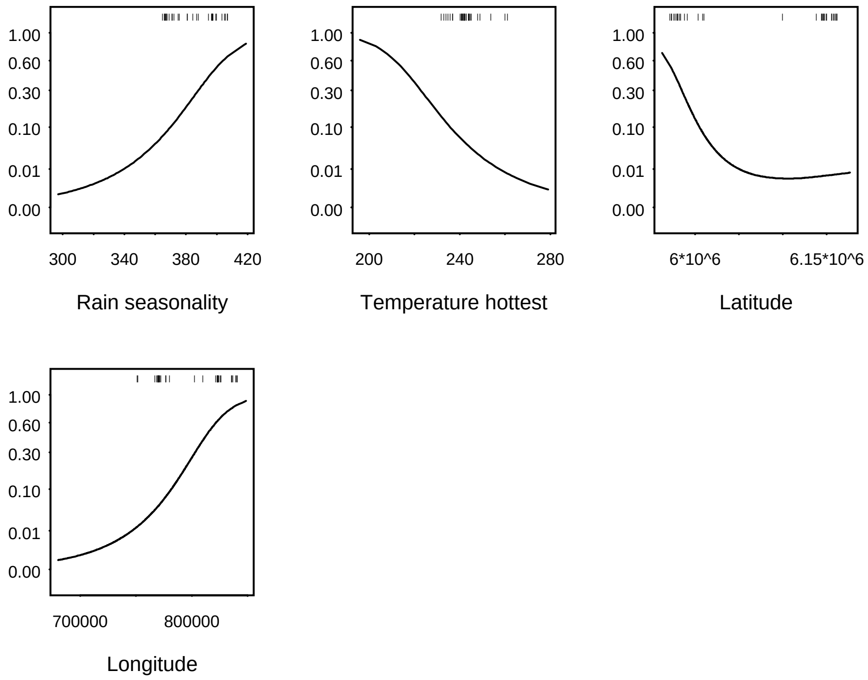
MODEL RESULTS FOR *POTOROUS TRIDACTYLUS* (LONG-NOSED POTOROO) FOR THE SOUTH COAST SUB-REGION

Potorous tridactylus

Long-nosed Potoroo

All records 32 Total pseudo sites 1032
Null deviance 88.72 on 1031 df
Residual dev. 33.32 on 1026 df
Deviance explained 62.45 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainseas	1	38.41	0.000
Temphot	1	13.64	0.008
Latitude	2	11.36	0.003
Longitude	1	4.44	0.035



SOUTH COAST LONG-NOSED POTOROO MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *ISOODON OBESULUS* (SOUTHERN BROWN BANDICOOT) FOR THE SOUTH COAST SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types, altitude and lithology. Numerous vegetation types were chosen from the Southern CRA Draft Vegetation map by Andrew Claridge (NSW NPWS) and classified as core habitat. Areas that were >600m in elevation according to the DEM layer were excluded from this model, as were areas that did not have sandier soils (i.e. acid volcanic, basalt, limestone and metamorphic soils).

SOUTH COAST SOUTHERN BROWN BANDICOOT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PETROGALE PENICILLATA* (BRUSH-TAILED ROCK-WALLABY) FOR THE SOUTH COAST SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on ruggedness, aspect and known locations. Areas that were classified as having a high (45 to 198) 'Roughness' value were classified as core habitat. A core buffer (1km in diameter) was also placed around validated known species records. All areas with an aspect between 90 to 270 degrees were excluded from the model.

SOUTH COAST BRUSH-TAILED ROCK-WALLABY MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PTEROPUS SCAPULATUS* (LITTLE RED FLYING-FOX) FOR THE SOUTH COAST SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on the validated *Pteropus poliocephalus* (Grey-headed Flying-fox) model as experts agreed that *Pteropus scapulatus* would use the same food resources and roost sites when in the area.

SOUTH COAST LITTLE RED FLYING-FOX MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *CHALINOLOBUS DWYERI* (LARGE PIED BAT) FOR THE SOUTH COAST SUB-REGION

The model contains core buffers (100m in radius) and intermediate buffers (2km in radius) around validated known locations. There was no valid statistical model for this species due to the lack of records, and no expert model was created due to the lack of expert knowledge about the species and the low number of records.

SOUTH COAST CHALINOLOBUS DWYERI MODEL TO BE INSERTED HERE

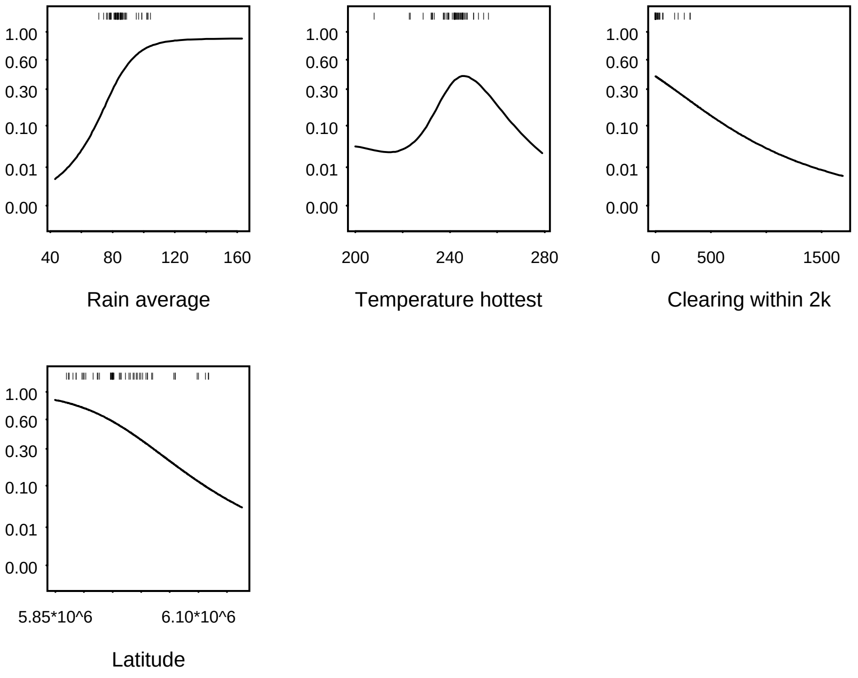
MODEL RESULTS FOR *SCOTEANAX RUEPPELLII* (GREATER BROAD-NOSED BAT) FOR THE SOUTH COAST SUB-REGION

Scoteanax rueppellii

Greater Broad-nosed Bat

All records 53 Total pseudo sites 1050
Null deviance 146.95 on 1049 df
Residual dev. 99 on 1042 df
Deviance explained 32.63 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	1.92	5.94	0.000
Temphot	2.91	4.11	0.006
Clear2k	1	9.58	0.049
Latitude	1	12.06	0.001



SOUTH COAST GREATER BROAD-NOSED BAT MODEL TO BE INSERTED HERE

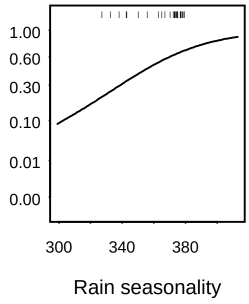
MODEL RESULTS FOR *MORMOPTERUS NORFOLKENSIS* (EASTERN LITTLE MASTIFF-BAT) FOR THE SOUTH COAST SUB-REGION

