Evaluation of effectiveness of derived forest ecosystems as surrogates for invertebrate biodiversity, and identification of hotspots of invertebrate endemism.

[Southern Region]

A project undertaken as part of the NSW Comprehensive Regional Assessments

July 2000

Evaluation of effectiveness of derived forest ecosystems as surrogates for invertebrate biodiversity, and identification of hotspots of invertebrate endemism.

SOUTHERN REGION

Australian Museum

A project undertaken for
the Joint Commonwealth NSW Regional Forest Agreement Steering Committee
as part of the
NSW Comprehensive Regional Assessments
project number NS 12/EH

For more information and for information on access to data contact the:

Resource and Conservation Division, Department of Urban Affairs and Planning

GPO Box 3927
SYDNEY NSW 2001

Phone: (02) 9228 3166
Fax: (02) 9228 4967

Forests Taskforce, Department of the Prime Minister and Cabinet

3-5 National Circuit
BARTON ACT 2600

Phone: 1800 650 983
Fax: (02) 6271 5511

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The project has been overseen and the methodology has been developed through the Environment and Heritage Technical Committee which includes representatives from the New South Wales and Commonwealth Governments and stakeholder groups.

Paul Flemons managed the Project and compiled the report.
Lance Wilkie managed the field work, laboratory and data compilation components of the project.
Rebecca Harris, Jaynia Tarnawski, Helen Smith, Scott Lassau, and Phil Coleman carried out field and laboratory work.
Michael Elliott, Derek Smith and Elizabeth Jeffreys carried out laboratory work and identifications.
Melissa Whitfield, Michael Shea, Nicola Saltman, Laura Collins and Solange Villarroel carried out laboratory work.
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CONTENTS

EXECUTIVE SUMMARY

This report describes a project undertaken as part of 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 major forest areas of New South Wales. These agreements will determine the future of these forests, providing a balance between conservation and ecologically sustainable use of forest resources.

Project Objectives

1. To evaluate the effectiveness of forest ecosystems for the Southern CRA region, as surrogates for invertebrate diversity.
2. To use the outcome of Objective 1 to identify the most appropriate level of forest ecosystem subdivision for representing invertebrate diversity.
3. Develop a GIS layer identifying hotspots of invertebrate narrow range endemism for inclusion in RFA negotiations.

Additional Objectives added at completion of field work

4. Investigate whether geographic distance is a significant factor in invertebrate species turnover in the Southern CRA area.
5. Identify whether sampling across the geographic range of forest ecosystems is likely to increase the level of biodiversity conservation.

Methods

120 sites were sampled, 5 pitfall traps per site, for 21 days. Target groups were beetles, ants, spiders. All samples were sorted, identified and curated at the Australian Museum. Matrix Correlation Analysis was used to assess which heirarchically related forest ecosystem classifications were best surrogates for invertebrate biodiversity.
The species turnover of each of the target groups was assessed in relation to geographic distance to determine what variation in biological dissimilarity could be explained by geographic distance.
Endemism layers were produced by weighting each species' predicted distribution inverse to its area. These were then averaged to create a GIS layer that identifies areas most likely to contain a relatively large number of endemic invertebrate species.

Key Results and Products

1. The surrogate evaluation produced an ambiguous result suggesting that current surrogacy techniques are inadequate for analysing the effectiveness of hierarchically related surrogates.
2. Based on the results from 1 it is not possible to recommend a scale of forest ecosystem classification most suitable as a surrogate for invertebrate biodiversity.
3. A Geographic Information System layer identifying hotspots of narrow range invertebrate endemism for inclusion in Regional Forestry Agreement negotiations.
4. Geographic distance is a significant factor in the species turnover of beetles within the Southern CRA region. For spiders and ants, geographic distance was not significant in species turnover.
5. Following 4, sampling across the geographic range of forest ecosystems will increase the level of biodiversity conservation.

1. INTRODUCTION

1.1 BACKGROUND

The Commonwealth/NSW Scoping Agreement dictates that the environment and heritage assessments include a biodiversity component within the CRA process. The criteria to be addressed in conducting this biodiversity assessment are specified in the JANIS report *Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia* (1997).

The JANIS criteria place considerable emphasis on using '*forest ecosystems*' as a broad surrogate for biodiversity. The criteria also recognise that a concordance between mapped forest ecosystems and the distributions of all elements of biodiversity is unlikely. The previous CRA study carried out for the Upper North East and the Lower North East CRA regions found that broad forest ecosystem classifications were a poor surrogate for invertebrate biodiversity. Performance of forest ecosystem mapping as a surrogate for invertebrates was improved significantly by subdivision of broad ecosystems into finer units. This however is possibly due to the relatively high rate of spatial turnover in invertebrate diversity, compared to vertebrates (S.Ferrier pers. comm.).

The Southern CRA region did not have comprehensive coverage of forest ecosystem mapping as in the Upper and Lower North East CRA areas. A suitable mapped forest ecosystems layer needed to be developed for use in the Southern CRA negotiations. This layer could be produced for use at a number of different classification scales, from broad to fine. This study sought to identify which level of forest ecosystem mapping was likely to be most representative of invertebrate biodiversity. The forest ecosystems mapping was not available in time for the analysis described in this report. The site based vegetation classification which was used to derive the forest ecosystems was used in the analysis. The conclusions should equaly apply to the forest ecosystem mapping.

Analysis of data from the northern CRAs indicate that fine scale forest ecosystem mapping was a better surrogate for biodiversity than broad scale. Additionally, the high spatial turnover in invertebrate species meant that invertebrate composition of units of the same forest ecosystem increased in dissimilarity with increased geographic distance well within the scale of the Northern CRA study areas. The implications are that to maximise biodiversity conservation the reserve system will need to sample each forest ecosystem across its geographic range. Another objective of this study was to establish whether the same invertebrate turnover occurs in the Southern CRA area.

Knowledge of invertebrate biodiversity in the Northern CRAs was characterised by the identification of endemic hotspots. These are localised areas that contain high numbers of species endemic to the area of interest. An initial survey of Australian Museum data revealed that invertebrate data for the Southern CRA area was scarce relative to the Northern CRA areas. Data sources were diversified to make the derivation of a GIS layer of endemic invertebrate hotspots possible. The third objective of this project therefore was to create a GIS layer of narrow range invertebrate endemism, for use in the negotiations.

2. DATA ACQUISITION

2.1 SURVEY DESIGN

In consultation with NSW NPWS the invertebrate survey was confined to a sub area of the Southern CRA Region. This sub-area covered forests identified by NPWS as of major focus in the CRA process.The sampling strategy was set at 120 sites with 5 pitfall traps at each site. As no appropriate forest ecosystems map was available to select sites, existing vegetation survey sites were used. NPWS had classified the vegetation survey sites, using the PATN (Belbin 1995) software, into a 16 class classification and a 140 class classification (a 191 class classification was later developed byNPWS and used in the analysis phase of this project). From the 16 class classification three classes of greatest interest from an NPWS perspective were selected. From within each of these 3 classes, approximately three classes were chosen from the 140 class classification. Sites were chosen on the basis that they, fell into the classifications mentioned above, were relatively accessible and were spread over a range of geographical elevations, aspects and distances of separation. Figure 1 shows the sites surveyed.

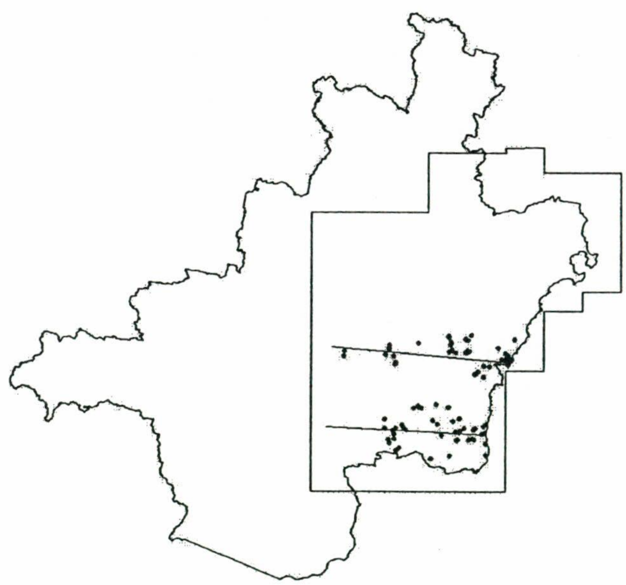


Figure 1 Southern CRA Region Showing South Coast Sub Region and Invertebrate Survey Sites

2.1.1 Target groups

Ground dwelling insects and spiders were used as target groups because they are commonly collected by passive collecting techniques (pitfall traps) and the availability of taxonomic expertise at the Australian Museum. A number of families were examined to express a broad range of functional groups. These groups and some of their familial attributes are as follows:

Carabidae

- individuals are large and easy to identify
- family is only moderately speciose and taxonomically well-known
- family contains mostly active predators or seed collectors
- many species are flightless and may be adversely affected by habitat fragmentation

Scarabaeoidea

- scarabaeoids are taxonomically well-known
- many species are associated with the carcases or dung of native herbivorous vertebrates, making them a potential surrogate of them
- their association with vertebrates makes them potentially vulnerable to habitat fragmentation
- functional groups include herbivores (Melolonthinae, Rutelinae and Aphodiinae), coprophages or necrophages (Scarabaeinae, Hybosoridae, Trogidae and Aphodiinae)
- many species are flightless and may be adversely affected by habitat fragmentation

Curculionidae

- highly speciose group that are very abundant in pitfall traps
- functional groups include xylophagous and phytophagous species
- many species are flightless and may be adversely affected by habitat fragmentation

Tenebrionidae

- highly speciose group that are very abundant in pitfall traps
- functional groups include predatory and phytophagous species
- many species are flightless and may be adversely affected by habitat fragmentation

Formicidae

- ants are highly speciose, abundant, and are known to be keystone species in ecosystem functioning

- ants have been commonly used as indicators of disturbance and environmental change
- ant species richness and abundance are known to be influenced by complexity of vegetation
- the taxonomy of ants is relatively well-known
- ants are commonly collected in pitfall traps

Araneae

- spiders are commonly collected in pitfall traps
- the taxonomy of the NSW spiders is relatively well-known
- spiders represent another class of arthropods aside from insects

2.2 SAMPLING DETAILS

Each site consisted of a 20m x 20m grid, within which 5 pitfall traps (subsamples) were positioned. The traps were arranged on the grid in a quincunx formation (one trap at each corner, with the fifth in the centre). This gives a spacing of 20m between each trap on the edges, and a separation of just over 14m between the central trap and each of the corner traps. The traps themselves consist of 1kg plastic jars (depth = 140mm, diameter = 95mm), sunk flush with the ground and 1/3 filled with Ethylene Glycol as the preservative. Traps were covered with a roof consisting of an upturned 110mm pot plant saucer with three clothes pegs attached to the lip of the saucer to act as legs. The roofs are used to prevent traps flooding during rain.

Owing to time constraints, only a single sampling session was conducted. Traps were opened over a period from the 15th of February to the 24th February 1999 and closed between the 8th of March and the 17th of March 1999. Each trap was left open for 21days.

