CSIRO PUBLISHING
www.publish.csiro.au/journals/wr *Wildlife Research*, 2005, **32**, 369–375

Fire, landscape heterogeneity and wildlife management in Australia's tropical savannas: introduction and overview

Peter J. Whitehead[A], *Jeremy Russell-Smith*[B,C] *and John C. Z. Woinarski*[B,D]

[A]Key Centre for Tropical Wildlife Management, Charles Darwin University, Darwin, NT 0909, Australia.
[B]Tropical Savannas Management Cooperative Research Centre, Charles Darwin University, Darwin, NT 0909, Australia.
[C]Bushfires Council of the Northern Territory, PO Box 37346, Winnellie, NT 0821, Australia.
[D]Parks and Wildlife Service, Department of Infrastructure Planning and Environment, PO Box 496, Palmerston, NT 0831, Australia.

Abstract. Despite an apparent structural integrity, the savanna landscapes of northern Australia are in flux. Important elements of the fauna have contracted in range and are less abundant than in the relatively recent past. Vegetation patterns are changing as populations of some important woody plants decline in some parts of the savannas while, in other places, different trees and shrubs are substantially increasing in density. These sorts of changes are occurring in lands under all tenures and subject to a variety of management goals and practices, including conservation reserves. Fire, large grazing animals and, more recently, invasive plants have all been implicated as drivers of adverse change. An important general, albeit inadequately tested, theory about apparently widespread faunal decline is that these influences have, jointly or separately, compromised landscape heterogeneity. It has been proposed that resource-rich patches that sustain savanna fauna through seasonal and longer-term peaks and troughs have been reduced in number, become more widely separated in space and time, or have been reduced in quality so that wildlife dependent on the rich patches struggle to use them effectively. The issues connected with these ideas were explored in a conference on fire and savanna management at Charles Darwin University in July 2003. Congruent with the theme of the symposium in which they were presented – Managing for Heterogeneity – the subset of papers presented here is diverse in origins, issues, perspectives and the spatial and temporal scales with which they deal. We consider that they make an important contribution to debate about conservation and development in northern Australia. Not because they answer the important questions, but because they illustrate the need for a shift in emphasis: from tentative exploration of pattern and weak inference about process to a harder-edged examination of the features of savanna habitats that influence their capacity to support viable wildlife populations.

Synthesis

How do large natural systems work? This is a fundamental question for ecologists, and part of ecology's enduring fascination. In this special issue, we ask this question for the extensive environments of northern Australia, a landscape suitable for such inquiry because the patterning of its ecology, topography and climate is relatively simple and orderly; and because it has been relatively little transformed by modern development. Although this landscape provides a geographic focus to this collection, the uniting theme is of the ecological and management significance of heterogeneity. The coarse simplicity of the region's landforms and its recurring sameness of climatic seasonality mask the importance of finer-level spatial and temporal patchiness and variability. Fires are pervasive, but their ecological consequence is nuanced by their timing and spatial characteristics. People are few in the landscape, but the pattern of their occurrences and absences, of their activities and inactivities, give the environment its detail, and that detail underpins the health and diversity of its nature. Our interest in this landscape and ecology is but partly inquisitive. Most of the papers in this issue involve aspects of managing this landscape, for this large natural system is no longer working as it should. In part, this ecological dysfunction is associated with dysfunction in the human societies embedded in, manipulating and dependent upon this landscape. Very deliberately our subject material here draws upon the interdependency of humans and natural landscapes, and the necessity and challenge of imposing management on those natural landscapes, of attempting to maintain and support intricate variation across vast scales.

Fires, grazing and invasions

Thinking about fire is a necessary preoccupation for all natural resource managers in northern Australia, because fre-

10.1071/WR05069 1035-3712/05/050369

quent fires are an inescapable consequence of the north's intensely seasonal monsoonal environment. Periods of high rainfall favouring rapid growth of herbaceous plants alternate with prolonged seasonal droughts that reliably create – for several months of every year – a large standing crop of dry, highly combustible fine fuels extending over huge areas.

