The response of small mammals to the invasion of coast wattle (*Acacia longifolia* var. *sophorae*) in a fragmented heathland, south-west Victoria

Ellen Mitchell and **Barbara A. Wilson,** School of Ecology and Environment, Deakin University, Geelong, Victoria 3217, Australia.

Abstract

This study aimed to assess the impact of the environmental weed, *Acacia longifolia* var. *sophorae* (Labill.) Benth. on small mammal communities in fragmented coastal heathlands. The study was undertaken near the Portland Aluminium Smelter in south-west Victoria, within an area considered to have high plant diversity and several rare and threatened fauna species. Fauna surveys for small mammals were conducted between 1979 and 2004 using a combination of cage and Elliott traps in grid and line formations. The results of the small mammal fauna surveys and several vegetation surveys conducted were analysed. Significant changes in vegetation composition were the loss of wet heathland areas, decline in native species and the increase in cover of environmental weeds, *A. longifolia* var. *sophorae* (coast wattle) and *Leptospermum laevigatum* (Sol. ex Gaertn.) F.Muell. (coast tea-tree). Vegetation analysis found a strong negative correlation between *A. longifolia* var. *sophorae* cover and plant species richness. A 50% loss in the floristic species present significantly altered the vegetation structure and composition. Vegetation communities have changed from short open heathlands to shrublands with a dense overstorey. This has had a significant effect on the small mammal populations as preferred habitat is no longer available and several threatened habitat specialists, including *Pseudomys shortridgei*, have disappeared.

Rabbits, foxes and feral pigs – how do they impact on weeds?

Tim Bloomfield[A] and **Steve McPhee**[B]
[A] Department of Primary Industries, 219 Main Street, Bacchus Marsh, Victoria 3340, Australia.
[B] Agricultural Technical Services Pty. Ltd., 177 Ballan Road, Werribee, Victoria 3030, Australia.

Background

The impact pest animals have on the economy is around $420 million per year. These loses are mainly related to agricultural production as environmental loss and long-term land degradation is difficult to estimate. Around $60 million per year is spent by landholders and governments to control pest animals and a further $20 million per year is spent on research (Bomford and Hart 2002). The impact weeds have on the economy is over $4 billion dollars every year due to lost production and control effort (CSIRO 2006). Since the arrival of the first Europeans, more than 28 000 exotic plants have been brought into Australia, a few accidentally but most deliberately. Now, more than 2500 species of introduced plants are established in the wild (CSIRO 2006). Plant invasion involves two essential stages: first, transportation of organisms to a new location; and second, establishment and population increase in the invaded locality (Chase and Chesson 2002). But a third worrisome stage is the regional spread from initial successful site of invasion. Pest animals can assist in the spread of seeds into regional areas by creating conditions that suit weed invasion and provide a continued source of viable seeds and plant material capable of maintaining the invasion.

To tackle the impacts of invasive species, conservation agencies usually rationalize their resources by establishing management teams that specialize in the different plant or animal species. This can mean that single species are managed in isolation as single identities. The consequences of removing an invasive species from a complex ecosystem can have unexpected or undesirable affects. This paper is not a review of the topic, but provides examples of the impact pest animals can have on ecosystems and the consequences of removing pest animals from complex ecosystems.

Pest animals role in changing the landscape

Impact of rabbit grazing on the weed component of pasture

Several studies (Fenton 1940, Myers and Poole 1963) observed that rabbit grazing can produce floristic changes to sown pasture. A more recent study, carried out at Cowra in eastern NSW, by Croft *et al*. (2002), demonstrated that rabbits grazing pasture at a high-density reduced the valuable pasture content and increased the weed content in the pasture. Pasture composition was monitored in grazing plots, stocked at the district average of eight merino wethers per hectare and then supplemented with 0, 24, 48 and 72 rabbits per hectare. Major changes in pasture composition occurred after three years. The proportion of weeds such as barley grass increased and proportion of beneficial pasture such as sub-clover decreased in the grazing plots with the highest rabbit density (Figure 1). The change in pasture composition was due to barley grass invading areas that were denuded by rabbit grazing and scratching. Also, rabbits reduce the sub-clover content by cropping this plant to ground level, digging up seed reserves, thereby reducing flowering, and future seed set. This study provides evidence that excessive grazing of pasture by rabbits reduces desirable plant species and increases the less desirable weed component of the pasture.