Sites were located using a Magellan™ 2000 XL Global Positioning System (GPS). Sites were located as close as possible to the pre-selected areas described in the preceding section. Unfortunately, changes in accessibility of fire trails and logging trails in some of the State Forests meant that some sites had to be located at some distance from the pre-selected location. Access to some sites was not possible at all. Consequently, of the original 120 sites, only 110 were ultimately sampled.

At each site, a record was made of the aspect and slope. Also, a rough description of the vegetation, and estimates of the proportion of leaf litter and rockiness of substrate were made.

2.3 LABORATORY PROCESSING

Upon return from the field, samples were sieved from the ethylene glycol and transferred to sample containers of 100% ethanol (ETOH). Specimens were then progressively sorted, identified and curated to Australian Museum specifications using

the procedures developed within the Centre for Biodiversity and Conservation Research (Wilkie *et al.*, 1999).
Subsequent to taxonomic assessment, material was databased on the Taxonomic and Ecological Relational Database developed in the Centre for Biodiversity and Conservation Research. Rigorous quality control mechanisms were employed at all stages of the laboratory sorting and data collation process (Figure 2).

2.4 HOTSPOTS – DATA ACQUISITION

The Australian Museum had relatively limited pre-existing data available for the hotspots analysis. The sampling effort for the target invertebrate groups in the Southern CRA Region has been spasmodic. To overcome the shortfall, data from other agencies such as the CSIRO and Queensland Museum, were obtained to enable the production of a GIS layer for hotspots and invertebrate endemism.

Upon collation of these datasets, the extent of the data volume and coverage required the hotspots analysis to be confined to the coastal sub region.

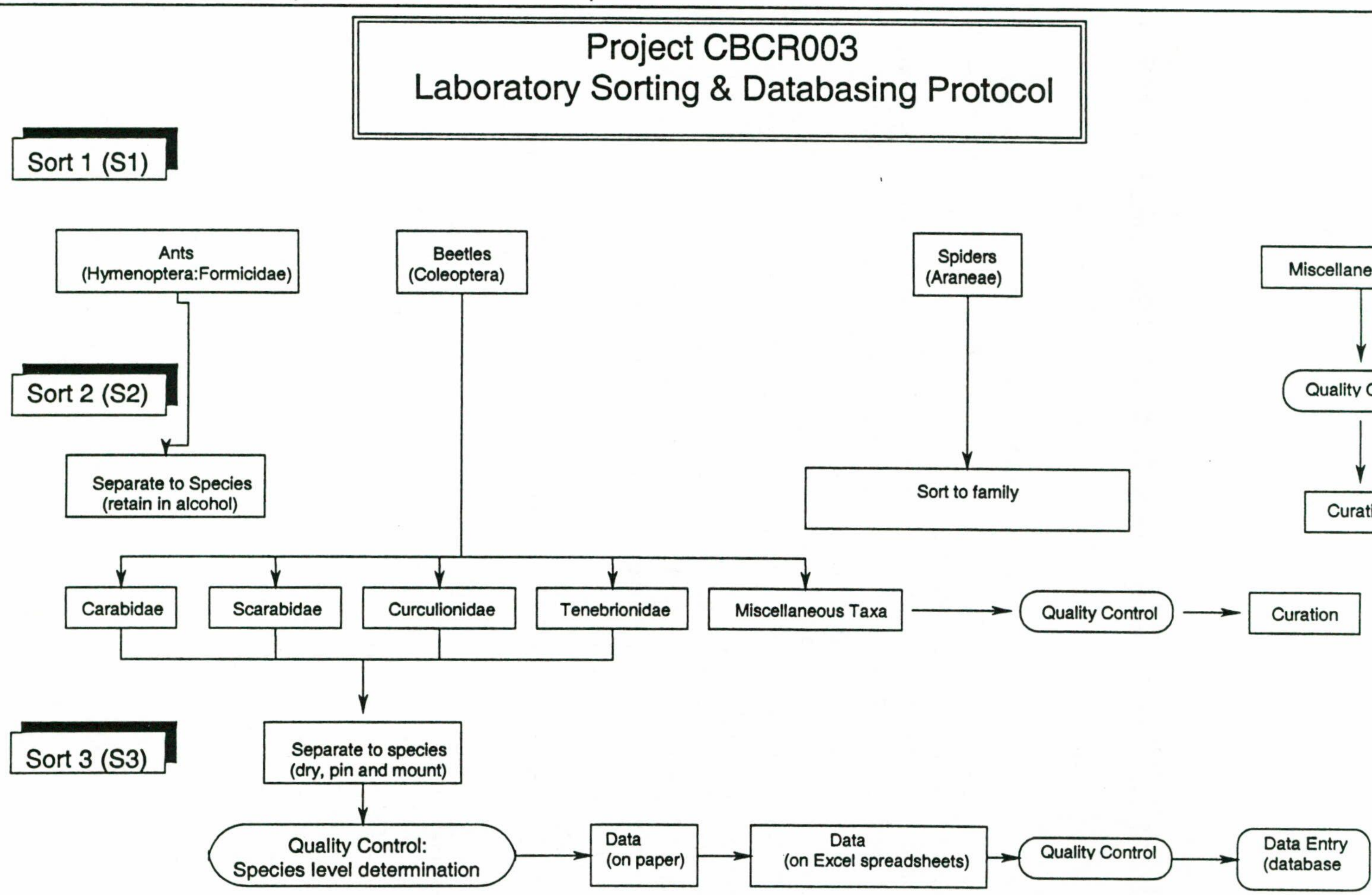


Figure 2 Laboratory Sorting and Databasing Protocol

3. ANALYTICAL PROCEDURES

3.1 SURROGATES

The species data used in the surrogate analysis were all obtained from the described pitfall trapping.

The final forest ecosystem data layer was not available for assigning classes to each pitfall sample site. Instead a PATN classification of 191 classes developed by NPWS from all available vegetation site data was used. The dendrogram from this classification was used to assign classes to sample sites. The dendrogram was split so that each sample site fell into 7 heirarchical classes (Table 2) from broad to fine scale. There were 22 of the 191 classes represented at sample sites (Table 1).

Seventy eight of the 112 sites were used in the surrogate analysis. The remaining sites were more than 200 metres from the vegetation survey sites upon which the vegetation classification was based. This was deemed too far to be confident that the pitfall traps were set in the same vegetation class present at the vegetation survey site.

The seven different levels of vegetation classification were assessed as surrogates for invertebrate diversity, using the Matrix Correlation Analysis of Surrogate Efficiency developed by Ferrier and Watson (1996).

TABLE 1 DESCRIPTION OF CLASSES OF VEGETATION SITE DATA

Class	Description
1	Coastal Escarpment and Hinterland Shrub/Fern Dry Forest - E. muelleriana
2	Coastal Hinterland (Buckenboura) Shrub/Cycad Dry Forest - Corymbia gummifera
3	Coastal Hinterland Gully Rainforest
4	Coastal Lowlands Cycad/Shrub Dry Forest - Corymbia maculata
5	Coastal Lowlands Riparian Herb/Grass Forest - various eucs
6	Eastern Deua dry shrub Forest - Angophora costata
7	Eastern Tableland and Escarpment Shrub/Fern Dry Forest - E. radiata/E. sieberi/Leucopogon lanceolatus
8	Eastern Tableland Fern/Herb/Grass Moist Forest - E. fastigata
9	Ecotonal Granite Dry Rainforest - Backhousia myrtifolia/Acmena smithii/Angophora floribunda/Pittosporum undulatum/Doodia aspera
10	Hinterland Heath Shrub Dry Forest - Corymbia gummifera/Syncarpia glomulifera
11	Northern Coastal Hinterland Moist Shrub Forest - C. maculata/E. pilularis
12	Southern Coastal Hinterland Dry Gully Rainforest - Backhousia myrtifolia
13	Southern Coastal Hinterland Shrub Dry Forest - E. sieberi
14	Southern Coastal Hinterland Shrub/Tussock Grass Dry Forest - E. sieberi
15	Southern Coastal Hinterland Shrub/Vine/Grass Moist Forest - E. cypellocarpa/E. muelleriana
16	Southern Coastal Lowlands Shrub/Grass Dry Forest - E. globoidea/E. longifolia

17	Southern Escarpment Edge Moist Shrub Forest - E. fraxinoides
18	Southern Escarpment Edge Moist Shrub/Fern Forest - E. fraxinoides/E. cypellocarpa
19	Southern Escarpment Shrub/Fern/Herb Moist Forest - E. cypellocarpa/ E. fastigata
20	Tableland Acacia Moist Herb Forest - E. pauciflora/E. dalrympleana/Acacia dealbata/Helichrysum scorpiodes
21	Tableland and Escarpment Moist Herb/Fern Grass Forest - E. radiata/E. viminalis/Viola spp
22	Tableland and Escarpment Wet Layered Shrub Forest - E. fastigata/Olearia argophylla/Dicksonia antarctica

From the pitfall data, a prescence/absence site by species data matrix was created. A dissimilarity value was then calculated for each site pair using the Bray-Curtis (Bray and Curtis 1957) measure. Additionally, a site by site dissimilarity matrix was created using the Bray Curtis measure for each vegetation classification. A Spearmans Rank Correlation Coefficient was then calculated between a vegetation classification dissimilarity matrix and that of each of the invertebrate groups. Monte Carlo resampling was then used to establish whether the coefficient is significantly greater than zero. Bootstrapping was used to calculate the confidence limits for each coefficient.

TABLE 2 LEVELS OF VEGETATION CLASSIFICATION

Level	Number of classes in sites visited	Number of classes in total PATN classification
1	3	6
2	6	43
3	9	88
4	12	120
5	16	152
6	19	162
7	22	191

3.2 TURNOVER

The technique used to assess the species turnover of invertebrates follows Ferrier *et.al.*(1999). Species turnover was assessed in relation to 29 bioclimatic environmental variables (Table 3) and geographic distance.
Site by site dissimilarity matrices (based on the Bray-Curtis dissimilarity measure (Belbin 1991)) were created for each group. Matrices were also prepared for each of the environmental variables and geographic distance. In the case of the geographic distance variable each cell of the matrix contained the geographical distance between a pair of sites. For the environmental variables it was the absolute difference between values of a given variable between a pair of sites.

Selection of an optimal model for each biological data matrix was achieved by stepwise addition and subtraction of environmental independent variables using a purpose-built routine in S-Plus (MathSoft Inc. 1999). The response variable (biological data) was regressed against each of the environmental variables (EV) to find the one that reduces the residual standard error of the model the most. If significant it is then added as a predictor. The remainder of the EVs are then sequentially examined following the same procedure. This repeats until no further addition of predictors reduces the residual standard error.

To determine the significance of each of the EVs the elements of the biological data are rearranged in random order. The difference in residual standard error between the model with that environmental variable and the model without that variable is calculated. This is repeated (eg 100) to produce a distribution of residual standard error differences. If the observed value is higher than 95% of the randomised values then it is significant at the 5% level.

