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The 'making of' the Mulligans Flat – Goorooyarroo experimental restoration project

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What happens when park managers and ecological researchers join forces to build an evidence-based approach to restoring a nature reserve? This project shows how a spirit of cooperation and inventiveness overcome a range of challenges at one of the National Capital region's most valuable examples of critically endangered box-gum grassy woodland.

Key words: *box-gum grassy woodlands,* Eucalyptus blakelyi, Eucalyptus melliodora, *evidence-based conservation, feral animal-proof fence, Mulligans Flat – Goorooyarroo Woodland Experiment.*

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Figure 1. The Mulligans Flat (from mid ground to base of hills) and Goorooyarroo (foreground) landscape.

Introduction

The Mulligans Flat – Goorooyarroo Woodland Experiment, on the outskirts of Canberra, Australia's capital, integrates a restoration project with research in a highly accessible way. This carefully designed project aims to restore an important area of critically endangered grassy box-gum woodland degraded by about 150 years of livestock and rabbit grazing, and more recent overgrazing by the native eastern grey kangaroo (*Macropus giganteus*). Because the project also provides an opportunity for gaining insight into the efficacy of a range of restoration techniques, and answering some interesting theoretical questions, the treatments were designed experimentally to provide insight into both practice and theory.

The project is now well established, with the collection of baseline data and implementation of different restoration treatments completed. While there has been some formal publication of the experiment's design and initial results (McIntyre *et al.* 2010; Manning *et al.* 2011), this feature aims

to tell the story of how the project was set up as a partnership between ACT Government researchers, ACT Government land managers and university researchers, and how the opportunities and challenges of some of the project's more practical aspects were met. These practical aspects include the establishment of feral animal and kangaroo exclusion fencing, introduction of woody debris and fire treatments and feral animal removal. Cooperative interactions between researchers, government land management staff and the neighbouring residents are highlighted, showing how this 'outdoor laboratory' for ecological restoration research will also function as a site for community learning in coming years.

The sites and management challenges

Two adjacent nature reserves – Mulligans Flat and Goorooyarroo Nature Reserves (hereafter referred to as MFG reserves) in north-eastern ACT – together total 1623 ha and contain 1146 ha of Yellow Box – Blakely's Red Gum Grassy Woodland (Box 1) (Manning *et al.* 2011), some of the largest protected areas of Yellow Box – Blakely's Red Gum Grassy Woodland in the National Capital region (ACT Government 2004, Figs 1 and 2). The MFG reserves are significant in the ACT in that they include some of the lower hill slopes that would usually be used for suburb construction.

Like much of what remains of this now critically endangered ecological community (Department of Environment and Heritage 2006), the two reserves required restoration interventions to ensure their long-term

Box 1. Pre-existing plant community and condition prior to treatment

The study site was once leasehold grazing land, with some areas of past cropping and pasture improvement. Box-gum grassy woodland – dominated by Blakely's Red Gum (*Eucalyptus blakelyi*) and Yellow Box (*E. melliodora*) and containing patches of naturally treeless grassland – dominate the lower slopes, while the upper slopes are covered with forests of Red Stringybark (*E. macrorhyncha*), Scribbly Gum (*E. rossii*) and Brittle Gum (*E. mannifera*). This combination of grassland, woodland and forest is largely reflective of what would have existed in 1788, although in comparison, there are probably now fewer mature trees and a much higher density of sapling and pole stage eucalypts (Gammage 2011).

We can only speculate on the nature of the understory vegetation in 1788 and the impacts of the domestic livestock that were introduced shortly thereafter. Sheep are likely to have maintained grazing pressure on palatable leguminous shrubs and contributed to grass dominance. Their removal prior to the commencement of the experiment does not seem to have significantly reduced grazing pressure, and at the time of the first vegetation survey in 2007 (before the treatments were established), drought conditions and high macropod densities meant that ground cover biomass averaged 570 kg/ha across the reserves. While this grazing pressure was higher than recommended even under commercial grazing (McIntyre *et al.* 2010), the soil was stabilized by litter, plant basal area and lichens. Only 13% of the ground was bare, and much of this, while previously eroded was stable (Fig. 3a). This suggests that recovery of infiltration and nutrient cycling processes may be more important to recovery in coming years than stabilization of the soil, although with heavy rainfall, there has been evidence of overland flow transporting large quantities of litter from the system.

In our baseline survey in 2007, above-ground biomass of ground-layer vegetation was highest where the native Red-anther Wallaby Grass (*Joycea pallida*) dominated the poorer soils on the slopes. This tough grass is relatively unpalatable to herbivores and plays a critical role in maintaining sward structure in times of drought (Fig. 3b; McIntyre *et al.* 2010). Past fertilizer use was evident from sites having higher nitrate and available phosphorus levels; these sites were dominated by exotic species, particularly Phalaris (*Phalaris aquatica*) and the species of native Wallaby Grasses (*Austrodanthonia*) that are more tolerant of high nutrients. Although a diversity of exotic species occurred at all sites, dominance of native grassy woodland grasses and herbs (approximately 90% of the total biomass) was high at the beginning of the experiment, reflecting the value of the area as a nature reserve.

The site also contained many potentially dominating weed species including Serrated Tussock (*Nasella tricotoma*) and Sweet Briar (*Rosa rubiginosa*) that are systematically controlled by park managers. There is a range of other smaller invasive species including Catsear (*Hypochoeris* spp.), Clovers (*Trifolium* spp.), Shivery Grass (*Briza* spp.) and Centuary (*Centaurium* spp.); all of which persist under low levels of available phosphorus (Dorrough *et al.* 2011) but for which there are no practical means of control. A full description of the ground-layer vegetation at the commencement of the experiment is given in McIntyre *et al.* (2010).

