Making the matrix matter: challenges in Australian grazing landscapes

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Abstract. Many ecological theories are based on the concept of patches. Patches are a useful starting point for conservation efforts, but a focus on patches alone will not always achieve desired conservation outcomes. Conservation strategies in the grazing landscapes of southeastern Australia suggest that large patches of trees are widely regarded as ‘habitat’ while other forms of habitat are largely ignored. We provide data on birds and reptiles from the Nanangroe grazing landscape that illustrate the potential habitat value of areas located between large patches of trees – that is, the matrix. Despite evidence on its potential value, present conservation strategies rarely consider the matrix. Possible reasons for this bias relate to the economics of farming and the history of land use, the current environmental law framework, and also the reluctance of ecologists to study the matrix. More scientific evidence on the role of the matrix will be crucial if conservation strategies are to consider not only patches, but entire landscapes. However, for science to be relevant to land management, there is a need for new research approaches. First, an increased consideration of environmental policy and law will increase the likelihood of scientific findings being adopted by policy makers. Second, at an applied level, more practical on-ground research into farming practices and clearer communication are necessary to achieve more sustainable matrix management in Australian grazing landscapes.

Introduction

The concept of ‘patches’ is central to many ecological theories (Stephens and Krebs 1986; Wiens et al. 1993; Antrop 2001) and conservation strategies (e.g., Diamond 1975). At the global scale, networks of large patches that are reserved from production (e.g., national parks) are widely regarded as an important backbone of successful biodiversity conservation (Diamond 1975; Higgs and Usher 1980; Kitchener 1982; Margules and Pressey 2000). Similarly, at the landscape scale, patches of remnant vegetation are considered important for conservation efforts in modified landscapes (Saunders et al. 1987). However, an exclusive focus on patches of trees may lead to suboptimal conservation outcomes in some modified landscapes. This is because areas outside patches – that is, the ‘matrix’ – often play an important complementary role for a range of organisms (Daily 2001; Luck and Daily 2003).

In this paper, we consider a case study from a grazing landscape in south-eastern Australia, and highlight key ecological functions of the matrix for birds and

reptiles. In addition, we discuss potential barriers to improved matrix management and how they may be overcome. We conclude that for conservation biology to make a useful contribution to improved matrix management, more interdisciplinary investigations are needed. For example, an increased understanding of environmental law will help influence the environmental policy framework, and detailed on-ground research examining the effect of farming practices on matrix condition will help identify more sustainable management regimes. Finally, the clear communication of ecological complexity will be important to highlight that habitat is more than large patches of trees, and that a 'soft matrix' can provide habitat for a range of organisms.

Reptiles and birds in the Nanangroe grazing landscape

The Nanangroe area is located in southern New South Wales, southeastern Australia (34°58' S, 148°29' E). It has a temperate climate with relatively hot summers (daily maxima often above 30 °C), and cool winters with occasional night-time frost events. Prior to European settlement, much of the Nanangroe area was covered by native eucalypt woodlands, particularly those dominated by Yellow Box/Blakely's Red Gum (*Eucalyptus melliodora*/*E. blakelyi*) and White Box (*E. albens*; Yates and Hobbs 1997). Today, native tree cover is reduced to approximately 15%, and most cover takes the form of relatively small woodland remnants (generally less than 15 ha), or semi-isolated trees in the pastures (termed 'paddock trees'). Isolation distances between habitat remnants or semi-isolated trees range from dozens to hundreds of metres. The area is best described as variegated (*sensu* McIntyre and Barrett 1992; McIntyre and Hobbs 1999). That is, the matrix between substantial woodland remnants is characterised by gradual changes in vegetation cover and scattered paddock trees rather than sharp boundaries.

The Nanangroe grazing area incorporates several private grazing properties, covering a total area of approximately 200 km². Several bird and reptile surveys were conducted over the last 4 years (Tables 1 and 2). Birds were surveyed using point count techniques (Table 1). Reptiles were surveyed using pitfall trapping and active searching at 144 ten by ten metre plots, and artificial coverboards (*sensu* Grant et al. 1991) at 125 additional locations (Lindenmayer et al. 2001; Fischer et al., unpublished data) covering a range of environments. Each fauna survey was accompanied by surveys of habitat structure, which included the quantification of fallen timber, rocks and various vegetation attributes.