TABLE 3 VARIABLES V1-V27

Variable Number	Variable Description
V1	Annual Mean Temperature
V2	Mean Diurnal Range
V3	Isothermality
V4	Temperature Seasonality
V5	Maximum Temperature of the Warmest Period
V6	Minimum Temperature of Coldest Period
V7	Annual Temperature Range
V8	Mean Temperature of Wettest Quarter
V9	Mean Temperature of Driest Quarter
V10	Mean Temperature of Warmest Quarter
V11	Mean Temperature of Coldest Quarter
V12	Annual Precipitation
V13	Precipitation of Wettest Period
V14	Precipitation of Driest Period
V15	Precipitation Seasonality
V16	Precipitation of Wettest Quarter
V17	Precipitation of Driest Quarter
V18	Precipitation of Warmest Quarter
V19	Precipitation of Coldest Quarter
V20	Annual Mean Radiation
V21	Highest Period Radiation
V22	Lowest Period Radiation
V23	Radiation Seasonality
V24	Radiation of Wettest Quarter
V25	Radiation of Driest Quarter
V26	Radiation of Warmest Quarter
V27	Radiation of Coldest Quarter
V28	Roughness Index
V29	Topographic Index

Variables V1-V27 were based on those used by the BIOCLIM (Busby,J.R. 1991)modelling package, V28 and V29 were developed by NPWS.

Initially geographic distance was ignored as a predictor when developing the model. It was then added as a predictor to each of the regression models to evaluate how much additional variation in biological dissimilarity it could explain, after controlling for environmental differences between sites.

3.3 HOTSPOTS

The volume and distribution of data for the Southern CRA area was patchy and limited (Figure 3f). Consequently, it was necessary to confine the hotspots analysis to the Coastal Subregion where the pitfall data were collected.

All available data were collated together into two datasets :-
Prescence/absence dataset - 3961 records of 774 species collected through pitfall (Figure 3e) trapping from the SCRA invertebrate survey
Prescence only dataset - 3956 records of 306 species. This dataset was created by accepting only those species with 5 or more records from the following data sources:-

2200 records of 89 beetle species (Figure 3a) and 602 records of 101 ant species (Figure 3b) data from CSIRO
294 snail records of 60 snail species from Queensland Museum (Figure 3d),
1142 records of 118 snail species from the Australian Museum's collections(Figure 3c)
1564 records of 509 various insect species from the Australian Museum,
1705 records from the pitfall dataset - 133 species were also in the prescence only data.

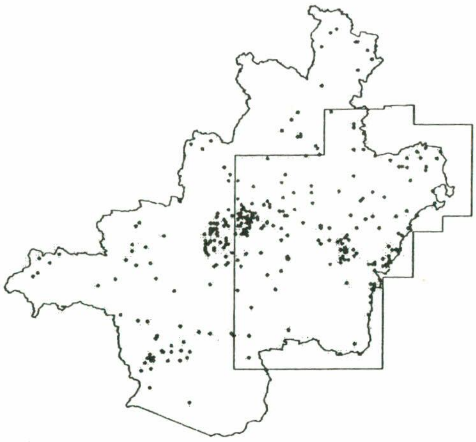
These datasets were sent to Dr David Stockwell of the San Diego Super Computer Centre for modelling. Dr Stockwell used two different modelling techniques, Genetic Algorithm for Ruleset Production (GARP) (Payne and Stockwell 1999) and Generalised Linear Modelling (GLM) which has been used extensively for species modelling (Austin et al 1990, Nicholls 1991).

Both GARP and GLM predict the potential distributions of species from raster based environmental data and biological data. For each species GARP uses randomised rule production to create a large number of prediction rules, from which the best fit set of rules are used for making the model. GLM uses stepwise selection of combinations of environmental variables to derive the best fit from which it creates the species model

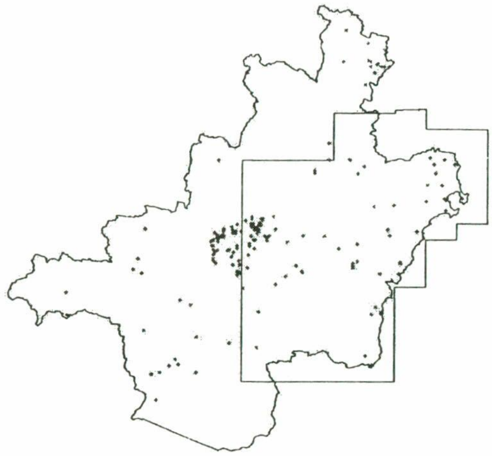
Each of these modelling techniques were applied in the following ways:-
GARP using the prescence absence dataset (Figure 8c)
GARP using the prescence only dataset and pseudo abscences (Figure 8e)
GARP using prescence only data (Figure 8a)
GLM using the logit link on prescence/absence dataset (Figure 8d)
GLM using the logit link on the prescence only and pseudo abscences dataset (Figure 9)
GLM using the logit link on the prescence only dataset (Figure 8b)

Endemism layers were produced separately using each of the modelling techniques. Each endemism layer is the average (predicted.i*end.i) for each species.i where end equals one minus the proportion of the study area covered by the model (ie the modelled range).

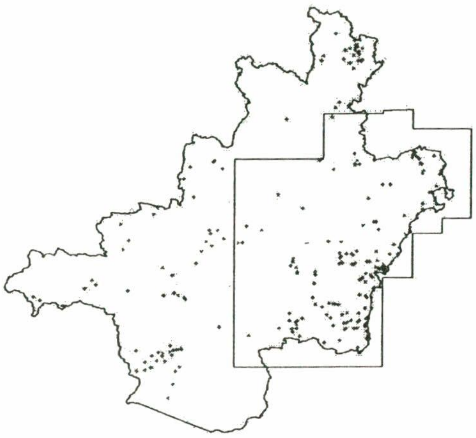
These endemism layers were then normalised and multiplied to produce the final narrow range invertebrate endemism hotspot layer.



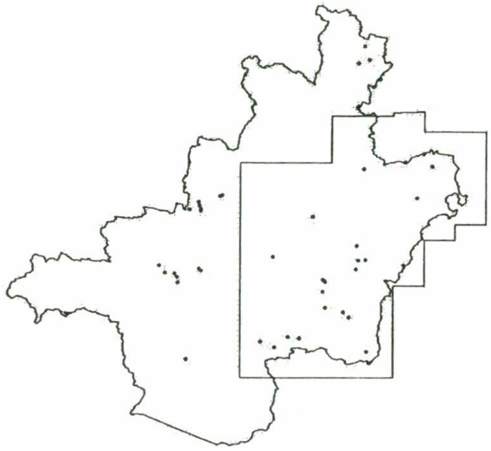
a. Coleoptera - CSIRO and Australian Museum



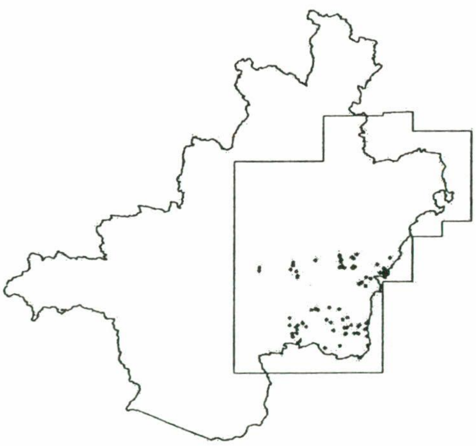
b. Formicidae – CSIRO and Australian Museum



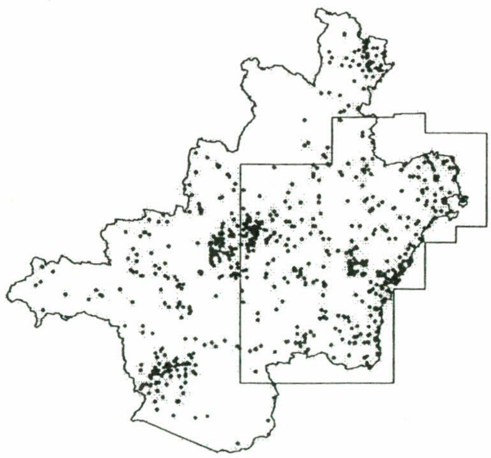
c. Australian Museum snails



d. Queensland Museum snails



e. SCRA Pitfall data (beetles, ants and spiders)



f. All data collated for SCRA

Figure 3 Distribution of specimen record locations for each of the datasets obtained

4. RESULTS AND DISCUSSION

4.1 SURVEY RESULTS

Table 4 gives a brief summary of the diversity of the fauna collected from the invertebrates survey and of data acquired from other sources used in this analysis.

Appendix 1 gives a listing of all the species collected during the SCRA invertebrates survey.

TABLE 4 FAUNA COLLECTED FROM THE INVERTEBRATES SURVEY AND OF DATA ACQUIRED FROM OTHER SOURCES

Group (Order)	No. of Families	No. of Genera	No. of Species	No. of Prescence/Absence Records	No. of Prescence Only Records
Spiders (Araneae)	34	32[NB]	88	954[&]	705[*]
Beetles (Coleoptera)	41	56	144	1455[&]	1649[*]
Ants (Hymenoptera)	1	51	170	1552[&]	246[*]
Flies (Diptera)	3	6	12	-	88[#]
Butterflies and Moths (Lepidoptera)	1	2	2	-	13[#]
Scorpion Flies (Mecoptera)	1	1	1	-	11[#]
Dobson Flies (Megaloptera)	1	1	1	-	7[#]
Lacewings (Neuroptera)	6	9	9	-	60[#]
Snails (Orthurethra)	1	2	2	-	19[#]
Stone Flies (Plecoptera)	3	6	10	-	65[#]
Book lice (Psocoptera)	6	11	13	-	111[#]
Snails (Sigmurethra)	7	26	47	-	982[#]
Total	77	139	402	3961	3956

[&] Records obtained from the SCRA invertebrates survey
[*] Contain some records from SCRA invertebrates survey
[#] Records obtained from other sources - ie Queensland Museum, CSIRO, Australian Museum' speciem collection
[NB] A number of species were not named at the genus level, thus the apparent disparity in this figure

4.2 SURROGACY

Spearmans Correlation Coefficient values (Table 5) obtained for each of the heirarchical vegetation classifications show similar patterns for each of the taxonomic groups. In the case of spiders and beetles (Figure 6 and Figure 7) the surrogate efficiency (as described by Spearmans Correlation Coefficient) increases significantly between the very broad (3 class) vegetation classification and the finer 6 class category. It then levels off for the 9,12,16,19 class surrogates before dropping off sharply at the 22 class category to a level similar to the 3 class surrogate. For ant diversity (Figure 5) and the three groups combined (Figure 4) the pattern begins the same but drops off in steps from the 9 class to the 12 and 16 and then down to the 19 and 22 class surrogates. The value for the 19 class surrogate for beetles appears to be an anomaly.

