Rabbits and Native Plant Biodiversity

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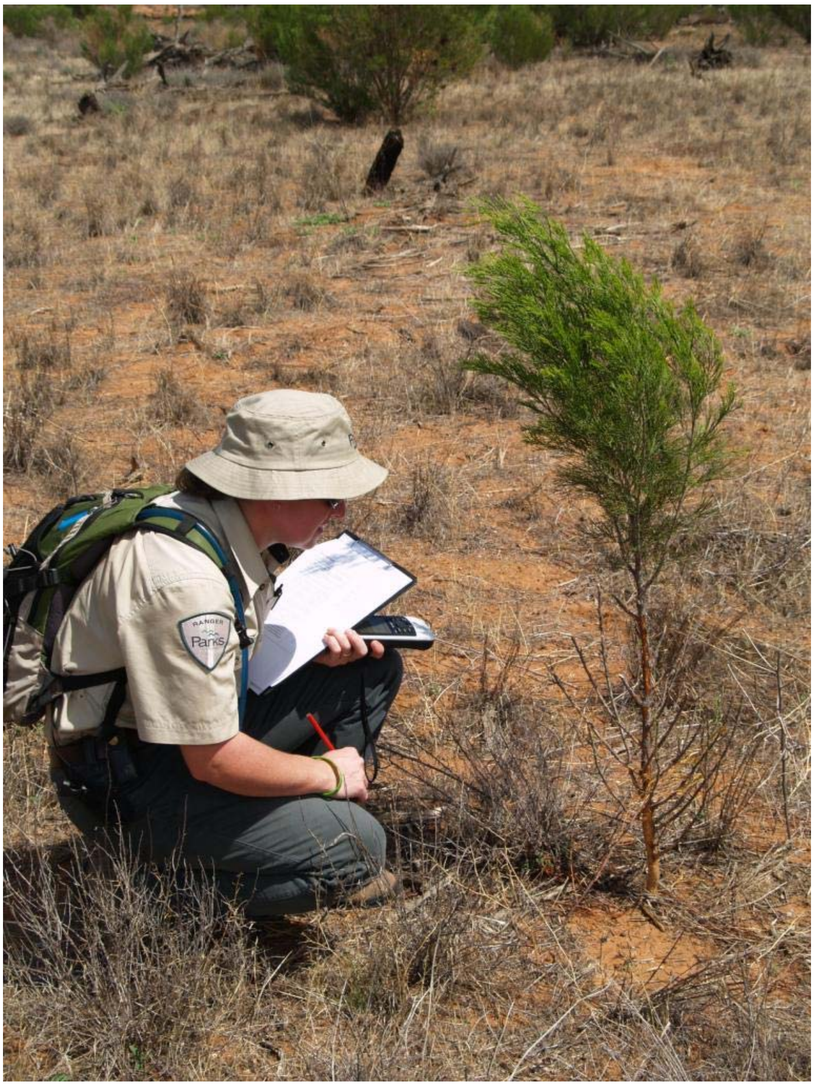

Parks Victoria Ranger Danielle Southon examining a native pine damaged by rabbit

Rabbits and Native Plant Biodiversity

A report complied for Australian Wool Innovation and Meat and Livestock Australia as part of the Invasive Animals Co-operative Research Centre Project 7.T. 6 - Biodiversity Impact of Rabbits

August 2007

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Executive Summary

A literature review of the impact of rabbits on Australian vegetation and ecosystems highlighted the effects of rabbits on a wide range of native trees and shrubs. By removing seedlings and promoting weeds rabbits are a significant factor contributing to native vegetation decline and biodiversity loss.

Despite rabbits having been kept low for some years by Rabbit Haemorrhagic Disease, a survey of remnant vegetation at 220 sites adjacent to farmlands in south-eastern Australia indicated that rabbits were present in 54% of sites visited and were causing noticeable vegetation damage in 26% of sites (i.e. about half the infested sites). Rabbits are more widespread in south-eastern South Australia, western Victoria and Tasmania than in eastern Victoria, New South Wales and south-east Queensland.

A major result from this survey is that low numbers of rabbits (1 - 2/ha) are capable of removing all seedlings of the more palatable native tree and shrubs and exacerbating weed competition with native flora. However, most land managers are not aware that a problem exists except where acute rabbit damage is observed.

Data obtained during the survey have been used to develop and calibrate rapid methods for scoring rabbit abundance and vegetation damage. This has enabled development of an assessment tool that land managers can use to quickly reach a decision on actions necessary for reducing rabbits and maintaining biodiversity. It is applicable for native vegetation on roadsides, reserves and natural shrub-lands used for pasture. The method has been tested using Landcare groups, farmers and government agency staff and progressively improved to increase its robustness and practicality.

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Introduction

Rabbits are renowned pests of agriculture in Australia but their impact on natural biodiversity is not well understood. Ratcliffe (1948) raised general awareness of the rabbit's contribution to soil erosion and vegetation loss and observations on regeneration of native grasslands and shrubs followed in the wake of myxomatosis (e.g. Lines 1952). Nevertheless, one of the first detailed descriptions of rabbit impact on Australian shrubs, *Acacia cyclops* and *Myoporum insulare*, comes from South Africa where both the shrubs and rabbits were introduced to off-shore islands; Gillham (1963) describes the rabbits' impact, referring to the lack of seedlings and a distinct browse line on the lower foliage of older shrubs.

At about the same time, the University of Adelaide Botany Department, also recognized the impact of rabbits largely through studies of arid-zone vegetation in the T.G.B. Osborn Reserve (formerly the Koonamore Vegetation Reserve) in north-eastern South Australia. Hall et al (1964) experimentally demonstrated that rabbits prevented regeneration of mulga *Acacia aneura* in the reserve. Crisp and Lange (1976), Lange and Purdie (1976), Crisp (1978) and Lange and Graham (1983) subsequently expanded those studies showing that rabbits reduced the ability of many arid zone Acacias to regenerate successfully. Among these were: *Acacia papyrocarpa* (=*A sowdenii*), *A kempeana*, *A. oswaldii*, *A. burkitii*, and *A aneura*). Silander (1983) described a lack of regeneration of *Cassia (Senna) nemophila*, attributable to heavy rabbit grazing. Foran, Strong and Low (1985) confirmed that such impacts extended to other arid areas. In the Alice Springs district they found that *A kempeana* seedlings were rare in experimental sites that were subject to rabbit grazing.

In higher rainfall areas Johnston (1968) showed that rabbits damaged the seedling of white cypress pine *Callitris glaucophylla* in southern Queensland and Cooke (1987) demonstrated that rabbits prevented sheoaks *Allocasuarina verticilliata* from regenerating successfully in the Coorong National Park in coastal South Australia. Information continues to accrue, and Lord (2002) has recently provided information on the impact of rabbits on the endangered purple wood acacia *A. carnei*.

