

Discussion

The biodiversity benefits of the Holbrook Landcare supported projects are not known, they can only be predicted at this point in time using the best available knowledge. The full suite of biodiversity benefits that Holbrook Landcare may provide will take decades or even centuries to be fully expressed. For example, it may take 150 years before the trees established by the Holbrook Landcare are old enough and damaged enough to supply tree hollows for the large diversity of native fauna that use or are dependent on hollows (Gibbons and Lindenmayer 2002).

In the meantime, a preliminary assessment of the potential benefits of Holbrook Landcare activities has been conducted against the broad objectives and specific guidelines developed by the Group. Specifically, the Holbrook Landcare activities have been assessed for their potential to protect and rehabilitate significant areas of native vegetation and revegetation.

This preliminary assessment has been based only on analysing mapped on-ground works through a GIS with broad vegetation classes. This preliminary assessment has been possible because about \$73,000 was invested to map the on-ground works. This estimate of cost was based on two staff days per farm property with on-ground works (about 150 properties) at about \$30/hr and on average 40 km travel at \$0.59/km. This mapping established a protocol so that future updates and mapping of other areas could be done for much less.

The mapping could be improved by providing more detail regarding the attributes of each mapped polygon of on-ground works. Table 10 is our recommended minimum list of fields (attributes) that are needed to adequately describe each mapped polygon. These fields should appear within an attribute table constructed within a GIS such as ArcView. In particular, it would have been useful to have had more information on primary and secondary purposes, e.g. to know were there was planting or just fencing in the riparian zones, or if there was any remnant enhancement plantings. Table 11 lists further (optional) fields that may prove to be useful for future analysis.

Table 10. Recommended minimum fields (attributes) needed to assess the potential biodiversity benefits of mapped on-ground works. Projects may have multiple files for data on inputs and these can be linked. Those fields with (*) appeared in the Holbrook data provided to CSIRO.

Suggested Field Name	Description	
Site ID	A unique number needed for each mapped activity (polygon). This number should link to a file number and/or site number Linked to economic and social data and monitoring data bases	*
Date	Date of on ground activity (e.g. year)	*
Objective 1	The primary purpose of the on-ground works (e.g. habitat conservation)	*
Objective 2	The secondary purpose of the on-ground works (e.g. protection of a threatened species)	
Action 1	The primary action may be remnant fencing or revegetation (e.g. riparian)	
Action2	The secondary action may include remnant enhancement (e.g. direct seeding of understory species) If this is only in part of the protected area then it needs to be mapped separately.	
Geomorphic position	Ridge, upper or lower slope of valley, drainage line, creek,	
Width	Minimum width of shelterbelt or riparian strip.	
Vegetation type	e.g. dry sclerophyll forest, riparian, open box woodland, grassland. Where possible, vegetation descriptions should be based on state wide mapping or broad descriptions from the National Vegetation Information System	*
Condition	e.g. intact remnant, scattered trees, exotic pasture, weed infested,	
Input1	e.g. fencing funded by the project (km)	
Input2	e.g. tube stock planted	*
Input3	e.g. direct seeding (km or kg)	
Input4	e.g. weed removal, fire or other preparations	
Planting origin	e.g. local, non-local or exotic species or mixed	
Planting life form	e.g. trees, shrubs or grasses or mixed	
Planting species	Dominant species (may be more fields here)	*
Landholder ID	This only needs to be a number (key) to link to the confidential information held elsewhere.	

Table 11. Optional or additional fields may be obtained for describing the nature and extent of site-based activities. Additional fields can be held within GIS software or held in linked relational databases. If the data is linked, the SiteID is the “key” between databases.

Optional fields	Description
Funding	Source of funding
Project ID	e.g. NHT project number
Area (ha)	The area of on ground works can be calculated by a GIS, but this field can be a useful check against the GIS
Coordinates	Coordinates for each polygon can be calculated from a GIS, but coordinates from a GPS can be a useful cross-check
Datum	The datum used to obtain the GPS coordinates is needed, datums can differ by up to 100 m.
Photo point	Digital photos can be linked to each site (polygon) within some GIS software
Output1	Survival of plantings (e.g. number surviving per 100 planted)
Output2	Regeneration (e.g. seedlings/10 m)
etc	

Other benefits

The CSIRO assessment of the likely benefits of the Holbrook Landcare on-ground works was deliberately limited to potential biodiversity benefits. An assessment of the social (community) benefits of Holbrook on-ground works was beyond the scope of this report. However, it should be noted that many people have been directly involved in Holbrook Landcare activities. The social benefits of Holbrook are likely to be just as significant as any potential benefits to biodiversity. The wide range of on-ground works shown in the Holbrook GIS are represent a large inflow of economic values including employment and support of businesses through purchases of fencing and tubestock. Again, the Holbrook GIS provides the basis for a fully integrated analysis of environmental, social and economic benefits flowing from these on-ground actions. The CSIRO Heartlands Initiative (<http://www.clw.csiro.au/heartlands/overview/>) is aiming to analyse these multiple benefits.

Conclusions

Holbrook Landcare supported on-ground works have accumulated into a substantial enhancement of native vegetation across the Upper Billabong Creek Catchment. We have been able to provide some examples of the likely biodiversity benefits of these activities by analysing the mapped on-ground works. The quality of this mapping could be improved by providing more detail in the fields (attributes) describing each mapped polygon of on-ground works. The numerous and in many cases extensive on-ground works in the Holbrook area warrant substantial and prolonged investment in monitoring due to its extensive nature and the availability of mapped on-ground works.

The preliminary assessment of the potential biodiversity benefits of the Holbrook Landcare activities, as described in this report, has been conducted as a means of testing the utility of our four-step assessment process or framework (Appendix 1). This draft framework is best used by those people and organisations directly involved in the inception, implementation and monitoring of vegetation enhancement projects. CSIRO was only indirectly involved in the relatively long history of Holbrook Landcare so our report should not be seen as a definitive assessment. Rather our report is an example of how a regional organisation and its stakeholders may wish to conduct an assessment of the biodiversity benefits of their projects.

Acknowledgments

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Appendix 1

Assessing the benefits of vegetation enhancement

Appendix 1

A Draft Framework for Assessing and Improving the Biodiversity Benefits of Vegetation Enhancements

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Introduction

One of the objectives of programs such as the National Heritage Trust is to improve biodiversity by supporting activities that enhance native vegetation such as tree planting, weed removal and fencing of native bush to control grazing. Are these on-ground activities useful ways to protect and improve biodiversity? How do we plan and implement new on-ground activities that are most beneficial to biodiversity? Australian Government Department of the Environment and Heritage (DEH) and the CSIRO, in consultation with the Biodiversity Benefits Task Group (set up by the Land, Water and Biodiversity Committee), have developed the following framework or process as one way of addressing these questions. This framework has two objectives to:

1. Provide a way of designing a monitoring program to assess the biodiversity benefits of past and current vegetation enhancement projects.
2. Provide a way of designing new vegetation enhancement projects that have clear objectives, clear expected outcomes and tightly integrated monitoring and assessment procedures.