In the same study, the change in pasture composition due to high rabbit density also reduced the productivity of the medium to strong wool merino wethers. After three years, wethers grazed within the high rabbit density plots had lighter body weights, poorer body condition, grew less wool and had lower gross $ return per hectare than wethers run at the other three densities of rabbits. (Fleming *et al*. 2002).

Foxes and their impacts on plant communities

Top predators, like foxes can have powerful direct effects on prey populations, however it is debated that these effects go to the base of terrestrial food webs. The example put here from Croll *et al.* (2005) is of a trophic cascade strong enough to alter the abundance and composition of an entire plant community. The introduction of arctic foxes (*Alopex lagopus*) to the Aleutian archipelago created a significant effect on the productivity of plants and the changed the plant community structure. The fox predation on seabirds reduced the transfer of nutrients from the sea to the land. Thus soil fertility was changed and a transformation from grassland to dwarf shrub/forb dominated ecosystem occurred.

The Aleutian archipelago is a 1900 km island chain extending westward from the Alaska peninsular. These remote physical similar volcanic islands support 29 species of breeding seabirds, >10 million individuals that deliver nutrient rich guano from productive ocean waters to the nutrient limited plant communities. Seabirds inhabited most of the >400 island chain but following the collapse of the maritime fur trade in the late 19th and early 20th century, foxes were introduced as an additional source of fur. Several of the islands remained fox free either due to no introductions or failed introductions. Thus a large-scale experiment was begun over 100 years ago similar to the colonization of the Australian mainland with introduced predators (fox, dingo/wild dog) to the exclusion of Tasmania.

Croll *et al*. (2005) used the Aleutian Islands 'experiment' to show how differing seabird densities on islands, with and without foxes, affected soil and plant nutrients; plant abundance, composition, productivity; and nutrient flow to higher tropic levels. The results are based on the comparison of 18 islands (nine with foxes and nine fox free) matched for size and location on the archipelago. They found that breeding seabird densities were almost two orders of magnitude higher on fox free islands than on fox infested islands. The reduction in seabird abundance translated to a decline in annual guano input from 361.9 g to 5.7 g per square metre. This difference in marine nutrient input was reflected in soil fertility with the total soil phosphorous on fox free islands being three times greater than fox infested islands. They also noted that although sea bird colonies are on the perimeter of island, guano derived nutrients are broadly redistributed across islands and not solely concentrated within the colonies. The differences from guano deposition were reflected in strong shifts in the biomass and nutrient status of terrestrial plants. Grass biomass was three times higher, on the fox free islands where grasses dominated whereas fox infested islands were less productive with changes to the normal distribution of grasses, shrubs, and forbs occurring. Fox free islands where strongly subsidized by marine derived nutrients, which inturn assisted in fuelling the ecosystem at higher trophic levels. Croll *et al.* (2005) looked at the effect of artificially fertilizing sites on fox infested islands and demonstrated that the input of fertilizers in trial plots created plant responses similar to the effect of guano induced changes from seabirds on fox free islands. The results from Croll *et al.* (2005) showed that the introduction of foxes to the Aleutian archipelago transformed the island from grassland to maritime tundra. They suggested; 'there is growing evidence that the flow of nutrients, energy and material from one ecosystem to another can subsidize populations and influence the structure of food webs'.