Rabbits are known to eat a wide range of native herbaceous plants, reducing biomass and biodiversity (Leigh et al 1987; Norman 1988; Kirkpatric and Bridle 1999), and proposals for the conservation of rare plants often include plans for protecting plants from rabbits. For example, Todd (2000) includes reducing rabbit grazing as part of the recovery plans for several taxa of terrestrial spider orchids *Caledenia* R Br.

Rabbit damage to herbaceous plants and tree seedlings may be obvious; characteristic scratching up of roots, secateurs-like severing of flower heads or twigs, gnawing of bark and browse-lines on foliage 40 - 50 cm above the ground are tell-tale signs. However, if freshly germinated seedlings are selectively eaten while still very small, damage may be completely overlooked. A lack of seedlings in a patch of remnant native vegetation seldom arouses curiosity and there may be little to suggest rabbits as a factor among many other potential causes. Nevertheless, a lack of regeneration inevitably leads to loss of plant diversity as old trees and shrubs die without being replaced by younger ones. The disappearance of trees and shrubs is most noticeable among palatable, short-lived species like acacias and casuarinas whereas long-lived, less palatable eucalypts may be more likely to persist.

Impact of rabbits on natural ecosystems

The slow disappearance of remnant native vegetation from roadsides and other reserves is often lumped together with general habitat loss and attributed to a variety of causes such as land-clearance or over-grazing without trying to distinguish the role of rabbits. Historically it is true that many factors contributed to loss of vegetation (Tiver and Andrew 1997; Spooner and Lunt 2004), but in trying to restore vegetation on roadsides where stock no longer graze or in paddocks being spelled to allow regeneration, the failure to consider rabbits as an obstacle to plant recruitment can lead to failure (Treloar 2006).

In arid pastoral areas of South Australia rabbits are known to retard regeneration of acacias such as Victoria wattle *A victoriae* and wide-spread recruitment usually occurs during occasional years of high rainfall when grazers have abundant herbage to eat and shrubs grow vigorously. After very wet years, such as 1973-74, cohorts of acacias of similar age dominated the landscape in parts of South Australia's Flinders Ranges for 15 – 20 years before senescing then disappearing from large areas (Cooke, pers obs).

There has been considerable debate about the relative importance of rainfall and grazing pressure as factors limiting regeneration. In inland Australia effective shrub recruitment is associated with a series of years of exceptionally heavy rainfall;Chesterfield and Parsons (1985) and Read (1995) showed that at Roxby Downs, in the driest part of Australia, regenerating seedlings of the white cypress *Callitris glaucophylla* died as drought intensified even if they were guarded from rabbits. He also showed that past regeneration was associated with uncommon, prolonged periods of above average rainfall. Nevertheless, this is not the case in more temperate climatic zones. Mutze, Linton and Greenfield (1998) recorded recruitment of Victoria wattle even during years of average rainfall in the Flinders Ranges National Park, and the recent regeneration of buloke *Allocasuarina leumanii* in the Hattah-Kulkyne National Park following suppression of kangaroos and rabbits also occurred during a series of years of below average rainfall (Murdoch 2006). Evidence from rabbit-proof exclosure studies in the Coorong National Park (Cooke 1987) and at Kinchega, NSW (Denham and Auld 1995) showed that tree and shrub seedlings may become established even in years of average rainfall once rabbit grazing pressure is removed.

In temperate southern Australia at least, adequate control of rabbits would allow for more frequent recruitment of trees and shrubs and more stable ecosystems would clearly result. The preservation of a normally functioning ecosystem should be the aim of managing larger areas of natural vegetation. Murdoch (2005) has recently shown that individual bulokes in the Hattah-Kulkyne National Park have unique genomes and there is little evidence of clusters of genetically identical trees or clones. This means that prior to European settlement the buloke population was maintained by germination from seed and not by development from root suckers as widely thought. A natural, self-maintaining population of bulokes maintained by regeneration from seed should therefore be the preferred management goal rather than using hand planting or induction of suckering around old trees to maintain a population.

Species such as drooping sheoak *Allocasuarina verticilliata*, are not only highly palatable to rabbits but also to domestic stock. Consequently, seedlings stand little chance of survival where rabbits and sheep or cattle exert heavy grazing pressure. Additionally, the adult trees are relatively short-lived, surviving for perhaps a century. As a result, these trees have disappeared from huge tracts of land since European settlement in the 1800s. On the western side of Eyre Peninsula for example, former sheoak woodlands have disappeared (Bishop and Venning 1986), leaving the country open and bare.

Obviously, the loss of these extensive woodlands was not caused by rabbits alone. Deliberate clearing and fires as well as grazing are to blame. Nevertheless, the potential severity of uncontrolled rabbit grazing must be allowed for when considering how these woodlands might be restored. The management of livestock alone to reduce grazing pressure is unlikely to be enough if rabbits remain unchecked. Following experiments in the Coorong National Park, Cooke (1987) suggested that as few as 3 or 4 rabbits/ha could remove all the sheoak seedlings. However, more recent work carried out in the same area (P. Bird, Animal and Plant Control Group, SA, pers comm.) showed that, even after extensive rabbit control and the arrival of rabbit haemorrhagic disease had lowered rabbit density to about 1 rabbit/ha, unguarded sheoak seedlings still failed to survive although 60% of seedlings protected by rabbit-proof guards survived. The few sheoaks that regenerated naturally in the area while rabbits were kept low did so because they germinated and grew up in the protection of less palatable shrubs such as coastal wattle (*Acacia longifolia sophorae*). Seedlings of Sweet Bursaria *Bursaria spinosa* a common under-story shrub in sheoak woodlands are probably less palatable than sheoaks but in the Coorong experiments their seedlings also failed to survive unless protected from rabbits.

While most literature concerns the impact of rabbits on perennial vegetation, possibly because it is easy to see, there is clearly a flow-on to other native plants and animals reliant on that vegetation. This was perhaps best shown by events that followed the spread of Rabbit haemorrhagic Disease (RHD) across Australia.

Davidson (2002) has neatly summarized many of the relevant details yet omitted one remarkable example, a sudden abundance of the native hopping mouse *Notomys alexis* over large areas around Roxby Downs in South Australia, where it had never been recorded before (Read 2003). Massive seed set by perennial grasses seems to have been the key.

Much of the information available is in the ‘grey’ literature, obtainable only from internal reports and the internet. Mutze and Linton (n.d.), for example, considered the impact of rabbit grazing on regeneration in the Flinders Ranges National Park and an adjacent sheep station. Rabbit control by warren ripping and follow-up fumigation reduced total grazing pressure by 30%. Kangaroos, mainly red kangaroos and euros, moved onto experimental areas freed from rabbits reaching twice the numbers seen on nearby areas where rabbits remained. Sheep responded more slowly. When RHD arrived, sheep and kangaroos spread out to graze across the whole area once again.

Bird and Mutze (n.d.) indicate that control of rabbits in the Coorong National Park by poisoning, ripping and fumigation resulted in an increase in biomass of perennial grasses at the expense of introduced annual weeds. Western grey kangaroos and common wombats increased 3- and 7-fold respectively. After RHD arrived, kangaroos dispersed and wombats continued to increase in areas they had re-colonized. Nevertheless, recovery of rabbit numbers over the last 3 years and associated overgrazing has seen the wombat population decline once more.