This framework is not a recipe or an alternative to existing planning, monitoring and evaluation procedures. Rather, it is one way of working through the many complex issues involved in assessing the biodiversity benefits of past projects and designing new ones. The framework may prove useful for catchment authorities, Landcare Groups and individual land managers to:

- Think about the fuzzy concept called biodiversity;
- Set clear biodiversity enhancement objectives;
- Understand the importance of scale;
- Identify threatening processes;
- Select the most appropriate enhancement activity;
- Make predictions about expected benefits
- Design ways to monitor the expected benefits of enhancement activities;
- And assess actual changes against expected benefits.

These issues need to be worked through whether assessing the biodiversity benefits of previous on-ground activities or planning new activities.

Vegetation enhancements

In Australia, we generally accept that having trees and shrubs—particularly native trees and shrubs—in urban and rural areas and rangelands will create an environment that is better for living in than concrete or cleared paddocks and bare ground. As a result, and thanks to billions of dollars and much enthusiastic toil, many millions of trees, shrubs and grasses have been planted or protected from grazing in the last ten to twenty years, in Landcare and other community vegetation projects. In all states and territories, you can now find paddocks or creeks with fenced-off areas of native vegetation. Hectares of ground dotted with newly established young plants protected by sun-bleached juice cartons are now a common sight. A useful overall name for these activities is ‘vegetation enhancement’.

Vegetation enhancement includes those on-ground activities that:

- *protect* native vegetation such as fencing (e.g. to control grazing); or the establishment of off-stream watering points; or protection from damage or removal
- *rehabilitate* native vegetation, such as reseedling of understory, weed removal, stabilisation of dunes, controlled burning and re-establishment of flooding regimes in riverside woodland;
- *revegetate*, or in other words dramatically alter plant composition by planting with seedlings or seeds of native species—for example, planting of woodland species into a pasture dominated by exotic species. It can include agroforestry plantings and commercial plantations.

Years of work: what are the outcomes?

With the next phase of the Natural Heritage Trust (NHT) just beginning¹ (NHT2), it is timely to visit completed vegetation enhancement projects, and see what they have achieved.

- What benefits are flowing from the vegetation enhancement?
- Are particular types of vegetation- or land-management activities more successful than others?
- Should any types of vegetation enhancement activities be avoided altogether?
- Can new projects be planned with better biodiversity objectives and outcomes in mind?
- And how many years does it take until benefits begin to be noticeable or measurable?

Other activities

Many policies and processes are of benefit to biodiversity but are not termed ‘vegetation enhancement’; for example:

- selection and acquisition of conservation reserves,
- social and institutional processes (e.g. incentives) supporting on-ground actions.
- regulations to control land uses.

These policies and processes are essential in supporting and improving the benefits of on-ground activities that enhance native vegetation.

Once these questions are answered and the resulting lessons communicated, new projects should build on the successes of earlier projects and avoid repeating earlier mistakes. If we understand the benefits already coming from vegetation enhancement, we should have more realistic expectations of the benefits likely to flow from new projects.

¹www.nht.gov.au/overview.html

Biodiversity Benefits

Vegetation enhancements involve an investment in time and money which, for most projects, will not carry an immediate monetary return. Rather, the return on investment may take decades and be hard to measure. Much of the investment provided by the NHT was to improve biodiversity which is more than improving monetary values of native vegetation. But the concept of biodiversity is fuzzy and hard to quantify. Biodiversity (a contraction of the words ‘biological diversity’) is often taken to mean simply the variety of life-forms in which living things exist, from DNA to whole ecosystems. Many discussions appear to consider that ‘biodiversity’ means only the numbers of individuals of the various species in an area. However, it is much more than that.

‘Biodiversity’ implies that individuals and species are distributed in ways that allow them to function sustainably. Even from the start of international concern for biodiversity (1986) it was noted² that to understand biodiversity we must consider biodiversity *composition* (e.g. DNA, species or communities) *structure* (e.g. how species are arranged in space and time) and *function* (what they all do).

Therefore the biodiversity status of a place is a description of how ‘liveable’ it is, for both native and introduced species (including agricultural species) as judged by humans. It is an expression of the species that are there, and how well they are functioning or working together. By describing biodiversity like this, we can see that it is an abstract quality that can vary between places even if they are occupied by similar numbers of species.

In an area where components (say, trees and shrubs) or functions (say, soil stability and absence of salinity) are gradually failing, or where just one species (say, kangaroos) is dominant, the biodiversity status is probably low. Conversely, in an area where a broad range of desirable species appears to be flourishing and providing many ecosystem services, the biodiversity status is probably medium to high.

Biodiversity, the variety of life, is impossible to describe or measure in its totality. The best we can do is quantify attributes or characteristics of biodiversity. All we can do is measure what we think are important aspects of biodiversity and compare them from one place or time with another. Assessing the biodiversity benefits of vegetation enhancements is about measuring changes in those attributes of biodiversity people think important. This can include charismatic wildlife species such as birds and koalas, the structure or number of layers of vegetation in a woodland, or the health of trees and soils.

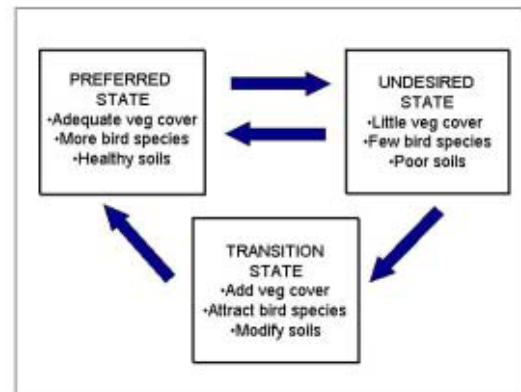
Why bother?

Vegetation enhancement activities will only be needed in areas where the status or condition of biodiversity is not as people wish it to be (i.e. biodiversity is in an *undesired* condition). Enhancement activities may help an area into a *transition* condition, and the activities will be intended to bring biodiversity of an area ultimately to a *preferred* condition or state. Figure 1,

² Franklin J.F. (1988) In Wilson E.O. (ed.) *Biodiversity*. National Academy Press, Washington, DC, USA.
Noss R.F. (1990) *Conservation Biology* 4, 355–364.

which represents the ‘State and Transition’ concept, devised by Westoby and coworkers³, is one way to think about why develop and implement an enhancement activity. Setting clear goals and objectives is fundamental to the following four-step process for improving and assessing biodiversity benefits. Setting clear objectives requires describing the characteristics of the current *undesired* state of biodiversity, and deciding how to make a *transition* to a preferred *state* of biodiversity or the environment in general.