In Australia, introduced predators can impact on the survival of native prey (Saunders *et al*. 1995 and Kinnear *et al.* 2002) and these effects can occur over large areas of entire ecosystems. Kinnear *et al.* (2002) in the seminal work 'The red fox in Australia—an exotic predator turned biocontrol agent' expressed; 'That the introduced fox (*Vulpes vulpes*) might reasonably be classified as a keystone species that qualifies as a 'diversity-reducing' predator. The impact of the red fox in concert with habitat degradation can be more fully appreciated, if the red fox were recognized for what it really is—an exotic predator, pre-adapted to assume the role of a biocontrol agent. Thus loss of native habitat and fox predation may be jointly proximate—that is, both habitat restoration and predator control, may be needed to produce a positive population response for endangered flora and fauna species'.

There is need to identify and to assess the risk to all species of wildlife posed by the red fox and we suggest that the effect of the red fox on native wildlife may inturn effect plant communities. Red foxes have eliminated or severely impacted on the distribution and density of many native animal species that interact; feed upon and are involved in the movement of plant/fungal material. The loss of potoroos, bettongs, numbats, bandicoots, wallabies, and quolls may have a cascading, as yet unquantified effect on plant diversity and survival.

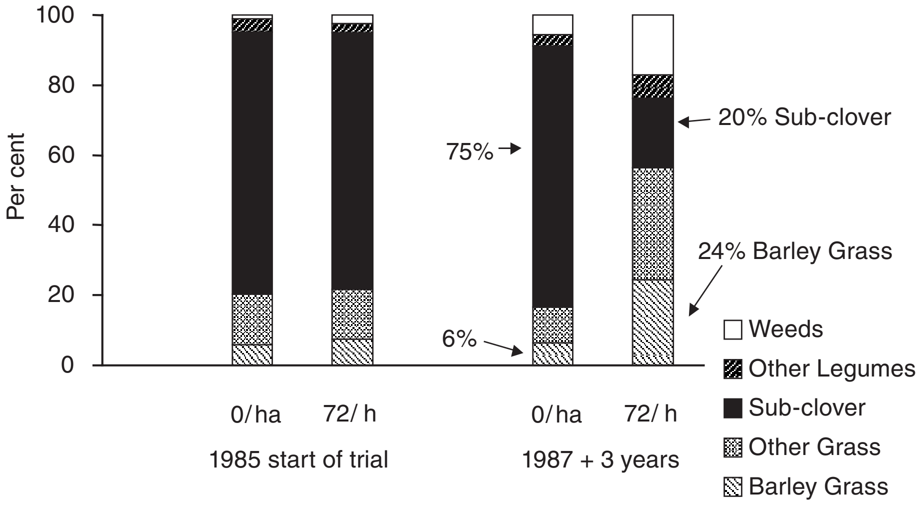

Figure 1. The change in pasture composition, after three years, for grazing plots stocked with eight merino wethers per hectare and supplemented with either no rabbits or with 72 rabbits per hectare.

Pest animal's role in the spread of weeds

Rabbits as vectors of seeds

It has been established that animals may spread plants when seeds become attached to their bodies or by ingesting seeds at one location and defecating them at another location (endozoochorous seed dispersal).

Spanish researchers Marlo and Suarez (1995) studied the dispersal of herbaceous seeds after ingestion and distribution in faeces of herbivorous mammals. The dispersal of seed via the digestive tracts of rabbits, fallow, red deer, and cattle were examined in a Mediterranean climate near Madrid in Spain. Dung seed content was determined by glass house cultivation of samples collected at fortnightly intervals between February and August 1990. The seeds of a large number of the Mediterranean herbaceous species survived herbivore ingestion. The density of germinated seeds and the number of species collected from the dung of the four herbivores were considerably high. The seeds of 107 plant species were collected from the dung of the four herbivores, with rabbit dung containing 52 species, red deer 66, fallow deer 67 and cattle 78. Species richness, the number of different species found in a sample followed a similar pattern for rabbits 17, deer 20, and cattle 25. The number of seeds dispersed in herbivore dung was high. Taking excrement density and defecation rates into account a rabbit can disperse around 500 seeds per day, a fallow, or red deer 20 000 and cattle over 300 000. The authors concluded; 'Herbivores are powerful seed vectors though their relative importance compared with other modes of seed dispersal is most likely understated'.