Many human inhabitants of the Australian savannas have a long history of using fire to manipulate aspects of the landscape (Dyer and Stafford Smith 2003; Whitehead *et al*. 2003) and, in the wider contemporary society, others seek to protect property, or simply enjoy lighting fires. Additionally, natural ignitions occur through lightning, especially in the dry–wet season transition (e.g. Bowman *et al*. 1988). Consequently, fires are not only frequent but also often intense and burn over large areas, especially when they occur late in the dry season (Russell-Smith *et al*. 2003*a*). They influence vegetation structure (e.g. Bowman *et al*. 2001; Russell-Smith *et al*. 2003*b*), floristics (Russell-Smith *et al*. 2003*b*), nutrient flows (Cook 2003) and even processes such as erosion (e.g. Miller *et al*. 2003).

Fire is arguably the most pervasive influence on the condition of wildlife habitats in northern Australia. But it is not the only important one. Most of the northern Australian landscape is also grazed by large introduced herbivores, some being under active management, but large feral populations are effectively unmanaged apart from the few places where there is intensive harvesting. Pastoral interests have also promoted introduction of many new plants, a number of which have proven highly invasive. Many ecologists fear that a number of these plants, especially the grasses, substantially increase the risk of widespread change associated with fire, because such grasses produce larger fuel loads that cure later and burn more intensely (e.g. Rossiter *et al*. 2003).

Fire, grazing animals and introduced plants are likely to interact in complex ways to influence the condition of wildlife habitats. It is increasingly recognised that the apparent structural integrity of north Australian landscapes has obscured some unwelcome changes in their capacity to support wildlife populations. Important elements of the terrestrial fauna, particularly granivorous birds (Franklin 1999) and small mammals (Woinarski *et al*. 2001) are in decline over large areas of the savannas. Although there is general agreement that fire, ferals and weeds are likely to have played key roles in driving change, their relative importance and the mechanisms by which they influence wildlife habitats remain uncertain. As a consequence, the priority that wildlife managers should assign to management of these pressures and the methods they should adopt to counter detrimental change are also unclear.

An important general, but so far inadequately tested, theory about widespread change in Australian savanna landscapes is that these influences have jointly or separately compromised heterogeneity (Woinarski 1999). It is argued that the resource-rich patches that sustain savanna biota through seasonal peaks and troughs in resource availability have been reduced in abundance, have become more widely separated in space and time, or have been reduced in quality. The group of papers presented in this issue explore some of the issues connected with this set of ideas.

The papers

The papers in this issue comprise a subset of presentations given in July 2002 at a conference organised by the Tropical Savannas Management Cooperative Research Centre and the Australian Research Council Key Centre for Tropical Wildlife Management, both at Charles Darwin University in Darwin, in the Northern Territory of Australia. An associated volume was published in late 2003 (Volume 12, Issues 3 and 4 of the *International Journal of Wildland Fire*), presenting an overview of methods of detecting fire, analysing the spatial and temporal patterns of burning and relating those patterns to change in northern Australian landscapes. The current issue complements that work by exploring the implications of improved knowledge about fire regimes in northern Australia for understanding the condition and management of wildlife habitats. It also extends that exploration to include some assessment of the independent or related effects of grazing and exotic plants on wildlife populations. Finally, it also touches on some of the social determinants of our capacity to respond to challenges in managing for conservation across huge, sparsely populated savanna regions.

In their introductory paper, Woinarski *et al*. (2005) provide context for the studies to follow. They emphasise the continuity of savanna landscapes spanning huge areas with little topographic variation. In these 'landscapes without boundaries' many species have large distributional ranges and species turnover is low even at widely separated sites. But superimposed on this backdrop of continuity is subtle but critical variation in resource availability. The authors show, using 'model' organisms that have adapted quite differently to exploit the savanna landscape, how diffuse and often short-term but recurrent impacts on resource distribution and density, usually associated with grazing and fire, can compromise persistence in landscapes that otherwise appear structurally intact.

