Notes & Abstracts

GRASSLAND/GRASSY UNDERSTOREY

2.12

'Dorrobbee Grass': Relic of the past or icon of the future? Ralph Woodford (PO Box 8024, Dunoon, NSW 2480, Australia. Email: woodford1@optusnet.com.au).

Key words: *balds, community involvement, grassland, openings, rainforest landscape*.

'Dorrobbee Grass' is a 10 ha patch of grassland dominated by Kangaroo Grass (*Themeda triandra*), crowning the highest hilltop north of the village of Dunoon, near Lismore in far north-eastern New South Wales. It is one of a small number of surviving natural grassy patches which were previously scattered within and around the once extensive 'Big Scrub' subtropical rainforest (Stubbs 2001).

In a region where restoration of rainforest is the prime focus (there being less than 1% of the 'Big Scrub' remaining) it is not surprising that conservation of the many grassy openings has been overlooked in recent decades. However, lack of recognition of these 'grasses' was not always the case. Stubbs (2001) reconstructed the distribution of 56 grassy openings (e.g. 'Molly's Grass', 'Chillcott's Grass', 'Byrangery Grass') recognised and named by early white settlers to the district. These patches were highly valued as stock camps during the cedar-getting period of the mid to late nineteenth century, prior to the sowing of introduced pasture on the cleared rainforest areas; and we can only speculate on how important they may have been to previous generations of Aboriginal landholders in terms of networks of open hunting, camping and ceremonial sites complementing the closed 'Big Scrub' environment.

The significance of these patches is also enhanced by the proposal that they are not necessarily modern artefacts of clearing or fire but may be remnants of ecosystems which occurred more extensively prior to rainforest colonization of the area, maintained by the shallow, rocky soils and propensity to lightning strike (Stubbs 2001). Deliberate Aboriginal management may also have kept these sites open, as grasses are well known for playing an important role in Aboriginal economies (McBryde 1978).

While many of the patches were simply absorbed into the surrounding agricultural landscape after clearing of the rainforest, a number of them, including Dorrobbee Grass, were set aside in public ownership at the time of early settlement. Stubbs (2001) lists 15 other patches in the Dunoon area but of these, only Minyon Grass and Byrangery Grass have an intact native grass component. Of the patches that were previously entirely surrounded by rainforest, Dorrobbee Grass is the only one that still has an intact, albeit modified, grassy component.

Conservaton and restoration of the 'grass'.

Historical condition. Dorrobbee Grass was reserved on the 9 December 1878 as a camping site for travelling stock (Stubbs 2002). Over the past 50 years the area has been continuously grazed. Observation of the site over the past 6 years made local residents aware that the area of Kangaroo Grass was diminishing in favour of invading exotic species such as Setaria (*Setaria* sp.), Crofton Weed (*Ageratinum adenanthum*), cotton bushes (*Asclepias curassavica* and *Gomphocarpus fruiticosus*), Tall Fleabane (*Conyza albida*) and Verbena (*Verbena rigida*). Weed invasion has been particularly noticeable over recent dry years, compounded by the effect of grazing. A Reserve Trust was formed in 2003 to initiate and guide a restoration project which will encompass both biophysical restoration and restoration of a more appreciative relationship between the local community and 'the grass'.

Just prior to the Trust taking over the management of the reserve, the lessee slashed and burnt the site. The Trust decided to discontinue grazing in order to monitor the recovery of the vegetation on the bare burnt site. Early in the recovery period, close observation was made of the grass and forb species on the site after the grazing, slashing and burning, to try to identify the likely prior community composition and structure. Initially Native Violet (*Viola betonicifolia*), Flax Lily (*Dianella longifolia*) and Glycine (*Glycine tabacina*) were regularly found in the bare gaps between the sprouting Kangaroo Grass clumps, probably arising from rootstocks. Lespedeza (*Lespedeza juncea* subsp. *sericea*) was widespread particularly in disturbed areas, and several other Faboideae species occurred occasionally (Table 1). Other forbs also occurred more rarely, including *Ranunculus* sp. and *Hypoxis* sp. as well as terrestrial orchids including Sun Orchid (*Thelymitra* sp.), an Onion Orchid (*Microtis* sp.) and Ladies' Tresses (*Spiranthes sinensis* subsp. *australis*). Of the grasses, Kangaroo Grass was the dominant, but other grass species present were Plume Grass (*Dichelachne micranthra*), Brown's Lovegrass (*Eragrostris brownii*), Weeping Grass (*Microlaena stipoides*), Broad-leaved Basket Grass (*Oplismenus aemulus*) and *Poa labillardieri*.

Several relict and regenerated trees also occur on the site, suggesting that at some stage in its history it may have been a grassy woodland. The most common is Pink Bloodwood (*Corymbia intermedia*). The other species are a Red Gum species and Swamp Mahogany (*Tristaniopsis suaveolens*). Blackwood (*Acacia melonoxylon*) is an ever-present colonizer, as are the woody exotics

Table 1. Ferns and herbaceous species at Dorrobbee Grass. (D. Bailey 20.11.04)

Forbs	Grasses
Centella asiatica	*Agrostis avenacea* var. *avenacea*
Commelina cyanea	*Bothriochloa decipiens*
Derris involuta	*Capillipedium spicigerum*
Desmodium heterocarpon var. *hetrocarpon*	*Chloris truncata*
Dianella caerulea	*Cymbopogon refractus*
Dianella longifolia	*Dichelachne micrantha*
Dichondra repens	*Imperata cylindrica*
Euchiton sp.	*Microlaena stipoides* var. *stipoides*
Geitonoplesium cymosum	*Poa labillardieri*
Glycine microphylla	*Sporobolis elongatus*
Hypericum japonicum	*Themeda australis*
Oxalis sp.	
Polymeria calycina	**Sedges**
Polygala japonica	*Carex breviculmis*
Pratia purpurescens	*Carex inversa*
Ranunculus lappaceus	*Juncus usitatis*
Veronica cinerea var cinerea	
Vigna vexillata var. *angustifolia*	
Viola betonicifolia	

Camphor Laurel (*Cinamomum camphora*) and Small-leaved Privet (*Ligustrum sinense*).

Current condition and proposed treatments. At 12 months after burning and the removal of grazing, the site is now dominated by Kangaroo Grass. It is a dense, even sward around 70 cm high with no noticeable gaps. The orchids and most of the forbs did not reappear in the spring of 2004, possibly due to competition from Kangaroo Grass, as most exotics are also considerably reduced. Very dry seasonal conditions, however, cannot be ruled out as a factor explaining both lower native diversity and lower weed dominance. To optimise natural regeneration and consolidation of existing native species, a series of treatments has been designed and is underway, based on managed disturbances (involving slashing, fire, grazing and herbicide) as prescribed for some grassland sites in other parts of Australia (McDonald 2000; McIntyre *et al.* 2002). The Trust plans to develop a partnership with Southern Cross University in Lismore to allow us to identify which treatments result in better control of weed and enhancement of native species diversity. At the same time we will systematically remove the woody weeds from the site.

Further identifying pre-existing floristics. Concurrent with regeneration treatments (and prior to considering any potential for reintroductions), we need progressively to try to understand more about the range of species that may have existed naturally on the site. While the early surveyor's map described the vegetation as 'open grassy woodland surrounded by lush scrub' (Richmond River Historical Society), no mention is made of species other than the dominant Kangaroo Grass.

The task of identifying the likely pre-existing suite of grass and forb species in the Lismore district is very difficult for two reasons. First, intensive grazing, particularly combined with the fertilising and exotic sowings involved in 'pasture improvement', has led to a conversion of most native grassy understoreys close to settlements to exotic pasture. While Dorrobbee Grass has not been 'pasture improved', the grazing over the past 50 years is likely to have led to the loss of palatable species sensitive to grazing and with short seed viability. Second, the high rainfall, fertile soils, proximity of frugivore-spread species, and low frequency/high intensity of fire occurring in this region is likely to have led to rainforest colonisation of sclerophyll sites near rainforests, confining grassy understoreys to drier ridges and poorly drained floodplains (Stubbs 2001). As a result, there are few, if any, local examples of undamaged grassy understoreys, making the task of identifying previous floristics extremely difficult. Identification of pre-existing ground flora is therefore likely to be dependent on optimising natural regeneration on the site itself – as well as observing the species occurring in nearby grassy openings. Two other grassy woodlands occur nearby on basalt-derived soils similar to those at Dorrobbee Grass. Both are dominated by Kangaroo Grass, although they have a different dominant tree – Tallowwood (*Eucalyptus microcorys*) – which is absent from Dorrobbee Grass. As part of an effort to inform the management of Dorrobbee Grass and other such local sites, local bush regenerators and botanists are proposing to systematically list all native species in as many local grassy sites as practicable over the next 5 years.

