Australian Government
Land & Water Australia

Conserving biodiversity in highly-modified production landscapes

Ten key strategies

10

THIS PUBLICATION IS PRODUCED BY THE NATIVE VEGETATION AND BIODIVERSITY R&D PROGRAM

Conserving biodiversity in highly-modified production landscapes. Ten key strategies. Joern Fischer, David Lindenmayer, Adrian Manning and David Salt

Published by: Land & Water Australia
Postal address: GPO Box 2182, Canberra ACT 2601
Office location: L1, The Phoenix
86 Northbourne Avenue, Braddon ACT
Tel: (02) 6263 6000
Fax: (02) 6263 6099
E-mail: Land&WaterAustralia@lwa.gov.au
Web: <www.lwa.gov.au>

Disclaimer

The information contained in this publication is intended for general use, to assist public knowledge and discussion, and to help improve the sustainable management of land, water and vegetation. It includes general statements about scientific research. Readers are advised, and need to be aware that this information may be incomplete or unsuitable for use in specific situations. Before taking any action or decision based on the information in this publication, readers should seek expert professional, scientific and technical advice. To the extent permitted by law, the Commonwealth of Australia, Land & Water Australia (including its consultants and employees) and the authors do not assume liability of any kind whatsoever from any person's use or reliance upon the content of this publication.

Product code: PN21582
ISBNs: 978-1-921544-06-4 (hard copy)
978-1-921544-07-1 (electronic)

Cover photos: Front: Guy Roth. Back: courtesy of Greening Australia Capital Region
Design: Angel Ink
Print: Paragon Printers
September 2008

The challenge of our times

Conserving biodiversity in our forestry and agricultural landscapes is a massive challenge for managers, planners, producers and researchers. Our existing system of conservation reserves is not sufficient to protect biodiversity, and commodity production relies on vital services provided by biodiversity. Biodiversity also enhances the landscape's resilience — its capacity to recover from disturbances (such as droughts) or management mistakes.

Until recently there hasn't been a science-based practical set of strategies outlining how biodiversity can best be conserved in production landscapes. This has now been addressed by ecologists at The Australian National University who have compiled a list of ten such strategies.

These strategies fall into two categories. The first five address landscape patterns (that is the size, shape and composition of different components that make up the landscape), and the second five focus on ecological processes (that is interactions between the various components that make up the landscape). In combination, the ten strategies are a practical guide to the management of production landscapes that recognises the complementarity between patterns and processes in landscape ecology.

Elements of the strategies will already be familiar to those involved in planning and managing for conservation. However, elements of these strategies are often considered in isolation or taken at 'face value'. Considering the strategies as a whole, and understanding the ecological basis and assumptions behind each one, is important for more effective on-ground conservation outcomes. It will also help develop capacity and confidence amongst those faced with the challenge of planning and managing for conservation outcomes in production landscapes.

Pattern-oriented strategies

Strategy 1: Maintain and create large, structurally complex patches of native vegetation

Strategy 2: Maintain structural complexity throughout the landscape

Strategy 3: Create buffers around sensitive areas

Strategy 4: Maintain or create corridors and stepping stones

Strategy 5: Maintain landscape heterogeneity and capture environmental gradients

Process-oriented strategies

Strategy 6: Maintain key species interactions and functional diversity

Strategy 7: Apply appropriate disturbance regimes

Strategy 8: Control aggressive, over-abundant, and invasive species

Strategy 9: Minimise threatening ecosystem-specific processes

Strategy 10: Maintain species of particular concern

This technical note is based on Fischer, J., Lindenmayer, D.B. & Manning, A.D. 2006, 'Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes', *Frontiers in Ecology and Environment*, vol. 4, pp. 80–86.

Pattern-oriented strategies

Strategy 1: Maintain and create large, structurally complex patches of native vegetation

The species–area relationship is one of the few general principles in ecology. It states that other things being equal, larger patches tend to support more species than smaller patches. In addition to its area, the structure of a given patch of native vegetation is fundamentally important for biodiversity. Again, other factors being equal, structurally characteristic and complex vegetation tends to support higher levels of biodiversity than structurally simple or degraded vegetation.

