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Applying landscape-ecological principles to regional conservation: the WildCountry Project in Australia

11.1 Introduction

One of the great challenges facing humanity in the twenty-first century is the conservation and restoration of biodiversity (Convention on Biodiversity 1992). In this chapter we present the landscape-ecological underpinnings of a new nongovernment organization (NGO)-driven conservation initiative in Australia, namely the WildCountry Project.

Global and national analyses highlight the extent of environmental degradation and the need for urgent protection and restoration of biodiversity (e.g., SEAC 1996, Environment Australia 2001, World Resources Institute 2001, NLWRA 2002). Such analyses also suggest that existing conservation strategies and plans are insufficient to prevent continuing losses.

The primary question, at the most general level, is: how can a conservation system be designed and implemented for Australia that is likely to maintain biodiversity for centuries to millennia? Dedicated protected areas are a core component of a nation's biodiversity conservation system. By our calculations (Fig. 11.1) only about 6 percent of Australia is in a secure protected area. There is no theoretical or empirical basis to the proposition that this level of reservation, while necessary, is sufficient for securing the conservation of Australia's biodiversity. In any case, protected area networks are largely the result of various historical contingencies rather than the principles of modern reserve design (Margules and Pressey 2000). We suggest that the percentage of Australia reserved in protected areas is unlikely to ever exceed 10–15 percent. Our calculations (Fig. 11.1) also show that about 84 percent of the Australian continent has a native vegetation cover, is outside a protected area, and is not used for agriculture or forestry. Of this 84 percent, about 56 percent

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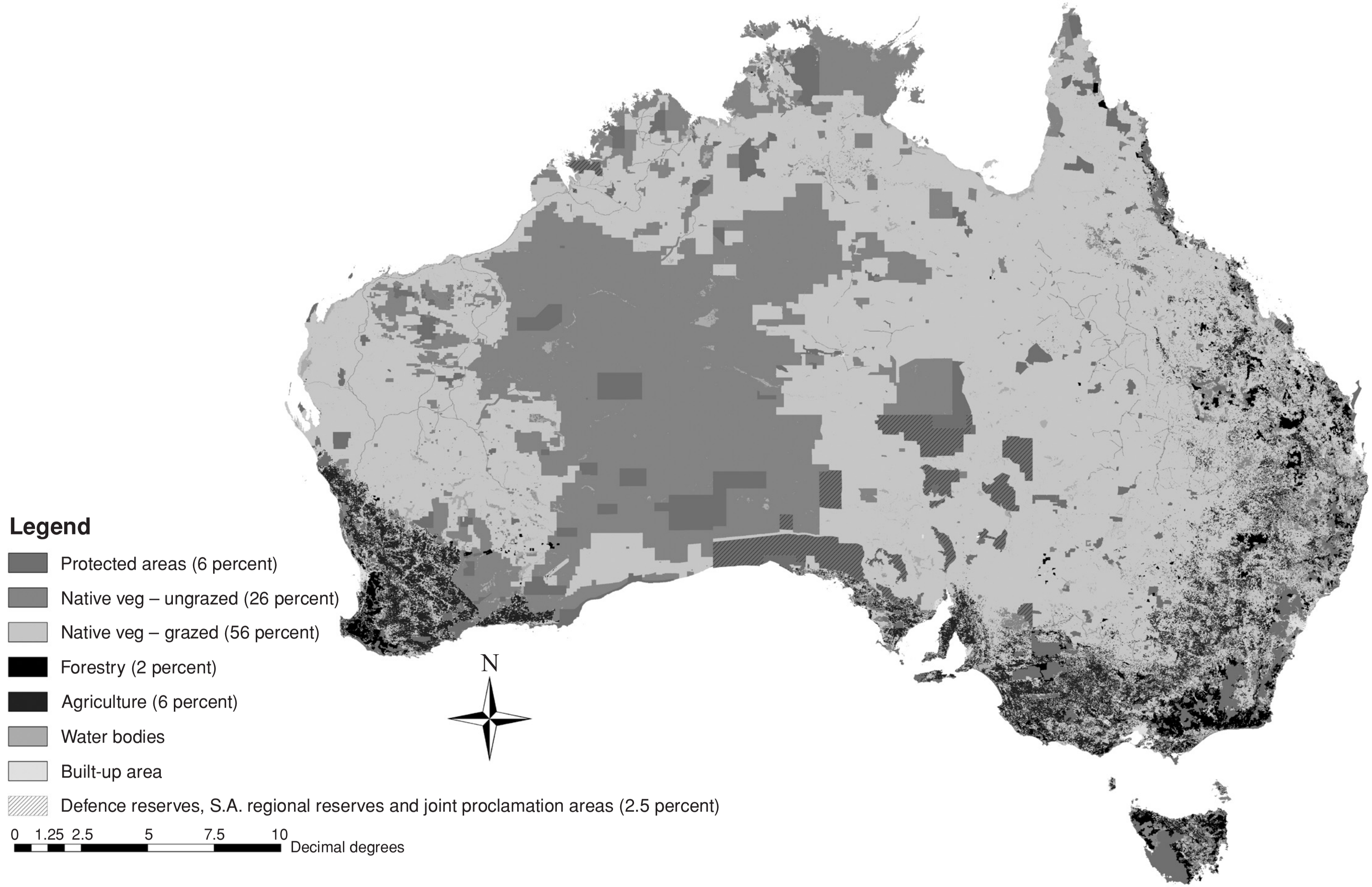