In the Coorong National Park RHD was thought to suppress rabbits mainly over the winter-spring period although there was improved survival of young rabbits in the population in summer presumably because summer food shortage was no longer severe. This meant that annual plants that flower in spring (e.g. orchids) benefited from RHD more than the seedlings of perennial shrubs. Orchids increased 8-fold in abundance when rabbits were suppressed.

Rabbit impact on tree regeneration also flows through to bird populations and insect populations. Examples can be provided that link the loss of the glossy black cockatoo *Calyptorhynchus lathami halmaturinus* from mainland South Australia to the loss of sheoak woodlands in which rabbits probably played a significant role (Joseph 1989; Pepper 1997). There are more complex relationships such as the interdependence between spiny-cheeked honey-eaters and mistletoes that parasitize arid zone acacias and these in turn can be affected by the dynamics of acacia populations (Read 1990; Lavorel et al 2004).

Remnant native vegetation in farmlands is also important as a refuge for native mammals (Bennett 1988). However, these habitats can quickly lose their complexity, as a result of loss of acacias from the under-storey for example, leading to a breakdown of normal ecological processes.

Importance of Remnant Native Vegetation in farmlands

Lockwood et al (2000) surveyed land-holders in north-eastern Victoria and the Riverina in New South Wales to assess their perceptions of the benefits of native vegetation as part of an economic study of vegetation conservation on private property. The responses show that remnant vegetation is seen as an asset but there are also costs that were not accounted for in the survey. For example, in the table it is clear that, despite increased agricultural production being listed highly, this did not apply to crop production. ‘Habitat for animals which control pests’ generally relates to insect predators and some respondents made reference to native vegetation harbouring both pest animals and those that control pests.

Table 1. Perceived on-farm benefits of remnant native vegetation**.**
(From Lockwood *et al* 2000)

Benefit	**Victoria (% participants [a])**	**New South Wales (% participants [a])**
Aesthetics	89	95
Timber for firewood and fencing	86	68
Increased agricultural production	77	73
Recreation	73	54
Habitat for animals which help control pests	69	61
Increased stock production	62	84
Cleaner water	60	49
Nutrient recycling/ soil formation	45	42
Other	37	38
Increased crop production	0	25
No benefits	0	0

[a] More than one alternative could be selected by each participant.

The survey information indicates general public interest in retaining native vegetation as an important part of rural landscapes and this is reinforced by legislation protecting vegetation on roadsides (e.g. the Victorian "*Planning and Environment Act 1987"*) and management plans and by-laws developed by regional councils, see for example Harden Shire. ACT State of the Environment Report 2004, ACT Commissioner for the Environment.

Among listed threats to remnant vegetation communities are:

- weed invasion
- weed control
- grazing and trampling by stock
- erosion and sedimentation
- road maintenance
- communications, power, water and gas supply
- pest animals
- harvesting of firewood
- waste disposal and dumping
- high frequency or high intensity fires
- salinity
- climate change.

Clearly rabbits are only one factor among many that cause vegetation degradation and add to the fragmentation of remnant plant communities. However, there are examples in the literature showing specific concerns about rabbits. Phillimore and English (1999), for example, considered that in the Geraldton area of Western Australia rabbits were a major threat to the endangered Scaly-leaved Feather Flower (*Verticordia spicata*) because of "*warren construction and increased nutrients and weeds from rabbit droppings as well as browsing.*"

Lack of recognition of rabbit problems

To manage natural vegetation in conservation reserves, national parks, pastoral land, farms and road and water reserves, it is important to have a simple method for asking whether or not rabbits are reducing biodiversity and deciding if rabbit control is needed. This is immediately apparent if recent events in the Hattah-Kulkyne National Park are considered. Despite achieving enormous conservation gains in the years following the spread of RHD when rabbits were low and kangaroos well managed, the impact of resurgent rabbits from 2003 onwards went largely unnoticed and within two years many of the gains in pasture regeneration since 1996 had been reversed. Even in early 2007 effective measures had not been taken to again reduce rabbits to the levels at which the buloke-pine ecosystem could function normally and improve through natural recruitment.

While the problem in Hattah-Kulkyne National Park provides a well documented case history, it is clear that a similar situation applies in farming areas in central and north-western Victoria and adjacent areas of South Australia where rabbit numbers have steadily increased in recent years. Farmers have scrambled to rip warrens and protect crops but there is little evidence of systematic rabbit control work specifically to protect other assets such as remnant native vegetation. Even in some areas where direct seeding and tree planting has been implemented to re-establish natural vegetation, all too often community groups have been unaware that rabbits have undone their efforts.

Rabbit abundance

Although spotlight counts from a moving vehicle, counts of active entrances in rabbit warrens and other assessment methods are commonly used to compare rabbit populations in Australia, signs of rabbits such as faeces, latrines or 'buck heaps', tracks, scratches and rabbit burrows and warrens provide an instant confirmation of the presence of rabbits. Photographs of faeces, buck-heaps, scratches and warren entrances are provided (Appendix I).

Parer (1982) and Parer and Wood (1986) showed that the number of rabbits present on a site was related to the number of active warren entrances, although there was no simple linear relationship that could be applied throughout the year. Wood (1988) showed that the number of rabbit faeces detected in an area was related to the number of rabbits and the time they spent on the site. This was expressed as accumulated 'rabbit days'.

In rabbit control experiments that have used changes in the numbers of active warren entrances as a measure of treatment effectiveness it has been usual to use a log-conversion, i.e. *log* (active warren entrances +1), to normalize the data and reduce variance when estimating rabbit density (Cooke 1981, Cooke and Hunt 1987).

Clearly, when dealing with well established rabbit infestations, the abundance of rabbit faecal pellets and other signs depends on their conspicuousness and persistence. Rabbit faeces, for example, are known to persist for some time. Although they may be broken down by rain or eaten by termites, old weathered faecal pellets have been found in enclosures 3 years after rabbits were excluded. The presence of very fresh rabbit pellets on a site might indicate current infestation levels but taking all pellets into account, whether fresh or old, simplifies procedures and gives a more comprehensive picture of the density of rabbits over the past year. By contrast, in light sandy soil, rabbit scratches may remain recognizable only until the first strong wind or heavy rain. Rabbit warrens are persistent but it may be difficult to assess their size if they are covered by bracken, blackberries or coastal acacia.

A few minutes spent on an area can usually enable an assessment of whether rabbits are absent or present and whether they are relatively scarce or abundant. Setting a few simple rules for scoring rabbit sign enables infestations to be quickly ranked on a scale of 0 to 5.

Rabbit damage

On a single visit to a site rabbit damage to pastures or ground cover may be easiest to detect where rabbits have over-grazed areas around their warrens. Weeds tend to proliferate on the warrens while on less heavily used areas some native perennial grasses or shrubs may persist.