In the long term, the criteria for improved condition of the ground-layer vegetation would be reductions in the biomass of exotic species and increased diversity of native species and increases in the biomass of grazing-sensitive native shrubs, grasses and forbs (e.g. see Table 1 in Dorrough *et al.* 2011). The kangaroo density and burning treatments are likely to be of particular importance to ground-layer condition.

ecological health. At the commencement of the project, they presented a range of management challenges that are typical of grassy woodlands in south-eastern Australia's agricultural zones. That is, a previous history (since the mid-19th century) of livestock grazing, patch cropping, pasture improvement and removal of timber for fencing, firewood and reducing rabbit harbour has altered soil condition, contributed to species extinctions, changed vegetation structure, introduced weeds and allowed development of eroded water courses.

Since the land was resumed, initially for urban development purposes, populations of eastern grey kangaroo have risen because of habitat changes, establishment of protected areas and reduced culling by former rural landholders (ACT Government 2010). This has hampered native plant recovery that might have been expected after the removal of livestock by maintaining overall total grazing pressure, particularly in the context of recent extended droughts (Box 1) (Howland 2008, unpublished data; McIntyre *et al.* 2010). The accumulated effects of introduced predators (primarily foxes) and loss of deadwood have also reduced suitability of habitats for fauna and led to significant and ongoing wildlife population decline and, in some cases, local extinction (Box 2). In particular, some pre-existing species of small mammals, which could be key to ecosystem functioning, are now locally extinct (Ford & Manning in prep). Such challenges require effective solutions if the conservation management goals of protected areas are to be met.

Context for establishment of the project

The first step in conserving these areas was undertaken when Mulligans Flat was established as a nature reserve in 1994, after a major campaign by community groups. Protection for Goorooyarroo was announced in 2003, following a reassessment by the ACT Government of its conservation priorities in the face of new residential development (Fig. 2; ACT Government 2004, p. 99). This reflected a shift in the National Capital Open Space System from reserving hills and ridges as a backdrop for the city, to greater consideration of nature conservation and threatened species and communities.

A further step was taken in 2002, when the ACT Government gave new impetus to its general responsibility for nature conservation by initiating a review of strategies and actions directed at conservation of the ACT's threatened species and ecological communities. This review generated a new series of Action Plans required under ACT legislation to be prepared for each listed species, community or threatening process. The first of these plans 'Woodlands for Wildlife: ACT Lowland Woodland Conservation Strategy Action Plan No. 27' (ACT Government 2004) covered Yellow Box-Red Gum Grassy Woodland (listed as endangered), ten threatened plant and animal species associated with lowland woodlands generally, and the threats that needed to be managed as part of a conservation strategy.

Action Plan No. 27 identified priority actions for government agencies, community groups and private interests to adopt. These included proposals for expanding the ACT's nature reserve system by adding high conservation value woodlands, improving connectivity for wildlife movement in and through the ACT, additional surveys to improve knowledge about woodland understorey and habitats, and assisting landholders to adopt best practice and adaptive management of woodlands. The latter action (best practice management) implied that access to knowledge and/or practical experience would be critical to improved woodland management, and in this context, promote woodland biodiversity and healthy ecosystem function (ACT Government 2004, p. 75).

The Mulligans Flat – Goorooyarroo Woodland Experiment arose directly in response to Action Plan No. 27's list

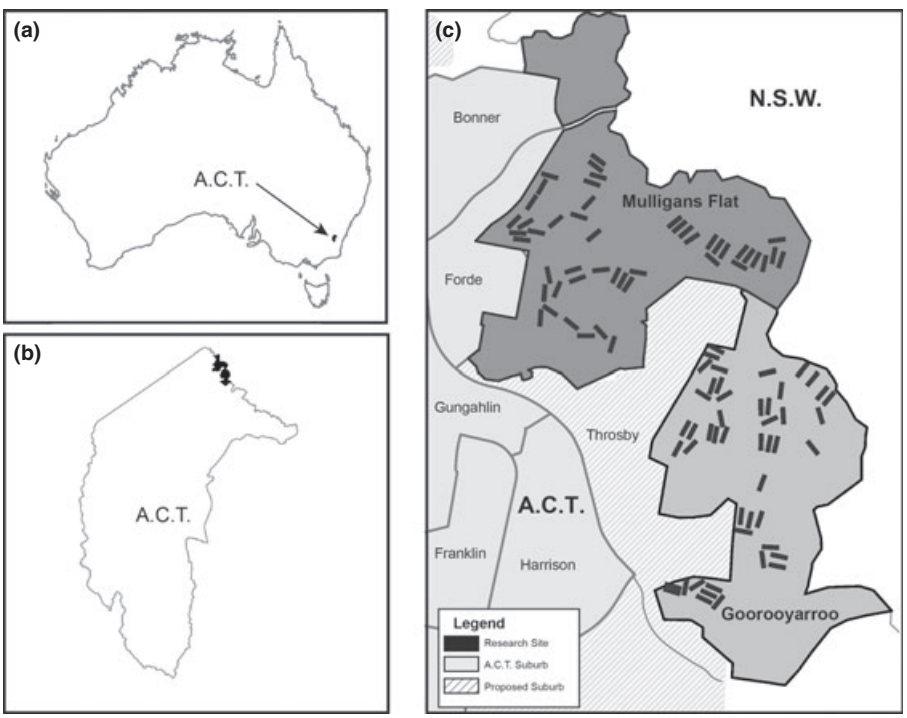

Figure 2. The location of Mulligans Flat and Goorooyarroo Nature Reserves in north-eastern Australian Capital Territory (ACT). (a) The ACT within Australia. (b) The reserves within the ACT and (c) the experimental 1 ha sites within both reserves.