Hobbs (2005) questions whether the processes affecting fauna using these apparently unfragmented landscapes are actually different in kind from the problems confronting wildlife in more obviously modified lands. On the basis of experience in the agricultural regions of temperate Australia, he argues that the conventional view of the matrix in fragmented landscapes as entirely hostile to fauna is often wrong. And a view of fragments as providing uniformly favourable habitat is also misleading, because processes going on in the matrix often affect the remnants adversely. In both the 'unbounded' and classically fragmented situations, fauna depend on an ability to exploit patches of relatively resource-rich habitat in a resource-poor matrix. Their

capacity to do so is in both situations compromised by reductions in the quality, quantity and accessibility of resources offered by the apparently superior patches. In one case (the conventionally fragmented) the configuration of the more favourable patches is obvious, but in the structurally unmodified landscapes of northern Australia, much less so. The sobering conclusion is that the impacts of diffuse change on some elements of the fauna may be just as severe in the apparently unmodified landscapes of the tropics as the acute and obvious change in highly modified regions.

Hobbs (2005) also makes the important point that we cannot rely long-term on contemporary disinterest in the less fertile or otherwise more challenging parts of the northern landscape to protect the biota from the effects of agricultural or similar use. History suggests that technology-driven increase in exploitation of a range of environments is more likely than not (e.g. Bowman 2002).

This caution resonates with the contribution from Franklin *et al*. (2005). They show that, over the vast span of the tropical savannas, decline in the distribution and abundance of a large suite of granivorous birds is worse in areas with higher densities of cattle, especially where rainfall is more variable, but ameliorated to some extent in topographically heterogeneous regions. They argue that landscape heterogeneity compromises use of some lands for pastoralism and, at finer scales, also protects parts of the landscape from uniform use by grazing animals in those topographically variable areas still subject to pastoral use. But relying entirely or principally on these natural buffers to maintain this important component of the savanna avifauna is unlikely to provide a robust long-term strategy.

Bradstock *et al*. (2005) consider the implications of patchiness of fire at a much finer scale. They review the utility of what they call the fire mosaic paradigm. The paradigm is based on the notion that a landscape with patches of different ages since the last fire will more successfully support a diverse fauna. They demonstrate that there are many conceptual problems with this idea, not least the impossibility of applying it in the crude form in which it is often expressed. A configuration of patches of different ages that favours one species is unlikely to equally favour others. There are no clear rules for selecting one regime from the infinite number of combinations that are possible in any landscape of reasonable size. They illustrate their arguments with a habitat model for another bird, the malleefowl (*Leipoa ocellata*), and show the dependence of local populations on complex fire regimes that maintain important habitat elements over the long term. In common with Woinarski *et al*. (2005), they conclude that choice of favourable regimes will often depend on explicit consideration of fire–species–landscape interactions at a scale that is well matched to the needs of the target organism.

Price *et al*. (2005*a*) present an analysis of trends in heterogeneity of fire patterns in both space and time in Kakadu National Park, a World Heritage area whose managers have sought to restore fire patterns akin to those previously imposed by the Aboriginal owners of the land. They show that Kakadu has ostensibly achieved one of the characteristics thought to be associated with Aboriginal customary burning regimes, namely increases in spatial heterogeneity of burns at relatively fine spatial scales (1–25 ha) over the period 1980–2000. Moreover, they found greater heterogeneity in topographically variable landscapes, consistent with the suggestion of Franklin *et al*. (2005) that the homogenising effects of fire and associated impacts on resources used by savanna granivores may be mitigated in such places.

But in reporting a study in peri-urban Darwin, Price *et al*. (2005*b*) add another caution about over-interpretation of such indirect measures of the status of wildlife habitats. They find that few mammals are present in apparently little modified savannas in one part of their study area, but healthy populations of those same mammals occur in highly fragmented environments in an adjoining area. They show that, as expected, the fragmented area was less often burned, but they were unable to identify features of the fire regime in the unfragmented area that could be described as particularly unfavourable for this fauna. These counter-intuitive observations exemplify the need for detailed understanding of the habitat features that sustain viable wildlife populations, and the limitations of coarse-scale correlative studies based on relatively crude hypotheses such as those that support the fire mosaic paradigm analysed by Bradstock *et al*. (2005).

Moreover, whereas fire and grazing are pervasive in the savannas, they are clearly not the only pressures that are patterned in the landscape or have impacts on underlying ‘natural’ ecological patterns. The remaining papers in the volume focus on other anthropogenic drivers of change in the savannas, including invasive plants and harvest and how such influences might be better managed.