Ecological functions of the matrix

Lindenmayer and Franklin (2002) argued there were two different, but related definitions of what constituted the 'matrix': (1) the area outside reserves, or (2) the area between patches of remnant vegetation. The Nanangroe landscape is a

Table 1. Synthesis of recent research on birds in the Nanangroe area that demonstrated the benefits of a soft matrix for birds.

Research topic	Area surveyed	Methods	Key findings	Interpretation	References
Use of small patches by birds	The entire Nanangroe study area	105 patches surveyed using point interval count method with multiple observers (Cunningham et al. 1999; Lindenmayer et al., unpublished data)	91 species detected in patches between 0.4 and 16 ha; 74 species used patches smaller than 1 ha	Small patches were a valuable complement to large patches. Because by themselves small patches cannot support many bird species, small patches must have been part of a habitat continuum for many bird species.	Fischer and Lindenmayer (2002a)
Use of paddock trees by birds	Two properties (appr. 10 km ²)	70 paddock trees sites (single trees and small clumps of trees) surveyed by one observer for 20 min at a time	Over 40 species of birds were observed to use paddock trees	A substantial proportion of bird species is not restricted to woodland patches, and may benefit from scattered trees in the matrix.	Fischer and Lindenmayer (2002b)
Paddock trees as stepping stones for birds	As above	As above; but arrival and departure direction of birds was recorded	Birds tended to depart in the direction opposite to their arrival direction; some species followed areas where trees were scattered relatively densely	Paddock trees may serve as a stepping stone purpose for some birds.	Fischer and Lindenmayer (2002c)

Table 2. Overview of the reptiles observed in the Nanangroe area (Lindenmayer et al. 2001; Fischer et al., unpublished data). The table is a subjective summary that indicates which species used woodland patches or the matrix, respectively. An asterisk indicates species that were observed too infrequently to comment on their use of the matrix.

Species	Use of landscape elements	Important habitat features in the matrix
Olive Legless Lizard (<i>Delma inornata</i>)	Largely matrix	Half-buried rocks were used for shelter
Bearded Dragon (<i>Pogona barbata</i>)	Largely matrix	Wooden fenceposts and logs on the ground were used for basking
Striped Skink (<i>Ctenotus robustus</i>)	Largely matrix but to some extent patches	Logs, rocks and grass tussocks were used for shelter
Common Long-necked Tortoise (<i>Chelodina longicollis</i>)	Observed rarely, only in matrix	*
Tree Skink (<i>Egernia striolata</i>)	Observed rarely, only in matrix	Observed on several occasions sheltering in a large decaying log, or under a rock
Dwyer's Snake (<i>Suta spectabilis dwyeri</i>)	Observed rarely, only in matrix	*
Cunningham's Skink (<i>Egernia cunninghami</i>)	Observed rarely, both in patches and matrix	Observed to shelter under building debris in the matrix, and in boulder outcrops in a patch
Southern Water Skink (<i>Eulamprus heatwolei</i>)	Patches and matrix	Large rocks along watercourses used for basking
Four-fingered Skink (<i>Carlia tetradactyla</i>)	Patches and matrix	Logs and shrubs were used for shelter
Boulenger's Skink (<i>Morelia boulengeri</i>)	Patches and matrix	Rocks and logs were used for shelter
Jacky Lizard (<i>Amphibolurus muricatus</i>)	Patches and matrix	*
Lace Monitor (<i>Varanus varius</i>)	Patches and matrix	Trees used as refuge, especially large hollows in White Box
Red-bellied Black Snake (<i>Pseudechis porphyriacus</i>)	Patches and matrix	*
Eastern Brown Snake (<i>Pseudonaja textilis</i>)	Patches and matrix	*
Red-throated Skink (<i>Bassiana platynota</i>)	Observed rarely, usually in patches	*
Marbled Gecko (<i>Christinus marmoratus</i>)	Largely patches	Granite outcrops and exfoliating rocks used for shelter
Stone Gecko (<i>Diplodactylus vittatus</i>)	Largely patches	*
Copper-tailed Skink (<i>Ctenotus taeniolatus</i>)	Largely patches	*
Three-toed Skink (<i>Hemiergis decresiensis</i>)	Largely patches	*

