Tier 1 Representative Landscapes

A review and development of ranking methods for biodiversity assessment.

by

Ben Bayliss

November 2004

A report prepared for the Department of Conservation and Land Management

[Note: Due to illness, Ben Bayliss was unable to complete editing and re-drafting. The report is made available because it is a useful contribution to the field, and captures and tests ideas that should be in the public domain. *Ken Wallace, project manager*]

Introduction

SIF Biodiversity Objectives

The Salinity Investment Framework (SIF) was established by the State Salinity Council to:

- "Guide the public investment in salinity management initiatives at State, regional and catchment levels."
- "Ensure that public investment is directed to projects with best potential to protect assets of high public value that are at threat from salinity".

Phase I of the SIF (SIF 1) initiated processes for identifying high importance assets threatened by salinity as defined within the following classes:

- Biodiversity
- Water resources
- Agricultural Land
- Rural Infrastructure
- Social Assets.

For Biodiversity assets the goal is:
"To protect, conserve and where necessary and possible, restore Western Australia's natural biodiversity" (DoE, 2003) with reference to delivering a range of human values representing key management drivers.

Three principle biodiversity asset types were identified and examined through the phase 1 process:

1. Rare[1] species
2. Rare plant and animal communities
3. Areas providing good representative samples of biodiversity at a landscape scale i.e. Representative Landscapes (RL).

Project Objectives - Ranking Representative Landscapes

From the SIF I biodiversity assessment, three classes of RL were defined in terms of relative biodiversity importance and degree of salinity threat. Of these classes the Tier 1 (T1) group representing high biodiversity value subject to high salinity threat is the focus of this study.

The objectives of this project are to:

- *Review methods used to rank representative samples of biota, and recommend an approach to be adopted for the Salinity Investment Framework (phase II).*

- *Develop and apply quantitative methods for ranking representative landscapes (Tier I group) with respect to their biodiversity value.*

---

[1] The term "rare" is generally used for something that is uncommon or unusual. This is the sense in which it is used here, and not the statutory meaning defined under the *Wildlife Conservation Act 1950*.

- *Compare the results of all methodologies used to rank representative landscapes and recommend an approach to be adopted by the Department*

Project constraints

Underlying the aforementioned objectives were several guiding constraints/principles. These were that:

- Consideration should only be given to the current biodiversity value of the RLs. The argument follows that assessment of current biodiversity value needs to be independent of viability and threat criteria; as these are largely management driven values, they should not determine *a priori* the status of a biodiversity asset. "Costs should be excluded from early priority setting stages with the focus primarily on current biodiversity value". (p67 DoE, 2003). Further arguments for this position in relation to quantitative biodiversity assessment models are outlined in Faith et al (2003), Margules et al (2002) and for natural biodiversity management by Wallace *et al*., 2003. Habitat configuration and connectivity could be considered viability parameters and so are not explicitly addressed in this study, although it is acknowledged that these parameters are an important consideration in viability assessment.
- Ranking representative landscapes at a State level should take into account the biodiversity values of these entities independently of their regional context.
- Methods employed in ranking representative landscapes should be based on objective and quantitative parameters independent of expert judgement.
- Low weighting to be given to threatened species and community information[2]. Processes for selecting threatened and specially protected species have received specific attention in SIF 1 as separate asset types (see previously). DRF and TEC criteria were, however, included in the analysis of the Target Landscapes in the SIF 1 GIS analysis of biodiversity value (DoE, 2003).

Defining Representative Landscapes.

The methodology by which the T1 RLs were defined is described in the SIF 1 interim report (DoE, 2003, pp86 - 89) and is summarised in Figure 1. It is worth reviewing the "ontogeny" of the selection of RLs and to note the two processes by which the Tier 1 elements were derived.

Type 1 RL -
Target Landscapes (TL)

These are the product of a GIS grid analysis of remnant vegetation occurrence. The method originated from a concept based on an approach to landscape conservation assessment methods that focussed on viable populations. A comprehensive description of the process is given by Beecham (Appendix 3, Wallace *et al.*, 2003). In summary, hexagonal tessellation sample grid units were defined by a notional biogeographic catena estimated to reflect biotic turnover in the wheatbelt (Wallace *et al*. 2003). The tessellation units were systematically identified at various proportional thresholds of intersected remnant vegetation, with 25% being estimated as likely to

---

[2] Wallace, K., Extension of Biological Survey Program, Salinity Investment Framework – Phase 2, Ranking Individual Biodiversity Assets. Minutes of meeting held at CALM Woodvale 25 Nov 2003, participants included: Stuart Halse, Greg Keighery, Mike Lyons and Norm McKenzie.

accommodate the minimum representative sample of biota. TLs were resolved by amalgamating, across multiple offset grids, adjacent cells satisfying the remnant vegetation threshold. Salinity risk was determined by the proportion of threatened (as distinct from currently affected), remnant vegetation within the TL using information from the Land Monitor Project[3].

Type II RL:
Existing Natural Diversity Recovery Catchments (ENDRC)
ENDRCs represent areas for which catchment management boundaries have been established. They encompass a range of biophysical attributes or assets identified by experts as having high biodiversity value and high vulnerability to salinity threat. Particular ENDRCs may encompass quite specific assets with particular biodiversity values, eg Toolibin Lake ENDRC; a Ramsar listed freshwater wetland, also represents a threatened ecological community (Wallace pers. comm., 2004). In other examples, the ENDRCs represent a complex of biotic communities, biophysical features and processes that encompass a broader range of biodiversity values under threat.

Potential Natural Diversity Recovery Catchments (PNDRC)
PNDRCs differ from ENDRCs in that their catchment management boundaries have not been formally recognised. They represent notional entities encompassing a range of potential biodiversity assets and the origins of which lie in an expert assessment drafted by Keighery and Lyons as part of a CALM submission to the WA Salinity Taskforce.

The key biophysical features on which both classes of Natural Diversity Recovery Catchment were identified is summarised in Keighery and Lyons (2001).

Target landscapes, then, are a relatively objective quantitative spatial definition of biodiversity value represented by native remnant vegetation selected using specific, quantified parameters of biodiversity and salinity threat. Both ENDRCs and PNDRCs represent the product of expert opinion not necessarily following defined quantifiable selection criteria.

With respect to the geographic boundaries of these RLs, only the ENDRCs conformed to subcatchment management units, PNDRCs being notional polygons enclosing potential biodiversity assets (however, for the analyses in this project, these boundaries were taken, for the most part, to sub-catchment boundaries). TLs reflected a hexagonal sampling geometry unrelated to hydrological boundaries.

The heterogeneous derivation of these RLs raises some issues concerning their comparability, particularly in the way data used to assess the relative biodiversity value of these RLs may be correlated.

---

[3] The extent of salt affected land was determined through productivity models interpreted from remote sensing imagery with reference to current remnant vegetation extent. The low-lying area with potential for shallow water tables was calculated using the 0-0.5 m height-above-flowpath interim data. The area thus calculated was intersected with vegetation associated with the estimated extent of salt affected land to determine level of biodiversity threat. "Height above flow path" is a measurement of the vertical elevation from areas of high flow accumulation. Areas within a discrete (0 – 0.5) height class above the flowpath were identified. These generally represented low lying areas with the potential for shallow water tables. (DoE, 2003) and (Bowyer, 2001).

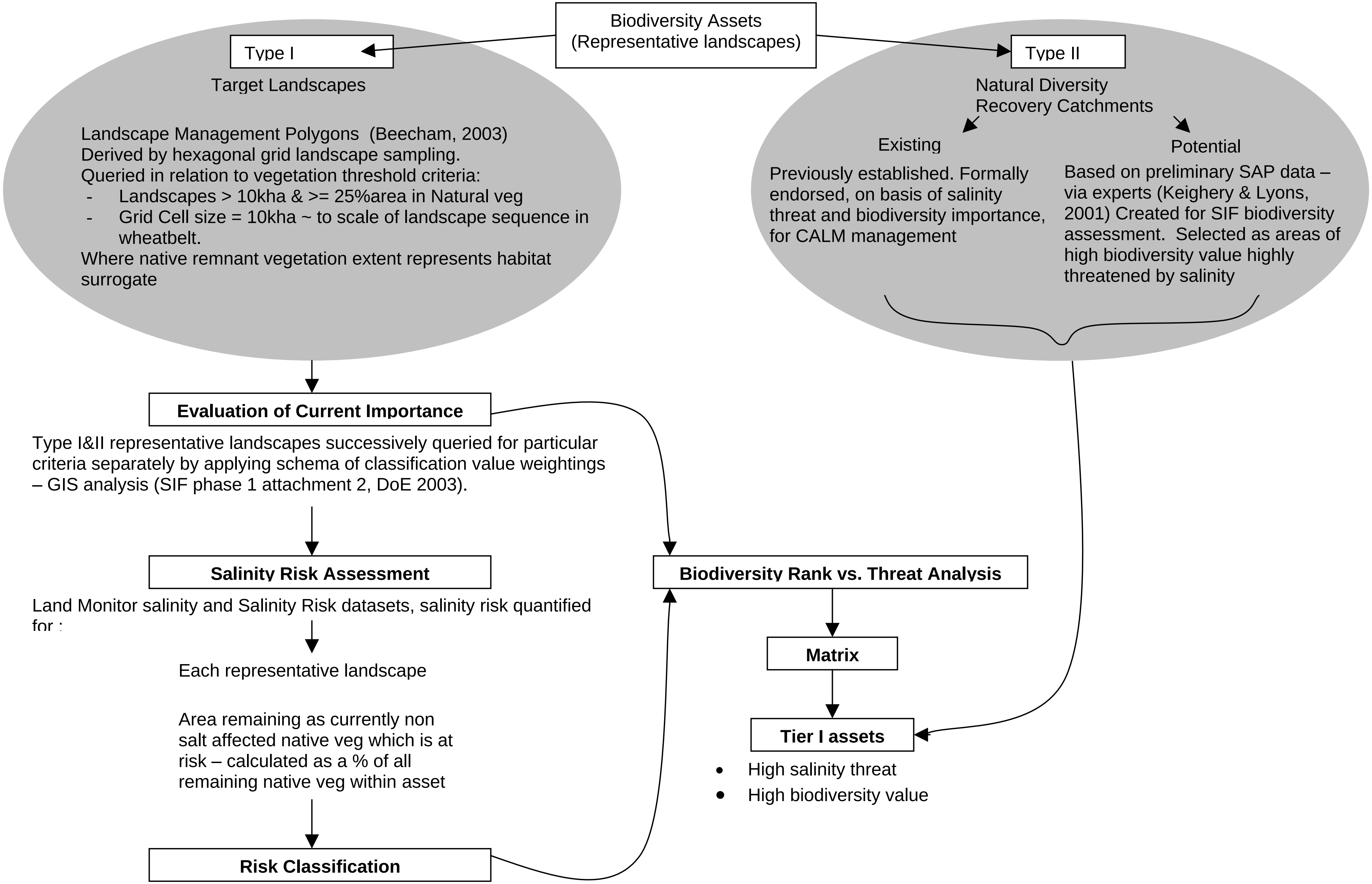


Figure 1: SIF Phase I Biodiversity Assessment process to identify Tier 1 Representative Landscapes

Regional context

The SIF 1 project area boundaries essentially represented the South West Agricultural Region defined by the coast and clearing line. Where the level of salinity threat was determined for the TLs, RFA and Perth Metropolitan areas were excluded from the analysis (DoE, 2003). For the most part, the regional boundary applied to this study was similarly defined, however for some of the datasets examined, the boundary was also determined by other factors inherent in the data or by the nature of the analyses. For example, the regional boundary that might be applied to Beard's vegetation association data follows that of the SW botanical province. This has been redefined by the WA herbarium from the relevant IBRA subregions (Environment Australia, 2000) compatible with Beard's original phytogeographic concept. This natural division ensures that no vegetation associations would be truncated by, or occur outside the boundary area. For the wheatbelt survey data the boundary was defined by the catchment parameters of the irreplaceability analysis as outlined in Walshe (2004).

Defining Biodiversity

For the SIF Phase 1 process the definition of biodiversity was adapted from The National Strategy for the Conservation of Australia's Biological Diversity, (DoE 2003): "The variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form". The proviso being that the abiotic parts of the ecosystem should be excluded on the basis that combining tangible biological entities and intangible processes may present difficulties in developing an effective classification system (DoE 2003).

The conceptual and practical framework which carries this definition is a subject of much debate, involving issues of scale, data surrogacy, and what constitutes the fundamental representative units within which biophysical processes may be summarised, whether this is based on a focal species driven concept (Lambeck, 1999), species turnover within some defined biogeographic catenae (Wallace, 2003) or hydrological management unit, i.e. sub/catchment.

Approaches to Biodiversity Assessment in Australia

Many approaches to biodiversity assessment have been developed – some of those pertinent to Australia as well as initiatives that have been or are currently being pursued by the Department are outlined in Appendix 1.

Concurrent studies – the irreplaceability model.

Of particular interest in relation to the objectives of the Tier 1 biodiversity ranking is an irreplaceability approach being examined by CALM's Science Division in conjunction with the University of Western Australia Centre for Excellence in Natural Resource Management. Data from the Wheatbelt biological survey has been analysed as part of a project involving the application of an interactive irreplaceability modelling methodology. This is discussed in more detail in subsequent sections of this report.