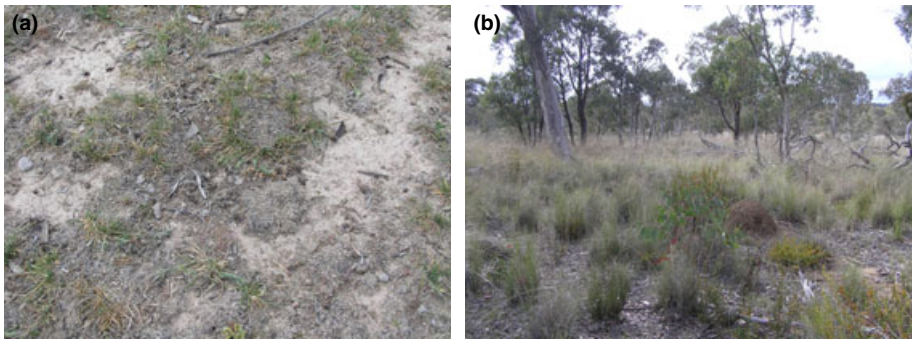

Figure 3. (a) Grazing pressure on the more fertile soils was extremely high during the 2007 survey, resulting in low biomass (in this case *Austrodanthonia* spp.). Past and present grazing has created areas of bare, eroded but stable, B horizon. Rainfall infiltration is low under these conditions allowing organic matter to be transported large distances with overland water flows (Photograph by Sue McIntyre). (b) The native *Joycea pallida* dominated the less fertile, more acidic soils in the reserves and provided soil protection and habitat for ground fauna on the hills and slopes, even during severe drought (Photograph by Sue McIntyre).

of actions for the management of woodlands: 'Promoting research into conservation management of Lowland Woodland' and its corresponding performance criterion: 'Research and monitoring are undertaken and the results used to inform managers of measures to improve ecological condition and habitat qualities' (ACT Government 2004) (p 87).

At the same time, researchers working with the Fenner School of Environment and Society at the ANU were looking for sites to undertake applied management trials, and the MFG reserves site was soon recognized as an ideal location to establish an

Box 2. Threats to fauna and outline of fauna monitoring

The decline of small mammal and many bird species in Australia is well known (see Manning *et al.* 2011 for references). In the Canberra region, many species persist, but others have declined. For example, once common Brown Treecreepers (*Climacteris picumnus)* are now rare and Bush Stone Curlews (*Burhinus grallarius*) are locally extinct. The faunal group that has suffered most is small native mammals. This is part of a much broader pattern of extinction in Australia, driven by introduced predators such as foxes *Vulpes vulpes* and cats *Felis catus,* competition from domestic livestock and introduced rabbits *Oryctolagus cuniculus* and hares *Lepus europaeus*, direct eradication by human, plus overgrazing by native fauna, habitat loss and modification, and altered fire regimes (Morton 1990; Short & Smith 1994; Smith & Quin 1996; Short 1998). As a result, the Canberra region has lost many formerly widespread woodland small mammals (see below).

To monitor the outcomes of the project for fauna, we are currently tracking the response of a range of taxonomic groups. These groups are as follows: (1) birds, (2) small mammals, (3) reptiles and (4) invertebrates. Birds are surveyed annually in spring with the help of expert bird observers from the Canberra Ornithologists Group. Involvement of expert volunteers has been critical to surveying 192 survey points rapidly and efficiently. Small mammals are surveyed twice a year using tracking tunnels, which record presence of animals that leave footprints (Fig. 4). Reptiles are surveyed in late summer (so that both adults and young reptiles from the preceding year are counted) using eight experienced observers to actively search 961 ha sites. Invertebrates have been sampled at various intervals using small 'pitfall' traps. A CSIRO-funded PhD student was appointed to investigate invertebrates in detail. To date, we have found that small mammals and reptile numbers to be very low, reptile abundance and richness is low and some once abundant woodland bird species are absent or in low numbers (Manning *et al.* 2011). This suggests that, while in relative terms, this box-gum grassy woodland is in good condition (compared with many former woodland areas), it has lost a significant amount of the abundance and diversity of fauna. After only a few years, we have detected significant effects of the coarse woody debris and kangaroo exclusion treatments on invertebrates and reptiles (Barton *et al.* 2011; Manning *et al.* In review).

Some locally extinct species will be unable to return unaided. Therefore, a major task of the experiment and Sanctuary (Box 4) is the re-introduction of locally extinct species (Box 4). We began this process by undertaking a systematic review of what species are likely to have inhabited the woodlands ACT (Ford & Manning in prep). We then selected a shortlist of priority species: Bush Stone Curlew, Southern Brown Bandicoot (*Isoodon obesulus*), Eastern Bettong (*Bettongia gaimardi*) and New Holland Mouse (*Pseudomys novaehollandiae*). This includes two species (the bettong and the bandicoot) that are 'ecosystem engineers' that are likely to help the restore soil-related functions. The Eastern Bettong (Fig. 5a) was chosen as the top priority, because of its digging of soil to find fungi (which, has effects that can include improving soil conditions, encouraging water infiltration and spreading beneficial fungal spores; Fig. 5b) and because it is currently totally absent from the wild on the mainland. Its re-introduction is now the subject of a major research grant (LP110100126).

Figure 4. Placing of footprint tracking tunnels to detect small mammals (Photograph by Adrian Manning).

Figure 5. (a) An Tasmanian or 'Eastern' Bettong (*Bettongia gaimardi*), a species known to have occurred in the district prior to the development of the ACT. Translocation of 60 bettongs from Tasmania will provide the founders for the re-introduction. (b) Bettongs are 'ecosystem engineers' that disturb the soil while digging for fungi. In this photograph, a digging can be seen with seedlings germinating on the loose soil, in this way they could affect vegetation community dynamics (Photographs by Adrian Manning).