Eldridge and Myers (2001) showed that at Yathong Nature Reserve there was lower plant diversity on rabbit warrens than on the areas around them. Rabbit grazing removed palatable plants in an area radiating out from the warren and unpalatable weeds such as horehound *Marrubium vulgare* came to dominate the warrens.

Table 2. Diversity of plant species associated with rabbit warrens at Yathong Nature Reserve (after Eldridge and Myers 2001). Introduced species were mainly unpalatable weeds.

Plant Species	Warren mound	Grazed area	Ungrazed areal	Total
Native	8	17	21	**26**
Introduced	9	7	6	**9**
Total	**17**	**24**	**27**	**35**

The major point to make about these results is that biodiversity of native plant species on the warren mound was severely reduced from 21 to 8 species (about 60%) and introduced weeds had increased from 6 to 9 species (50%).

Eldridge (2006) continued the work and extended observations to the recovery of vegetation on ripped rabbit warrens. He found that although vegetation quality had improved it had not resumed the level seen further away from the warren site. Eldridge suggests that such restoration of the original woodland vegetation after warren ripping is likely to be a very slow process. On that basis, the weediness of sites reflects the past history of rabbit grazing as well as immediate impacts. Cooke (1998) showed that following rabbit exclusion from sites in the Coorong National Park it took several years for native herbs and spear grass (*Stipa* sp) to replace introduced weeds such as pimpernel *Anagallis arvensis* and rat's tail fescue *Vulpia myuros*.

Nevertheless, the impact of rabbits on quickly growing annual vegetation such as grasses, clover or weeds is difficult to assess unless it is severe. Furthermore, as annual pasture come and go across the year, they cannot be used as the basis for comparing levels of rabbit damage between sites visited at different times of the year.

For measuring rabbit impact on native biodiversity it is preferable to use tree seedlings or small shrubs that persist even during summer and tend to accumulate evidence of recurrent episodes of rabbit browsing.

Photographs in Appendix I show typical damage caused by rabbits. They show severing of twigs, gnawing of bark and typical browse lines about 400 – 500 mm above the ground. Where a clear browse line is seen it is usual that equally palatable herbage, ground cover and seedlings have been removed.

Damage to seedlings can be ranked despite changes in species composition although, where possible, widespread taxa known to be damaged by rabbits should be examined. These include *Allocasuarina,* different species of *Acacia*, *Bursaria spinosa*, *Senna* (*Cassia*) species. In contrast, *Eucalypt* seedlings generally appear to suffer relatively little rabbit damage and are poor indicator species.

As the data of Eldridge and Myers (2001) show, rabbits may promote weeds and these in turn may change soil conditions and inhibit or compete with new seedlings of native plant species. Scoring the weediness of sites is problematic in that weed species change quite dramatically across eastern and southern Australia. In Queensland for example, weeds can include species such as mother of millions (*Bryophyllum* spp) or prickly pear (*Opuntia* spp) whereas, in southern areas, blackberry (*Rubus fruticosus*), horehound (*Marrubium vulgare*), wild oats (*Avena fatua*) and even invasive pasture species such as *Phalaris* spp can be considered as weeds in the context of roadside vegetation. Despite this, 'weediness' can be scored in broad categories to help understand the extent of damage to native biodiversity.

A survey of rabbits and biodiversity in south-eastern Australia

For this survey, it was initially anticipated that an assessment of the impact of rabbits on biodiversity would include numerous sites on farmland. However, heavy livestock grazing, particularly during the drought of 2006, often overwhelmed the smaller impacts of rabbits. As a result, the decision was taken to concentrate on gaining a measure of the impact of rabbits alone.

Two hundred and twenty sites across south-eastern Australia were visited and assessed for rabbits. These were not randomly selected. Rather they were generally sites such as wide stock routes, interfaces between State forest and farmland, water reserves, creek edges and rail reserves which were considered large enough to support rabbits.

The objective was to obtain information on the effects of rabbits on natural biodiversity in a wide range of habitats. The minimum requirements were that (a) there were at least 2 ha land in which rabbits could persist and (b) enough remnant native vegetation persisted to allow an estimate of rabbit impact.

Some sites already being used to monitor rabbit populations were also visited. These were useful reference points for establishing that the quick survey methods gave a realistic picture of rabbit populations. However, these study sites were not included in subsequent analyses where we sought to obtain a picture of rabbit infestations in general.

At each site, 15 -20 minutes was taken to score rabbit abundance (0 – 5), weediness of the site (0 – 5) and estimate the biodiversity impact according to the abundance of seedling shrubs less than 500 mm high (score 0 – 5) and levels of rabbit damage (score 0 – 5). The location of each site was recorded using a Garmin hand-held GPS and photographs were taken to support a general site description as well as recording examples of rabbit damage.

Where possible the number of rabbit warrens on the surveyed site was recorded and the number of active warren entrances was counted or estimated using the average number of entrances recorded from a smaller subset of the warrens. When warren counts were made, the area surveyed was estimated using a GPS or calculated from the width of the vegetated road reserve and the length traversed as recorded from the vehicle odometer.

A data sheet in Appendix III summarizes the criteria used.

Where there was a marked transition across a survey site (e.g. a stony hill adjoining waterlogged flats), rabbit density scores and damage scores were often quite different for the two sections. The results were averaged to provide the best general overview of the site.

General survey results

Calibrating the rabbit abundance score

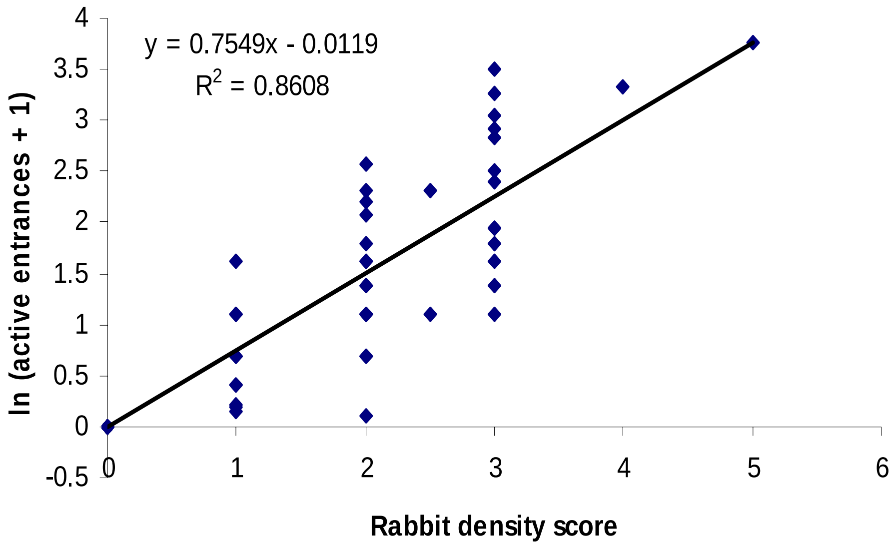
Although scoring the general abundance of rabbits on a scale of 0 to 5 provided a rapid means of comparing rabbit abundance on different sites, it was also important to have some idea of what each value represents in terms of the actual density of rabbit populations (rabbits / ha).

