DRAFT

DEFINING BIODIVERSITY ASSETS + VALUES: DEVELOPMENT + APPLICATION OF TERMINOLOGY FOR CONSERVATION IN THE SOUTHWEST AGRICULTURAL REGION + AVON CATCHMENT

FOR
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

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syrinx environmental pl
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1.0 INTRODUCTION

1.1 BACKGROUND

The Salinity Investment Framework (SIF) was developed by the State Salinity Council to improve the way funding is distributed to salinity initiatives at State, regional and catchment levels. The aim of the SIF is to ensure that funds are directed to projects with the best potential to protect high value public assets.

The Minister for the Environment and Heritage, the State Salinity Council, the Avon Catchment Council, Department of Conservation and Land Management, Department of Agriculture and the Water and Rivers Commission are conducting a trial or ground-truthing of the SIF for the southwest agricultural region and within the Avon natural resource management region. This process is expected to produce the following outcomes:

- State priorities for salinity action;
- A priority listing of projects for the Avon NRM region;
- A documented SIF process;
- An evaluation of the process as applied during the trial;
- A set of guidelines on how to implement the process;
- Criteria used in the analysis to make decisions;
- Details of information sets needed to make decisions;
- Skills required by the people involved; and
- The approximate cost of implementing the process.

The Department of Conservation and Land Management, as the key agency for biodiversity conservation, is participating in both the State and regional level components of the SIF project.

To assist with this project, the Department has appointed Syrinx Environmental PL to help the project team refine some of the steps in the priority setting process.

Four types of assets will be considered under the SIF – biodiversity, land, water and rural infrastructure. This review focuses only on the biodiversity component of the priority setting process.

1.2 PROJECT TASKS

Three key tasks have been identified as requiring input from Syrinx Environmental PL:

1 - Conduct a literature survey of parameters used to characterise biodiversity conservation assets and provide a revised list of parameters.

2 - Through literature review, discussion with personnel and a workshop, prepare a draft list of selection criteria for ranking landscapes with significant biodiversity conservation values.

3 - Undertake a literature review and prepare a summary of methods used to allocate priorities among biodiversity conservation assets, and between biodiversity conservation and other goals including land conservation, water conservation and infrastructure protection.

This paper presents results of the first project task for circulation and comment. The paper is intended to provide a basis for discussion amongst scientists and managers, and will be modified on this basis.

2.0 STUDY APPROACH

The resolution of the key SIF project objectives outlined in Section 1 requires the development of one or more frameworks to guide a decision process. The first task, which is to derive a list of biodiversity assets that is to have agreement amongst conservation agencies, managers and scientists, needs a framework which is fully inclusive of the components of biodiversity and their current values, since this stage underpins the priority selection phase. This first stage must present a means of compartmentalising all information across all scales which may have input into the conservation selection process. In other words, in deriving a list of biodiversity assets, the process of addition and subtraction, which is largely driven by human goals and needs, must be made transparent. This allows progressive changes to asset lists with time as more information becomes available for species, communities, landscapes, and species habitat requirements.

Through the course of this literature study it became apparent that conservation biologists, ecologists, and others contributing to the sphere of biodiversity conservation, use a plethora of terms that are poorly defined and inconsistently applied. This problem was raised as early as 1935 by Tansley (1935) who cited the dangers such confusion causes to scientific understanding and conservation biology. Moreover, few papers have dealt with the concept of biodiversity from a multidisciplinary or philosophic perspective, a situation considered by one author to reflect the tendency of post-Aristotelian science to be driven by specialisation and poor appreciation by many scientists for fields outside of their specific area (Naeem 2002). Similarly, classification frameworks for assessing conservation significance of areas are uncommon (but see Semeniuk and Semeniuk 1997 and the RAMSAR convention for a global and regional classification of wetlands respectively). Moreover, the concepts of value judgements, and risk or threat analysis, while used widely in resource economics and the social and health sciences, has not always sat comfortably with scientists and has only relatively recently been used in this State (eg. Priority codes for flora/fauna, TEC's). However, managers of biodiversity must engage these concepts on a daily basis to effect practical management of conservation areas with limited financial resources.

The approach taken in this paper is to:

1 - Review the literature and;

2 - Derive a framework based on the literature, as well as on the objectives and outcomes in relation to SIF, for defining biodiversity assets.

Using the literature, in context with the goal of biodiversity conservation given as the driver to the State conservation process (Wallace et al., 2002, Appendix 1), this framework defines the process gap between establishing the goal and defining the biological asset.

The structure of the report is as follows:

1 - A preamble is given on the current definitions and values of biodiversity as used in recent literature, and a comment on measures of biodiversity (which remain controversial);

2 - A discussion on papers that deal with (explicitly or implicitly) the notion of biodiversity assets as defined by Wallace et al., (2002) and it's component parts (i.e. entity, characteristic, value);

3 - A proposed framework for defining biodiversity assets in general;

4 - A revised list of biodiversity assets for the Wheatbelt region.

3.0 BIODIVERSITY

3.1 DEFINING BIODIVERSITY

Definitions of biodiversity vary in the literature, but typically the term is used to refer to 'the total (and irreducible) complexity of all life, including species variety and their varying behaviour and interactions' (Williams *et al.* 1999). The global biodiversity strategy defines biodiversity as 'the total of genes, species and ecosystems in a region' (World Resources Institute (WRI), 1992), which adds a scalar perspective. Williams *et al.,* (1999) add that biodiversity is 'a quantifiable value that is both broadly shared among the people for whom they are acting and considered as being in need of protection', which adds a common 'value' and 'measure' component to the definition. Biodiversity is usually categorised into its components, namely genetic diversity, species diversity and ecosystem diversity (Cogger, 1993; Department of Environment, Sport and Territories (DEST), 1993; Sattler, 1993; Cohen and Potter, 1993; Williams et al., 1999). Fundamental to the concept of biodiversity are the different levels of biological organization ranging from landscapes to genes

Biological diversity conservation is dependent on the level of information and awareness among the communities in any country (Nkosi 2002). 'Biodiversity loss is not primarily a biological problem but a sociological one involving both moral/ethical issues and self-interest/utility issues...only fundamental changes in human economic, ethical and social systems can reduce current rates of biodiversity loss' (Cogger 2000). Wallace et al., (2002) emphasised that biodiversity assets must reflect the goal, and the goal, being a human notion, must reflect the human need or more correctly, perceptions of need. Wallace, Beecham and Bone (in draft 2002) also correctly note that at this level, ie. the top of the process chain, we as humans do not all share the same understanding of our genetic and cultural need for biodiversity. From the beginning, the generation of a framework for assessing conservation priorities and implementing conservation objectives, is driven by and limited by human culture.

3.1.1 Biodiversity Values

Values are generally discussed in the literature in relation to human needs (eg. Williams *et al.,* 2002; Beattie, 1993; Vane-Wright, 1996; D.E.S.T, 1993). Although it is not the purpose of this paper to fully review biodiversity values, they are briefly summarised to maintain the context of discussion.

Wardell-Johnson (1996) and Horwitz (1996) state that high value areas must be identified before they can be managed to conserve biodiversity. This presupposes an agreed value set of some sort. Williams *et al.* (2002) states that the value chosen for conservation of biodiversity should be broadly shared by the people and preferably ought to be quantifiable (at least in relative terms) for arguments presented to economists, politicians and their constituents.

DEST (1993) and Williams (1996) identifies biodiversity value under the following groups; ecosystem services, biological resources and social benefits. Services and resources included in these groups are beneficial to maintain biodiversity. In the wheatbelt, natural biodiversity contributes to the following community values that have been specifically detailed in Wallace, Beecham and Bone, (in draft).

