Habitat management for tanks and Tuans: Evolving approaches at Puckapunyal Military Area

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Through a combination of on-ground actions, policies and plans, this military training area – set within an important Box–Ironbark Ecosystem – is being managed in a manner that provides compatibility with the conservation of biodiversity.

**Introduction**

Puckapunyal Military Area (Puckapunyal) is located in central Victoria. It is one of the most heavily and intensively used Army training areas in Australia, particularly for field firing and manoeuvre training by tanks, other tracked and wheeled armoured vehicles and artillery (Fig. 1). Since its initial establishment in 1939 to the present day, it has been the temporary home of tens of thousands of Australian soldiers undergoing basic and advanced military training.

It is also 'home' to 44 000 ha of the Box–Ironbark Ecosystem, an ecosystem of which about 85% has been cleared in Victoria. The native vegetation at Puckapunyal constitutes one of the largest discrete areas of this ecosystem in Victoria, including about 19 000 ha of remnant forest and woodland (Environment Conservation Council 2000). The site contains 16 vegetation communities (including 15
Box 1. What do we manage? The biodiversity of Puckapunyal

Plant communities. In a total area of 44 000 ha, native vegetation communities, including revegetation areas, occupy about 57% of Puckapunyal. The remainder is pasture grassland dominated by *Phalaris*, either entirely or in an open woodland context. There are 16 native Ecological Vegetation Communities present in Puckapunyal, of which 10 are endangered, 2 are vulnerable, 3 are depleted and 1 is of least concern. In particular, high-quality areas of Creekline Grassy Woodland, Alluvial Terraces Herb-rich Woodland Complex, Red Gum wetland and other types of wetlands are present (Environment Conservation Council 2000).

Two communities of national conservation significance are listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*:

1. Buloke Woodlands of the Riverina and Murray-Darling Depression (Endangered) with the largest area of about 110 ha and smaller areas at another 16 sites, especially in the central and north of Puckapunyal
2. White Box–Yellow Box–Blakely’s Red Gum Grassy Woodland and Derived Native Grassland Community (listed as Critically Endangered in 2006) with about 200 ha in Puckapunyal.

Although not recognized under legislation, there are also areas of mature Red Ironbark (*Eucalyptus tricarpa*) woodland. These comprise large trees many hundreds of years old, each with at least 1 m diameter at breast height.

Plant species. About 481 indigenous and 225 introduced vascular plant species are present, with 170 non-vascular plant species recorded (lichens, mosses and fungi). About 32 weed species of particular concern occur. Two plant species, Clover Glycine (*Glycine latrobeana*) and Trailing Hop-bush (*Dodonaea procumbens*), are listed as nationally vulnerable under the EPBC Act, 11 species are of Victorian significance and about 116 species are of regional conservation significance.

The fauna groups of Puckapunyal are represented by the following species:

* Birds (185 native species and 9 introduced species). Two nationally endangered species, 12 State endangered species, 7 species with other formal State conservation status and about 14 species of regional status
* Terrestrial and arboreal mammals (17 indigenous species and 15 introduced species). Four species of State conservation significance
* Bats (12 species). One species of State conservation significance
* Reptiles (18 species) and amphibians (12 species). One species of National conservation significance and 3 species of State conservation significance
* Fish (seven native species and four introduced species). Four species of National or State conservation significance
* Invertebrates (unknown, but over 140 species are recorded to date, including one species of State conservation significance).

Climate, soils and hydrology. Puckapunyal has cool to cold, frosty winters during which most of the rainfall occurs and warm to hot summers. It has an average annual rainfall of 596 mm, with a range of 296–1078 mm. Winter droughts occur and summer and autumn droughts are frequent. Terrain is highest in the south around Mount Puckapunyal (413 m) and Mount Kappe (384 m), with a series of rocky ridges and low hills (about 150–250 m) extending north to south. Rolling, undulating and alluvial terraces and floodplains are present in between the hills.

Soil types are mostly duplex soils (relatively low natural fertility and water-holding capacity), with smaller areas of deep, silty or sandy alluvium, cracking clays and gravelly to rocky ridges with skeletal soils. Most soils have high to extreme potential for accelerated erosion following disturbance (Spate 1980). Surface drainage lines are orientated mostly north to north-east with all systems flowing into the Goulburn River. All creeks on Puckapunyal are annual and cease flowing during summer.
that are listed as Threatened at state or national level); and over 1000 plant and animal species (of which 48 are listed as Threatened species at state or national level) (see Box 1).

**Goals of management**

Puckapunyal is not a national park. The site is owned by the Commonwealth and controlled by the Department of Defence (Defence) (Fig. 2). The Australian Defence Force (ADF) capability requirements are heavily reliant on access to high-quality training areas such as Puckapunyal. Any major adverse environmental impact that effectively removes large areas from the land-use training budget will have an adverse impact on the training timetable and on the capability of Defence. Consequently, all high-risk issues are carefully managed and it is in the direct interest of the ADF to sustainably manage these environments so they meet the capability requirements of the ADF safely and with nil or minimal long-term adverse environmental impacts.