Ferdinands *et al*. (2005) describe a growing threat to ecologically and economically critical elements of the savanna landscape, namely pasture grasses invading seasonally inundated floodplain wetlands. These areas are particularly significant for pastoralism in the Top End, with large numbers of cattle being agisted there in the dry season, fattening before live export. The same sites are also recognised as nationally significant for waterbirds (Whitehead and Chatto 1996). In efforts to increase the productivity of these black-soil plains, government agronomists have promoted the use of an array of exotic semi-aquatic grasses. This paper examines the potential for one of those exotics (para grass, *Brachiaria mutica*) to continue its spread and assesses its present and potential effects on both plant and animal diversity in the wetlands. They found that at sites with well established para grass, diversity of other plants was greatly reduced, and such areas supported lower numbers and lower

diversity of wetland avifauna than other sites. Para grass is likely to come to dominate the shallower wetlands that presently support a range of vegetation types including substantial densities of wild rice (*Oryza meridionalis*), the seeds of which are a key element of wetland food chains.

The floodplains are also important for the region's Aboriginal customary (non-market) economies. Many species are harvested and a large proportion of the most productive hunting and foraging effort takes place in and around wetlands (Altman 1987). Brook and Whitehead (2005*a*, 2005*b*) consider the dynamics of both customary and recreational harvests of magpie geese (*Anseranas semipalmata*), focusing on the implications of uniform management of a spatially and temporally heterogeneous resource. They conclude that failure to adjust management regimes to regionally variable circumstances will result in both reduced harvest and increased risk of acutely depressing or even extinguishing populations.

In the last in this sequence of papers, Altman and Cochrane (2005) consider the place of people in keeping the Australian savannas in good condition from a social sciences perspective. As well as the particular challenges of fire management, the history of settlement and patterns of land use in northern Australia has unleashed a range of other influences that demand active intervention. Growing arrays of aggressive invasive plants and huge numbers of feral animals of many sizes and types of impacts render the 'lock it up and leave it' approach to management untenable in even the remotest regions. In this paper, the authors focus on a region of 10 000 km^2 in central Arnhem Land and document the contemporary resource-management activities of Aboriginal community rangers supported by a robust regional organisation. Extrapolating from this case study, they explore the institutions that will be necessary to secure the full participation of Aboriginal people, who own ~20% of the Australian land mass, in management of wildlife in northern Australia. The authors particularly point to the heterogeneity of interests and approaches that must be accommodated to achieve optimal results, including application of both indigenous and scientific knowledge and balancing commercial use with customary use of wildlife. They particularly emphasise the need for robust institutions to build, in all of the regions, novel solutions for bringing rigorous and sustainable management regimes to bear on the entire array of existing and emerging problems.

Looking ahead

We suggest that this somewhat eclectic group of papers collectively illustrates some important directions for the future of wildlife management in northern Australia and offers some useful perspectives for the management of large natural landscapes more generally. This eclecticism is neither accidental nor unhelpful: rather, it is another recognition of the importance of heterogeneity. Approaches from different perspectives, disciplines and foci are necessary to understand and manage these lands.

If, as these papers indicate, unfavourable fire and grazing regimes are already dominant drivers of widespread changes in biodiversity values, in the absence of active and effective intervention, the prognosis for wildlife conservation in these savannas is far from good.

Fire is likely to become harder to manage because sources of ignition will increase with rising human populations, which are growing most rapidly in the larger centres in remote areas inhabited chiefly by Aboriginal people (Taylor 2003). In some of those regions, knowledge of fire behaviour and effects and the best approaches to fire management are being lost through reduced opportunities to be active on country and breakdown of customary arrangements for land custodianship (e.g. Yibarbuk and Cooke 2001). Workers developing infrastructure for pipelines, mines and transport corridors bring additional reasons for lighting fires (to protect property) into regions previously free of such demands. Many more ignitions are likely to be ill-informed or capricious. Invasive pasture grasses are changing patterns of wet-season growth and dry-season curing patterns and hence the temporal and spatial distributions of fuels. Customary practice among those who retain the knowledge will require time, experience and access to new technology to respond and adapt to new challenges. But without much better fire-management plans and acquisition of increased resources to secure the commitment and capacity of regional communities to implement them, there is every reason to predict a further deterioration in the level of state and private control over fire extent and frequency.