- Consumptive use values;
- Productive use values;
- Opportunity values;
- Ecosystem service values;
- Amenity values;
- Scientific and educational values;
- Recreational and tourist values;
- Spiritual/sense of place values.

Ecosystem services are becoming increasingly linked with sustainable use of the planet, although there is no robust evidence on what level of biodiversity is essential for this (Cairns 2002). Ecosystem services include protection of water resources, soils formation, maintenance of biological diversity, soil structure formation and protection and the retention of moisture and nutrient levels. Such benefits as nutrient storage and cycling assist in food production for multiple levels of ecosystems, from bacteria to higher life forms. This has a dramatic flow down effect, with influences on such things as pollution breakdown and absorption, vegetative influences on micro- and macro-climates. Furthermore, maintaining healthy ecosystems improves the chances of recovery of plant and animal populations from unpredictable natural catastrophic events (DEST, 1993).

Biodiversity in the context of a biological resource primarily refers to the heavy dependence of humans and other organisms on primary producers (mainly plants). The wild gene pool has incredible value to the agricultural sector as it provides disease resistance, improved productivity and different environmental tolerances (DEST, 1993). Many Australian native species are also reputed to have great food potential as some have greater amounts of protein, fats, carbohydrates, minerals and vitamins compared to cultivated foods. A number of Australian species are also recognised to be the basis of medicinal products. Wood products, ornamental plants, breeding stocks and population reservoirs are all additional values placed by humans on biological resources. Future resources are also an important as there are a large number of as yet undiscovered plant species which could provide future benefit to society (Beattie, 1991).

Using plants or animals for research, education and monitoring purposes are examples of the social benefits of biodiversity (Beattie, 1991; DEST, 1993; Burbidge, 1993). Natural areas provide excellent living laboratories for such studies, for comparison with other areas under different systems of use, and for valuable research into ecology and evolution (Barker, 2002; DEST, 1993). Social values also include aesthetic, recreational, cultural and spiritual aspects.

Returning to the Wallace et al., (in press) wheatbelt values, these might be broadly re-grouped as follows:

1 - Biological Resource - Consumptive use values; Productive use values; Opportunity values

2 - Ecosystem Service Values - Opportunity values;

3 - Social/Spiritual Benefits - Amenity values, Scientific and educational values; Recreational and tourist values; Spiritual/sense of place values.

These are the values that should drive the goal (which has been set as the conservation of biodiversity). They are also the umbrella values that must drive the definition of assets or quantifiable values.

3.1.2 Biodiversity Measures

Most of the arguments in biodiversity conservation centre on differences in quantifying or measuring biodiversity value (Humphries et al., 1995; Barker, 2002). Williams et al. (2002) and others (Faith et al., 2001; Sakara, 2002; Petchey and Gaston, 2002) suggest that no single objective measure of biodiversity is possible, only measures relating to particular purposes or applications (Williams et al., 2002). The debate on measures of biodiversity relate to 'what' is measured and 'how' it is best measured. This is largely the realm of later stages of the present project, and will not be addressed further in terms of defining biological assets, although is considered at some level in terms of clarifying terminology.

Main biodiversity measures are linked to diversity scales, and include genetic richness (Coates and Atkins, 2001; Williams et al., 2002), species richness, community richness (English and Blythe, 1999), complementarity-derived focal taxa (eg. Lund and Rahbek, 2002) and a range of biodiversity surrogates (Humphries et al., 1995; Ferrier, 2002; Moritz, 2002). Williams et al., (2002) and others (see Cohen and Potter, 1993) argue for a single currency approach using genetic diversity as a basis for measuring species diversity (for their relative richness in different genes) and ecosystem diversity (for the relative richness in the different processes to which the genes ultimately contribute). Species richness as a common measure of community and regional diversity (Magurran, 1988), is an elusive quantity to measure properly (May, 1988), and ecologists have recently been taken to task for not appreciating the effects of abundance and sampling effort on richness measures and comparisons (Gotelli and Colwell, 2001).

3.2 BIODIVERSITY ASSETS

The term 'asset' is described by the Macquarie Dictionary, (1997) as being 'an item of property, a person, thing or quality regarded as useful or valuable to have'. Wallace et al., (2002) defines biological assets as 'physical entities with specific biodiversity characteristics that are of value to humans'. Therefore it must be tangible, and therefore might be redefined simply as a 'valuable 'thing' (for biodiversity). Note that Wallace et al., (2002) uses both 'biological asset' and 'biodiversity asset'. It is suggested that the latter is used to maintain the hierarchical connection to biodiversity values and the biodiversity goal.

It should be noted at the outset that the concept of 'asset' as used by Wallace et al., (2002) has not previously been applied to biodiversity in the literature. Most authors deal with definitions of biodiversity, the value of biodiversity, and the measure of biodiversity as discussed above. The implied 'asset' is only dealt with as a component of biodiversity when deriving measuring techniques, i.e. the term 'asset' may be equated with 'quantifiable values'.

Although not used in the literature, the term biodiversity asset provides a concept that demands specificity and therefore is considered an essential link between the science and philosophy of biodiversity and operations. However as it stands, as pointed out by Wallace et al., (2002), it requires clarity and discussion.

Wallace et al., (2002) note that it is essential to identify those biodiversity assets that need to be protected and restored to achieve the goal. Note however that the goal is set by the values (i.e. biological resource, ecosystem services, social), so defining biodiversity assets must also satisfy the values, which means assets need to meet biological resource, ecosystem service and/or social values. This is important since the current proposed list of biodiversity assets (Appendix 2) implies a refined values list (e.g. rare, endemic), which while fitting in to broad current biodiversity values, exclude future values. The immediate intent of this paper for now is to develop a framework for defining assets at a point in time, ignoring viability values into the future. These will need to be addressed at a later stage.

3.2.1 Separating Assets and Function

The validity or otherwise of excluding function and process concepts from the definition of biodiversity assets is discussed in this section. Wallace et al., (2002) states that 'we manage the processes to protect the assets to achieve the goal to deliver the human values derived from biodiversity', and states that consequently, functional elements can be removed from defining biological assets. However, the ecological service value of biodiversity implies ecological function (Cairns, 2002), which means function is inextricably linked to both the goal and the definition of the assets. Indeed, all entities have functions. Further, the emerging paradigm that biodiversity governs ecosystem function is rapidly evolving – ie. the asset dictates the function or processes, rather than the processes dictate the asset. This debate has redirected ecology to focus on the feedback between ecosystem function and biodiversity rather than studying them independently (Naeem, 2002). For this reason, a review of the logic sequence as it relates to changing landscapes, such as the wheatbelt region, is needed before an asset definition can be resolved.

Existing data on landscapes modified by large-scale process change, such as salinity and waterlogging, show in some cases at least, species are declining in numbers and have or are expected to become extinct (Recher and Lim 1990, Saunders and Ingram 1995, Menge and Sutherland 1987, M. Carey, unpubl data), ie. natural systems respond in accordance with current community ecology theory where the distribution and abundance of species is a function of altered abiotic (physical and chemical conditions) and biotic (species interactions) factors. The relative importance of environment-species, or species-environment interactions is likely dependent on the rate of change and frequency of disturbance, more so than spatial impact of change (consider the history of fire impacts in the south-west for instance, which have shown altered species composition). As stated in Wallace et al (2002), the most striking example is that increasing salinity threatens some 450 species of plants and numerous native animals with extinction (Keighery 2000).