FIGURE 11.1

Broad categories of land use and land cover for Australia that identify regions where different approaches are needed for implementing landscape-wide conservation assessment and planning that promotes ecological connectivity. The legend also indicates the percentage of the Australian continent covered by each class. (Source: *1996/97 Land Use of Australia*, Version 2, National Land and Water Resources Audit.) The boundaries of the reserves that permit grazing in S.A. were extracted from the NPWSA Property Boundaries Data set from the National Parks and Wildlife S.A., Department for Environment and Heritage. Note that the protected area boundaries for NSW are current as of 2003, whereas the boundaries for Victoria and W.A. are based on the best available land tenure data which were compiled *circa* 1997.

is commercially grazed. For Australia's biodiversity to persist in the long term, more targeted and better configured reserves are needed in poorly protected country, and conservation must be integrated into the land management objectives of much of the remaining 84 percent, and especially the 56 percent of grazed, extensive country.

Civil society has now joined the government sector in attempting to formulate appropriate responses to the challenge of conserving Australia's biodiversity. As defined by international law (Convention on Biodiversity 1992), biodiversity refers to genetic, species, and ecosystem diversity, and thus encompasses, *inter alia*, the diversity found within species and the different vegetation types, food webs, and landscape ecosystems found in a region. Amidst other nongovernment initiatives such as Greening Australia (2004), The Wilderness Society Australia has launched the WildCountry Project (hereinafter WildCountry) in partnership with other civil society organizations, government at state and local levels, industry and private landowners, and the Wildlands Project USA. WildCountry builds upon the Wilderness Society's mission, namely, "to protect, promote and restore wilderness and natural processes for the wellbeing and ongoing evolution of the community of life across Australia." The WildCountry project reflects the following concepts: the need for a significant improvement in the protected area network and off-reserve management, community engagement with stakeholders to help catalyze and sustain "coalitions of the willing" capable of helping to develop and locally implement conservation assessment and planning and action on a regional basis, and recognition that assessments, plans and management must be grounded in and informed by a scientifically based understanding of what is needed to ensure the long-term conservation of biodiversity. As such, WildCountry is consistent with government policy both at the national and state level, and related conservation strategies and programs (Commonwealth of Australia 1997, Commonwealth of Australia 1999, ANZECC 2001, Commonwealth of Australia 2001a, 2001b, 2002).

The authors of this paper constitute a voluntary WildCountry Science Council, constituted in order to provide independent advice on the scientific concepts, principles, and methods needed to underpin the WildCountry project. Are existing methods for reserve design adequate? Do prevailing approaches to conservation assessment and planning provide the necessary information? Are there critical ecological phenomena and processes not yet incorporated into currently existing conservation methodologies? This paper provides an initial response to these and related questions and in so doing represents the first step in articulating a WildCountry scientific framework. In the following sections we discuss the historical and conceptual underpinnings of WildCountry and the necessary scientific principles. We conclude by considering some implications of these for WildCountry implementation.

As noted above, WildCountry assumes that, for much of Australia, voluntary changes based on partnerships between stakeholders will be the way forward. NGOs such as the Wilderness Society are well placed to help such partnerships. Governments can be constrained by inertia, vested interests or prior policy decisions. NGOs, on the other hand, can have greater flexibility and, often, greater longevity, than governments. This approach to conservation will invariably need to mesh with other programs that aim at redesigning agricultural and pastoral systems to ensure sustainability (e.g., Landcare Australia 2004). In order to facilitate such a partnership approach, education of and engagement with local communities will be key components of a WildCountry framework. Whilst acknowledging the importance of these social dimensions to WildCountry, our focus in this chapter is on the necessary scientific components of a WildCountry framework – though the social dimensions are touched upon in those sections below that address broad-scale threatening processes and approaches to systematic planning.