Defence also recognizes its responsibilities to manage areas of the environment to the best extent practicable. Within Puckapunyal, Defence and the wider community formally recognized an intrinsic compatibility between a military training land use and conservation management after completing an inventory of the area’s biological values from 1995 to 1997 (Australian Army 1996, 1997). Puckapunyal is registered as a Land for Wildlife property, is listed in the Register of the National Estate on the basis of its national biological significance, and has also been listed as a Commonwealth Heritage Site in the Australian Heritage Database (Department of the Environment and Heritage 2004).

Listing Puckapunyal, one of the most intensively used military training areas in Australia, as a site of major national biological significance was a positive endorsement of Defence’s environmental management. People who remember the site during their training in the 1940s to the mid-1980s recall bare, eroded ground (most often as mud or dust) and have difficulty recognizing the site as it is today.
article provides a summary of the use and history of the area, and the evolution of soil conservation and ecological restoration works carried out at Puckapunyal over the last 50 years.

**Defence context**

Defence personnel must ‘train in peace as they would fight in war’ (Major M. Roberts, pers. comm., 1992). Although simulation and other techniques are now available to complement field-training activities, in-field training, live firing and opportunities for realistic tactics training (especially at individual, troop and squadron level for armoured vehicles and combined force training) are essential components of a contemporary training program. A training area used exclusively for military training and controlled by Defence is therefore essential to allow training to be undertaken any time of the day or night safely without affecting public safety.

Puckapunyal is divided into four main areas and three main range areas based on the suitability of the areas for the type of training or other land use required. The four major areas are Range East, Range West, Joint Proof and Experimental Unit (JPEU), Graytown, and Cantonment (see Fig 2). Many different regular and reserve military units are resident or use the site including armour, artillery, transport-logistics, infantry, signals and combined force training. Each group has different land-use requirements. Many of these field uses require nothing more than a track network or a relatively large area of open to lightly wooded country while others require a variety of landscapes (e.g. for training to patrol or conduct an ambush or a road block). Some sites, such as small arms ranges, static firing points for large calibre ammunition and other gunnery sites, require relatively clear land to allow for training soldiers, observation of the activity and to minimize the risk of bush fires. Conversely, many others require that vegetation is present in order to provide realistic training scenarios; and danger templates (safety buffer areas) are mandatory around areas of live firing. Some of these buffer areas must comprise cleared areas, such as grassland, while others are vegetated with woodland and forest.

Puckapunyal is gazetted as a Defence Practice Area. Between 60 000 and 70 000 training days and up to 12 000 vehicles use Puckapunyal annually and up to 1000 live-firing activities are undertaken each year. Between 2000 and 3500 people per day use Puckapunyal, including the Cantonment, which is a larger population than many small towns. This includes families living at the base, personnel living off-base and working there, Defence civilians, contractors and visitors.

**Past environmental impacts**

1836 to 1938: Early settlement and use

The most significant environmental impacts occurred in central Victoria during the first 100-year period after European colonization (Creagh 1991). When the expeditions of Hamilton Hume and William Hovell (1825) and Major Thomas Mitchell (1836) explored the region, they found high-quality areas of native grassland, open woodland and water. Subsequent squattting and selection of land for grazing of sheep and cattle was closely followed by gold mining and harvesting of the box and ironbark forests for timber and firewood. With people, livestock, clearing and habitat fragmentation came weeds, pest animals and heavy grazing pressure on land that was on relatively poor (infertile) soil types. This soon resulted in degradation of the land and the accelerated erosion was severe.

1939 to 1968: Early use by Defence

When Defence purchased the original land area in October 1939, it inherited a legacy of the previous 100 years of degradation. At that stage, environmental impact was of less concern than today as Australia was at war and the imperative was to train soldiers as quickly as possible. Some additional areas had to be cleared to fit training requirements and land management was minimal. The training imperative continued after World War II, with Citizen Military Force and National Service training requirements (Australian Construction Services 1990). Over this period (until 1993), sheep grazing also continued on Puckapunyal. The early decades of grazing were well managed and caused limited additional damage to the land. Nonetheless, the legacy of historical impacts plus heavy military use and little maintenance was obvious by the 1960s. About one-third of Range East was impassable during a typical winter because of waterlogging and the hazards caused by severe erosion. Centurion tanks and trucks were regularly and deeply bogged during this time and more time was spent de-bogging vehicles than training.

**Addressing impacts:**

The Puckapunyal Restoration Program

1969 to 1986: Initial works and expansion of the site

It must be remembered that, at this time, Defence did not have specific policy requirements for environmental management. Local policies applied, usually as site directives and Range Standing Orders (i.e. the rules of conduct for military activities), which included general prescriptions such as the protection of specific areas, grazing lessee property and native fauna. In 1969, Defence reviewed its options for the future use of Puckapunyal, including reducing training, abandoning the area or rehabilitating it. The latter was the option chosen. From 1971 to 1985, the Puckapunyal Restoration Program was established and implemented. CSIRO provided the background data, science and management, while the Victorian Soil Conservation Commission provided the erosion control expertise (Puckapunyal Pasture Advisory Committee 1985).