TABLE 5 SPEARMANS CORRELATION COEFFICIENTS

Number of Vegetation Classes	Alltaxa	Ants	Beetles	Spiders
3 (6)	0.1613	0.1318	0.1150	0.0849
6 (43)	0.4105	0.3513	0.2318	0.1398
9 (88)	0.3937	0.3394	0.2227	0.1369
12 (120)	0.3204	0.2416	0.2346	0.1444
15 (152)	0.3211	0.2349	0.2224	0.1339
19 (162)	0.2376	0.1426	0.1049	0.1401
21 (191)	0.2047	0.1390	0.1712	0.0983

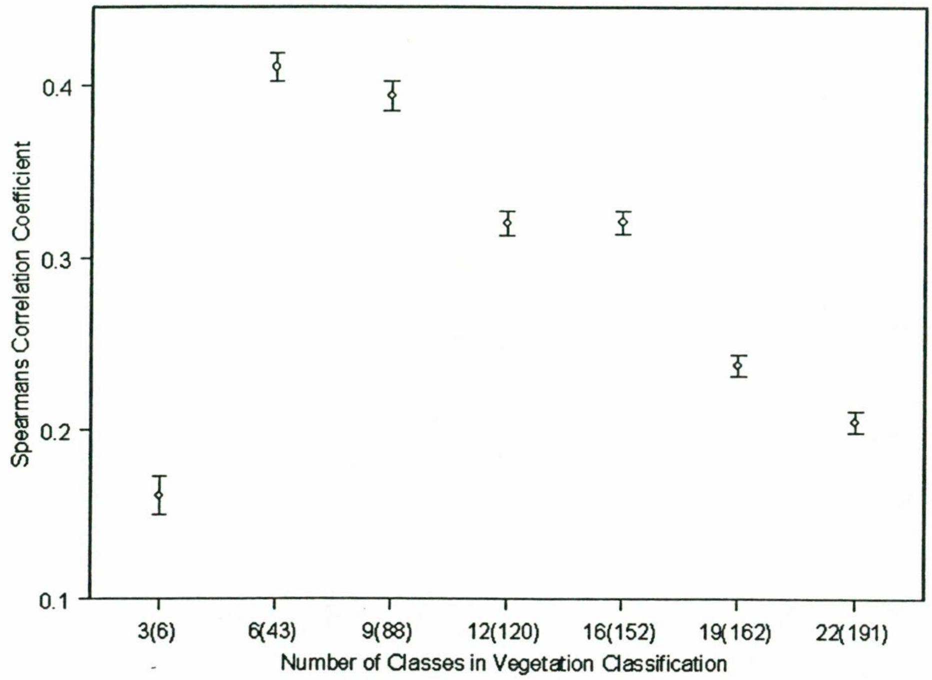


Figure 4 Comparison of hierachical vegetation classification as surrogates for diversity of ants, beetles and spiders.

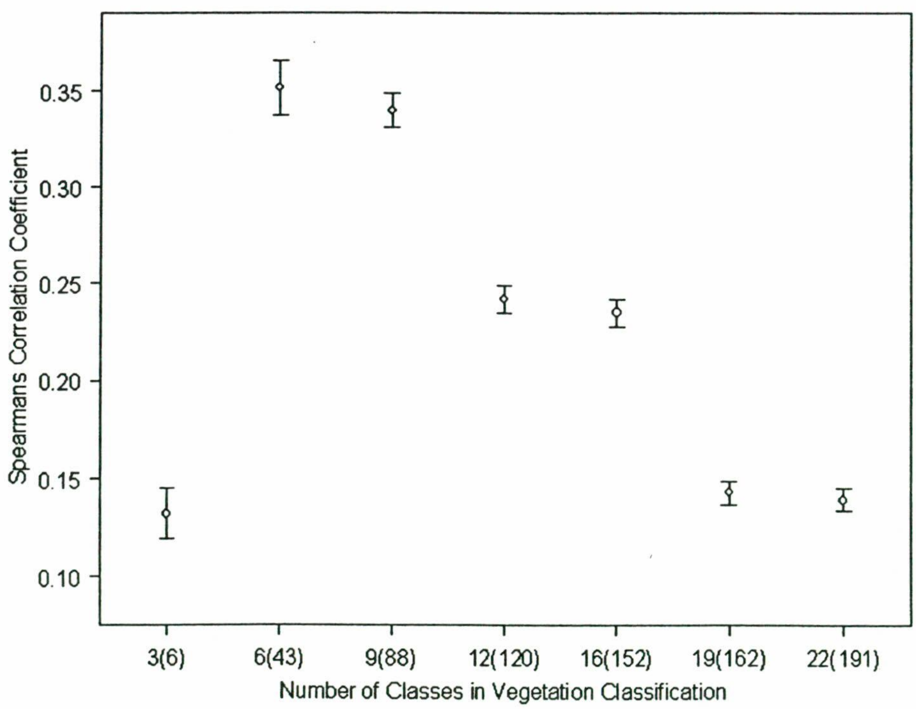


Figure 5 Comparison of hierarchical vegetation classification as surrogates for ant diversity.

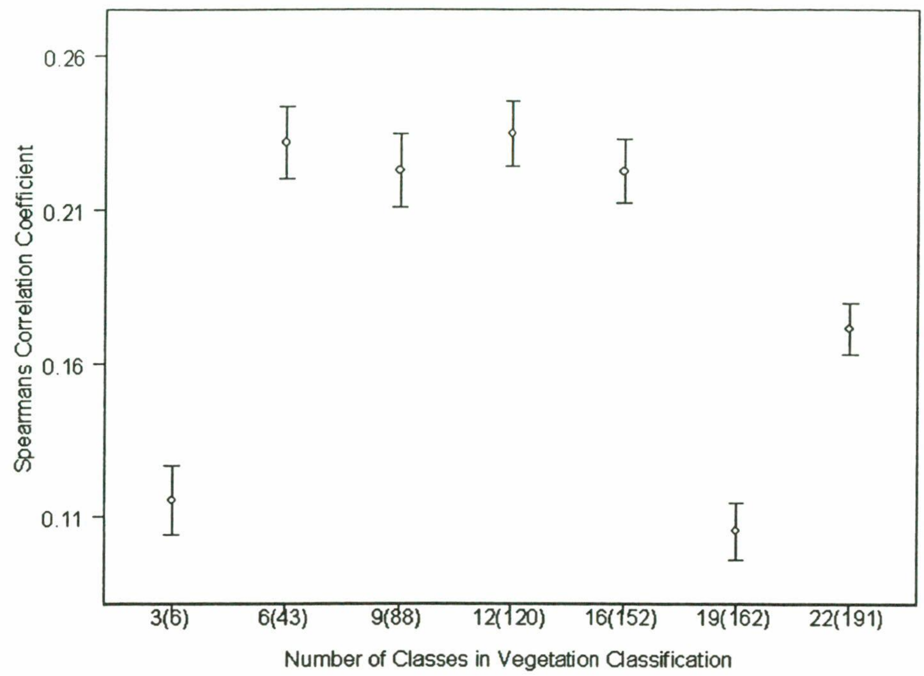


Figure 6 Comparison of hierarchical vegetation classification as surrogates for beetle diversity.

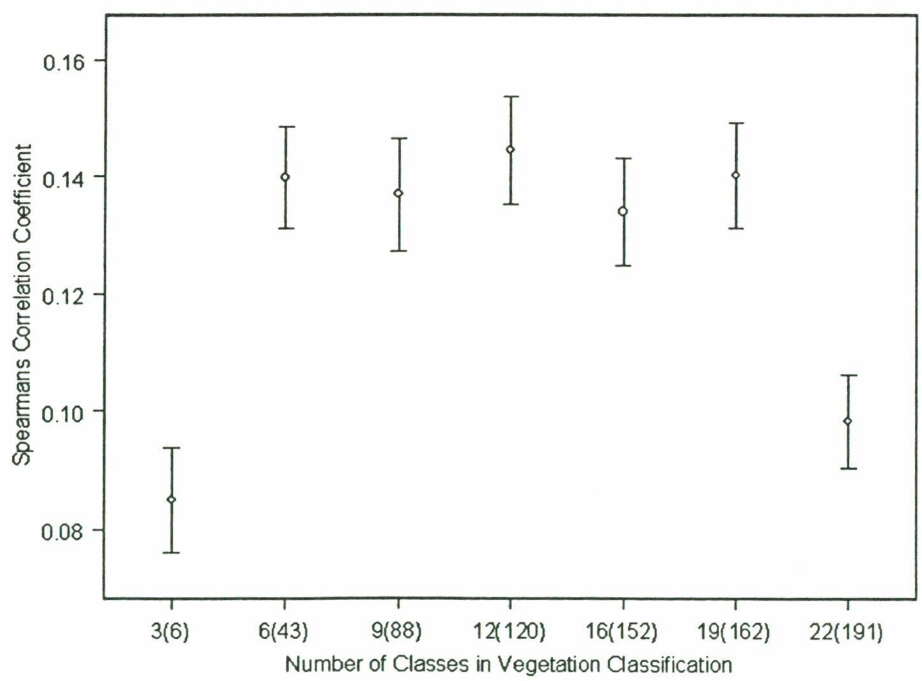


Figure 7 Comparison of hierarchical vegetation classification as surrogates for spider diversity.

These results contradict what might be expected for invertebrates, which have been shown to have a relatively high species turnover geographically (Ferrier et al 1999). More finely mapped vegetation surrogates might be expected to be better correlates than the broad scale ones. Two possible explanations for the results obtained here are:-

1. increasing the detail of vegetation mapping beyond a relatively broad categorisation does not improve the performance of site based vegetation classifications as a surrogate for invertebrate biodiversity - specifically spiders, beetles and ants.
2. the Matrix Correlation Analysis technique (Ferrier and Watson 1996) is not suitable for comparing heirarchically related surrogates.

It may be that the study area was too restricted; if the pitfall sites had been spread over the entire study area the finer classifications may have been better surrogates. Some support for this idea can be found in the results for the turnover analysis (4.3) where geographic distance was only found to be significant in the distributions of the beetles, and not the spiders or ants.

The variation in disturbance, understory vegetation and moisture within each of the broad vegetation classes may have been almost as great as between classes. This would greatly reduce the true difference between vegetation classes, in terms of factors that might influence invertebrate habitat, at the finer scales.

More work needs to be done on determining suitable techniques for comparing the performance of heirarchically related biodiversity surrogates. The second of the above possibilities could be tested using synthetic data.

4.2.1 Significance for Southern CRA

The surrogate evaluation produced an ambiguous result suggesting that current surrogacy techniques are inadequate for analysing the effectiveness of hierarchically related surrogates.
It is not possible to recommend a scale of forest ecosystem classification most suitable as a surrogate for invertebrate biodiversity.

4.3 TURNOVER

Turnover analysis was not included in the original project objectives, nor was it taken into account when designing the field survey. The results obtained reflect this, for the relatively small area sampled, geographic distance was a significant factor (at the 95% confidence level) only for beetles, not spiders or ants. This contrasts with the results for the Northern CRA areas where geographic distance was a significant factor in the distribution of all of these groups. This difference is possibly due to the smaller area over which the survey sites were distributed for the SCRA, 7654 km2 (109 km between the most separated sites), as opposed to 68552 km2 (491 km between the most separated sites) for the NCRAs. This **may** indicate that the threshold at which geographic distance affects species turnover for spiders and ants is approached by the scale of the SCRA invertebrates survey.

4.3.1 Significance for Southern CRA

Geographic distance is a significant factor in the species turnover of beetles within the Southern CRA region. For spiders and ants, geographic distance was not significant in species turnover.
Sampling across the geographic range of each forest ecosystem will increase the level of biodiversity conservation.