'outdoor laboratory' in partnership with the landholder, the ACT Government.

Making the Case for Funding and Formation of Partnerships

An ACT Government examination of policies for managing eastern grey kangaroos in the ACT (ACT Kangaroo Advisory Committee 1996a,b, 1997) recommended that management of kangaroos should be based on sound scientific method and that management policies would benefit from external scientific advice. While evidence-based conservation management was not an entirely new practice to ACT land managers, adoption of these recommendations by the ACT Government and its land management agency (ACT Parks and Conservation Service) led to broader appreciation of the value of evidence-based management policies and practices for other natural resource management issues. The supportive policy context and increasing recognition of the need for evidence-based conservation provided the ideal conditions for establishing the research partnership. On-ground staff were acutely aware that the new reserves were suffering from the impacts of overabundant kangaroos, predation by foxes and cats, and encroaching suburban development.

In 2004, the Research and Monitoring Unit at Environment ACT (now Conservation Planning and Research within the Environment and Sustainable Development Directorate) secured additional ACT Government funding for threatened species and woodland conservation. With this new commitment to funding research, the Research and Monitoring Unit approached the Australian National University regarding establishing a research partnership that would be focused on learning what was needed to restore the woodland reserves to a condition that was closer to that prevailing before development of the National Capital (see Box 1 and Box 3). Previous links with the university researchers demonstrated to field staff, who were largely unfamiliar with involvement in a long-term experimental approach to ecological restoration, that there was genuine academic interest in generating evidence-based and practical techniques. They recognized that there was a real opportunity for them to improve the conservation values of the woodlands under their management, using measures beyond, and in addition to, traditional approaches (e.g. weed, rabbit and kangaroo control).

As the potential for the research/management partnership developed, political support became more apparent in the form of a direct interest in woodland conservation from the ACT Chief Minister, who was also the Minister responsible for land management. As each party developed a stake in the partnership proposal, government research and field staff became more optimistic that tangible senior management and political support was growing and, in turn, this helped generate commitment and enthusiasm about their involvement in a project that was outside their normal responsibilities and experience (Box 3).

Experimental Treatments on the Sites

The overarching aim of both research and management for this project is to improve conditions for native wildlife, reverse declines and, where locally extinct, encourage re-colonization by natural means or by re-introduction. It was recognized that a systematic trialling of a range of treatments within an experimental framework could provide insights into cause and effect (Manning *et al.* 2011). These would be important in the future for improving the capacity to identify and refine management approaches for this and other similar sites.

The design of the experiment and associated monitoring is described in

Box 3. Cooperative long-term partnership between the ACT Government and the Australian National University

The need to identify appropriate restoration management actions for the reserves and other similar sites, coupled with the commitment of researchers to research questions that would make a difference on the ground, led to a natural partnership between the ACT Government, the Fenner School of Environment and Society of the ANU and the CSIRO. Funding was obtained through an Australian Research Council Linkage Grant (LP0561817) – a scheme designed to foster genuine collaboration between Universities and 'Industry Partners' (in this case the ACT Government's land management and conservation agencies). CSIRO obtained separate funding through the Australian Government's Natural Heritage Trust and Caring for our Country programmes (and later joined in the second major ARC grant LP110100126).

The major contributions to the partnership came from (i) the Fenner School that provides research expertise, in-kind contribution of staff time and accommodation for researchers; and (ii) the ACT Government, specifically the ACT Parks and Conservation Service and Research and Monitoring Unit (now Conservation Planning and Research), which provides a secure, long-term site (MFG reserves), cash and in-kind contributions (including logistic support for sourcing and distributing deadwood, fencing, control of existing feral animals), and extensive knowledge of the site and research relating to the ACT environment.

The MFG reserves contain some of the best and largest examples of critically endangered Yellow Box-Blakely's Red Gum Grassy Woodland managed primarily for nature conservation in south-eastern Australia and are one of the few places where an array of management regimes (and their interactions) can be investigated in a comprehensive manner. Key features associated with the reserves include availability of extensive fine-scale mapping data of vegetation cover, structure and past management history from ACT Government databases and records; one long-term owner and land manager – the ACT Government; very strong support from the management agency for the MFG reserves (ACT Parks and Conservation Service) for this project, particularly the implementation of experimental treatments (from Manning *et al.* 2011).

In addition, the MFG reserves are situated near a large and growing centre of population of Canberra (especially Gungahlin), and universities and research institutions, which means they are especially suitable as an 'outdoor laboratory' for research, teaching and learning at all levels and can draw upon the presence of a well-educated local community and special interest groups that actively support woodland conservation and restoration activities.

Manning *et al.* (2011). In brief, 24 areas of vegetation were identified, within which four 1 ha 'sites' were placed. These 96 sites (Fig. 2) are subjected to a range of management treatments and contain 'plots' where the monitoring is undertaken.

The Mulligans Flat feral animal-proof fence, constructed as part of the project, protects 485 ha or 63.4% of the reserve (Fig. 6; ACT Government 2009) and will allow the managed re-introduction of locally extinct species of animals (see Boxes 2 and 4). It is anticipated that some of the lost species will have effects on the ecosystem including changes in soil structure, water infiltration, nutrient cycling and flora and fauna communities. These effects may interact with the experimental treatments in interesting ways and have significant implications for conservation management (Box 2).