Pastoralism in many parts of northern Australia is entering a phase of substantial intensification (see Ash *et al.* 2004), associated with increasing levels of corporate ownership of clusters of pastoral leases, correspondingly greater access to capital to improve management infrastructure, and access to tools that enhance the value of improved infrastructure by allowing distribution of grazing effort to be better matched to the state of forage. Although these changes promote the economic sustainability of pastoral production by helping managers to avoid localised or wider overgrazing, they also extend the reach of cattle into parts of properties that were less used in the past. Suppression of the density of resources important for native fauna is therefore likely to extend over a greater proportion of the landscape. Such trends will be exacerbated if pasture improvement involving more introductions of exotic grasses is part of the process of intensification.

Some important sociopolitical trends also have critical implications for the management of wildlife and their habitats. The growth of regional populations of predominantly Aboriginal people of employment age is projected to greatly outstrip mainstream employment opportunities, increasing livelihood reliance on the customary economy and/or

welfare support (Altman 2005). Both indigenous and non-indigenous leaders portray the inactivity associated by them with welfare dependence as inherently destructive (e.g. Pearson 2000), and are consequently engaged in a search for enterprise options suitable for remote, infrastructure-poor lands (Altman 2004, 2005). These involve both unconventional commercial uses of native wildlife (e.g. Whitehead 2003) and expansion of orthodox agriculture, mining and forestry. For example, the Northern Territory Indigenous Economic Development Strategy (Anon. 2005) calls for 35 000 additional cattle on Aboriginal land in the next few years. Such activity will undoubtedly increase risks of weed invasion, but even in the absence of such change, exotic plants and feral animals will continue to increase in range and abundance, putting at risk some of the most biodiverse lands in northern Australia.

What do these papers tell us about how wildlife researchers and managers should respond to the challenges posed by such processes? In regard to the knowledge base, there are several important messages.

(1) Potential gains from correlative studies conducted at coarse levels of resolution – for example, in regard to biotic assemblages rather than individual species or done at spatial and temporal scales that are not well matched to the ecology of the organisms and habitats of interest – have probably reached the bounds of severely diminishing returns, even at the northern frontier. This is not to suggest that studies with a biogeographic emphasis based on mining of existing datasets should be discontinued. But in preference to churning of different combinations of low-resolution data seeking insights into the impacts of landscape change, efforts should be increasingly focused on generating improved environmental and other thematic datasets at spatial scales and levels of resolution better matched to understanding of wildlife–habitat relations (Woinarski *et al*. 2005; Hobbs 2005; Franklin *et al*. 2005; Bradstock *et al*. 2005; Price *et al*. 2005*b*).
(2) Future studies of the effects of fire and grazing should focus on organisms that appear to be most vulnerable to shifts in resources of the sort most directly affected by variation in these processes, and seek to test at least crude hypotheses about the nature of the relationships (Woinarski *et al*. 2005; Bradstock *et al*. 2005). To be most effective in raising wildlife conservation as a necessary component of land-management choices, ecological studies should be embedded within broad-scale trials of management options, including variants of pastoral intensification, and in collaboration with landowners and managers whose goals are primarily exploitative: the Pigeon Hole grazing management trial (Hunt *et al*. 2003) provides such a model.
(3) Studies seeking better understanding of the effects of fire and grazing should be sited to explore wildlife–habitat relationships where the signals are expected to be strongest, including through the use of tightly focused experimental landscape manipulation (Woinarski and Ash 2002; Williams *et al*. 2003; Andersen *et al*. 2003). For example, in the case of granivorous birds, studies are most likely to be incisive in regions where rainfall variance is greatest and at sites with strongly contrasting grazing histories (Franklin *et al*. 2005).
(4) Well articulated models (preferably quantitative) should be developed to explore the implications of changed management practice on the hypothesised dependencies of wildlife on particular resources (Woinarski *et al*. 2005; Bradstock *et al*. 2005; Ferdinands *et al*. 2005; Brook and Whitehead 2005*a*, 2005*b*).
(5) There is an acute need for better understanding of realistic options for employment in regional (chiefly Aboriginal) communities, including natural and cultural resource management, and valuation of the ecosystem services that such work can deliver to the wider Australian community. The implications of wildlife-based enterprise for the status of wildlife used in the customary economy and commercially also warrant study (Altman and Cochrane 2005).