Assessing biodiversity benefits via four steps, in a framework



In response to a request from the Biodiversity Benefits Task Group (under the Land, Water and Biodiversity Committee) CSIRO Sustainable Ecosystems has proposed a four-step assessment process that can be used to design ways to identify the benefits of vegetation enhancement activities anywhere in Australia and at any scale

Whether a project is in progress, already completed, or being planned, the draft four-step process allows a user to examine the effects a project has had or is likely to have on biodiversity. Inputs and objectives can be listed and discussed in the light of the actual or predicted outcomes for biodiversity, at local, landscape or regional scales. The four steps can be used to decide how to go about monitoring and assessing the changing biodiversity of completed and current activities. It can also be used to guide groups developing and prioritising new projects. The four steps can lead a user to consider the biodiversity status of an area and how it can be brought to (or maintained in) a preferred state.

The steps are organised into a framework that has been designed specifically for use with vegetation enhancement work. It may also have application for assessing the benefits of other kinds of environmental projects.

At each step, the user lists observations appropriate to the ‘questions’. For convenience the ‘questions’ are arranged as row and column headings in a table.

The framework can be applied while a vegetation enhancement project is being planned, or while it is in progress, or after it has been completed. Steps 1–4 below are worded as if the project is in a planning stage. For projects that are complete, the user must apply the steps in retrospect. Steps 1&2 are about setting objectives and actions (planning), Steps 3&4 are monitoring and evaluation stages following from the previous two steps.

³ Westoby M., Walker B. & Noy-Meir I. (1989) *Journal of Range Management* **42**, 266–274.

- Step 1. Identify the most immediate threats to biodiversity that are likely to be causing the undesired status (condition or state of biodiversity) and decide on actions (e.g. vegetation enhancements) that could best reduce these threats.
- Step 2. Describe the improvements to biodiversity that are expected to result from the chosen actions (e.g. vegetation enhancement activities).
- Step 3. Choose methods for monitoring the benefits to biodiversity that are expected.
- Step 4. Monitor the actual changes that followed the actions, and compare them to the changes that were expected. Have various measures of biodiversity improved as expected?

The four steps are based on several key questions.

First, what is the problem with the area in terms of biodiversity status? Why is it thought to be unsustainable or undesirable in its present condition or land-use?

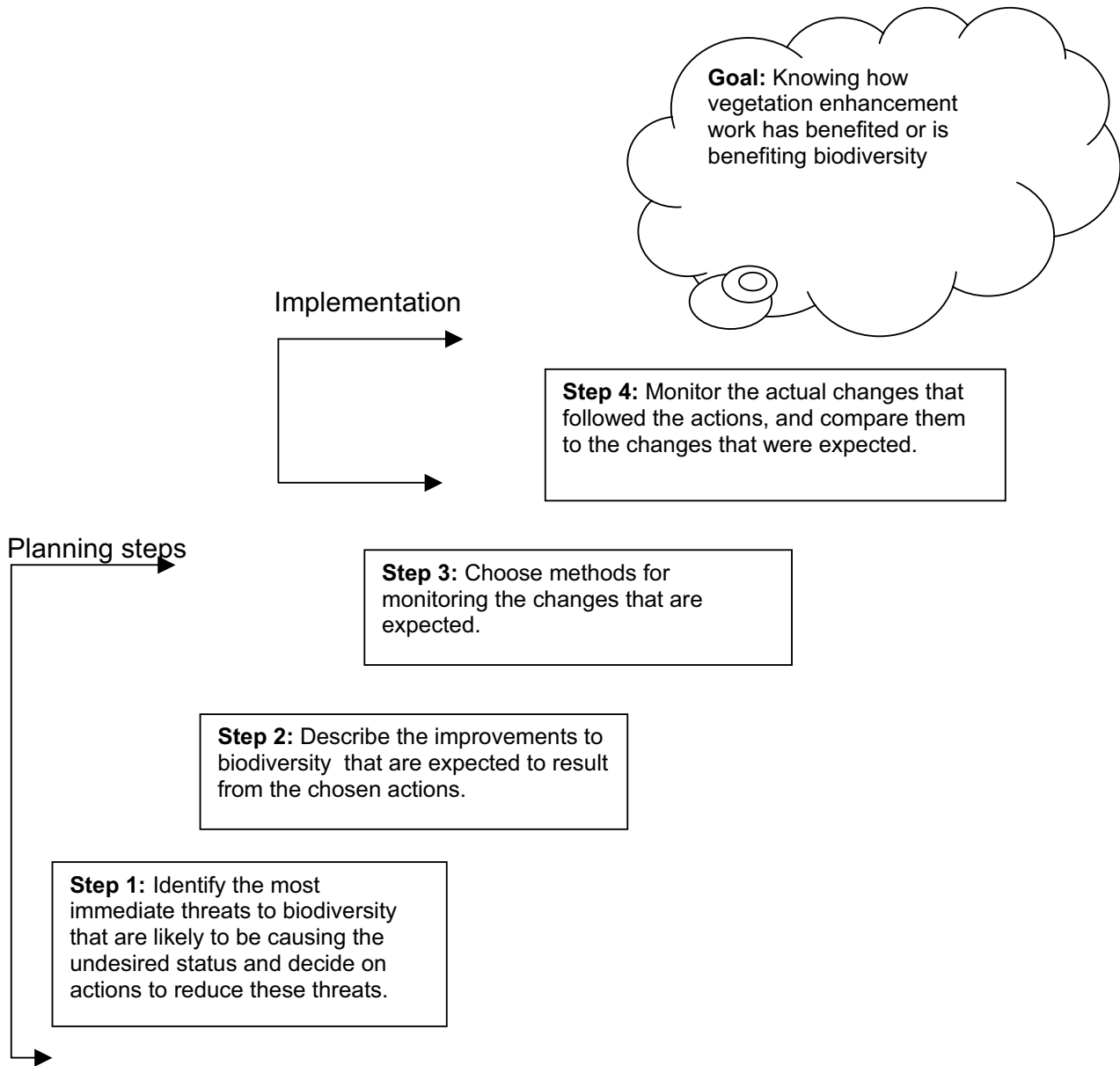
Second, how could the perceived problems be fixed by management actions or changes in land-use? How long could the improvement be expected to last?