Interpretation of Representative Landscape Asset Management boundaries.

As previously outlined, the SIF 1 process generated a somewhat heterogeneously derived set of T1 RLs linked by the common theme of salinity threat. Subsequent to the release of the interim SIF 1 report, these T1 RLs were redefined, to conform more closely to subcatchment boundaries, by URS consulting as part of a feasibility study into salinity management strategies (URS 2004). The criteria for redefining these boundaries was not explicitly stated in the draft consultant's report (April 2004) but appeared to follow the rationale taken by Anthea Jones in an earlier, unpublished internal departmental document [4]. This document described the criteria by which T1 PNDRCs and TLs were realigned to conform to Water Resources Commission (WRC) and SACRED subcatchment boundaries. The RL asset management boundaries presented by URS consulting appeared to follow closely those defined by Jones. Subsequent documentation received from URS (Burnside, May 2004) outlined criteria based on "functional types of natural systems" in relation to remnant vegetation configuration, landscape position and salinity threat.

Figure 2 indicates the RL boundaries used in this study and have been based on Arcview shapefiles supplied by URS (May 2004).

It may be worth noting that

- WRC and SACRED subcatchments appear to vary considerably in the way they interpret surface hydrology for the same areas.
- RLs, as currently defined by catchment management boundaries, appear to be a variable combination of both WRC and SACRED subcatchment divisions.

This may have implications where a homogeneous basis for subdivision of biodiversity management units is an issue.

The Enquiry Process:

To support the development of an appropriate biodiversity assessment methodology, it was considered important to provide a framework to direct not only the current enquiry process but also implications for future development.

The enquiry process is summarised in Figure 3. The key elements involve:

- Establishment of lines of inquiry or common interest, pertaining to particular data sources and ways they might be applied or developed to address particular biodiversity priority area assessment issues;
- Identifying data that is accessible, whether primary or derived;
- Establishing the analytical approaches that could be used for biodiversity assessment; and
- Providing avenues for feedback and review throughout the process.

The process allows the outcome from each line of enquiry to feed into a review workshop involving relevant experts. These workshops are designed to assess outputs, methods and implications for further development in biodiversity assessment. This includes the opportunity to consider whether certain lines of enquiry are viable or not.

---

[4] A. Jones, Approximating Management Boundaries of "Tier One Representative Landscapes" using a Geographic Information System (GIS) – summary of methodology, January 2004.

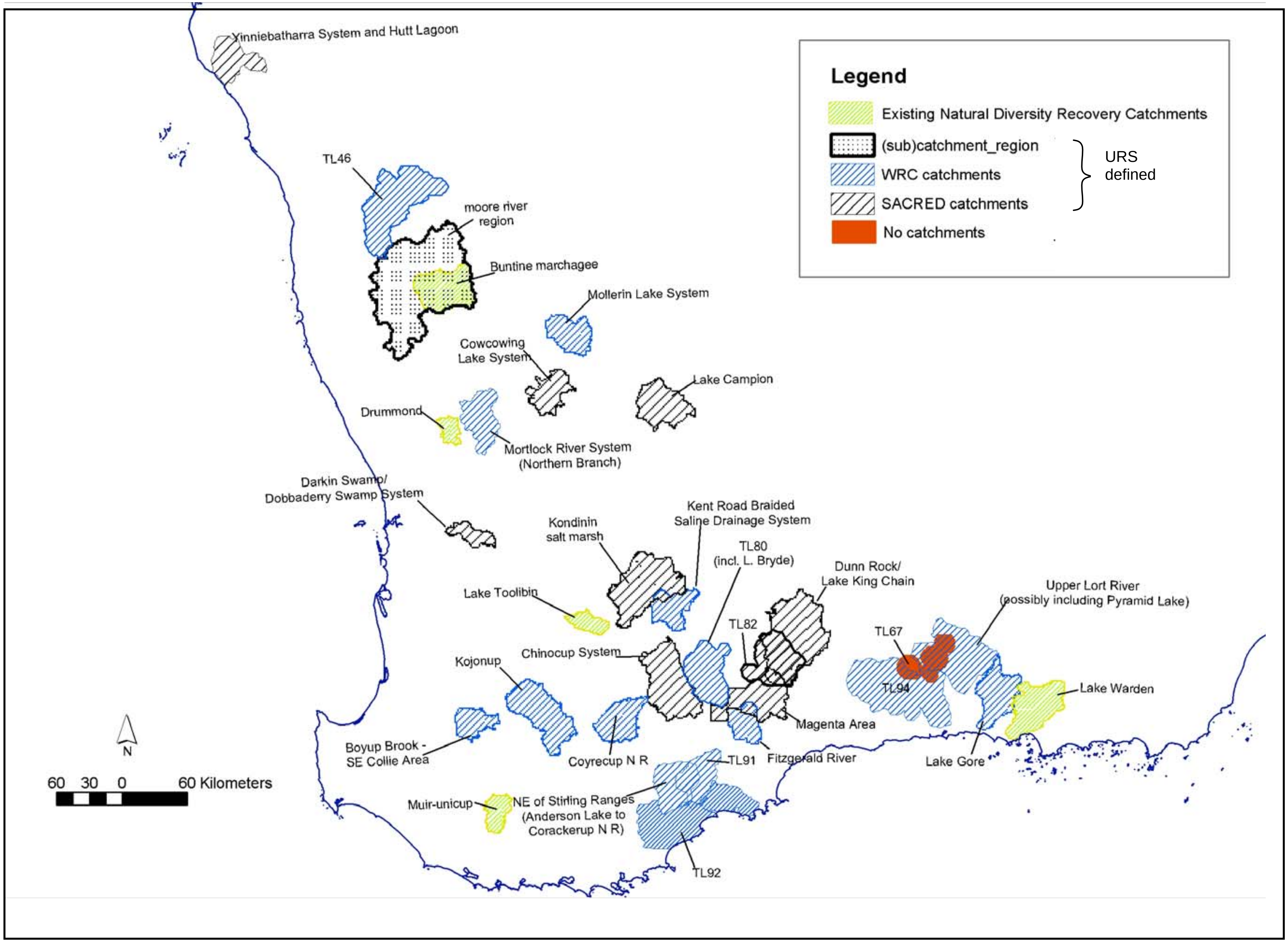


Figure 2 Tier 1 Representative landscapes: defined in SIF Phase 1
Modified by URS Australia Pty Ltd for Assessment of State Assets for Feasability (27/05/2004)

An important component of the framework is documenting the information generated from the enquiry process, such as review comments, discussions and communications that may have taken place in relation to the project. This includes documentation of enquiries and analytical techniques that "fail", so that people do not re-do work that has already been done, or fail to learn from past experiences.

The Analytical model

The proposed approach was to rank RLs according to their relative biodiversity value assessed by scoring each RL against several sets of biological data within some form of GIS model . *[5]

The methods used for such an approach are frequently based on some form of grid analysis as exemplified in the SIF 1 TL biodiversity value assessment and SCRIPT project described in Appendix 1.

Such models can be conceptually straightforward, transparent and in the appropriate context quite valid. However, it can be difficult to interpret information derived from the amalgamation of different datasets to derive a single value for biodiversity.

A typical consideration in simple grid summation models is the bias from values associated with particular grids contributing to the output. This may be addressed by systematically weighting each dataset according to the relative contribution each should make, or reclassifying all data according to some uniform scale of value. Reclassifying data introduces notions of viability, qualitative judgement, or can change the type of data. For example, if the data is classified, values may change from interval to nominal or ordinal and therefore some of the information in the data is lost.

Invariably, data points are less frequent than the scale at which the elements are to be measured, for example, RLs need to be analysed using data at an appropriate scale to achieve an accurate output. If these data points represent inherently continuous phenomena, then areas between data points may be interpolated to provide a continuous surface. From such a surface, values may be inferred over areas of interest for which there are no measured data points. The appropriateness of doing so depends on the nature of the phenomena, the density of data, and also the scale at which the data is to be analysed.

For nominal data such as Beard's vegetation mapping, the distribution of attributes has already been inferred from field surveys as well as expert opinion involved in the mapping process. The data, then, may be a series of discrete vector polygons of measurable area that are converted to a grid model. Or data may represent statistically derived probability surfaces with no explicit values, as is the case with the Gioia - Hopper endemism and richness maps derived from herbarium records.

[5] Wallace, K., Extension of Biological Survey Program, Salinity Investment Framework – Phase 2, Ranking Individual Biodiversity Assets. Minutes of meeting held at CALM Woodvale 25 Nov 2003, participants included: Stuart Halse, Greg Keighery, Mike Lyons, Ken Wallace and Norm McKenzie.

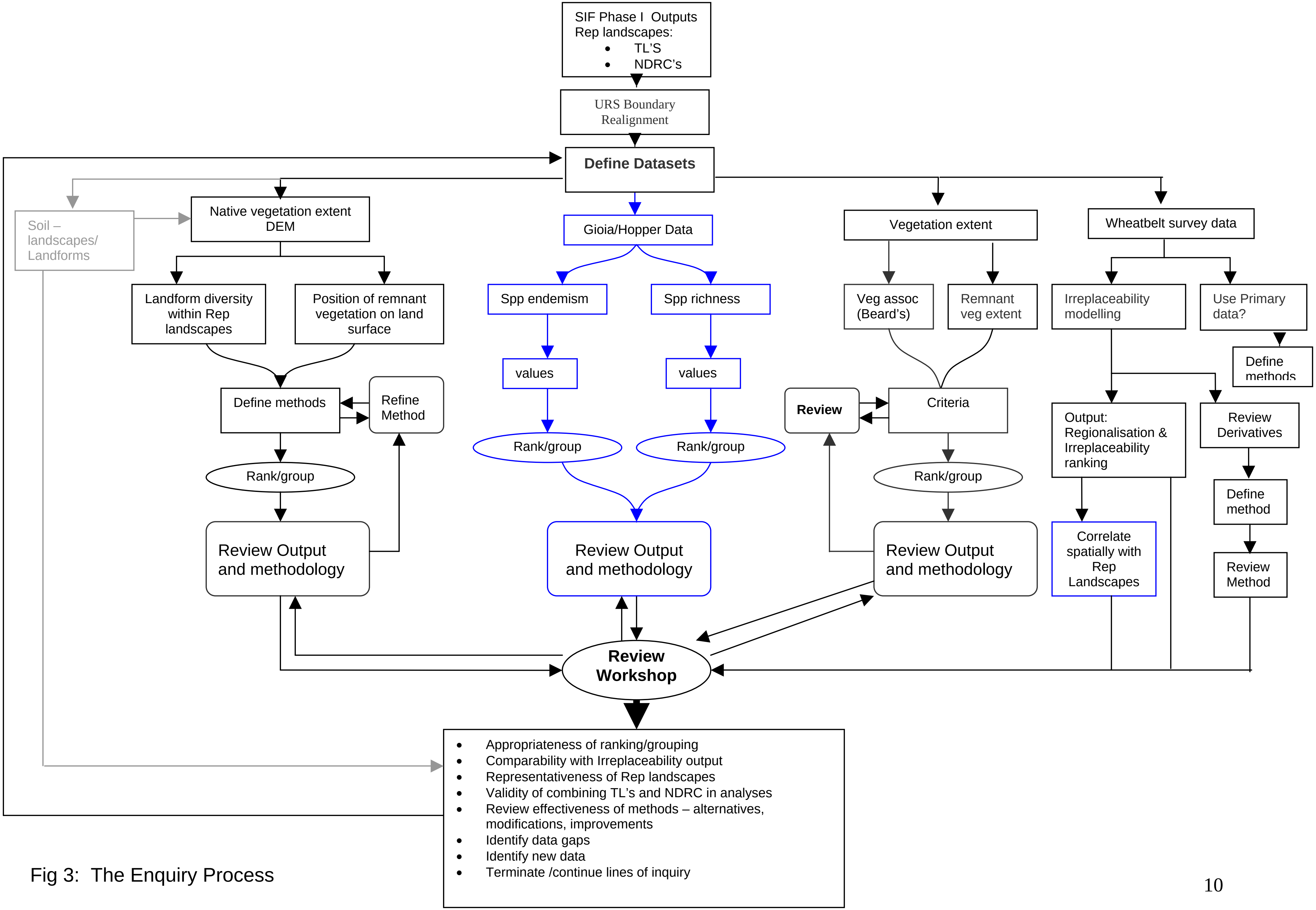


Fig 3: The Enquiry Process

Integrating different data, such as that derived from Beard's mapping with the Gioia-Hopper work, into a congruent grid model often requires reclassification of data values into comparable units. This is essential if different data grid layers are to be amalgamated to provide an overall value for a particular point. Or the grids may be analysed separately according to particular criteria and the outputs for each analysis correlated by some other process.

To accommodate these kinds of issues, analytical models may need to use a number of techniques to address differences in data properties. Although such methods may be more analytically robust, they can be complex and require significant expertise to interpret the results.

For these reasons it was not possible, given the expertise and time available during this project, to develop an integrated methodology providing a definitive set of output biodiversity values for RL ranking. Rather, the process will follow the strategy shown in Figure 3. Each potential dataset will be examined and where possible correlated with the RL by the simplest accessible methods. Outputs will be reviewed by an expert panel that will decide the best approach to refine or rework the methods.