Rationale for treatments

The experimental treatments were chosen to address several important restoration issues for the MFG reserves. The experimental treatments are as follows: (1) exclusion of kangaroo grazing, (2) addition of deadwood, (3) prescribed burning (Goorooyarroo only) and, recently a fifth treatment has been added: the exclusion of bettong digging in Mulligans Flat. Varied tree and shrub densities are also used as a treatment for data analysis purposes.

1 Kangaroos are an important component of box-gum grassy ecosystems. However, in recent years, kangaroo densities in the ACT have become very high by national standards (ACT Kangaroo Advisory Committee 1997; Howland 2008, unpublished data; ACT Government 2010), with significant effects on biodiversity in the MFG reserves (McIntyre *et al.* 2010; Barton *et al.* 2011; Manning *et al.* In review). This occurs through grazing causing a reduction in biomass (which affects food and shelter availability for fauna) and alteration of moisture retention, nutrient cycling, plant community structure and composition (Manning *et al.* 2011). Examining experimentally whether excluding kangaroos with fencing (see Supplementary Information, Data S1 for fence design) could improve biodiversity was an important question for managers, and relates to the recommendations of the Kangaroo Advisory Committee.

2 Dead standing and fallen timber is critical to woody ecosystems globally (Harmon *et al.* 1986). It has a vital role in nutrient cycling and storage, soil formation and retention, retention of moisture and enhances water infiltration, accumulates litter and encourages

Figure 6. The feral animal-proof fence is based on the design from Arid Recovery, but was adapted by ACT Parks and Conservation Service for local conditions. The 11.5-km fence costs $1.3 million and encloses 485 hectares (Photograph by Adrian Manning).

fungi growth, provides shelter and a foraging substrate for animals and nursery sites for plants (Harmon *et al.* 1986; Lindenmayer *et al.* 1999, 2002; Debeljak 2006; Opdam *et al.* 2006). However, as European settlement occurred, deadwood has been lost or greatly diminished from most box-gum grassy woodlands, with consequent effects on biodiversity (Driscoll *et al.* 2000; Manning *et al.* 2007; Gibbons *et al.* 2008; Weinberg *et al.* 2011), it was therefore considered important to examine whether adding deadwood could reverse declines in dependent species.

3 Fire is a critical ecological process in Australian temperate woodlands, yet limited research has been conducted on fire in this ecosystem type (Hobbs 2002; Prober *et al.* 2004). Fires can assist nutrient recycling, promote regeneration of some plant species, reduce the dominance of others and contribute to the maintenance of species richness in the ground and understorey layers (Prober *et al.* 2002). Re-introducing fire in an experimental framework is an important part of ecologically transitioning of the site from livestock grazing to conservation management. Fire is also used as a tool to reduce biomass and protect property. It was clear to the ACT Government that there was likely to be an increasing need to undertake prescribed burns in reserves as new suburbs developed in adjacent areas (Fig. 2c). Managers were therefore interested in understanding what effects burning would have on animals and plants, with the aim of developing approaches that protect property and conservation values.

4 Bettongs – Many locally extinct small-to-medium-sized mammals played a significant role in ecosystem function through digging soil for fungi and truffles, and thereby improving soil conditions and water infiltration and modifying, maintaining or creating habitat for other organisms – often called 'ecosystem engineers' (Jones *et al.* 1994)). This in turn would have affected plant communities. Rat kangaroos (bettongs and potoroos) were once highly abundant in the woodlands and forests of the area that became Canberra (Gillespie 1992; Short 1998), however, by the early 1900s were locally extinct (Short 1998). It is likely that their loss had a profound negative effect on the functioning of box-gum grassy woodlands. However, they became extinct on the Australian mainland so long ago, their loss is not listed as a threatened species under ACT or Commonwealth legislation (ACT Government 2004; Department of Environment and Heritage 2006). It was clear to the experimental partnership that this was a major gap in our management knowledge, and this led naturally to the idea of building the sanctuary (Box 4) and re-introducing a lost ecosystem engineer (the Eastern Bettong) (Fig. 5) (Box 2). The exclusion of the effects of Eastern Bettongs from some of the treatment sites using small fences will help us quantify the effect of returning Eastern Bettongs to box-gum grassy woodlands (Supplementary Information, Data S3).

How were treatments implemented?

Dead wood

A total of 2000 tonnes of logs was required for the experimental treatments. There were four different types of treatment: no logs, 20 tonnes/ha in a dispersed pattern, 20 tonnes/ha in a clumped pattern and 40 tonnes/ha with a mix of clumped and dispersed (see Manning *et al.* 2011 for full details). This was a major undertaking and was only possible with the skills and enthusiasm of ranger staff – aided by their close relationship with other parts of the ACT's land management agency. This illustrates the strength of the collaborative approach, because major logistical activities are generally beyond the scope of universities and research organizations. Sourcing and moving this quantity of deadwood was a significant logistical exercise. Sources of significant quantities of deadwood were from an ACT Government programme of street tree renewal and logs stock-piled from trees felled for fire safety reasons along roads outside the city. A forestry forwarder was used to distribute logs to

Figure 7. A forestry forwarder was used to place logs onto experimental sites. The specialist procurement skills of ACT Parks and Conservation staff were essential to the organization of logistics for this treatment (Photograph by Adrian Manning).

Figure 8. A kangaroo exclusion fence added to an existing cattle fence. The contrast between outside (left) and inside (right) in terms of grass growth can clearly be seen. The design was developed by ACT Parks and Conservation staff (see Supplementary Information, Data S1 for diagrams). (Photograph by Jenny Newport).

experimental sites (Fig. 7). This was organized by ACT Parks and Conservation Service staff using their experience in government procurement procedures and funding from an ARC Linkage grant (Box 3).