In 1976, the Army put forward a proposal to acquire land to the west of Range East, which resulted in the
doubling of the size of the training area in 1979 (Department of Defence 1976). The extra land (Range West) was a mixture of State forest and private grazing land.

By the end of 1985, a massive transformation of earthworks, water and erosion control, and revegetation had been completed on over 20 000 ha of land, including the newly acquired area of Range West. Over 5000 ha of bare land had been repaired and reshaped to manage water and various forms of accelerated erosion, and 16 000 ha of improved pasture established (Creagh 1991).

With broad area restoration work having been completed and a larger area available for ‘rotational’ use and the use of new weapons systems, the next stage was to develop management regimes so as to avoid the problems of the past.

1986 to 1993: Improved planning and implementation

This period saw the consolidation of gains made under the Puckapunyal Restoration Program. Large- and smaller-scale plantings occurred onto high-priority areas, such as water recharge areas and saline sites (Fig. 5). A Land Management Crew was employed to work with a Scientific Officer appointed by the Army, and CSIRO continued to undertake research and monitoring into understanding and rectification of the problems in the ranges (Creagh 1991; Cuddy 1991).

A rest and restore program commenced for some areas. These became restricted access areas (‘No Go’ areas in Army terms) and included young revegetation sites, areas that were being overused, environmentally sensitive sites and environmental reference sites. Range Standing Orders were revised to reflect these requirements.

Figure 3. Comparison of largely denuded landscapes prior to and after revegetation on two of the sites at Puckapunyal: (a) Barker Hill in 1985 compared with (b) the same view in 2005, and (c) Mount Puckapunyal in 1985 compared with (d) the same view in 2005. Revegetation methods have evolved over the decades to include strategically protecting remnant vegetation and fostering its regeneration, coupled with linking patches of habitat with planted areas. Although a range of ‘native’ species were used in the early plantings, only locally collected species from the Box–Ironbark Ecosystem have been used in the last 20 years. (Photos: Defence 1985 and Michael Bryce 2005, courtesy Department of Defence).
The first Land Management Plan (LMP) was developed over 6 years and was finalized and implemented in 1987 with subsequent revisions occurring up to 1993 (Australian Army 1987). This plan defined and guided the management of the key land management risks on the range areas. Specific action plans developed for Puckapunyal during this period focused on the management of land, water, fire, pest species and pollution. Smaller components of these plans included specific environmental management tasks, such as the development of a seed bank of species from the area and subsequent use of these in direct seeding and tube-stock propagation; development of formal ‘hardened’ crossing points on watercourses for use by armoured vehicles; and implementing the use of geographic information systems in the management and monitoring of the ranges.

A major problem during this era was maintaining sufficient groundcover to cushion the impact of armoured vehicles (Box 2 and Fig. 4), especially over the summer to early autumn. It soon became apparent that heavy grazing pressure by sheep and increased use of Puckapunyal by the Army was not compatible. This resulted in the cessation...
of sheep grazing in 1993, which was followed by other changes in the management and assessment regimes at Puckapunyal.

Because of the combination of *Phalaris*-based pastures (required to cushion the impacts of armoured vehicles) and live-firing activities, Puckapunyal has a high fire danger rating during the fire danger season. Control of pasture growth is required, and cattle, which (depending on regime) can have less environmental impact on the land surface than sheep, were introduced for this purpose under a strictly controlled regime.

Another major issue was the increasing population of Eastern Grey Kangaroo (*Macropus giganteus*) during the 1980s and 1990s. A number of kangaroo monitoring and condition investigations were undertaken through the 1990s, which along with annual population census data from 1983 onwards, resulted in the development of a Kangaroo Management Plan (Coulson & Morgan 1999). By 2001 and especially the drought year of 2002–2003, grazing by kangaroos and cattle exceeded the available food resources, causing adverse public comment. This led to the removal of cattle from the range and the control of the kangaroo population by contractors using nationally approved humane procedures.

At the same time as the last revision of the LMP was released, the Environmental Policy of the Australian Army was developed. This recognized the importance of the environment with its key message of ‘Preparing a land force capable of conducting activities in an environmentally responsible manner’ (Australian Army 1995). The LMP now had a firm basis in policy and endorsement from the top down.

1994 to 2006: Consolidation and integration

An adaptive management regime was introduced in 1995, with Defence Environmental Officers appointed to plan and coordinate the LMP. An annual program of on-ground actions and works continued, implemented by the Land Management Crew and contractors, with failures as well as successes informing the subsequent work. One of the main successes was that many of the revegetation works from previous years were having a significant beneficial environmental impact, particularly in terms of ground stability, water quality and increasing areas of vegetation potentially usable by native fauna. Two of our failures were the dismal performance of about 90 ha of direct-seeded areas due to a combination of poor quality seeds and severe grazing pressure by cattle and Brown Hare (*Lepus capensis*) and the overgrazing of an important area of native tussock grassland by cattle in JPEU, Graytown.