11.2 Foundation principles

11.2.1 Core areas

It is axiomatic that dedicated core areas must be a key component in the WildCountry framework. These are areas, primarily managed for their conservation values, that contain relatively intact ecosystems (e.g., minimal broad-scale vegetation clearing) and that have low exposure to anthropogenically driven threatening processes (however, note the discussion below on management). At a regional scale, core areas should represent all major landscapes. Another key consideration in defining dedicated core areas is the long-term prospects for retaining or improving the quality of relative wildness. Dedicated core areas must be sufficiently large to have the capacity to "self-manage" through natural processes that include the dispersal of biota and their propagules, natural selection, species evolution, and biotic regulation of local biogeochemical and water cycles (Gorshkov *et al.* 2000). There is, however, no simple answer to the question of how large an area needs be to retain core-area characteristics. Given the extent of anthropogenic perturbation in Australia (particularly in the intensive land-use areas, Fig. 11.1), we can readily anticipate that in certain landscapes it will not be possible to find large areas that have not been subject to broad-scale clearing, overgrazing, large-scale disruption of hydrological regimes, and other intensive land uses. Thus, an emphasis on linking relatively intact habitat cores that represents "the best that is left," together with substantial ecological restoration, will be necessary.

Given the importance of core protected areas to WildCountry, a logical starting point in defining the components of an appropriate scientific framework is to consider the criteria developed for the Australian Regional Forest Agreement (RFA) process (AFFA 2003). Three main criteria were adopted for the RFA, namely: comprehensiveness, adequacy, and representativeness (CAR). Comprehensiveness refers to the extent to which the pre-European distributions of forest ecosystem types are captured by the protected-area network. Representativeness refers to how well the within-forest type variability is sampled by the protected-area network. Adequacy refers to the likelihood that the protected-area network will ensure the long-term viability of the biodiversity that resides therein. In practice, the criteria of adequacy and representativeness were not substantially applied in the RFA process, and targets were only set for the first criterion – "comprehensiveness." Thus, following extensive assessments, forest tenure was changed in each region so that a nominated percentage of the pre-European distribution of forest types ecosystems was included within the protected-area network. Targets were also set to ensure a percentage of the potential habitat of threatened and rare vertebrate animal and vascular plant species were captured within the protected-area network. Interestingly, wilderness targets were also prescribed but on the basis that wilderness quality reflects a social value of no biodiversity conservation relevance.

The RFA criteria, as applied to date, have been useful in helping to promote the implementation of explicit conservation criteria and systematic reserve design in Australia (e.g., GBRMPA 2003). While they remain relevant to WildCountry, it is equally important to appreciate their limitations. The RFA criteria ignore landscape condition and thus do not explicitly consider the impact of human land-use activity on ecosystem structure and function, and animal habitat. Furthermore, landscape variation in primary productivity was not considered. Thus, in identifying priority conservation areas the distinction was not necessarily made between heavily perturbed, low productivity and relatively intact, high productivity forests.

In practice, the setting of percentage targets for representation (i.e. the comprehensiveness criterion) proved to be a relatively arbitrary process without strong and explicit scientific foundation. In any case, it is arguable whether the concept of setting percentage targets for representation is relevant in intensively cleared landscapes where only fragments of native vegetation remain. In these circumstances it could be argued that all the remnant patches have conservation value. Similarly, experience gained from studying land degradation in southern Australia has yielded little by way of guidelines as to the ecologically permissible percentage of native vegetation that can be cleared within intact landscapes. In both these contexts, the risk with a CAR approach as applied in the RFA process is to promote ecologically and numerically minimalist conservation outcomes, whereas the WildCountry conservation objectives are expansive and long-term. Nonetheless, the CAR criteria as originally conceived remain useful and relevant to the problem of systematic reserve design, and as such are one set of inputs to a WildCountry scientific framework.

11.2.2 The Wildlands Project

Additional guidance was sought from the methodology and scientific principles underlying the Wildlands Project (hereinafter Wildlands) in North America (Foreman 1999). The vision of Wildlands is to protect and restore North America's ecological integrity. The project is creating an alternative, map-based land-use plan for the continent, with the emphasis on connectivity and the restoration of ecological interactions. Formed in 1991 by scientists and conservationists, Wildlands emphasizes maintaining, connecting, and buffering wild lands, repairing landscapes that have been compromised by such factors as habitat fragmentation and loss of species, maintaining natural disturbance regimes, and communicating the ecological values of wilderness, plants, and animals (Soulé and Terborgh 1999). The approach is to restore missing species and processes, and to anticipate climatic and landscape changes that might compromise natural values and society's opportunities for enlightened economies. This is called "rewilding" (Soulé and Noss 1998). Wildlands recognizes that the application of these broad conservation principles will vary depending on regional ecology, the history of disturbance, and existing land use.