The questions relevant to the separation of asset and function from a management perspective are 1. how does one define the point at which biodiversity 'becomes a slave of the environment' (Naeem, 2002), rather than a major determinant of the environment?, and 2. is this reversible with management, or through natural arrest of stress processes?, eg. as catchments reach a new hydrologic equilibrium. This is key since it determines to what extent managers must 'manage the processes to protect the assets', or 'manage the assets to protect the processes'. According to the new 'Biodiversity-Ecosystem Function' paradigm (Naeem 2002), the latter will be true; according to conventional community ecology theory, the former will be true. In reality, both are true (Naeem 2002). Few would disagree that *Homo sapiens* (the asset) has altered environmental processes dramatically on a global scale, and that this in turn has impacted on *Homo sapiens* in a feedback loop.

In any case, returning to the concept of biodiversity asset, whilst it is clear that a function or a process is not an asset, what is unclear is whether defining the asset is a sufficient step in setting priorities for conservation, or whether defining function is a better step, such that assets are ranked according to function, and conservation priorities are driven by ecological redundancy and complementarity principles, ie. an ecosystem approach rather than an organism (community) approach.

Once again, if we return to the goal of biodiversity conservation, we are forced to concede that:

1. Whilst function and processes are important, they are important for meeting human needs; this includes meeting the needs of other species needed to meet human needs;
2. The entity or entities performing the functions and processes we have identified as central to meeting human needs, is the (current) asset worth preserving for the service it provides;
3. This means that interactions (between assets) are necessary to provide some human needs (eg. air plus soil plus water plus mycorrhiza = edible plant; the edible plant might be considered the asset, but the plant is dependent on the soil, water and mycorrhiza – the plant might be considered the primary asset, the soil, water and mycorrhiza the dependent assets). The scale and nature of these dependencies, and interdependencies, will need to be defined for assessing viable

4. assets at a later stage, but also become key for determining the scalar boundaries of an asset, and assisting with the 'how' rather than 'what' issues of conservation;
5. If the entity stops providing such services, it is no longer an asset worth preserving (ie. low viability value).

Note that other assets may be defined by non-functional characteristics or values (eg. rarity). The issue of interdependency of assets need to be defined for particular (organism-level) assets such that areas set aside for conservation of such assets are large enough or intact enough to incorporate the required ecosystem functions associated with the asset. This is revisited in later sections.

In summary, it is logical to agree with Wallace (2002) that function and process are not the assets, however these concepts are central to the process of defining and valuing assets. For example, a species that contributes a specific, non-replicated function or group of functions will be of more value as an asset than one that contributes a generic function or set of functions. Of course the risk here is that the full suite of functions and processes provided by, or influenced by, a particular organism are not at all well understood, and will not be understood within the time scales required for effective conservation in changing landscapes such as the wheatbelt. From this perspective, a way forward would be to incorporate function as a characteristic or attribute of an asset.

3.2.2 Asset Components

The Wallace et al., (2002) definition of biodiversity asset includes three concepts: entities (physical), characteristics and values. In order to define a specific biodiversity asset, each of these concepts needs to be defined.

3.2.2.1 Entities

Biodiversity entities referred to in the literature are derived from the components of biodiversity, ie. genetic diversity, species diversity, ecosystem or community diversity, and regional diversity (Magurran, 1988; Williams et al., 2002; Sarkar, 2002; Cogger, 1993; Sattler, 1993; Cohen and Potter, 1993). Others use the terms alpha diversity (number of species in each habitat), beta diversity (turnover of species between habitats) and gamma diversity (regional species pool) (Ward and Tockner, 2001). In either case, the entity is gene, species, ecosystem, landscape, region described along a geographical or biological scale (e.g. Cogger, 2000; Sattler, 1993), or gene, species, habitat, where the scale at the gamma level is not fixed (e.g. Ward and Tockner, 2001). In either case, most authors use a hierarchical model to resolve biodiversity components, or entities. These hierarchies, although in detail the subject of many different viewpoints, (eg. Groves et al., 2002; Sattler, 1993; Noss, 1990) are normally in use as either ecological hierarchies and/or geographical hierarchies. For example, Aronson and LeFloc'h, (1996) suggest an ecological hierarchy as follows:

gene < individual < population < community < ecosystem < landscape < matrix < biogeographical region < biosphere.

They define 'ecosystem' in the classical sense as 'a biotic community and its biogeophysical environment, including all the interactions between and among them' (Tarnsley, 1935 in Aronson and LeFloc'h, 1996). They, and many other ecologists, define 'landscape' according to Forman and Godron, (1986) in Aronson and LeFloc'h, (1996), as 'a heterogeneous portion of land consisting of a recognisable cluster of ecosystems that interact in ways producing spatially repeatable patterns'.

Sattler (1993), suggests a hierarchy of biodiversity grouped into four levels including:

regional landscapes > ecosystem > species > genetic variation (see Appendix 4).

Regardless of the type of hierarchy used, it is clear, and most authors agree, that we must be explicit about scale (Aronson and LeFloc'h, 1996; Allen and Hoekstra 1987; Ward and Tockner 2001; Groves et al., 2002). In summary, entities are either biological or biogeographical, and are defined in a scalar context in the literature. The question of scale is relevant to the definition of assets at each scale, as well as to the scales of management as discussed by Wallace et al (2002). In a theoretical sense, all scales must be included to derive biodiversity assets comprehensively; in a management sense, the appropriate scale can be selected based on geographical, political and economic objectives and constraints Forman (1997).

Wallace et al (2002) addressed the need for selecting appropriate scales of management and noted that the type of physical scale used will often reflect a mix of characteristics best suited to the task at hand. From the standpoint of planning and implementing operational management, Wallace and Beecham (1998) found the following scales most useful:

- individual organisms;
- populations;
- specific, identifiable areas of bushland;
- landscapes; and
- bioregions and larger scales

3.2.2.2 Characteristics

The dictionary definition of 'characteristic' is '... relating to, constituting, or indicating the character or peculiar quality; typical; distinctive, a distinguishing feature or quality' (M.U, 1997).

Wallace et al., (2002) use the term 'characteristics' to link a 'value' to a 'thing'. Therefore, if a value is 'biological resource', and the entity is a 'species', a characteristic might be 'palatability'. If a value is 'ecological services' and the entity is gene, the characteristic may be salt-tolerant. In any case, the term characteristic may be useful for separating out the objective features of an entity, from those we consider at present to have a biodiversity value (asset).

The terms 'characteristic' or 'character' are used in the literature to define traits (e.g. phenotypic traits such as different chemicals, morphological features, functional behaviour)

(Williams et al., 2002). In these instances the term is objective, or at least is absolute, not relative, and furthermore it is suggested that characters are treated as of equal value given uncertainty about future values (Williams et al., 1994; Humphries et al.,1995). Such an approach allows flexibility in adding to an assets description as the current body of research expands, thereby reducing the exclusion principle, which at present is in danger of being built into the biodiversity asset concept. As an example, an individual population of a species (entity) may at present be considered a low priority for conservation, but may in time be found to contain ecotypic variants (characteristic) that add to genetic diversity and therefore contribute value (according to the human values defined earlier). This population then becomes a current biodiversity asset. This of course presumes that research must continue in the determination of 'future assets' in potentially unprotected areas, or run the risk of losing potential future assets – the acceptability or otherwise of these risks becomes part of the priority selection process. This choice is underpinned by the current 'aspirational goal' as defined by Wallace et al (2002) for the wheatbelt, which 'means that conserving, etc. the full range of natural biodiversity is the object of the goal. Thus provided the full range of natural biodiversity is conserved and replicated, it will be acceptable to allow some natural populations and individuals to be unprotected'.