production landscape, and as such, the entire study area is part of the matrix according to the first definition. For the remainder of this paper, we use the second definition of the matrix – that is, we are concerned with the areas between patches of native woodland. The delineation of patch boundaries in a variegated landscape is by necessity somewhat subjective. In Nanangroe, we used aerial photographs to delineate patch boundaries, and patch sizes thus obtained ranged between 0.4 and 16 ha.

To describe the nature of the matrix, the terms ‘soft’ and ‘heterogeneous’ are used in this paper to reflect relatively high complexity of vegetation structure, and ground cover (see Franklin 1993). While there was substantial variability of these attributes throughout the Nanangroe landscape (Fischer et al., unpublished data), the overall heterogeneity of the Nanangroe landscape was high compared to similar farming landscapes in the region (e.g., relatively high levels of fallen timber, rock cover, some native shrubs).

A soft matrix can provide habitat

The matrix in the Nanangroe landscape was characterised by a relatively high amount of heterogeneity expressed through the presence of scattered trees, fallen timber, rocky patches and areas with relatively tall grass (mostly introduced species). A key function of the matrix was to provide habitat for several species of birds and reptiles. For example, more than 90 species of birds were observed in the Nanangroe study area (Table 1; Lindenmayer et al., unpublished data), although only approximately 15% of the original woodland cover remained. Most of these species were not restricted to large woodland patches, and even small patches (<1 ha) contributed highly to cumulative species richness across the entire study area (Table 1). In addition, during a survey of scattered trees in the matrix, we found that almost every second species of bird in the study area used the matrix (Table 1). Thus, the variegated nature of the landscape and its relatively soft matrix contributed substantially to local bird diversity. This was because many species of birds used very small woodland patches and scattered trees in the matrix as part of a larger habitat mosaic (Table 1).

The matrix also was used by nearly three quarters of the reptile species recorded in the Nanangroe area, and features such as rocks, logs and other tree-related habitat attributes were important refuge sites for many species (Table 2). Other studies in a range of different ecosystems have also shown that the matrix should not be neglected as potential habitat (reviewed by Lindenmayer and Franklin 2002). In northern Victoria, Lumsden et al. (2002) demonstrated that most bat species utilised the matrix for foraging, although some species were reliant on larger forest patches for roosting sites. The matrix may be equally important to complement existing patches in very different environments. For example, Fernández-Juricic (2000) found that wooded streets in the city of Madrid (Spain) contributed substantially to urban bird diversity. Similarly, selectively logged forests in northern Borneo have the potential to support a diverse array of butterfly species, provided

habitat heterogeneity is maintained (Hamer et al. 2003). The ability of species to persist in the matrix can be a key factor in determining their extinction proneness (Laurance 1991; Gascon et al. 1999). Hence, the maintenance of a wide range of different habitat features throughout the matrix can be important for the maintenance of regional biodiversity.

While some initial habitat relationships have been established in Australian grazing landscapes (e.g., Tables 1 and 2), there is ample scope for more detailed research. A possible guiding framework may be 'countryside biogeography', which recognises the need to study and manage biodiversity in human-modified landscapes (e.g., Daily 2001; Luck and Daily 2003). A wide range of issues can be addressed using this framework. For example, a series of studies in the Las Cruces farming landscape in southern Costa Rica provides clues as to what sorts of research questions may be worth asking in Australian grazing landscapes (Daily 1999, 2001). Examples include an explicit assessment of the effect of landscape context on biodiversity (Ricketts et al. 2001; Horner-Devine et al. 2003; Luck and Daily 2003), and an appraisal of how the matrix is used by various species. For example, it can be important to know if the matrix can provide breeding habitat for native species, or if it is mainly used for foraging (e.g., in the case of birds; see Hughes et al. 2002).