A major component of rewilding in North America is the maintenance of ecologically effective populations of large mammalian carnivores and other highly interactive species, the loss of which initiates cascading or dissipative changes through the ecosystem (Soulé *et al.* 2003). There is persuasive scientific evidence that such strongly interacting species and processes are vitally important to healthy ecosystems. Because large predators require extensive space and connectivity, the modeling of their habitat requirements is a key tool in network design in North America. Reconciling this rewilding approach with the more traditional methods of biodiversity conservation has been one of the greatest challenges for Wildlands, but is also what distinguishes its approach from that of most other conservation groups (Soulé and Noss 1998).

Following the principles of systematic conservation planning (Margules and Pressey 2000), the Wildlands regional plans feature explicit goals, quantitative targets (based on defensible ecological calculations), rigorous methods for locating new reserves, and explicit criteria for implementing conservation action. Focal species analysis can complement the incorporation of special elements and representation of vegetation types by addressing questions concerning the size and configuration of reserves and other habitats necessary to maintain species diversity and ecological resilience over time.

Wildlands provides three key concepts that are potentially relevant to the WildCountry scientific framework in Australia, namely: (1) continental and regional connectivity of large core reserves as required to support the long-term conservation requirements of large carnivores and other spatially extensive ecological processes (Soulé and Terborgh 1999), (2) complementary land management in surrounding landscapes, and, (3) where necessary, restoration of natural processes and disturbance regimes, the control of invasive species, and the reintroduction of native species. Of particular interest was the first principle, regarding the need for conservation-area designs to reflect continental and regional connectivity, the pivot points of which are large core reserves. Is this principle of large-scale connectivity equally relevant to the Australian situation, or are there major differences in the ecologies of Australia and North America that require the concept to be revisited for WildCountry?

11.2.3 Connectivity revisited

As noted above, in a North American context, large-scale connectivity has been considered by the Wildlands project in terms of the maintenance of ecologically effective populations of large mammalian carnivores and other wide-ranging focal species. The absence of large predators often leads to numerical release (abnormally high abundances) and behavioral release (e.g., abnormal levels of foraging or predation) of herbivores and mesopredators, thereby changing community composition, dynamics, and the structure of vegetation. More generally, Wildlands emphasizes the need to maintain ecologically effective populations of keystone and other highly interactive species at the regional scale (Soulé and Noss 1998, Crooks and Soulé 1999, Terborgh *et al.* 1999, Soulé *et al.* 2003).

From this perspective, planning for connectivity means ensuring large core areas to be embedded within landscapes that include compatible-use areas and habitat linkages (Frankel and Soulé 1981, Noss and Cooperrider 1994, Hobbs 2002a). It is argued that a conservation-area design based on this principle is better able to sustain the long-term ecological viability of these large species compared to a conventional system of isolated parks and reserves. This approach requires working at spatial and temporal scales exceeding those normally employed to manage natural areas and natural resources.

There are major differences in the ecologies of Australia and North America that suggest the Wildlands principle of large-scale connectivity for large mammalian carnivores may not be as relevant to WildCountry. First, and most importantly, Australia lost its megafauna around 50 000 years ago (Beck 1996). Thus, the long-term requirements of large predators might appear irrelevant in the framing of a continental conservation strategy for Australia. A second difference between Australian and North American ecology stems from the climatic systems that dominate these continents. Much of Australia is characterized by extreme variability in the distribution of rainfall as well as deeply weathered landscapes of low relief and low soil fertility. These dominating factors have generated distinctive ecological responses in the plants and animals everywhere, but particularly in the arid and semi-arid zones (Friedel *et al.* 1990, Morton *et al.* 1995).

Notwithstanding these differences, large-scale connectivity may still be an important conservation planning principle for Australia but primarily for different reasons than in North America. The following sections consider a set of ecological phenomena and processes that operate at large scales in both space and time. We argue that their ongoing functioning is necessary for the long-term resilience of landscape ecosystems, the maintenance and regeneration of habitat, and ultimately the viability of populations. Furthermore, we suggest that the landscape linkages necessary to maintain their functioning have yet to be substantially integrated into conservation assessment and planning.