References

McBryde I. (1978). *Records of times past; ethnohistorical essays on the culture and ecology of the New England tribes*. Australian Institute of Aboriginal Studies, Canberra.

McDonald T. (2000). Strategies for the ecological restoration of woodland plant communities: harnessing natural resilience. In: *Temperate Eucalypt Woodlands in Australia: Biology Conservation, Management and Restoration*. (eds R. J. Hobbs and C. J. Yates) pp. 286–97. Surrey Beatty & Sons, Chipping Norton.

McIntyre S. J., McIvor, and Heard K. M. (eds) (2002). *Managing and Conserving Grassy Woodlands*. CSIRO Publishing, Canberra.

Stubbs B. J. (2001). The 'Grasses' of the Big Scrub District, north-eastern New South Wales: their recent history, spatial distribution and origins. *Australian Geographer* **32**, 295–319.

Stubbs B. J. (2002). Dorroughby or Dorrobbee? A fresh look at the origins of a Richmond River district place name. *Bulletin, Richmond River Historical Society* **182** (September), 3–4.

2.13

Grassland indicator species predict flowering of endangered Gaping Leek-orchid (*Prasophyllum correctum* D. L. Jones). Ian D. Lunt,[1] Fiona Coates[2] and Peter Spooner[1] ([1]The Johnstone Centre, Charles Sturt University (PO Box 789 Albury, NSW 2640, Australia. Email: ilunt@csu.edu.au) [2]Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment (PO Box 137, Heidelberg, Victoria 3084, Australia)).

Key words: *indicator species, monitoring, native grassland.*

Introduction. Temperate native grasslands are endangered ecosystems in Australia. Grassland plant diversity is often maintained by regular disturbances such as fire that reduce competition from dominant grasses (e.g. Kangaroo Grass, *Themeda triandra*). Without disturbance, dominant grasses often outcompete smaller herbs, sometimes reducing plant diversity irreversibly (Grime 1973; Collins *et al*. 1999; Lunt & Morgan 2002). Grassland managers require simple methods to rapidly assess grassland structure and diversity. Recently, Lunt (2003) suggested that management effects might be rapidly estimated by comparing the vigour of carefully selected indicator species exposed to contrasting disturbance regimes. The rationale behind this approach is that accumulating grass cover would reduce the vigour of the indicator species (e.g. Lunt 1994; Morgan 1997) before causing more permanent reductions in diversity.

The relevance of indicator species to the responses of other species is often questionable (Landres *et al*. 1988; Simberloff 1998), so it is important that indicator species are selected and tested carefully. Lunt (2003) screened a regional quadrat database to select potential indicator species using a series of explicit criteria. Only three of 364 native species on the Victorian western plains were selected: Lemon Beauty-heads (*Calocephalus citreus*), Common Everlasting (*Chrysocephalum apiculatum*) and Scaly Buttons (*Leptorhynchos squamatus*). This approach identified species with a high potential to act as indicator species, but did not test the proposition that changes in the vigour of these species would reflect actual changes in the vigour, abundance or diversity of other plants.

Native grasslands support many threatened species including orchids (Scarlett & Parsons 1993). Orchid flowering is notoriously erratic and flowering is known to be affected by rainfall, temperature, competition from other plants, and disturbances such as fire and grazing (e.g. Hutchings *et al*. 1998; Light & MacConnaill 1991; Gregg 2004). Little is known about the ecology of most Australian orchids, and there is an urgent need to identify ways to boost populations of many orchid species to prevent their extinction.

The Gaping Leek-orchid (*Prasophyllum correctum*) is a nationally endangered orchid that occurs in two small populations on mainland Australia, in Gippsland, Victoria. For 12 years, orchid dormancy, emergence and flower production have been recorded every spring by observing permanently tagged plants in the largest population (Coates *et al*. 1999; and unpubl. data). In a parallel project, annual changes in flower production by a suite of grassland forbs were assessed at the same site from 1993 to 1999, including two of the suggested indicator species, Common Everlasting and Scaly Buttons. This enabled us to appraise the utility of the suggested indicator species by asking: 'to what extent do annual changes in vigour (as measured by flower production) of the suggested indicator species correspond to annual changes in emergence and flowering of the Gaping Leek-orchid?'

Methods. From 1993 to 1999, the density of flowering plants and the total number of flower heads of Common Everlasting and Scaly Buttons were assessed every spring in regularly spaced 1 m^2 plots (see methods in Lunt 1994). During the same period, the total numbers of dormant, emerged and flowering Gaping Leek-orchids were monitored (Coates *et al*. 1999). In this paper, data are restricted to the north-east sector of the area surveyed by Lunt (1994), where the orchid is most abundant. Spearman's non-parametric rank-order correlation coefficients (SPSS version 11.5) were used to test associations between flower production by the two indicator species and the number of emerged and flowering Gaping Leek-orchids in each year.

Table 1. Spearman's rank correlations between flowering and emergence of the nationally endangered Gaping Leek-orchid (*Prasophyllum correctum*) and flower production by two potential indicator species between 1993–1999 (n = 7) at the largest population of the Gaping Leek-orchid in Gippsland, Victoria. ns, not significant.

Indicator species	Gaping Leek-orchid (*Prasophyllum correctum*)			
	No. emerged		No. in flower	
	Rs	***P***	***Rs***	***P***
Scaly Buttons (*Leptorhynchos squamatus*)				
No. plants in flower	0.929	0.003	0.709	0.074 (ns)
Total no. flowers	0.964	< 0.001	0.818	0.024
Common Everlasting (*Chrysocephalum apiculatum*)				
No. plants in flower	0.857	0.014	0.782	0.038
Total no. flowers	0.857	0.014	0.782	0.038

Results. There was a highly significant positive correlation between the number of emergent Gaping Leek-orchids and the number of Scaly Button plants in flower (Rs = 0.929, P = 0.003, n = 7 years) and the total number of Scaly Button flowers (Table 1). There was also a significant positive correlation ($P < 0.05$) between the number of Leek-orchids in flower and the total number of Scaly Button flowers (Table 1). Similarly, the number of emergent and flowering Leek-orchids was significantly ($P < 0.05$) positively correlated with the number of Common Everlastings in flower and the total number of Common Everlasting flowers (Table 1).

Discussion. Many studies have attempted to explain annual variations in orchid flowering patterns (Wells 1981; Hutchings 1987; Kindlmann & Balounová 1999; Brzosko 2002). However, none appear to have compared orchid flowering against other non-orchidaceous herbs. Our results suggest that annual variations in Gaping Leek-orchid flowering reflect processes shared by many other grassland forbs. There was a surprisingly strong correlation between emergence and flowering of Gaping Leek-orchids and flower production by both indicator species, especially the total number of Scaly Button flowers (Rs = 0.964). Flowering Scaly Buttons and Common Everlastings can be easily assessed visually, providing a relatively simple method for estimating flower production of the cryptic Gaping Leek-orchid.

Flower production by Scaly Buttons declines dramatically as grass competition increases (Lunt 1994) and is presumably also influenced by annual weather conditions. Similarly, detailed analyses of Gaping Leek-orchids show that time-since-fire, grass biomass and annual weather conditions interact to control emergence and flowering (Coates & Lunt, unpubl. data). This supports ecological models which predict that plant diversity in productive grasslands is promoted by disturbances that reduce grass biomass and competition for light (Grime 1973; Collins *et al*. 1999; Lunt & Morgan 2002).

These results support Lunt's (2003) proposition that changes in the vigour of carefully selected indicator species can provide useful information on the behaviour of other co-occurring plant species. In particular, repeated declines in the abundance of flowers on indicator species may provide an early warning that other species of note may also be declining in vigour, perhaps because of increasing biomass levels or other factors. Further studies of the relationships between potential indicator species and other grassland attributes (e.g. plant diversity) may greatly assist conservation of these threatened ecosystems.

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References

Brzosko E. (2002). Dynamics of island populations of *Cyprepedium calceolus* in the Biebrza river valley (north-east Poland). *Botanical Journal of the Linnaean Society* **139**, 67–77.

Coates F., Lunt I. and Wapstra H. (1999). *Recovery Plan 2000–2002 Prasophyllum correctum D. L. Jones (Gaping leek-orchid).* La Trobe University, Bundoora, Victoria.