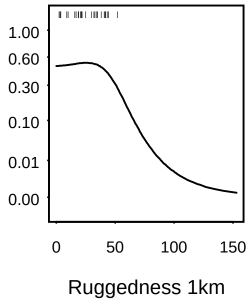
Mormopterus norfolkensis

Eastern Little Mastiff-bat

All records 27 Total pseudo sites 1024
Null deviance 74.86 on 1023 df
Residual dev. 58.09 on 1020 df
Deviance explained 22.4 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainseas	3	7.38	0.007
Rgh1000	1	9.38	0.009





SOUTH COAST MORMOPTERUS NORFOLKENSIS MODEL TO BE INSERTED HERE

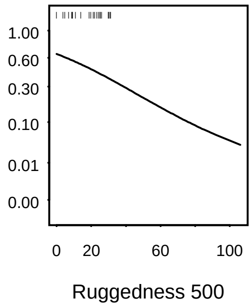
MODEL RESULTS FOR *MORMOPTERUS SP 1* (UNNAMED MASTIFF-BAT) FOR THE SOUTH COAST SUB-REGION

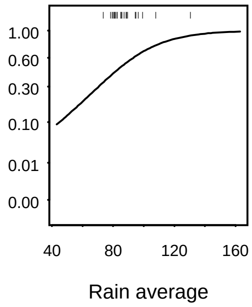
Mormopterus sp 1

undescribed mastiff-bat

All records 22 Total pseudo sites 1019
Null deviance 61 on 1018 df
Residual dev. 53.38 on 1016 df
Deviance explained 12.49 %
Model type: GAM

Predictors	DF	Dev	Sig
Rgh500	1	2.88	0.091
Rainfav	1	4.73	0.031





SOUTH COAST MORMOPTERUS SP 1 MODEL TO BE INSERTED HERE

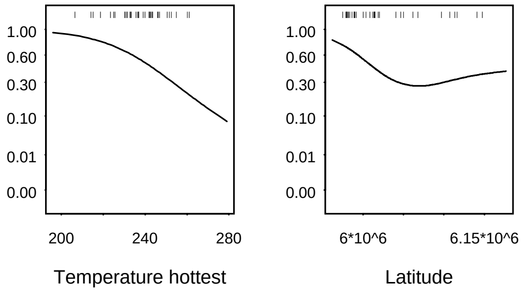
MODEL RESULTS FOR *FALSISTRELLUS TASMANIENSIS* (GREAT PIPISTRELLE) FOR THE SOUTH COAST SUB-REGION

Falsistrellus tasmaniensis

Great Pipistrelle

All records 35 Total pseudo sites 1035
Null deviance 97.04 on 1034 df
Residual dev. 76.96 on 1031 df
Deviance explained 20.69 %
Model type: GAM

Predictors	DF	Dev	Sig
Temphot	1	12.35	0.015
Latitude	2	8.76	0.012



SOUTH COAST FALSISTRELLUS TASMANIENSIS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *KERIVOULA PAPUENSIS* (GOLDEN-TIPPED BAT) FOR THE SOUTH COAST SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on proximity to rainforest vegetation. Areas that are classified as ‘moist’ and ‘rainforest’ within the Eastern Bushlands Database (EBDB) and ‘rainforest’ within the API layer were classified as core habitat. Areas that contained high values (21 to 185) in the ‘Rainforest within 1km’ layer were also classified as core habitat, whilst areas outside the core with high values (5 to 197) in the ‘Rainforest within 2km’ layer were classified as intermediate habitat.

SOUTH COAST KERIVOLVA PAPUENSIS MODEL TO BE INSERTED HERE

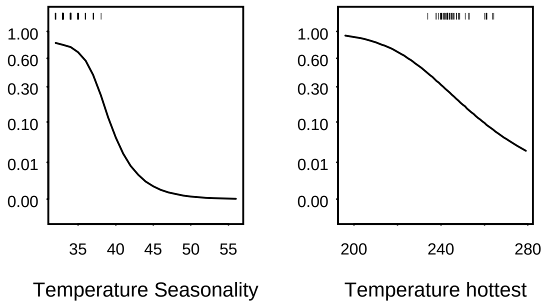
MODEL RESULTS FOR *RHINOLOPHUS MEGAPHYLLUS* (EASTERN HORSESHOE BAT) FOR THE SOUTH COAST SUB-REGION

Rhinolophus megaphyllus

Eastern Horseshoe-bat

All records 50 Total pseudo sites 1050
Null deviance 138.63 on 1049 df
Residual dev. 86.51 on 1046 df
Deviance explained 37.6 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempseas	1.94	8.39	0.000
Temphot	1	13.36	0.009



SOUTH COAST RHINOLOPHUS MEGAPHYLLUS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PTEROPUS POLIOCEPHALUS* (GREY-HEADED FLYING-FOX) FOR THE SOUTH COAST SUB-REGION

An expert model was created to show the predicted habitat for this species. Buffers were placed around known roost sites and classified as core habitat. Intermediate and marginal habitat were based on vegetation types from the API layer that include potential food tree species on advice given by Peggy Ebby, private consultant.

SOUTH COAST PTEROPUS POLICEPHALUS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *MINIOPTERUS SCHREIBERSII* (COMMON BENT-WING BAT) FOR THE SOUTH COAST SUB-REGION

The model contains buffers around validated maternity roost sites and other roost sites. Maternity roost sites were given a core buffer of 1km, an intermediate buffer of 10km and a marginal buffer of 30km. All other roost sites were ranked based on their size, number of bats and vulnerability. Roost sites ranked 1 were given a core buffer of 750m, an intermediate buffer of 5km and a marginal buffer of 30km. Roost sites ranked 2 were given a core buffer of 100m, an intermediate buffer of 3km and a marginal buffer of 15km. Roost sites ranked 3 were given a core buffer of 50m.

SOUTH COAST MINIOPTERUS SCHREBERSII MODEL TO BE INSERTED HERE

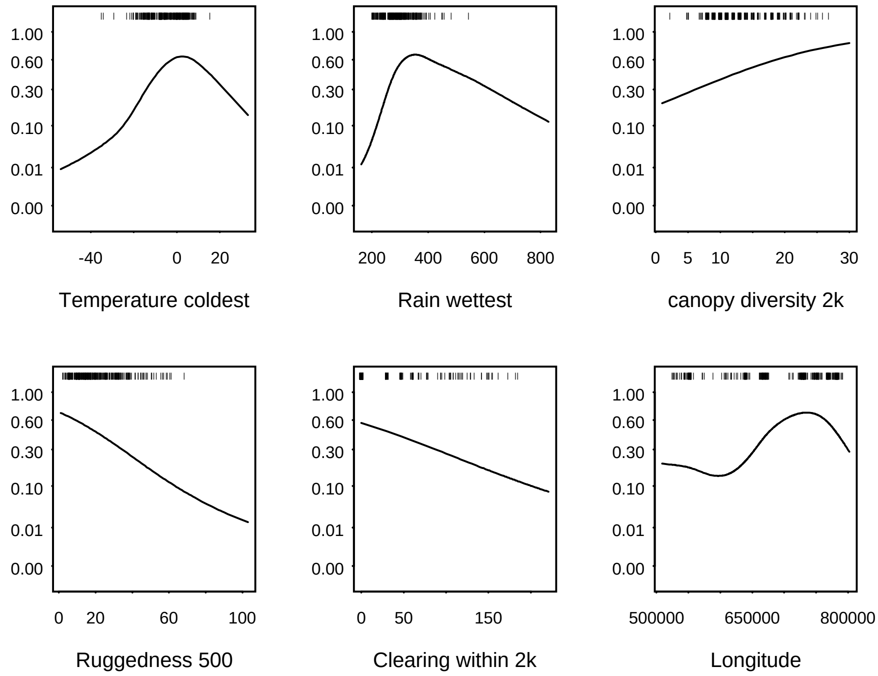
MODEL RESULTS FOR *PETAUROIDES VOLANS* (GREATER GLIDER) FOR THE TABLELANDS SUB-REGION