4.4 HOTSPOTS

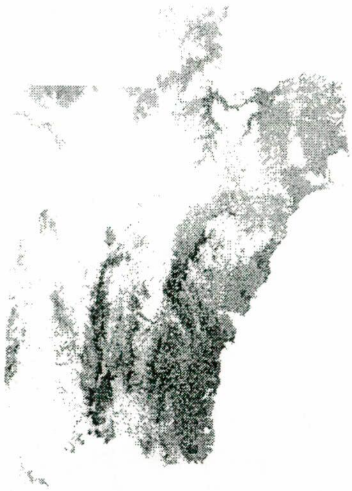
Six narrow range endemism (NRE) hotspot layers (Figures 8a-f,9) were produced using the six different modelling techniques described in section 3.3. In assessing which layer to submit as best representing invertebrate endemism in the South Coast Sub Region, three criteria were considered by taxonomic experts at the Museum:-

- the individual species models used to create each of the endemism layers - ie individual species models needed to be considered sensible in terms of their predicted distributions
- the relationship between the location of the data points and the distribution of the endemism hotspots - ie reject endemism hotspots in areas of poor data coverage
- comparison of endemism layer with experts knowledge and understanding of patterns of biodiversity and endemism distribution in the region.

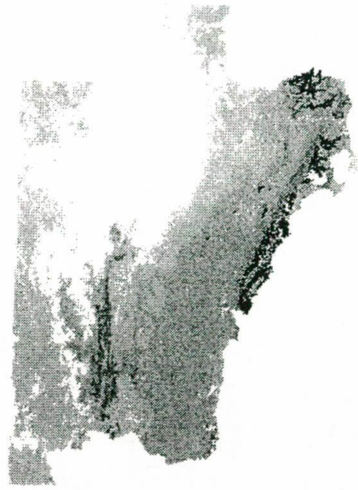
Having applied the above criteria to the six modelled endemism layers, two stood out as being superior to the others, Logit Endemism (Figure 8a) and Pb_Logit Endemism (Figure 9). Pb_Logit Endemism (see Appendix 2 for metadata) was preferred to Logit Endemism as the final Narrow Range Endemism Layer for submission to the project as its areas of endemism were more discretely defined.

4.4.1 Significance for Southern CRA

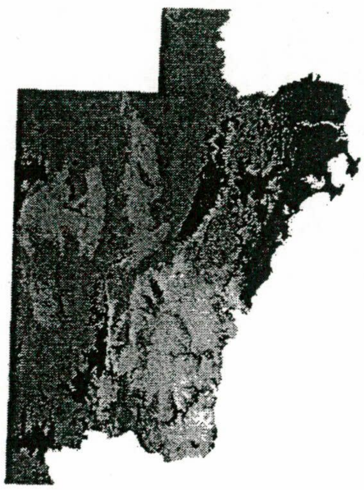
A GIS layer (Figure 9) identifying areas of narrow range invertebrate endemism for inclusion in Regional Forestry Agreement negotiations.



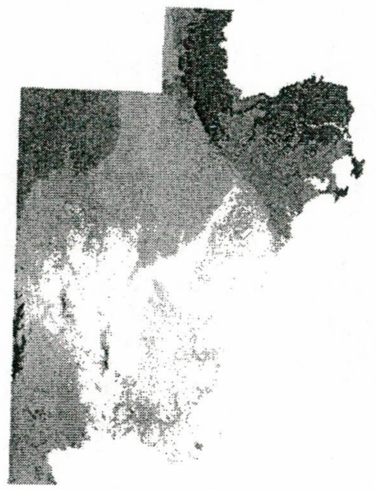
a. Garp endemism



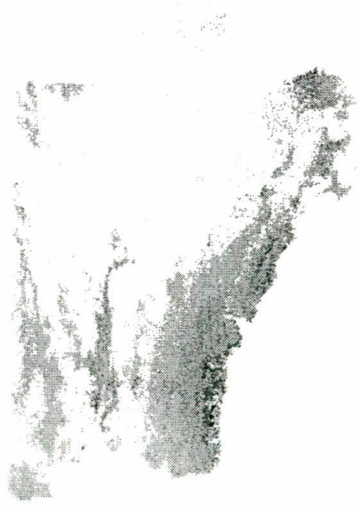
b. Logit endemism



c. Presence/absence Garp



d. Presence/absence Logit



e. Pb_Garp endemism

Figure 8 Images of the different Endemism layers produced for this project

Figure 9 Pb_Logit endemism GIS layer as submitted to the SCRA negotiations

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6. APPENDIX 1

Species No.	Order	Family	Genus	Species
1	Araneae	Amaurobiidae		cbcr3-001
2	Araneae	Amaurobiidae		cbcr3-002
3	Araneae	Amaurobiidae		cbcr3-003
4	Araneae	Amaurobiidae		cbcr3-004
5	Araneae	Amaurobiidae		cbcr3-005
6	Araneae	Amaurobiidae		cbcr3-006
7	Araneae	Amaurobiidae		cbcr3-007
8	Araneae	Amaurobiidae		cbcr3-008
9	Araneae	Amaurobiidae		cbcr3-009
10	Araneae	Amaurobiidae		cbcr3-010
11	Araneae	Amaurobiidae		cbcr3-011
12	Araneae	Amaurobiidae		cbcr3-012
13	Araneae	Amaurobiidae		cbcr3-013
14	Araneae	Amaurobiidae		cbcr3-014
15	Araneae	Amaurobiidae		cbcr3-015
16	Araneae	Amaurobiidae	Storenosoma	cbcr3-001
17	Araneae	Amaurobiidae	Storenosoma	cbcr3-002
18	Araneae	Amaurobiidae	Storenosoma	cbcr3-003
19	Araneae	Anapidae		cbcr3-001
20	Araneae	Anapidae		cbcr3-002
21	Araneae	Anapidae		cbcr3-003
22	Araneae	Anapidae		cbcr3-004
23	Araneae	Araneidae	Araneus	cbcr3-001
24	Araneae	Araneidae	Araneus	cbcr3-002
25	Araneae	Archaeidae	Austrarchaea	hickmani
26	Araneae	Clubionidae	Clubiona	cbcr3-001
27	Araneae	Clubionidae	Clubiona	cbcr3-002
28	Araneae	Clubionidae	Clubiona	cbcr3-003
29	Araneae	Corinnidae		cbcr3-003
30	Araneae	Corinnidae		cbcr3-004
31	Araneae	Corinnidae		cbcr3-005
32	Araneae	Corinnidae		cbcr3-006
33	Araneae	Corinnidae		cbcr3-007
34	Araneae	Corinnidae		cbcr3-008
35	Araneae	Corinnidae		cbcr3-009
36	Araneae	Corinnidae	Supunna	cbcr3-001
37	Araneae	Corinnidae	Supunna	cbcr3-002
38	Araneae	Cyatholipidae	Matilda	cbcr3-001
39	Araneae	Cycloctenidae	Cycloctenus	cbcr3-001
40	Araneae	Desidae	Toxopsoides	cbcr3-001
41	Araneae	Desidae	Toxopsoides	cbcr3-002
42	Araneae	Gnaphosidae	Asadipus	cbcr3-001

43	Araneae	Gnaphosidae	Asadipus	cbcr3-002
44	Araneae	Gnaphosidae	Asadipus	cbcr3-003
45	Araneae	Gnaphosidae	Asadipus	cbcr3-004
46	Araneae	Gnaphosidae	Asadipus	cbcr3-005
47	Araneae	Gnaphosidae		cbcr3-1
48	Araneae	Gnaphosidae		cbcr3-10
49	Araneae	Gnaphosidae		cbcr3-11
50	Araneae	Gnaphosidae		cbcr3-12
51	Araneae	Gnaphosidae		cbcr3-13
52	Araneae	Gnaphosidae		cbcr3-14
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54	Araneae	Gnaphosidae		cbcr3-16
55	Araneae	Gnaphosidae		cbcr3-18
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60	Araneae	Gnaphosidae		cbcr3-27
61	Araneae	Gnaphosidae		cbcr3-28
62	Araneae	Gnaphosidae		cbcr3-29
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64	Araneae	Gnaphosidae		cbcr3-30
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68	Araneae	Gnaphosidae		cbcr3-7
69	Araneae	Gnaphosidae		cbcr3-8
70	Araneae	Gnaphosidae		cbcr3-9
71	Araneae	Gnaphosidae	Hemicloea	cbcr3-001
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75	Araneae	Hahniidae		cbcr3-004
76	Araneae	Hexathelidae	Atrax	cbcr3-001
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78	Araneae	Hexathelidae	Atrax	cbcr3-003
79	Araneae	Hexathelidae	Parembolides	cbcr3-001
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84	Araneae	Linyphiidae		cbcr3-10
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86	Araneae	Linyphiidae		cbcr3-12
87	Araneae	Linyphiidae		cbcr3-13
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89	Araneae	Linyphiidae		cbcr3-9
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91	Araneae	Linyphiidae		cbcr3-15
92	Araneae	Linyphiidae		cbcr3-16
93	Araneae	Linyphiidae		cbcr3-17
94	Araneae	Linyphiidae		cbcr3-2
95	Araneae	Linyphiidae		cbcr3-3