Collins S. L., Knapp A. K., Briggs J. M., Blair J. M. and Steinauer E. M. (1999). Modulation of diversity by grazing and mowing in native tallgrass prairie. *Science* **280**, 745–747.

Grime J. P. (1973). Competitive exclusion in herbaceous vegetation. *Nature* **242**, 344–347.

Gregg K. B. (2004). Recovery of showy lady's slippers (*Cypripedium reginae Walter*) from moderate and severe herbivory by white-tailed deer (*Odocoileus virginianus Zimmerman*). *Natural Areas Journal* **24**, 232–241.

Hutchings M. J. (1987). The population biology of the early spider orchid, *Ophrys sphegodes Mill*. I. A demographic study from 1975 to 1984. *Journal of Ecology* **75**, 711–727.

Hutchings M. J., Mendoza A. and Havers W. (1998). Demographic properties of an outlier population of *Orchis militaris* L. (*Orchidaceae*) in England. *Botanical Journal of the Linnaean Society* **126**, 95–107.

Kindlmann P. and Balounová Z. (1999). Flowering regimes of terrestrial orchids: unpredictability or regularity? *Journal of Vegetation Science* **10**, 269–273.

Landres P. B., Verner J. and Thomas J. W. (1988). Ecological uses of vertebrate indicator species: a critique. *Conservation Biology* **2**, 316–329.

Light M. H. S. and MacConnaill M. (1991). Patterns of appearance in *Epipactis helleborine* (L.) Crantz. In: *Population Ecology of Terrestrial Orchids* (eds T. C. E. Wells and J. H. Willems) pp. 77–87. SPB Academic Publishing, The Hague, The Netherlands.

Lunt I. D. (1994). Variation in flower production of nine grassland species with time since fire, and implications for grassland management and restoration. *Pacific Conservation Biology* **1**, 359–366.

Lunt I. D. (2003). A protocol for integrated management, monitoring, and enhancement of degraded *Themeda triandra* grasslands based on plantings of indicator species. *Restoration Ecology* **11**, 223–230.

Lunt I. D. and Morgan J. W. (2002). The role of fire regimes in temperate lowland grasslands of south-eastern Australia. In: *Flammable Australia: The Fire Regimes and Biodiversity of a Continent*. (eds R. Bradstock, J. Williams and A. M. Gill) pp. 177–196. Cambridge University Press, Cambridge.

Morgan J. W. (1997). The effect of grassland gap size on establishment, growth and flowering of the endangered *Rutidosis leptorrhynchoides* (*Asteraceae*). *Journal of Applied Ecology* **34**, 566–576.

Scarlett N. H. and Parsons R. F. (1993). Rare or threatened plants in Victoria. In: *Flora of Victoria. Volume 1, Introduction*. (eds D. B. Foreman and N. G. Walsh). pp. 227–255. Inkata, Melbourne.

Simberloff D. (1998). Flagships, umbrellas, and keystones: is single-species management passe in the landscape era? *Biological Conservation* **83**, 247–257.

Wells T. C. E. (1981). Population ecology of terrestrial orchids. In: *The Biological Aspects of Rare Plant Conservation* (ed. H. Synge) pp. 281–295. John Wiley & Sons Ltd.

Table 1. **Native plant occurrence in sward structures (patch types) resulting from different grazing pressures in sub-tropical grassy understorey (derived from McIntyre *et al*. 2003). Unclassifiable species included those that were too rare to detect a response.**

Response type	Patch type preferred	No. of native plants species in response group
Grazing decreaser	Tall-ungrazed (no livestock grazing)	41
Intermediate	Tall-grazed (light grazing)	19
Low grazing intolerant	Any patch type within pastures	7
Grazing increaser	Short (heavily grazed)	20
Generalists	Any patch type	49
Unclassifiable	Unknown	86

2.14

Biodiversity attributes of different sward structures in grazed grassland.

S. McIntyre (CSIRO Sustainable Ecosystems, GPO Box 284, Canberra, ACT 2601, Australia. Email: Sue.McIntyre@csiro.au).

Key words: *birds, grassy woodlands, grazing, invertebrates, plants.*

Introduction. In native grasslands, the effect of grazing is to change the structure and the plant species of the ground layer. Tall, little-grazed grasslands support large-growing tussock grasses, with smaller grasses and forbs growing in-between. With selective grazing, the large palatable tussocks are reduced and grazing-tolerant perennial grasses form a short sward between the tussocks. With extreme grazing, a 'lawn' is formed, the large tussocks are eliminated and replaced by small tufted and/or creeping grasses and forbs (short patches).

Biodiversity is affected by these changes in grassland structure, both directly due to the effects of defoliation and trampling, but also due to changes in the nature of the habitat created by different sward structures. Here we discuss the effects of grassland structure on biodiversity from our own observations and using published information. We conclude that the presence of all structural types is optimal for the conservation of biodiversity, although the extent of tall patches is likely to be limiting to biodiversity conservation, owing to the large number of species preferring tall grassland structure and the tendency for these habitats to be eliminated by grazing.

Grazing effects on plant biodiversity. Native grassland plants exhibit a variety of responses to grazing pressure. In McIntyre *et al.* (2003) we described the flora of tall-ungrazed, tall-grazed, and short patches. It can be seen in Table 1 that for the different structures sampled, there is a range of possible species responses. All patch types are preferred or tolerated by more than one species, so to maintain plant diversity, a mix of sward structures is desirable in landscapes. Some plants are generalists

– they tolerate all grazing pressures. A large number of species were too rare for a response to be detected. Apart from these, the largest response group amongst native plants was the generalist group. However, for plant diversity conservation we suggest that the amount of tall patch in pastures is a critical factor (tall-grazed) as it is optimal habitat for 19 native species with intermediate grazing response. Although the 41 grazing decreasers are most abundant in ungrazed habitats, ungrazed areas are very restricted in area (roadsides, stock routes) and leniently grazed native pasture could represent a lower quality but extensive habitat for them.

Effects on vertebrate habitats. Tall tussock structure provides habitat for nesting birds and for ground-dwelling mammals such as bettongs and bandicoots. As well as shelter, ungrazed grasses can provide seed sources for birds and concealment while foraging. While these principles are broadly understood, exactly what vertebrates require in terms of grassland structure is rarely identified. One exception is a study of the Plains-wanderer by Baker-Gabb *et al*. (1989). This bird was found to need lightly grazed tussock grassland of specific cover, density and height to enable it to forage, remain cryptic and detect predators. Heavily grazed areas can also be a resource for vertebrate herbivores, which can benefit from the high quality of forage associated with grazing lawns, in the same way the livestock do. From the point of view of a whole community, a study of British grassland birds concluded that the needs of all species could be met by providing the range of sward structures, areas of bare ground and seeding grasses (Perkins *et al*. 2000).

Effects on invertebrate habitats. The distribution of soil dwelling animals is affected by vegetation patchiness over a range of scales, from hundreds of metres to centimetres (Ettema & Wardle 2002), and invertebrate diversity is related to diversity in plant composition and structure (Quinn & Walgenbach 1990). In relation to grazing patchiness, the responses of invertebrates are similar to that of plants in two respects. First, there is substitution of less tolerant by more tolerant species as grazing intensity increases. For example, grazing promotes grasshopper populations and other species that depend on actively growing soft plant tissue (Tscharntke & Greiler 1995) while groups that are sensitive to the loss of litter and/or the effects of trampling, decline with grazing (e.g. earthworms, Cluzeau *et al*. 1992; Collembola and nematodes, King & Hutchinson 1983). The second point is that there are a larger number of species that require tall grassland swards so that diversity here tends to be higher (e.g. Dennis *et al*. 1997; Cagnolo *et al*. 2002; Kruess & Tscharntke 2002) and some groups are particularly dependent on them (e.g. web-spinning spiders, Gibson *et al*. 1992; flower or seed feeders, Tscharntke & Greiler 1995). Although there is general agreement that structural diversity is important for invertebrate diversity, the concept of structural diversity can be expressed at different scales, for example a mosaic of short and tall-grazed patches, or alternatively to describe a tall tussock patch as structurally complex. Therefore, recommendations for management of invertebrate diversity have been to maintain a mosaic of short and tall patches (Dennis *et al*. 1997; Tscharntke & Greiler 1995) or to increase the areas of tall tussock (Kruess & Tscharntke 2002).