Petauroides volans

Greater Glider

All records 290 Total pseudo sites 1290
Null deviance 804.05 on 1289 df
Residual dev. 449.63 on 1276 df
Deviance explained 44.08 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempcold	2.8	116.27	0.000
Rainwet	3.1	99.35	0.000
Gibbon2k	2.9	30.59	0.000
Rgh500	1	35.78	0.000
Clear2k	1	36.49	0.000
Longitude	4	19.79	0.000



TABLELANDS GREATER GLIDER MODEL TO BE INSERTED HERE

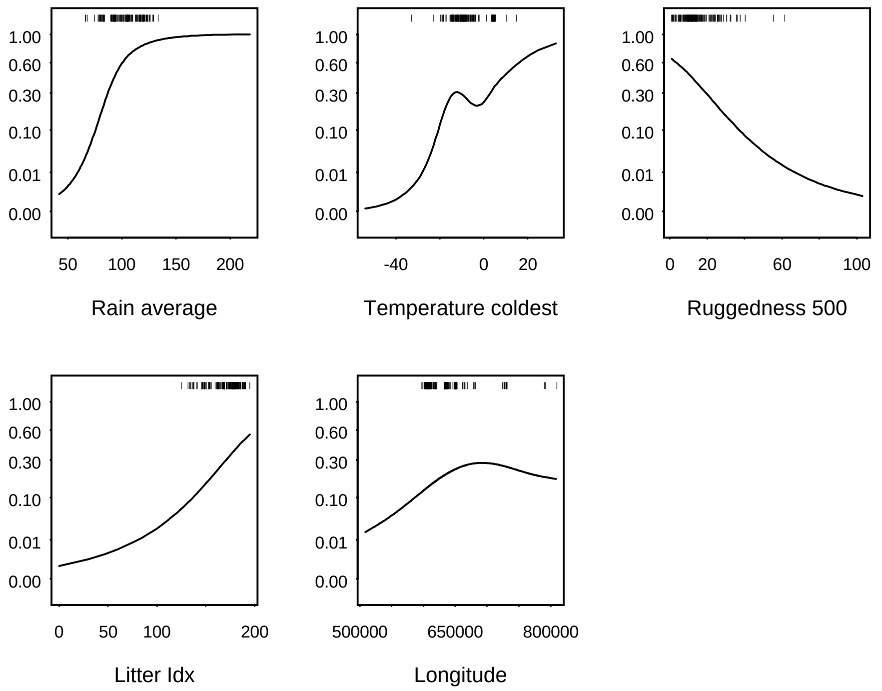
MODEL RESULTS FOR *PETAURUS AUSTRALIS* (YELLOW-BELLIED GLIDER) FOR THE TABLELANDS SUB-REGION

Petaurus australis

Yellow-bellied Glider

All records 158 Total pseudo sites 1158
Null deviance 438.07 on 1157 df
Residual dev. 167.35 on 1147 df
Deviance explained 61.8 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	1.98	9.73	0.000
Tempcold	3.94	5.33	0.000
Rgh500	1	28.02	0.000
Litter500	1	10.61	0.031
Longitude	2	6.54	0.037



TABLELANDS YELLOW-BELLIED GLIDER MODEL TO BE INSERTED HERE

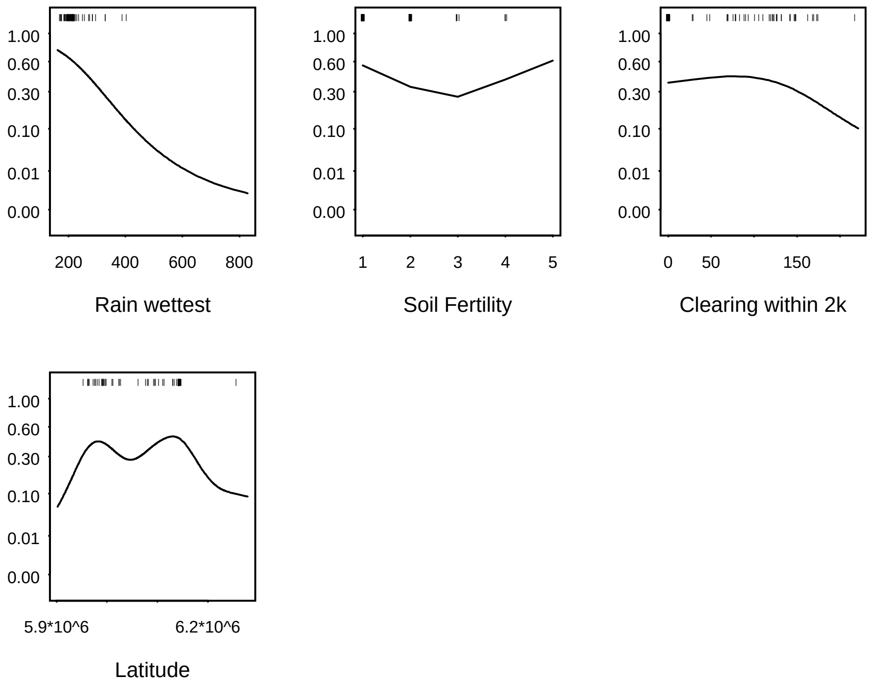
MODEL RESULTS FOR *PHASCOLARCTOS CINEREUS* (KOALA) FOR THE TABLELANDS SUB-REGION

Phascolarctos cinereus

Koala

All records 61 Total pseudo sites 1061
Null deviance 169.13 on 1060 df
Residual dev. 109.04 on 1051 df
Deviance explained 35.53 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainwet	1	29.12	0.000
Fertility	2	15.49	0.004
Clear2k	2	9.58	0.047
Latitude	4	14.63	0.005



TABLELANDS KOALA MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PETAURUS NORFOLCENSIS* (SQUIRREL GLIDER) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on non-winter flowering woodland vegetation types. Numerous such vegetation types were selected from the API vegetation layer and classified as core habitat, except for the Byadbo area in southern Kosciuszko National Park that was classified as marginal habitat.

TABLELANDS SQUIRREL GLIDER MODEL TO BE INSERTED HERE

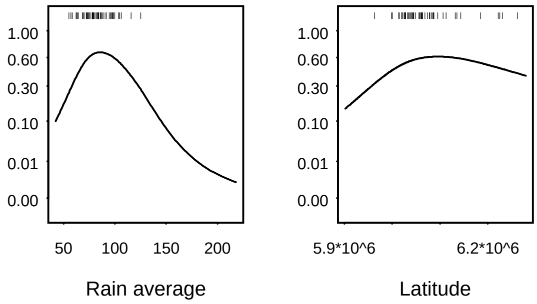
MODEL RESULTS FOR *NINOX STRENUA* (POWERFUL OWL) FOR THE TABLELANDS SUB-REGION

Ninox strenua

Powerful Owl

All records 53 Total pseudo sites 1053
Null deviance 146.95 on 1052 df
Residual dev. 123.42 on 1047 df
Deviance explained 16.01 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	2.81	8.15	0.001
Latitude	2	5.93	0.049



TABLELANDS POWERFUL OWL MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *TYTO TENEBRICOSA* (SOOTY OWL) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on proximity to rainforest vegetation. All areas that are classified as ‘moist forest’ within the Eastern Bushlands Database (EBDB) layer and ‘rainforest’ within the API layer were classified as core habitat.