Where data on the numbers of warrens and active burrow entrances were collected this provided a means of calibrating the rabbit abundance score against specific measures of rabbit abundance (Parer 1982; Parer and Wood 1986). Sites were excluded from such calculations if warren entrances could not be accurately counted because of dense vegetation cover or because rabbits shared warrens with other animals such as wombats (*Vombatus ursinus*).

For those sites where warrens were found a simple regression was fitted to the data after log-transformation of the number of active warren entrances to normalize variance:

ln (Active warren entrances +1) = 0.7549* (faeces score) – 0.0119

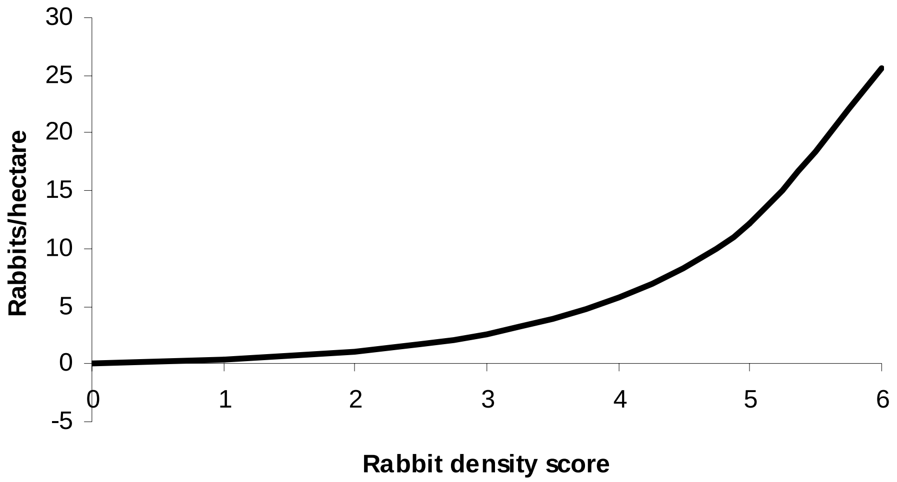
Figure 1. Relationship between visual rabbit density score and the number of active warren entrances/ha.



The median number of active warren entrances for each score value was then converted to an approximate density of rabbits using the relationship derived by Parer (1982) i.e. 1.6 active warren entrances/rabbit.

Figure 2 shows how actual rabbit density is likely to increase with the rabbit density score based on the abundance of rabbit faeces. Clearly, there is not a simple linear relationship and large errors and underestimation of rabbits is likely when the rabbit density score is high. Nevertheless, from a practical perspective, low rabbit abundance scores over the range of 0 – 3 are more sensitive, and these lower scores cover the critical area where rabbit damage first becomes noticeable.

Figure 2. Approximate relationship between rabbit density score and rabbits/ha.



Independent support for these estimates was obtained using data from other sources. For example, in the Coorong National Park, rabbit dung is collected from a series of quadrats in the Park each year and the annual rate of deposition calculated. From the amount of dung collected in February 2007 it was calculated that there were between 6 – 12 rabbits/ha on the site (G. Mutze and P. Bird unpublished). When the site was visited in March 2007, the density score given on the basis of obvious rabbit faeces was 5, corresponding to the maximum estimate made by Mutze and Bird.

Murdoch (in prep.) has recently confirmed that between rabbit abundance scores of 0 and 3 there are significant linear correlations between the score allocated on the basis of faeces distribution and both the number of active warren entrances/ha and the average counts of faeces obtained by randomly throwing a 0.25 m^2 quadrat 15 times.

Proportion of sites with rabbit infestations

Overall, rabbits were detected on 46% of the 220 sites visited during the survey. Infestation levels were low on a further 18% but rabbits were judged to be having some impact on biodiversity on a further 16% and a major impact on about 12% of sites.

Rabbits were found more frequently at sites in south-eastern South Australia (81% of sites) and western Victoria (70% of sites) than in eastern Victoria (30% of sites), eastern New South Wales (35% of sites) and southern Queensland (27% of sites). In Tasmania rabbits were recorded at 47% of sites visited.

Rabbits and weeds

Data collected in this study suggest that the presence of rabbits and the presence of weeds significantly correlated although the relationship is not strong ($R^2 = 0.100$). There are many sites that are heavily infested with weeds that are rabbit free. Nevertheless, all sites with abundant rabbits are also weedy and this is consistent with the idea that rabbits promote weeds. This is not unexpected given the observation that rabbits remove palatable species from pastures (Myers and Poole 1963, Croft et al 2002, Eldridge and Myers 2001) although rabbits may also heavily exploit some weeds as food sources (see Martin et al 2007).

Weed score = 0.395 (±0.080) * R + 1.553 (±0.114)

ANOVA	Degrees of freedom	Sum of Squares	Mean Square	*F* ratio	Probability
Regression	1	44.221	44.221	24.43	<0.001
Residual	219	369.386	1.810		
Total	220	440.606			

The situation becomes even more complicated when we look at regeneration of native tree and shrub species. Multivariate analysis of the survey data suggests that the prospects for regeneration are significantly reduced as rabbit numbers increase but the weediness of a site appears to have an even more powerful role.

The fitted equation:

Regeneration prospect = 4.107 (±0.147) – 0.313 (±0.080) *R – 0.715(±0.064) * W

Where R = rabbit faeces score and W = weeds score

ANOVA	Degrees of freedom	Sum of Squares	Mean Square	*F* ratio	Probability
Regression	2	302.78	151.39	93.05	<0.001
Residual	218	354.64	1.63		
Total	220	657.42			

It would require experimental work to determine whether the effects of rabbits are under-played. Nevertheless, it seems likely that while rabbit browsing may cause direct seedling loss rabbits may further exacerbate the lack of regeneration by disturbing the soil and encouraging competing weeds.

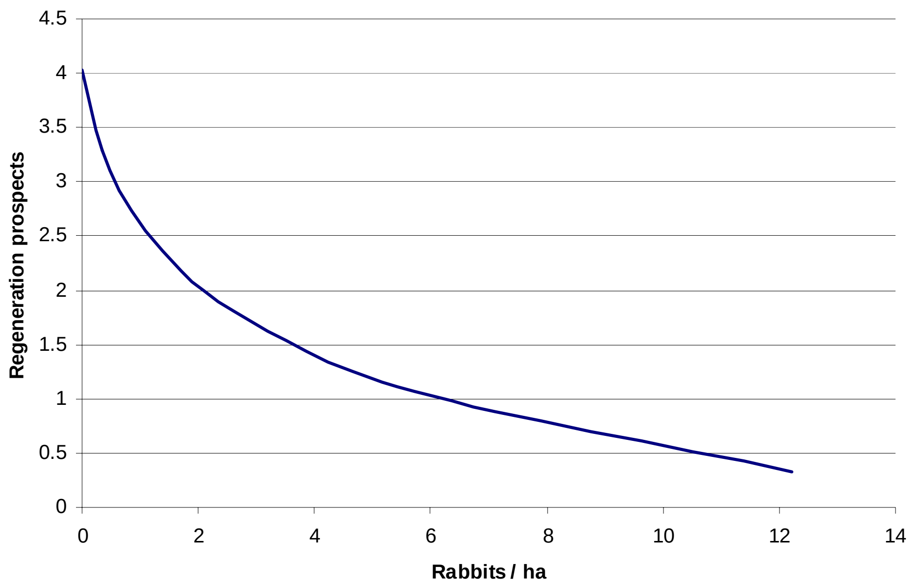
Care needs to be taken interpreting correlations of this kind. Weeds clearly spread independently of rabbits and rabbits may capitalize on degraded pastures, colonizing areas because of past damage. Additional variables such as rainfall and climatic zone (e.g. hot, low rainfall, warm, intermediate rainfall and cool, high rainfall) were also considered as explanatory variables but these were not found to be significant.