Summary of response of biodiversity to sward structure. It is clear that the presence of all the patch structures in the landscape will be advantageous to the maintenance of biodiversity. The studies discussed so far have not considered the relative proportions of different patches that might be needed to maintain diversity. All we can infer is that while areas of bare ground and short grass swards are used by a variety of organisms, a greater number of species are dependent on, or prefer, areas that are ungrazed or lightly grazed by livestock. We suggest that tall grassland patches are likely to be required in greater quantity in landscapes than short patches, based on the premise that there are more species dependent on them.

While few studies have examined explored thresholds in terms of the amount of different patch types, the importance of connections between patches has been shown. Weins *et al*. (1997) found that a highly active beetle (with a movement scale hundreds of metres) needed 20% grassland patches to experience habitat connectivity. However, we need to consider the most limited organisms in terms of mobility in landscapes. These might include plants with dispersal distances of a few metres, or invertebrates such as soil nematodes with dispersal distances of less than a metre. Theory identifies a critical threshold of 60% – an amount of habitat above this value in landscapes, provides connectivity of habitat for organisms even with the most limited mobility (described in McIntyre 2003). This critical threshold could be reduced in grassland for organisms with increased mobility or a tendency towards habitat generalization. Obviously, it is not possible to provide 60% cover of both short and tall patches, and taking into account the need to maintain soil condition and the larger number of species associated with taller patches, we suggest that connectivity be biased towards tall and intermediate patches.

In terms of biodiversity, there is still little reason to change the existing recommendation to 'Graze conservatively to maintain dominance of large and medium tussock grasses over 60–70% of the native pastures' [But see refinement in McIntyre & Tongway 2005, this issue]. The proposed threshold rests on the hypothesis that connectivity of tall and intermediate grassland structure will adequately maintain protection for the soil and connectivity for organisms of low mobility dependent of these structures.

References

Baker-Gabb D. J., Benshemesh J. S. and Maher P. N. (1989). A revision of the distribution, status, and management of the Plains-wanderer *Pedionomus torquatus*. *Emu* **90**, 161–168.

Cagnolo L., Molina S. I. and Valladares G. R. (2002). Diversity and guild structure of insect assemblages under grazing and exclusion regimes in a montane grassland from Central Argentina. *Biodiversity Conservation* **11**, 407–420.

Cluzeau D., Binet F., Vertes F., Simon J. C., Riviere J. M. and Trehen P. (1992). Effects of intensive cattle trampling on soil-plant-earthworms system on two grassland types. *Soil Biology and Biochemistry* **24**, 1661–1665.

Dennis P., Young M. R., Howard C. L. and Gordon I. J. (1997). The response of epigeal beetles (Col.: *Carabidae*, *Staphylinidae*) to varied grazing regimes on upland Nardus stricta grasslands. *Journal of Applied Ecology* **34**, 433–443.

Ettema C. H. and Wardle D. A. (2002). Spatial soil ecology. *Trends in Ecology and Evolution* **17**, 177–183.

Gibson C. W. D., Hambler C. and Brown V. K. (1992). Changes in spider (*Araneae*) assemblages in relation to succession and grazing management. *Journal of Applied Ecology* **29**, 132–142.

King K. L. and Hutchinson K. J. (1983). The effects of sheep grazing on invertebrate numbers and biomass in unfertilized natural pastures of the New England Tablelands (NSW). *Australian Journal of Ecology* **8**, 245–255.
Kruess A. and Tscharntke T. (2002). Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biological Conservation* **106**, 293–302.
McIntyre S. (2003). The Landscape Game: a learning tool for demonstrating landscape design principles. *Ecological Management & Restoration* **4**, 103–109.
McIntyre S. and Tongway D. (2005). Grassland structure in native pastures – links to soil surface condition. *Ecological Management & Restoration* **6**, 43–50.
McIntyre S., Heard K. M. and Martin T. G. (2003). The relative importance of cattle grazing in sub-tropical grasslands – does it reduce or enhance plant biodiversity? *Journal of Applied Ecology* **40**, 445–457.
Perkins A. J., Whittingham M. J., Bradbury R. B., Wilson J. D., Morris A. J. and Barnett P. R. (2000). Habitat characteristics affecting use of lowland agricultural grassland by birds in winter. *Biological Conservation* **95**, 279–294.
Quinn M. A. and Walgenbach D. D. (1990). Influence of grazing history on the community structure of grasshoppers of a mixed-grass prairie. *Environmental Entomology* **19**, 1756–1766.
Tscharntke T. and Greiler H.-J. (1995). Insect communities, grasses and grasslands. *Annual Review of Entomology* **40**, 559–85.
Weins J. A., Schooley R. L. and Weeks R. D. (1997). Patchy landscapes and animal movements: do beetles percolate? *Oikos* **78**, 257–264.

2.15

Monaro Grassland Conservation Management Network. David A. Eddy (Monaro Grassland Conservation Management Network. Tel. 61-2 6242 8484; Email: MGCMN@myaccess.com.au).

Key words: *grassland, grassy understorey, industries, integrating ecosystems.*

The largely sheep-grazing Monaro region in southern NSW has historically contained significant areas of natural grassland. For a range of environmental and socioeconomic reasons, extensive areas of native grass dominant vegetation persists on private grazing land, with smaller but important patches on public land (e.g. council parks and reserves, cemeteries, road verges, and travelling stock reserves). Based on a model developed elsewhere (Prober & Theile 2001), the Monaro Grassland Conservation Management Network has been established to link native grassland areas of significant conservation value, irrespective of tenure (Fig. 1). Landholders, managers and other interested people are connected to the Network by a regular newsletter, Monaro Grassland Mail, and members can meet each other and exchange ideas at field days and visits to local grasslands (Fig. 2). Landholders and managers can also gain support and expert advice through the Network, including advice on formal protection for areas of high conservation value. The Network is being supported by the Southern Rivers CMA under its Snowy Monaro Biodiversity Conservation Strategy and is overseen by the Monaro Grasslands Advisory Committee.

There are currently about 120 people on the Network contact list, about 50 being private landholders collectively responsible for managing over 17 000 ha of native grass-dominant vegetation, including an estimated 6000 ha of native grassland. Both RLPB (Cooma and Bombala) are also members, as well as three local governments (Cooma-Monaro, Snowy River and Bombala) and corporations including Snowy Hydro. One of the main messages being transferred to members is the management of native grassy swards to integrate conservation and production. Recent poor seasons have seen successional recovery in many pastures, indicating that if this can occur unintentionally, intentional efforts to manage grasslands could be richly rewarded, to the benefit of both biodiversity conservation and agricultural production.

Figure 1. Member sites of the Monaro Grassland Conservation Management Network are identified by a distinctive (green on cream) sign, visible from the road.

Figure 2. Field trip (organised by Friends of Grassland) to Monaro Grassland Conservation Management Network sites. (Photo courtesy David Eddy.)

Reference

Prober S. M. and K. R. Theile (2001). The Grassy Box Woodlands Conservation Management Network: Picking up the pieces in fragmented woodlands. *Ecological Management & Restoration* **2**, 179–188.

2.16

Flyer for self-guided tourist drive of 28 Traveling Stock Reserves in the Monaro and Bega Valley areas of NSW. David A. Eddy (Monaro Grassland Conservation Management Network. Tel. 61-2 6242 8484; Email: MGCMN@myaccess.com.au).

Key words: *ecotourism, education, grassland, grassy understorey.*

A flow-on from WWF Australia's survey of remnant native grasslands on public land in the Monaro region of NSW (Eddy 2000) has been the development of a flyer for a self-guided tourist drive around the TSRs to promote native grassland and the Monaro region. The flyer contains a description and a map of a suite of 20 reserves on the Monaro and eight in the Bega valley that are in better condition and contain many native plant species of interest. All the reserves in the scheme are dominated by Kangaroo Grass (*Themeda triandra*), in some cases in strong contrast to the immediately adjacent land, and have a high density and diversity of other herb species including threatened and other uncommon species. The flyer was a collaborative project between the Cooma, Bombala and South Coast Rural Lands Protection Boards (RLPB), WWF Australia and NPWS, with funding from NHT. It is available at RLPB offices, other government agency offices, and tourist information outlets in the region. The project also funded some fencing repairs, weed control and signage to allow visitors to the area to identify the reserves readily from the road. As members of the public are allowed to stop their car and walk around the TSR, this provides an important opportunity for the local and broader community to enjoy the high quality grasslands and the species occurring in them; particularly if promoted in the flowering season. Additional educational value is provided by the flyer's detailed information on the history of the TSR, grassland values and processes, and the Monaro Grassland Conservation Management Network, of which the 28 Reserves are foundation member areas.