Kangaroo exclusion

Exclosures were established around half (48) of the sites (24 sites in each of MFG reserves) to significantly reduce the number of kangaroos inside the exclosures compared with the areas outside the exclosures. Two types of fences were built: (i) by raising the height of existing fences (in Goorooyarroo; Fig. 8) and (ii) completely new exclusion fences (in Mulligans Flat) (see Supplementary Information, Data S1). Fences were built by ACT Government staff, Conservation Volunteers Australia (http://www.conservationvolunteers.com.au) and a fencing contractor. The fences were not designed to completely exclude kangaroos, and therefore, it is necessary for ACT Parks and Conservation Service staff to herd excess kangaroos out of the exclosures from time to time.

Fire

Fire was applied to nearly half of the 48 sites in Goorooyarroo. The fire treatment was implemented in May 2011. Until then, there had been insufficient fuel in the ground layer to justify burning. Factors reducing biomass included kangaroo grazing (Box 1) (Howland 2008, unpublished data; McIntyre *et al.* 2010) and the prolonged drought. For reserve staff, burning the sites demonstrated the tension between their primary responsibility for protecting conservation values (i.e. not burning), conducting research into ecological effects of deliberate burning and asset protection. Support for implementing the burn treatment came from the 'Research Management Committee' (which oversees research within the two reserves), comprising key research stakeholders and government staff, and from Conservation Planning and Research, who together provided advice and evidence for the implementation of the burns by government staff.

The logistical input from the Parks and Conservation Service was significant when establishing the burn treatment (Fig. 9). Over 130 staff days were used, with the Fire Unit and the Service's vegetation ecologist provided strong support. Bringing so many staff to Goorooyarroo for the first time generated enthusiasm across the Service for woodland research.

Feral Animal-Proof Fence

Fence design and adaptive construction

The feral animal-proof fence is 11.5 km long and encloses approximately 485 ha of Mulligans Flat Nature Reserve. It traverses a variety of landforms including undulating open and closed grassy woodlands, steep gradients that link the forest vegetation along the ACT/NSW border to the lower woodlands and some seasonally wetter areas associated with the main drainage channels. The fence avoids significant patches of woodland

Figure 9. (a) Organization of prescribed burning of experimental sites was a significant logistical exercise, requiring levels of planning and precision burning that are not usually required. At the start of each burn, a detailed briefing, including explanation of the experiment and its aims, was given. (b) A relocated log being scorched during the prescribed burn. This illustrates how treatments can interact, for example, some highly mobile beetles are attracted to logs that have recently been burned. (Photographs by Adrian Manning).

species and required removal of <0.3 ha of native trees and shrubs.

The design of the fence (Fig. 6; see Supplementary Information, Data S2) was based on similar fences (e.g. Arid Recovery in South Australia, Moseby & Read 2006) with significant modifications developed by staff of the ACT Parks and Conservation Service that included the fencing experience of rangers in ACT reserves and consultation with local fencing contractors. The fence is 1.8 m high with seven plain wires supporting rabbit mesh (30 mm), two electric wires, a 60 cm 'floppy overhang' and with trenched/buried netting for a width of 45 cm on either side of the centre of the fence (see Supplementary Information, Data S2). The fence 'corridor' is approximately 10-m wide and largely follows constructed trails so that environmental and costing issues associated with future management access around the fence were minimized or contained.

Hindrance of natural movement of kangaroos and other fauna across Mulligans Flat and Goorooyarroo was a consideration in its design and location. To ameliorate this potential impact, the fence was constructed well within the existing boundary of the Reserve, providing space for movement of wildlife (e.g. kangaroos, wombats, echidnas) that may be affected by a physical barrier and less hospitable (urban and rural) habitats outside the nature reserve. Standard rabbit-proof mesh can let young rabbits through. Therefore, a smaller-size mesh (30 mm) was used along the base to minimize this.

A series of self-closing gates along the entire length of the fence allows for routine and emergency vehicle and/or visitor access and were designed by staff to maintain the integrity of the barrier to predators. These are monitored by a remote telemetry system. Routine checking of the closing mechanisms is incorporated into the fence checking routines. The feral animal-proof fence allowed the creation of the Sanctuary. This is managed by an independent Trust and Board of Management (Box 4).

Pest management within the fence

Management of feral animals (primarily foxes, cats, rabbits and hares) is part of the normal operational responsibilities of the ACT Parks and Conservation Service. However, in the case of Mulligans Flat Nature Reserve, there is an additional requirement to eliminate (ultimately) these species from the Sanctuary. As part of its preparation for managing the Sanctuary, the Service approached the Invasive Animals Cooperative Research Centre (CRC), which is based at the University of Canberra, for assistance to prepare a Pest and Over-abundant Species Management Strategy (Pest Management Strategy). The aim for that strategy:

> Minimize and where possible eradicate the fox, feral cat and wild dog and their predation impacts on native wildlife and impacts of feral and over-abundant herbivores in conserving the natural habitat within the Mulligans Flat Woodland Sanctuary.

Several guiding principles and a range of challenges governed pest management actions namely: ensuring that all pests are treated humanely throughout control and management programmes in accordance with model codes of practice and standard operating procedures; working cooperatively with rural neighbours and urban residents; ensuring community consultation and support for the removal of feral animals from the Sanctuary; and ensuring the safety of all Parks, Conservation and Land staff, contractors, volunteers and users during pest and feral animal control and management operations.

As a result of actions prior to the establishment of the Sanctuary project, Mulligans Flat Nature Reserve had already been approved as a trial site for the CRC's new toxin for foxes (PAPP). The Service worked closely with the CRC and has removed all foxes, cats and wild dogs. The Sanctuary may develop into one of the CRC's demonstration sites, which are located around the country to demonstrate to land managers and others the products of the CRC. Effort to reduce fox populations in land adjacent to Mulligans Flat has been increased to provide a buffer for the Sanctuary where these pests have been eliminated.