Some key questions to ask in this panel review process are:

- Does the data represent biodiversity in a way that is meaningful for comparative ranking of representative landscape assets?
- Does the data directly represent a biodiversity attribute or is it at some level a surrogate – if so, has the legitimacy of the surrogacy relationship been substantiated?
- What are the underlying properties of the data that may have implications for the way it is analysed and interpreted?
- Is the data complete, thematically or spatially – if not, can this be rectified, if so, what is required for future enquiries?
- Is the scale of data congruent with the scale of phenomena being measured in relation to RL biodiversity value?

Data summary:

The following is a summary of data relevant to achieving the project objectives.

Gioia-Hopper species endemism/richness data:

Extent: SW Botanical Province (Beard)
Scale: 0.25deg grid.
Data type/format:
Grid cell values represent indices of endemism or richness.
Based on herbarium collection records (presence only).
Data statistically normalised for sample bias.

- Richness data averaged over 100 sub samples of WAHerb records based on up to 520 records per grid cell (or up to available data), randomly sampled from 0.25 deg grid.
- Endemism is expressed in terms of range restriction i.e. < 10,000km^2.

Pre-European Vegetation Theme (Beards Vegetation Associations,) [6]

Represents an updated, state-wide vegetation map that is compliant with the standards of the National Vegetation Information System (NVIS). Database captured from Beard's 1:250,000 vegetation survey map sheet series and with correction of dataset attribution at map-sheet edges. Part of the south-west corner of the State not originally covered by Beard's mapping has been compiled in a thematically consistent approach from existing data by Hopkins (Department of Agriculture and CALM 2002).

The current dataset involves contemporary vegetation systems mapping as well as the integration of more detailed attribute data compliant with the NVIS.

Polygons represent separate vegetation associations but in some cases are divided by 1:250,000 map sheet boundaries into contiguous but separate polygons representing the same association.
Extent: State-wide
Scale: 1:250 000 for the SW agricultural region, 1:1 000 000 for the remainder of the State.

Native Remnant Vegetation extent *(Shepherd et al. 2002).*

Original 1980s data capture updated by Orthophotographic corrected classification of satellite imagery (Landsat TM) and results released in 2000.
Extent: South west agricultural district
Scale: various scales of capture – Shepherd (2002) recommended that the dataset not be used at scales finer than 1:25,000.

Present Vegetation Type and Extent *(Shepherd et al. 2002).*

Pre-European vegetation type and present extent datasets have been intersected to generate a surrogate data coverage of present vegetation type and extent.
Extent: South West Agricultural district.
Scale: determined by Pre European Vegetation theme i.e. 1:250,000

Wheatbelt biological survey data

(Derivatives applied to an analysis of irreplaceability)

This dataset was generated by a wheatbelt regional survey undertaken by CALM's Science Division. Work was funded under the 1996 State Salinity Action Plan (SAP), and continued under the later Salinity Strategy. A series of terrestrial and wetland areas were surveyed under the program, and data were collected on vascular plants, ground-dwelling vertebrates and selected invertebrate fauna (spiders and scorpions). Other data collected included soil and water physicochemical parameters. From these primary data, terrestrial and wetland biotic assemblages were identified according to patterns of species co-occurrence. Species association richness values were calculated for each survey area.

Spatial variation in species richness for each assemblage was linearly interpolated between survey areas. This was done using a GIS Triangulated Irregular Network

[6] *Pre European Vegetation - Western Australia (NVIS Compliant version),* Metadata statement 29th April 2004, D. Shepherd, Spatial Resources Information Group, Department of Agriculture, Western Australia

(TIN) function, and thus a continuous grid surface of richness values for each assemblage was derived. For a given assemblage surface, grid cell values coincident with Water Resource Catchments (WRC) subcatchment centroids were identified. These centroid values represented an assemblage's species richness for each subcatchment comprising the wheatbelt study region.

Variation in the spatial extremity of richness values for each association represented by the TIN function was addressed by extrapolation to a series of fixed peripheral zero value points which defined a congruent regional boundary for all association richness values.

Scale of data:
Data for terrestrial and wetlands biota were sampled from 24 survey areas across the study region covering the South West Agricultural Region. The grid surfaces interpolated from the defined points representing these survey areas, were comprised of 5km by 5km cells.

Data analyses

Gioia-Hopper Species Endemism/ Richness data

Approach:
The plant species endemism and richness data supplied by P. Gioia were intersected with the RL boundaries and a summary value obtained for each representative landscape providing the basis for simple numerical ranking.

Method:
In ARC GIS the 25 degree grids of species endemism and richness were reprojected and vectorised generating polygons representing the amalgamation of adjacent grid cells of equal value. These underlying cell values appeared as polygon attributes.

Each RL polygon was intersected with this vector version of the grid data and the mean taken of all values associated with the intersected RL polygon.

The results were entered into an Excel spreadsheet and mean values for each asset sorted in descending order by endemism values and richness values separately.

Results:
Figures 4 and 5 illustrate the relationship of the RL polygons to the underlying grid data for plant species endemism and richness respectively.

Tables 1 and 2 show the comparative ranking of RLs based on mean plant species endemism and richness values respectively.

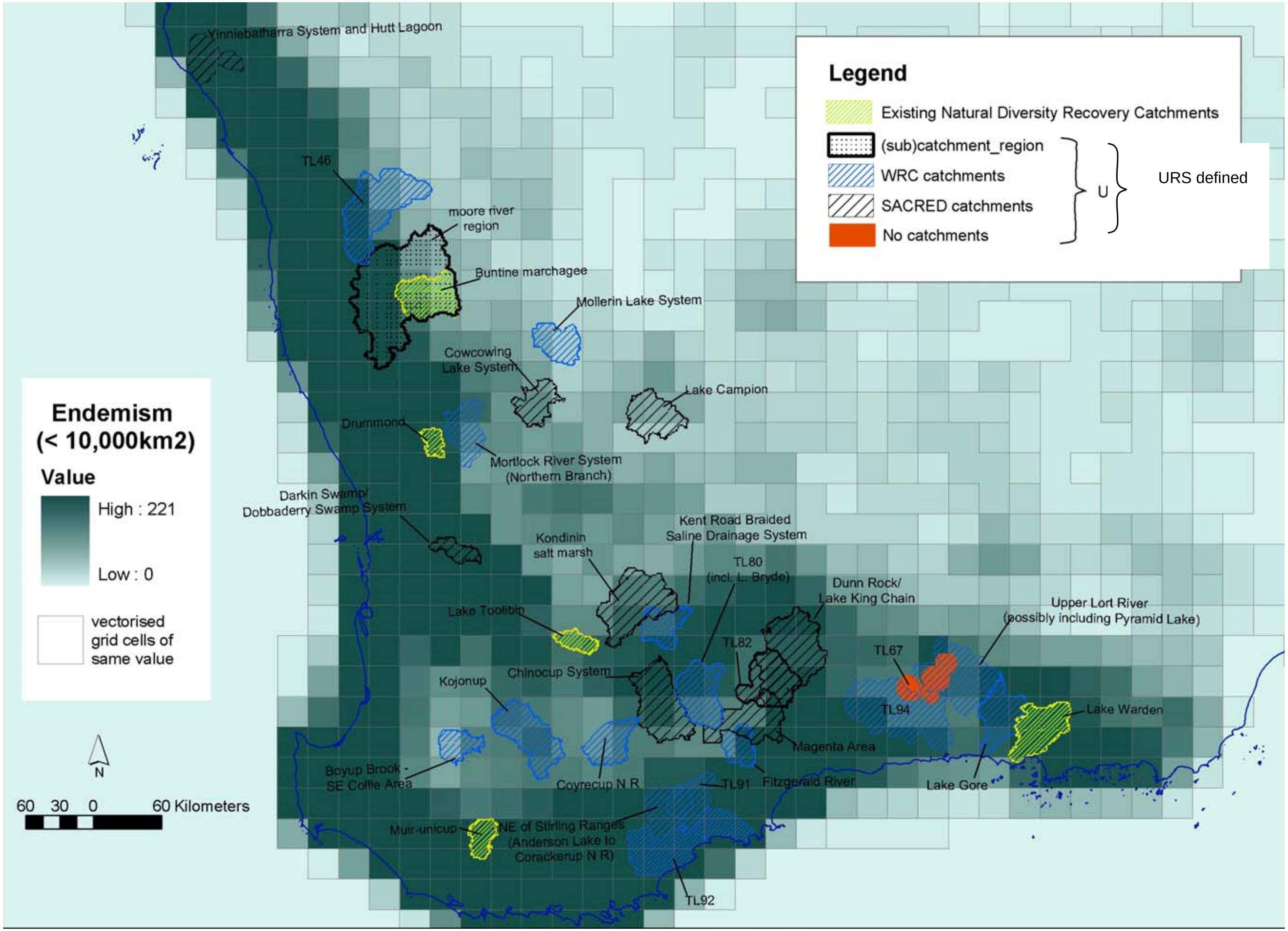


Figure 4: Overlay of T1 Representative landscapes with endemism grid data .

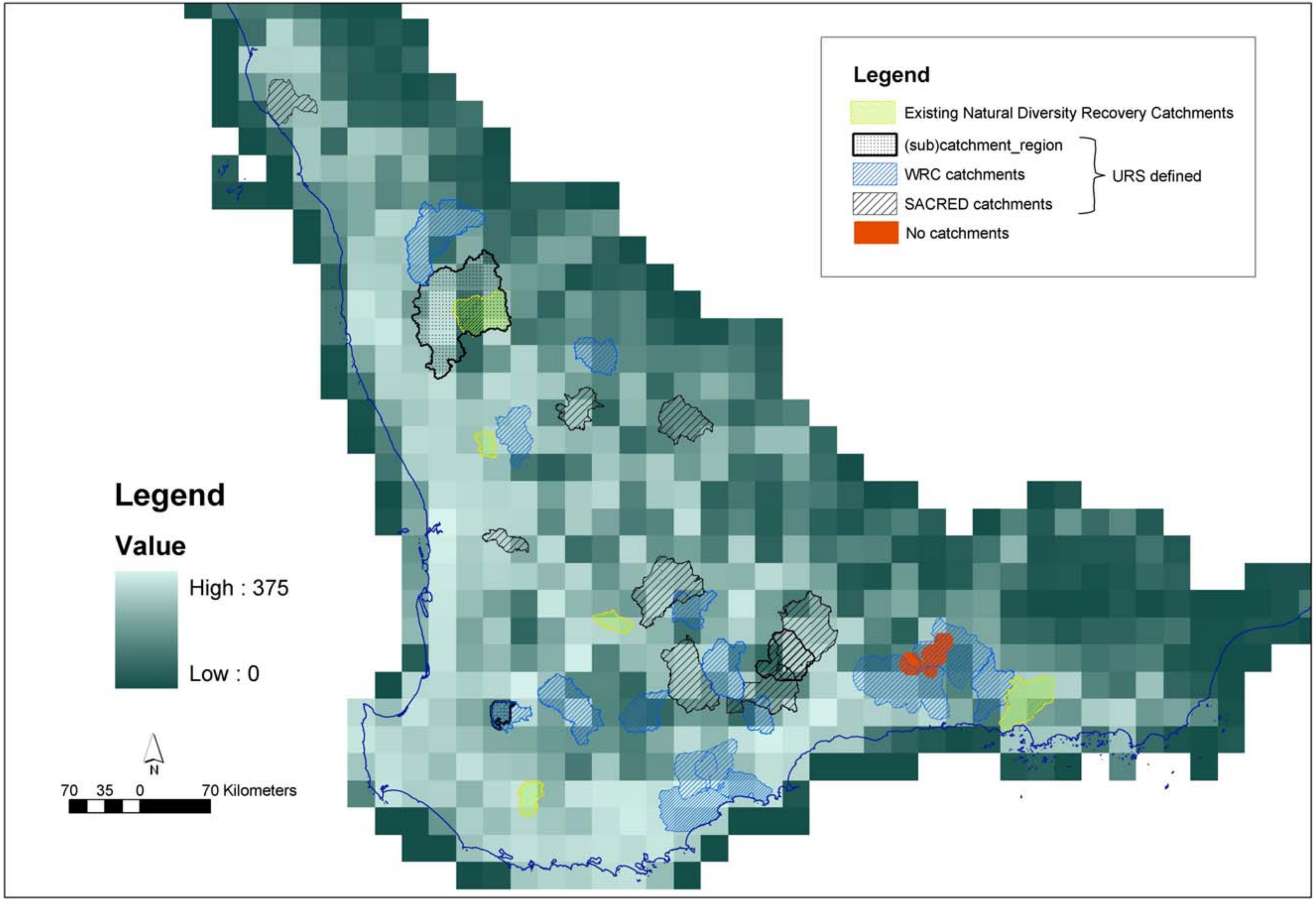


Figure 5: Overlay of T1 Representative landscapes with sp richness grid data

Values represent mean for all grid cells intersected by given RL polygon.

Grid represents 0.25degree cells

Original Grid data supplied 24/05/2004 by P. Gioia, WA Herbarium in ARC/Info interchange file format, GDA 94, Lambert conformal.