Some structural elements are particularly important because a large number of species and ecological processes rely on them. What constitutes such "keystone structures" varies between ecosystems, and can range from ephemeral water bodies in recently ploughed agricultural fields to tree hollows in woodlands and forests.

The maintenance of large, structurally complex patches of native vegetation is particularly important in landscapes where many species are area-sensitive and confined to native vegetation, and where locations outside these patches are entirely uninhabitable by many native species.

Strategy 2: Maintain structural complexity throughout the landscape

The area surrounding patches of native vegetation is often termed the "matrix". The matrix is the dominant landscape element in production landscapes (in a farming landscape the matrix is often cleared fields, in a pine plantation landscape the matrix is usually a single species of pine. The matrix exerts an important influence on ecosystem function. A matrix that has a similar vegetation structure to patches of native vegetation (i.e. that has a low contrast) will supply numerous benefits to ecosystem functioning.

Three key benefits of a structurally complex matrix are the provision of habitat for some native species, enhanced landscape connectivity, and reduced edge effects.

The value of a structurally complex matrix as potential habitat has been demonstrated for a range of organisms in landscapes throughout the world, including agricultural and forestry landscapes in Central America, Australia, Europe and North America.

In addition to providing permanent habitat for a range of species, a matrix that is structurally similar to patches of native vegetation will also provide landscape connectivity which can facilitate enhanced movement through the area by a number of organisms. This, in turn, facilitates the spatial continuity of important ecological processes, such as pollination or seed dispersal.

Finally, a structurally complex matrix will reduce negative edge effects at the boundaries of native vegetation patches. Edge effects are ecological changes that arise at the boundaries between the matrix and patches of native vegetation. For example, microclimatic changes near patch boundaries will affect the physical environment, making it more suitable for species that are adapted to disturbance. Many weeds and some types of predators benefit from edge environments, and can exert substantial pressures, including competition or predation, on a range of native species.

The maintenance of a structurally complex matrix is particularly important where the proportion of land occupied by the matrix is large, and where areas of native vegetation are small or poorly connected.

Photo courtesy of Greening Australia Capital Region.

Strategy 3: Create buffers around sensitive areas

As outlined in Strategy 2, a structurally complex matrix can mitigate some of the negative impacts of edge effects on biodiversity. An alternative, and not mutually exclusive, strategy is to specifically create buffers around patches of native vegetation. These can help to lessen negative edge effects, for example by "sealing off" vegetation patches from strongly altered conditions in the matrix.

Features other than patches of native vegetation may also benefit from vegetation buffers around them. Aquatic ecosystems are obvious examples, and buffers are widely used to protect streams in forestry systems or to help preserve wetlands. Although the concept of buffers is widely applicable, the precise nature of what constitutes a suitable buffer is likely to depend on the specific situation. In particular, it is important to consider which external forces could have an impact on the sensitive area, and to what extent they may be able to penetrate a particular type of buffer.

Buffers need not be confined to the local scale; hundreds of UNESCO biosphere reserves around the world include regional-scale buffering strategies for sensitive areas. Buffers are particularly important where surrounding land exerts strongly negative influences on sensitive areas, such as providing a source of invasive species or chemical pollutants.

Strategy 4: Maintain or create corridors and stepping stones

A structurally complex matrix can contribute to the connectivity of habitat patches for some species, and may enhance the connectivity of some ecological processes (Strategy 2). A complementary strategy to enhance landscape connectivity is to create or maintain corridors and stepping stones between large patches of native vegetation.

In the context of vegetation, corridors are elongated strips of vegetation that link patches of native vegetation; stepping stones are small patches of vegetation scattered throughout the landscape.

This strategy is an important adjunct to matrix management (Strategy 2), because different species and ecological processes will respond favourably to different strategies. Corridors, for example, have been shown to enhance connectivity for seed-dispersing birds in South Carolina. Similarly, semi-isolated fruit trees in Central American grazing landscapes are used as stepping stones by seed-dispersing bats and birds. These trees therefore contribute not only to habitat connectivity, but also play a key role in maintaining genetic exchange between plant populations. To maintain connectivity for a wide range of species and ecological processes, a mix of strategies should be used, thus recognising the complementarity of a structurally complex matrix, corridors with different attributes, and stepping stones.