The relevance of these studies to grazing systems is important, as a large number of these herbaceous species of Mediterranean origin are invasive species on the Australian continent. The Spanish studies indicate that rabbits, deer and domestic livestock have the potential to be major contributors to the dispersal of seeds for the maintenance and distribution of invasive weeds.

The rabbit and the warren: contribution to the spread of weeds.

The contributions rabbits make to soil fertility were examined in a semi-arid site in the south-east of Spain. Soil fertility was assessed using barley plants grown in soils collected from within or isolated from rabbit latrine sites (dunghills). Soil from latrine sites grew a greater biomass of barley than soil collected from non-latrine sites. Soil from the latrine sites also had higher concentrations of organic soil nutrients. The authors suggested; 'Although latrine sites comprise approximately 0.1% of the ground surface area of warren systems they make significant localized contributions to soil fertility and therefore may be important in establishing and maintaining plant cover' (Willot *et al.* 2000).

There is strong anecdotal evidence that warren areas seasonally support the growth of dense patches of weeds such as horehound, nettles, and thistles. The warren is the centre of the feeding activity and the areas around warrens are stripped of nutritious plants. Feeding rabbits bare the soil surface around the warrens and their scratching behaviour tills the surface. The density of latrine sites is also greatest around the warren systems, so rabbits not only till the soil they fertilize it as well. Rabbits routinely feed away from the warrens and on their return bring a wide variety of seeds back to the nutrient rich, warren areas for cultivation. The intense grazing around the warren areas removes the more desirable plant species and allows the less palatable weed species to flourish. Weed covered warrens then provide foci for the spread of weeds into the surrounding areas.

Foxes as vectors of seeds

Among many other items, the scats of foxes contain the remnants of fruit and berries from native and introduced species. Introduced plant species found in fox scats include boxthorn (*Lycium ferocissimum*), sweet briar (*Rubus rubiginosa*), blackberry (*Rubus fruticosus* agg.), (Bloomfield personal communication). Foxes are presumed to be legitimate dispersers of seeds for they can consume and defecate viable seeds. The passage of time for a seed to pass through the digestive system of an Arctic fox ranged between 4 to 48 hours (Graae *et al.* 2004). If this time scale is similar for the red fox in Australian then this allows enough time for seeds to be distributed over the various locations of the home range and over greater distances when foxes are migrating. A studied carried out in Chile (Bustamante *et al*. 1992) showed that seeds defecated by the native fox (*Dusicyon culpaeus)* had higher germination rates than control seeds. But in the field the foxes deposited seed in habitats not favouring germination and survival.

Feral pigs as vectors of seeds

Feral pigs occupy a wide range of habitats in Australia, including the subalpine grasslands, forests, semi-arid floodplains, rainforests, and dry woodlands. The cost of feral pig damage to agricultural production is at least of the order of $100 million annually and it may be considerably more. They prefer moist areas that provide a reliable and adequate supply of food, water, and cover for seclusion and protection from extremes of temperature. The plant items eaten by feral pigs in Australia vary from region to region, but include many species such as; sweet briar (*Rubus rubiginosa*), *Acacia* spp., *Portulaca oleracea*, grasses, legumes including introduced clovers and lucerne, *Paspalum paspaloides*, *Poa* spp. and sedges, rushes such as *Eleocharis* spp., *Cyperus rotundus*, *Setaria sphacelata*, *Phragmites* spp., *Typha* spp., *Scirpus* spp. and *Juncus* spp.; bracken (*Pteridium esculentum*), dock (*Rumex* spp.), thistles (Family Asteraceae), native geranium (*Geranium solanderi*) and *Oxalis* spp. They also consume underground fungi and animal material (Choquenot *et al.* 1996).