In some cases the term characteristic is grouped with attribute, which is described by MU, (1997) as 'belonging to, resulting from, owing to, or having caused, and can be assigned or ascribed and can otherwise be known as a characteristic'. The term attribute is used much more widely in the literature, and a series of vital ecosystem attributes (VEA's) and vital landscape attributes (VLA's) have been identified to aid quantitative evaluation of structure, composition and functional complexity over time (Aronson et al., 1993; Aronson and Le Floc'h, 1996). Kelly and Harwell (1990) and Lefroy and Hobbs (1993) detailed similar attribute lists for riparian and agricultural ecosystems respectively. Sattler (1993) refers to biodiversity descriptors such as numbers, population structure and composition at each hierarchical level as 'patterns'.

Although the list of attributes developed by Aronson et al., (1993) and Aronson and Le Floc'h, (1996) were intended to assist in resolving restoration ecology problems, many of the ecosystem and landscape traits listed are equally useful here reinterpreted as characteristics that are considered to be useful for defining current biodiversity assets (note they are not in themselves assets). For example, a landscape (entity) with high (value) ecosystem diversity (structural characteristic) is a biodiversity asset; an ecosystem (entity) with high (value) productivity (functional characteristic) is a biodiversity asset. For this reason they are included below, although it is noted that they are a guideline list only intended to illustrate an approach; these should be modified for each relevant setting, scale and purpose. Note attributes relating to viability (eg. human impacts) are given in grey and are not considered useful for current asset definition.

The Aronson et al., (1993) VEA list is as follows:

1 - VEAs related to ecosystem structure

- Perennial species richness
- Annual species richness
- Total plant cover

- Soil-borne seed bank
- Above ground phytomass
- Beta diversity
- Life form spectrum
- Keystone species (presence or activity)
- Microbial biomass
- Soil biota diversity

2 - VEAs related to ecosystem function

- Biomass productivity
- Soil organic matter (OM)
- Soil surface conditions (SSC)
- Coefficient of rainfall infiltration (CRI)
- Maximum available soil water reserves (WR)
- Rain use efficiency (RUE)
- Cation exchange capacity (CEC)
- Length of water availability period
- Nitrogen use efficiency (NUE)
- Microsymbiont effectiveness
- Cycling indices

The Aronson and Le Floc'h (1996) VLA list is as follows (anthropogenic components deleted in grey):

- Type number and range of landforms.
- Number of ecosystems.
- Type, number and range of land units.
- Number and proportion of land use types.
- Number and variety of ecotones.
- Number and types of corridors.
- Diversity of selected critical groups of organisms (functional groups).
- Range and modalities of organisms regularly crossing ecotones.
- Cycling indices of flows and exchanges of water, nutrients, and energy within and among ecosystems.
- Pattern and tempo of water and nutrient movements.

A comprehensive list of attributes that apply similarly to finer biological scales (community, population, species, individual, gene) is not covered here, but again can generally be considered in terms of structure, function and composition. These attributes, or characteristics, provide an important matrix for attaching specific biodiversity values to individual entities, thereby deriving biodiversity assets.

Each of the characteristics described above and in Wallace et al (2002) can be separated more simply into the following structural characteristics:

- Number
- Type
- Area
- Range
- Diversity
- Representativeness

Number, type, area and range are better viewed as units of measure under the characteristic 'scarcity'.

Functional characteristics can be simplified as follows:

- Pattern
- Cation exchange capacity (CEC)
- Biomass productivity
- Hydroperiod
- Nutrient, physico-chemical flux
- Cycling indices of flows and exchanges of water, nutrients, and energy.

Note, each of these characteristics apply to biotic, rather than abiotic entities, which also have characteristics of value, if only accepted as important as secondary to the survival of particular organisms (see discussion in Semeniuk et al 2002). Natural history and geo-heritage features also have (often global) conservation significance (Semeniuk et al 2002 and references therein), and must also be considered in the conservation priority selection process.

3.2.2.3 *Values*

As mentioned in earlier sections, values are normally framed in the broad context of ecological services, biological resources and social benefits. However, individual entities (genes, species, communities etc) are mainly ranked in a conservation priority sense in terms of relative scarcity, i.e. rare, unique, endemic etc), which are the terms used by Wallace et al., (2002) as 'attributes' for describing assets, and currently in use globally (at least in theme) for prioritising conservation (Appendix 2). Rarity no doubt, is an important biodiversity value in the sense that it may reflect speciation (new genes) and relictual genes, unique genetic conglomerations, and unique aesthetic landscapes for example, but common species/communities/landscapes may also hold these values.

The genetic approach to measuring biodiversity argues for maximum variability, rather than rarity, as the key parameter for prioritising conservation (Coates 2001, Moritz 2002). Rare organisms have unusual traits that add to the gene pool, and are therefore necessarily covered by maximising variability in conservation reserves. A high degree of variability can also be considered as a value of a biodiversity asset, ie. the greater the variability (from a species through to landscape level), the higher the conservation value.

A third component relating to the value of biodiversity assets is a high level of representativeness within a region or landscape. Common species are accommodated in the Wallace et al (2002) list of assets under this value. This parameter places importance on the 'centre of distribution', 'parent gene pool' and dominant or typical characteristics at each geographical and biological hierarchical level. This is an important value since it takes into account common organisms and associations, which supplement genetic variability and optimise opportunities for adaptive change, and may hold future values unknown at a point in time.

To address all ecological service, biological resource and social benefit biodiversity goals, other umbrella value attributes are required. Most of the remaining biodiversity assets can be defined at the value level in terms of their functional values, and might be grouped under the broad heading 'usefulness'.

Much of this involves a revisit of the role of function in defining biodiversity assets as discussed above. Functional characteristics are, more often than not, unavailable for most ecosystems or landscapes; so at a practical level, the description of assets will be based on structural descriptors more so than functional descriptors. Returning to the current biodiversity-ecosystem function paradigm, the resolution may be to accept the following assumptions:

1. structural characteristics are a surrogate for function;
2. changes to structural characteristics will be reflected in changes to functional characteristics (at one or more scales); and
3. changes to functional characteristics will be reflected in changes to structural characteristics (at one or more scales).

If we accept this, for the purpose of defining current assets (ie. at a point in time) function is subsumed into the type, number, area, diversity and range within each entity scale, and for the purpose of defining future assets, or viable assets, changes to both structural and functional characteristics must be considered.

However, the value placed on structural characteristics may not represent the uniqueness or importance of specific ecological functions, and in most instances, the progress of research will normally identify values in parallel to characterising ecological function. For example, if a species is found to have the ability to accumulate metals (functional characteristic), its value or usefulness to humans will be immediately known. By including the term 'usefulness' as a biodiversity value, areas and organisms with known functional importance are included in the priority selection process. This accounts for current assets that have a known 'use' at this point in time, and also allows the option of adding biodiversity assets to the accepted list over time.

The term 'usefulness' may alternatively be called 'habitat value', since it implies all processes and functions necessary for the survival and health of individual organisms (including humans). For example, if passive recreational opportunities are granted as a fundamental human need, a management unit (say landscape) must be of an appropriate size and diversity to satisfy the value requirement of each recreational activity – bushwalking for instance requires a contiguous area on the scale of tens of kilometres to have high value, recreational swimming requires a water body with a range of limits on salinity, nutrients and heavy metals. Similarly, a landscape fragment may have high value as a breeding ground for a range of migratory species, and a cluster of landscape fragments may have high value for the (cross) breeding of sedentary species. On a global scale, ignoring all other values, the Amazon Basin has a significant (critical) functional role in the generation of the earth's oxygen supply.