Corridors and stepping stones are particularly important where the matrix provides a genuine barrier to movement in many species or to important ecological processes.

Strategy 5: Maintain landscape heterogeneity and capture environmental gradients

From the perspective of biodiversity conservation, vast areas of unmodified land are likely to be optimal. Representative areas of "wilderness" are key to biodiversity conservation and such areas should be protected in nature reserves. However, where humans do use landscapes for the production of agricultural or forestry commodities, there is widespread evidence that heterogeneous landscapes, which resemble natural patterns, provide greater biodiversity benefits than intensively-managed monocultures.

Heterogeneity is the spatial patchiness and variability in landscape patterns, and it can occur at multiple scales. The maintenance of heterogeneity at all scales is considered a key determinant of biodiversity in European agricultural landscapes, and is a likely reason for relatively high levels of biodiversity in Central American farming landscapes. Similar general patterns have been found in forestry landscapes, where intensive monocultures support less biodiversity than forests that are managed to resemble patterns of natural heterogeneity.

A key consideration in all production landscapes is the spatial distribution of different types of land use. Throughout the world, the trend is for the most productive areas with fertile soils to be modified most heavily. This is undesirable for conservation because different species depend on different conditions along environmental gradients of temperature, moisture, or primary productivity.

Heterogeneity of land uses and land-use intensities should therefore occur across environmental gradients. At least some highly productive land should be protected or kept for low intensity usage.

Summary of pattern-oriented management strategies

Implementation of these five pattern-oriented strategies will result in heterogeneous production landscapes. Throughout these landscapes you would find large and structurally complex patches of native vegetation, and these patches would be connected by corridors and stepping stones. And the production matrix should contain structural characteristics similar to those of native vegetation. If this is achieved, the resulting production landscape is likely to sustain higher levels of biodiversity and will be more resilient to external shocks (such as drought) than more simplified systems.

Further safeguards for biodiversity, ecosystem function, and resilience may be achieved by implementing the five additional, process-oriented management strategies (strategies 6–10).

Photo courtesy of David Lindenmayer.

Process-oriented management strategies

Strategy 6: Maintain key species interactions and functional diversity

When you modify a landscape for commodity production, you alter the composition of ecological communities. This changes the way species interact, impacting on processes such as competition, predation, and symbiotic relationships (such as fungi growing on tree roots improving the nutrient uptake of those trees). Two approaches focusing on species interactions may protect important ecosystem functions. The first is conserving keystone species; the second is maintaining species diversity within functional groups.

Photo Nadeem Samnakay.

Keystone species are those whose presence or abundance has a disproportionate effect on ecosystem processes. Examples include large predators whose abundance influences the balance of species at lower levels of the food chain; species like the endangered bilby, which created tunnel structures used by many other species; and seed dispersers such as bats, that exist in many tropical farming landscapes.

The maintenance of keystone species is important because their loss may result in a range of cascading changes throughout an ecosystem. For example, if bats are lost from tropical farming landscapes, native fruit trees scattered throughout these areas may no longer regenerate. The loss of these trees may, in turn, reduce gene flow between tree populations in nearby rainforest remnants, with potentially far-reaching consequences for the long-term viability of the flora and fauna in these remnants.

More generally, functional diversity and response diversity are important properties for maintaining ecosystem function and resilience. **Functional diversity** refers to the spectrum of ecosystem functions fulfilled by different species — including a wide range of processes from waste decomposition to predation of large herbivores.

Response diversity, in contrast, refers to the diversity of responses to an external change, such as drought or a land management decision, as seen within species of a given functional group. Multiple species within a given functional group provide insurance against negative consequences from an external change. This is because although some species may be severely reduced in numbers as a result of an external change, others may be unaffected or may even benefit. Thus, when many species occur within a single functional group, the risk of a specific ecosystem function being entirely lost from the landscape is reduced.

Managing for species interactions and functional diversity requires the identification of key ecosystem processes, the species involved in these processes, and the management actions required to maintain these species. Species interactions require particular management attention in landscapes when there are known or suspected interactions that may be at risk, such as those between plants and pollinators.