A soft matrix can enhance connectivity

An important consideration for regional conservation is to maintain habitat connectivity to facilitate movement between areas of habitat and thus maintain viable populations (Saunders and de Rebeira 1991; Taylor et al. 1993; Ferreras 2001). Traditionally, connectivity in modified landscapes has been thought to be best achieved through the establishment of wildlife corridors that link 'habitat patches' (reviewed by Lindenmayer 1994, 1998; Beier and Noss 1998; Bennett 1998). However, wildlife corridors will have certain physical attributes and link certain habitat types at one or few spatial scales that may suit some, but not all species. Given these and other limitations of corridors (see Simberloff et al. 1992), it is important to consider the potential of a soft matrix to increase connectivity for species across a range of scales and habitat types.

At Nanangroe, we found some indication that scattered trees in the matrix were particularly important landscape elements that contributed to landscape connectivity for various species of birds. For example, some bird species were more likely to travel through the landscape in directions where trees were scattered relatively densely (Table 1). In addition, after landing in a semi-isolated tree in the matrix, many birds returned to their point of origin, or departed in the direction opposite to their arrival direction, which indicated the potential role of scattered trees as stepping stones for birds (Table 1). Additional habitat features may be needed to assist other organisms to move through the matrix. For example, decaying logs and half-buried rocks were used by several species of reptiles that used both the matrix and patches (Table 2). It is possible that without these

features in the matrix, currently continuous populations of some reptile species may become isolated. Importantly, the permeability of the matrix (*sensu* Gascon and Lovejoy 1998) can depend on different habitat features for different species. Hence, the creation or conservation of a heterogeneous matrix can benefit a range of species.

Landscape context and heterogeneity also have been found to be important in other parts of the world (e.g., McGarigal and McComb 1995; Villard et al. 1999; Hamer et al. 2003). The role of the matrix as a connecting landscape element has been noted in various studies, for example, for many vertebrates in the Amazon basin (Gascon et al. 1999; Laurance 2002), the Iberian Lynx (*Lynx pardinus*) in Spain (Ferrerias 2001), or small mammals in an agricultural area of central-west Indiana (Nupp and Swihart 2000). While several authors have pointed out species-specific differences in their ability to tolerate the matrix (e.g., Laurance 1994; Nupp and Swihart 2000), a soft matrix can often be a starting point to enhance connectivity for organisms whose populations in different patches are otherwise isolated (Rosenberg et al. 1997).

A soft matrix can link multiple habitats for a given species

Not all species are restricted to one habitat type throughout their life history. The most striking example of this phenomenon is semi-aquatic organisms, which typically breed in wet environments, but spend other parts of their life cycle in drier environments. At Nanangroe, outside its breeding season, the Eastern Banjo Frog (*Limnodynastes dumerillii*) was pitfall-trapped in locations several hundred metres away from the nearest potential breeding environment (Fischer et al., unpublished data). Work in northern Europe also demonstrates that a soft matrix can be crucial to enable semi-aquatic species to move between breeding and non-breeding environments. For example, the Common Toad (*Bufo bufo*) may move more than 2 km every year between its aquatic breeding environment and summer or winter habitats respectively (Blab and Vogel 1996). The nature of the matrix encountered by individual toads during these migrations is crucially important to their survival – for example, deaths from road traffic are a substantial source of mortality in northern European amphibians (Blab and Vogel 1996; Hels and Buchwald 2001). A similar situation was reported for threatened turtle species in Maine (USA). Joyal et al. (2001) found that turtles were using multiple small wetlands, and throughout the year frequently moved several hundred metres between wetlands through the landscape matrix. This finding led the authors to conclude that wetland protection by itself was insufficient to ensure the survival of turtle populations, and matrix management was a critical component of the protection of turtle habitat. Despite the special situation of semi-aquatic organisms, animals that do not undergo major biological changes throughout their life history can also undergo changes in habitat use depending on their age (e.g., pre- and post-dispersal habitat; see Palomares et al. (2000) for an example of the Iberian Lynx in Spain).