Damage as a function of rabbit abundance

Rabbits directly damage native vegetation but they may also have an indirect affect by promoting weeds and further suppressing regeneration. Indeed, regeneration prospects of native vegetation (Figs 3 & 4) were better explained using both rabbit and weed scores than the rabbit score or weed scores alone. To illustrate how rabbit impact changes with rabbit density (rabbits/ha), the curve in Figure 3 was derived starting with the high regeneration prospects in a rabbit and weed-free environment but assuming that weediness increases with rabbit abundance according to the relationship found between rabbit abundance and weed infestation levels.

Regeneration prospects are halved at an estimated 2 rabbits/ha and palatable species within reach of rabbits can be severely damaged especially during times of stress such as summer drought. Browse lines on palatable shrubs may sometimes be seen at this level of rabbit infestation (rabbit score 2 – 3) although becoming more apparent at higher population densities.

Figure 3. Curve showing how regeneration prospects for native shrub and tree seedlings are likely to decline with increasing rabbit density.



When regeneration prospects of native vegetation from each survey site are plotted against rabbit abundance scores a wide spread of data can be seen. For example, even when rabbits are absent, good recruitment of seedlings is by no means guaranteed; there are clearly other factors that inhibit regeneration of native shrubs and trees. Nevertheless, it is clear that as the rabbit abundance score increases the prospects for good recruitment fall away rapidly and recruitment prospects were very low where rabbit population density was scored at 5.

This variability in the data set was taken into account in developing the assessment tool (see Appendix I) and setting the criteria for deciding when rabbit control should be undertaken.

Figure 4. Recruitment prospects *vs*. rabbit density score. The chances of good recruitment of native shrubs and trees decline rapidly once rabbit density score exceeds 2. (~2 rabbits /ha)

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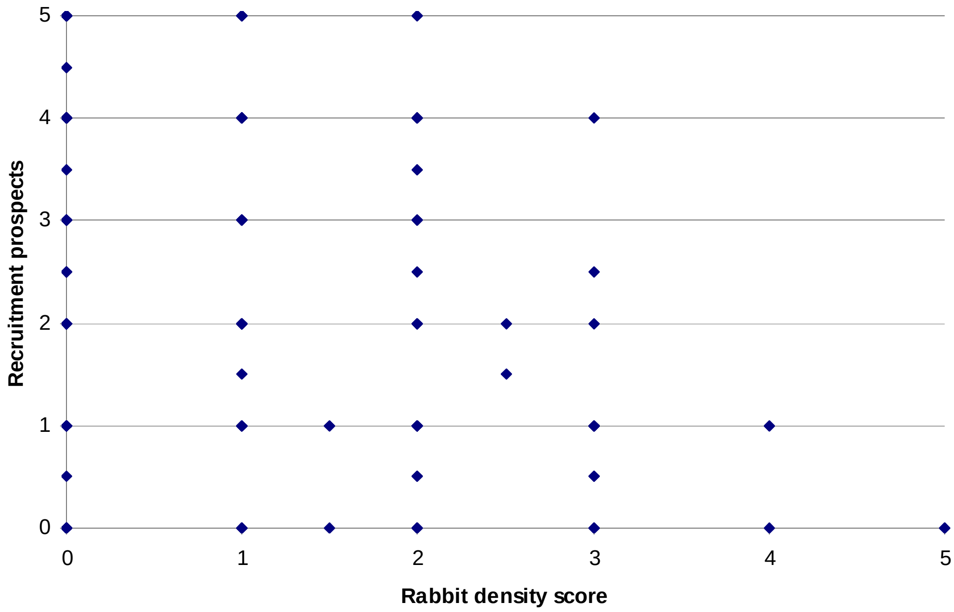


Biodiversity impact

From Figure 3 it is arguable that there is no ‘safe’ level of rabbits. We also know that species such as *Allocasuarina verticilliata* in sparse communities have little prospect of successful recruitment even with rabbits at about 1 rabbit/ha. However, where adult trees are dense, some seedlings survive.

A curve like that in Figure 3 would be expected given that some shrub and tree species are highly palatable, e.g. drooping sheoke (*Allocasuarina verticilliata*) and boobialla (*Myoporum insulare*), while others such as *Eucalyptus* spp are only eaten only during times of severe stress when rabbits are short of food.

It is implied that rare, very palatable species such as orchids would be at risk even from low densities of rabbits. Indeed, while collecting the data used in these analyses, orchids were only seen at sites where there were no rabbits.

Development of an assessment tool

Choosing reliable methods for assessing the size of rabbit populations is not just a matter of using measures that enable accurate comparison of rabbit numbers between sites or at the same site over time. Equally as important, these measures must also be readily understood by people with little previous experience in assessing rabbit problems.

Consequently, during developmental work, considerable effort was spent in assessing peoples' ability to read the tell-tale signs of rabbits such as faeces, scratches and burrows to estimate the relative size of rabbit populations. This was done by using groups of people including landholders, Landcare group members and government officers, including National Parks rangers, in practical trials. Steve McPhee took on the task of organizing groups and providing support for testing various versions of the assessment tool. By comparing the results of participants and obtaining feedback, the good points and usefulness of the methods as well as those parts of the methodology that proved confusing could be identified and readjusted as necessary.

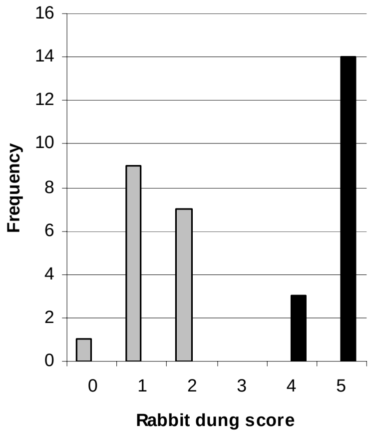
Perceptions of rabbit abundance

Many observers were not familiar with signs of rabbits and so, during preliminary description of the practical assessments, photographs of rabbit faeces, buck-heaps, scratches and signs of rabbit damage were shown (Appendix I). Examples were also drawn to the attention of observers at the beginning of practical exercises in the field.