Third, if the new approach or land-use involves vegetation enhancement activities, what actual benefits could realistically be expected?

Fourth, how could the benefits be measured, in the near future and in many years time?

Fifth, how long are we prepared to wait for benefits to appear after our actions, before we choose some other management approach or land-use, or some other way of measuring benefits?

Flow diagram of the four step assessment framework



So far the framework as outlined here seems simple to apply. Complexity appears when we start to think about each step in detail, because for each step it is important to consider the biodiversity status at *three scales*: the very local scale (patch scale), the surrounding landscape scale, and the regional scale.

Also, as explained above, biodiversity is not just a wealth of species; it is also how well species are arranged in space and how well they interact—and that is quite a difficult matter to decide at three scales, or even at one scale. Rather than give up here, we need to choose a measure or *attribute* that can we use to reveal something useful about the complex nature of biodiversity.

Characteristics of habitat (say, number of and cover provided by layers of vegetation) are often useful attributes because they are relatively easy to measure—little or no expert knowledge is needed. Many studies have shown that the more untidy and complicated the habitat structure, the greater the variety and abundance of species living there. Likewise, it is easier to measure the organic carbon content of soil, than the network of millions of soil microbes that contribute to soil carbon status.

Giving more depth to the assessment of benefits

It is not enough just to choose any measurable attribute and assume it is an indicator of for all biodiversity. We should also be able to show at least a conceptual link between the attribute and biological diversity. In fact, it takes more than one attribute to really begin to capture the complexity of biodiversity.

Ideally, therefore, when considering each set of cells in the tables below, we must think about a *range* of attributes that in total are linked to all three aspects of biodiversity: composition, structure and function. Although it is not easy to do, including several attributes will give much more depth to an assessment.

‘Bird populations’ can be a compositional attribute of biodiversity status at patch, landscape and regional scales. It is easiest to measure in small patches—but to measure it for a landscape or larger area we need more than bird counts in a just few patches of enhanced vegetation. We must also assess whether the occupied patches are the only ones in the landscape or if they are part of a network of well connected and occupied patches. Is the species found throughout its range? Here we are combining ‘bird populations’ with the broad structural attribute ‘pattern of suitable vegetation’ in the landscape and the region, to give us a feel for the benefits of our vegetation enhancement work. You can begin to see that it is essential to consider more than one scale.

It may be easier to assess how the vegetation enhancement work has benefited the structure of habitat for local birds, rather than count the birds themselves. Has the work increased the average size of local and regional vegetation patches? Is there now less distance between patches? Do the

Attributes that have proven useful for indicating biodiversity status

- Bird populations (C)*
- Threatened species (C)
- Trees with hollows (S)
- Densely vegetated riverbanks (S)
- Woodlands with diverse understorey (S)
- Water quality (F)
- Size of patch of trees and shrubs (S)
- Distance between woodland patches (S)
- Amount of dead wood on the ground (S)
- Soil organic carbon (F)

*C, S or F indicate Compositional, Structural or Functional attributes of

patches consist of *layers* of cover, from ground-level to tall tree canopies? Are there more local plant species (not weeds) now in the landscape and patches? Again, this assessment is using a range of attributes (vegetation structure, size of patch, diversity of species) to give it depth and breadth.

While you are learning to use the framework, it is best to concentrate on one step at a time, and think about one column or row at a time in each of the small tables below. Where possible, decide on the benefits of a project to all three dimensions of biodiversity (composition, structure, function) and at three scales (patch, landscape, region). Finally, once you are familiar with the table-filling process, you will be able to address the framework as a whole.

Step 1. Identify the most immediate threats to biodiversity and decide on actions that could best reduce these threats.

The table (a) shows the various aspects of Step 1. The status is seen to be an expression of the effects of ‘threatening processes’ on the attributes chosen to indicate biodiversity status in the area. Threatening processes are simply management practices that have a negative effect on a desired characteristic of biodiversity. Any management practice creates both ‘winners’ and ‘losers’. Wheat, galahs and people are ‘winners’ from clearing of woodlands for agriculture, whereas native orchids and robins, for example, are ‘losers’: they are threatened by large-scale clearing.

The **status** columns in the Step 1 table are for those elements of biodiversity that you value and do not want to lose. Other examples of biodiversity status are shown in the filled-in table (b).

The next thing to consider within the status columns is the **scale** of concern. Are native orchids threatened or missing only from the particular patch of vegetation being considered for enhancement, or are orchids missing from almost all the neighbouring patches? (If the orchids are missing from the entire catchment, then re-introductions may be needed, once the threatening processes have been sufficiently controlled.)

Step 1 table (a)

Scale	Status			Threatening processes causing the status		Management action(s)	
	Composition	Structure	Function	Modification	Removal	Vegetation enhancement	(Other)*
Patch							
Landscape (subcatchment)							
Region (catchment)							

*The ‘other’ column is a reminder that management actions other than vegetation enhancement can also change biodiversity status

Step 1 table (b)

Scale	Status			Threatening processes causing the status		Management actions
	Composition	Structure	Function	Modification	Removal	Vegetation enhancement
Patch	Loss of	Degraded	Saline	Grazing and	Clearing	Fencing and

	individual birds	habitat structure, e.g. loss of shrubs	scalds and gully erosion	lack of fire		planting understorey plants
Landscape (subcatchment)	Loss of bird populations	Isolation of habitat patches	Rising saline watertables	Cumulative effects of grazing	Cumulative effects of clearing	Increasing size of patches of vegetation and vegetation corridors
Region (catchment)	Extinction of bird species in this region	Inadequate regional tree cover, e.g. less than 30%	High levels of salt in rivers	Intensification of agriculture	Intensification of agriculture	30% cover target for each broad vegetation type

Moving across to the right of the Step 1 table, try and identify the most important **threatening processes** affecting the biodiversity attribute of greatest concern. This is rarely easy. Consider your chosen biodiversity attributes: are they being disadvantaged by *modification* of the environment—perhaps by grazing, fire, feral predators or competition from superabundant species—or is their status a consequence of the *removal* of habitat, say by historical or recent tree clearing?

Finally, think about the **management actions** that can reduce the key threats identified in the previous columns. Fencing of remnant vegetation may potentially reduce habitat modifications caused by intensive grazing by livestock. In contrast, revegetation activities may reduce some of the threats due to habitat removal. Remember that vegetation enhancement actions may only be part of the solution: feral predators may need to be controlled, for example, or contour banks may be needed to reduce severe erosion.