Grid data vectorised and intersected with biodiversity asset polygons as supplied by William Blackshaw (URS) 27/05/2004

Biodiversity	**Mean**		**Asset Type**		
Asset	**Endemism**	**Richness**	**SIF I defined**	**SIF ID code**	**URS catchment defined**
TL92	89	324	TL	TL92	WRC Catchments
Darkan Swamp	85	303	PNDRC	15	SACRED Catchments
NE of Stirling Ranges	79	292	PNDRC	21	WRC Catchments
Yinniebatharra	67	264	PNDRC	1	SACRED Catchments
Drummond	61	299	ENDRC	14	ENDRC
TL91	61	295	TL	TL91	WRC Catchments
Moore River	61	228	PNDRC	3	(sub)catchment region
Muir Unicup	50	301	ENDRC	17	ENDRC
Fitzgerald R	45	234	PNDRC	13	WRC Catchments
Lake Warden	39	251	ENDRC	24	WRC Catchments
TL94	38	226	TL	TL94	WRC Catchments
Lake Gore	37	223	PNDRC	23	WRC Catchments
Magenta area	37	202	PNDRC	10	SACRED Catchments
Dunn Rock	34	227	PNDRC	9	SACRED Catchments
Kent Rd	34	222	PNDRC	8	WRC Catchments
TL82	33	222	TL	TL82	SACRED Catchments
TL80	32	229	TL	TL80	WRC Catchments
Mortlock	31	271	PNDRC	5	WRC Catchments
Chinocup	31	241	PNDRC	12	SACRED Catchments
TL 46	31	192	TL	TL 46	WRC Catchments
TL67	30	201	TL	TL67	Original Target Landscape
Upper Lort River	30	189	PNDRC	22	WRC Catchments
Lake Toolibin	28	260	ENDRC	19	ENDRC
Buntine - Marchagee	26	204	ENDRC	2	ENDRC
Kondinin	25	242	PNDRC	6	SACRED Catchments
Kojonup	24	232	PNDRC	18	WRC Catchments
Coyrecup NR	23	142	PNDRC	20	WRC Catchments
Boyup Bk (B)	18	238	PNDRC	16	WRC Catchments
Boyup Bk (A)	17	243	PNDRC	16	subcatchment region
Cowcowing	16	198	PNDRC	7	SACRED Catchments
Lake Campion	13	168	PNDRC	25	SACRED Catchments
Mollerin	9	169	PNDRC	9	WRC Catchments

TL - Target Landscape
PNDRC - Potential Natural Diversity Recovery Catchment
ENDRC - Existing Natural Diversity Recovery Catchment

Table 1 Representative Landscapes ranked by plant species endemism value

Assets sorted by plant species Richness values -

Values represent mean for all grid cells intersected by given RLt polygon.

Original Grid data supplied 24/05/2004 by P. Gioia, WA Herbarium in ARC/Info interchange file format, GDA 94, Lambert conformal. Original cell values represent data averaged over 100 subsamples of WAHerb records base on up to 520 records per grid cell (or up to available data),

Randomly sampled from a 0.25deg grid

Grid data vectorised and intersected with biodiversity asset polygons as supplied by William Blackshaw (URS) 27/05/2004

Biodiversity Asset	Mean		Asset Type		
	Endemism	Richness	SIF I defined	SIF ID code	URS catchment defined
TL92	89	324	TL	TL92	WRC Catchments
Darkan Swamp	85	303	PNDRC	15	SACRED Catchments
Muir Unicup	50	301	ENDRC	17	ENDRC
Drummond	61	299	ENDRC	14	ENDRC
TL91	61	295	TL	TL91	WRC Catchments
NE of Stirling Ranges	79	292	PNDRC	21	WRC Catchments
Mortlock	31	271	PNDRC	5	WRC Catchments
Yinniebatharra	67	264	PNDRC	1	SACRED Catchments
Lake Toolibin	28	260	ENDRC	19	ENDRC
Lake Warden	39	251	ENDRC	24	WRC Catchments
Boyup Bk (A)	17	243	PNDRC	16	subcatchment region
Kondinin	25	242	PNDRC	6	SACRED Catchments
Chinocup	31	241	PNDRC	12	SACRED Catchments
Boyup Bk (B)	18	238	PNDRC	16	WRC Catchments
Fitzgerald R	45	234	PNDRC	13	WRC Catchments
Kojonup	24	232	PNDRC	18	WRC Catchments
TL80	32	229	TL	TL80	WRC Catchments
Moore River	61	228	PNDRC	3	(sub)catchment region
Dunn Rock	34	227	PNDRC	9	SACRED Catchments
TL94	38	226	TL	TL94	WRC Catchments
Lake Gore	37	223	PNDRC	23	WRC Catchments
Kent Rd	34	222	PNDRC	8	WRC Catchments
TL82	33	222	TL	TL82	SACRED Catchments
Buntine - Marchagee	26	204	ENDRC	2	ENDRC
Magenta area	37	202	PNDRC	10	SACRED Catchments
TL67	30	201	TL	TL67	Original Target Landscape
Cowcowing	16	198	PNDRC	7	SACRED Catchments
TL 46	31	192	TL	TL 46	WRC Catchments
Upper Lort River	30	189	PNDRC	22	WRC Catchments
Mollerin	9	169	PNDRC	9	WRC Catchments
Lake Campion	13	168	PNDRC	25	SACRED Catchments
Coyrecup NR	23	142	PNDRC	20	WRC Catchments

TL - Target Landscape
PNDRC - Potential Natural Diversity Recovery Catchment
ENDRC - Existing Natural Diversity Recovery Catchment

Table 2 Representative Landscapes ranked by richness value

Discussion:
This analysis represents the most simplistic “cookie cutting” approach. By the nature of the data, it is apparent that the values attributed to the RL polygons as a result of the intersection can only be interpreted in terms of probabilities and not as absolute values of either species richness or endemism. The scale at which the grids define these values also determines the level at which the results may be interpreted. That is, no reliable interpretation can be made of the likely distribution of endemism or richness values within RLs. The dimensions of the RLs probably represent the limit of resolution for the data.

However at a regional scale, this approach may help contribute to an initial grouping or “first cut” of RLs by their representation of higher or lower areas of endemism or richness. From this, more appropriately scaled data would have to be examined to confirm what this notional first cut shows.

It is apparent that ordering on mean endemism compared to richness values produces a somewhat different RL ranking. There are arguments in the literature to support the inefficiency of using species richness in place prioritisation (Sarkar and Margules 2002). Compared to richness, endemism might be viewed as a greater indication of “uniqueness” (i.e. restricted distribution) amongst RLs. Gioia has indicated (pers comm.) that as the endemism and richness values represent correlated data there could be problems with co-variance if combined within the same analysis and recommended that they be considered separately.

Wheatbelt biological Survey data (Irreplaceability analysis)

Background
The Wheatbelt biological survey represented a major source of biodiversity data; however, in its raw form it was not useable in the project time frame. Considerable experience and understanding of the survey design, biota and biophysical relationships is required to interpret the data and any derivatives in order to carry out a meaningful assessment of biodiversity value. Towards this goal, methods are being developed by the CALM science group to analyse the data following principles of irreplaceability through the application of the customised software package c-plan[7] developed for the NSW National Parks and Wildlife Service by Pressey (Smart et al 2000)

A detailed account of the principles underlying the analytical processes carried out by c-plan and how these have been applied to the survey data is given in Walshe *et al.* (in press). Examples of applications in other bioregional studies can be found in Eardley (1999) and Smart (2000). Essentially, the process attempts to determine the minimum (most efficient) set of catchments that satisfies representation of all assemblages in terms of species richness criteria identified for each assemblage. This process also allows for negotiating subcatchment reservation status, as well as target criteria thresholds, so that their effects on the efficiency and distribution of the minimum sub catchments set can be examined.

---

[7] C-Plan overview and contact details: www.ozemail.com.au/~cplan

Given that it was not feasible to use the raw survey data, the possibility of using data derivatives was explored as a measure for asset ranking. It did not make sense to try to independently develop such derivatives from the data given the time and expertise already applied by others as part of the irreplaceability analysis. On the basis of field experience and knowledge of relating species patterns to broad environmental gradients, it was considered by Walshe *et al*. (in press), that most of the interpolated surfaces provided a reasonable approximation of richness trends where assemblages were restricted to one or two centres of high richness. The exceptions were assemblages such as those associated with granite outcrops, and of patchy distribution where the interpolation procedure failed to discriminate high and low richness nodes. These exceptions as well as upland assemblages, considered to be of low salinity threat, were excluded from their analysis.

Approach
A brief summary of how the species richness surfaces were derived from the primary survey data has been given previously under the relevant data description, and a more detailed account is given in Walshe *et al*. (in press).

Initially, consideration was given to using the irreplaceability analysis results in a similar way to that applied to the Gioia data. That is, performing a simple intersection of the RL polygons with each of the interpolated association richness grids. From the results of this intersection, a summary value for the grid cells intersected by each asset could be obtained, and using these values the following approaches taken:

- RLs sorted by rank order of richness for each association and some statement made about the comparative nature of the rank ordering.
- RLs sorted by rank order of combined association richness values for each RL.

However, both of these approaches are limited in that a simple combined richness value reveals little about the relationship between the species associations and the distribution of richness values. For instance, the way in which association richness values comprising different RLs of similar summed richness quotients might be proportioned.

The appropriateness of using the association species richness surfaces in this way is also doubtful given that their derivation and applicability had only been validated in the context of the irreplaceability analysis explored by Walshe *et al*. For this reason, consideration was given to examining how T1 RLs could be assessed as part of the irreplaceability methodology and what outputs this could generate that might enable RL ranking.

It was envisaged that each asset could be examined for its relative influence on the minimum or optimum set of catchments in meeting some notional target threshold of association richness. Where all subcatchments are potentially “negotiable” in the analysis, only sub catchments representing a given RL might be introduced as mandatory *a priori* members of the minimum set similar to the way the ENDRCs were treated in the original analysis by Walshe *et al*.

The relative effectiveness of RLs in representing species association richness could be assessed in terms of the catchments required to meet target criteria. That is by defining “mandatory” RL catchment groups in the analysis and examining how each of these groups influenced the identification of additional irreplaceable catchments to meet association species richness targets, RLs could be compared and possibly ranked.

The concept was discussed with Walshe and he agreed to run the analysis incorporating the RLs. Preparatory to this exercise, all RLs had to be redefined by whole WRC subcatchments in order to conform to the basic analytical unit used in the original analyses of the wheatbelt biological survey data.

T1 RLs varied in the congruency with which they conformed to WRC subcatchments – as outlined previously, some had already been redefined according to WRC subcatchments, others by SACRED subcatchments and one, TL67, which retained the original target landscape tessellation geometry, was unrelated to any subcatchment definition.

In ARCinfo T1 RL shapefiles were intersected with the WRC subcatchments coverage. Those subcatchments for which greater than 50 % of their area comprised a RL were identified as part of that RL and those less than 50% excluded from the RL - unless containing some significant biophysical attribute. For instance, the greater proportion of the WRC catchment containing Lake Gore occurred outside the Lake Gore RL boundary, so this subcatchment was obviously retained so as not to exclude the core water body asset and its biota.

TL 67 was not identified in the analysis as there was no meaningful translation of its boundary to whole WRC subcatchments, noting however that it is almost completely overlapped by RLs TL94 and Upper Lort River.

The results and detailed discussion from Walshe's perspective in relation to the original association analyses are presented in Attachment 1.

Results.
The principle outputs indicated:

- The relative importance in terms of irreplaceability of catchments additional to the contribution of T1 RLs as a group (Attachment 1 fig 1)
- The degree of redundancy or effectiveness that RL subcatchments exhibit for assemblage representation equivalent to a notional richness target.

This is more of an assessment of the biodiversity value of RL's as a group in relation to its regional context, and so perhaps not strictly within the terms of reference for this project.
However there is a basis for making broad distinctions within the RL group:

- Those RL's that most effectively (or efficiently) represent biodiversity values – as represented by interpolated species richness values for assemblages identified from the wheatbelt survey data. That is, catchments comprising the RLs: Yinniebatharra, TL46, NE corner of Moore River, Mollerin, Lake Campion, TL94, Lake Gore and Lake Warden (attachment 1 figure 2)
- Those RLs that are identified as redundant – or, in terms of what they represent according to the assumptions of the analysis, are the least efficient use of management resources.

Table 1 (Appendix 2 to Attachment 1) shows the proportional representation (%) of wheatbelt assemblages contributed by each T1 RL for the given species richness target threshold. From this data the rarity of some assemblages within the RL group is apparent i.e. they are represented in only a few RLs, while other assemblages are ubiquitous in their distribution. The corollary is that some RLs represent more assemblages than others.

Using these relationships, purely on presence/absence of assemblages, it is possible to rank assemblages according to rarity and ubiquity – most infrequently represented assemblages being ranked highest and most ubiquitous (least critical) the lowest (Table 3). RLs can be ranked according to number of assemblages represented i.e. highly ranked RLs having the greatest number of different assemblages and lowest ranked RLs having the least (Table 4).

A further order of combined ranking can be computed by identifying all RLs in which the least ubiquitous assemblages appear and, within this group of RLs, sort on the total number of assemblages present. This can be carried out progressively from least to most ubiquitous associations until all RLs have been successively identified, (Table 5). For instance, association W2 has only one occurrence in any of the RLs i.e. Yinniebatharra, in which the most number of associations happen to be represented i.e. 14. Thus Yinniebatharra RL is the most highly ranked RL. The results of such a ranking are shown in Table 5.