The first full inventory of Puckapunyal’s wildlife occurred from 1995 to 1997 and this provided an understanding of the biological significance of much the site, including its threatened species and areas of particular value or containing rare species. At the same time as this inventory, increases in the population of some pest plants and animals were noted, especially Red Fox (*Vulpes vulpes*), which is well known to have an impact on small mammals elsewhere (Burbridge & McKenzie 1989; Risby et al. 2000; Kinnear et al. 2002). The changes in environmental legislation, particularly the Common-wealth Endangered Species Protection Act 1992, the forerunner of the current Environment Protection and Biodiversity Conservation Act 1999, resulted in the definition of matters of national environmental significance. Defence had obligations to avoid or minimize impacts on threatened communities and species, plus assist in the active management of these and threatening processes listed under these Acts.

The LMP was converted into an Environmental Management Plan in 1998, followed by development of an Environmental Management System (EMS) in 2003. The EMS has its basis in the Environmental Vision for all of Defence namely: ‘The Department of Defence will be a leader in sustainable environmental management to support the ADF’s capability to defend Australia and its national interest’ (Department of Defence 2001). It provides a systematic approach to identifying and managing environmental impacts and in controlling the high risk and prioritized environmental management issues. The EMS functions via a cycle of continuous improvement through ‘plan, do, check, act’. In effect, the EMS formalized many of the management activities already being undertaken in Puckapunyal and it provided support to the whole-of-Defence environmental management policies being issued (Corporate Services and Infrastructure-Puckapunyal 2005).

The Puckapunyal EMS achieved certification to the AS/NZS ISO 14001 Standard in September 2005, the second Defence site in Australia to do so.

Management and its outcomes

As described above, extensive incremental restoration works have been undertaken at Puckapunyal since the 1970s. These included works to achieve natural regeneration of over 4000 ha of native vegetation (i.e. by changing use protocols, fenc ing out or controlling herbivores and controlling weeds) and direct seeding and planting works to reinstate about 2800 ha of native tree and shrub species. In addition, a major pest animal control project commenced across all of Puckapunyal in 1994. Monitoring of the pest animal program was carried out concurrently to identify its direct and indirect impacts on some native animal species.

As part of the EMS, a formal data collection and management system has also been adopted. This allows for data entry and production of overlays of all relevant information such as the use of particular areas and the location of particular works (relating to pest plant and animal control, revegetation and threatened flora and fauna).
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Summary information allows for relatively rapid comparison of data and detection of trends, which feeds information back into management.

Changing use protocols

A key vehicle for environmental management is Range Standing Orders, and since the introduction of the EMS, these include detailed environmental controls to ensure the sustainable management of ecosystems, to protect significant species and habitats from impacts of Defence activities. Specific Range Standing Orders, for example, prohibit entry of military vehicles (and certain types of activities) in 'No Go' areas, with a high level of compliance observed to occur. This is part of the 'check' aspect of the EMS. Maps of 'No Go' areas (Fig. 5) are provided to all units and highlighted at the daily briefing for units, and these areas are also marked and avoided during the planning of each military activity.

Each unit undertaking an exercise on the range completes an Environmental Clearance Certificate (ECC) giving permission for that activity to occur and highlighting any mitigation and management that is required during and after the activity. After each activity, a post-activity inspection is completed by Defence and if there has been a breach of the ECC conditions it is reported to the Environmental Officer and the unit and corrective action is implemented. Along with the operational controls, active monitoring of the populations of flora and fauna and environmental impacts is undertaken to ensure that compliance under policy, legislation and access requirements are being met and cumulative and combined impacts are avoided or minimized.

An environmental awareness presentation has been developed and all personnel and contractors attend the presentation before permission is being granted for access to the range. This presentation details the significant areas on the range that are not to be entered, the procedure to follow if an incident was to occur, and general guidelines for sustainable management.

Figure 5. Location of 'No Go' areas and revegetated areas at Puckapunyal Military Area. A combination of restricted access and other rehabilitation interventions has resulted in natural regeneration of over 4000 ha of native vegetation communities (which includes some of the 'No Go' areas). Revegetation by direct seeding and (mainly) planting has reinstated about 2800 ha of native tree and shrub species. The two treatment types overlap where revegetated areas require protection from vehicles. (Base map courtesy Department of Defence. Revegetation and access location data provided by Bob Anderson)
of Puckapunyal. Annual re-training of all individuals is mandatory.

Planning of all training and management activities takes place. From a holistic perspective, this allows for forecasting of work priorities, timing and budgets, to allow for briefing of new personnel and passing on the lessons learned in the past.

**Revegetation: Evolving approaches**

Revegetation goals and techniques have evolved over the decades at Puckapunyal, reflected in an annually revised revegetation plan. When the Restoration Program commenced in the 1970s, its main goals were to reduce the amount of bare ground, control surface flooding and rising (saline) water tables, and establish pasture areas that would protect the soil surface from the movement of armoured vehicles and allow for grazing (Box 2). Consequently, early works included extensive (16 000 ha) sowings of a mix of introduced pasture species especially *Pbratis* and planting of some high-priority hills and slopes (recharge sites) with nearly 400 000 bare-rooted seedlings of ‘native’, but at that time not necessarily locally native, trees and shrubs.