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100	Araneae	Lycosidae		cbcr3-21
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102	Araneae	Lycosidae		cbcr3-4
103	Araneae	Lycosidae		cbcr3-5
104	Araneae	Lycosidae		cbcr3-6
105	Araneae	Lycosidae		cbcr3-8
106	Araneae	Lycosidae	Lycosa	lapidosa
107	Araneae	Malkaridae	Malkara	cbcr3-001
108	Araneae	Micropholcommatidae	Micropholcomma	cbcr3-001
109	Araneae	Micropholcommatidae	Micropholcomma	cbcr3-002
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115	Araneae	Mysmenidae		cbcr3-001
116	Araneae	Mysmenidae		cbcr3-002
117	Araneae	Mysmenidae		cbcr3-003
118	Araneae	Nemesiidae	Stanwellia	cbcr3-001
119	Araneae	Nicodamidae		cbcr3-001
120	Araneae	Nicodamidae		cbcr3-002
121	Araneae	Oonopidae		cbcr3-001
122	Araneae	Oonopidae		cbcr3-002
123	Araneae	Orsolobidae	Tasmanoonops	cbcr3-001
124	Araneae	Orsolobidae	Tasmanoonops	cbcr3-002
125	Araneae	Orsolobidae	Tasmanoonops	cbcr3-003
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151	Araneae	Salticidae		cbcr3-16
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153	Araneae	Salticidae		cbcr3-18
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159	Araneae	Tetrablemmidae	Tetrablemma	cbcr3-001
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161	Araneae	Theridiidae	Episinus	cbcr3-001
162	Araneae	Theridiidae	Euryopis	cbcr3-001
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167	Araneae	Theridiidae		cbcr3-003
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173	Araneae	Thomisidae	Tharpyna	cbcr3-001
174	Araneae	Zodariidae		cbcr3-001
175	Araneae	Zodariidae		cbcr3-002
176	Araneae	Zodariidae		cbcr3-003
177	Araneae	Zodariidae		cbcr3-004
178	Araneae	Zodariidae		cbcr3-005
179	Araneae	Zodariidae		cbcr3-006
180	Araneae	Zodariidae		cbcr3-007
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185	Araneae	Zodariidae		cbcr3-012
186	Araneae	Zodariidae		cbcr3-013
187	Araneae	Zodariidae		cbcr3-014
188	Araneae	Zodariidae		cbcr3-015
189	Araneae	Zoridae		cbcr3-001
190	Araneae	Zoridae		cbcr3-002
191	Araneae	Zoridae		cbcr3-003
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193	Araneae	Zoridae		cbcr3-005
194	Araneae	Zoridae		cbcr3-006
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198	Coleoptera	Aderidae		cbcr3-4
199	Coleoptera	Aderidae		cbcr3-5
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202	Coleoptera	Anobiidae		cbcr3-2
203	Coleoptera	Anobiidae		cbcr3-3
204	Coleoptera	Anobiidae		cbcr3-4
205	Coleoptera	Anobiidae		cbcr3-5
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207	Coleoptera	Anthicidae		cbcr3-2
208	Coleoptera	Anthicidae		cbcr3-3
209	Coleoptera	Anthicidae		cbcr3-4
210	Coleoptera	Anthicidae		cbcr3-5
211	Coleoptera	Anthicidae		cbcr3-6
212	Coleoptera	Anthicidae		cbcr3-7
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214	Coleoptera	Anthribidae		cbcr3-2
215	Coleoptera	Anthribidae		cbcr3-3
216	Coleoptera	Archeocrypticidae		cbcr3-1
217	Coleoptera	Cantharidae		cbcr3-1
218	Coleoptera	Cantharidae		cbcr3-2
219	Coleoptera	Carabidae		cbcr3-1
220	Coleoptera	Carabidae		cbcr3-2
221	Coleoptera	Carabidae		cbcr3-3
222	Coleoptera	Carabidae		cbcr3-4
223	Coleoptera	Carabidae		cbcr3-5
224	Coleoptera	Carabidae		cbcr3-6
225	Coleoptera	Carabidae		cbcr3-7
226	Coleoptera	Carabidae		cbcr3-8
227	Coleoptera	Carabidae		cbcr3-9
228	Coleoptera	Carabidae		cbcr3-1
229	Coleoptera	Carabidae		cbcr3-2
230	Coleoptera	Carabidae	Sarothrocrepis	cbcr3-1
231	Coleoptera	Carabidae	Carenum	bonelli
232	Coleoptera	Carabidae	Eurylynchus	dyschirioides
233	Coleoptera	Carabidae	Eurylynchus	blagravei
234	Coleoptera	Carabidae	Eurylychnus	cbcr3-1
235	Coleoptera	Carabidae	Helluo	costatus
236	Coleoptera	Carabidae	Lacordairia	cbcr3-1
237	Coleoptera	Carabidae	Notonomus	variicollis
238	Coleoptera	Carabidae	Notonomus	resplendens
239	Coleoptera	Carabidae	Notonomus	cbcr3-1
240	Coleoptera	Carabidae	Notonomus	cbcr3-2
241	Coleoptera	Carabidae	Notonomus	cbcr3-3
242	Coleoptera	Carabidae	Notonomus	cbcr3-4
243	Coleoptera	Carabidae	Notonomus	cbcr3-5
244	Coleoptera	Carabidae	Notonomus	rainbowi
245	Coleoptera	Carabidae	Notonomus	cbcr3-6
246	Coleoptera	Carabidae	Philophloeus	cbcr3-1
247	Coleoptera	Carabidae	Philophloeus	cbcr3-2
248	Coleoptera	Carabidae	Promechoderus	cbcr3-1
249	Coleoptera	Carabidae	Prosopogmus	cbcr3-1
250	Coleoptera	Carabidae	Prosopogmus	cbcr3-2
251	Coleoptera	Carabidae	Siagonyx	blackburni
252	Coleoptera	Cerambycidae	Ancita	cbcr3-1
253	Coleoptera	Cerambycidae	Anthemistus	cbcr3-1
254	Coleoptera	Cerambycidae	Anthemistus	cbcr3-2

255	Coleoptera	Cerambycidae	Anthemistus	cbcr3-3
256	Coleoptera	Chrysomelidae	Paropsisterna	cbcr3-1
257	Coleoptera	Chrysomelidae	Trachymela	cbcr3-1
258	Coleoptera	Chrysomelidae	Coenobius	cbcr3-1
259	Coleoptera	Chrysomelidae	Eboo	cbcr3-1
260	Coleoptera	Chrysomelidae	Candezea	cbcr3-1
261	Coleoptera	Chrysomelidae	Longitarsus	victoriensis
262	Coleoptera	Chrysomelidae	Trachyaphthona	cbcr3-1
263	Coleoptera	Chrysomelidae	Cassida	cbcr3-1
264	Coleoptera	Ciidae		cbcr3-1
265	Coleoptera	Ciidae		cbcr3-2
266	Coleoptera	Ciidae		cbcr3-3
267	Coleoptera	Ciidae		cbcr3-4
268	Coleoptera	Clambidae		cbcr3-1
269	Coleoptera	Coccinellidae		cbcr3-1
270	Coleoptera	Coccinellidae		cbcr3-2
271	Coleoptera	Coccinellidae		cbcr3-3
272	Coleoptera	Coccinellidae		cbcr3-4
273	Coleoptera	Coccinellidae		cbcr3-5
274	Coleoptera	Colydiidae	Ciconissus	cbcr3-1
275	Coleoptera	Colydiidae		cbcr3-1
276	Coleoptera	Colydiidae	Epistranus	cbcr3-1
277	Coleoptera	Colydiidae	Epistranus	cbcr3-2
278	Coleoptera	Colydiidae	Faecula	cristata
279	Coleoptera	Corylophidae		cbcr3-2
280	Coleoptera	Corylophidae		cbcr3-3
281	Coleoptera	Corylophidae		cbcr3-4
282	Coleoptera	Corylophidae		cbcr3-5
283	Coleoptera	Corylophidae		cbcr3-6
284	Coleoptera	Corylophidae		cbcr3-7
285	Coleoptera	Corylophidae		cbcr3-8
286	Coleoptera	Corylophidae		cbcr3-9
287	Coleoptera	Corylophidae		cbcr3-10
288	Coleoptera	Corylophidae		cbcr3-11
289	Coleoptera	Corylophidae		cbcr3-12
290	Coleoptera	Corylophidae		cbcr3-13
291	Coleoptera	Corylophidae		cbcr3-14
292	Coleoptera	Corylophidae		cbcr3-15
293	Coleoptera	Corylophidae		cbcr3-16
294	Coleoptera	Corylophidae		cbcr3-17
295	Coleoptera	Curculionidae		cbcr3-1
296	Coleoptera	Curculionidae		cbcr3-2
297	Coleoptera	Curculionidae		cbcr3-3
298	Coleoptera	Curculionidae		cbcr3-4
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300	Coleoptera	Curculionidae		cbcr3-6
301	Coleoptera	Curculionidae		cbcr3-7
302	Coleoptera	Curculionidae		cbcr3-8
303	Coleoptera	Curculionidae		cbcr3-9
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305	Coleoptera	Curculionidae		cbcr3-11
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307	Coleoptera	Curculionidae		cbcr3-13

308	Coleoptera	Curculionidae		cbcr3-14
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331	Coleoptera	Curculionidae		cbcr3-37
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333	Coleoptera	Curculionidae		cbcr3-2
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374	Coleoptera	Curculionidae		cbcr3-43
375	Coleoptera	Curculionidae		cbcr3-44
376	Coleoptera	Curculionidae		cbcr3-45
377	Coleoptera	Curculionidae		cbcr3-46
378	Coleoptera	Curculionidae		cbcr3-47
379	Coleoptera	Curculionidae		cbcr3-48
380	Coleoptera	Curculionidae		cbcr3-49
381	Coleoptera	Curculionidae		cbcr3-50
382	Coleoptera	Curculionidae	Xyleborus	cbcr3-1
383	Coleoptera	Endomychidae		cbcr3-1
384	Coleoptera	Endomychidae		cbcr3-1
385	Coleoptera	Eucinetidae		cbcr3-1
386	Coleoptera	Eucinetidae		cbcr3-2
387	Coleoptera	Geotrupidae	Bolborhachium	lacunosum
388	Coleoptera	Hobartiidae		cbcr3-1
389	Coleoptera	Hydraenidae		cbcr3-1
390	Coleoptera	Hydraenidae		cbcr3-2
391	Coleoptera	Hydraenidae		cbcr3-3
392	Coleoptera	Hydrophilidae		cbcr3-1
393	Coleoptera	Hydrophilidae		cbcr3-2
394	Coleoptera	Hydrophilidae		cbcr3-3
395	Coleoptera	Hydrophilidae		cbcr3-4
396	Coleoptera	Hydrophilidae		cbcr3-5
397	Coleoptera	Latridiidae		cbcr3-1
398	Coleoptera	Latridiidae		cbcr3-2
399	Coleoptera	Latridiidae		cbcr3-3
400	Coleoptera	Latridiidae		cbcr3-1
401	Coleoptera	Latridiidae		cbcr3-2
402	Coleoptera	Latridiidae		cbcr3-3
403	Coleoptera	Leiodidae		cbcr3-1
404	Coleoptera	Leiodidae		cbcr3-1
405	Coleoptera	Leiodidae		cbcr3-2
406	Coleoptera	Leiodidae		cbcr3-3
407	Coleoptera	Leiodidae		cbcr3-4
408	Coleoptera	Leiodidae		cbcr3-5
409	Coleoptera	Leiodidae		cbcr3-6
410	Coleoptera	Leiodidae		cbcr3-7
411	Coleoptera	Leiodidae		cbcr3-8
412	Coleoptera	Leiodidae	Colon	cbcr3-1
413	Coleoptera	Leiodidae		cbcr3-1

414	Coleoptera	Leiodidae		cbcr3-2
415	Coleoptera	Leiodidae		cbcr3-3
416	Coleoptera	Lucanidae	Rhyssonotus	jugularis
417	Coleoptera	Lucanidae	Lissapterus	cbcr3-1
418	Coleoptera	Melyridae		cbcr3-1
419	Coleoptera	Mordellidae		cbcr3-1
420	Coleoptera	Mordellidae		cbcr3-2
421	Coleoptera	Mordellidae		cbcr3-3
422	Coleoptera	Mycetophagidae		cbcr3-1
423	Coleoptera	Nitidulidae		cbcr3-1
424	Coleoptera	Nitidulidae		cbcr3-2
425	Coleoptera	Nitidulidae		cbcr3-3
426	Coleoptera	Nitidulidae		cbcr3-4
427	Coleoptera	Nitidulidae		cbcr3-5
428	Coleoptera	Nitidulidae		cbcr3-6
429	Coleoptera	Nitidulidae		cbcr3-7
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435	Coleoptera	Nitidulidae		cbcr3-13
436	Coleoptera	Nitidulidae		cbcr3-14
437	Coleoptera	Nitidulidae		cbcr3-15
438	Coleoptera	Oedemeridae		cbcr3-1
439	Coleoptera	Phalacridae		cbcr3-1
440	Coleoptera	Phalacridae		cbcr3-2
441	Coleoptera	Ptiliidae		cbcr3-1
442	Coleoptera	Ptiliidae		cbcr3-2
443	Coleoptera	Ptiliidae		cbcr3-3
444	Coleoptera	Ptiliidae		cbcr3-4
445	Coleoptera	Ptiliidae		cbcr3-5
446	Coleoptera	Rhyzophagidae		cbcr3-1
447	Coleoptera	Scarabaeidae		cbcr3-1
448	Coleoptera	Scarabaeidae		cbcr3-1
449	Coleoptera	Scarabaeidae		cbcr3-2
450	Coleoptera	Scarabaeidae	Automolius	cbcr3-1
451	Coleoptera	Scarabaeidae		cbcr3-1
452	Coleoptera	Scarabaeidae		cbcr3-2
453	Coleoptera	Scarabaeidae		cbcr3-3
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455	Coleoptera	Scarabaeidae		cbcr3-5
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458	Coleoptera	Scarabaeidae		cbcr3-8
459	Coleoptera	Scarabaeidae		cbcr3-9
460	Coleoptera	Scarabaeidae		cbcr3-10
461	Coleoptera	Scarabaeidae	Amphistomus	speculifer
462	Coleoptera	Scarabaeidae	Aulacopris	reichei
463	Coleoptera	Scarabaeidae	Lepanus	bidentatus
464	Coleoptera	Scarabaeidae	Lepanus	sp. nov. nr. pisoniae
465	Coleoptera	Scarabaeidae	Lepanus	australis
466	Coleoptera	Scarabaeidae	Lepanus	illawarrensis