Reference

Eddy D. A. (2000). Conservation management of native grassland in travelling stock reserves and cemeteries of the Monaro. *Ecological Management & Restoration* **1**, 64–5.

2.17

Competitive relationships between four native Cumberland Plain grassland species in an addition-style experiment on post-mining land at Penrith Lakes. Tim Berryman, PhD candidate (University of Western Sydney, 19 Glenbrook Rd, Glenbrook, NSW 2773, Australia. Email: tim@cpseeds.com.au).

Key words: *competition, framework species, grassland reconstruction, weed control.*

Preliminary results are emerging from a 10-year field trial examining competitive relationships between four grassland species indigenous to the Cumberland Plain, in western Sydney. The practical objective is to identify potential mixes of species that can be sown simultaneously to provide an interlocking, productive and somewhat weed-resistant, matrix as a basis for reconstructing indigenous grassy understories in reclaimed agricultural, recreational or industrial lands. The four natives (*Chloris ventricosa*, *Austrodanthonia racemosa*, *Mocrolaena stipoides* and *Glycine microphylla*) were selected on the basis of propagule availability, persistence in the landscape, and assumed compatiblity (i.e. sun/shade tolerance, growth form, life histories and seasons of growth). The field trial involved planting the four species in monocultures, 2:1 and 1:2 binary mixtures and 1:1:1 trinary mixtures at four starting densities of 20, 40, 80 and 160 plants/m^2 in an addition style experiment on post-mining land at Penrith, NSW. The total number of treatments (including plots left unplanted) totalled 54 treatments replicated four times. Non-destructive measures of changes in density (including recruitment), and repeated measures of plant height, basal circumference and inflorescence numbers of four plants (per plot per species) in autumn, winter, spring and summer were undertaken to better understand the relative competitiveness of the species in this environment. Destructive herbage mass measures was also undertaken 10 years after planting.

Results of short-term (i.e. 1–2 years) competition patterns contrasted with results from the longer-term (10 year) monitoring. In the short term, mixed stands showed generally higher net productivity than monocultures, although the monocultures were superior performers at some temporal points, and *Microlaena* was generally a weaker competitor than *Chloris* or *Danthonia*. In the longer term, however, 85.7% of the best plots have *Microlaena* in the mix or as a monoculture, and monocultures (which were originally only in 24.1% of the original treatments) now represent 34.3% of the group of best plots (i.e. those with 50% plus native cover). While the role of weed removal (not carried out in the last 8 years) needs to be considered, these results raise questions about whether these grassland species may take a number of years to 'sort' and may perform better in small monocultured spots forming mosaics such as those found in remnants. If generalisations were possible from these data, this may mean that mixed plantings at the time of revegetation may not be the preference of the natives and that consideration might need to be given to creating small mosaics of single species stands at the outset.

2.18

Grassy Groundcover Research Project. Paul Gibson Roy (Grassy Groundcover Research Project Leader, C/O Burnley College, 500 Yarra Boulevade, Burnley, Victoria, Australia. Tel. 61-3 9250 6846; Email: roypg@unimelb.edu.au).

Key words: *direct seeding, grassland restoration, multi-species seed mixtures.*

Over the past 7 years, a series of grassland restoration studies have been conducted at the University of Melbourne's Burnley Campus. These studies investigated the establishment of indigenous herbaceous species via direct seeding, focusing on issues such as seed collection, seed production, seed testing, site preparation and the use of multi-species seed mixtures to reinstate functional and persistent plant communities (Gibson Roy 2004). This work represents a current and comprehensive development of this restoration technique for multiple herbaceous species under Australian conditions. Further, its findings indicate considerable potential for broad-scale restoration outcomes using direct seeding.

To capitalise on these developments, and utilize the skills and expertise of a state-wide network of vegetation specialists, landholders and community interest groups, Greening Australia will undertake a 3-year multi-regional grassland/grassy woodland restoration project that will further trial the establishment of these complex communities using direct seeding. This will involve a series of scientifically designed on-ground restoration projects at 15–20, 1 ha sites within the Wimmera, North Central, Glenelg Hopkins and Corangamite regions – with a view to providing important practical information related to the landscape-level application of direct seeding. The project's objective is to develop a series of 15–20 direct-sown species-rich grassland and grassy woodland understorey demonstration sites that will provide practical and experimental advancement of the techniques needed to increase the extent and range of these highly threatened vegetation communities. This will in-turn enhance the opportunity for landholders and land managers to apply these techniques elsewhere. The project will establish general protocols for seed harvest and production, site preparation, and the construction of complex multi-species seed mixtures. Together, these factors will allow the reintroduction of complex functional communities on private and public lands, and form a major step in reversing the ongoing decline in the extent of indigenous grassy communities in this State.

References

Gibson Roy P. (2004). *The restoration of indigenous grassland communities from direct-sown seed mixtures.* PhD Thesis. Institute of Land and Food Resources, The University of Melbourne.

2.19

Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. (2004) J. Dorrough, A. Yen, V. Turner, S. G. Clark, J. Crosthwaite and J. R. Hirth. *Australian Journal of Agricultural Research* 55, 279–295.

Key words: *agriculture, ecosystem function, grazing strategies, perennial grasses, sustainability, vegetation heterogeneity.*

There is an increasing interest in the development of livestock grazing management strategies that achieve environmental sustainability and maintain or improve the long-term production capacity of commercial grazing systems. In temperate Australia, these strategies are generally focused on reducing perennial pasture decline, soil loss, acidity and salinity. An additional challenge facing land managers and researchers is developing grazing strategies that also maintain and enhance local and regional biodiversity. However, few studies have assessed the compatibility of management practices for maintaining long-term productivity and biodiversity conservation. We still have only a very basic understanding of the effects of different grazing strategies and pasture management on biodiversity and this is a major impediment to the development of appropriate and compatible best management practice. We argue that although there is an increasing desire to find management strategies that protect and enhance biodiversity without hindering long-term agricultural production, in many cases this may not be possible. Current knowledge suggests that compatibility is most likely to be achieved using low-input systems in low productivity (fragile) landscapes, whereas in highly productive (robust) landscapes there is less opportunity for integration of productive land-use and biodiversity conservation. There is an urgent need for improved communication and collaboration between agronomic and ecological researchers and research agencies to ensure that future programs consider sustainability in terms of biodiversity as well as pasture and livestock productivity and soil and water health.

2.20

AusGrass: Grasses of Australia. (2002). Donovan Sharp and Bryan K. Simon. *Australian Biological Resources Study.* Identification Series CSIRO Publishing, Canberra.

AusGrass is a computer-based interactive identification guide to 1323 species of native and naturalised grasses in Australia. The guide employs Lucid software (tested in other identification systems and proven to be user-friendly) which enables the user to key out the species using any character, although dichotomous keys are also provided. These facilities, including very useful illustrations of taxa, grass characters and plant habits, will not, of course, obviate the need for microscopic (or at least hand lens) examination of a specimen; and it is important to recognise that grasses have specific botanic terminology (hence the provision of a very useful glossary). Some users also may find that, with only one window visible on the screen at one time, ease of comparison of fine details between closely-related taxa may not be as easy as with hard copy keys. The guide is priced reasonably (AU$99) and would be attractive to dedicated grass people and professionals, although bush regenerators are likely to find the information they want (and more readily) in smaller local grass identification guides that focus on the subset of species found in their region. (To view a sample, go to http://www.publish.csiro.au/)
Review for EMR by Jan de Nardi

WEEDS & FERAL ANIMAL ISSUES & SOLUTIONS

20.14

Cattle grazing for Para Grass management in a mixed species wetland of north-eastern Australia.
Paul R. Williams[1], Eleanor M. Collins[1] and Anthony C. Grice[2] ([1]Queensland Parks and Wildlife Service, PO Box 5597, Townsville, QLD 4810, Australia; [2]Sustainable Ecosystems, CSIRO, Townsville, PMB Aitkenvale, QLD 4814, Australia; Email: Paul.Williams@epa.qld.gov.au; Eleanor.Collins@epa.qld.gov.au; Tony.Grice@csiro.au).

Introduction. Introduced grasses can have significant negative effects on the conservation of native habitats. These grasses can reduce biodiversity by smothering out native plants and by increasing fire intensity, causing higher fire-induced mortality (Hoffmann *et al.* 2004; Stoner *et al.* 2004).