4.0 A FRAMEWORK FOR DERIVING BIODIVERSITY ASSETS

4.1 SETTING THE SCALE FOR DEFINING BIODIVERSITY ASSETS

Aronson and Le Floc h (1996) noted that establishing a clear conceptual hierarchy is essential in the elaboration of a true landscape approach to restoration and rehabilitation ecology. The same clearly applies to biodiversity conservation, since management decisions must be made in the context of a range of competing priorities, limited resources and practical constraints to achieve an agreed goal (as mentioned by Wallace et al 2002).

Using the above literature review, this section attempts to outline a framework for deriving biodiversity assets using the evolution of terms and hierarchies discussed above. The framework follows the logic followed in above sections, ie. separating entities and sub-entities at various spatial scales, defining characteristics that apply at each sub-entity (which may be viewed as purely biological, purely physical, or a combination of these), and defining current values (for biodiversity characteristics only).

The proposed framework, given in Appendix 3, is based on a biogeographical hierarchy:

Supra-region > bioregion > landscape > ecosystem

And a biological hierarchy:

Community> population > organism > gene

Sattler (1993) used the biogeographic approach for developing a nationwide biodiversity strategy for Queensland, which is represented in the form of a pyramid structure (Appendix 4). This type of framework has value beyond the identification of biodiversity assets, such as at the next level of defining current and future values. Noss (1994) suggests two hierarchies, firstly a biological organisation (eg. genes, populations, communities-ecosystems, and landscapes), and functional hierarchies including the sequence: genetic processes, demographic processes-life histories, interspecific interaction-ecosystem processes, landscape processes and disturbances-land use trends.

Note that ecosystem is included separate to community in the proposed framework adhering to original definitions, where community is an interaction amongst organisms (ie. biotic), and ecosystem is the interaction between biotic and abiotic components. Note that in terms of management in this State, community is often used rather than ecosystem because the boundaries of these as management (and research) units are easier than ecosystem units, which are often fragments. In terms of management however, they are managed as a cluster of communities within a bushland remnant, which are often actively managed in terms of ecosystem processes (eg. fire, hydrologic change, salinity). That is they are defined as communities and managed as ecosystems.

The framework used in this section is used for the purpose of ensuring characteristics and values (hence biodiversity assets) are described at each scalar level, ie. for the moment ignoring what may be more useful in a management sense which can effectively be abstracted from the main framework.

Definitions of ecological terms vary widely in the literature, and the best one that suits the purpose is applied here with as much adherence to classical definitions as possible. Note this does not necessarily deal with the problems of quantifiable definitions (e.g. for ecosystem) or how these are to be measured, or the inconsistencies in types (e.g. 'Wetland ecosystem' – which is defined by abiotic geomorphic and/or hydrologic characteristics, versus 'Woodland ecosystem' – which is defined by biotic factors).

The structure of the frameworks is based on the entity, characteristic, asset or value attribute and value as discussed in previous sections above. Note the framework is by no means a comprehensive listing of characteristics or of assets at this stage. Note also that future values are ignored at this stage.

The term characteristic is used to describe a biodiversity entity. Note that the list of characteristics provided is incomplete, and in itself can be broken down into more helpful levels, which has already been done by many authors, but again rarely in the same manner (eg. Wiens 1999, Sattler, 1993; Aronson and Le Floc'h, 1996; Noss, 1990).

The biogeographical entities are defined as fixed in scale (temporal and spatial). Their definitions are as follows:

1 - Bioregion is as defined by the National Land and Water Audit (NLWA), and in use by SIF and has been used by Sattler (1993). The term supra-region is included above this level to accommodate migratory species whose habitats (and therefore conservation requirements) are often at inter-regional scales.

2 - Landscape is almost always included in biological hierarchies and refers to, 'a heterogeneous portion of land consisting of a recognisable cluster of ecosystems that interact in ways producing spatially repeated patterns' (Forman and Godron 1986)

3 - Ecosystem was originally coined by Tansley (1935), 'a biotic (group of) communities and (their) biogeophysical environment, including all the interactions between and among them', and was intended to deter the natural human prejudice of focussing on organisms rather than on the system as a whole. The term ecosystem is widely used in biological hierarchies (eg. Aronson and Le Flo'ch 1996, Sattler 1993, Groves et al., 2002; Noss, 1990; Ward and Tockner, 2001) although as noted by Sarkar (2002), 'the highly fashionable term … is about the worst-defined in the ecological literature. The original definition by Tansley (1935) is used here.

The biological entities are considered non-fixed in scale (temporal and spatial). Their definitions are as follows:

4 - Community is used at the last level to refer to 'clusters of populations of different species having mutual relationships among themselves and to their environment' (Dark 1997). The emphasis of 'community' is on the biota, rather than the interactions. The term community is used widely as a management unit in the State, particularly in defining threatened communities for conservation protection.

5 - Population is defined as 'a genetically stable group of randomly interbreeding individuals' (Dark 1997). Populations of different species make up communities, and in the case of vagile species, may belong to more than one community in time and space.

6 - Organism is a single individual of a species, and can conceivably belong to multiple populations, multiple communities, multiple ecosystems and multiple regions.

7 - Gene is the 'functional unit of heredity' (Dark 1997) and as with organisms, and to greater scale, individual genes may be present across and within all biogeographical scales, as well as across organisms. From a scalar perspective, genetic diversity is a powerful entity for measuring biodiversity as the base 'currency' of all living things (Williams et al 1996, King and Schreiber 1999).

At odds with other hierarchical systems, the term 'habitat' is considered as a non-fixed spatial entity, which is the group of communities and ecosystems within and across regions required for the survival of an individual organism and/or population. Habitats exist at all biogeographical levels, depending on species. Disjunct plant populations will have several habitats within a landscape; migratory birds will have habitats that extend beyond the regional scale. For example, the monarch butterfly, *Danaus plexippus* has two migratory populations, one as far south as Mexico and one northern migration towards Canada, which is considered an 'endangered biological phenomenon' (Brower and Malcolm in Sarkar, 2002). A single species habitat requirement may comprise different ecosystems at different times of the year, or may be confined to a single community. As a concept that crosses hierarchies, habitat is a powerful tool for resolving some of the conflicts in conservation management, such as how big is a 'significant' reserve, since the habitat (size, shape, composition, functions) is determined by an understanding of a species requirement. Whilst this level of research is not possible for all species, the identification of critical habitats can be handled in this manner.

The concept of critical habitat has recently been accepted at Federal level, with a register of critical habitat recently erected (Environment Australia 2002). This new concept adds a value scale to habitat similar to that discussed above for species and communities. In the context of the framework presented here, the term habitat is only used in the sense of adding value to an entity or characteristic or set of characteristics of an entity. Therefore it is not an asset as such, but provides the required entity and set of processes needed to support an asset, which in the case of habitat, will always refer to an organism.

4.2 DERIVING BIODIVERSITY ASSETS

Scarcity, variability, representativeness and usefulness can be considered umbrella values used to identify biodiversity assets at each of the scales given above. These are presented in Appendix 3, with assets defined across all bio-geographical and biological scales

Revisiting the broad biodiversity values, the relative 'importance' levels of scarcity (whether in density, type, distribution or function), variability (genetic or spatial), representativeness (genetic or spatial) and usefulness provides a relative measure of conservation value. Table 1 below attempts to organise the characteristics used to determine the value of a biodiversity asset in accordance with the broad biodiversity goals, the entity (in terms of geographical and biological hierarchies) and the value scales used against each characteristic.