Although feral pigs are often regarded as having deleterious effects on the environment, very little objective information on their impact is available. The most important environmental impacts they are likely to have are habitat degradation through selective feeding, trampling damage and rooting for underground parts of plants and invertebrates. Their impact on plants is largely unknown, as is the extent of their role in eating or dispersing seeds. The viability of seeds from pig droppings is largely untested in Australia. There is mounting evidence of pigs spreading rootrot fungus (*Phytophthora cinnamomi*). (Choquenot *et al.* 1996).

Similarly, extensive trampling or rooting of vegetation or the ground by pigs and the succeeding invasion of weeds may be dramatic evidence of the presence of pigs, but may not necessarily be important in terms of the long-term processes of plant dynamics or community structure. Alexiou (1983) found that the areas of sub-alpine vegetation most susceptible to damage by pig rooting at Smokers Gap, in the Australian Capital Territory, were along drainage lines, in depressions and around grassy flats. About 32% of these areas showed signs of pig damage. Revegetation was slow and the dominant grassy vegetation and some small native herbs were greatly reduced in abundance at disturbed sites. Feral pigs have also damaged the Strzelecki National Park on Flinders Island (Statham and Middleton 1987). Extensive rooting in the moist rich gullies led to erosion, loss of regenerating forest plants and their replacement by thick, impenetrable stands of bracken fern (*Pteridium esculentum*).

The effect of pigs on rare or endangered plants and on plant succession in Australia, however, is unknown. Feral pigs are likely to eat a much greater range of fruits and seeds than has been reported, but the viability of the seeds in pig faeces may depend on the size of the seeds, the feeding behaviour of the pigs and where the faeces are deposited. However measuring or identifying environmental impact by feral pigs can be difficult.

Shooters relocating feral pigs

Feral pigs are commonly translocated by shooters to provide pig hunting in their local area or to cause upset to public land managers. Feral pig populations close to urban areas are often sustained by an almost continuous supply of pigs from other areas particularly New South Wales. This behaviour of shooters increases the opportunity for the introduction of weed species via the dung of pigs, being carried on their bodies, and of course via the vehicles used in the translocation.

How do weeds respond to pest animal control?

The management of pest animals generally focuses on the species being controlled without fully considering the consequences of removing pest animals from complex ecosystems. For either native and exotic animals or plant species there are complex predator prey interactions combined with herbivore and plant interactions. Traditionally, pest animal control operations concentrated on removing the target animals and measuring their decline due to treatment. The modern pest animal manager is aware of the need to monitor impacts of the control operation on the ecosystem but is poorly resourced to do so.

The complexities of the impact of invasive species removal on whole-ecosystems were explained in one review by Zavaleta *et al*. (2001). Describing the herbivore and plant interactions the authors stated: 'When exotic herbivores and plants co-occur, the removal of the herbivores can lead to an increase in the productivity of exotic plants. Where exotic herbivores had been removed from islands, the resulting resurgence of exotic plants did not always benefit native vegetation'. Included are some examples of unfavourable exotic plant response to the removal of exotic animals cited in the review:

1) Rabbits eradication on Round Island, Mauritius, led to the recovery of endemic plants and reptiles but caused the expansion of a previously sparse exotic grass.
2) Asiatic water buffalo were eradicated from Kakadu National Park resulted in regeneration of the wetlands. But exotic plant species also proliferated with one particular species, parra grass, now covering approximately 10% of the flood plain.
3) The removal of feral pigs, sheep and goats from lowland-grasslands in Hawaii, allowed some native plant species to recover but the cover of flammable exotic grasses caused an increase in the frequency of fires and a loss of native woodland and forests.

Without sufficient planning, successful control or eradication programs can have unwanted and unexpected impacts on native species and ecosystems (Zavaleta *et al*. 2001). Where pest animal control affects native and exotic species the impact should be monitored and the monitoring processes included as an integral component of pest animal management strategies.