Measures to control rabbits and hares include ripping of warrens (for rabbits), poisoning, introduction of calicivirus and shooting. As part of the initial establishment phase of the Sanctuary, warren ripping and poisoning were applied.

Relations with the Surrounding Urban Area

The ACT community has a strong sense of 'ownership' of ACT nature reserves and other open spaces. About

a third of all nature reserves have a ParkCare, 'Friends of' or other volunteer group associated with them (ACT Commissioner for Sustainability and the Environment 2011). Members of these groups meet regularly and work in partnership with the ACT Parks and Conservation Service with on-the-ground assistance in the form of activities such as weeding, planting and monitoring the condition of their local area. As new nature reserves are

Box 4. Foundation of a fenced Woodland Sanctuary

The idea of a feral animal-proof fence around most of Mulligans Flat Nature Reserve was first raised in the original campaign for its reservation (Lindenmayer 1992). Moves to make this a reality developed quickly following a joint Australian National University–ACT Parks and Conservation Service visit in 2006 to the Arid Recovery (http://www.aridrecovery.org.au) at Roxby Downs in South Australia. The proposal was quickly recognized as having great potential to support the ACT Government's commitment to woodland conservation and to support a move beyond 'business-as-usual' approaches. Within the context of significant urban development proposed for its western and southern edge, it was also realized that an opportunity existed to create a nationally significant, community-led conservation project where research and learning could be integral to the restoration process, with a potential to act as a catalyst for ambitious conservation thinking, and the establishment of similar restoration projects elsewhere in south-eastern Australia.

The ACT Government convened a Steering Committee comprising government and nongovernment members. The Steering Committee then established a Species Management Panel comprising wildlife experts to advice on the re-introduction and management of faunal populations. The Steering Committee officially became the Mulligans Flat Woodland Sanctuary Board of Management in 2011 and shares management control of the Sanctuary via a Service Level Agreement with the ACT Parks and Conservation Service. Fence design and route selection, drawing on the experience of the Arid Recovery and of ACT Parks and Conservation Service rangers, quickly followed, to be supplemented by environmental, cultural heritage and visual assessments and preparation of a Development Application to the ACT Planning and Land Authority. A section of demonstration fence allowed testing of construction methods and materials and served as a 'taste' of what would be delivered by the whole project. The demonstration fence was also important in assisting to secure support for the project and re-assuring stakeholders of its viability, practicality and potential.

In September 2008, a workshop was held that brought together people with experience from other sanctuaries: Arid Recovery, Karori Sanctuary (now called Zealandia, http://www.visitzealandia.com), Maungatautari and Ecological Island (http://www.maungatrust.org) in New Zealand, and the Australian Wildlife Conservancy). Relevant research agencies (CSIRO, Invasive Animals Cooperative Research Centre, Australian National University) and community representatives attended. The workshop provided an opportunity for key people and organizations to meet and for knowledge transfer from experienced sanctuary managers to ACT land managers, rangers and the Steering Committee. A discussion on the unique challenges, pitfalls and risks associated with the Sanctuary being developed at Mulligans Flat was critically important to future management decisions. The expert visitors were also interviewed on local radio, along with the Senior Ranger at Mulligans Flat, which helped start the process of publicizing the plans for the new Sanctuary.

These preparatory steps, involving assessments, knowledge sharing and drawing upon a wide range of expertise, resulted in significant and beneficial changes to the eventual route of the fence, its design and construction. The addition of emergency exit gates (required by ACT Emergency Services in case of bush fire) and electronic telemetry resulted in cost increases that required additional commitment by the ACT Government.

With all preparations completed, construction of the fence commenced in November 2008, and on 10 June 2009, the main gate to the Mulligans Flat Woodland Sanctuary was officially 'closed' at a ceremony conducted by the ACT Chief Minister, Jon Stanhope MLA. At the time Mr Stanhope said that 'Eventually we hope to reintroduce native species not seen in the area for over 50 years'. The completed fence is 11.5 km long, encloses 485 ha of Mulligans Flat Nature Reserve and was delivered at a capital cost of $1.3 million. The website for the Sanctuary is http://www.mulligansflat.org.au

The Chief Minister also initiated development work for a Capital Woodlands and Wetlands Conservation Trust, which is a new model for planning and management of the Mulligans Flat Woodland Sanctuary, and another significant ACT conservation area, the Jerrabomberra Wetlands Nature Reserve (ACT Government 2011). The Trust was formally established in November 2011 and will invite partnerships with the business community and drive innovation in protected area management. The Chairs of the two Boards of Management (for Mulligans Flat Woodland Sanctuary and Jerrabomberra Wetlands Nature Reserve) are members of the Trust. Accessing community and philanthropic support for conservation is a new initiative for the ACT and which will drive support for projects that are above and beyond the standard 'duty of care' responsibility of government for nature reserves such as at Mulligans Flat.

established or new suburbs developed near to natural areas, groups of residents have taken the opportunity to develop partnership arrangements with the Parks and Conservation Service, often through the Service's ParkCare coordinator.

In the case of MFG reserves, residents began to populate the new adjacent suburbs of Forde from 2009 and later Bonner (Fig. 2c). A 'Friends of Mulligans Flat' group was established in late 2011 with the encouragement of the new Board of Management for the Mulligans Flat Woodland Sanctuary [formal successor to the Steering Committee (Box 4)] and the ACT Parks and Conservation Service (see Fig. 10). Park Rangers keep members of the group informed via Google groups (http://groups.google.com/group/mulligans-friends). It is envisaged that in time, suitably trained members will be able to assist the Sanctuary by participating in monitoring activities and visitor education programmes as these are developed.