11.3 Large-scale connectivity

Connectivity is generally considered in terms of wildlife corridors – narrow bands of native vegetation connecting core habitat areas (Lindemayer and Nix 1993). Here the word is used to draw attention to large-scale ecological phenomena and processes that require the maintenance of landscape linkages at regional to continental scales. The necessary landscape linkages may include core areas, comprise continuous habitat such as riparian corridors and appropriately spaced stepping-stones (Dobson *et al.* 1999, Roshier *et al.* 2001), or reflect some other kind of spatial "teleconnection."

11.3.1 Trophic relations and interactive species

Whilst Australia lacks the large mammalian carnivores of North America, species at any given trophic level can play a major role in regulating resource availability and population dynamics over species at other levels, e.g., large herbivores (Oksanen and Oksanen 2000), pollinators (honeyeaters; Paton *et al.* 2000) and mesopredators such as the dingo *Canis lupus dingo* (Caughley *et al.* 1980). Maintaining large-scale connectivity for such trophically interactive species (Soulé *et al.* 2003) is critical to consider in conservation planning.

The broader implications of maintaining and/or restoring trophic levels in a food web on a landscape-wide basis have generally not been used in Australia to guide conservation assessment and planning.

11.3.2 Hydroecology

The term hydroecology describes the role that vegetation plays in regulating surface and subsurface hydrological flows, and in turn the importance of water availability to plants and animals (Mackey *et al.* 2001). The significance in Australia of hydroecology is amplified by high year-to-year variability in rainfall (Hobbs *et al.* 1998). Hydroecological processes can be observed in all regions of Australia, including Cape York Peninsula (Horne 1995, Horne *et al.* 1995), the Southern Tablelands of NSW (Starr *et al.* 1999), the Central Highlands of Victoria (Vertessey *et al.* 1994), and inland Australia (Friedal *et al.* 1990, Stafford Smith and Morton 1990). Generally, our land management has not protected catchment-scale processes that affect groundwater recharge and discharge, although these are critical for maintaining perennial springs and water holes, river base flows, and perennial stream flow. Biodiversity conservation and planning must pay particular attention to such whole-of-catchment processes.

11.3.3 Long-distance biological movement

Both vertebrates and invertebrates can have stages in their life cycles that are associated with large-scale movement. A vast diversity of organisms and their propagules forage, disperse, and migrate (Cannon and Gardner 1999, Drake *et al.* 2001, Isard and Gage 2001). Examples of ecologically significant long-distance biotic dispersal include the use of rainforest patches by animals in Northern Australia (Palmer and Woinarski 1999, Shapcott 2000, Bach 2002), and dispersive avifauna in Australian woodlands and open-forest (Paton *et al.* 2000, NLWRA 2002). Thus, there is a need to maintain networks of suitable habitat for dispersive species over large regions. A conservation system is needed that is extensive enough to embrace the full breadth of continental variability in climate, productivity, and vegetation, and the resultant fauna dynamics (Nix 1974).

A type of biological movement of special conservation interest is dispersal to and from refugia – places where populations of a species can persist during a period of detrimental change occurring in the surrounding landscape. Thus, refugia are locations that provide refuge from threatening processes. They enable species to maintain their presence in landscapes and are potential sources for reestablishment. Refugia can be defined at a range of scales and with respect to various threatening processes, including inappropriate fire regimes (Mackey *et al.* 2002), global climate change (Lovejoy 1982), and drought (Stafford Smith and Morton 1990). Refugia are probably important in all ecosystems (thought not all movement associated with refugia is necessarily large scale) but only rarely has their significance been considered in conservation assessment and planning.

11.3.4 Ecologically appropriate fire regimes

Fire is a natural part of virtually all Australian landscapes and has an important influence on the biological productivity, composition, and landscape patterning of ecosystems (Reid *et al.* 1993, Williams *et al.* 1994, Whelan 1995, Bradstock *et al.* 2002, Catchpole 2002, Mackey *et al.* 2002). The conservation implications of ecologically inappropriate fire regimes can be substantial. In systems fragmented by human activity, broad landscape processes have been disrupted leading to altered fire regimes (Gill and Williams 1996, Hobbs 2002b). Remnant vegetation in agricultural areas may suffer from the absence of fire over long periods. In large core conservation areas, there may be an overriding need for deliberate and carefully planned fire management, allowing for large and/or high intensity wildfires. The role of Aboriginal burning practices demands special attention especially in Northern Australia (Price and Bowman 1994, Williams and Gill 1995, Bowman *et al.* 2001, Yibarbuk *et al.* 2001, Keith *et al.* 2002).