Figure 1. Results of bird surveys conducted at 16 landscape units in the Nanangroe area in 2001/2002 (Fischer et al., unpublished data – see text for details). The data illustrate that bird species richness tended to be higher in more productive valley environments than on ridge tops.

The matrix samples the most productive parts of the environment

Human landscape modification is not a random process (Burgman and Lindenmayer 1998). Humans choose areas for production on the basis of accessibility and productivity. This bias means that many nature reserves are in steep and unproductive terrain unsuitable for other purposes (Margules and Pressey 2000; Paton 2000). Similarly, in production landscapes, most remnant vegetation occurs on the less productive hilltops (Lemckert 1998; Gibbons and Boak 2002). Given this bias, the matrix can be an important area for conservation management, because it has the potential to support different elements of biodiversity than less productive areas. Our most recent field survey of birds in Nanangroe illustrated this finding. During our reptile surveys in 2001/2002 we also surveyed 16 landscape units for birds. Each landscape unit measured approximately 2.5 ha, and landscape units were stratified on the basis of their topographic position (valley or ridge) and relative canopy cover (high or low). Repeat bird surveys were conducted for 10 days at each landscape unit when pitfall traps were visited. The results of our bird surveys illustrated that productive valley environments with above average tree cover supported a higher number of bird species than less productive ridge tops with similar levels of tree cover (Figure 1). Similarly, although more data would be needed for conclusive evidence, valley environments with below average tree cover tended to support more bird species than ridge environments with below average tree cover (Figure 1). These considerations highlight the potential value of restoring parts of the landscape matrix because it often coincides with the most productive parts of the landscape, and thus can provide ecological benefits that less productive environments cannot offer.

Current conservation practices and the future of the matrix

A soft matrix can provide habitat and facilitate connectivity, and will often sample the most productive parts of the environment. However, most conservation strategies in the grazing landscapes of south-eastern Australia do not target the matrix, but focus solely on patches of remnant woodland. The two most widespread conservation activities are (1) fencing off selected woodland areas from grazing, and (2) tree planting in fenced off areas (Bennett et al. 2000). These practices are a useful starting point, since they aim to ensure that some habitat can recover from grazing pressure, and create new habitat in other places. However, we are concerned that while these activities take place, much habitat and ecological continuity will be lost because of continuing and severe degradation of the landscape matrix.

In many grazing landscapes of southeastern Australia, the neglect of the matrix will lead to a lack of tree regeneration due to grazing pressure. For example, large parts of the Nanangroe landscape are characterised by an almost complete lack of natural tree regeneration. In 144 of 10 m × 10 m, plots established for pitfall trapping, 94 trees were measured, and there were no trees shorter than 150 cm, and only two trees with a diameter at breast height of less than 5 cm. A similar finding was made by Spooner et al. (2002) in a more extensive investigation of tree regeneration in the south-west slopes of south-eastern Australia. These workers found no tree regeneration in 87% of unfenced woodland remnants. A recent study by Saunders et al. (2003) demonstrated that the threat of a rapid future loss of tree cover was equally pertinent in Western Australia. Repeat surveys of all individual trees in a 15 ha grazed woodland remnant showed a significant decline in tree condition between 1978 and 1998. In addition, Saunders et al. (2003) noted there had been no tree regeneration throughout the entire remnant since grazing commenced in 1929. In the absence of tree regeneration in the wheat-sheep regions of Australia, there will be a severe decrease in tree-associated habitat features in the areas between fenced off patches. A lack of tree regeneration will lead to a deterioration in matrix heterogeneity, and may mark the transition of currently variegated landscapes into fragmented or relictual landscapes (*sensu* McIntyre and Hobbs 1999).