Parallel to the establishment of the Mulligans Flat – Goorooyarroo Woodland Experiment and the Sanctuary, and prior to the arrival of local residents in the new suburb of Forde, government and nongovernment groups felt the need to establish a consultation process amongst community, government and the development industry that would serve to engage the broader Gungahlin Community in local biodiversity conservation issues. Thus in 2004, the 'Bush on the Boundary' reference group was established under the general care of the Ginninderra Catchment Group and with the active support of developer Delfin/Lend Lease, the Land Development Agency (the joint developers of the suburb of Forde) and the ACT Parks and Conservation Service. The group meets bi-monthly and provides a forum for sharing information concerning appropriate management of the urban–bush interface, such as management of domestic pets, fire management, weed escapes and waste dumping, recreational pressures and infrastructure developments. In addition to the industry and government agencies mentioned earlier, membership includes the research community (Australian National University and CSIRO), and the broader community (Conservation Council of the ACT and Region, Canberra Ornithologists Group, Friends of Grasslands, Greening Australia). A PhD project ('Social Perspectives of Nature Reserves and Developing Urban Areas'), funded by the ACT Land Development Agency has also been initiated to examine the relationship between residents and their nature reserves.

Figure 10. The Friends of Mulligans Flat group was founded at an event towards the end of 2011. Coordination of the group is via social media sites such as Google groups (Photograph by Jenny Newport).

Progress to Date and Future Directions

The project has made considerable progress and is now established (Manning *et al.* 2011). All our original treatments (addition of deadwood, kangaroo exclusion and prescribed burning) are in place. We are also beginning to see a positive response from invertebrates (Barton *et al.* 2011) and reptiles (Manning *et al.* In review). Vegetation surveys in spring 2011 are also indicating that ground-layer vegetation is showing signs of recovery. The Sanctuary is also developing well, with the fence in place it has now been possible to eradicate foxes and cats. Some rabbits and hares remain in the reserves, but there are vigorous efforts to remove the last animals, including the use of rabbit-detecting dogs. The translocation of the first Eastern Bettongs from Tasmania is underway, coordinated by ACT Government staff from Conservation Planning and Research. Some animals are being managed at specialist facilities at Tidbinbilla Nature Reserve first, before moving to the Mulligans Flat Woodland Sanctuary, and others will be released directly into the Sanctuary. A captive population will also be developed at Tidbinbilla, with the aim that both populations will provide founders for further re-introductions mainland. At the time of writing, the first releases are expected in April 2012; these will be the first Eastern Bettongs seen in a wild situation on the mainland for over 80 years. It is also expected that a trial release of New Holland Mouse will begin in 2012 (Box 2).

The MFG reserves are part of a larger vision for the surrounding rural landscape (called Greater Goorooyarroo)

that straddles the ACT-NSW border and includes patches of box-gum grassy woodland and other native vegetation in a complex rural production matrix. If restored habitats and predator control amongst cooperative landholders can be achieved in Greater Goorooyarroo, there is potential for the Sanctuary to become a future source of species (e.g. Eastern Bettong and southern brown bandicoot) ready for re-introduction to the broader local landscape.

How has the project changed the ACT Government?

Conceiving, planning and implementing the project has had significant impacts on the ACT Government staff from both the ACT Parks and Conservation Service and Conservation Planning and Research at both the individual level and on the agency as a whole. Although at times imposing a considerably higher-than-normal workload on staff responsible for Mulligans Flat and Goorooyarroo Nature Reserves, this has been mostly accepted with enthusiasm, commitment and pride. The restoration experiment, together with the establishment of the Sanctuary has introduced a new dimension to ranger duties, and for some, reignited their motivation for a career in nature conservation management.

Early evidence from the ecological research and Sanctuary programmes is also beginning to inform and exert some influence on the ACT Parks and Conservation Service's land management policies and programmes. A programme is being developed that will extend the introduction of dead wood to other woodland reserves; some ranger staff are being dedicated to particular reserves, which supports a learning culture and personal commitment to management of 'their' reserve; involvement of staff from across the agencies in research treatments and activities (such as the experimental burns and kangaroo surveys) generates interest in the research and its application. The fact that the research has not unduly interfered with normal reserve management operations has allowed confidence in the partnership and mutual respect for the different skills of the partners to grow, potentially laying the foundation for other partnerships to develop.

The establishment phase of the experiment at Mulligans Flat and Goorooyarroo is almost complete. The journey so far has been rewarding, but also challenging, and there has been a 'steep learning curve' for all involved. However, the rewards are starting to be realized through the influence of evidence generated on conservation management and policy (Fig. 11), and the emergence of conservation outcomes that move beyond 'business-as-usual'. In particular, the development of the site as a Sanctuary and 'outdoor laboratory' for engaging the community and demonstrating how we can restore temperate woodlands is important to all the partners (Box 4). The recent establishment of the Capital Woodland and Wetlands Conservation Trust (Box 4) to attract additional funding to support further innovative management promises a self-sustaining community–Government partnership into the future.

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Figure 11. Invertebrate researcher, Dr Philip Barton, explains the results of his research to staff from the Environmental Stewardship programme of the Australian Department of Environment, Heritage and Water. This illustrates how the 'outdoor laboratory is beginning to influence conservation policy. Senior Ranger Peter Mills (far left) then went on to explain the practical aspects of the project (Photograph by Adrian Manning).

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Data S1. Kangaroo exclusion fence diagram. Designed by Peter Mills.

Data S2. Feral animal-proof fence design adapted from Arid Recovery to local conditions by Peter Mills and colleagues.

Data S3. Bettong-exclusion fence diagram. Designed by Peter Mills.

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