Photo Alison Pouliot.

Strategy 7: Apply appropriate disturbance regimes

Landscape change often results in a change to historical disturbance regimes. Such changes can substantially alter vegetation structure and species composition, and may trigger cascades of change that have fundamental and potentially irreversible impacts on ecosystems. Pronounced ecological changes in production landscapes can result from changed fire regimes (including intensity, frequency, and spatial extent), changed grazing regimes, and logging.

Understanding the impacts that particular disturbance regimes have on ecosystem functioning is therefore important for ecosystem management. In general, disturbance regimes that attempt to mirror historical ones are probably a useful starting point for management. Managing disturbance regimes is especially important where it is known or suspected that many species depend on particular perturbations or successional stages (such as frequent, low intensity fires in old-growth forest).

Strategy 8: Control aggressive, over-abundant, and invasive species

Landscape change for commodity production tends to result in the loss of habitat for many species. However, it also often strongly favours a small number of native or introduced species. Some of the species which benefit from anthropogenic landscape change can become overly abundant, and may negatively affect other species through aggressive behaviour, competition, or predation. For example, in southeastern Australia, widespread land clearing for agriculture has led to expanded populations of the noisy miner (*Manorina melanocephala*). This native honeyeater is highly aggressive and out-competes many other native birds. The resulting decline in insectivorous birds has, in turn, been linked to insect outbreaks and reduced tree health in many agricultural landscapes.

Similarly, introduced species are often a major cause of extinction because they are effective predators or competitors of native species that are not adapted to their presence. Controlling invasive species therefore plays a key role in maintaining biodiversity in production landscapes, particularly in ecosystems where strong negative effects of invasive species are known or suspected.

Photo Roger Charlton.

Strategy 9: Minimise threatening ecosystem-specific processes

Although agriculture and forestry can threaten biodiversity, they are by no means the only threats; a range of other processes can be equally or more important in some landscapes. Examples include chemical pollution and hunting by humans. Such ecosystem-specific threats need to be considered in the management of biodiversity in production landscapes, and situation-specific action taken to mitigate them.

Strategy 10: Maintain species of particular concern

The guidelines have focused on maintaining biodiversity in general, and functional groups in particular, with the aim of maintaining ecosystem resilience. These approaches are likely to benefit a number of different species. However, some species may still "fall through the cracks". Unless they are keystone species, highly threatened species often have naturally low abundances, and may contribute little to overall ecosystem function. Nevertheless, maintaining such species should still be an important priority before they are lost forever.

The management of threatened species has a long history in conservation biology, and highly focused case-specific recovery plans are often needed to mitigate the decline of particular species. Determining the potential presence of rare or threatened species is an important first step in maintaining species of particular concern.

Summary of process-oriented management strategies

The process-oriented strategies listed here focus on the maintenance of desirable species (keystone species, threatened species), and the control of undesirable ones (invasive species — pests and weeds). In addition, disturbance regimes are most likely to maintain biodiversity if they mirror historical disturbance regimes. Highly specific threats such as hunting or pollution need to be considered on a case by case basis.

From principles to practice

The strategies presented here are general and generality, by necessity, comes at a cost — the loss of specific details and local customisation. This means that these strategies, alone, do not provide a prescriptive list of management actions that will solve all conservation problems in every production landscape. For example, the details of how large patches need to be, or which introduced species should be controlled, need to be established on a case-by-case basis. They do, however, provide the broad strategies that research and practical experience suggest will lead to better biodiversity outcomes in production landscapes. When combined with local data, information and experience, they will indicate the suite of on-ground actions most likely to make a difference.

It should be kept in mind that the first guiding principles and strategies for the design of nature reserves were also broad and non-quantitative. Yet, in the 30 years since those general principles were proposed, sophisticated algorithms have been developed that take into consideration the size, representativeness, and complementarity of what's being conserved by nature reserves. And that process is being refined all the time.

It is expected that the successful integration of conservation and production will, over time, be at least as important as protecting biodiversity in formal nature reserves. Moreover, biodiversity in production landscapes is fundamental to ecosystem functioning, which ultimately provides the basis not only for biodiversity conservation but also for the continued production of marketable commodities.