After 1983, the plan was revised (on the basis of soil and hydrological data from a study by CSIRO) to ensure that a more strategic and holistic approach was applied to revegetation. This included planning and undertaking revegetation on a catchment and subcatchment basis and placing equal focus on both water recharge and discharge areas in the landscape. At the time, the issue of the provenance of seed sources was also considered. From the mid-1980s, species native only to Puckapunyal were planted, although only trees were planted, usually as bare-rooted tubestock. By the late 1980s, a seed bank of species collected entirely from Puckapunyal was being established, and this has been maintained until the present day, with collections from all areas of the range being made to ensure that genetic variation is represented. Equally important has been the inclusion of as many as practicable of the common tree, shrub and understorey species, as well as species that are rare. Direct seeding has been undertaken in some areas, and both it and tubestock grown from the seed bank have been used on the site, including the Cantonment, since 1985.

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Once land stability had been achieved, planning of strategic revegetation corridors and connections commenced in 1996. Over the last 10 years, fencing was undertaken to exclude grazing from existing vegetation along many watercourses and roadside areas and linkage plantings have been established between discrete and isolated areas of remnant old woodland and between and around the perimeter of biological significant sites.

The greatest gains in revegetation, however, have occurred naturally through the permanent and temporary fencing of ‘No Go’ areas and the exclusion of stock grazing, reduction of Kangaroo numbers, banning the removal of timber (except where specifically authorized by an ECC), and the improvement of quality of vegetation (by protecting old growth and large dead trees and allowing deadfall timber to remain on the ground). An example of this is the areas of remnant Buloke (*Allocasuaria luebmannii*) woodland in Range East, which are the largest in the region and which were established as ‘No Go’ areas in 1990-1991. However, the first fruit and seeds on these trees did not occur until 2002. It took over 10 years for the trees to recover from the impacts of rabbits, sheep and cattle and tanks sufficiently to commence enough new growth to support flowering and fruiting. These trees have produced seeds every year since then and their population is now expanding through both seedlings and root suckers.

It must be emphasized that the Puckapunyal Restoration Program operated on the basis that bigger was better and without repairing sites at a larger landscape level, re-establishing soil and watercourse stability, few environmental gains would have been made. The fact that problems such as accelerated erosion, salinization and tree dieback have been largely controlled on Puckapunyal (when similar untreated areas off Puckapunyal remain degraded) supports the validity of this approach. For example, many of the sites that were originally bare ground with deep erosion gullies but which were revegetated three to four decades ago, now provide habitat for Hooded Robin (*Melanodryas cuculta*), Speckled Warbler (*Chthonicola sagittata*) and Diamond Firetail (*Stagonopleura guttata*) – all species belonging to a group of woodland birds with declining populations in southeast Australia (Robinson 1994; Robinson & Traill 1996; Ford et al. 2001).

**Control of pest plants**

Since 1992 the list of weeds has expanded from about eight species (originally only including those of agricultural concern) to about 30 species (including all declared noxious and environmental pest plants). From 1992 to 2006 about 17 000 h of weed control have been undertaken. This control has contributed significantly to the success of planting and natural regeneration to protect areas of threatened plant communities and species.

An outstanding example is that of Clover Glycine (*Glycine latrobeana*), a nationally vulnerable native legume assessed to be in decline on the site in...
the early 1990s, primarily due to the impacts of herbivory and weeds. In 1995, the density of the population of Clover Glycine was 1 plant/m² at the 'best population' and typically 1 plant/10 m². Following rabbit and weed control from 1996 to 2000, the populations were recovering and by 2005 (and additional rabbit control) the monitoring program being undertaken by the Land Management Crew (Fig. 6) indicated that a typical population density was 9 plants/m² and up to 20 plants/m². Some of these populations are now massive and occupy areas of 1 km².

Control and monitoring of pest animals

A total of 32 pest animal species are present in Puckapunyal and specific control programs have been developed and are implemented annually for the highest risk species. Control of pest animals such as European Rabbit (Oryctolagus cuniculus), Red Fox and Domestic-feral Cat (Felis catus) has been undertaken for over 30 years through baiting, habitat control, trapping and shooting by contractors. In the last 15 years, this represents an investment of 35 000 h, with many thousands of introduced pest animals being removed by baiting, shooting and trapping.

**Cats**

Cats were trapped using baited cages on the range and in and adjacent to the Cantonment in 1996 and each year thereafter until 2006. In 1996 and each year thereafter, an annual fox-shooting program (carried out by contractors to uniform specifications) commenced throughout all of Puckapunyal (excluding the Cantonment and along the boundary) usually with three to six separate control periods from January to April. Areas supporting both adult and sub-adult foxes were inspected and the location of dens marked in the field. These were then destroyed by deep ripping with a backhoe. Each former den site was inspected annually to assess if it had been re-opened or if a new den had been opened nearby. All data are considered in a report by the contractor, which includes location data that are entered annually onto the geographic information system for Puckapunyal.