A single management action is likely to reduce threats and improve the status of many different attributes of biodiversity at a range of scales. For example, revegetation in the form of strips (such as shelter-belts) should also improve a functional attribute of biodiversity such as soil stability or crop productivity. The same revegetation activity can reduce the isolation of remnant patches of bush (a structural attribute) where these are few and far between. In this second situation, the underlying threatening process is assumed to be a loss of living space for birds or other animals, leading to reduced viability or sustainability for that population of that species. If this same strip of revegetation is part of a much larger project to link up widely distributed remnants, then at a regional scale it could reduce some chosen measure of fragmentation of biodiversity.

Table (b) above is a fictional example of a filled-in table for Step 1. It uses birds to show the status of composition, and other examples for the status of structure and function. A project doesn't need to address each and every cell of the table. Some projects may only be trying to improve a functional attribute such as dryland salinity; however, there may also be some benefits to wildlife and habitat structure from directly modifying salinity.

Step 2. Describe the benefits to biodiversity that are expected to result from the chosen on-ground actions.

We do not know for certain that vegetation enhancement activities can reduce threatening processes and improve the status of some attributes of biodiversity. We have only been trying to rehabilitate landscapes for a few decades. The best we can do, as scientists or land managers, is to predict what vegetation enhancement might do for some attributes of biodiversity, biased by our preference for managing and researching at the patch scale.

We expect some good outcome from vegetation enhancement (or we wouldn't do it), and our expectation is usually based on some sort of **model**. These models are often nothing more than wishful thinking, but even that is usually based on some sort of conceptual understanding of how a vegetation system might work. In the models column of table (a) for Step 2 (below) we can identify our conceptual model(s) instead of suppressing them. Models are a useful and essential means of simplifying the complexity of ecosystem processes across time and space. An assessment of the benefits of vegetation enhancement activities needs to be based on available models (such as the State and Transition concept or model above) and should aim to improve these models.

The Step 2 table links your management actions to your predicted responses via the model. It may be easiest to use this table one row at a time and one management action at a time. The management actions are the same as those identified in Step 1. The attributes for the composition, structure and function columns should also have been identified in Step 1. To complete this Step 2 table you need to identify the expected benefit of each management action for each attribute of biodiversity considered in Step 1. Step 2 table (b) shows some examples of ways of thinking about each row and column.

Step 2 table (a)

Scale	Management action(s)	Model	Predicted biodiversity responses		
			Composition	Structure	Function
Patch					
Landscape					
Region					

When filled in, the cells in Step 2 table (a) above ought to show attributes of the preferred state we are aiming for. For many people, these attributes include healthy trees with rich canopies, trees with hollows, densely vegetated riverbanks, woodlands with diverse understorey structures, and landscapes that leak less water and nutrients. If better water use (less water percolating to the watertable) and profitable farm enterprises are the only major attributes of a stakeholder's preferred state, then expanding the cover of a deep-rooted perennial pasture plant such as lucerne may be the only vegetation management technique required for the transition to that preferred state. However, if stakeholders also want to have diverse native wildlife within the landscape of concern, then transition to the preferred state may require fencing of remnant vegetation and replanting of a number of native species to recreate a complex habitat structure.

Step 2 table (b)

Scale	Management intervention	Model	Predicted biodiversity responses		
			Composition	Structure	Function

Patch	Fencing and planting understorey plants	State and transition model (transition from undesired state to preferred state)	Individual birds protected	Improved habitat complexity, e.g. understorey species establish successfully and help others recover	Saline scalds and eroded gullies repaired.
Landscape	Increasing size of patches of remnant vegetation and corridors	State and transition model	Populations of birds protected and enhanced	Enlarged and connected patches of remnant vegetation	Saline watertables are lowered
Region	30% tree cover target and how those trees are arranged		Species recovery	10% increase in tree cover	Better water quality at end-of-catchment

Step 3. Choose methods for monitoring the benefits to biodiversity that are expected.

The next step is to monitor the results of the vegetation work and see if there are signs of the expected changes. In the Step 3 table, the choice of monitoring method depends on the assessments in all the other columns and rows:

- scale,
- biodiversity attributes of interest,
- type of management action(s),
- the expected response to the action, and
- the model that underlies the desired response.

Note that this table is based on the scale and biodiversity attributes chosen in Steps 1 and 2.

Step 3 table (a)

Scale	Method appropriate for each attribute at each scale			Required time scale	Required spatial replication
	Composition	Structure	Function		
Patch					
Landscape					
Region					

There are many **methods** for monitoring biodiversity benefits, particularly at a patch scale. They can include wildlife surveys, if wildlife is one of your attributes of composition. As another example, piezometers that detect changes in the shallow watertables may be all the technology required for assessing the effects of an agroforestry block on reducing drainage of water below the rooting zone. Several state government environment agencies are developing specific monitoring systems of their own for biodiversity benefits; for instance, the Dept of Sustainability and Environment (Victoria) has developed a ‘habitat-hectares’ scoring system⁴.

The four-step process here is a framework to give context to those and any other suitable methods.

Moving to the right of the Step 3 table, consider the **time intervals** over which the monitoring needs to take place. At the patch scale, bird and vegetation surveys will be needed at least twice a year to tease out the differences between seasonal changes and changes due to vegetation enhancement activities. At the landscape scale, repeat aerial surveys once every five years should detect increases in the patch sizes of remnant woodland and the density of riparian vegetation, if these are the expected responses to fencing at the scale of a subcatchment. An analysis of relatively inexpensive Landsat TM satellite data over a ten-year time series can be used to assess cumulative changes in woody vegetative cover at a catchment scale, if woody cover is the structural attribute of interest.

The last column in the Step 3 table (**spatial replication**) is just as important as deciding about time intervals. At the patch scale, ask yourself if only one patch is going to be monitored, or a sub-sample of patches that have been fenced off or replanted, instead? If you plan to monitor a sub-sample of patches, think about whether you will monitor only one type of vegetation patch—say woodlands—or if you will check grasslands and creeklines as well. Whatever you decide, you need to write a monitoring plan, and develop a recording system for your observations and measurements.

Monitoring at the landscape scale requires the same sort of considerations, but it is more appropriate for a *group* to monitor at regional and landscape scale. With your team, will you monitor only one subcatchment or multiple subcatchments? Monitoring more than one landscape or subcatchment is more expensive, but provides much more information. The results from monitoring only one subcatchment cannot be assumed to be relevant to any other catchment—you cannot generalise from only one replicate. Monitoring three or more subcatchments may

⁴ Parkes D., Newell G. and Cheal D. (2003) *Ecological Management and Restoration* 4 (supplement), S29–38.

allow you not only to make some general statements about landscape responses to a vegetation enhancement action, but also to note how each catchment responds differently in other ways.