The intent is that these ten strategies will be refined by the scientific and management community over time. A key challenge for future work will be to better understand the trade-offs and potential inconsistencies between different management strategies, both from an ecological and production perspective.

Biodiversity, production landscapes and the future

The body of research work completed to date clearly indicates that fundamental and potentially irreversible losses in ecosystem function become more likely as more of the original land cover is lost to intensive commodity production. Policy and management must therefore maintain a balance between intensive management with higher short-term economic profits, but a high risk of system collapse in the long run, and lower intensity management with perhaps more modest short-term profits but a higher resilience to environmental change in the long run.

An important consideration for all production landscapes is therefore not only whether they appear to function at present, but also what their future trajectory is likely to be — especially in the case of events such as drought, fire, cyclones, or climate change. Biodiversity, and particularly diversity within functional groups, is an important insurance that enhances the ability of an ecosystem to withstand such external shocks.

Photo Siwan Lovett.

Useful references for further reading

Bengtsson, J.P., Angelstam, P., Elmqvist, U. et al. 2003, 'Reserves, resilience and dynamic landscapes', *Ambio*, vol. 32, pp. 389–96.

Benton T.G., Vickery J.A. & Wilson J.D. 2003, 'Farmland biodiversity: is habitat heterogeneity the key?', *Trends in Ecology & Evolution*, vol. 18, pp. 182–88.

Clavero M. & Garcia-Berthou E. 2005, 'Invasive species are a leading cause of animal extinctions', *Trends in Ecology & Evolution*, vol. 20, p. 110.

Daily G.C. (Ed.), 1997, *Nature's services: societal dependence on natural ecosystems*, Island Press, Washington, DC.

Elmqvist, T., Folke, C., Nyström, M. et al. 2003, 'Response diversity, ecosystem change, and resilience', *Frontiers in Ecology and the Environment*, vol. 1, pp. 488–94.

Fischer J., Fazey I., Briese R. & Lindenmayer D.B. 2005, 'Making the matrix matter: challenges in Australian grazing landscapes', *Biodiversity and Conservation*, vol. 14, pp. 561–78.

Fischer J., Lindenmayer D.B. & Manning A.D. 2006, 'Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes', *Frontiers in Ecology and Environment*, vol. 4, pp. 80–86.

Harper K.A., Macdonald S.E., Burton P.J. et al. 2005, 'Edge influence on forest structure and composition in fragmented landscapes', *Conservation Biology*, vol. 19, pp. 768–82.

Levey, D.J., Bolker, B.M., Tewksbury, J.J. et al. 2005, 'Effects of landscape corridors on seed dispersal by birds', *Science*, vol. 309, pp. 146–48.

Lindenmayer, D.B. & Fischer, J. 2006, *Landscape change and habitat fragmentation*, Island Press, Washington DC.

Lindenmayer, D.B. & Franklin, J. 2002, *Conserving forest biodiversity*, Covelo, CA: Island Press.

Ricketts, T.H. 2001, 'The matrix matters: effective isolation in fragmented landscapes', *American Naturalist*, vol. 158, pp. 87–99.

Ricketts, T.H., Daily, G.C., Ehrlich, P.R. & Michener, C.D. 2004, 'Economic value of tropical forest to coffee production', *Proceedings of the National Academy of Sciences of the USA*, vol. 101, pp. 12579–82.

Ries L., Fletcher R.J., Battin J. & Sisk T.D. 2004, 'Ecological responses to habitat edges: mechanisms, models, and variability explained', *Annual Review of Ecology, Evolution and Systematics*, vol. 35, pp. 491–522.

Walker, B. & Salt, D. 2006, *Resilience thinking: sustaining ecosystems and people in a changing world*, Island Press, Washington, DC.

This report is published by Land & Water Australia through the Native Vegetation and Biodiversity R&D program.

For more information on the program, see
http://www.lwa.gov.au/nativevegetation

The report can be accessed from
http://products.lwa.gov.au/

THIS PUBLICATION IS PRODUCED BY THE NATIVE VEGETATION AND BIODIVERSITY R&D PROGRAM