It is uncertain how to interpret this ranking as it does not take into account species association richness values - only notions of rarity and ubiquity within the RL group. Or looking at it from another view, rarity may be more an expression of poor representation by the RLs as a group rather than significant rarity in a regional context. However the eight RLs identified as most effective in the irreplaceability analysis were also the eight most highly ranked by the methods generating the values shown in table 5.

Table 3

Rank (Rarity)	Assemb	No RLs
1	W2	1
2	TL_2	2
3	W_12	2
4	W_3	3
5	T_16	4
6	W_11	4
7	T_7	5
8	T_6	7
9	T27_33	7
10	W4	7
11	W_18	8
12	W16	10
13	W_10	14
14	W20	15
15	W_1	15
16	W_17	17
17	W_9	19
18	W_14	19
19	W_8	20
20	T8A	25
21	W_13	29
22	W5	30
23	W6	30

Table 4

Rank (No assemb)	Rep Landscape	No Assemb
1	Yinniebatharra	14
2	Coyrecup NR	14
3	TL94	13
4	NE Stirling	13
5	Chinocup	13
6	Kojonup	12
7	Muir Unicup	11
8	Moore River	11
9	Lake Gore	11
10	TL92	10
11	TL80	10
12	TL 46	10
13	Magenta area	10
14	Lake Warden	10
15	Drummond	10
16	Boyup Bk (B)	10
17	Boyup Bk (A)	10
18	TL91	9
19	Mortlock	9
20	Kondinin	9
21	Kent Rd	9
22	Fitzgerald R	9
23	Upper Lort River	8
24	TL82	8
25	Mollerin	8
26	Dunn Rock	8
27	Darkan Swamp	8
28	Cowcowing	7
29	Lake Toolibin	6
30	Lake Campion	6
31	TL67	not in analysis
32	Buntine - Marchagee	not in analysis

Table5

Rank Rarity/Assemb	Rep Landscape
1	Yinniebatharra
2	Mollerin
3	Lake Campion
4	Moore River
5	TL 46
6	TL 94
7	Lake Gore
8	Lake Warden
9	NE stirling
10	Muir unicup
11	upper lort
12	Cowcowing
13	Coyrecup NR
14	Kojonup
15	Drummond
16	Boyup Bk (A&B)
17	Mortlock
18	Darkan Swamp
19	TL80
20	Magenta area
21	TL82
22	Chinocup
23	TL92
24	TL91
25	Fitzgerald R
26	Dunn Rock
27	Lake Toolibin
28	Kent rd/ Kondinin

Potential analyses

Discussions within CALM and allied agencies highlighted a number of potential primary and derivative data sources as well as approaches to their analysis that could aid biodiversity assessment. It became apparent that certain themes held a common interest, if not specifically in ranking SIF T1 RLs, and then more broadly related to:

- The interpretation and evaluation of biodiversity patterns within the SW agricultural region.
- The requirements for appropriately representing the biodiversity values of the region.
- How existing and notional areas, currently identified for representation and management of biodiversity (including T1 RL), may relate to these queries.

Previous efforts to analyse biophysical data to rank biodiversity assets have been outlined above. Some of these methods have been applied. For others, fundamental questions must be framed and answered before proceeding with any kind of analysis.

In addition, there is often an expectation by clients that the geospatial analysis process will help work out what the fundamental questions are. However, it is essential that such questions are worked out before undertaking analyses. (Although, of course, the results of analyses will affect the drafting of the next round of fundamental questions.)

From the literature review and discussions during this project, several data sources and their derivatives were identified as having potential for biodiversity assessment including RL ranking. However, there are also technical and conceptual issues that needed to be resolved before such data may be analysed effectively.

Beards Vegetation Associations (pre-clearing extent and intersection with native remnant vegetation extent.).

Natural vegetation and floristics have been widely used as a surrogate for biodiversity. Various vegetation types have also been used to classify terrestrial environments – for examples, woodlands, heathlands and forests.

For example, Lambeck (1999) in arguing the merits of a focal species based approach to landscape planning for biodiversity conservation in the WA Wheatbelt, considered dominant vegetation associations were biologically meaningful units for landscape assessment.

Studies on the Box Iron Bark Ecosystem of Central Victoria (McNally *et al*. #) examined the use of ecological vegetation classes as “biodiversity management units”. Mc Nally *et al*. considered that the biotic relationships these units represented could account “reasonably well” for certain groups of biota such as birds, mammals and tree species, but not reptiles and invertebrates.

Brooker and Margules (#), as part of an examination of relative conservation value of wheatbelt native vegetation, used plant communities as a basis for ranking vegetation patches in order of assumed conservation value. Communities in the Brooker and Margules case study were identified by numerical classification of floristic survey data. In contrast, the other studies explored broader regional classifications derived from a combination of qualitative and quantitative methods interpreting remotely sensed and ground survey data.

Arguments for the application of vegetation association data to biodiversity assessment have been explored in a number of ways, for example:

- Vegetation associations, in conjunction with identified ecological communities, have been viewed as appropriate units with which to develop a CAR protected area system for nature conservation (Hopkins 1999a 1999b). In this context Hopkins proposed the use of vegetation types, as ecosystem surrogates, identified and mapped at the association level.
- A multi-attribute GIS based approach to a assessment of native vegetation conservation values (Shepherd 2002) involved using Beard’s vegetation association data for prioritising conservation of remnant vegetation patches.

- As part of the SIF 1 assessment methodology, Ben Carr (CALM, Wildlife Branch) and Meagan Hillier (CALM, GIS) tackled the notion of how to interrogate association coverages in relation to place prioritisation at a more regional level (2003, not documented).

The issues raised by these enquiries, as well as from further discussions with Hopkins and Wallace, highlighted the challenges in framing the appropriate questions upon which to base an analysis of data. Figure 6 illustrates the kind of thought processes involved when looking at the relative representation of vegetation associations within T1 RLs. This is not necessarily purported to be the best or correct approach, but exemplifies the type of query that may be required and suggests the type of analytical framework capable of supporting it. At some point the query process comes round to how the relative value of a vegetation association represented within the RL group is influenced when considered in a regional context. For instance, RLs more highly rated on the basis of particular associations represented within them relative to other RLs, may not be so highly rated where those associations are ubiquitously represented regionally. However it should be noted that one of the failings in the regional vegetation based mapping of environments is that they do not necessarily take into consideration species turnover across landscapes (Burgman, 1988).

The intersection of Beard's Vegetation Association mapping with remnant native vegetation extent data enables comparison of current and inferred pre-clearing extents. Criteria for identifying the viable representation of existing associations as a proportion of their pre-clearing extent, have been used in determining biodiversity conservation thresholds (eg: Shepherd 2002), and a practical biodiversity assessment model may require the capability to accommodate such criteria in a way that allows them to be varied according to circumstances.

By structuring the vegetation association data as an area by attribute matrix, in which the values represent some function of association area for a given analytical unit (eg subcatchment), the irreplaceability model is an option. Application of this approach would be a more straightforward process than that involving the wheatbelt survey assemblages. That is, the vegetation associations are spatially explicit and the target criteria directly specified as a proportion of pre-clearing extent for each association. Conceptually the analysis would provide a way of ranking RLs by their relationship to the regional distribution of irreplaceability based on vegetation association occurrence.

RLs could also be ranked, independently of their regional context, on the presence or absence of vegetation associations according to rarity and ubiquity in a manner similar to the analyses outlined for the wheat belt survey assemblages. Again this would not take into account the amount of area represented by each vegetation association.

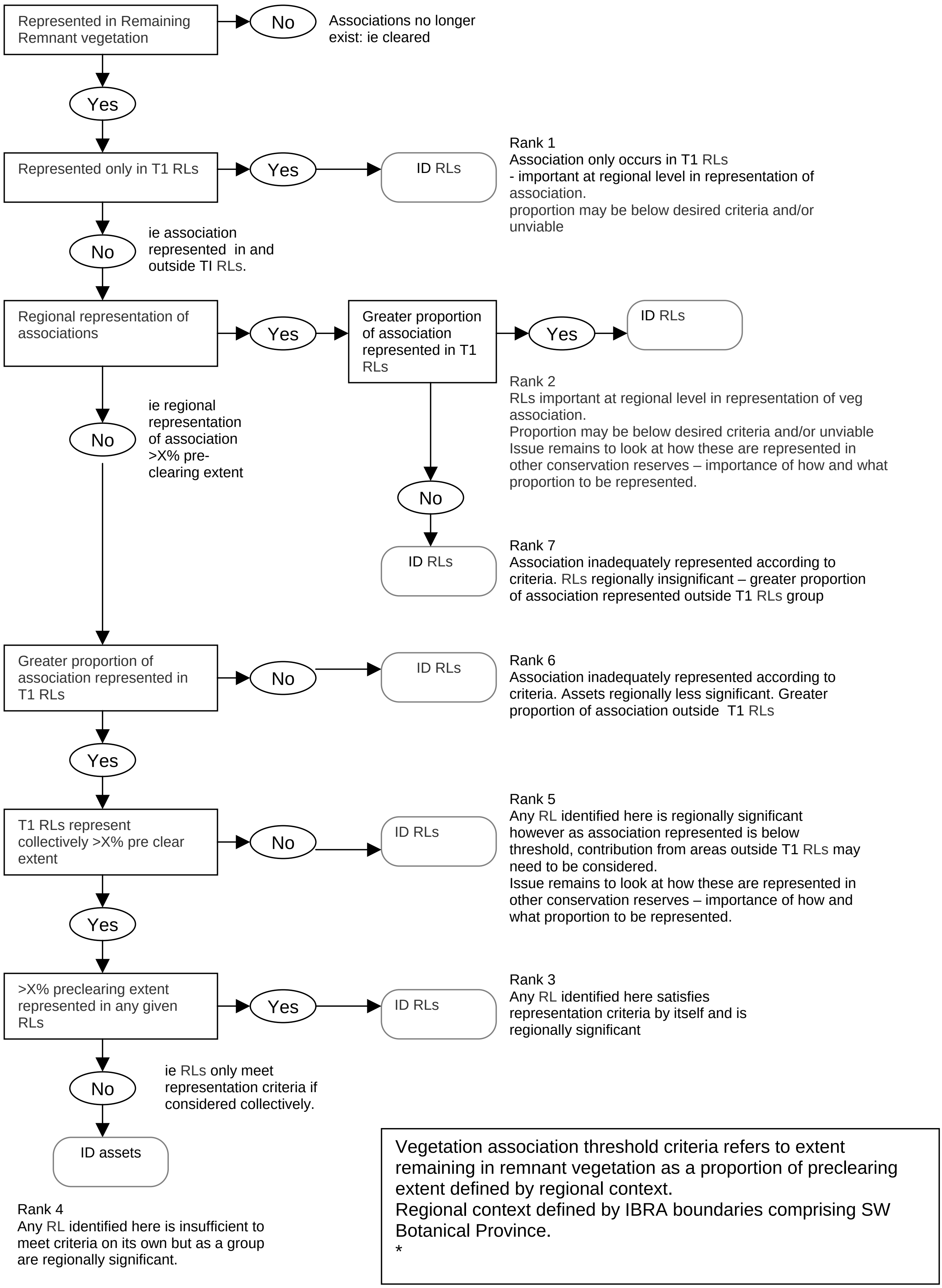


Fig 6: Ranking of Tier 1 biodiversity assets – Analysis of vegetation associations*

Position of remnant vegetation in Landscape

Discussions with Hopkins and Keighery indicated that the concept of remnant vegetation position in the landscape is worthy of consideration. The argument being that for fauna, in particular, speciation has been observed to reflect parameters related to landscape position and variation.

For the Wheatbelt biological survey, sampling of terrestrial biota was stratified according to landform and soil type/genesis (McKenzie, in press).

When discussing extrapolation to regional scales of locally derived biophysical relationship models defined by vegetation associations, Lambeck (1999) refers to position in landscape as a basis for helping identify functionally homogeneous units.

In a more general sense, terrain and the correlated surface morphology parameters: elevation, slope, relief and aspect, represent a subset of environmental data that Williams et al (2002) considers potentially useful as surrogates for biodiversity. Digital elevation models (DEMs) can provide a consistent and accessible regional database with which to correlate environmental data and infer other biophysical parameters.

However, where remnant vegetation is considered a valid habitat surrogate, defining its landscape position is not straightforward. The notion is explored only briefly here but should perhaps be highlighted as an area of enquiry worth pursing by those with appropriate expertise.

The approach might involve looking at the variety of landform units represented in remnant vegetation associated with RLs - for example, by intersecting them with:

- Some function of landscape variation or surface morphology i.e. DEM.
- Native remnant vegetation extent.

Conceptually, intersecting the occurrence of remnant vegetation with a DEM would indicate its landscape position. However, the challenge is to quantify this in some way that would, for instance:

- Allow positional criteria to be defined i.e. most basically, what is upland, mid-slope, lowland.
- Define the degree of ruggedness or roughness i.e. “frequency” of terrain variation.

Some index of positional occurrence of remnant vegetation and frequency of terrain variation could provide a viable surrogate for biodiversity value in ranking RL areas. It should be noted however, that T1 RLs *ipso facto* have, to some extent, already been defined in terms of landscape position: through the SIF 1 assessment methodology positional criteria were implicit in the salinity threat analysis as outlined earlier in this document (Defining Representative Landscapes: Target Landscapes). That is, the creation of Target Landscapes incorporated information from the Landmonitor Project where one of the components for estimating salinity risk was derived from position in landscape – i.e. intersection of current vegetation extent with height above flowpath.