11.3.5 Climate change and variability

As a consequence of human-forced climate change (IPCC 2002), it is likely that Australian ecosystems will be exposed in the coming decades to an increase in the frequency of extreme weather events, higher average daily temperatures (especially higher minimum daily temperatures), and changes in the spatial and seasonal distribution of precipitation (CSIRO 2001). Such changes have direct and indirect impacts on all aspects of biodiversity, including species distributions, community structure, and ecosystem processes (Mackey and Sims 1993, Hannah and Lovejoy 2003, Thomas *et al.* 2004). Providing connectivity to promote biotic adaptation to climate change is a formidable challenge, but is central to continental- and regional-scaled conservation assessment and planning for the coming decades (NTK 2003).

11.3.6 Coastal zone fluxes

There are two perpendicular directions of flow in the coastal zone. One is the flux of matter and energy between sea and land; the other direction of flow is parallel to the coast, such as the migration of marine organisms, including shorebirds, and the movement of coastal currents. Connectivity of land/coastal-zone flows is particularly important given the concentration of Australia's population in coastal regions (Cosser 1997). Terrestrial conservation assessment and planning must include these important links with the marine environment. A landscape could have conservation value primarily because it contributes to ecosystem function in the adjacent coastal zone. Indeed, a "source to sea" planning framework is essential. A more comprehensive treatment of these connectivity processes will be published elsewhere.

11.4 Research and development issues

11.4.1 Dispersive fauna

Conservation planning for dispersive fauna requires data at landscape and continental scales on movements and the spatial and temporal distribution of habitat resources, including the dispersion of food resources in response to environmental variability. Meeting these information needs is conceptually tractable but logistically will require a significant investment in IT-based systems. Data from various sources (remotely sensed, field-survey records, digital maps) and themes (climate, topography, substrate, vegetation, wildlife, land use, land tenure) must be assimilated into usable formats at the best available resolutions across the continent. Advances in GIS, environmental modeling and remote sensing provide the capacity to describe, classify, and map landscapes in ways that are relevant to the assessment of fauna distributions and habitat requirements (Mackey *et al.* 1988, 1989, 2001, Lesslie 2001, Mackey and Lindenmayer 2001, Nix *et al.* 2001). They can also be used to directly track temporal variability in the distribution and availability of primary production and food resources. Critically, these analyses can now be undertaken at a continental scale with high spatial and temporal resolutions. Of particular interest are high-resolution digital elevation models (Hutchinson *et al.* 2000) and land-cover data derived from satellite-borne sensors such as MODIS (~250 m spatial resolution), Landsat TM (~25 m resolution) and JERS-1 SAR (~18 m resolution). Derived remotely sensed products now include various estimates of food resource production in response to environmental variability, including net primary productivity, above ground biomass, leaf-area index, and land-cover classes (Landsberg and Waring 1997, Austin *et al.* 2003, NASA 2003). These analytical capabilities add to existing technologies and aid in both identifying core protected areas and in designing the necessary buffers, corridors, linkages, and management changes in the surrounding landscape matrix.

11.4.2 Protected-area and off-reserve management

The design and establishment of core areas for biodiversity conservation can only be part of a WildCountry framework. Decisions must also be made about the ongoing management of such areas together with the necessary off-reserve management regimes. Management of core conservation areas will affect neighboring lands (and hence the regional community's attitude to WildCountry values and outcomes) and vice versa. In Australia, almost all lands, including protected areas, are affected by the increasing impact of feral animals and plants and altered disturbance regimes. Feral animals degrade the most remote deserts of central Australia, and feral animals and weeds transform the furthest reaches of central Arnhem Land. In the absence of preventative management, these threats drive the landscape and its natural values further into decay. It is an abrogation of responsibility to leave the conservation values of lands unprotected from the array of new elements that are altering these landscapes.

We noted above that an effective system of reserves requires high levels of connectivity either by managing the "matrix" (all areas that are not part of the network of lands and waters under some kind of biodiversity protection) to allow for the movement and dispersal of plants and animals or by creating linkages specifically for that purpose. It is unrealistic to assume that all essential connectivity can be contained within a system of reserves in isolation. It is more reasonable to assume that large areas of habitat (or landscape components that contribute to ecological function) will remain outside the reserve system. The way the matrix is managed will be critical for the long-term conservation of biodiversity (Hale and Lamb 1997, Lindenmayer and Recher 1998, Lindenmayer and Franklin 2002), including the effectiveness of the linkages needed to maintain the connectivity of large-scale ecological processes.

Off-reserve land can have a vital role to play in protecting and restoring hydrological relations, accommodating the impacts of long-term climate change, providing for the seasonal and episodic movements of animals, the dispersal of propagules, and the exchange of genetic material between core areas. For these reasons, the capacity to manage effectively will depend on the willingness of adjoining landowners and leasees to change management practices to enhance conservation outcomes. There is a growing number of examples where off-reserve conservation can serve as a key element in engaging landowners and other stakeholders in the conservation process, especially if the engagement includes the development of local capacity and understanding (e.g., Dilworth *et al.* 2000).