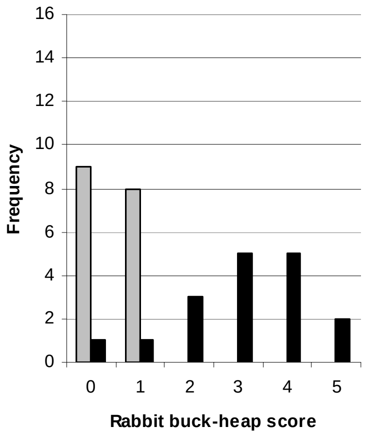
Observers were then asked to spend 15 minutes walking steadily around a defined 2 ha area and at the end of the time they scored their impressions of rabbit abundance on the site according to earlier versions of the criteria given in Appendix III.

As results in Figure 5 show, a total of 17 observers (Parks Victoria staff) scored contrasting rabbit populations known to be 'high' and 'low' and we assessed how well they discriminated between the two sites on the basis of different kinds of rabbits sign.

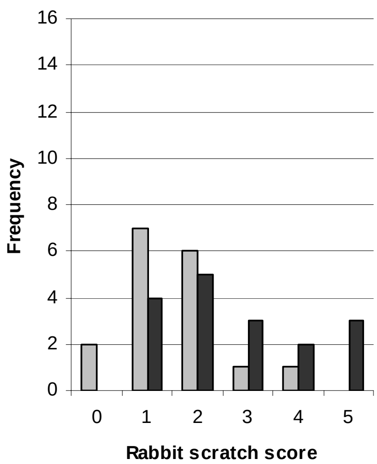
Figure 5. a, b and c. Perceptions of rabbit sign.



(a) Scores of 17 observers based on rabbit dung distribution on two sites. Good discrimination between high (black) and low (grey) rabbit infestations is shown by observers.



(b) Observer scores based on rabbit buck-heaps on the same two sites. Overlap between scores and scores of zero by several observers show that buck-heaps provide a relatively poor index



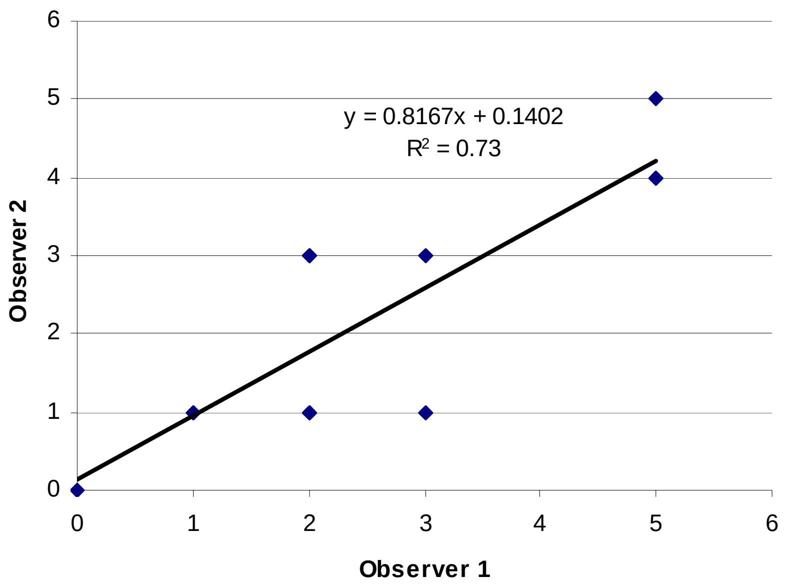
(c) Observers scores based on rabbit scratches on the two sites. There was poor discrimination. In areas where rabbits had heavily disturbed the soil, subsequent wind erosion and rain obscured older scratches that went unnoticed by many observers.

The results showed that the best discrimination was obtained using faeces score alone. The general results obtained showed that all observers clearly distinguished sites of high and low rabbit abundance.

Repeatability of observations

After a specific method was singled out for use as an assessment tool the robustness of its general use was tested by asking whether different observers obtained similar results when they assessed rabbit infestation levels on the same sites. Figure 6 shows results from two observers who each assessed the same 12 sites. The data were well correlated, the results obtained by one observer explained over 70% of the variance of the other's observations, and the intercept (close to zero) and the slope (close to 1) did not diverge too strongly from expectations.

Figure 6. Results obtained by two observers independently examining the same 12 sites to score rabbit abundance.



High correlations ($R^2 > 0.7$) were generally obtained between selected pairs of observers who examined a range of different sites, however there were exceptions. For example, R^2 values obtained for seven observers compared with the instructor were: 0.94, 0.91, 0.88, 0.86, 0.86, 0.54 and 0.18. The reason why two observers obtained results lower than the acceptable level of $R^2 > 0.7$ was not fully clarified. However, discussion following the exercise revealed ambiguities in the written instructions that needed correcting.

Detection of rabbit damage

Observers were asked to score the abundance of seedlings less than 0.5 m tall on two sites, one with relatively few rabbits (Buloke) and a second site (Stockyard) where rabbits were abundant. They were also asked to score the level of damage to the seedlings encountered. Comparison of pooled data from participants showed that in general their observations were grouped and, in the area where rabbits were most abundant, they generally recognized that there were fewer seedlings and that damage was more apparent.

Table 3. Number of observers scoring seedling abundance relative to seedling damage for high (Stockyard) and low (Buloke) rabbit abundance

Buloke

Seedling Abundance	Damage 0	1	2	3	4	5
0						
1			**2**			
2		**1**	**2**	**2**	**1**	
3		**2**	**3**	**3**	**1**	
4			**1**			
5						

Stockyard

Seedling Abundance	Damage 0	1	2	3	4	5
0					**1**	
1				**3**	**3**	**2**
2			**1**	**3**	**4**	**1**
3				**1**		
4						
5						

Interpretation of results

Generally, once a score of relative rabbit abundance is obtained, regenerating vegetation noted and observations of rabbit damage recorded it is possible to quickly assess a situation and reach clear conclusions about likely rabbit impact on biodiversity.

At one extreme, if there is little evidence of rabbits (rabbit abundance score = 0 or 1), damage to seedlings is minimal (seedling damage score = 0 or 1) and there are young trees and shrubs of all ages from seedlings to well established saplings, it is safe to conclude that rabbits are not reducing tree and shrub diversity.

At the other extreme, if rabbits are abundant (rabbit abundance score = 4 or 5), there is a rabbit ‘browse line’ on foliage of adult shrubs and no seedlings or only heavily damaged seedlings (seedling damage score = 4 to 5) are present it would be hard to remain unconvinced that rabbits were not reducing biodiversity.

Accumulated data from south-eastern Australia shows that rabbit impact varies from site to site but in general, at intermediate levels of rabbits (rabbit abundance score = 2 or 3), evidence of rabbit browsing on seedlings becomes more conspicuous.

It is important to note, nonetheless, that the method developed in this report does not replace detailed methods for monitoring rabbit populations or vegetation damage but rather, it provides a quick way of estimating the abundance of rabbits and asking if rabbits are likely to reduce the abundance and diversity of native vegetation in the long term.