Once you have made the decisions needed to work through the three steps so far, you may then be able to tackle questions such as these:

- (i) Does vegetation enhancement bring back a range native wildlife and improve tree health? (patch scale consideration)
- (ii) Do we expect vegetation enhancement activities to significantly increase the sizes of mean remnant patches of woodlands, forests or grasslands? (patch and landscape scales)
- (iii) Will vegetation enhancement link fragments of native bushland or grassland? (landscape scale)
- (iv) Is significant progress being made towards achieving catchment targets for water quality and cover of native vegetation?(regional scale)

You should not underestimate the technical skills needed to apply relatively simple monitoring methods. Even something as apparently simple as a survey of woodland birds is full of assumptions, errors and compromises. Analysis of remotely sensed data requires careful refinement of the scene, well-targeted checking on the ground and sophisticated mathematical statistics to make an accurate interpretation over a time-sequence of many satellite images.

If nothing else, the draft four-step process is a useful starting point from which to engage community stakeholders, ecologists and statisticians in developing detailed monitoring procedures and methods, once the other elements of this framework have been addressed: scale, attribute, threat, intervention, response and model.

Here is Step 3 table (b), filled in with examples for each row and column.

Step 3 table (b)

	Method appropriate for each attribute at each scale			Required time scale	Required spatial replication
Scale	Composition	Structure	Function		
Patch	Surveys, before and after vegetation enhancement for each species group of interest, e.g. birds	Habitat complexity score ⁵	Landscape function analysis ⁶ and tree health	Seasons within decades	Patches within a subcatchment
Landscape (subcatchment)	Well stratified surveys, before and after vegetation enhancement for each species group of interest, e.g. birds in small and large	Distribution of patch sizes and measures of isolation	Salinity of farm dams	Years within decades	Subregions across bioregions

⁵Catling P.C. & Burt R.J. (1995) *Wildlife Research* **22**, 271–288.

⁶ Tongway D.J. & Hindley N. (1995) *Assessment of Soil Condition in Tropical Grasslands*. CSIRO Wildlife and Ecology (now Sustainable Ecosystems), Canberra.

	patches of vegetation				
Region	Comprehensive national surveys (e.g. Bird Atlas)	Remote sensing of woody cover	Landscape health ⁷	Decade intervals	Continental

Step 4. Monitor the actual changes that followed the actions, and compare them to the expected benefits to biodiversity.

In the final step of the assessment process you apply the monitoring methods of choice, focused at the critical scale of interest and on the biodiversity attributes of greatest concern. This step is for assessing measured *outcomes* against expectations.

You can also use the Step 4 table to assess whether *inputs* such as fencing and revegetation have actually been carried out as planned. This part of the matrix easily accommodates the current Bushcare Monitoring and Evaluation Program, which is assessing whether planned enhancement activities have been substantially implemented.

In tables (a) and (b) for Step 4, the ‘planned activities’ column comes from Step 1. The ‘predicted responses’ column comes from Step 2.

Step 4 table (a)

Scale	Inputs		Observed response (outcomes)			Predicted response		
	Planned activities	Actual activities	Comp.	Structure	Function	Comp.	Structure	Function
Patch								
Landscape								
Region								

⁷ Land and Water Audit, www.nlwra.gov.au

Step 4 table (b)

Scale	Inputs		Observed response (outcomes)			Predicted response		
	Planned activities	Actual activities	Comp.	Structure	Function	Comp.	Structure	Function
Patch	Hectares of revegetation	Hectares of <i>surviving</i> revegetation	Some birds persist	A small proportion of vegetation patches enlarged	Some gullies repaired	Individual protected birds	Improved habitat complexity, e.g. understory species establish successfully and let others recover	Less wind and water erosion.
Landscape	Project activities	Project activities	Some bird populations persist	Some shelterbelts connect vegetation patches	Highly fluctuating watertables	Populations of birds protected and enhanced	Enlarged connected patches of remnant vegetation	More uptake of rainfall, less percolation to watertable
Region	\$\$ invested	\$\$ invested	No. species taken off threatened species list	2% increase in woody cover	Highly fluctuating measures of water quality	Species recovery	10% increase in tree cover	Better water quality at end-of-catchment

This part of the framework brings together the key features of the four-step process. It forces you to consider scale, and choose ideally at least three biodiversity indicators that include attributes of composition, structure and function. To fill in the cells, you need to identify the predicted or desired outcomes of the various planned and implemented enhancement activities.

For those projects that are too recent to have outcomes yet, the table also allows you to predict biodiversity benefits from inputs if they (on-ground activities) have been mapped and if appropriate models are available to predict the benefits of on-ground actions.

This table, though complicated, allows for detailed assessment across an unlimited number of attributes of biodiversity across all scales of interest. Alternatively, it can be used to assess a single vegetation enhancement activity at a single patch focusing on individuals of a single species. As with the tables for the other steps, do not feel obliged to fill in every cell of each row and column. On the other hand, the cells give you the chance to think about how actions at patch scale might affect biodiversity at larger scales.

Now that you have seen the four steps, you can place the assessment of even a single patch in a much broader context, as you consider status, threatening processes, predicted responses to management interventions and the underlying conceptual or theoretical models. If the four steps are united, they look like the Framework at the end of this report.

Applying this proposed four-step assessment process

The four-step process makes it possible to assess the biodiversity benefits of vegetation enhancement, but the assessment is not a trivial activity. In fact, it is probably impossible to fill in the four tables or the Framework entirely for any one set of activities—there is not yet enough

understanding of how biodiversity works at anything larger than the scale of a few hectares. The examples above are made up for illustration, and would not be so completely filled in from any one set of activities.

This assessment can be used in two ways:

- (i) to assess benefits of past projects, and
- (ii) to help design new projects.

The most rigorous way to assess benefits is to have a monitoring program organised before even the first tree is planted or the first fence erected. Pre-project (baseline) measurements and photographs can help you detect and understand changes over the next few years or decades. Only collect baseline data that are relevant to your planned activities and their desired outcomes.

For an enhancement project focused on lowering watertables, piezometer measurements of the existing depth to watertable each month could be useful baseline data. For a project that aims to enhance the number of species in the area, detailed vegetation and wildlife surveys before enhancement begins are fully justified.

Step 1 of this assessment process is critical. This is where the project objectives and scale of operation need to be chosen. What is the problem? Which attributes of biodiversity status are of concern in your area? What threatening processes are involved? What management action do you expect would reduce the threats? The other three steps in the process hinge on the choices you make at Step 1.