**Red Fox**

Control of Red Fox has employed three approaches: baiting, shooting and den destruction. Baiting commenced in 1994, followed (in 1998) by less intensive annual baiting treatments. All baiting treatments involved the laying of 4600 FOXOFF 35 g baits (Animal Control Technologies, Melbourne, Vic.) by a Defence-appointed contractor. Initially these were applied along the edge of all of the main and minor tracks and the boundary in Puckapunyal, excluding the Cantonment. After 1998, bait stations were applied only along major access tracks and the boundary of Puckapunyal, which resulted in fewer bait stations.

In 1996 and each year thereafter, an annual fox-shooting program (carried out by contractors to uniform specifications) commenced throughout all of Puckapunyal (excluding the Cantonment and along the boundary) usually with three to six separate control periods from January to April. Areas supporting both adult and sub-adult foxes were inspected and the location of dens marked in the field. These were then destroyed by deep ripping with a backhoe. Each former den site was inspected annually to assess if it had been re-opened or if a new den had been opened nearby. All data are considered in a report by the contractor, which includes location data that are entered annually onto the geographic information system for Puckapunyal.

Monitoring of Red Fox and cats was carried out by three methods: spotlighting, cage traps along transects, and scat collection and analysis. Spotlighting was used by two observers travelling on a slow moving vehicle (5–10 km/h) along all of the main roads in Puckapunyal, excluding the Cantonment. The standard transect for Puckapunyal (monitored twice annually) measured 184 km during 1994–1996,
with a series of shorter transects used to validate the larger one. In all subsequent years, the transect was about 200 km. Each transect was assessed over three nights before treatment and this was repeated after treatment. No untreated controls were retained due to the potential of untreated areas to impact on treated zones. All foxes and cats seen were recorded and a location map of occurrence were compiled.

Large wire cage traps were established along 1 km of five watercourses (10 traps per transect) in January or April every 3 years, and 'spot trapping' using cage traps occurred annually (ongoing) at 30 sites across all of Puckapunyal during January. Similar transects were undertaken annually around the edge of the Cantonment and 'spot trapping' in the Headquarters area of JPEU, Graytown.

Areas with high fox numbers detected were reviewed during the day and potential den sites were marked on maps and scats were collected from these locations. The latter were analysed to provide an indication of the prey and other food items.

Results show that the numbers of Red Fox observed 5 weeks after the first intensive baiting treatments in 1994 were much lower (34 animals for the total 184 km of survey) than those observed before baiting (84 animals observed) (Coman & Robinson 1995). By 6 weeks after baiting, the count had reduced to nine foxes observed. Subsequently, 18 animals were recorded in January 1995 and relatively low numbers continued to be recorded until January 1997 when the number of foxes observed had increased to 40 along 200 km of road and have remained in the vicinity of 40–60 per 200 km since that date.

It is very important to note, however, that since shooting commenced in 1996, higher numbers of foxes have been shot per year in Puckapunyal than were being observed during the spotlighting monitoring. Since the 2002–2003 season, the number shot has exceeded the number of foxes observed at the commencement of the annual treatment program. This raises serious questions about the effectiveness of baiting and of spotlighting in detecting foxes or may point to other issues relating to the suitability of the monitoring design to detect foxes migrating into the site from other properties.

Analysis of fox scats showed that Tuan (Phascogale tapoatafa) formed part of the diet of fox and cat, particularly from November to February (summer) when the young animals were becoming independent and dispersing. Between 1995 and 1999, between 9% and 14% of all fox scats (n = 92) and 16% of cat scats (n = 19) contained Tuan hairs (Australian Army 1997; R. Anderson, unpubl. data, 1995–2006).

Monitoring of native fauna species
Species observed and the different methods used

Since the year after Red Fox and cat control programs commenced, formal monitoring has been undertaken on many native faunal species with some of the key species being Bush Stone-curlew (Burhinus grallarius), Tuan, Common Dunnart (Sminthopsis murina), Powerful Owl (Ninox strenua) and Barking Owl (Ninox connivens). Informal counts of Lace Monitor (Varanus varius) have also been made. All of these species are listed as Threatened in Victoria (Bennett 1999).

Small mammals such as Common Dunnart and Tuan – as well as the reptile Lace Monitor – were monitored using pitfall traps, medium-sized and large-sized Elliott traps (Elliott Scientific Equipment, Melbourne, Vic.), cage traps and spotlighting in assessment sites established throughout Puckapunyal. (Common Dunnart and Lace Monitor were captured by both trapping methods, while Tuan was only recorded by Elliott and small cage traps.) Audiotape calls of Bush Stone-curlew were played through a loudspeaker across all regions of Puckapunyal during November, January, and March–April each year from last light to first light for at least three nights per month. The number of birds responding to calls and their location was recorded on maps of the area. Later, on nights with a full moon or near full moon, the sites where birds responded were revisited by listening for calls and identifying the number of birds present by the number of calls. The number of birds was then confirmed by spotlighting. Over the past 11 years, the territories for each pair of birds were recorded and these territories were assessed for the presence of the species as adult and young birds annually.