Para Grass (*Urochloa mutica* (Forssk.) T. Q. Nguyen) was introduced to northern Australia as a pasture grass suited to seasonal wetlands. It has become a serious pest of conservation lands because of its dense smothering habit and its high fuel loads (Douglas & O'Connor 2004). This paper reports an assessment of the effect of cattle grazing on the composition and percentage cover of species within a wetland containing Para Grass and native grasses and herbs within the Townsville Town Common Conservation Park (referred to throughout this paper as the 'Town Common').

The Town Common is located 6 km north-west of the centre of Townsville, north Queensland (19°11′30″S, 146°45′30″E). Townsville experiences summer wet seasons, with 78% of the 1143 mm mean annual rain falling between December and March. The Town Common was used in the 1880s to 1970s as a communal area for people to agist their livestock. The land was gazetted as an Environmental Park in 1980 over an area of 3245 ha, primarily in recognition of its water bird habitat. In December 1994, the Town Common became a Conservation Park under the Queensland Nature Conservation Act (1992).

The date of introduction of Para Grass onto the Town Common is unknown, but it was present in low density during the 1970s (P. Johnson, pers. comm., 2004). Since the removal of cattle in the late 1970s prior to gazettal as an Environmental Park, Para Grass has expanded and increased in density throughout most wetlands on the Town Common. The dominance of Para Grass has lead to a dramatic decline in wetland bird numbers (G. Blackman, pers. comm., 1996).

As the Town Common is a Conservation Park, rather than a National Park, the Queensland Nature Conservation Act (1992) allows for the use of cattle grazing if it can be demonstrated to enhance the management of the park's natural values. Due to extensive distribution of Para Grass over wetlands on the Town Common and the poor success of herbicide programs, a trial was instigated over a small section of the park to assess the value of cattle grazing for managing Para Grass density.

Methods. A total of 37 cattle were introduced into a 58 ha paddock on the Town Common in October 2002. This paddock contained approximately 7 ha of Para Grass infested seasonal wetland, including some areas with a mixture of Para Grass and native grasses, particularly the tall Common Reed (*Phragmites australis*) and the Native Couch (*Cynodon dactylon*) (taxonomy follows Henderson 2002, other than for the recent inclusion of Para Grass within *Urochloa*). The remainder of the 58 ha paddock contained mainly Carbeen (*Corymbia tessellaris*) woodlands with ground layer dominated by Guinea Grass (*Panicum maximum*). In June 2003, the cattle were allowed access to a further 40 ha in an adjacent paddock containing approximately 12 ha of Para Grass.

In order to evaluate the effect of grazing on both Para Grass and native grasses, six permanent 50 m^2 plots (10 m × 5 m) were established on 4 October 2002 in the original 58 ha paddock. The plots were intentionally located in an area containing a mixture of Para Grass and the (natives) Common Reed and Native Couch. Three randomly selected plots were fenced prior to the introduction

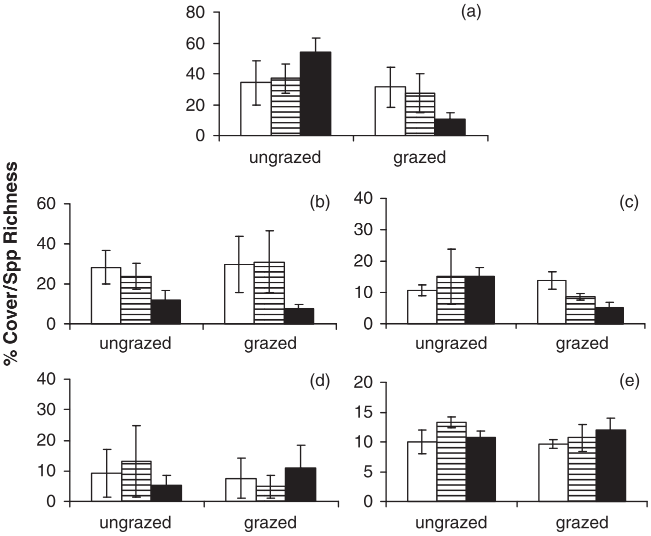

Figure 1. **Percentage cover and species richness changes on the Town Common in 2002 pre-treatment ( ); 2003 ( ) and 2004 ( ); with and without cattle grazing, for (a) Para grass (*Urochloa mutica*); (b) *Cynodon dactylon*; (c) *Phragmites australis*; (d) Phyla nodiflora; and (e) Species richness (*n* = 34 species). Error bars are one standard error.**

of cattle with a wire mesh, which inhibited the cattle from feeding through the wire into the fenced plots. A pre-treatment survey was undertaken on 2 October 2002, approximately 3 weeks prior to the introduction of cattle. The six plots were re-surveyed on 9 July 2003 and 18 August 2004. Thus, the time of sampling in each year was mid to late dry season and, therefore, few annual species were recorded in any survey. Sampling in each year consisted of estimating the percentage cover of all species within 20, 1 m^2 quadrats per plot, with percentage cover of all species plus bare areas and the dry Para Grass straw layer totaling 100% within each quadrat. The 20 quadrats were laid out consecutively in two parallel 10 m long transects, 1 m inside each long edge of the plots.

An average percentage cover from the 20 quadrats was calculated for each species per survey of each plot. A repeat measures ANOVA, with two levels (grazed and ungrazed) and year as the repeat measure factor, was used to determine the statistical significance of differences between treatments for the four dominant species and species richness per plot. Homogeneity of variances was confirmed using a Cochran's test (Underwood 1997).

Results. The cover of Para Grass declined with cattle grazing over the 22 months, with a significant interaction detected between treatment and year ($F_{2,8} = 7.71$; $P < 0.02$; Figure 1). No significant changes in cover were found for Common Reed or the native herb Carpet Weed (*Phyla nodiflora*). A significant year effect was detected for Native Couch, with cover being lowest in 2004, irrespective of treatment ($F_{2,8} = 8.42$; $P < 0.02$; Figure 1). There was no significant difference in species richness between the grazing treatments or across years (Figure 1).

Discussion. Cattle grazing significantly reduced Para Grass cover on the Town Common. The significant interaction for Para Grass between year and treatment indicates a uniform cover prior to treatments and that significant changes occurred following the implementation of the trial, with grazing significantly reducing Para Grass cover compared with ungrazed plots.

Other than the decline in Native Couch in 2004 in both grazed and ungrazed sites, there was no corresponding statistically significant effect on the three most common native species, even though some decline in Common Reed with grazing was noticeable. This suggests that short-term grazing impacts Para Grass to a greater extent than some native wetland grasses and herbs. However, given some decline in Common Reed and a reduction in its seed production (pers. obs.), it will be important to document the longer-term effects of grazing on this dominant native species.

The decline in Para Grass cover did not lead to a significant increase in species richness. This may be due to the dead straw that covered otherwise bare ground. This straw cover may inhibit the recruitment of additional species and the use of fire to remove the straw layer and promote native herbs is worth investigating. The two common native grasses, Native Couch and Common Reed, are known to resprout following burning, and the effects of fire on these and Carpet Weed will need investigation.

Acknowledgements The authors are grateful to the Queensland Department of Primary Industries for maintaining the cattle in this trial; Pat Salter for help in establishing the plots; and to Robert Graham, Ranger in charge of the Town Common. This study is one aspect of a larger project on Para Grass control and has benefited from discussions with Mike Nicholas (CSIRO).

References

Douglas M. M. and O'Connor R. A. (2004). Weed invasion changes fuel characteristics: Para grass (*Urochloa mutica* (Forssk.) T. Q. Nguyen) on a tropical floodplain. *Ecological Management & Restoration* **5**, 143–5.

Henderson R. J. F. (2002). *Names and distribution of Queensland plants, algae and lichens*. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Hoffmann W. A., Lucatelli V. M. P. C., Silva F. J., Azeuedo I. N. C., Marinho M. da S., Albuquerque A. M. S., Lopes A. de O. and Moreira S. P. (2004). Impacts of the invasive alien grass *Melinis minutiflora* at the savanna-forest ecotone in the Brazilian Cerrado. *Diversity and Distributions* **10**, 99–103.

Stoner J. R., Adams R. and Simmons D. (2004). Management implications of increased fuel loads following exotic grass invasion. *Ecological Management & Restoration* **5**, 68–9.

Underwood A. J. (1997). *Experiments in ecology: their logical design and interpretation using analysis of variance.* Cambridge University Press, Cambridge.