These biodiversity assets can be further prioritised (ie. ranked) according to condition (current, not viable), relative scarcity on a spatial level (eg. globally rare has greater value than locally rare), and existing legislation (eg. already protected) for example. This is shown in Table 2 below.

Following on from the framework approach and relative value table, the list of biodiversity assets proposed by the draft document of Wallace et al (2002) has been revised and is summarised in Appendix 5. Note at this stage all geological, heritage, social and economic assets are excluded from the assets list, although these must be addressed to meet the original biodiversity goal as currently set. This means that three of the original assets listed by Wallace et al (2002), (ie. numbers 9, 11, 12 Appendix 2) have been (temporarily) removed. A total of 24 assets have been listed thus far for biological values and three for natural or geo-heritage values. Note also that all 'condition' values have been ignored, such as for instance, 'low number of non-native species' which is considered better introduced at the next level of threat analysis.

At some point in the decision sequence, a list of operational or management objectives that are more about what is considered feasible at each level of the ecological/geographical entity hierarchy, and what management scale is practical, is needed to resolve prioritising of biodiversity assets (for instance, Wallace et al (2002) states that most of the wheatbelt must be managed at the landscape level).

Table 1. Proposed list of value attributes, units of measure and value scale applied to each biological and geographical entity.

DIVERSITY ATTRIBUTES	UNIT OF MEASURE	Value scale (high to low)	Biological unit
Scarcity			
Scarcity in density	Number	Rare → Common	Gene, species, populations, communities, ecosystems, landscapes.
Scarcity in space	Distribution	Endemic → Widespread	Species, ecotype, communities, ecosytems, landscapes.
		Edge → Non-edge	Gene, species, populations, communities, ecosystems
	Frequency (replication, patchiness)	Low → High	Species communities, ecosystems, landscapes, region (hotspot)
Scarcity in type	Association, Form	Unique → Common	Gene, species, populations, communities, ecosystems, landscapes, region (hotspot)
Scarcity in function	eg. Biogeochemical Hydrological Productivity Energy flow Water cycles Ecological phenomena (eg. migratory pattern) Climatic	Unique → Common	Gene, species, populations, communities, ecosystems, landscapes, region (hotspot)
Variability (heterogeneity)	Number and range of types (characters, species etc)	High → Low	Gene, species, populations, communities, ecosystems, landscapes, region (hotspot)
Representativeness	Composition	High → Low	Gene, species, populations, communities, ecosystems, landscapes, region (hotspot)
Usefulness	eg. consumptive productive future opportunity recreational educational amenity	High → Low	Gene, species, populations, communities, ecosystems, landscapes, region (hotspot)

Table 2. Proposed ranking of biodiversity assets.

Biodiversity Assets Defined at Landscape Level of Management	Scale Rank (highest to lowest)					Condition Rank (highest to lowest)		
A rare gene, species, population, community or landscape remnant	Global	National	State	Region	Landscape	Excellent	Average	Poor
An endemic species, ecotype, community or landscape remnant	Global	National	State	Region	Landscape	Excellent	Average	Poor
An organism, species, population, community or landscape remnant at the edge of its distribution	Rare	Restricted	Common			Excellent	Average	Poor
A species or community poorly replicated elsewhere	National	State	Region	Landscape		Excellent	Average	Poor
A gene, species, population, community or landscape remnant unique in form, composition or type.	Global	National	State	Region	Landscape	Excellent	Average	Poor
A gene, species, population, community, landscape remnant or series of landscape remnants that fulfil a unique ecological function or set of ecological functions (eg. critical habitat).	Global	National	State	Region	Landscape	Excellent	Average	Poor
A landscape or landscape remnant with a high level of internal variability, including a wide diversity of genes, populations, or communities.	Global	National	State	Region				
A landscape or landscape remnant with a high proportion of genes, species, populations, and communities representative of the region.	Large Area	Small Area				Excellent	Average	Poor
A landscape or landscape remnant with significant organism, species or population values, including productive, recreational, medicinal, educational, and/or wilderness.	Large Area High number of uses	Small Area Low number of uses				Excellent	Average	Poor

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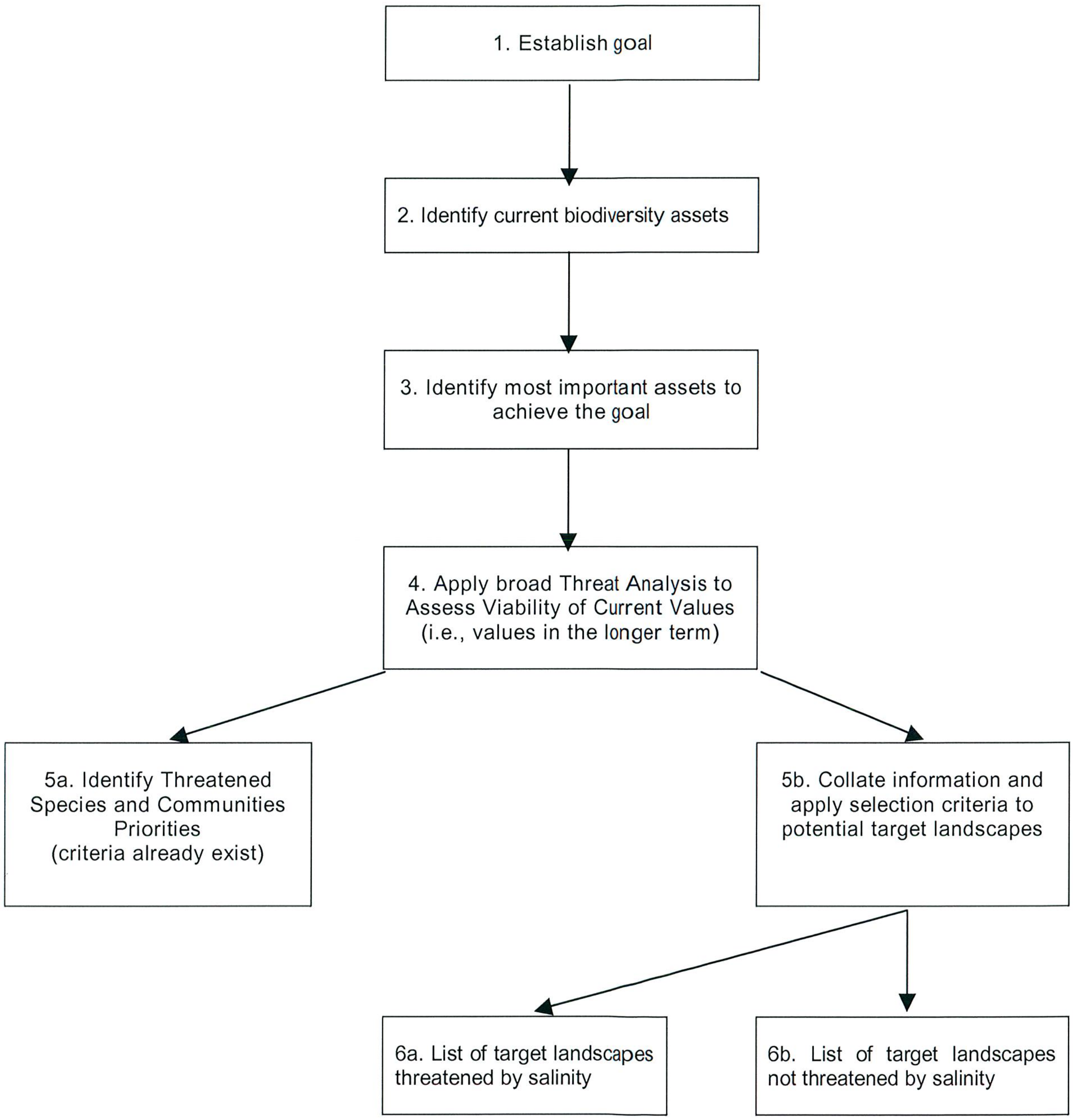
6.0 APPENDICES

APPENDIX 1

Flow diagram of process for establishing biodiversity conservation priorities for the South-west Agricultural Region



Note: it is proposed that sites outside 5a, 6a and 6b should be offered funding and assistance under a remnant vegetation protection scheme, Land for Wildlife, and other similar schemes. Thus we end up with target species, communities, landscapes and remnant habitats.

