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European settlement of the island continent, Australia, occurred only two centuries ago. Over that time there have been profound shifts in the perceptions, values and understanding of the complexity and diversity of the Australian flora. This transition is neatly bracketed by the naming of the site where Captain Cook landed in 1770 as 'Botany Bay', in response to the shock-of-the-new flora and the last half-century of botanical scholarship recorded in the *Australian Journal of Botany.* The great diversity of the Australian flora presented botanists and ecologists with an enormous number of ongoing tasks including: classification of species and vegetation; mapping of species and vegetation distributional patterns; enumeration of species abundance and identification of their environmental correlations; documentation of animal and plant species interactions; and determination of physiological processes. Furthermore, a geological and biogeographical context was required to understand the evolution of the largely endemic Australian flora and to gauge how species and vegetation responded to the great climatic changes that have characterised the Cainozoic and particularly the Pleistocene ice ages. To some degree these basic steps deflected attention away from the relatively shorter and sometimes more subtle, changes that were occurring to native vegetation in the period following settlement. Clark (1990) has argued that the cause of this botanical blind spot was that such century-scale changes neither fell within the palaeo nor the ecological time scales. However, for the USA at least, such century-to-decadal scale ecological history is increasingly being recognised as a key to the formulation of sustainable land management strategies (see Parsons *et al*. 1999; Foster 2000; Egan and Howell 2001). Indeed, such recognition of the importance of recent ecological history is in step with the major changes that are occurring to scientific approaches designed to tackle the accelerating rate and global scale of anthropogenic environmental change. There has been an explicit shift away from narrowly focused problem-solving approaches, characteristic of pure and applied science, towards more socially complex and far less certain modes of scientific analysis, sometimes described as 'post-normal science' (Funtowicz and Ravetz 1993; McMichael 2001).

The recognition of the inherently dynamic nature of Australian landscapes has proven to be enormously problematic for land managers, particularly given the mounting evidence that Australian landscapes at the time of settlement were the product of more than 40 000 years of human moulding by landscape burning and game management and therefore were as much 'cultural' as 'natural' (Head 2000). This conundrum was summed up by Jones (1969) in the conclusion of his influential article 'Fire-stick Farming' where he posed the following rhetorical question: 'Do we want to conserve the environment as it was in 1788, or do we yearn for an environment without man …?'.

Fundamentally, land management is about making choices in a complex social and political milieu and the core elements of the 'land management equation' include human values and perceptions, recognition of biological diversity and ecological complexity, a lack of certainty and therefore risk that is exacerbated by practical, moral, legal and economic constraints.

Clearly, there are no simple answers to the question 'what are we managing for?' Indeed, it is increasingly accepted that biodiversity conservation and land management demand expertise from the humanities as much as they do from the sciences (e.g. Ludwig 2001; Ludwig *et al*. 2001). For this reason the emerging fields of environmental history (from the humanities) and historical ecology (from the sciences) are proving to be invaluable intellectual arenas whereby the great challenges of land management can be tackled (e.g. Egan and Howell 2001; Bowman 2001). For example, Pickard (this volume) argues that because the general public, conservationists and conservation professionals are all too often unaware of the inherent dynamism of native vegetation, sequences of photographs of the same location have an important educational role in demonstrating this point.

However, Pickard notes that 'the same photograph may be interpreted differently by different people' and therefore it is important that repeat photography is not used in isolation from other historical techniques. Problematically, the temporal and spatial precision and accuracy of all other data sources used in historical ecology studies are *all* idiosyncratically constrained. Imagination is thus required to make sense of the fragmentary and imperfect knowledge of landscape change. This mix of facts, interpretations and extrapolations favours the narration of 'stories' about the possible patterns and significance of changes in the land. Griffiths (this volume) explores the role of narratives in his essay on the significance and meaning of changed densities of trees in some Australian forested landscapes since settlement. He shows that the significance of landscape change fundamentally hinges on how the world is perceived, valued and understood by people and that the way people see landscapes also changes through time.

Lunt (this volume) demonstrates that the application of historical ecology to century-scale Australian landscape changes has been geographically uneven, with most attention being focused in humid, particularly forested, environments and the least in arid landscapes. He also shows that five major types of studies have been favoured by Australian ecologists: (1) growth of individual tree species, often inferred by dendrochronology; (2) analysis of forest age/size distributions to infer forest dynamics; (3) changes in floristic composition in response to different land-use history, particularly grazing by stock; (4) historical landscape reconstruction based on historical sources; and (5) pollen analysis. One technique that did not neatly fit within this

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classificatory scheme was the analysis of stable isotopes, which can provide powerful insights into both past and present ecological process. For example, Witt (this volume) demonstrates that stable carbon isotope analyses have great potential for understanding the dynamics of the boundaries between tropical grassland (dominated by plants with the C_4 photosynthetic pathway) and woody vegetation (dominated by plants with the C_3 photosynthetic pathway) as well as changes to the diet of native and introduced herbivores at a variety of time scales following the settlement of Australia. However, he acknowledges a number of limitations of this technique, particularly the inability to discriminate between plant taxa beyond those with either the C_3 and C_4 photosynthetic pathways. Like Pickard, he argues that this particular technique should be integrated with other sources of historical data.