The four-step process and its tables are a guide to help individuals, groups and agencies think in a structured way about assessing the benefits to biodiversity from vegetation enhancement activities. There are no rights or wrongs in this: only better ways of learning. Enhancing biodiversity is a new business and science for us all. The best we can do is to learn from our successes and failures, and that's where the four-step process comes in. We hope you find it useful.

Framework of four steps for assessing how biodiversity benefits from vegetation work

Steps		Patch scale	Landscape scale	Regional scale
<p>Step 1 Identify the most immediate threats to biodiversity that are likely to be causing the undesired status state of biodiversity and decide on actions that could best reduce these threats and</p> <p>Step 2: Describe the improvements to biodiversity that are expected to result from the chosen actions (e.g. vegetation enhancement activities)..</p>	<i>Status</i>			
	Composition Structure Function			
	<i>Threatening processes causing the status</i>			
	Modification Removal			
	<i>Management action</i>			
	<i>Model</i>			
	<i>Predicted biodiversity responses</i>			
<p>Step 3: Choose methods for monitoring the changes that are expected.</p>	<i>Method for each attribute at each scale</i>			
	Composition Structure Function			
	<i>Required time scale</i>			
	<i>Required spatial replication</i>			
<p>Step 4: Monitor the actual changes that follow the management actions, and compare them to the changes that were expected.</p>	<i>Inputs</i>			
	Planned activities Actual activities			
	<i>Observed response (outcomes)</i>			
	Composition Structure Function			
	<i>Predicted response</i>			
	Composition Structure Function			

Further information

CSIRO has been engaged by DEH to apply the four-step process to at least six large case studies around Australia. The results will be made public when available.

Some background to the development of this assessment framework can be found at <http://www.ea.gov.au/> [insert URL for full document].

There is more detail about biodiversity in the main report, *Assessing the benefits of vegetation enhancement: a draft framework*, from which this summary report has been derived, and more examples showing how the four-step process or framework might be used.

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Appendix 2

GIS Analysis

Data preparation

The assessment was carried out using ArcView 3.2 as this was thought to be more widely available, than Arc GIS, and compatible to the extension Spatial Analyst. Spatial analyst was required to run Patch analyst (see below)

Initial layers obtained

In AGD 1996 Zone 55 projection:

- Mapped on-ground works
- Vegetation layer
- Orthophoto image

In GDA 1994

- Roads, town, watercourses (used in the Location map)

The orthophoto image helped interpret the maps of vegetation and on-ground works. As only some of the data was attributed and an assessment on all the mapped works was desired, rough assumptions were made on the unclassified data as to which actions were remnant protection and which were revegetation. Polygons, which overlaid more than 50 % of a remnant, were classified as remnant protection along with a few identified on the satellite image as being over unmapped remnants e.g. riparian vegetation. Further classification into categories such as remnant enlargement, remnant enhancement, revegetation for erosion or riparian restoration could be made with more time and local knowledge.

Change in vegetative cover of the subcatchment was based on an initial merged layer of existing veg (Before) then enlarged by a layer of all on-ground works which occurred outside the existing vegetation layer (After). This included proposed works and eliminated instances when works intersected (e.g. revegetation occurring in a remnant protection block or completed works over proposed polygon).

Spatial Analysis of Landscapes

Patch Analyst for ArcView

1. Introduction

Patch Analyst is a freely available suite of extensions for ArcView GIS which allows users to spatially analyse landscapes. It focuses on landscape spatial metrics such as connectivity, nearest neighbour analysis, edge-area ratios, contiguity and many other indices. Patch Analyst is available for raster and vector data models (GRIDS and Shapefiles) with the raster version using the algorithms developed for Fragstats, the stand-alone landscape analysis software. Patch Analyst can be downloaded from <http://flash.lakeheadu.ca/~rrempel/patch/> and requires ArcView GIS. To use the Patch Grid option in Patch Analyst, ArcView Spatial Analyst is required and all data must be converted to raster format (ArcView GRID). The raster version of Patch Analyst offers a number of additional landscape indices not available in the vector version. Foremost of these indices is nearest neighbour analysis, core area analysis and some additional diversity and interspersion metrics.

Patch Analyst adopts a hierarchy of analysis based on the concept of landscapes, classes and patches and allows users to derive metrics for either of these. A landscape includes all the patches, classes and polygons in a study area. A class includes all patches, polygons, contiguous cells or shapes in a theme or landscape that have the same value for a given attribute. Each individual polygon or contiguous set of identical grid cells is a patch. Each patch has a separate record, or row, in the theme attribute table (or grid value) (Patch Analyst Help File, 2003).

2. Performing an Analysis

The following example assumes that Patch Analyst extension has been installed correctly and enabled (Figure 1 and instructions available at <http://flash.lakeheadu.ca/~rrempel/patch/>) and that Spatial Analyst is installed. The example focuses on the derivation of the nearest neighbour index for a landscape containing newly revegetated patches. The nearest neighbour index provides an estimate of the connectivity inherent in the landscape. Users are encouraged to explore the suite of other landscape indices available in Patch Analyst as they may have more relevance for their case study.

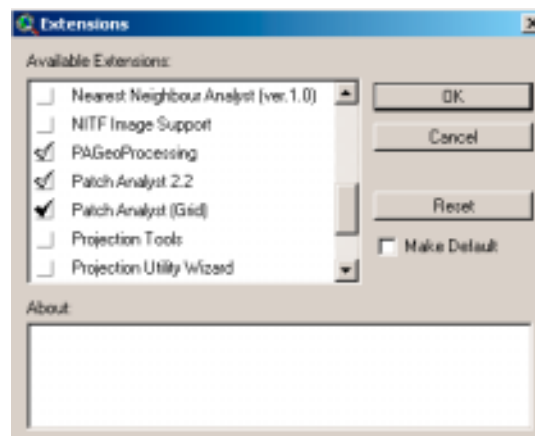


Figure 1. Enabling the Patch Analyst Extension in ArcView

Figure 2 shows the ArcView interface and the PatchGrid drop-down menu being used to perform an analysis. In this simple example we will extract the nearest-neighbour index for this hypothetical landscape. The example data is in ArcView GRID format. From the PatchGrid menu select Spatial Statistics (PatchGrid>Spatial Statistics).

Figure 3 shows the Patch Analyst interface for selecting landscape metrics for analysis. In our case study we will calculate the Mean Nearest Neighbour Distance, Number of Patches, Mean Patch Size, Total Edge and some Diversity and Interspersion metrics. Our analysis will be at the Landscape level as our data shows either vegetated or non-vegetated patches. In some instances, for example when dominant species information is available for each patch, a Class level analysis may be appropriate.