The papers in this volume are linked by their consideration of variability as a lynchpin to the workings of this landscape. They demonstrate that this focus may provide a useful approach to understanding and managing these lands. But we recognise that our works are still rudimentary and speculative. Heterogeneity, patchiness and mosaics are convenient generic terms, but their inherent complexity and shiftiness can be bewildering to define, investigate and maintain in the real world. Thus, this issue is far from definitive. Instead, it outlines a theme on which to build a systematic research and management program.

The challenges confronting northern Australia's wildlife managers are daunting. Even with detailed high-quality knowledge, the capacity of northern Australia's sparse human resources (~1% of the nation's people) to assert a significant measure of control over processes that pervade the vast areas of the savannas (more than 25% of Australia's land area) is questionable. Particular implications are:

(1) Interventions need to be focused on the highest-priority issues, so there must be an active process for setting and reviewing priorities.
(2) Presently loose regulation of the introduction and use of exotic plants (Ferdinands *et al*. 2005) and animals (especially those already present in the country) needs to be strengthened, preferably through legislation that establishes mechanisms for independent review.
(3) The role of existing, and preferably expanded, reserve networks will be pivotal, and improved systems for reporting on the extent to which they have achieved operational and conservation goals will be critical (Price *et al*. 2005*a*).

(4) Effective engagement of a large proportion of the north Australian regional (and especially remote) population in active management of landscapes and wildlife is essential if there is to be a realistic prospect of coping with the array of challenges.
(5) Engagement of the north Australian population will require that there be incentives for their participation that go beyond invocations of community spirit. Real resources must be brought to bear in creative ways that meld existing public sector investments with new financing (Altman and Cochrane 2005), including contributions from the private (commercial) sector (Altman and Dillon 2004). Dependence on compartmentalised, conventional solutions does not appear to be plausible at costs that the evidence suggests will be politically tolerable.
(6) One of those incentives will be the necessary development of local management capacity so that management responses can be matched to the scale demanded by the needs of the managed organisms (Brook and Whitehead 2005*a*, 2005*b*). Building this capacity will be dependent on regional and national government recognition of the contribution of local resource managers to the achievement of national biodiversity and landscape conservation goals and the potential to increase that contribution (Whitehead 2000).

Despite its small size and limited resources, the wildlife research and management community with an interest in northern Australian has an impressive record of achievement. As illustrated by this collection of papers and the studies on which they build, that community and contributors from outside the region have done a great deal to provide early warning of the challenges and opportunities as well as point the way to plausible responses. It remains to be seen whether early recognition of unwelcome change will culminate in a concerted and considered effort to go beyond rhetoric about the benefits of acting in advance of marked deterioration, or follow the much more frequently trodden path of acting only after trends are so self-evidently entrenched as often to be irreversible.

References

Altman, J. C. (1987). 'Hunter-Gatherers Today: An Aboriginal Economy in North Australia.' (Australian Institute of Aboriginal Studies: Canberra.)

Altman, J. C. (2004). Economic development and indigenous Australia: contestations over property, institutions and ideology. *Australian Journal of Agricultural and Resource Economics* **48**, 513–534. doi:10.1111/j.1467-8489.2004.00253.x

Altman, J. C. (2005). Development options on Aboriginal land: sustainable indigenous hybrid economies in the twenty-first century. In 'The Power of Knowledge, The Resonance of Tradition'. (Eds L. Taylor, G. W. Ward, G. Henderson, R. Davis and L. A. Wallis.) pp. 34–48. (Aboriginal Studies Press: Canberra.)

Altman, J. C., and Cochrane, M. (2005). Sustainable development in the indigenous-owned savanna: innovative institutional design for cooperative wildlife management. *Wildlife Research* **32**, 473–480.

Altman, J. C., and Dillon, M. C. (2004). A profit-related investment scheme for the Indigenous estate. Centre for Aboriginal Economic Policy Research Discussion Paper 270/2004. Australian National University, Canberra.

Andersen, A. N., Cook, G. D., and Williams, R. J. (Eds) (2003). 'Fire in Tropical Savannas: The Kapalga Experiment.' Ecological Studies No. 169. (Springer-Verlag: New York.)