Lunt also highlights the great reliance Australian ecologists have placed upon chronosequence studies that substitute landscape spatial variation for that of time and notes the corresponding absence of studies based on repeated observations. The paper by Brown *et al*. (this volume) provides a sobering reminder of the inherent weakness of such chronosequence studies and the often unexpected findings derived from permanent quadrat studies. Their remeasurement of plots established 20-years previously revealed only minor change in the structure and floristic composition of an area representative of the landscapes of south-western Tasmania. Contrary to the generally accepted theory of vegetation dynamics for that region, the changes that occurred seemed best explained by the effect of the introduced pathogen *Phytophthora cinnamomi*, rather than being due to landscape fire.

The review by Lunt (this volume) also identified a general absence of studies exploring the possible impacts of resource exploitation that followed European settlement. The case studies in this volume demonstrate a variety of different approaches to tackling this important problem. Harle *et al*. (this volume) demonstrate the potential for pollen and trace-element analyses and lead-210 isotope dating of fine-scale sampling of lake sediments in documenting changes induced by European land use during the 19th and 20th centuries. In general, their findings are in concordance with the recorded history of mineral prospecting and mining in western Tasmania. The striking exception was their conclusion that the most significant anthropogenic impacts coincided with the escalation of open-cut production between the 1950s and the 1970s rather than earlier phases of smelter produced pollution, a period widely believed to have been the most environmental destructive. Start and Handasyde (this volume) used a large collection of repeat landscape photography taken between 1952 and 1990 to trace changes to riverine vegetation following the construction of the Ord River impoundment in north-western Australia. Despite the acknowledged limitations of the technique, they were able to identify gross floristic and structural changes in the vegetation caused by the change from an extreme hydrological regime characterised by wet-season flooding and the absence of flows in the dry season to year-round, less-variable flows. However, they noted that the near complete absence of any historical data on the character of the riverine vegetation before the study period prohibits a complete understanding of the impact of European settlement.

Appreciating how landscapes will be affected by global environmental changes driven by elevated atmospheric CO_2 presents enormous scientific challenges. As Keenan (this volume) explains, this problem is of considerable national and international significance given the ongoing negotiations of national 'carbon' budgets. Fundamentally, the problem of predicting global changes hinges on the fact that $N = 1$ and thus it is impossible to undertake replicated planetary-scale experiments in order to precisely estimate the probability of various possible trajectories. Certainly, modelling studies such as those undertaken by Berry and Roderick (this volume) enable both retrospective and predictive studies of the response of landscapes to the recent anthropogenic changes to the concentration of atmosphere CO_2. Their modelling exercise led them to formulate the remarkable hypothesis that 'an increase in atmospheric [CO_2] would have the same net effect as a decrease in disturbance' and to conclude that anthropogenic atmospheric change has to some degree offset the impact of changed disturbance regimes that followed settlement of Australia. Such modelling exercises are valuable not only because they enable a coherent synthesis of process and descriptive studies but also because they serve as a catalyst for further field research and validation.

A critical requirement for such validation is the analysis of data at appropriate spatial and temporal scales. Dodson and Mooney's (this volume) meta-analysis of pollen, charcoal, and physical and chemical attributes from lake and swamp sediments in south-eastern Australia demonstrates the importance of placing the impact of European settlement in the context of the late Holocene, a period of relative stability of climate and the concentration of CO_2. While all of the cores they studied registered massive changes in the surrounding catchments following settlement, the signal of this impact varied significantly between them, highlighting the importance of the interaction between the surrounding vegetation and specific disturbances. Fensham and Fairfax (this volume) and Pearson and Searson (this volume) argue respectively that the potential of the existing aerial photographic records and dendrochronology have been barely tapped in exploring Australian century-scale landscape changes. Pearson and Searson noted that tree-ring records, especially in the genus *Callitris*, provide extremely accurate spatial and temporal data on annual changes that stretch back over the last three centuries or more and include

data on recruitment, growth and sometimes landscape fires at the local, regional and continental scale. Fensham and Fairfax (this volume) note that advantages of aerial photography over other sources of remotely sensed data include continental coverage, time depth (typically commencing since the Second World War), large spatial scale and capacity to observe vegetation in three dimensions. These attributes enable detailed detection of change in vegetation structure, biomass and in some cases even species composition. They note that a great challenge presented by this data source is to identify the factors that drive landscape change.

A recurrent theme in this volume is that there is no single approach to study landscape change because the available historical records and techniques to interpret natural archives all have specific constraints, differing levels of precision and sensitivities to various environmental signals. Despite these limitations, historical ecological knowledge remains a prerequisite to tackle the great challenges of managing dynamic landscapes, particularly in the face of accelerating global environmental change. A great scientific challenge is to develop teams of researchers that can creatively combine various approaches to recover the unique history of an area, which can then assist in the formulation of ecologically sustainable land management strategies (e.g. Swetnam *et al*. 1999). It must be accepted, however, that it is impossible to perfectly describe and understand even the most recent past. For this reason, historical research requires imagination to extrapolate between disparate data points and to breathe life into historical ecological data. However, because the imagination is coloured by subjective experience, a diversity of high-quality data is required to both assist and discipline the minds of the producers and consumers of research into landscape history. The following papers describe indispensable tools to assist with the exploration of the past centuries of Australian landscape change.

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