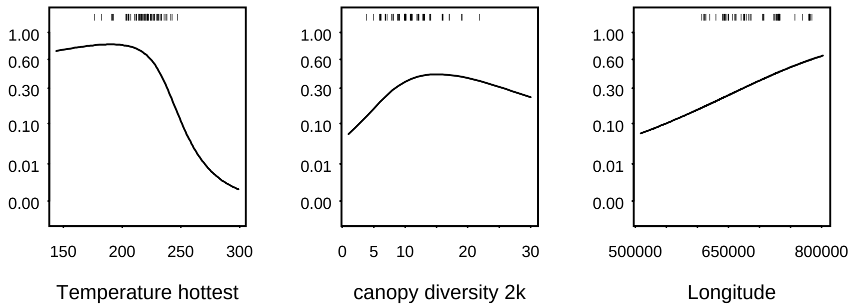
TABLELANDS SOOTY OWL MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PSEUDEMOIA SPENCERI* (SPENCERS SKINK) FOR THE TABLELANDS SUB-REGION

Pseudemoia spenceri

All records 67 Total pseudo sites 1067
Null deviance 185.76 on 1066 df
Residual dev. 113.47 on 1061 df
Deviance explained 38.92 %
Model type: GAM

Predictors	DF	Dev	Sig
Temphot	1.9	62.18	0.000
Gibbon2k	2	10.71	0.028
Longitude	1	4.92	0.026



TABLELANDS SPENCERS SKINK MODEL TO BE INSERTED HERE

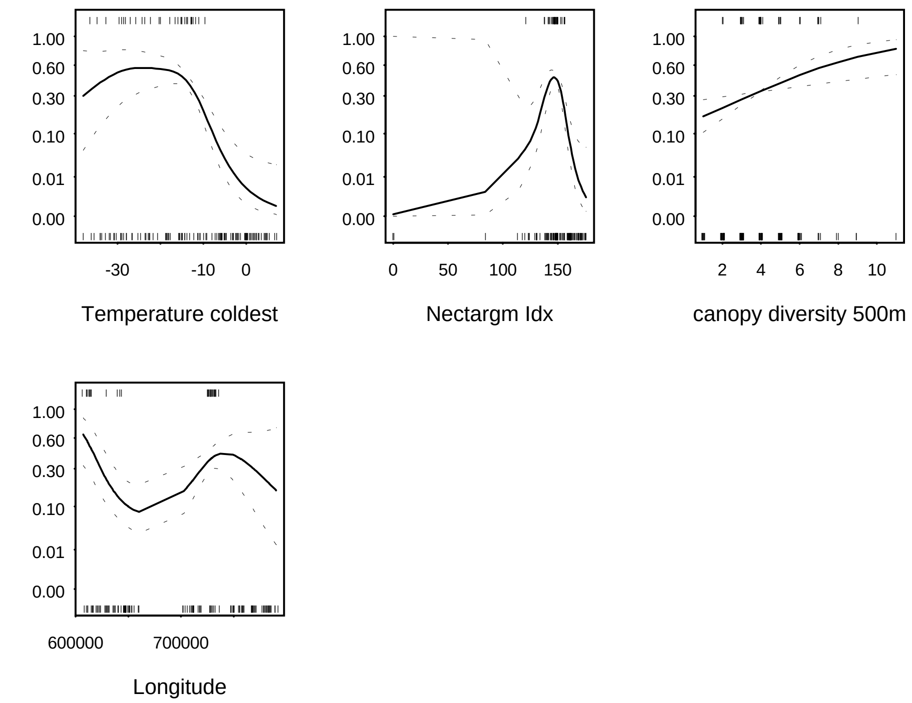
MODEL RESULTS FOR *NANNOSCINCUS MACCOYI* (MCCOYS SKINK) FOR THE TABLELANDS SUB-REGION

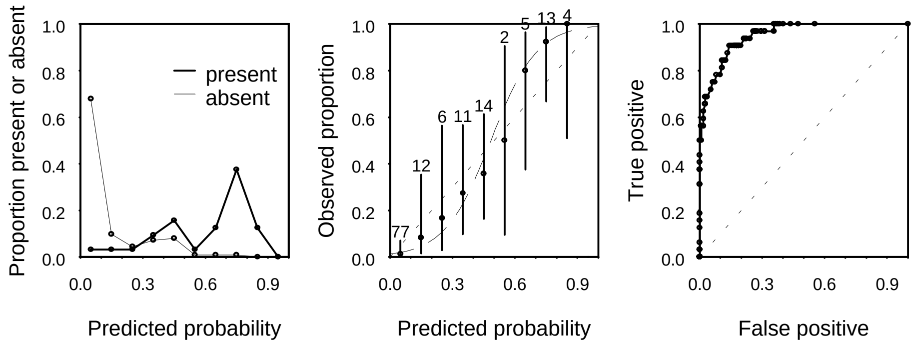
Nannoscincus maccoyi

McCoy's Skink

Presence sites 32 Total sites 144
Null deviance 152.56 on 143 df
Residual dev. 70.42 on 133 df
Deviance explained 53.84 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempcold	2.93	9.27	0.000
Nectargm5	2.93	0.05	0.000
Gibb500m	1	13.39	0.009
Longitude	3	11.72	0.008





TABLELANDS MCCOYS SKINK MODEL TO BE INSERTED HERE

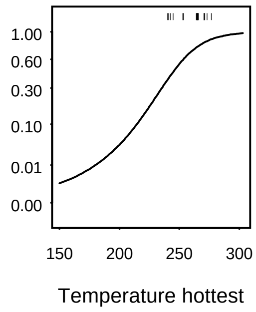
MODEL RESULTS FOR *VARANUS ROSENBERGI* (HEATH MONITOR) FOR THE TABLELANDS SUB-REGION

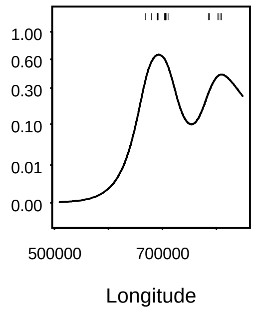
Varanus rosenbergi

Heath Monitor

All records 21 Total pseudo sites 1021
Null deviance 58.22 on 1020 df
Residual dev. 29.86 on 1015 df
Deviance explained 48.72 %
Model type: GAM

Predictors	DF	Dev	Sig
Temphot	1	16.42	0.002
Longitude	4	17.72	0.001





TABLELANDS HEATH MONITOR MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *MORELIA SPILOTA VARIEGATA* (CARPET PYTHON) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types, aspect and soil, and excluded all areas less than 500m in altitude. Core habitat was based on vegetation types that contain *Eucalyptus macrorhyncha*, *E. blakelyi*, *E. albens* and *E. camaldulensis* (from the API layer) which occur on granite and on N-NW facing slopes, or where API special features identifies rock or rock/plateaux complex. Intermediate habitat was based on the same vegetation types listed above regardless of geology or aspect classes. Marginal habitat was based on the remaining forest types within the Eastern Bushlands Database (EBDB).