Barriers to matrix management

Despite repeated calls for more integrated landscape management in production landscapes (e.g., Noss 1983; Hobbs et al. 1993; Barrett et al. 1994; Morton et al. 1995), on-ground changes have been few in the grazing landscapes of south-eastern Australia. Achieving fundamental changes is not straightforward – there are important socio-economic, historical, policy, and legal constraints that need to be overcome to achieve more sympathetic matrix management in the future.

Economic and historical constraints

Land managers have tangible economic reasons to be interested in the short-term output of produce from their land. Conservation considerations are a relatively recent concern to these stakeholders – for example, in Australia, the clearing and ‘improvement’ of land was for many years rewarded by the government through tax incentives (Saunders 1994; State of the Environment Advisory Council 1996).

The allocation of land for production or conservation respectively (rather than landscape scale matrix management) is currently the most popular way of conservation management since it requires no fundamental changes to land management practices (Lindenmayer and Franklin 2002). For example, fencing off certain patches to be ‘sacrificed’ for conservation is costly in terms of the funds required for labour and materials (Fenton 1997), but these measures can be implemented without fundamental changes to land management elsewhere on the property. This natural tendency towards solving conservation issues through land allocation strategies is enhanced by the fact that clearing has been biased in the past – that is, the most productive areas are often already cleared (Lemckert 1998; Gibbons and Boak 2002), and the largest patches of semi-natural vegetation are often located in areas that are relatively unsuitable for production anyway. Thus, excluding these areas from production is a sacrifice that may be costly in terms of materials and labour, but can be integrated relatively easily with existing farming practices. Further, Bennett et al. (2000) showed that most revegetation activities on Australian farms aimed to establish linear strips of vegetation, which could be easily integrated with current paddock boundaries and were easiest to work around during farming operations (e.g., cropping). Indeed, Bennett et al. (2000) found that the primary reason for revegetation activities was to enhance production, not to aid biodiversity conservation.

Unlike fencing off patches or establishing linear plantings, sympathetic matrix management may be more difficult to reconcile with many existing management strategies because it requires heterogeneity across the entire landscape – for example, it may involve changes to stocking/cropping regimes, or the establishment of additional temporary or permanent fences, and coordination of multiple landholders. Thus, while there is considerable momentum in the farming community to work towards sustainable management practices with respect to nature conservation (e.g., Davidson 1995; King 1995; Milne 1995; Fenton 1997), there are short-term economic and historical barriers that work against changes to matrix management. Future research in this area is critical to establish ways to manage entire landscapes more sustainably. What exactly are the economic barriers to more sustainable matrix management? What are the short- and long-term costs and benefits from various different conservation and production activities? Do ecologically diverse systems provide a larger amount of ecosystem goods and services (Daily 1999, 2001)? The answers to these and related questions may provide useful ways forward because they may highlight economic incentives to sustainably manage agricultural land that have been overlooked to date.

Legal constraints

The ecologically undesirable paradigm of land use allocation to address issues of biodiversity conservation is also apparent in current environmental legislation. The disregard for the matrix in existing legislation most likely arises from a degree of ignorance about its importance, and political pressure to avoid conservation measures that are unpopular. Australia's land clearing rate is still among the highest in the world, partly because of high clearing rates in the state of Queensland (Glanznig 1995; Glanznig and Kennedy 2000). Nevertheless, other states also continue to clear land, and current environmental legislation highlights the disregard for the potential value of remnant vegetation scattered throughout the landscape matrix.

The New South Wales *Native Vegetation Conservation Act 1997* aims to provide for the management of native vegetation in accordance with the principles of ecologically sustainable development. While it generally prohibits the clearing of native vegetation without development consent, it contains several exemptions which allow clearing of native vegetation. Current practices falling under these exemptions include the clearing of up to 2 ha of native vegetation every year on an individual property. Similarly, seven trees per hectare may be removed in any given year for on farm purposes. Finally, all tree regeneration in the matrix that is younger than 10 years of age may be cleared (Department of Land and Water Conservation 1999; Sundstrom 2001; Bates 2002). These exemptions demonstrate which aspects of native vegetation are considered worthwhile conserving – small patches and recently regenerated trees in the matrix are essentially deemed worthless for nature conservation. Hence, the current legal framework in New South Wales contrasts starkly with the actual ecological importance of small patches and scattered trees in the landscape matrix. Similarly, the legal frameworks for native vegetation conservation in other Australian jurisdictions contain a wide range of exemptions that are rarely grounded in ecological reality (Bates 2002).