Although there are four resident owl species at Puckapunyal, only the two largest species – Barking Owl and Powerful Owl – have been monitored in detail. Individual owls with known territories were reviewed by observing their diets, their nesting trees and preferred roosting sites commencing in October to November each year. This provided information about the success of breeding as fledged juveniles would usually be present at this time. The sites were reviewed again in January and March–April to review the status of young birds and sometime in August to assess breeding success in the subsequent year. Taped calls of the two owl species were played on separate nights at sites throughout all of Puckapunyal from March to April to assess the response of known birds and the presence of new birds. Three to five nights’ repetition of taped call playback occurred for each time period.

All of these assessments have been repeated annually since 1995.

Changes in native fauna
Mammals

Tuan was considered rare in Victoria (Bennett 1999) and many sections of Puckapunyal in the early to mid-1990s (Coman & Robinson 1995) and was
not recorded at many sites that contained apparently suitable habitat for the species. The original assessment in 1955–1956 recorded Tuan hairs from only 5% of all traplines \((n = 172)\) and particularly low numbers of juveniles were found over the December–April period each year (Australian Army 1996). Since control of Red Fox and cats commenced, there have been steady increases in the observations of Tuan by trapping. Although a dip occurred over 2002–2004 during and following a severe drought, by 2006 the species was recorded in 46% of all traplines \((n = 150)\). In addition, increases of up to 65% in numbers of juveniles have been found in the population over the summer to autumn period during this time. Over the same time, there has been a significant decrease in the number of fox and cat scats containing Tuan hairs from between 9% and 14% \((n = 92)\) during 1995–1999 to 6% \((n = 57)\) during 2004–2006 for fox, and from 25% \((n = 19)\) to 8% \((n = 25)\) for cat over the same period (R. Anderson, unpubl. data, 2006).

Common Dunnart was rarely recorded at the site and all 10 records of it over 1995–1996 were from Range West (Australian Army 1996). By 1997 Common Dunnart was recorded at three other sites and by 2000–2001 the species was being recorded throughout Puckapunyal, including in Range East. Although it is still rare, its distribution and population has increased from 13 sites to 67 sites. Most occurrences are as a single animal, although females with suckling young have been recorded on four occasions.

**Birds**

In 1953, Bush Stone-curlew was known to inhabit the rifle range area of Puckapunyal (Whitbourn & Robinson 1954) but was considered rare in Puckapunyal and the district in 1995 (Coman & Robinson 1995; Robinson & Johnson 2004). During the period of fox and cat control, Bush Stone-curlew numbers have slowly increased from three pairs and a total of nine birds (Coman et al. 1997) to 14 pairs and 31 birds in 2006, albeit with a decrease during the drought year of 2002–2003. Of interest is that a pair of this species is still present in the vicinity of the earliest recorded sighting of the species in Puckapunyal (in 1953).

In terms of the owls, one record showed that Powerful Owl was present in Range West during the 1970s, with two pairs of birds known to occur here (Australian Army 1996). During the early years of intensive pest fauna control (1995–1997), four pairs of Powerful Owl and several single birds were present in Puckapunyal. By 2006, 11 breeding pairs and at least three single birds were recorded entirely in Puckapunyal or with home ranges that overlap its boundary (Fig. 7).

There are relatively few historical records of the Barking Owl for the region and no records that we are aware of for Puckapunyal during the 1950s to the 1980s. Although the species may have been present in small numbers, it was not obvious enough to be recorded. In 1995 (after pest species control commenced), the first positive records of Barking Owl were established for the site and the first breeding pair was confirmed as present in 1997. Since then we have found five breeding pairs in residence at Puckapunyal and at least four single birds are also present (in 2005), with a further two pairs with territories that overlap the Puckapunyal boundary.

**Reptiles**

Large individuals of Lace Monitor (i.e. >1 m in length) have been observed on Puckapunyal since the 1950s, but small animals were rarely reported (Fig. 8). The first juvenile Forest Monitor was trapped in Puckapunyal in 2000 and this general age class has continued to be recorded every year since then as 1-, 2- and 3-year-old animals. In particular, first-year animals are now relatively common each year.

Can we attribute increases in fauna to management actions?

As rainfall was below average in 1994 but above average in 1995 when the Red Fox control program started, increased rainfall may at least partly explain the apparent increases in native fauna after the commencement of the program to control Red Fox in 1995; although this cannot be tested as, predrought, data on native fauna are not available for comparison. Another important explanation (but also untestable due to lack of predrought data) could be that revegetated areas on Puckapunyal have provided additional good quality habitat for a variety of flora and fauna species. This may be enhanced by the fact that the revegetation has also expanded the areas of patches to the point where...
they have reached critical size and habitat complexity values for different species and provided connectivity between previously fragmented areas. For example, a number of native fauna species, including Tuan and Squirrel Glider (*Petaurus norfolcensis*) have been observed using a vegetated corridor that was established in 2000 to connect two areas of remnant old-growth woodland. Combined with the remnant old-growth trees and branch and log litter, these habitats could be ‘maturing’ and providing the vital combination of characteristics for the species.