The challenges facing off-reserve land-use management vis-à-vis connectivity will vary depending on the environmental context, regional conservation objectives, land-use history, the degree of degradation of the habitat, and management regimes. In Australia, three broad categories of land use and land cover can be recognized (Fig. 11.1). First, there are extensive areas in the tropical north and arid, central and southern Australia that have suffered minimal clearing of native vegetation, but are now witnessing the loss of biodiversity as the result of introduced herbivores and predators, livestock, weeds, and altered fire regimes (Finlayson 1961, Morton 1990, Woinarski *et al.* 1992, Russell-Smith *et al.* 1998, Franklin 1999, Woinarski *et al.* 2001, Lewis 2002). However, this category retains the potential for effective connectivity. Second, there are landscapes dominated by agricultural production where the pre-European settlement vegetation has been largely removed, and only isolated and usually degraded remnants persist; examples include the sheep/wheat belts of southeast Australia and southwest Western Australia. The maintenance of ecological flows is far more challenging in such areas (Saunders and Hobbs 1991, Hobbs *et al.* 1993, McIntyre and Hobbs 1999). Third, there are areas that are dominated by native tree vegetation, but are subject to substantial resource extraction, in particular, forest ecosystems in southern and eastern Australia.

We cannot assume that the matrix is benign for native plants and animals. Indeed, the nature of the matrix will vary depending on the prevailing land use, and closer attention to the impact of different matrix types on species' movement and survival is needed (e.g., Davies *et al.* 2001). Some matrix areas will be ecological sinks, although species will respond differently to different kinds and degrees of disturbance, pollution, and degradation. Other areas will retain some capacity to contribute to biodiversity and the maintenance of ecosystem processes. Within the categories of landscapes just described there are significant differences in the management practices needed to restore and buffer core areas, promote ecological connectivity, protect off-reserve biodiversity, and protect on-reserve biodiversity from off-reserve hazards. Identifying the appropriate mix of complementary management practices remains an ongoing research challenge.

11.4.3 Fire regime management and social values

Management of landscapes for biodiversity conservation is not only about remedial or preventative work on invasive organisms. Effective management demands good relationships with the human communities that inhabit these landscapes. While the livelihoods of all communities in regional Australia are coupled to access to land, for Aboriginal Australians, lands cut off from people are considered "lands without life." It follows that conservation planning in the areas of Australia that are legally recognized as Aboriginal land (about 13 percent of the continent, largely but not exclusively in central and northern Australia) cannot be separated in practice from issues related to the social and economic aspirations of Aboriginal Australians. To our knowledge, Aboriginal Australians did not generally engage in broad-scale clearing or silviculture. Rather, fire was the most important component of Aboriginal land management. Substantial parts of the Australian landscape probably still reflect the impact of past Aboriginal fire management practices. In some areas, the management system persists. Understanding past and present fire regimes is a critical research task for integrating fire management into large-scale conservation planning in Australia. The challenge of integrated fire management for biodiversity conservation is no less complex when considering the management systems, values, aspirations, and rights of nonindigenous pastoralists in regional Australia.

11.4.4 Whole-of-landscape conservation planning

Significant advances have been made in identifying networks of dedicated reserves that represent some kind of optima with respect to representativeness of biodiversity at a regional scale, their spatial configuration, and the potential impact of removing land from other land uses. Systematic reserve design usually also incorporates information generated from population viability analysis undertaken for target species. The whole-of-landscape approach promoted by WildCountry suggests a similar, but more complex planning process. "Landscape viability analysis" is needed, which enables the entire landscape to be evaluated and the optimum set identified of dedicated reserves, areas of connectivity, and off-reserve management requirements.

If the problem of how to optimally allocate conservation effort can be properly formulated as a decision-theory problem then decision theory-algorithms can help solve the problem efficiently (Possingham *et al.* 2001). It is important in this context to separate the following three parts of conservation planning:

(1) *Defining the problem* in terms of the objectives and constraints – this is where the conservation values (and related socioeconomic values) that the planning is intended to promote or protect are quantified using some kind of mathematical formulation.
(2) *Describing the system state and its dynamics* – as per the target components of biodiversity and the large-scale processes discussed in this paper. This means answering such questions as: What and where are the habitat/ecosystem types? How do different activities (zoning into reserves or other uses) affect the viability of species? What are the

consequences of zoning decisions on ecological processes? And what are the consequences of spatial relationships of different human activities for ecological processes and species viability? The system state and its dynamics can include socioeconomic variables and sub-models.