Approach:
A two metre DEM coverage (WRC) is available over most of the South West agricultural region. One approach arising from discussions with EA Griffin (AgWA) proposed examining the distribution of elevation values for RL terrains in relation to those values representing RL areas on which remnant vegetation occurs. It might then be possible to mathematically define the relationship and systematically classify the landscape position occupied by remnant vegetation.

Method:
The feasibility of such an approach was explored by intersecting several RL polygons, Darkan Swamp PNDRC, Mollerin PNDRC and TL46 and their associated vegetation remnants with the WRC DEM.

Each RL vector polygon was converted to a raster grid of cell size identical to that of the DEM and the elevation values of the corresponding cells in the DEM identified. Remnant vegetation associated with RLs was clipped from the remnant vegetation extent coverage and the resultant polygons similarly converted to a raster grid and elevation values of the corresponding cells in the DEM identified. Histograms of the respective RLs and remnant vegetation elevation values were generated and compared.

Figures 7a, Darkin Swamp PNDRC, 7b Mollerin PNDRC and 7c TL46 show the overlay of remnant vegetation for the respective RL DEMs. Figures 8a, 8b and 8c show the histograms of elevation values for the RLs and remnant vegetation terrain elements.

A comparison of these histograms can illustrate the relationship between remnant vegetation and RL elevation. The shape and area of the respective histograms can be compared to obtain some idea of how the distribution of vegetation relates to the elevational profile of the RL. The potential exists for the underlying data to be quantitatively defined through an appropriate mathematical model.

Soil- landforms/landscapes

Although the previous example touched superficially upon the contribution of physical landscape parameters to biodiversity assessment, soil landscapes/landforms, representing abiotic data, are probably outside the terms of reference for this project. However it is worth noting that from discussions during the course of these inquiries, interest was expressed in further examining terrain driven processes and data with relevance to biodiversity assessment and prioritisation.

Previous to this, Norm McKenzie has used landform, soil type and soil genesis as a means of stratifying terrestrial environments for biological surveys, and during the workshop held as a “wash-up”of the Dongolocking Project in 1998, it was agreed that a combination of landform, soil type/genesis and vegetation should be explored as a surrogate for mapping biodiversity (K. Wallace pers comm.).

Implicit in the stratification of sample sites for the Wheatbelt biological survey was an expert acknowledgment of soil landform elements.

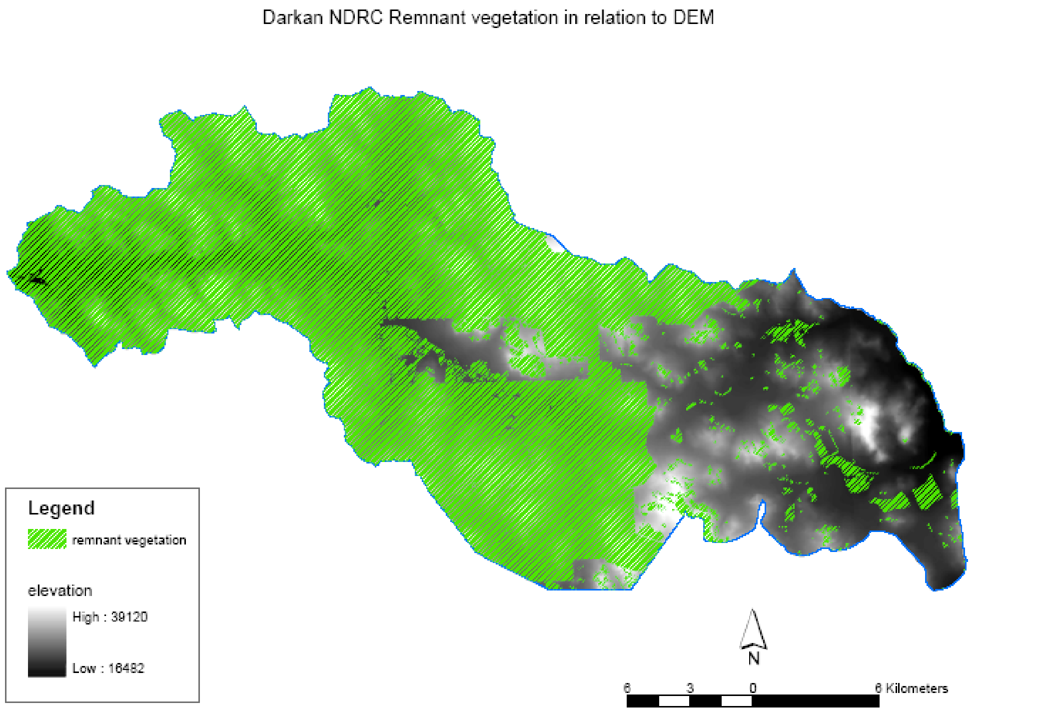


Figure 7a

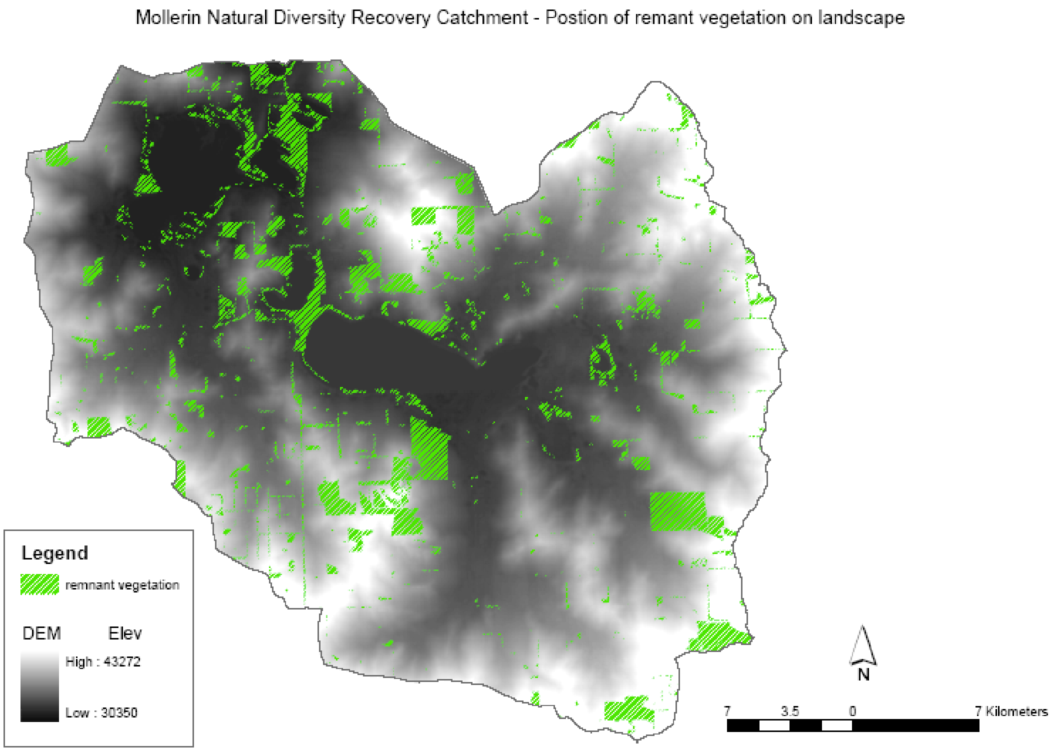


Figure 7b

TL46 remnant vegetation in relation to DEM

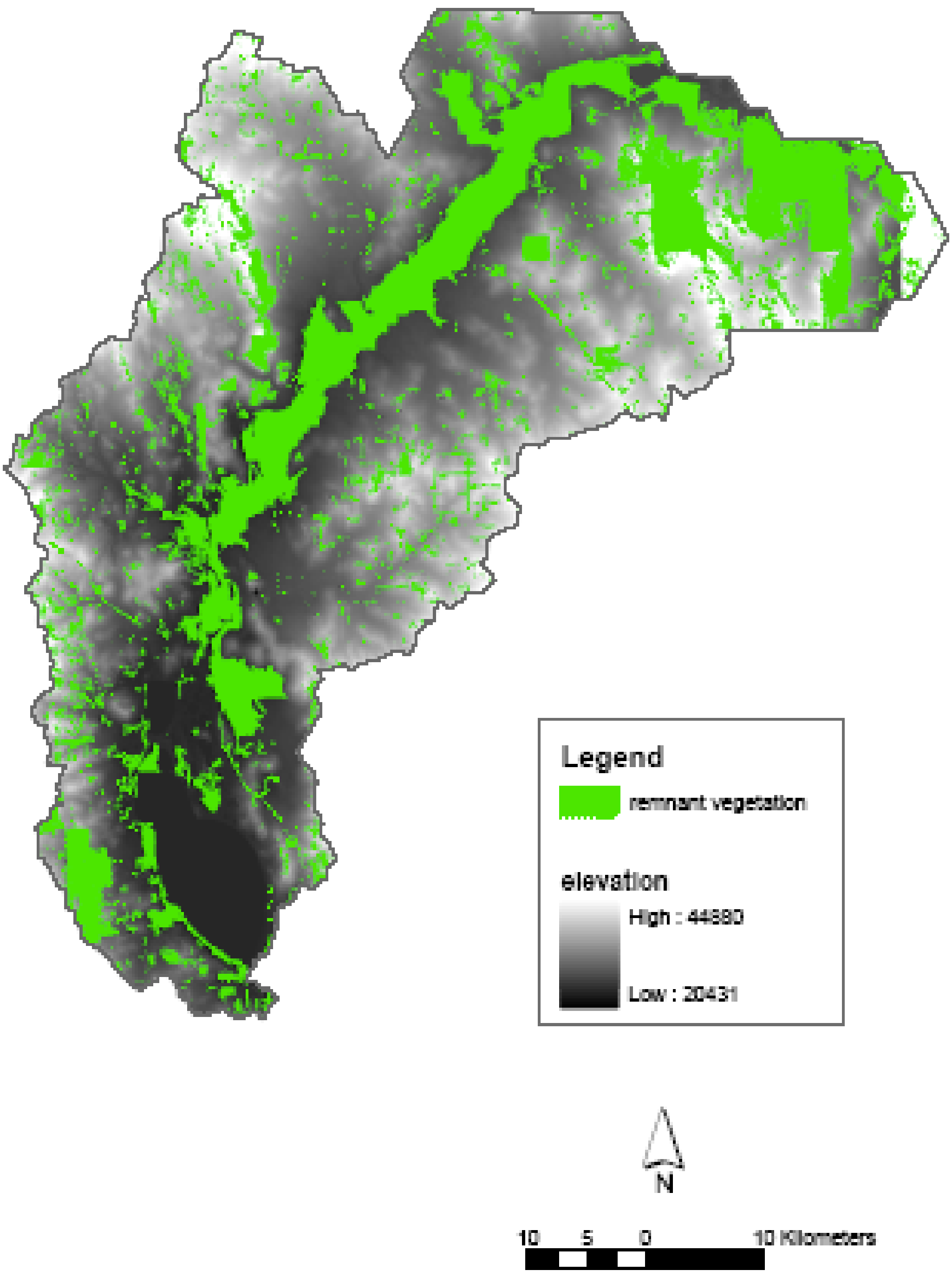
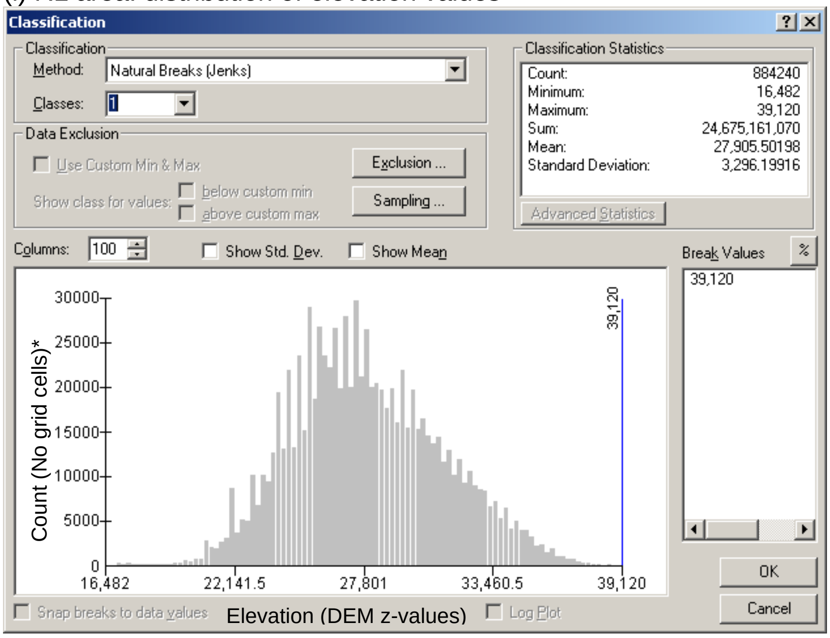