In addition to deficiencies in legislation to adequately account for the value of the matrix, a lack of sufficient law enforcement may render existing provisions ineffective. For example, in New South Wales, there is some concern that the number of cases where illegal clearing has been successfully prosecuted is negligible (Department of Infrastructure, Planning and Natural Resources, unpublished information). Thus, there is at least some suggestion that for legislation to be effective, prosecution may need to be more rigorous.

Scientific constraints

Economic, historical and legal constraints to more sympathetic matrix management can be further enhanced through the uncritical adoption of existing scientific paradigms. For example, the theory of island biogeography (MacArthur and Wilson 1967) was an important foundation of conservation biology (Diamond 1975; reviewed by Haila 2002). The resulting concept of patchy landscapes easily lent itself to a binomial classification of land into habitat and non-habitat (Lindenmayer et al.

2003), and thus was consistent with a conservation approach based on land use allocation. In addition, traditional scientific thinking is strongly based on hypothetico-deductive investigations, and therefore most scientists are likely to feel most comfortable dealing with clearly defined categories as provided by theoretical tools such as the patch-matrix model (Wiens 1995). However, while a binomial classification of land may be useful in some landscapes, more integrated management considering entire landscapes will be important in many cases.

An additional reason why scientists have been reluctant to act in accordance with calls for more integrated landscape management, may be the perceived political reality they find themselves in. Given a certain political climate, conciliatory approaches with land managers that do not require fundamental changes to land management sometimes appear more likely to be worthwhile than approaches that are more challenging to the land manager and advocate more fundamental changes. However, while a sense of realism with respect to the political climate is important, only ecologists will have the necessary information and a firm basis from which to argue for more sympathetic matrix management – indeed, economic and historical realities that may be of primary relevance to other stakeholders will not allow changes to matrix management unless ecologists clearly state well-founded reasons for an abandonment of the *status quo* and argue strongly for changes to matrix management.

Ways forward

For conservation biologists to be effective in bringing about changes to matrix management in Australian grazing landscapes, more scientific research is necessary, but this alone is not sufficient. Three additional factors complementing scientific work may be of key importance: (1) an improved understanding of the current policy framework, and the opportunities it provides for change, (2) improved communication with all stakeholders involved, and (3) more practical on-ground research that highlights potential avenues for more sustainable management practices.

Opportunities for change: understanding the legal framework

While the clearing exemptions in New South Wales highlight the current neglect of the matrix, a more detailed examination of the legal framework highlights several potential avenues through which change may be achieved. First, the exemptions under the *Native Vegetation Conservation Act 1997* are transitional provisions remaining from earlier legislation (State Environmental Planning Policy No. 46: Protection and Management of Native Vegetation). These exemptions may be removed or altered by either Regional Vegetation Management Plans or Native Vegetation Codes of Practice (Bates 2002). The Nanangroe area falls under one of two Regional Vegetation Management Plans that have already been gazetted, the

Riverina Highlands Regional Vegetation Management Plan 2003. While this Plan modifies the exemptions discussed above to some extent, subject to some conditions, it still allows for the annual removal of up to 10 trees per hectare and all regrowth younger than 10 years of age. Hence, the changes brought about in this case were somewhat insignificant with respect to their effect on matrix management. However, there are 19 Regional Vegetation Management Plans at various stages of development, to which input can still be made. Communicating the important role of a soft matrix to the relevant Regional Vegetation Committees may be a possible avenue to improve the legal protections accorded to the matrix. Indeed, provision of robust scientific data to these Committees is essential to assist them to adequately discharge their responsibilities (Thompson 2001).