It is logical to also speculate that a reduction in pest predators such as foxes and cats may have resulted in beneficial outcomes for a number of native faunal species. Because the original monitoring design could not include ‘before treatment’ data and untreated controls (as the program needed to be implemented without large untreated areas), such conclusions cannot be drawn from the monitoring data. We can say, however, that species of native fauna that are known to be prone to fox and cat predation have increased in recent years at both individual sites and across all of Puckapunyal. Although other factors such as drought and habitat improvements could also help explain this, control of foxes cannot be ruled out as a major factor. Other indications also add weight to the role of foxes. For example, we are not aware of Bush Stone-curlew occurring elsewhere in the district except at Mangalore Ammunition Depot, another Defence site 10 km east of Puckapunyal where fox control had also occurred – and decreases in this native bird occurred at this site when fox control was decreased. (R. Anderson, unpubl. data, 2006).

We have some concern, however, that anomalies between the fox-shooting data (which shows increasing numbers being shot each year) and results from spotlighting (carried out prior to each baiting event) raise new questions about whether spotlighting is effectively detecting foxes (Field *et al.*, 2005; Saunders *et al.*, 2006), or whether foxes are visiting from neighbouring properties to feed in Puckapunyal. These questions may require new approaches and techniques to monitor and control foxes. Whatever the actual patterns of Red Fox occurrence, however, it is important to acknowledge that increasing numbers are being eliminated each year and that this (at minimum) has implications for the importance of maintaining the control program on Puckapunyal.

An additional implication is that, subject to further monitoring of potential movement of foxes from neighbouring sites, substantial benefit would arise from encouraging fox control on neighbouring properties. This also raises the future need to compare the population of prey species from sites adjacent to Puckapunyal at which fox and cat control does not occur.

**Future directions**

Puckapunyal has learned from past unsustainable land use pressures. Through a combination of on-ground actions, accompanied by the development of policies and plans, Defence now seeks to manage a training area and live-firing range in a manner compatible with the conservation of biodiversity. That this is an appropriate and realistic goal is evidenced by extensive revegetation and significant recovery of both common and threatened plant communities and animal species in and adjacent to sites used intensively for training, despite the lack of certainty about specific causal factors. This has shown that, with commitment, much can be achieved in 10–20 years.

The EMS for Puckapunyal establishes clear directions for management, especially in relation to due diligence and legislative goals, but also in relation to conservation obligations and matters. Targets have been set and these are assessed against achievements annually. A key objective is to
continue to improve the management of the site and to undertake management actions that will sustain Puckapunyal for the next 100 years. Examples of this include:

- Thinning of regrowth patches to allow for the next generations of big trees to mature
- Implementing a nest-box program to assess if lack of hollows in some of the revegetation sites is limiting fauna use
- Refining the revegetation of earlier sites to incorporate more understorey species and complexity
- The use of fire as a tool to assisting regeneration

All of these activities are being undertaken under strict monitoring to provide future management information.

It is also hoped to provide others with an understanding of the management experiences of Defence. As has occurred in the past, this could include involving others through guided tours of the site via an ‘open day’ or similar. Unfortunately, there are both security and public safety issues associated with accessing parts of Puckapunyal. During the training year, it is very difficult to access many sections of the training areas because of live firing.

Improvements are also desirable in terms of monitoring. The condition of Puckapunyal’s vegetation communities, habitat and faunal species populations continue to be monitored, but there is an array of comparative assessments that could be undertaken within Puckapunyal and in the areas external to it, including the state forest and national park areas where large areas of Box-Ironbark Ecosystem are conserved or managed. In time, it is hoped that these can be undertaken, especially to improve habitat for the progeny of threatened species that are migrating from the site.

There is so much yet to be done on Puckapunyal. Over the past 12 years, we have been able to establish some rigorous field experiments, but others do not have such controls. Even so, the observations from them have been essential in understanding the relative impacts from various sources. All of the data, including large datasets for a wide range of other subjects not reported here, provide Defence with management information – and additional trials and monitoring will be established as necessary. The best expression of this is in the original LMP (1987) for the site: ‘The key to land management of Puckapunyal is understanding, monitoring and repairing.’

Puckapunyal’s control principles are based on a combination of military methods, common sense and science. The former are vital to military training and these are also of major benefit to maintaining the ecosystems of the area. But the management of Puckapunyal has never been easy. It is a balancing act, where training and sustainable use must take first priority. With such a large area, issues of fire management, trespass, ground cover, erosion control, water, pollution, changes in land use adjacent to the site, and the incursion of pest plants and animals are always to be considered.

Defence’s commitment is to maintain the environmental integrity and ecological diversity of Puckapunyal, consistent with the sustainable use of the area for military training. We believe that Puckapunyal provides an exceptional example of sustainable management in the Box-Ironbark Ecosystem and one that all Australians can be proud of.

Our final message is ‘Fix, control, connect, manage and monitor. Don’t stop.’

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