467	Coleoptera	Scarabaeidae	Onitis	cbcr3-1
468	Coleoptera	Scarabaeidae	Onthophagus	nurubuan
469	Coleoptera	Scarabaeidae	Onthophagus	squalidus
470	Coleoptera	Scarabaeidae	Onthophagus	macrocephalus
471	Coleoptera	Scarabaeidae	Onthophagus	hoplocerus
472	Coleoptera	Scarabaeidae	Onthophagus	cbcr3-1
473	Coleoptera	Scarabaeidae	Thyregis	kershawi
474	Coleoptera	Scydmaenidae		cbcr3-1
475	Coleoptera	Scydmaenidae		cbcr3-2
476	Coleoptera	Scydmaenidae		cbcr3-3
477	Coleoptera	Scydmaenidae		cbcr3-4
478	Coleoptera	Scydmaenidae		cbcr3-5
479	Coleoptera	Scydmaenidae		cbcr3-6
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481	Coleoptera	Scydmaenidae		cbcr3-8
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483	Coleoptera	Scydmaenidae		cbcr3-10
484	Coleoptera	Scydmaenidae		cbcr3-11
485	Coleoptera	Scydmaenidae		cbcr3-12
486	Coleoptera	Scydmaenidae		cbcr3-13
487	Coleoptera	Scydmaenidae		cbcr3-14
488	Coleoptera	Scydmaenidae		cbcr3-15
489	Coleoptera	Scydmaenidae		cbcr3-16
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496	Coleoptera	Scydmaenidae		cbcr3-23
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500	Coleoptera	Silvanidae		cbcr3-1
501	Coleoptera	Silvanidae		cbcr3-2
502	Coleoptera	Sphindidae		cbcr3-1
503	Coleoptera	Sphindidae		cbcr3-2
504	Coleoptera	Staphylinidae	Quediini	cbcr3-8
505	Coleoptera	Staphylinidae		cbcr3-1
506	Coleoptera	Staphylinidae		cbcr3-2
507	Coleoptera	Staphylinidae		cbcr3-3
508	Coleoptera	Staphylinidae		cbcr3-4
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511	Coleoptera	Staphylinidae		cbcr3-2
512	Coleoptera	Staphylinidae	Anotylus	cbcr3-1
513	Coleoptera	Staphylinidae	Anotylus	cbcr3-2
514	Coleoptera	Staphylinidae	Anotylus	cbcr3-3
515	Coleoptera	Staphylinidae		cbcr3-1
516	Coleoptera	Staphylinidae		cbcr3-2
517	Coleoptera	Staphylinidae		cbcr3-3
518	Coleoptera	Staphylinidae		cbcr3-1
519	Coleoptera	Staphylinidae		cbcr3-1

520	Coleoptera	Staphylinidae		cbcr3-2
521	Coleoptera	Staphylinidae		cbcr3-3
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526	Coleoptera	Staphylinidae		cbcr3-8
527	Coleoptera	Staphylinidae		cbcr3-9
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560	Coleoptera	Staphylinidae		cbcr3-3
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562	Coleoptera	Staphylinidae		cbcr3-1
563	Coleoptera	Staphylinidae		cbcr3-1
564	Coleoptera	Staphylinidae		cbcr3-2
565	Coleoptera	Staphylinidae		cbcr3-3
566	Coleoptera	Staphylinidae	Hesperus	haemorrhoidalis
567	Coleoptera	Staphylinidae	Thyreocephalus	lorquini
568	Coleoptera	Staphylinidae	Quediini	cbcr3-7
569	Coleoptera	Staphylinidae	Quediini	cbcr3-6
570	Coleoptera	Staphylinidae	Quediini	cbcr3-5
571	Coleoptera	Staphylinidae	Quediini	cbcr3-4
572	Coleoptera	Staphylinidae	Quediini	cbcr3-3

573	Coleoptera	Staphylinidae	Quediini	cbcr3-2
574	Coleoptera	Staphylinidae	Quediini	cbcr3-1
575	Coleoptera	Staphylinidae		cbcr3-1
576	Coleoptera	Staphylinidae	Sepedophilus	cbcr3-1
577	Coleoptera	Tenebrionidae	Archaeoglenes	australis
578	Coleoptera	Tenebrionidae	Encara	nigrum
579	Coleoptera	Tenebrionidae	Lepispilus	cbcr3-1
580	Coleoptera	Tenebrionidae	Uloma	cbcr3-1
581	Coleoptera	Tenebrionidae	Uloma	cbcr3-2
582	Coleoptera	Tenebrionidae	Apasis	puncticeps
583	Coleoptera	Tenebrionidae	Cardiothorax	undulaticostis
584	Coleoptera	Tenebrionidae	Cardiothorax	australis
585	Coleoptera	Tenebrionidae	Cardiothorax	cbcr3-1
586	Coleoptera	Tenebrionidae	Daedrosis	cbcr3-1
587	Coleoptera	Tenebrionidae	Daedrosis	cbcr3-2
588	Coleoptera	Tenebrionidae	Isopteron	cbcr3-1
589	Coleoptera	Tenebrionidae	Leptogastrus	cbcr3-1
590	Coleoptera	Tenebrionidae	Leptogastrus	cbcr3-2
591	Coleoptera	Tenebrionidae	Leptogastrus	cbcr3-3
592	Coleoptera	Tenebrionidae	Leptogastrus	cbcr3-4
593	Coleoptera	Tenebrionidae	Nolicima	cbcr3-1
594	Coleoptera	Tenebrionidae	Seirotrana	proxima
595	Coleoptera	Tenebrionidae	Adelium	cbcr3-1
596	Coleoptera	Tenebrionidae		cbcr3-1
597	Coleoptera	Tenebrionidae	Metriolagris	attonis
598	Coleoptera	Throscidae		cbcr3-1
599	Coleoptera	Throscidae		cbcr3-2
600	Coleoptera	Throscidae		cbcr3-3
601	Coleoptera	Trogidae	Omorgus	cbcr3-1
602	Coleoptera	Trogidae	Omorgus	cbcr3-2
603	Coleoptera	Trogidae	Omorgus	cbcr3-3
604	Coleoptera	Zopheridae		cbcr3-1
605	Hymenoptera	Formicidae	Cerapachys	macrops
606	Hymenoptera	Formicidae	Cerapachys	sp.005
607	Hymenoptera	Formicidae	Cerapachys	sp.006
608	Hymenoptera	Formicidae	Sphinctomyrmex	sp.005
609	Hymenoptera	Formicidae	Anonychomyrma	sp.005
610	Hymenoptera	Formicidae	Anonychomyrma	sp.006
611	Hymenoptera	Formicidae	Anonychomyrma	sp.007
612	Hymenoptera	Formicidae	Anonychomyrma	sp.008
613	Hymenoptera	Formicidae	Anonychomyrma	sp.009
614	Hymenoptera	Formicidae	Anonychomyrma	sp.004
615	Hymenoptera	Formicidae	Doleromyrma	sp.001
616	Hymenoptera	Formicidae	Dolichoderus	sp.005
617	Hymenoptera	Formicidae	Dolichoderus	sp.006
618	Hymenoptera	Formicidae	Iridomyrmex	rufoniger group
619	Hymenoptera	Formicidae	Iridomyrmex	sp.011
620	Hymenoptera	Formicidae	Iridomyrmex	viridiaeneus
621	Hymenoptera	Formicidae	Iridomyrmex	viridigaster
622	Hymenoptera	Formicidae	Iridomyrmex	sp.012
623	Hymenoptera	Formicidae	Iridomyrmex	sp.013
624	Hymenoptera	Formicidae	Iridomyrmex	sp.014
625	Hymenoptera	Formicidae	Iridomyrmex	sp.015

626	Hymenoptera	Formicidae	Iridomyrmex	sp.016
627	Hymenoptera	Formicidae	Iridomyrmex	sp.017
628	Hymenoptera	Formicidae	Leptomyrmex	sp.012
629	Hymenoptera	Formicidae	Ochetellus	glaber
630	Hymenoptera	Formicidae	Papyrius	sp.001
631	Hymenoptera	Formicidae	Tapinoma	sp.001
632	Hymenoptera	Formicidae	Technomyrmex	sp.001
633	Hymenoptera	Formicidae	Technomyrmex	sp.002
634	Hymenoptera	Formicidae	Technomyrmex	sp.003
635	Hymenoptera	Formicidae	Technomyrmex	sp.004
636	Hymenoptera	Formicidae	Acropyga	sp.005
637	Hymenoptera	Formicidae	Camponotus	intrepidus
638	Hymenoptera	Formicidae	Camponotus	consobrinus
639	Hymenoptera	Formicidae	Camponotus	sp.020
640	Hymenoptera	Formicidae	Camponotus	sp.021
641	Hymenoptera	Formicidae	Camponotus	sp.022
642	Hymenoptera	Formicidae	Camponotus	sp.023
643	Hymenoptera	Formicidae	Camponotus	sp.024
644	Hymenoptera	Formicidae	Camponotus	sp.025
645	Hymenoptera	Formicidae	Camponotus	sp.026
646	Hymenoptera	Formicidae	Camponotus	sp.027
647	Hymenoptera	Formicidae	Camponotus	sp.028
648	Hymenoptera	Formicidae	Camponotus	sp.029
649	Hymenoptera	Formicidae	Camponotus	sp.030
650	Hymenoptera	Formicidae	Camponotus	sp.031
651	Hymenoptera	Formicidae	Melophorus	sp.005
652	Hymenoptera	Formicidae	Melophorus	sp.006
653	Hymenoptera	Formicidae	Melophorus	sp.007
654	Hymenoptera	Formicidae	Melophorus	sp.008
655	Hymenoptera	Formicidae	Melophorus	sp.009
656	Hymenoptera	Formicidae	Melophorus	sp.010
657	Hymenoptera	Formicidae	Melophorus	sp.011
658	Hymenoptera	Formicidae	Melophorus	sp.012
659	Hymenoptera	Formicidae	Melophorus	sp.013
660	Hymenoptera	Formicidae	Notoncus	sp.003
661	Hymenoptera	Formicidae	Notoncus	sp.004
662	Hymenoptera	Formicidae	Notoncus	sp.005
663	Hymenoptera	Formicidae	Notoncus	sp.006
664	Hymenoptera	Formicidae	Paratrachina	minutula
665	Hymenoptera	Formicidae	Paratrachina	vaga
666	Hymenoptera	Formicidae	Paratrichina	sp.003
667	Hymenoptera	Formicidae	Paratrichina	sp.004
668	Hymenoptera	Formicidae	Paratrichina	sp.005
669	Hymenoptera	Formicidae	Paratrichina	sp.006
670	Hymenoptera	Formicidae	Plagiolepis	sp.003
671	Hymenoptera	Formicidae	Polyrhachis	sp.020
672	Hymenoptera	Formicidae	Polyrhachis	sp.021
673	Hymenoptera	Formicidae	Prolasius	sp.001
674	Hymenoptera	Formicidae	Prolasius	sp.002
675	Hymenoptera	Formicidae	Prolasius	sp.003
676	Hymenoptera	Formicidae	Prolasius	sp.004
677	Hymenoptera	Formicidae	Prolasius	sp.005
678	Hymenoptera	Formicidae	Prolasius	sp.006