Anon, (2005). Northern Territory Indigenous Economic Development Strategy. Northern Territory Government, Darwin.

Ash, A., Gross, J., and Stafford Smith, M. (2004). Scale, heterogeneity and secondary production in tropical rangelands. *African Journal of Range and Forage Science* **21**, 137–145.

Bowman, D. M. J. S. (2002). Biotechnology: evolutionary fire. *Nature Australia* **Autumn**, 82.

Bowman, D. M. J. S., Wilson, B. A., and Davis, G. W. (1988). Response of *Callitris intratropica* R.T. Baker & H.G. Smith to fire protection, Murgenella, northern Australia. *Australian Journal of Ecology* **13**, 147–159.

Bowman, D. J. M. S., Price, O., Whitehead, P. J., and Walsh, A. (2001). The 'wilderness effect' and the decline of *Callitris intratropica* on the Arnhem Land Plateau, northern Australia. *Australian Journal of Botany* **49**, 665–672. doi:10.1071/BT00087

Bradstock, R. A., Bedward, M., Gill, A. M., and Cohn, J. S. (2005). Which mosaic? A landscape ecological approach for evaluating interactions between fire regimes, habitat and animals. *Wildlife Research* **32**, 409–423.

Brook, B. W., and Whitehead, P. J. (2005*a*). Sustainable harvest regimes for magpie geese (*Anseranas semipalmata*) under spatial and temporal heterogeneity. *Wildlife Research* **32**, 459–464.

Brook, B. W., and Whitehead, P. J. (2005*b*). Plausible bounds for maximum rate of increase in magpie geese (*Anseranas semipalmata*): implications for harvest. *Wildlife Research* **32**, 465–471.

Cook, G. D. (2003). Fuel dynamics, nutrients and atmospheric chemistry. In 'Fire in Tropical Savannas: the Kapalga Experiment'. (Eds A. N. Andersen, R. Williams and G. D. Cook.) pp. 47–58. (Springer-Verlag: New York.)

Dyer, R., and Stafford Smith, M. (2003). Ecological and economic assessment of prescribed burning impacts in semi-arid pastoral lands of northern Australia. *International Journal of Wildland Fire* **12**, 403–413. doi:10.1071/WF03026

Ferdinands, K.,, Beggs, K., and Whitehead, P. J. (2005). Biodiversity and invasive grass species: multiple-use or monoculture? *Wildlife Research* **32**, 447–457.

Franklin, D. C. (1999). Evidence of disarray among granivorous bird assemblages in the savannas of northern Australia, a region of sparse human settlement. *Biological Conservation* **90**, 53–68. doi:10.1016/S0006-3207(99)00010-5

Franklin, D. C., Whitehead, P. J., Pardon, G., Matthews, J., McMahon, P., and McIntyre, D. (2005). Geographic patterns and correlates of the decline of granivorous birds in northern Australia. *Wildlife Research* **32**, 399–408.

Hobbs, R. J. (2005). Landscapes, ecology and wildlife management in highly modified environments – an Australian perspective. *Wildlife Research* **32**, 389–398.

Hunt, L. P., Petty, S., Cowley, R. A., Fisher, A., Goody, L., and MacDonald, N. (2003). Improving grazing distribution, productivity and land condition in extensively grazed landscapes. In 'Proceedings of the VIIth International Rangelands Congress, Durban, South Africa'. (Eds N. Allsopp, A. R. Palmer, S. J. Milton, K. P. Kirkman, G. I. H. Kerley, C. R. Hurt and C. J. Brown.) pp. 876–878.

Miller, J. D., Nyhan, J. W., and Yool, S. R. (2003). Modeling potential erosion due to the Cerro Grande Fire with a GIS-based implementation of the Revised Universal Soil Loss Equation. *International Journal of Wildland Fire* **12**, 85–100. doi:10.1071/WF02017

Pearson, N. (2000). 'Our Right to Take Responsibility.' (Noel Pearson and Associates: Cairns.)

Price, O., Edwards, A., Connors, G., Woinarski, J. C. Z., Ryan, G., Turner, A., and Russell-Smith, J. (2005*a*). Fire heterogeneity in Kakadu National Park, 1980–2000. *Wildlife Research* **32**, 425–433.