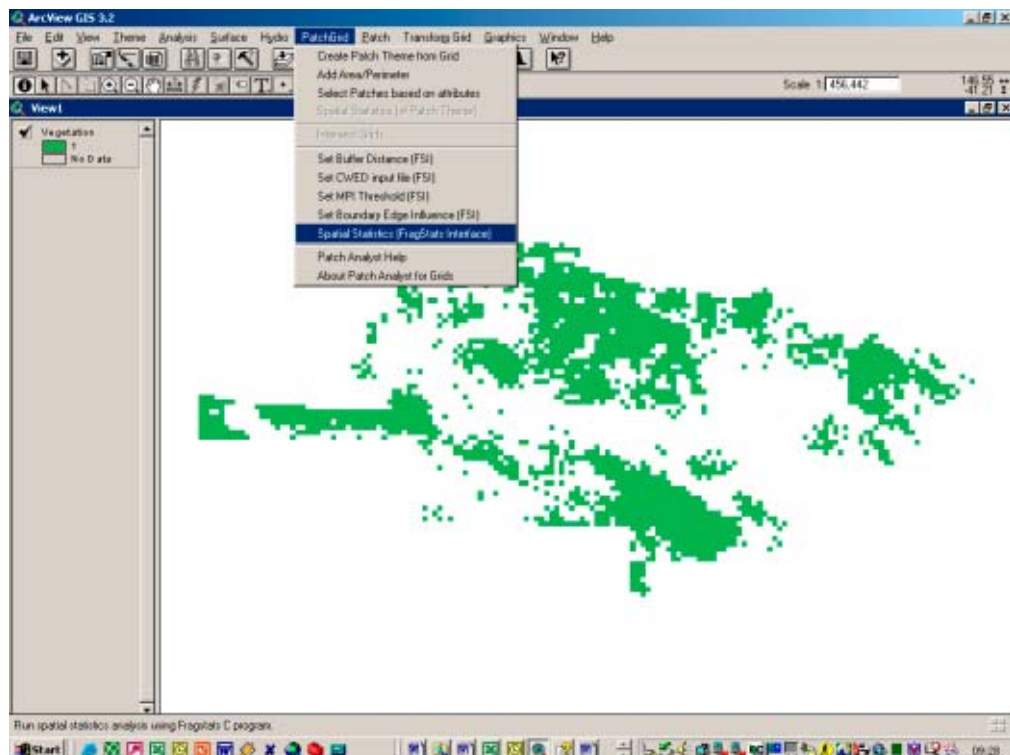


Figure 2. ArcView window showing an example raster data set of newly revegetated landscape in raster format (GRID). The drop-down menu shows the PatchGrid interface for calculating spatial indices for raster data.

Results from a Patch Analyst analysis are written to an ArcView table and appear as those shown in Figure 4. The Patch Analyst help file will be required to interpret the column headings. In the analysis conducted, we can see that our hypothetical landscape has an inter-patch mean nearest neighbour distance of 183.00 metres, it contains 1197 contiguous patches and the mean patch size is 250.68 metres. Users are encouraged to explore the suite of Patch Analyst options available and begin comparing statistics for different landscapes, classes or for different landscape management scenarios.

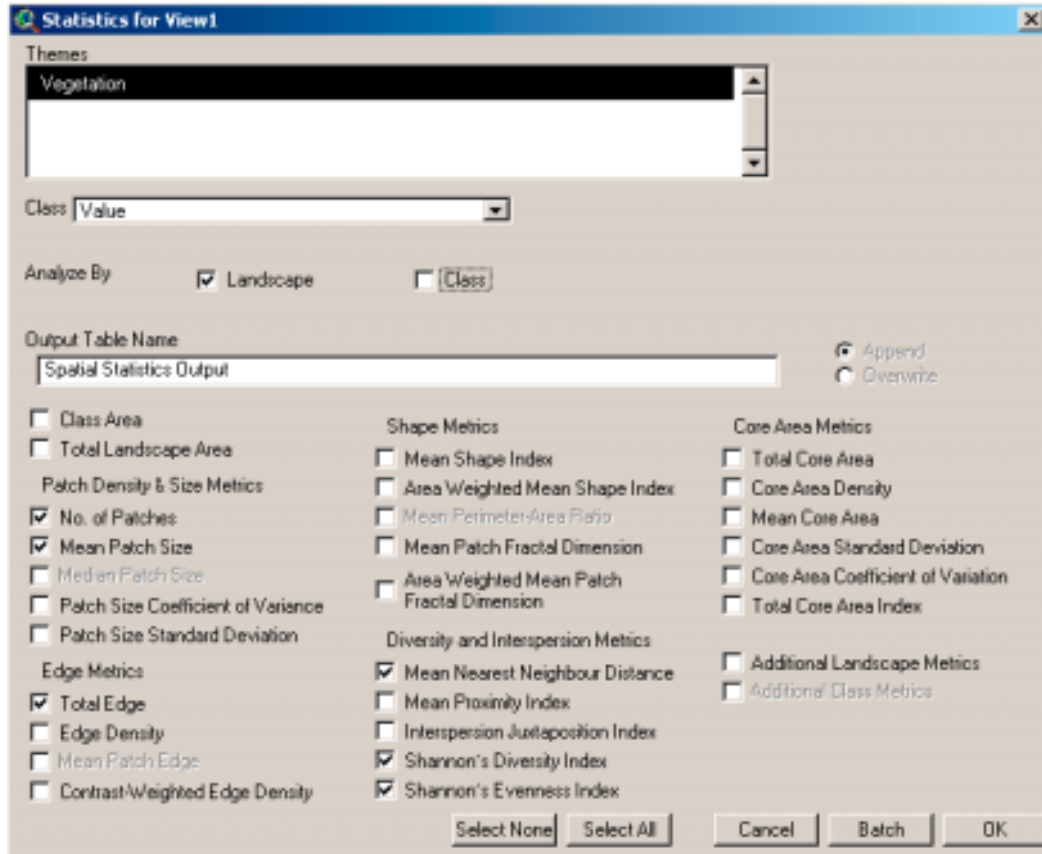


Figure 3. Patch Analyst interface for selecting landscape metrics for analysis

Name	RunDate	Run	Class	NumP	MPS	ANW	TE	SC	SEI
Vegetation	Fri Jun 20 09:39:01 2003	2	All	1197.00	250.68	183.00	6339400.00	0.00	0.00

Figure 4. Patch Analyst interface for selecting landscape metrics for analysis

Notes:

As Patch Analyst calculates distance metrics, it is critical that the correct map units are firstly defined in ArcView (View>Properties). Failing to do so will result in erroneous Patch Analysis indices.