TABLELANDS CARPET PYTHON MODEL TO BE INSERTED HERE

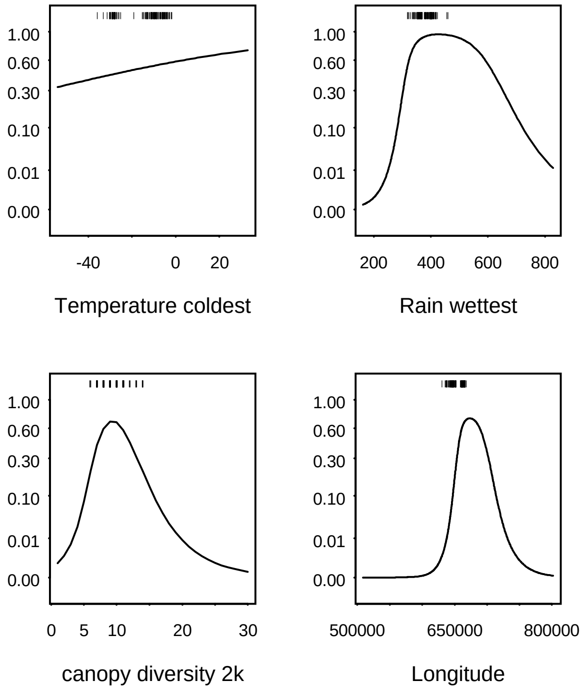
MODEL RESULTS FOR *PSEUDOPHRYNE PENGILLEYI* (NORTHERN CORROBOREE FROG) FOR THE TABLELANDS SUB-REGION

Pseudophryne pengilleyi

Northern Corroboree Frog

All records 131 Total pseudo sites 1131
Null deviance 363.21 on 1130 df
Residual dev. 46.31 on 1120 df
Deviance explained 87.25 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempcold	1	93.96	0.000
Rainwet	2.9	146.82	0.000
Rgh500	1	35.57	0.000
Gibbon2k	2.9	16.68	0.002
Longitude	3	37.33	0.000



TABLELANDS NORTHERN CORROBOREE FROG MODEL TO BE INSERTED HERE

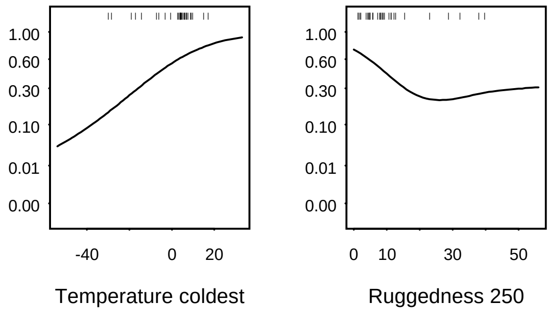
MODEL RESULTS FOR *PSEUDOPHRYNE BIBRONII* (BROWN TOADLET) FOR THE TABLELANDS SUB-REGION

Pseudophryne bibronii

Brown Toadlet

All records 30 Total pseudo sites 1030
Null deviance 83.18 on 1029 df
Residual dev. 66.63 on 1026 df
Deviance explained 19.89 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempcold	1	11.67	0.021
Rgh250	1.9	9.65	0.044



TABLELANDS BROWN TOADLET MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *LITORIA BOOROOLONGENSIS* (BOOROOLONG FROG) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on streams and roughness. 50m buffers around second, third, fourth and fifth order streams (from the stream order layer) where validated records occurred were classified as core habitat. The streams which did not encounter records but were in areas which had a higher (13 to 45) value of ‘Roughness within 500m’ were classified as intermediate habitat, to include areas of rocky ripples. Streams flowing east of the divide and within the upper Murrumbidgee catchment (Goodradigbee River) were rejected. All areas with pine plantations were excluded from the model.

TABLELANDS BOOROOLONG FROG MODEL TO BE INSERTED HERE

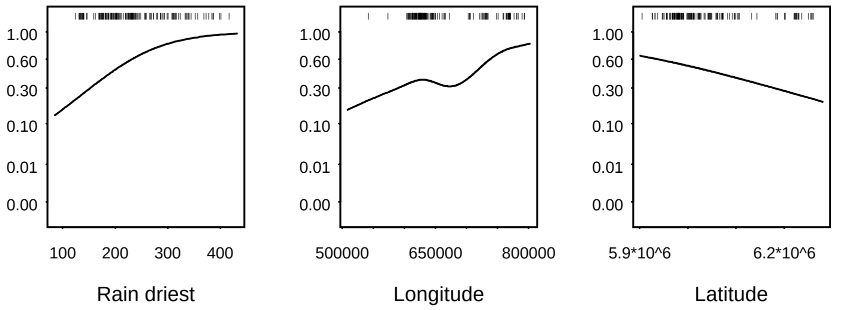
MODEL RESULTS FOR *CALYPTORHYNCHUS FUNEREUS* (YELLOW-TAILED BLACK-COCKATOO)FOR THE TABLELANDS SUB-REGION

Calyptorhynchus funereus

Yellow-tailed Black-Cockatoo

All records 145 Total pseudo sites 1145
Null deviance 402.03 on 1144 df
Residual dev. 339.85 on 1138 df
Deviance explained 15.47 %
Model type: GAM

Predictors	DF	Dev	Sig
Raindry	1	48.21	0.000
Longitude	4	13.09	0.009
Latitude	1	3.91	0.047



TABLELANDS YELLOW-TAILED BLACK-COCKATOO MODEL TO BE INSERTED HERE

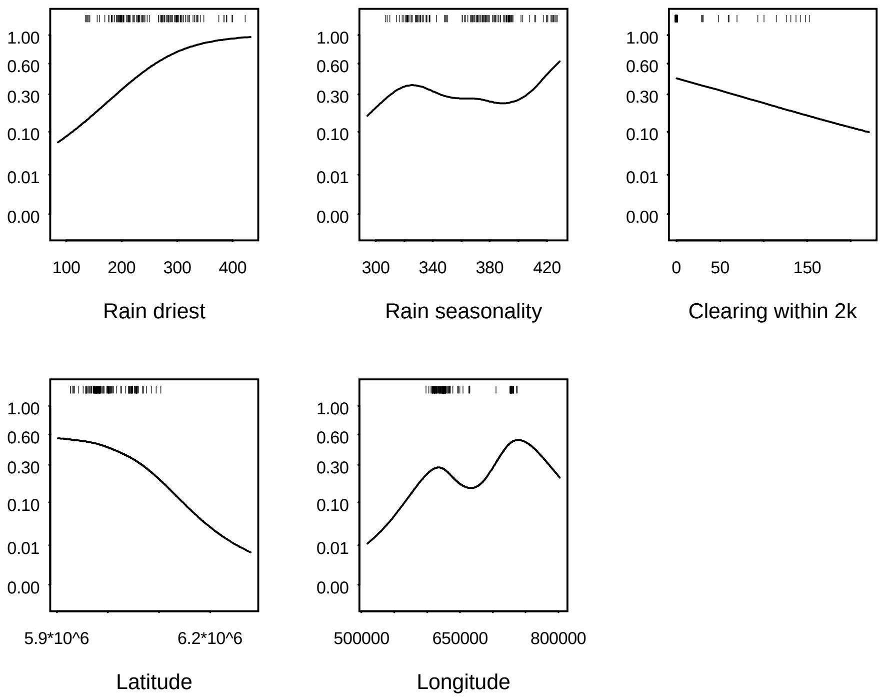
MODEL RESULTS FOR *PACHYCEPHALA OLIVACEA* (OLIVE WHISTLER) FOR THE TABLELANDS SUB-REGION

Pachycephala olivacea

Olive Whistler

All records 115 Total pseudo sites 1115
Null deviance 318.85 on 1114 df
Residual dev. 188.82 on 1102 df
Deviance explained 40.78 %
Model type: GAM

Predictors	DF	Dev	Sig
Raindry	1	75.38	0.000
Rainseas	4	21.65	0.000
Clear2k	1	15.26	0.004
Latitude	2	16.36	0.000
Longitude	4	14.15	0.006



TABLELANDS OLIVE WHISLTER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *CLIMACTERIS ERYTHROPS* (RED-BROWED TREECREEPER) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. Core habitat was based on 86 vegetation types and mosaics from the API layer, which are too numerous to list here (see raw validation workshop notes).