Price, O., Rankmore, B., Milne, D., Brock, C., Tynan, C., Kean, L., and Roeger, L. (2005*b*). Regional patterns of mammal abundance and their relationship to landscape variables in eucalypt woodlands near Darwin, northern Australia. *Wildlife Research* **32**, 435–446.

Rossiter, N. A., Setterfield, S. A., Douglas, M. M., and Hutley, L. B. (2003). Testing the grass-fire cycle: alien grass invasion in the tropical savannas of northern Australia. *Diversity and Distributions* **9**, 169–176. doi:10.1046/j.1472-4642.2003.00020.x

Russell-Smith, J., Whitehead, P. J., Cook, G. D., and Hoare, J. L. (2003*a*). Response of *Eucalyptus*-dominated savanna to frequent fires: lessons from Munmarlary, 1973–1996. *Ecological Monographs* **73**, 349–375.

Russell-Smith, J., Yates, C., Edwards, A., Allan, G. E., Cook, G. D., Cooke, P., Craig, R., Heath, B., and Smith, R. (2003*b*). Contemporary fire regimes of northern Australia, 1997–2001: change since Aboriginal occupancy, challenges for sustainable management. *International Journal of Wildland Fire* **12**, 283–297. doi:10.1071/WF03015

Taylor, J. (2003). Indigenous economic futures in the Northern Territory: the demographic and socioeconomic background. Centre for Aboriginal Economic Policy Research Discussion Paper 246/2003. Australian National University, Canberra.

Whitehead, P. J. (2000). The clever country: where cows manage wildlife. In 'Business as Usual: Local Conflicts and Global Challenges'. (Ed. R. Dixon.) pp. 155–168. (North Australian Research Unit, Australian National University: Darwin.)

Whitehead, P. J. (2003). Indigenous products from indigenous people: linking enterprise, wildlife use and conservation. In 'Seizing our Economic Future: A Forum Sponsored by the Northern Territory Government. 26–27 March 2003, Alice Springs'. http://www.indigenousforums.nt.gov.au/dcm/indigenous_policy/forums/pdf/Peter%20Whitehead.pdf.

Whitehead, P. J., and Chatto, R. (1996). Northern Territory. In 'A Directory of Important Wetlands in Australia'. (Ed. Australian Nature Conservation Agency.) pp. 119–176. (Australian Nature Conservation Agency: Canberra.)

Whitehead, P., Bowman, D., Preece, N., Fraser, F., and Cook, P. (2003). Customary use of fire by indigenous peoples in north Australia: its contemporary role in savanna management. *International Journal of Wildland Fire* **12**, 415–425. doi:10.1071/WF03027

Williams, R. J., Woinarski, J. C. Z., and Andersen, A. N. (2003). Fire experiments in northern Australia: lessons for ecology, management and biodiversity conservation. *International Journal of Wildland Fire* **12**, 391–402. doi:10.1071/WF03025

Woinarski, J. C. Z. (1999). Prognosis and framework for the conservation of biodiversity in rangelands: building on the north Australian experience. In 'People and Rangelands: Building the Future. Proceedings of the VIth International Rangelands Congress'. (Eds D. Eldridge and D. Freudenberger.) pp. 639–645. (VI International Rangelands Congress, Inc.: Aitkenvale, Qld.)

Woinarski, J. C. Z., and Ash, A. J. (2002). Responses of vertebrates to pastoralism, military land use and landscape position in an Australian tropical savanna. *Austral Ecology* **27**, 311–323. doi:10.1046/j.1442-9993.2002.01182.x

Woinarski, J. C. Z., Milne, D. J., and Wanganeen, G. (2001). Changes in mammal populations in relatively intact landscapes of Kakadu National Park, Northern Territory, Australia. *Austral Ecology* **26**, 360–370. doi:10.1046/j.1442-9993.2001.01121.x

Woinarski, J. C. Z., Williams, R. J., Price, O., and Rankmore, B. (2005). Landscapes without boundaries: wildlife and their environments in northern Australia. *Wildlife Research* **32**, 377–388.

Yibarbuk, D. M., and Cooke, P. (2001). Bininj mak balanda kunwale manwurrk-ken. *Ngoonjook* **20**, 33–45.