20.15

DNA-based detection of free-ranging pigs of domestic origin, in Western Australia. Jordan O. Hampton,[1] Tony Higgs,[2] Ted Knight[3] and Peter B. S. Spencer[1] ([1]Veterinary and Biomedical Sciences, Murdoch University, South Street, Murdoch, Western Australia 6150, Australia; [2]Department of Agriculture, 444 Albany Hwy, Albany, Western Australia 6330, Australia; [3]Department of Agriculture, Community Agriculture Centre, Albany Hwy, Mount Barker, Western Australia 6324, Australia; Email: P.Spencer@murdoch.edu.au).

Key words: *Bayesian assignment, domestic, ecosystem impacts, microsatellites, Sus scrofa.*

The impact of feral pigs in Australian ecosystems. Feral pigs are a significant threat to biodiversity, agriculture and are also involved in the spread of infectious diseases in Australia (Choquenot *et al*. 1996). Of further concern is that feral pigs appear to be increasing their distribution as a result of both natural (e.g. range expansion, increase in numbers) and non-natural activities (e.g. deliberate, illegal translocation; Choquenot *et al*. 1996; Hampton *et al*. 2004; Spencer and Hampton 2005). A number of studies have highlighted the ongoing problems of escape or abandonment of pigs into the natural environment (e.g. Hone 2002; Spencer and Hampton 2005). Whether population increases have been due to intentional release or natural dispersal events is generally poorly documented. A notable exception was the documentation of the accidental escape of domestic pigs from a truck overturn into the Namadgi National Park (in the Australian Capital Territory). In this case, the rate of expansion, possible impacts and control have been recognised (e.g. McIlroy *et al*. 1989; Hone 2002). An important limitation with detecting illegal introductions has been the difficulty of unambiguously identifying the origin of suspect pigs. The traditional techniques currently available (e.g. examination of morphological characteristics) are inadequate and thus, it has been difficult to catch and successfully prosecute the perpetrators of these illegal introductions.

Utilising a molecular approach to detect feral pests. Recently, new molecular approaches have been developed that can be extremely useful for discriminating the origin and population structure of invasive species (Taylor *et al*. 2000; Hampton *et al*. 2004). The processes underlying (re)invasion are important to identify for the management of pest species because any population reduction or localised eradication requires at least a basic knowledge of the population parameters and the dynamics for the species of concern (Spencer and Woolnough 2004). If long-term management strategies are to be successful, it is also important to identify the genetic contribution (e.g. 'fitness') that both past and present pigs (both individuals and populations) have had or continue to have in the maintenance of feral pig populations.

This paper documents the detection of a group of 15 domestic pigs that were 'free-ranging' and consequently had the potential to become, or at least interbreed, with truly feral pigs. The detection of these non-intentional releases, and the ability to determine the origin of illegally translocated wild pigs, will allow for better control (policing) of this highly destructive and invasive species.

Complete DNA profiles ('DNA fingerprints') at 14 variable microsatellite markers were generated for a subset ($n = 6$) of 15 free-ranging pigs that were sampled from the south of Western Australia (approx. location, 34°30′ of illegally-dumped pigs (Spencer and Hampton 2005)), assignment analysis was used to infer the genetic origin of the individuals. Feral and domestic pigs from the south-west of WA have been shown previously to have very different DNA profiles (Hampton *et al*. 2004; Spencer and Hampton 2005) and this allows unambiguous identification of any unknown individual as either of domestic or feral origin.

The complete genotypes of the test subset of six pigs were compared to those of 269 adult feral pigs and a small number of genetically distinct and locally raised commercial pigs of mixed ancestry (Large White and Landrace; $n = 36$; see Hampton *et al*. 2004). DNA fragments were scored manually, with the aid of Genescan (Applied Biosystems, Melbourne). We utilised a Bayesian statistics/clustering procedure to assign individuals to their most likely population of origin using Structure (Version 2.0; see Hampton *et al*. 2004). The results below were based on a burn-in period of 50 000 iterations with 1 000 000 iterations of a Markov chain simulation (Pritchard *et al*. 2000).

Table 1. Estimated genetic contribution (given as a percentages) of each of the eight potential population clusters adapted from Hampton *et al*. (2004). Values in bold indicate the most likely inferred population of origin for each of six suspected domestic pigs collected (sample numbers RG001 to RG006), indicating the strong clustering with domestic pigs (population cluster number 7). These data also show the low genetic contribution (< 2%) from each of the other seven potential clusters in our six pig samples.

Inferred population	Inferred population cluster							
	1	2	3	4	5	6	7	8
Perth Hills	**77.2**	2.0	4.1	2.7	1.1	1.7	6.0	5.3
Serpentine	15.0	**73.6**	3.2	2.6	1.4	1.5	1.4	1.3
Dandalup	9.1	1.4	**68.3**	7.3	1.3	4.3	7.5	1.0
Collie	1.7	1.4	2.2	**71.3**	13.3	5.7	1.0	3.7
Muir	1.0	0.5	1.8	10.6	**81.8**	3.3	0.5	0.5
Denbarker	1.2	0.6	1.1	1.0	1.2	**94.0**	0.6	0.4
Domestic	0.5	0.8	0.7	0.5	0.4	0.7	**95.8**	0.6
Northampton	0.3	0.5	0.4	0.5	0.3	0.5	0.9	**96.6**
Free ranging pig samples								
RG001	0.3	0.4	0.3	0.3	0.4	0.7	**97.1**	0.6
RG002	0.3	1.0	0.4	0.4	0.5	0.9	**95.5**	1.1
RG003	0.2	0.3	0.3	0.2	0.2	0.3	**98.0**	0.4
RG004	0.4	1.0	0.6	0.6	0.5	1.1	**95.3**	0.5
RG005	0.5	0.4	0.4	0.3	0.3	1.9	**94.7**	1.5
RG006	0.4	0.3	0.4	0.3	0.2	1.0	**96.9**	0.5

Using these data, we were able to estimate the genetic contribution of each of the eight predefined inferred groups to the six pigs in question (Table 1). We could identify with high probability that all six individuals were genetically most similar to the domestic/commercial pig sample (mean, 96.3%), compared with less than 2% association with any other of the seven groups we sampled (Table 1). This posterior probability estimate can be interpreted directly as the probability of origin of each individual (Manel *et al*. 2002). No admixture was detected with any feral pig group that we have sampled.

Impact of integrating domestic and feral pig stock. The fact that free-ranging domestic pigs can be in such close proximity to feral pigs (from other genetically different populations) creates an additional complexity in defining the boundaries, and to a degree the independence, of a 'natural' population, and how best to control them. The dynamics of the interaction between released or escaped domestic pigs with feral pigs would be difficult to infer without the evidence provided by the genetic information (Manel *et al*. 2002; Hampton *et al*. 2004). The presence of domestic pigs in a feral population or alternatively, the close proximity of feral pigs to high density farmed stock, will have significant impacts on any exotic disease control strategy and will make control and management actions more difficult. The positive identification of 'domestic-looking' pigs is problematic because feral pigs seem to revert rapidly to the wild phenotype (Choquenot *et al.* 1996). Despite a reasonable amount of anecdotal 'evidence' about the origin of feral pigs, morphological characteristics alone do not provide a good indication of the origin and rate of spread of truly wild pigs (our unpublished data), and until this work, there has been no documentation of any significant domestic stock in feral pigs in Western Australia (Hampton *et al.* 2004).

This study highlights the threat posed by the potential interaction of domestic and feral pig stocks. The existence of such contact may add to the expansion of their range (Saunders & McLeod 1999; Hone 2002) and compromise programs aimed at reducing the threat posed by feral pigs to the ecosystem.

Acknowledgments. The precise location of animals used in this study has not been disclosed for legal reasons, and to protect the identity of the landholder(s) involved. The authors are grateful for comments from an anonymous reviewer; Laurie Twigg and the US Department of Agriculture; and support from the US Pig Genome Coordination Project (Prof. M. Rothschild). This research was generously supported by the WA Department of Conservation and Land Management, Murdoch University and the Department of Agriculture Western Australia.

References

Caley P. (1997). Movements, activity patterns and habitat use of feral pigs (*Sus scrofa*) in a tropical habitat. *Wildlife Research* **24**, 77–87.

Choquenot D., McIlroy J. and Korn T. (1996). *Managing vertebrate pests: Feral Pigs*. Bureau of Resource Sciences, Australian Government Publishing Service.

Hampton J., Spencer P. B. S., Alpers D., Twigg L., Woolnough A. P., Doust J., Higgs T. and Pluske J. (2004). Molecular techniques, wildlife management and the importance of genetic population structure and dispersal: a case study with feral pigs. *Journal of Applied Ecology* **41**, 735–743.