Second, the *Native Vegetation Conservation Act 1997* also contains provision for property agreements. These are voluntary but enforceable agreements made between landholders and the Department of Infrastructure, Planning and Natural Resources, which include the development of a strategy for native vegetation management on individual or multiple properties, in conjunction with the provision of technical and financial assistance to the landholder (Department of Land and Water Conservation 1998; Ferrier et al. 1999). Again, communicating the importance of a soft matrix to the NSW Department of Infrastructure, Planning and Natural Resources, which administers these property agreements, and the farming community could result in the inclusion of more integrated matrix management into native vegetation management strategies. The advantage of this second example is that it also addresses to some extent the economic implications of a shift towards sympathetic matrix management.

While understanding the policy framework that governs matrix management can be useful to identify avenues for improvement, it is important to realise that achieving changes in environmental policy is not a straightforward task. There is a clear need for more interdisciplinary work examining the links between science, policy development and institutional structures to improve the implementation of scientific findings into policy frameworks (Ison and Russell 2000; Lindenmayer and Franklin 2002).

Communicating complexity and urgency

To achieve changes in matrix management, scientists will have to communicate with other scientists, government agencies and land managers. It will be important to explicitly distinguish between different audiences that scientists want to reach. The potentially important role of habitat features that do not coincide with large patches of remnant woodland needs to be communicated widely to land managers – it will be important to emphasise that habitat is more than trees, and that a soft matrix can provide habitat for a range of animals. However, confronting individual farmers and ‘demanding’ they implement integrated matrix management is bound to fail and is unrealistic given the economic realities with which individual farmers have to deal. Indeed, Fischer and Lindenmayer (2002a) argued that it was important

to realise that even small conservation efforts could be worthwhile, and should be encouraged. Conversely, the true complexity of ecological systems including the role of the matrix will need to be communicated to other scientists, to the farming community as a whole, and to politicians and policy makers. Sustainability as a goal of environmental management has become a popular catch phrase, but it is important to recognise that different levels of diversity may be conserved as a result of different conservation approaches. In the grazing landscapes of southeastern Australia, an approach of land use allocation will lead to 'patchy' landscapes, which may look somewhat reminiscent of northern Europe. On the other hand, a more integrated approach may lead to the conservation of different types of landscapes representing a range of different alteration states (see McIntyre and Hobbs 1999). Both approaches may eventually lead to a stable level of biodiversity, but the absolute amount of diversity supported is likely to be substantially higher if a more integrated approach to land management is employed that considers not only patches, but also the matrix. Given these considerations, it is by no means clear that ecological researchers are doing better, that is, conserving more biological diversity, by following a non-confrontational pragmatic approach to conservation through land use allocation. Indeed, in the context of the global reserve network, it is recognised that a global target of setting aside 10% of all land for conservation is likely to be vastly insufficient (Rodrigues and Gaston 2001).

The need for practical research

New research methods that complement reductionist approaches may be helpful to derive effective management tools. An increased use of systems dynamics approaches may be a useful starting point to assist us to better conceptualise complex environmental systems (Senge 2001), and may help integrate the knowledge and perspectives of a wide range of disciplines (Jackson et al. 2001). Multidisciplinary investigations will be necessary to consider the range of ecological, economic and social issues associated with changes in matrix management. At an applied level, future projects may include investigations into various grazing regimes and their effect on matrix condition, and the identification or establishment of 'model farms' that are managed sustainably.

Conclusions

Our case study illustrated that the concept of patches is deeply embedded in conservation strategies used in Australian grazing landscapes, and the role of the matrix is largely ignored. This finding highlights the potential negative effects that can arise from over- or misapplying ecological theories (see also Haila 2002). While much of our case study focused directly on New South Wales, the problem of undervaluing the matrix is not unique to Australia. For example, research in the USA suggests that small wetlands may be undervalued in a similar way to small

woodland patches in Australia (Semlitsch and Bodie 1998; Joyal et al. 2001). Addressing conservation issues in the matrix will require a sound scientific understanding of the matrix. However, insights from non-scientific disciplines also will be important.

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