APPENDIX 2

Characteristics that Describe Biodiversity Assets

Note that this list is a rough draft, and will be further developed during the SIF process. It will also be essential to define and develop criteria for ranking areas/sites for each value.

An area or site is of importance for biodiversity conservation where it contains:

- An excellent, representative sample of bioregional or sub-bioregional native biota (generally large nature reserves, or areas with significant levels of natural habitat remaining).
- Rare[1] native plants and animals.
- Rare ecological communities.
- High levels of biodiversity and/or endemism.
- Populations of plants or animals at the limits of their natural range.
- Populations of plants or animals that are uncommon phenotypic or genotypic variants.
- Habitats that are important for the conservation of an animal species, for example, by being a significant area where it breeds or congregates (e.g. a reserve serving as an important resting place or drought refuge for migratory or nomadic species, or important area for episodic colonial breeding).
- A wetland that satisfies criteria for nomination as a wetland of International Importance under the Ramsar Convention, or an important habitat for migratory animals as defined by an international treaty to which Australia is a party, or listed as important in the Directory of Australian Wetlands.
- The site of an important biological survey (e.g. Woyerline Wells, where Shortridge surveyed in 1908) or a type-locality of a plant or animal species
- An unusual community (e.g. there is perhaps only one site in the wheatbelt where *Allocasuarina campestris* and *Eucalyptus grossa* occur in association)

[1] As noted in the main text, once viability issues are taken into consideration, then rare entities may become assessed as threatened or in need of special protection.

- A unique or outstanding landscape features (e.g. a range, rock, spring or lake).

- A palaeontological site.

- A representative sample of a local ecotype.

- Relictual species (for example, Gondwanan biota).

- All biodiversity assets not included in (1) to (14). However, note that common species and their conservation should be covered under item (1).

Physical and cultural criteria – not appropriate for assessing biodiversity values.

APPENDIX 3

CLASSIFICATION FRAMEWORK

A. BIOGEOGRAPHICAL – spatial, physical

entity → **SUPRAREGION** ..scale of widest habitat range of a species within a region, eg migratory birds, butterflys etc

entity → **BIOREGION** eg. Avon WHEATBELT (NLWRA 2001)

sub-entity → **Catchment**, Land Zone, District

characteristics →

Geography	Boundary - size and shape of area and landscape types Climate (eg.dry warm mediterannean, winter precipitation 300-650mm/annum) - scarcity, variability, representativeness, usefulness; Total Area (eg. 93 520km^2); Landscape Units - types, number and extent of fragmentation (eg. 93% agriculture)
Geology	Geological (eg. Archaean granites with infolded metamorphics of the Yilgarn Block) - scarcity, variability, representativeness, usefulness
Hydrology	Hydrological Units - scarcity, variability, representativeness, usefulness
Vegetation	Vegetation Types - scarcity, variability, representativeness, usefulness
Fauna	Fauna Types - scarcity, variability, representativeness, usefulness

assets (current value) →

Geography cultural diversity	Geology geo-heritage diversity	Hydrological	**Biological** high level of remnant patch replication high level of vegetation intactness large size regional representativeness endemic ecosystems, communities, or species range of unique or significant ecological functions high gamma, beta, alpha diversity high level of heterogeneity	Social/ Economic

values
viability → ***STAGE 2***

entity → **LANDSCAPE –** 'a heterogeneous portion of land consisting of a recognisable cluster of ecosystems that interact in ways producing spatially repeated patterns' (Forman and Godron 1986)

⇩

sub-entity → Agricultural, **Natural (Remnant)**, Urban, Mixed etc.

⇩

Natural (Remnants)

⇩

characteristics (derived from Aronson and Le Floc'h 1996) →

Landforms	Type, number and range - scarcity, variability, representativeness, usefulness
Land Units	Type, size, shape and structure of land units (inc. remnant patches) - scarcity, variability, representativeness, usefulness
Soil Units	Type, number and range - scarcity, variability, representativeness, usefulness
Ecosystem Units	Type, number, area, diversity - scarcity, variability, representativeness, usefulness
Ecotones	Type, number and range - scarcity, variability, representativeness, usefulness
Corridors	Number and types of corridors - scarcity, variability, representativeness, usefulness
Hydrological Patterns	Local rainfall/evaporation, run-off areas and amounts, discharge areas and amounts - scarcity, variability, representativeness, usefulness
Vegetation	Vegetation Types - scarcity, variability, representativeness, usefulness
Fauna	Fauna Types - scarcity, variability, representativeness, usefulness

⇩

assets (current value) →

Geography	Geology	Hydrological	**Biological**	Social/ Economic
cultural diversity	geo-heritage diversity		large number of ecosystem or community types presence of unique ecosystems, communities or populations high connectivity between remnants large size of ecosystem or community remnants well replicated ecosystems or communities significant habitat values high degree of intactness presence of ecotones high gamma, beta, alpha diversity presence of endemic ecosystems, communities, species	

value
viability → ***STAGE 2***

⇩

entity →

ECOSYSTEM –	a biotic (group of) communities and (their) biogeophysical environment, including all the interactions between and among them (Tansley 1935)'

⇩

sub-entity → Woodland, Forest, Kwongan, Mallee, Halophytes, Wetlands (Beard 1990)

⇩

characteristics →

(derived from Aronson and Le Floc'h 1993)

Community	Types, number, area shape and structure of each community - scarcity, variability, representativeness, usefulness
Soil Units	Type, number and range of soil types - scarcity, variability, representativeness,
Vegetation	Vegetation types, number of types, structure, composition - scarcity, variability, representativeness, usefulness
Fauna	Fauna types, number and community composition - scarcity, variability, representativeness, usefulness
Environmental Patterns	Local environmental conditions (e.g. wind-temperature, nutrient levels, litter coverage etc.)

⇩

assets (current value) →

Geography	Geology	Hydrological	**Biological**	Social/ Economic
cultural diversity	geo-heritage diversity	freshwater seasonal	unusual or unique communities or populations endemic communities or species high connectivity between remnants ecosystem area of a significant size well replicated community type/s high community diversity high gamma, beta, alpha diversity for flora &/or fauna significant habitat values	

value
viability → ***STAGE 2***

⇩

B. BIOLOGICAL – biota

entity → **COMMUNITY –** cluster of populations of different species having mutual relationships among themselves and to their environment (adapted from Dark,1997)

sub-entity → eg. *Eucalyptus occidentalis* Woodland; *Melaleuca* Shrubland; Mallee Fowl Community

characteristics →

Populations	Demography, genetic variability - scarcity, variability, representativeness, usefulness
Vegetation	Structural diversity, composition - scarcity, variability, representativeness, usefulness
Flora	Floristic composition and richness - scarcity, variability, representativeness, usefulness
Fauna	Fauna composition and richness - scarcity, variability, representativeness, usefulness

assets (current value) →

Heritage *cultural*	**Biological**	Social/Economic
	unusual or unique species rare species edge of distribution species disjunct community unique or significant functions high genetic variability high floristic diversity high faunistic diversity high gamma, beta, alpha diversity	

value
viability → ***STAGE 2***

entity → **SPECIES POPULATION** – a (genetically) stable group of randomly interbreeding individuals (Dark,1997)

sub-entity → eg. Mallee fowl, *Eucalyptus salmonophloia*

characteristics →

Type	Scarcity, variability, representativeness, usefulness
Genetic Traits	Scarcity, variability, representativeness, usefulness
Phenotypic traits	Colour, habit etc - scarcity, variability, representativeness, usefulness
Demography	Age, structure, turnover - scarcity, variability, representativeness, usefulness