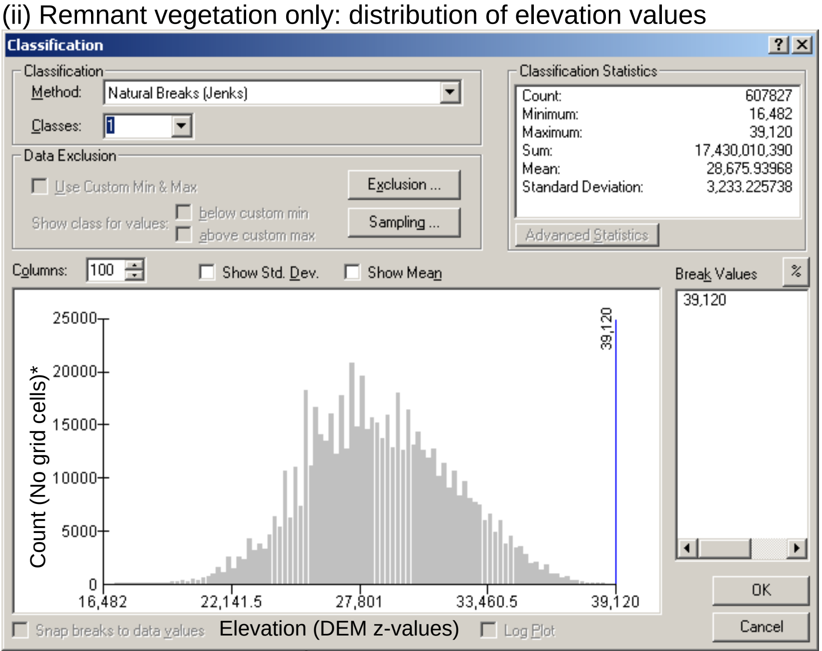
Figure 7c

Fig8a: Darkan/Dobaderry Swamp Representative Landscape (RL): elevation histograms

(i) RL area: distribution of elevation values



(ii) Remnant vegetation only: distribution of elevation values

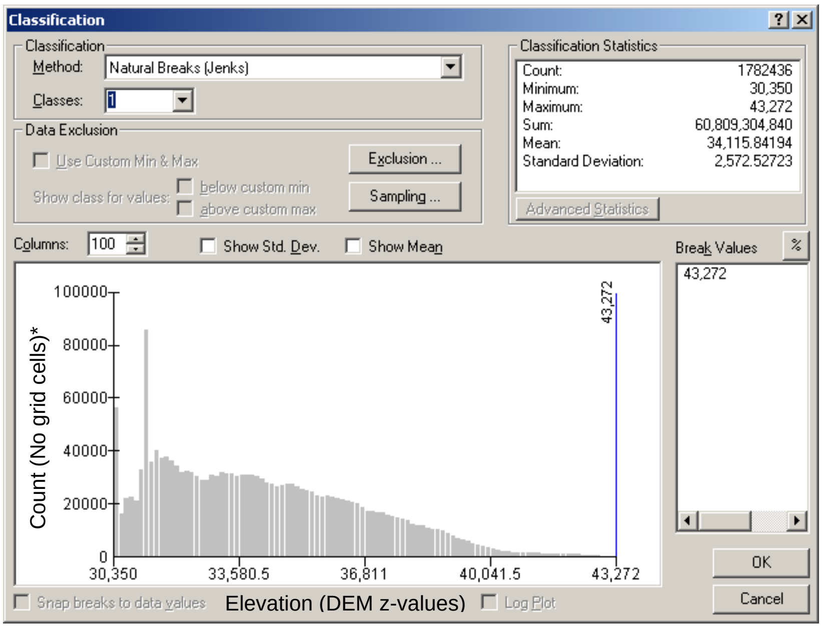


*Note grid cell dimensions = 2m^2

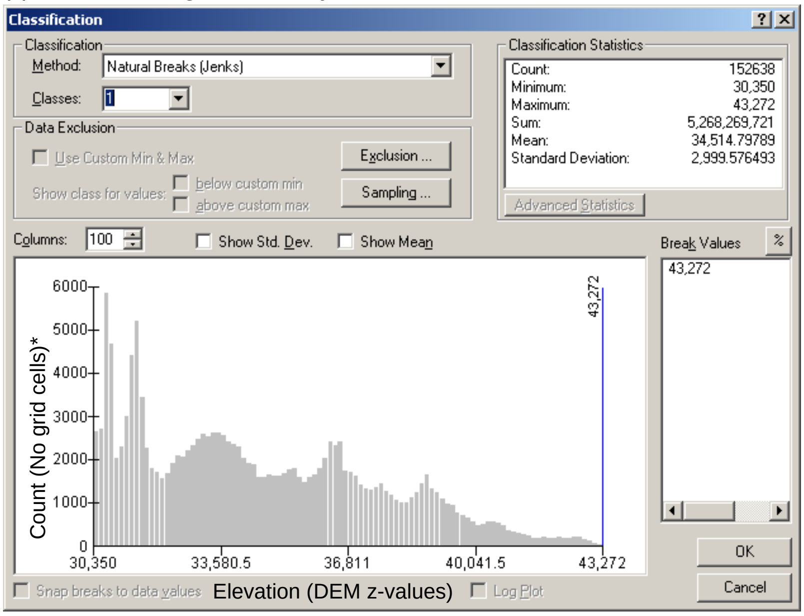
- The even proportion of elevation values at the higher and lower ends of the distribution, indicate a landscape without bias towards lowlands or uplands
- Similarity between (i) and (ii) in shape of their respective curves indicates that remnant native vegetation (ii), is distributed relatively evenly across the elevational range occurring within the RL (i).
- The difference in area under the curves (i) and (ii) indicates proportion of vegetation present within the RL . (i) ie: ~ 70%.

Fig 8b: Mollerin Representative Landscape (RL): elevation histograms

(i) RL area: distribution of elevation values



(ii) Remnant vegetation only: distribution of elevation values



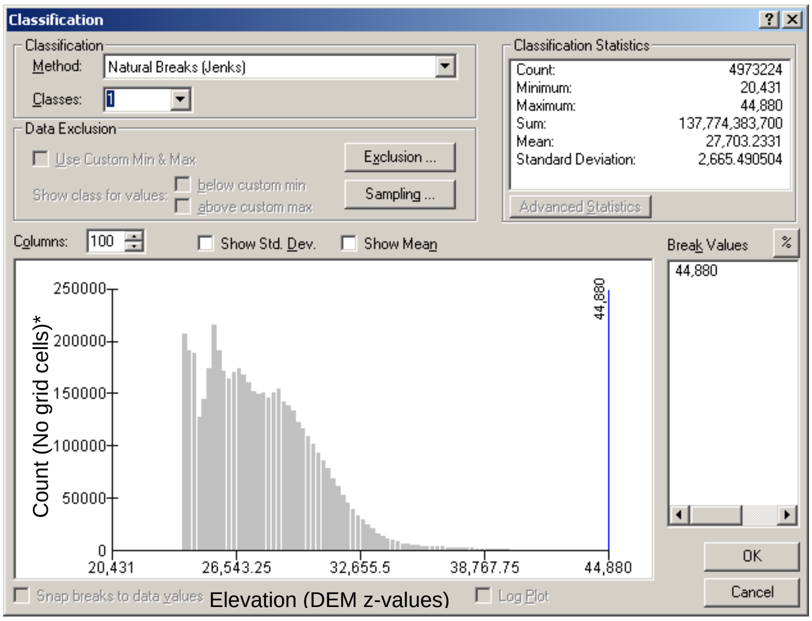
*Note grid cell dimensions = $2m^2$

- (i) curve indicates bias in elevation towards low elevations ie RL associated with lowland parts of landscape.
- Comparing (i) and (ii) in shape of their respective curves indicates that remnant native vegetation (ii), is distributed relatively evenly across the elevational range occurring within the RL (i) but with some bias towards the lower elevations ie lowlands.
- The difference in area under the curves (i) and (ii) indicates proportion of vegetation present within the RL . (i) ie: ~ 8%

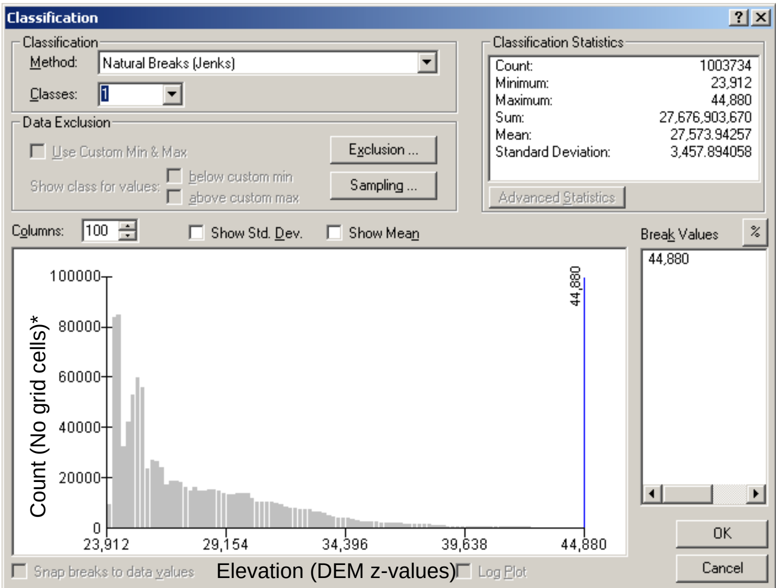
Over 75% of the RL is cleared , within which the remaining vegetation occurs more or less evenly throughout the elevational range within the RL. This range is biased towards the lower landscape.

Fig8c: TL46 Representative Landscape (RL): elevation histograms

(i) RL area: distribution of elevation values



(ii) Remnant vegetation only: distribution of elevation values



*Note grid cell dimensions = $2m^2$

- (i) Curve indicates strong bias towards low elevations i.e. RL associated with lowland parts of landscape.
- Comparing (i) and (ii) the shape of their respective curves indicates that remnant native vegetation (ii), is distributed with a strong bias towards lower elevations relative to the elevational range occurring within the RL but not completely absent from high elevations.
- The difference in area under the curves (i) and (ii) indicates proportion of vegetation present within the RL. (i) i.e.: ~ 20%

Over 75% of the RL is cleared, within which the remaining vegetation occurs mainly towards the lower elevations. This implies a tendency towards higher elevation (upland and midslope?) clearing.

Terrain related models currently exist to assist in natural resource planning eg BIOCLIM, ANUCLIM and their application have been documented eg: Cawsey et al (2002). Of note is that terrain data such as DEMs can often be some of the most highly resolved accessible regional data, enabling analysis at a wide range of scales. Soil-landscape mapping such as that produced by the AgWA (Schoknecht and Tille, 2004) are potentially useful for representing biophysical catenae including landscape position and soil landscape processes. However care needs to be taken when correlating such data with vegetation: where components of the soil landscape mapping have incorporated the occurrence of native vegetation into the interpretation process, this may lead to what Dirnbock (2000) refers to as an interpretational "vicious circle" or Walshe (pers comm.), statistical "double dipping".

Appraisal of methodologies

From the methods explored with the data available in this study, there was only scope to obtain specific outputs from one data source, i.e. the Gioia - Hopper species endemism and richness grids. The intersection of the RL polygons with these data represents the most obvious and basic approach to fulfilling the project criteria i.e. it is objective, quantitative, involved no threshold criteria or expert opinion and only took into account the values intersected by the RL polygons without reference to the regional distribution of values. The difference in rank order derived from the endemism and richness values is an obvious expression of the different parameters each index represents. The method is straightforward but is based on one biotic attribute and therefore whether the RL rankings can be construed as indicative of relative biodiversity value is dependent on how well the surrogacy relationships the data represents are understood.

The irreplaceability analysis involved a quite different conceptual paradigm, and the results of introducing the RLs to the process were less explicit than the endemism and richness intersections. It should be acknowledged that the opportunistic incorporation of RLs into an analysis developed primarily for examining the association data might not have generated the outputs that would have been achieved by consideration of all inputs during the construction of the data model. However the ability to analyse all permutations of the spatial relationships and proportional representation of values for all attributes suggests the method represents an alternative approach to the simple amalgamation of outputs, the arguments about which have already been outlined.

Where the data inputs can be appropriately structured as an area by attribute matrix, within a regionally defined unit of analysis, the potential exists to combine data such as the wheatbelt survey species association derivatives and Beard's vegetation associations as attributes into the same analytical matrix. Perhaps not entirely relevant under the criteria guiding the T1 RL ranking project but of interest to note: where management costs have been determined for subcatchment units congruent with those of the analysis, then theoretically these too could be incorporated into the data matrix and the implications for biodiversity values examined in relation to management criteria.

Walshe, however, cautions that, while multi attribute analyses are computationally possible, it requires careful consideration of the data relationships eg, degree of correlation, covariance – statistical "double dipping". Extra attributes cannot be "tacked onto" the end of existing analyses – each new suite of data needs to be considered in an integrated context to give full consideration to the analytical implications, as well as relevance of the outputs.

Conclusions

Whatever biodiversity assessment model is used, it is invariably the case that the input data will involve establishing/demonstrating some kind of valid surrogacy relationship. The relevance of, or confidence in outputs will reflect the nature and appropriateness of the data, and the questions being asked as much the functionality of the biodiversity assessment method or model. For much of the data examined in this study there were longstanding, unresolved issues, and their debate and resolution must be part of a structure that ensures a well-documented process of review and refinement of data and methods. Invariably this involves expert judgement by those who will use the biodiversity assessment outputs as well as those who are most intimately associated with the collection, interpretation and transformation of primary and derived biodiversity data inputs.

With respect to the underlying guiding principles outlined in the introduction:

- Consideration of current biodiversity value only
- Exclusion of viability, or threat criteria,
- Independence from expert opinion.