TABLELANDS RED-BROWED TREECREEPER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *POLYTELIS SWAINSONII* (SUPERB-PARROT) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on numerous vegetation types from the API layer – too numerous to list here. See raw validation workshop notes for details.

TABLELANDS SUPERB-PARROT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *CINCLOSOMA PUNCTATUM* (SPOTTED QUAIL-THRUSH) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types. A selection of dry forest vegetation types were selected from the API layer and classified as core habitat (see raw validation workshop notes for selection details). All areas with low solar radiation (< 15000) were excluded from the model, such that only dry ridge tops were included.

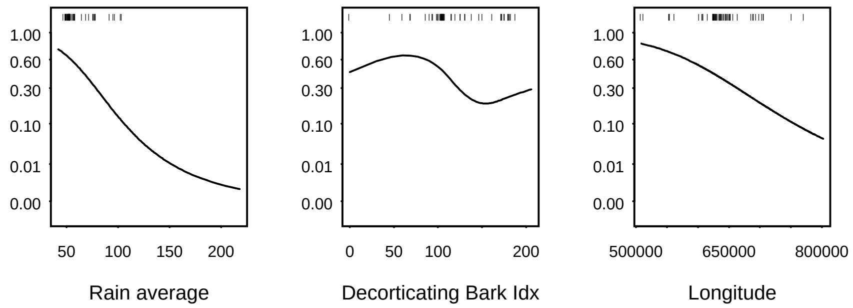
TABLELANDS SPOTTED QUAIL-THRUSH MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *CLIMACTERIS PICUMNUS* (BROWN TREECREEPER) FOR THE TABLELANDS SUB-REGION

Climacteris picumnus
Brown Treecreeper

All records 56 Total pseudo sites 1056
Null deviance 155.26 on 1055 df
Residual dev. 102.23 on 1050 df
Deviance explained 34.16 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	1	39.17	0.000
Decort500	2.9	10.78	0.027
Longitude	1	11.01	0.001



TABLELANDS BROWN TREECREEPER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *FALCUNCULUS FRONTATUS* (CRESTED SHRIKE-TIT) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on numerous vegetation types (similar to the 86 types selected for the expert Red-browed Treecreeper model with a few additional communities) from the API layer (see raw validation workshop notes for selection details).

TABLELANDS CRESTED SHRIKE-TIT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *MELANODRYAS CUCULLATA* (HOODED ROBIN) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types. Vegetation types were selected from the API layer and classified as core habitat (see raw validation workshop notes for selection details). Areas where these vegetation types were mapped as mosaics with other vegetation types, were classified as intermediate habitat. All areas with high values (> 10) in the 'Roughness 250m' layer were excluded from the model.

TABLELANDS HOODED ROBIN MODEL TO BE INSERTED HERE

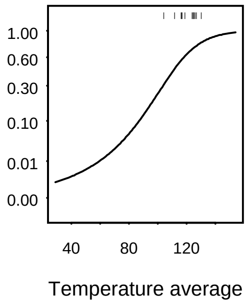
MODEL RESULTS FOR *EURYSTOMUS ORIENTALIS* (DOLLARBIRD) FOR THE TABLELANDS SUB-REGION

Eurystomus orientalis

Dollarbird

All records 14 Total pseudo sites 1014
Null deviance 38.82 on 1013 df
Residual dev. 30.17 on 1012 df
Deviance explained 22.28 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempav	1	13.82	0.007



TABLELANDS DOLLARBIRD MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *NEOPHEMA PULCHELLA* (TURQUOISE PARROT) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types and elevation. Vegetation types similar to that used in the expert Hooded Robin model were selected from the API layer. If they occurred in areas below 500m (according to the DEM layer) they were classified as core habitat, while areas between 501m to 700m were classified as intermediate habitat. All areas indicated as having API code of 2603 (*E. viminalis*/*E. meliodora*) and 2605 (*E. macrorhyncha*) regardless of altitude were classified as marginal habitat.

TABLELANDS TURQUOISE PARROT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PETROICA RODINOGASTER* (PINK ROBIN) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types. The following vegetation types were selected from the Eastern Bushlands Database (EBDB) and classified as intermediate habitat: Allocasurine, alpine system, degraded grassland, dry forest, frost hollow, integrated logging, moist forest, plateaux complex, rainforest, regrowth, severely disturbed, sub-alpine forest, wattle scrub, white cypress pine and woodland systems. No area was classified as core habitat.

TABLELANDS PINK ROBIN MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *XANTHOMYZA PHRYGIA* (REGENT HONEYEATER) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types. The model combined the vegetation types utilised within the expert Swift Parrot model, plus river oak (as identified in the API special features) and classified these types as core habitat. These vegetation types in the area around Byadbo in Southern Kosciuszko National Park were classified as intermediate habitat by experts.

TABLELANDS REGENT HONEYEATER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *LATHAMUS DISCOLOR* (SWIFT PARROT) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types. Vegetation types that include winter flowering eucalypts were selected from the API layer and classified as core habitat (see raw validation workshop notes for selection details).

TABLELANDS SWIFT PARROT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *LOPHOICTINIA ISURA* (SQUARE-TAILED KITE) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types. The following vegetation types were selected from the Eastern Bushlands Database (EBDB) and classified as intermediate habitat: dry forest systems, wattle scrub systems, wattle cypress pine and woodland. All areas with a high roughness (11 to 190 from the Roughness 250m layer) were excluded from the model. No area was classified as core habitat.

TABLELANDS SQUARE-TAILED KITE MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *MELITHREPTUS GULARIS* (BLACK-CHINNED HONEYEATER) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types and elevation. The vegetation types used within the expert Swift Parrot model were combined with areas that had an elevation of less than 500m (from the DEM) to develop core habitat. Intermediate habitat was classified by the same vegetation types in areas that had an elevation between 500 to 700m.

TABLELANDS BLACK-CHINNED HONEYEATER MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *GRANTIELLA PICTA* (PAINTED HONEYEATER) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on the vegetation types used in the expert Regent Honeyeater model with the Byadbo area of Southern Kosciuszko NP being excluded from the model. These vegetation types minus the exclusion were classified as core habitat.

TABLELANDS PAINTED HONEYEATER MODEL TO BE INSERTED HERE

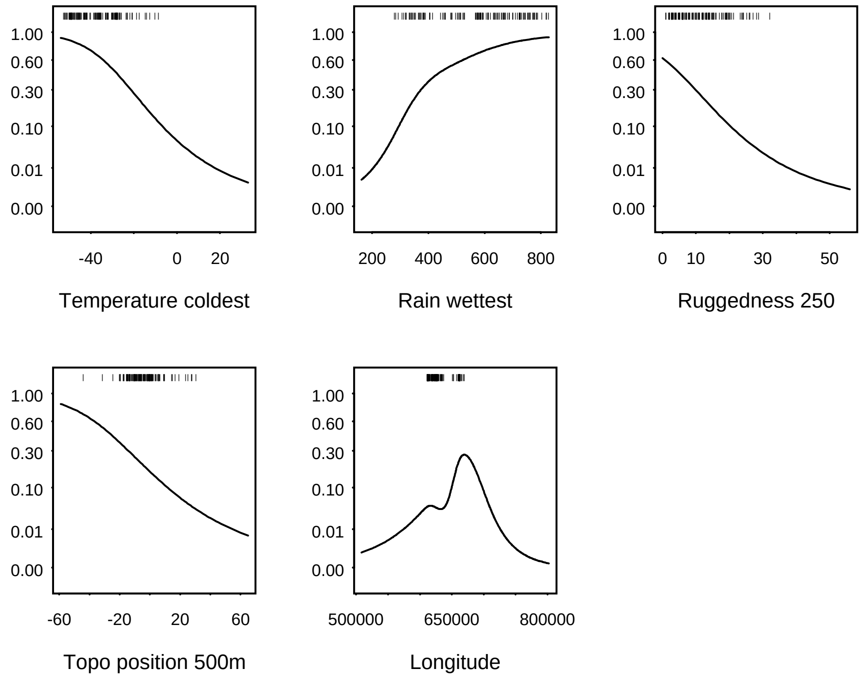
MODEL RESULTS FOR *MASTACOMYS FUSCUS* (BROAD-TOOTHED RAT) FOR THE TABLELANDS SUB-REGION