Hone J. (2002). Feral pigs in Namadgi National Park, Australia: dynamics, impacts and management. *Biological Conservation* **105**, 231–242.

Manel S., Berthier P. and Luikart G. (2002). Detecting wildlife poaching: identifying the origin of individuals with Bayesian assignment tests and multilocus genotypes. *Conservation Biology* **16**, 650–659.

McIlroy J. C., Braysher M. and Saunders G. R. (1989). The effectiveness of a warfarin poisoning campaign against feral pigs, *Sus scrofa*, in Namadgi National Park. *Australian Wildlife Research* **16**, 195–202.

Pritchard J. K., Stefens M. and Donnelly P. (2000). Inference of population structure using multilocus genotype data. *Genetics* **155**, 945–959.

Saunders G. and McLeod S. (1999). Predicting home range size from the body mass or population densities of feral pigs, *Sus scrofa* (Artiodactyla: Suidae). *Australian Journal of Ecology* **24**, 538–543.

Spencer P. B. S. and Hampton J. O. (2005). Illegal translocation and genetic structure of feral pigs in Western Australia. *Journal of Wildlife Management*, in press.

Spencer P. B. S. and Woolnough A. P. (2004). Size should matter: Distribution and genetic considerations for pest animal management. *Ecosystem Management & Restoration* **5**, 220–222.

Taylor A. C., Cowan P. E., Fricke B. L. and Cooper D. W. (2000). Genetic analysis of the mating system of the brushtail possum (*Trichosurus vulpecular*) in New Zealand farmland. *Molecular Ecology* **9**, 869–879.

ORGANISATIONS

24.15

Stipa Native Grasses Association (Stipa) is an organisation formed by concerned landholders, along with staff from government agencies involved in natural resource management. It is primarily concerned with the practical aspects of native grasses and their use in agriculture. Stipa's goals are: to promote native grasses (both for their productive and environmental value); hold field days, conferences and forums; produce newsletters and other publications (to enable land holders to understand the production value of native grasses and their ability to repair and prevent land degradation); form networks with other land holder associations; lobby government that grasslands have been overlooked in the repair of land degradation; enlighten conservationists in the regenerative value of native grasslands; and direct research towards a better understanding of native grasslands. For more information: Stipa Native Grasses Assoc., PO Box 500, Gulgong, NSW 2852, Australia.

24.16

Friends of Grasslands (FOG). FOG is a non-profit community volunteer group and its members are made up of many people, including ordinary people interested in conservation, landowners and managers, members of landcare and parkcare groups, professional scientists and ecologists, and private and company agencies. Members come from many parts of Australia and sometimes elsewhere. Goals are to increase community awareness and interest in native grassy ecosystems, promote their ecological importance, contribute to their on-ground conservation, and reverse their decline in area and quality. Membership costs $20 for an individual or family, $5 concession for a student or pensioner, and $50 for corporate bodies. ($30 AU for overseas members to also cover postage.) Contact: Friends of Grasslands, PO Box 987, Civic Square, ACT 2608, Australia. The group can be contacted through their website: http://www.geocities.com/friendsofgrasslands/ or through Communities Online website (www.actco.org.au/friendsofgrasslands/).

WEBSITES & WEBLISTS

25.17

The website of Conservation Management Networks (www.conservation-management-networks.net/mainpage.html) explains the CMN concept and the aims and goals of CMN, linking various groups throughout Australia. Examples of CMN in Australia include the Grassy White Box Woodlands CMN; the Monaro Grassland CMN (see separate abstract); and the Southern Tablelands Grassy Ecosystems CMN (facilitated by the NSW DEC in Queanbeyan. Contact: rainer.rehwinkel@npws.nsw.gov.au).

25.18

Envirotalk's Native Grasslands Meeting Room (http://www.envirotalk.com.au/forum/index.php?showforum=86). This mediated site is a potentially fertile method of exchanging news and views on grassland conservation and restoration, depending on the information received. Items relevant to grassland are posted, including media releases, imminent events and conferences, and recent publications. This is part of the larger Envirotalk site, a not-for-profit Australian online environmental discussion forum.

25.19

The website of the NSW Department of Primary Industries (http://www.agric.nsw.gov.au/reader/grassed-up/gu91.htm) contains an excellent list of research publications on the topic of management and restoration of native grasses prior to 2002. The site could do with expanding, however, to include more recent literature. Other links to summaries of recent research can be found through the AANRO database for agriculture and natural resources research funded by Australian Commonwealth and State Governments (http://www.aanro.net/page/home.html) as well as through the sustainable landscape management research innovations list on the website of Land & Water Australia (http://www.lwa.gov.au).

BOOK REVIEWS

26.22
Coastal-Marine Conservation: Science and Policy.
G. C. Ray and J. McCormick-Ray. (2004). Blackwell Science Ltd, Malden, MA, USA. ISBN 0 632 05537. 5xiv + 327 pages. Price US$69.95.

Conservation is the product of an interaction between scientific knowledge, public interest, political will and management skills. The authors position the coastal realm as a global ecosystem that is heterogeneous, complex and diverse whilst supporting the majority of humanity. They purport that conservation challenges faced in this ecosystem are among the most urgent faced by the world today. This book aims to enhance the reader's understanding of the science and policy behind the processes of coastal marine conservation. The book is divided into four sections: (i) Issues and Mechanisms; (ii) Science; (iii) Case Studies; and (iv) Analysis and Synthesis. In section one, primary conservation issues around the world are defined and discussed; examples include species extinctions and depletions, introduced species, ill health and abnormal behaviour. Secondary issues focussing on human behaviour and the regulation of those activities are reviewed with examples from fisheries and marine-based extractive industries. Physical alterations to the coast and river catchments are also highlighted. Tertiary issues such as algal blooms, anoxic bottom water, and mass mortalities are described as being systematic, chronic and difficult to address. Unfortunately, these difficult issues receive the briefest explanation.

Legislative mechanisms of conservation are explained by reviewing the historical development of conservation legislation. The hierarchy of governance is discussed from an international perspective, demonstrating that national governance is more enforceable than voluntary regional and international agreements.

Ecosystem-based approaches to conservation being used in the USA such as Coastal Zone Management and Integrated Coastal Zone Management are briefly described. More important though are the 'agents of change' – the social and political forces that get the conservation ball rolling. A broad overview gives the reader an insight into the conservation process, both past and present.

The second section discusses the physical and natural history of the coastal realm. Within 66 pages, readers are exposed to topics ranging from plate tectonics to the life cycle of the moon jelly (*Aurelia*). Many paradigms are presented, including concepts of ecosystem stability and equilibrium as well as coastal zonation. As the spatial scale decreases from oceans to bays and shores, the focus shifts from the world to the USA. The natural history of several North American species is used to describe concepts such as top-down control within a western Atlantic salt marsh and oyster beds interacting with water flows and turbulence. Unfortunately, all three case studies in section three – Chesapeake Bay, Bering Sea and the Bahamas – are from the northern hemisphere and border the USA. They are presented individually but have the same basic structure. The history of human influence on the region is outlined and the anthropogenic impacts on commercial or charismatic organisms are presented. Conservation policies are described along with the conflicting goals of business, government, science, indigenous rights and conservation. Few solutions are suggested, and the authors leave readers to develop the way forward.

The last section attempts a synthesis. Conservation through 'ecosystem management' is the obvious message. The concept of 'ecosystem health' is raised, as are the difficulties in defining and measuring it. In assessing ecosystem change, the authors suggest that a 'reference' is required, 'stressors' need to be identified, and the 'change' to the ecosystem then be described. Rightly, the authors highlight that the rapid rate of current change is a primary concern. Examples of fisheries, invasive species, pollutants, and physical alterations are all presented using this 'reference – stressors – change' methodology. The final chapter presents the challenges faced by conservationists. This book is essentially a text for people interested in the history of global and US conservation policy and procedures. By presenting the history of conservation policy and then combining this with the case studies the reader is able to glean a good understanding of the issues faced when attempting to conserve a large habitat or ecosystem. The science presented would give undergraduate students a platform for discussion and a starting point for further research. This appears to have been the authors' aim so they must be commended for that. The authors could have expanded on methods of achieving compliance with conservation legislation. This is an area where governments will expend significant resources in the future if they are to seriously protect the world's marine environments.

Review by James Webley (School of Environmental and Applied Sciences, Griffith University – Gold Coast Campus, PMB 50 GCMC, Bundall, Queensland 9726, Australia. Email: j.webley@griffith.edu.au).