It was not possible to develop a specific methodology for ranking T1 RL in the project time frame exclusive of expert assessment, and in an entirely objective and quantitative process.

Although there may be objective components involved, expert opinion is infused throughout the whole process of biodiversity assessment, from data collection through to interpretation of analytical outputs.

It should be noted that the smaller the analytical unit, the greater will be the flexibility in assessing the value of biodiversity assets. This will not only have implications for assessing asset value, but also allows greater flexibility where assets of varying scale need to be integrated with management at various scales.

The existing RLs provide a working framework for the current operational practicalities of salinity threat management. Concurrent explorations into the fundamental relationships and derivatives of "baseline" biophysical data can be continued in a less spatially constrained domain. Data models of a scale such as those developed by Gioia-Hopper may not provide the right sort of information for assessing RLs individually but provide a regional "baseline" reference with which to periodically assess and redefine RLs as group. That is, to determine how representative they really are in a regional context – and whether they represent biodiversity hotspots, if this is a key objective.

For the WA wheatbelt, the relationship between biophysical processes and measurable values of biodiversity is complex.

Dirnbock (2000) surmised that the highly diverse vegetation of South Western Australia may be inherently unpredictable in terms of its local distribution, and generalised schemata of catenary sequences may be useful only as broad generalisations and not as operational models on a local level.

None the less, Hopkins proposals for a CAR strategy (2003) and preliminary biodiversity assessment for the Northern Ag Region (2003) incorporating the thematic redefinition of Beards vegetation mapping and current vegetation extent data set represent examples of attempts to integrate regional and local scales of biodiversity assessment by the department. Beechams' (Wallace 2003) Target Landscapes provide an objective approach to defining functional habitats in relation to population viability, and are worth further attention.

The problematic situation of combining two different approaches – one based on expert opinion the other on a semi-quantitative analysis – to generate high value landscape assets was articulated in the SIF Phase I report. The criteria and methods developed under SIF phase I process, while considered to have provided a valuable starting point for priority setting, were acknowledged by it authors to have been inadequate in the longer term. It was noted that considerably more work was required to develop a more complete method based on a range of criteria. This continued to be an important issue in the current project and needs to be addressed through an analytically explicit enquiry.

Finally, it is apparent that any informed exploration of analytical methodologies for biodiversity assessment, whether successful at achieving a specified objective or not, will reveal some kind of important information about the underlying nature and relationships of data and how they can be interpreted most appropriately.

Recommendations

That application of irreplaceability models such as c-plan currently being assessed is pursued in relation to the T1 RLs, using additional available data and employing relevant expertise.

Within CALM and Allied agencies eg, AgWA, WRC, DoE: establish some manner of formal or at least informal expert panel, structured to periodically:

- Review, develop, refine and critique relevant aspects of data acquisition, management, analysis and application for biodiversity assessment and management objectives.
- Re-evaluate the lines of data enquiry outlined in this report, and determine whether these should be pursued or terminated with the relevant documentation.
- Enable feedback and communication of relevant information between the lines of data/analysis/methodology inquiry and the people and /or agencies associated with the expertise and facility for the pursuit of these lines of enquiry.

The shortcomings of combining different analytical approaches as part of a priority setting methodology articulated in both the SIF Phase 1 process and this project need to be reviewed and explicitly defined to enable the development of a sound analytical framework within which to continue building the SIF biodiversity assessment process.

References

Bowyer, J, *Lort and Young Rivers Catchment, catchment appraisal 2001*, Resource Management Technical Report 231, The Department of Agriculture

Brooker, and Margules

Cawsey, E.M., Austin, M.P., and B.L. Baker, *Regional vegetation mapping in Australia: a case study in the practical use of statistical modelling*, Biodiversity and Conservation, 11: pp 2239-2274, Kluwer, Netherlands, 2002.

Burgman M.A. 1988. *Spatial analysis of vegetation patterns in southern Western Australia: implications for reserve design.* Australian Journal of Ecology 13:415-429.

Department of Environment 2003, Salinity Investment Framework Interim Report – Phase 1, 2003, Department of Environment, Salinity and Land Use Impacts Series No. SLUI32.

Dirnböck, T., Hobbs, R.J., Lambeck, R.J., Caccetta, P.A and J.F.Wallace. *Vegetation distribution in relation to topographically driven processes in the Western Australian Wheatbelt*, unpublished report, CSIRO Wildlife & Ecology, 1st June 2000.

Eardley, K.A., *A Foundation for Conservation in the Riverina Bioregion*. Unpublished Report, NSW, NSW National Parks and Wildlife Service, 1999.

Environment Australia. *Revision of the Interim Biogeographic Regionalisation for Australia (IBRA) and Development of Version 5.1* - Summary Report, Environment Australia, November 2000

Faith, D.P., Carter, G., Cassis, G., Ferrier, S., and L. Wilkie, *Complementarity, biodiversity viability analysis, and policy-based algorithms for conservation.* Environmental Science and Policy 6, pp 311-328, Elsevier, 2003.

Faith, D.P., *Environmental diversity (ED) as surrogate information for species –level biodiversity*, Ecography 26:3, 2003.

Ferrier, S., Pressey R.L., and T.W., Barrett, *A new predictor of irreplaceability of areas for achieving a conservation goal, its application to real-world planning, and a research agenda for further refinement*. Biological Conservation 93, pp303-325, Elsevier, 2000.

Hopkins, A., and R Morgan, *Conservation of Ecosystems and Ecological Communities in Western Australia*. Discussion Papers 1 & 2 CALM April 1999.

Hopkins, A., *Northern Agricultural NRM Region, preliminary biodiversity assessment*, Draft Project Proposal, CALM 15th May 2003.

Hopkins, A.,(a) *Northern Agricultural NRM Region Preliminary Biodiversity Assessment*, draft project proposal CALM 15th May 2003.

Hopkins, A.,(b) *Establishment of a comprehensive, adequate and representative terrestrial conservation reserve system in Western Australia*., CALM January, 2003

Keighery, G. and M Lyons, Attachment E: *Existing and Potential natural diversity recovery catchments indicative list*, Calm submission to the WA Salinity Taskforce 6th July 2001).

Lambeck, R.J, *Landscape planning for biodiversity conservation in agricultural regions, A case study from the wheatbelt of Western Australia*., Biodiversity Technical Paper No. 2, Department of Environment and Heritage, 1999.

Mac Nally, R., Bennett, A.F., Brown, G.W., Lumsden, L.F., Yen, A., Hinkley, S., Lillywhite, P., and Darren Ward, How well do ecosystem-based planning units represent different components of biodiversity. date?

Margules, C.R., Pressey, R.L. and P.H. Williams, *Representing biodiversity: data and procedures for identifying priority areas for conservation*, J. Biosci. 27:4 Suppl. 2, July 2002.

Sahotra, S., and C Margules, *Operationalising biodiversity for conservation planning*, J. Biosci, 27:4, Suppl. 2, pp299-308, Indian Academy of Sciences, July 2002

Sakar, S., Aggarwal, A., Garson, J. , Margules, C., and J. Zeidler. *Place prioritisation for biodiversity content*, J. Biosci, 27:4, Suppl. 2, pp339-346, Indian Academy of Sciences, July 2002

Sarkar, S., and C. Margules, Operationalising biodiversity for conservation planning, J. Biosci, 27:4 Suppl. 2, pp 299-308, Indian Academy of Sciences, July 2002.

Schoknecht, N., and P. Tille, *Soil-landscape mapping in south-western Australia – an overview*. Department of Agriculture, Government of Western Australia, 2004.

Shepherd, D., A Method for the assessment of the Conservation Values of Native Vegetation Using Geographic Information Systems, Department of Agriculture, Government of Western Australia, September 2002

Shepherd, D.P., Beeston, G.R., and A.J.M., Hopkins, *Native Vegetation in Western Australia, extent, type and status*. Resource Management Technical Report 249, Department of Agriculture, Government of Western Australia, February 2002.

Smart, J.M., Knight, A.T. and M. Robinson. *A Conservation assessment for the Cobar Peneplain Biogeographic Region – methods and opportunities*. NSW National Parks and Wildlife Service, 2000.

URS, *Salinity Investment Framework, Phase II: Assessment of State assets for feasibility*, draft report to the Department of Environment 5th April 2004.

Wallace, K.J., Beecham, B.C. and B.H. Bone. *Managing natural biodiversity in the Western Australian wheatbelt*, Department of Conservation and Land Management, 2003.

Walshe, T.V., Halse, S.A., McKenzie, N.L. and N. Gibson, *Toward identification of an efficient set of conservation recovery catchments for Western Australian wheatbelt biodiversity*. In Press, 2004.

Williams, P.H., Margules, C.R., and D.W. Hilbert, *Data requirements and data sources for biodiversity priority area selection*. J.Biosci, 27:4, Suppl. 2, pp327-338, Indian Academy of Sciences, July 2002.

Appendix 1: Approaches to Biodiversity Assessment in Australia

It is not within the scope of this project to provide a critique of the full extent of the theoretical and practical principles of biodiversity assessment that have been explored in the literature. However, attempts to generate quantitative models that aim to infer the nature of biophysical relationships from a discrete set of data or infer other unmeasured variables of biodiversity from an explicit set of measured variables, highlight an important aspect of comparative biodiversity assessment analysis.

Examples of this can be found in studies by Cawsey et al (2002) in applications from a Central Lachlan (NSW) case study in practical use of statistical modelling incorporating multi-parameter natural land resource information for regional vegetation mapping and remnant patch prioritisation; Dirnböck et al (2000) assessed the performance of topographically driven variables in models of vegetation distribution in the WA central wheatbelt.

These types of enquiry often invoke some notion of surrogacy between a measured and modelled variable and thus can provide insights into the way data may or may not be correlated in attempting to raise some kind of meaningful index of biodiversity for place prioritisation.

Critical appraisal of quantitative models, strategies and cautionary principles associated with analysing biophysical relationships for area prioritisation in biodiversity NRM planning have been explored by: Williams et al (2002), Sarkar and Margules (2002), Sarkar et al (2002). Specific reference to principles and applications of irreplaceability and complementarity concepts have been explored by Faith et al. (2002), Margules et al (2002), and Ferrier et al. (1999). From a focal species perspective are the wheatbelt case studies of Lambeck (1999).

Review of Approaches to SW regional biodiversity quantitative assessment methods

Within the South West agricultural region there have been, or are currently being pursued, a number of efforts by CALM as well as other agencies in:

- Developing systematic methods of biodiversity assessment to direct prioritisation of management resources.
- Interpreting how environmental data can be used to identify regional patterns of biodiversity, eg “hot-spots”

The following are examples of recent projects undertaken or proposed by the department:

- Generation of Target Landscapes – as previously outlined, the method used a standard GIS patch analysis procedure to identify functional landscapes based on the proportion of remnant vegetation extent as a habitat surrogate for assessing population viability (Beecham 2003).

- Under SCRIPT (South Coast Initiative Planning Team) a pilot project was set up with the objective of capturing information and developing a grid-based analysis to determine biodiversity conservation priorities for the south coast region. The project tried to encompass a comprehensive input from a broad range of potential corporate and local sources of data pertinent to biodiversity assessment. Considerable effort was applied to:

  - Examining the data and potential derivatives in terms of the biodiversity assets they might represent,
  - Approaches to spatially defining biodiversity assets that are dispersed or manifest as non-discrete entities, eg mobile fauna.
  - Spatial issues of habitat size, connectivity, corridor distance.
  - Development of weighting criteria,
  - Determination of assessment scale, concepts of proportional representation with respect to some defined regional context.
  - Prioritisation of biodiversity assets in relation to cost/benefit, viability and threat.

  The maximum grid resolution used in the analysis was 50m and a series of surfaces were created in which all cell values were classified to create a congruently scaled set of comparative ordinal rank values. All classified grid surfaces where combined such that the output grid represented total estimated biodiversity value.

  To emulate continuous surface grids for DRF and Fauna point data, a density model incorporating a distance decay function using a 1000m kernel was applied.

  The process was a challenging task for the GIS officers involved in searching through data, discussing appropriate interpretations, transformations, weightings and classification of the data for use in a grid based model that would achieve explicable outputs accessible to regional stakeholders and natural resource managers. (Information from CALM's working notes, GIS Section, and from discussions with Trevor Smales.)

- The Northern Agricultural NRM Region preliminary biodiversity assessment. This is a proposed 3-phase project involving the creation of a primary database into which all regional data relevant to biodiversity assessment is being entered. In the process of so doing the aim is to:

  - Carry out a gap analysis of regional biodiversity values,
  - By using explicit procedures, prioritise those issues and land parcels requiring further examination.
  - Develop a ground survey program to support the local and regional objectives.

The proposal represents a strategy within which a substantial program of methods, actions and outputs will take place, the details of which are further outlined by Hopkins (2003a).

Establishment of a comprehensive, adequate and representative (CAR) terrestrial conservation system in Western Australia.

This represents a strategic response to a key departmental responsibility for the development of a CAR conservation reserve system. One of the key functions is the development of a spatial analysis framework that will provide a basis for setting land acquisition priorities and off-reserve management agreements. Inherent in the development of the strategy is a capability for interpreting and spatially quantifying meaningful functions of biodiversity. The full extent of this undertaking is outlined in a series of discussion papers (Hopkins 1999 and 2003b).