Gaps in knowledge

- The affect of rabbit feeding and seed dispersal in Victoria ecosystems.
- The affect native animal species have on the ecology and biology of native and introduced plant species.
- The affect fox predation has on native animal species in Victoria and the relationship with introduced and native plant species.
- The affect introduced animal species have on introduced and native plant species in Victoria.

Recommendations

Initial recommendations would involve informing the public and land managers of private and public land of the impacts of introduced wild herbivores on the natural and agricultural environment. And where pest animal control affects native and exotic species the impact should be monitored and the monitoring processes included as an integral component of pest animal management strategies.

References

Alexiou, P.N. (1983). Effect of feral pigs (*Sus scrofa*) on subalpine vegetation at Smokers Gap, Australian Capital Territory. *Proceedings of the Ecological Society of Australia* 12, 135-42.

Bomford, M. and Hart, Q. (2002). Non-indigenous vertebrates in Australia. *In* Biological invasions – economic and environmental cost of alien plant, animal and microbe species, ed. D. Pimentel (CRC Press).

Bustamante, R.O., Simonetti, J.A. and Mella, J.E. (1992). Are foxes legitimate and efficient seed dispersers – a field test. *ACTA Oecologica – International Journal of Ecology*, 13(2), 203-8.

Shea, K. and Chesson, P. (2002). Community ecology theory as a framework for biological invasions. *Trends in Ecology and Evolution* Vol. 17, No. 4 April.

Choquenot, D., McIlroy, J, and Korn, T. (1996). Managing vertebrate pests: feral pigs. (Bureau of Resources Sciences Australian Government Publishing Service Canberra).

Croft, J.D., Fleming, P.J.S. and van de Ven, R. (2002). The impact of rabbits on grazing system in eastern New South Wales. 1. Ground cover and pastures. *Australian Journal of Experimental Agriculture* 42, 909-16.

Croll, D.A., Maron, J.L., Estes, J.A., Danner, E.M. and Byrd, G.V. (2005). Introduced predators transform subarctic islands from grassland to tundra. *Science* 307, 25 March 2005 1959-1961.

CSIRO (2006). Ecology and Management of Australian Weeds Website:- http://www.csiro.au/csiro/content/standard/ps13b.

Fleming, P.J.S., Croft, J.D. and Nicol, H.I. (2002). The impact of rabbits on grazing system in eastern New South Wales. 2. Sheep production. *Australian Journal of Experimental Agriculture* 42, 917-23.

Graae, B.J., Pagh, S. and Bruun, H.H. (2004). An experimental evaluation of the Arctic fox (*Alopex lagopus*) as a seed disperser. *Arctic, Antarctic and Alpine Research* 36(4), 468-73)

Kinnear, J.R., Sumner, N.R. and Onus, M.L. (2002). The red fox in Australia—an exotic predator turned biocontrol agent. *Biological Conservation* 108, 335-59.

Marlo, J.E. and Suarez, F. (1995). Herbivorous mammals as seed dispersers in a Mediterranean dehesa. *Oecologia* 104, 246-55

Saunders, G., Coman, B., Kinnear, J. and Brayser, M. (1995). Managing vertebrate pests: foxes. (Department of Primary Industries and Energy. Australian Government Publishing Service Canberra).

Schoener, T.W. and Spiller, D.A., (1996). Devastation of prey diversity by experimentally introduced predators in the field. *Nature* 381, 691-94.

Statham, M. and Middleton, M. (1987). Feral pigs on Flinders Island. *Papers and Proceedings of the Royal Society of Tasmania* 121, 121-24.

Willott, S.J., Miller, A.J., Incoil, L.D. and Compton, S.G. (2000). The contribution of rabbits (*Oryctolagus cuniculus* L.) to soil fertility in semi-rid Spain. *Biology and Fertility of Soils* 31(5), 379-84.

Zavaleta, E.S., Hobbs, R.J. and Mooney, H.A. (2001). Viewing invasive species removal in a whole-ecosystem context. *Trends in Ecology and Evolution* 16(8), 454-9.