Mastacomys fuscus

Broad-toothed Rat

All records 128 Total pseudo sites 1128
Null deviance 354.89 on 1127 df
Residual dev. 109.54 on 1117 df
Deviance explained 69.14 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempcold	1	180.47	0.000
Rainwet	3	28.45	0.000
Rgh250	1	20.64	0.000
Topop500	1	12.49	0.013
Longitude	4	14.91	0.004



TABLELANDS BROAD-TOOTHED RAT MODEL TO BE INSERTED HERE

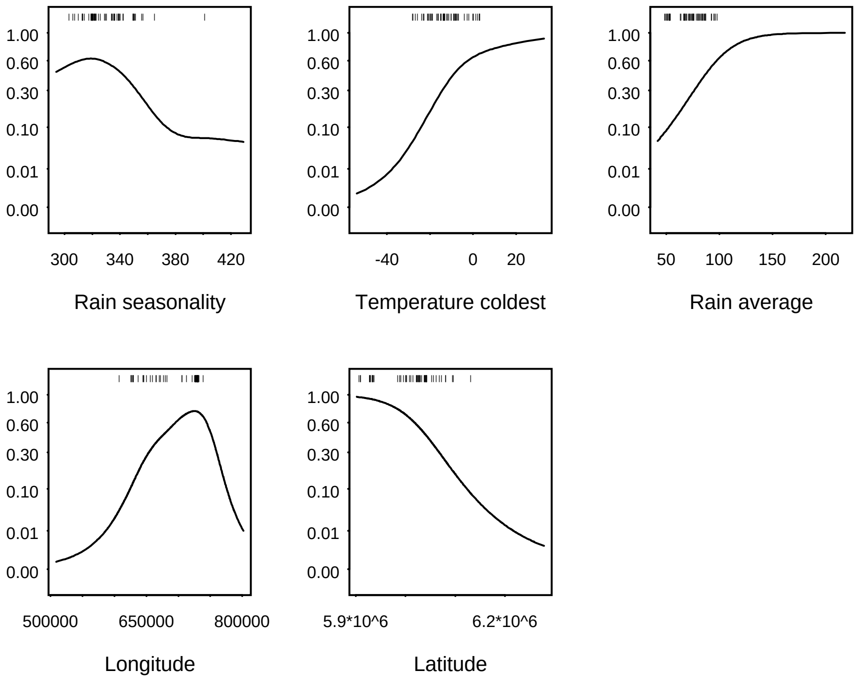
MODEL RESULTS FOR *DASYURUS MACULATUS* (TIGER QUOLL) FOR THE TABLELANDS SUB-REGION

Dasyurus maculatus

Tiger Quoll

All records 57 Total pseudo sites 1057
Null deviance 158.04 on 1056 df
Residual dev. 86.56 on 1045 df
Deviance explained 45.23 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainseas	2.9	15.41	0.004
Tempcold	2	12.58	0.012
Rainfav	0.9	10.13	0.036
Longitude	4	14.57	0.005
Latitude	1	15.69	0.000



TABLELANDS TIGER QUOLL MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PETROGALE PENICILLATA* (BRUSH-TAILED ROCK-WALLABY) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on buffering around validated records. Known populations in the northern area of the model were given a 2km core buffer around the validated records. All other records were given an intermediate buffer of 2km where areas had a high roughness value (20 to 190 in Roughness 250m layer).

TABLELANDS BRUSH-TAILED ROCK-WALLABY MODEL TO BE INSERTED HERE

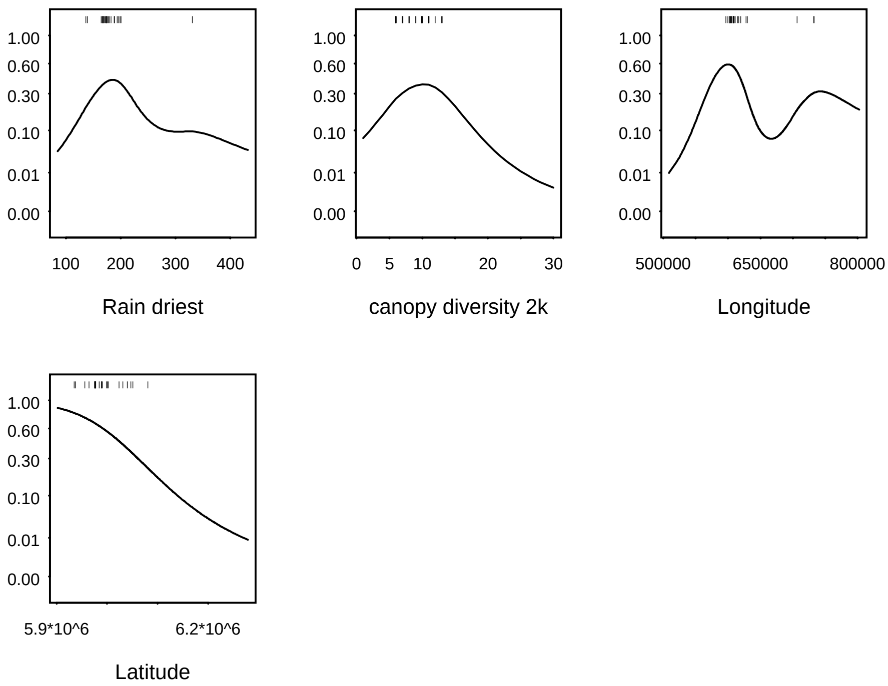
MODEL RESULTS FOR *PERAMELES NASUTA* (LONG-NOSED BANDICOOT) FOR THE TABLELANDS SUB-REGION

Perameles nasuta

Long-nosed Bandicoot

All records 23 Total pseudo sites 1023
Null deviance 63.77 on 1022 df
Residual dev. 30.15 on 1012 df
Deviance explained 52.71 %
Model type: GAM

Predictors	DF	Dev	Sig
Raindry	2.8	13.71	0.008
Gibbon2k	2.1	9.57	0.043
Longitude	4	13.47	0.008
Latitude	1	4.21	0.033



TABLELANDS LONG-NOSED BANDICOOT MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PSEUDOMYS FUMEUS* (SMOKY MOUSE) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on buffering around validated scat records. A 2km core buffer was placed around scat records and a 4km core buffer was placed around validated quoll scat records that contained Smoky Mouse remains.