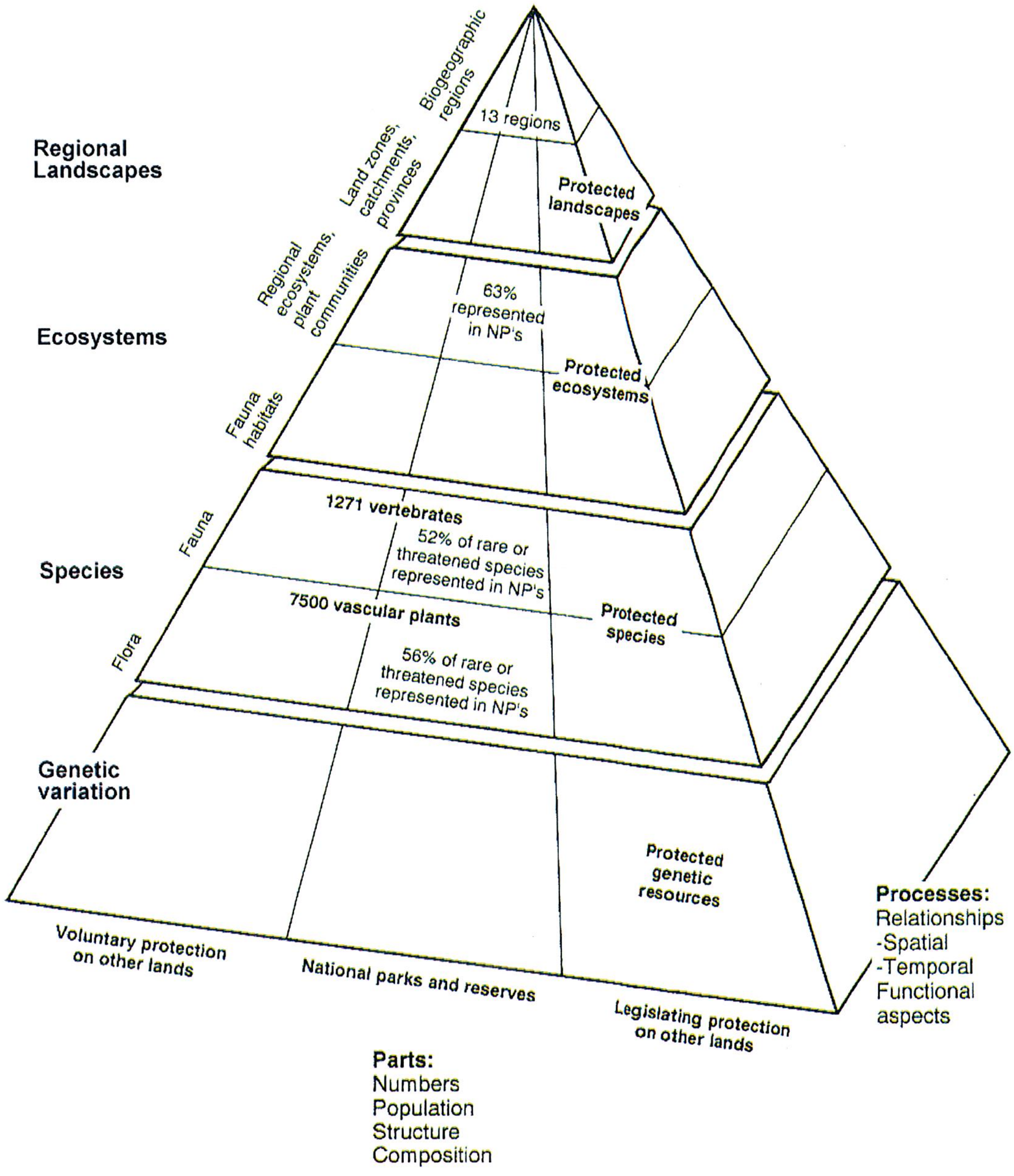
assets (current value) →

Heritage *cultural*	**Biological**	Social/Economic
	rare endemic edge of distribution species disjunct population unique functions high variability	

value
viability → ***STAGE 2***

entity	**SPECIES - ORGANISM**		
sub-entity	eg. Mallee fowl, *Eucalyptus salmonophloia*		
characteristics	***Genetic Traits*** ***Phenotypic Traits*** ***Life Cycle Traits***	Variation Phenotypic traits Age, sex	
asset	Heritage *cultural*	**Biological** rare or unique hybrid or subspecies edge of distribution unique functions unique characters	Social/Economic
value *current/future*	***STAGE 2***		
entity	**GENE -** the functional unit of heredity; the part of the DNA molecule that encodes a single enzyme or structural protein unit (Dark, 1997)		
sub-entity	eg. Dominant, recessive		
characteristics	Functional Traits	Colour, salt tolerance, biochemical etc	
assets (current value)	**Biological** rare gene critical function	Social/Economic	
value *viability*	***STAGE 2***		

APPENDIX 4



Sattler (1993). Hierarchy pyramid showing levels such as landscapes and ecosystems that have been used in the proposed classification framework.

APPENDIX 5

SUMMARISED LIST OF BIODIVERSITY ASSETS:

A. Biological

1 - A region or landscape containing regionally representative ecosystems or communities
2 - Ecosystems, communities, populations or species already protected under existing Conservation Acts (including those that satisfy relevant RAMSAR, JAMBA, CAMBA and other nationally listed conditions)
3 - A rare ecosystem or community
4 - An ecosystem or community with rare species present
5 - A community which contains relictual populations of species
6 - A region or landscape with a high level of ecosystem and/or community replication or remnant 'patchiness'
7 - A region, landscape, ecosystem or community with a high level of intactness
8 - Landscape remnants of 'significant' size or with other significant or critical habitat values for supporting one or more species requirements.
9 - Areas (region or landscape) with a high level of endemism at the ecosystem, community and/or species level.
10 - High regional (gamma), or ecosystem/community (beta) diversity
11 - A region or landscape with a high level of physical and biotic heterogeneity
12 - A region, landscape ecosystem or community that is unusual or unique or contains unusual or unique remnants or species.
13 - A landscape or ecosystem with high connectivity between habitat remnants
14 - An ecosystem or community with a high level of species (alpha) diversity
15 - An ecosystem with disjunct communities or a community with disjunct populations present
16 - A community or population which contains species at the edge of their distribution
17 - A community or population which has high species and genetic variability
18 - A community, population, species or gene which has unique biodiversity functions
19 - A community containing local ecotypes
20 - An organism or population which is or contains a rare, unique or uncommon genotypic or phenotypic variant
21 - An organism with unique or scarce functions (eg. salt tolerant, essential oil)
22 - An organism with unique genetic characters
23 - A gene with a critical function
24 - A rare gene

B. Natural Heritage or Geo-Heritage

25 - A unique or outstanding landscape features (e.g. a range, rock, spring or lake).
26 - A palaeontological site.
27 - Relictual species (for example, Gondwanan biota

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