679	Hymenoptera	Formicidae	Prolasius	sp.007
680	Hymenoptera	Formicidae	Prolasius	sp.008
681	Hymenoptera	Formicidae	Prolasius	sp.009
682	Hymenoptera	Formicidae	Prolasius	sp.010
683	Hymenoptera	Formicidae	Prolasius	sp.011
684	Hymenoptera	Formicidae	Prolasius	sp.012
685	Hymenoptera	Formicidae	Prolasius	sp.013
686	Hymenoptera	Formicidae	Prolasius	sp.014
687	Hymenoptera	Formicidae	Pseudonotoncus	sp.003
688	Hymenoptera	Formicidae	Pseudonotoncus	sp.004
689	Hymenoptera	Formicidae	Stigmacros	sp.005
690	Hymenoptera	Formicidae	Stigmacros	sp.006
691	Hymenoptera	Formicidae	Stigmacros	sp.007
692	Hymenoptera	Formicidae	Stigmacros	sp.008
693	Hymenoptera	Formicidae	Stigmacros	sp.009
694	Hymenoptera	Formicidae	Cryptopone	sp.005
695	Hymenoptera	Formicidae	Myrmecia	sp.015
696	Hymenoptera	Formicidae	Myrmecia	sp.016
697	Hymenoptera	Formicidae	Myrmecia	sp.017
698	Hymenoptera	Formicidae	Myrmecia	sp.018
699	Hymenoptera	Formicidae	Myrmecia	sp.019
700	Hymenoptera	Formicidae	Myrmecia	sp.020
701	Hymenoptera	Formicidae	Myrmecia	sp.021
702	Hymenoptera	Formicidae	Myrmecia	sp.022
703	Hymenoptera	Formicidae	Myrmecina	sp.005
704	Hymenoptera	Formicidae	Adlerzia	froggatti
705	Hymenoptera	Formicidae	Aphaenogaster	longiceps
706	Hymenoptera	Formicidae	Cardiocondyla	sp.003
707	Hymenoptera	Formicidae	Colobstruma	sp.005
708	Hymenoptera	Formicidae	Crematogaster	sp.001
709	Hymenoptera	Formicidae	Crematogaster	sp.002
710	Hymenoptera	Formicidae	Crematogaster	sp.003
711	Hymenoptera	Formicidae	Crematogaster	sp.004
712	Hymenoptera	Formicidae	Crematogaster	sp.005
713	Hymenoptera	Formicidae	Epopstruma	sp.005
714	Hymenoptera	Formicidae	Mayriella	sp.001
715	Hymenoptera	Formicidae	Mayriella	sp.002
716	Hymenoptera	Formicidae	Meranoplus	sp.005
717	Hymenoptera	Formicidae	Monomorium	sp.025
718	Hymenoptera	Formicidae	Monomorium	sp.026
719	Hymenoptera	Formicidae	Monomorium	sp.027
720	Hymenoptera	Formicidae	Monomorium	sp.028
721	Hymenoptera	Formicidae	Monomorium	sp.029
722	Hymenoptera	Formicidae	Monomorium	sp.030
723	Hymenoptera	Formicidae	Monomorium	sp.031
724	Hymenoptera	Formicidae	Monomorium	sp.032
725	Hymenoptera	Formicidae	Monomorium	sp.033
726	Hymenoptera	Formicidae	Monomorium	sp.034
727	Hymenoptera	Formicidae	Monomorium	sp.035
728	Hymenoptera	Formicidae	Monomorium	sp.036
729	Hymenoptera	Formicidae	Monomorium	sp.037
730	Hymenoptera	Formicidae	Oligomyrmex	sp.003
731	Hymenoptera	Formicidae	Oligomyrmex	sp.004

732	Hymenoptera	Formicidae	Orectognathus	sp.010
733	Hymenoptera	Formicidae	Pheidole	sp.001
734	Hymenoptera	Formicidae	Pheidole	sp.002
735	Hymenoptera	Formicidae	Pheidole	sp.003
736	Hymenoptera	Formicidae	Pheidole	sp.004
737	Hymenoptera	Formicidae	Pheidole	sp.005
738	Hymenoptera	Formicidae	Pheidole	sp.006
739	Hymenoptera	Formicidae	Pheidole	sp.007
740	Hymenoptera	Formicidae	Pheidole	sp.008
741	Hymenoptera	Formicidae	Podomyrma	sp.010
742	Hymenoptera	Formicidae	Podomyrma	sp.011
743	Hymenoptera	Formicidae	Quadristruma	emmae
744	Hymenoptera	Formicidae	Solenopsis	sp.003
745	Hymenoptera	Formicidae	Solenopsis	sp.004
746	Hymenoptera	Formicidae	Solenopsis	sp.005
747	Hymenoptera	Formicidae	Solenopsis	sp.006
748	Hymenoptera	Formicidae	Strumigenys	sp.005
749	Hymenoptera	Formicidae	Strumigenys	sp.006
750	Hymenoptera	Formicidae	Tetramorium	sp.005
751	Hymenoptera	Formicidae	Tetramorium	sp.006
752	Hymenoptera	Formicidae	Tetramorium	sp.007
753	Hymenoptera	Formicidae	Tetramorium	sp.008
754	Hymenoptera	Formicidae	Amblyopone	sp.003
755	Hymenoptera	Formicidae	Amblyopone	sp.004
756	Hymenoptera	Formicidae	Amblyopone	sp.005
757	Hymenoptera	Formicidae	Discothyrea	sp.003
758	Hymenoptera	Formicidae	Heteroponera	sp.005
759	Hymenoptera	Formicidae	Heteroponera	sp.006
760	Hymenoptera	Formicidae	Heteroponera	sp.007
761	Hymenoptera	Formicidae	Hypoponera	amsa-06
762	Hymenoptera	Formicidae	Hypoponera	amsa-01
763	Hymenoptera	Formicidae	Pachycondyla	sp.005
764	Hymenoptera	Formicidae	Pachycondyla	sp.006
765	Hymenoptera	Formicidae	Pachycondyla	sp.008
766	Hymenoptera	Formicidae	Ponera	sp.007
767	Hymenoptera	Formicidae	Rhytidoponera	metallica
768	Hymenoptera	Formicidae	Rhytidoponera	victoriae
769	Hymenoptera	Formicidae	Rhyditoponera	sp.006
770	Hymenoptera	Formicidae	Rhyditoponera	sp.007
771	Hymenoptera	Formicidae	Rhyditoponera	sp.008
772	Hymenoptera	Formicidae	Rhyditoponera	sp.009
773	Hymenoptera	Formicidae	Rhyditoponera	sp.010

7. APPENDIX 2

NSW CRA/RFA Metadata Proforma

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
DATASET	**Title**	Hotspots of Invertebrate Endemism
	Custodian	Australian Museum
	Jurisdiction	NSW
DESCRIPTION	**Abstract**	A continuous raster dataset defining those areas, which based on available data, are most likely to contain a relatively large number of beetle, ant and spider species endemic to the South Coast Sub Region.
	Search Word(s)	FAUNA Invertebrates
	Geographic Extent Name(s)	Southern CRA Region – South Coast Sub Region
	Geographic Extent Polygon(s)	NA
DATA CURRENCY	**Beginning date**	01Feb1999
	Ending date	01Sept1999
DATASET STATUS	**Progress**	Complete
	Maintenance and update frequency	NA
ACCESS	**Stored Data Format**	DIGITAL Arc/Info
	Available format types	DIGITAL Arc/Info
	Access constraints	Data has been compiled and manipulated for NSW CRA process and therefore the use of this data is restricted to projects being undertaken in NSW CRA process.

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
DATA QUALITY	**Lineage**	Input Datasets:- Biological Data Collection: Biological data was obtained by pitfall trapping carried out as part of this project. Environmental Data Layers: 29 bioclimatic layers based on BIOCLIM variables were derived in Arcview from a DEM supplied by NPWS and 4 climate variables produced by the ESOCLIM software. Roughness and topographic indices, developed by NPWS were also used. The distribution (within the study area) of each of the invertebrate species was modelled using a Generalised Linear Modelling approach and all of the environmental variables mentioned above. Each species model was then inversely weighted according to what proportion of the study area they covered. All the species models were then combined to produce the final invertebrate endemism grid.
	Positional accuracy	Not Relevant
	Attribute accuracy	The attribute of this dataset is a continuous value of invertebrate endemism from 0 to 150
	Logical consistency	The layer is an Arc/Info Grid layer that consists of continuous values from 0 to 150. Any cells outside the study area are coded as No-Data.
	Completeness	A gridcell value is present for the entire SCRA South Coast Sub Region. Any cells outside the study area are coded as No-Data. The lack of biological data available for the northern half of the study area meant that the modelling process focused on the southern half of the study area.

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
CONTACT ADDRESS	**Contact organisation**	Australian Museum
	Contact position	Manager – Spatial Systems Research Unit, Centre for Biodiversity and Conservation Research
	Mail Address 1	6 College Street
	Suburb/Place/ Locality	Sydney
	State/Locality 2	NSW
	Country	Australia
	Postcode	2010
	Telephone	02 9320 6343
	Facsimile	02 9361 5479
	Electronic mail address	paulf@amsg.austmus.gov.au
ADDITIONAL METADATA and DATE	**Metadata date**	8/10/99
	Additional Metadata	Paul Flemons (Australian Museum) L:\scra\hotspots\invert_end_c
CRA/RFA PAGE 1 INFORMATION	**CRA Project Name**	Evaluation of effectiveness of derived forest ecosystems as surrogates for invertebrate biodiversity, and identification of hotspots of invertebrate endemism.
	CRA Project Number	NS 12/EH
EXTENDED DESCRIPTION DETAILS	**Type of feature**	ARC/INFO Grid
	Attribute/Field List	Invertebrate Endemism – Continuous scale from 0 to 150.
	Attribute/Field Description	Continuous (arbitrary) scale of probability of occurrence of relatively large number of invertebrates endemic to the study area
	Scale/Resolution	1:250000
DATASET ENVIRONMENT	**Software**	ARC/INFO
	Computer Operating System	Windows NT
	Dataset Size	214kb

Note: All final copies of NSW CRA/RFA metadata proformas should be completed using the ANZLIC metadata entry tool or the Cradoco tool (see CRA Data Manual section 3.4 for details). This template is provided for use in writing draft versions only

EVALUATION OF EFFECTIVENESS OF DERIVED FOREST ECOSYSTEMS AS SURROGATES FOR

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