TABLELANDS SMOKY MOUSE MODEL TO BE INSERTED HERE

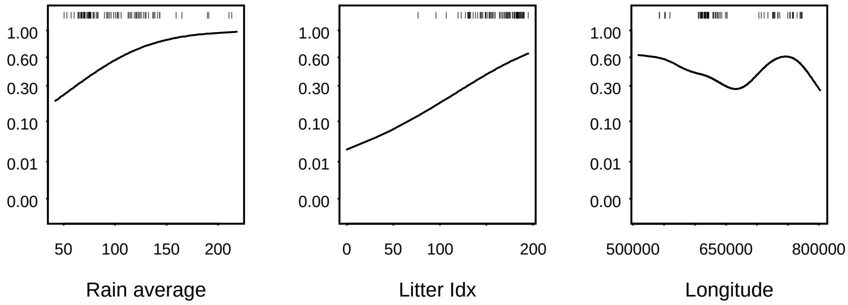
MODEL RESULTS FOR *FALSISTRELLUS TASMANIENSIS* (GREAT PIPISTRELLE) FOR THE TABLELANDS SUB-REGION

Falsistrellus tasmaniensis

Great Pipistrelle

All records 76 Total pseudo sites 1076
Null deviance 210.72 on 1075 df
Residual dev. 177 on 1069 df
Deviance explained 16 %
Model type: GAM

Predictors	DF	Dev	Sig
Rainfav	1	18.09	0.001
Litter500	1	10.88	0.031
Longitude	4	11.82	0.016



TABLELANDS FALSISTRELLUS TASMANIENSIS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *MINIOPTERUS SCHREIBERSII* (COMMON BENT-WING BAT) FOR THE TABLELANDS SUB-REGION

The model contains buffers around validated maternity roost sites and other roost sites. Maternity roost sites were given a core buffer of 1km, an intermediate buffer of 10km and a marginal buffer of 30km. Other roost sites were ranked according to their size, number of bats, and vulnerability. Roost sites ranked 1 were given a core buffer of 750m, an intermediate buffer of 5km and a marginal buffer of 30km. All other roost sites were given a core buffer of 100m, an intermediate buffer of 3km and a marginal buffer of 15km.

TABLELANDS MINIOPTERUS SCHREIBERSII MODEL TO BE INSERTED HERE

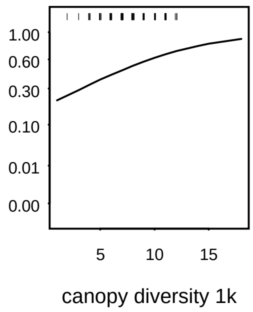
MODEL RESULTS FOR *MORMOPTERUS NORFOLKENSIS* (EASTERN LITTLE MASTIFF-BAT) FOR THE TABLELANDS SUB-REGION

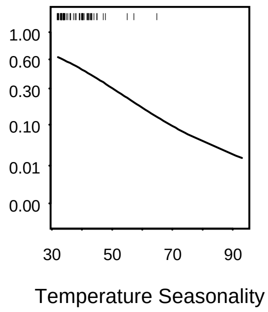
Mormopterus norfolkensis

Eastern Little Mastiff-bat

All records 64 Total pseudo sites 1064
Null deviance 177.45 on 1063 df
Residual dev. 159.21 on 1061 df
Deviance explained 10.28 %
Model type: GAM

Predictors	DF	Dev	Sig
Gibbon1k	1	16.61	0.002
Tempseas	1	11.12	0.024





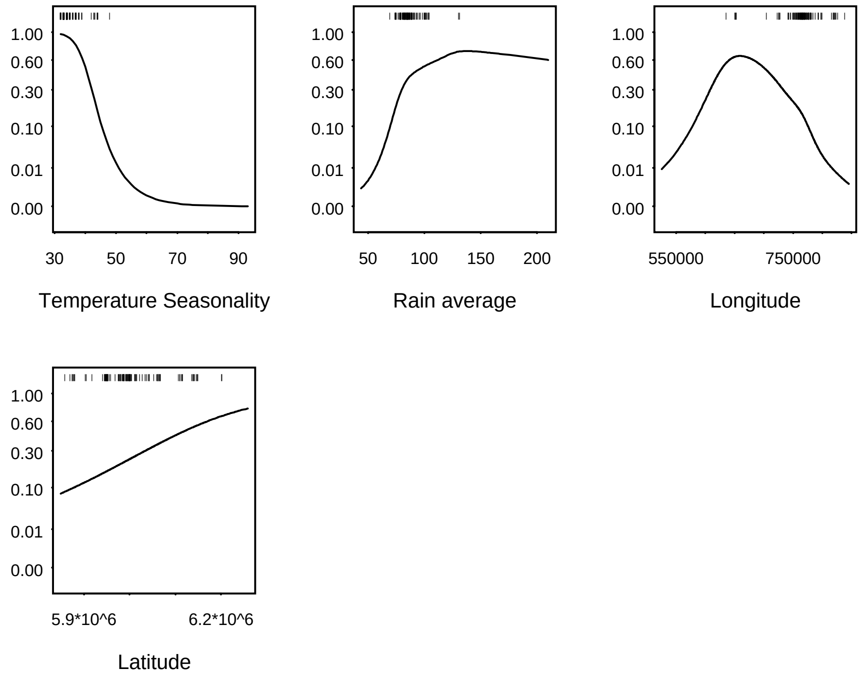
TABLELANDS MORMOPTERUS NORFOLKENSIS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *RHINOLOPHUS MEGAPHYLLUS* (EASTERN HORSESHOE BAT) FOR THE TABLELANDS SUB-REGION

Rhinolophus megaphyllus
Eastern Horseshoe-bat

All records 103 Total pseudo sites 1103
Null deviance 285.58 on 1102 df
Residual dev. 167.36 on 1093 df
Deviance explained 41.4 %
Model type: GAM

Predictors	DF	Dev	Sig
Tempseas	1	85.79	0.000
Rainfav	3	22.71	0.000
Longitude	4	11.27	0.023
Latitude	1	4.79	0.028



TABLELANDS RHINOLOPHUS MEGAPHYLLUS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *MYOTIS ADVERSUS* (LARGE-FOOTED MOUSE-EARED BAT) FOR THE TABLELANDS SUB-REGION

The model contains buffers around one validated maternity roost site. This roost site was given a 1km core buffer where water is within a 1km radius. An intermediate buffer was placed around the roost site were water is within a 10km radius. A riparian buffer was also placed around the edge of the lake. The buffer was made core when it was in a 3km radius from the roost site while the rest of the riparian buffer was classified as intermediate habitat.

TABLELANDS MYOTIS ADVERSUS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *CHALINOLOBUS DWYERI* (LARGE PIED BAT) FOR THE TABLELANDS SUB-REGION

The model contains 1km core habitat buffers and 2km intermediate habitat buffers around validated roost sites.

TABLELANDS CHALINOLOBUS DWYERI MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PTEROPUS POLIOCEPHALUS* (GREY-HEADED FLYING-FOX) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types from the API layer that include the most important food trees (*Eucalyptus melliodora*, *E. blakelyi* and *E. camaldulensis)*. The vegetation types were ranked according to their importance and then classified as core, intermediate and marginal habitat.

TABLELANDS PTEROPUS POLIOCEPHALUS MODEL TO BE INSERTED HERE

MODEL RESULTS FOR *PTEROPUS SCAPULATUS* (LITTLE RED FLYING-FOX) FOR THE TABLELANDS SUB-REGION

An expert model was created to show the predicted habitat for this species. The expert model was based on vegetation types from the API layer that include the most important food trees (*Eucalyptus melliodora*, *E. blakelyi* and *E. camaldulensis)*. The vegetation types were ranked according to their importance and then classified as core, intermediate and marginal habitat.

TABLELANDS PTEROPUS SCAPULATUS MODEL TO BE INSERTED HERE