(3) *Applying an algorithm* used to generate planning options. If the problem is properly defined and the system state and dynamics are adequately accounted for, then algorithms can be applied that find the best or some good solutions that aid or initiate the decision-making process. The algorithm often needs ancillary software to present alternatives and facilitate the use of potential solutions in the decision-making process. Ultimately the algorithm is no more than a decision support tool that uses computers to see possibilities that we may miss.

Traditionally the "reserve design" problem has been defined such that the objective is to minimize costs given a suite of conservation targets. However, there has been little analytical consideration of the connectivity issues discussed here. More recently, the Marxan family of software (www.ecology.uq.edu.au/marxan.htm) have been applied to solve spatial problems where the objective has a spatial component (minimize boundary length, minimum reserve size) and the targets attempt to deliver adequacy (Possingham *et al.* 2000, Possingham *et al.* 2001, Noss *et al.* 2002; also note the work of Andelman *et al.* 1999, Singleton *et al.* 2001). If issues of connectivity can be clearly defined, they can be incorporated into the algorithms. The challenge is to articulate the connectivity process issues discussed here so that they can be formulated mathematically. The existing Marxan algorithms then need to be modified to accommodate the required new kinds of objectives and constraints.

A computer-based planning tool is needed that draws upon these modified algorithms, accesses the spatial information base, and that can be used to prepare information and options for stakeholders interested in advancing biodiversity conservation in their region. As landscape viability is of equal concern for all users of the land resource, such a planning tool should be generally welcomed as a tool for meshing production and conservation objectives. Nevertheless, the difficulties with this approach should not be underestimated, as in many areas we lack basic information with which to guide landscape management, and we cannot always wait for complete information to make decisions. Simpler approaches that base decisions on partial information may stimulate activity and enthusiasm within local communities (e.g., Lambeck 1997, Dilworth *et al.* 2000). While these approaches can be criticized (e.g., Lindenmayer *et al.* 2002), they may form a useful kernel on which to build greater scientific sophistication that leads to action.

11.5 Conclusion

In summary, the WildCountry scientific framework draws from landscape ecology principles, which include the following main elements:

- Core protected-area networks must be based on systematic reserve design principles that build upon the criteria of comprehensiveness, adequacy, and representativeness, complimented by, among others, criteria related to primary productivity and landscape condition.
- Biodiversity conservation assessment and planning (including protected-area design) must move beyond traditional conservation design principles by aiming for the maintenance and restoration of large-scale (in space and time) ecological and evolutionary processes over the entire landscape. Assessments and plans must reflect the landscape linkages necessary to maintain large-scale ecological phenomena and processes related to trophic relations and interactive species, hydroecology, long-distance biological movement, refugia from threatening processes, ecological fire regimes, climate change and variability, and coastal zone fluxes.
- Proximity of the reserve system to sources of disturbance requires, as a minimum, buffering and consideration of complementary land uses and management. Whole-of-landscape conservation assessment and planning will be unavoidable; recognizing that the entire landscape (protected areas, leasehold land, Aboriginal land, unallocated crown land, private land) within which protected areas are embedded must be better managed to promote biodiversity conservation.

Regional planning must therefore include management guidelines and prescriptions for, among other things, broad-scale threatening processes including feral animals, weeds and ecologically inappropriate fire regimes, both in protected and unprotected areas. Ecological restoration in degraded landscapes will be necessary, particularly in the intensive land-use areas of Australia (Fig. 11.1). Restoration objectives should reflect the need to restore the identified large-scale connectivity processes. Landscape viability analysis will enable the entire landscape to be evaluated and the optimum set identified of dedicated reserves, areas of connectivity, and matrix (off-reserve) management requirements.

Management for biodiversity conservation that facilitates long-term ecological connectivity will remain an ongoing research and development challenge. It must be recognized that the matrix is never static, and it may be impossible to predict the quantity and quality (intensity) of development that could eventually occur on any specific parcel in any given region. Thus, the conservation utility of the matrix must be considered with caution and be recognized as complementary to dedicated core areas. In fact, it may be prudent to assume that the matrix will change, and, in the worst-case scenarios, lose all positive conservation values over time.

It must be noted that the emerging WildCountry framework described here goes beyond current reserve-based assessment and management, and hence needs a step-up in activity and funding. We acknowledge that it has proven difficult to maintain current levels of conservation management, with many agencies facing reduced budgets and having to deal with increasing threats. The challenge then is to recognize the full extent of the actions needed and convince land managers, communities, governments, and relevant agencies of the need for a broadly based landscape approach.

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