Final review of assessment tool

After a series of trials using early versions of the assessment tool a final ‘draft’ version was tested in August 2007. The people who took part in this included an office assistant, a Landcare co-ordinator for a Catchment Management Authority, a former shire engineer, three farmers, a company manager, several officers from DSE and DPI Victoria and a rabbit control contractor. A total of 9 sites with a range of rabbit infestations and levels of damage were assessed by at least 4 people on each site.

Despite different levels of experience with assessing rabbit problems, all participants arrived at similar conclusions about the rabbit infestations they surveyed, i.e. on some sites it was generally agreed that rabbit control should be implemented while on others there was a general uncertainty that rabbit control was necessary.

In areas where the management tool indicated that rabbit control should be implemented, the participating land-holder or rabbit control contractor had often formed the same opinion, quite independently, prior to the inspection. In effect the assessment tool helped inexperienced observers and generally sharpened-up peoples’ ability to identify problems and make decisions. However, it did not push those decisions outside the expectations of experienced managers.

During the evaluation phase of this project it was apparent that people experienced in rabbit management were not recognising the true extent of the rabbit browsing damage on native trees and shrubs. This rapid survey provided a valuable tool to educate people on the extent of the damage rabbits are inflicting on native vegetation.

Removing rabbits

Where rabbits are clearly reducing biodiversity and action needs to be taken to eradicate them or reduce their impact it is important to remember that the ‘*cure should not be* *worse than the disease*'. Obviously, if rabbits are living amongst remnant native vegetation on a roadside, the control methods chosen should not irreparably damage trees, shrubs and native herbage.

Several different methods of control will need to be used together to achieve adequate results. It is recommended that rabbits are first poisoned during summer to eliminate most of them, and that accessible warrens are then destroyed by ripping where this can be done without destroying perennial vegetation. Back-hoes have proved useful in some cases where access for a tractor is difficult or could cause severe damage to vegetation. It is often a matter of experienced judgement in deciding whether limited damage to vegetation will be more than off-set by enhanced regeneration prospects. Finally, fumigation is recommended to close the less accessible rabbit holes below trees and shrubs.

Although a combination of rabbit control techniques means more work and more expense, the low costs of keeping rabbits down in subsequent years quickly brings accumulated costs below those of repeated annual treatments such as using poisoning alone. Fumigation is the most expensive and least effective of treatments but its advantage when used to finalize treatment lies in the fact that fumigants such as phosphide tablets or small fumigation machines can be carried on a vehicle and used to treat re-opened rabbit holes immediately they are noted. Treating re-opened rabbit holes 'on the spot' during inspections every few months ensures that rabbits do not regain damaging numbers.

There is an added reason for carrying out rabbit control as effectively and thoroughly as possible. All rabbit control methods have come under scrutiny in recent years because of concerns over the inhumane treatment of animals and impact on natural fauna. Such concerns have led to considerable confusion among land managers who find it hard to balance the risks of pest control against the inevitable changes in natural ecosystems and loss of biodiversity that will occur if pests continue to cause damage.

Having truly humane methods of rabbit control may never be a fully achievable goal because getting rid of rabbits involves killing them. Nevertheless, using the methods available, it is possible to maintain rabbits at very low levels and so reduce the absolute number that need to be killed each year.

The assessment methods used for scoring rabbit numbers and rabbit damage set out above can be useful for measuring progress in rabbit control if records are kept and assessments are repeated over time.

Systems for recording data and planning control programs

During this survey some thought has been given to methods of recording data on a district-wide scale that could be used to facilitate rabbit control. For example, it would be useful for a regional rabbit control officer to be able to look at a map with rabbit infestations marked on it and make decisions about supplying bait for landholders in a particular area. Likewise, a bulldozer for ripping rabbits might work in one general district rather than each landholder organizing hire in a piece-meal fashion.

Several computer systems are available which can be combined with GPS data to provide an accurate mapping system. In this instance a small hand-held GPS was used. This could be down-loaded into a readily available program called OziExplorer enabling survey sites to be viewed on the National Mapping (Natmap) raster maps. Rabbit infestations were marked as "points of interest" and by double-clicking on a map point a file is opened giving a previously filed description of the site and rabbit infestation levels as well as photos of the site for added information.

Systems of this kind would certainly be useful for planning rabbit control at a district level by CMA officers and RLPB rangers.

Putting a price on rabbit impact on biodiversity

If rabbits continue to cause a slow decline in native vegetation in many areas, then remedial action will need to be considered in the long-term. Some of the information gathered for this report could be used to explore the options that range from (a) taking no action, (b) removing rabbits to allow natural regeneration, or (c) replanting to restore vegetation and managing rabbits to protect that investment.

Where the total length of roads in a given area is known, and the lengths of roads with native vegetation as well as the width of roadside reserves are recorded, it is possible to calculate the approximate area covered by roadside vegetation. Such information is becoming increasingly available through regional organizations. For example the Shire of Wongan-Ballidu (2005) provides precise data on the length of roads, the conservation status of roadside vegetation, width of roads and vegetated roadside as well as numbers of plant species and details of the use of adjoining lands.

The proportion of these areas likely to be damaged by rabbits could further be estimated from information like that collected in this survey, and the costs of managing those areas calculated. Generally the costs of managing rabbits on roadsides are known and replanting, despite being a poor substitute for maintaining the original ecosystems, is known to cost about $1200/ha at present day rates (Greening Australia).

Clearly, the costs of options for managing rabbits in relict native vegetation in farmlands, previously impossible to calculate, are coming within reach of serious economic consideration.

Conclusions

Data obtained during this review indicate strongly that, from a biodiversity perspective, it is difficult to say there is a 'safe' level of rabbits. Some reduction in condition of native vegetation of roadsides and reserves becomes apparent even when rabbits are at low numbers, about 1 rabbit / ha, and in general the potential for regeneration of native tree and shrub seedlings is halved at 2 rabbits/ha. Beyond this density, overt signs of rabbit damage such as browse lines on shrubs and young trees become obvious and native perennial grasses in open woodlands are increasingly damaged by rabbits, particularly in dry summer periods. Native grasses are largely replaced by weeds when rabbits reach about 10/ha.

The results of this study, although preliminary, have pointed to some interesting areas that should be investigated more thoroughly. For example, rabbits appear to affect the regeneration of native plants not only by direct browsing but also indirectly by disturbing the soil and promoting weeds.

Stopping on-going loss of biodiversity is not something we can leave to some lucky combination of weather and herbivore abundance. Livestock and large pests such as goats can be managed, but rabbit populations remain an unnoticed problem in many areas. Few land managers regularly assess rabbit populations or look at the damage rabbits cause. Additionally, many do not understand how to implement an effective rabbit control program that will help them meet land management goals. This project has set out to address at least the first part of that problem, namely to develop a simple method to enable land managers to quickly assess a situation and decide whether rabbit management is needed.

This report points out that many rural communities are keen to retain remnant vegetation but this will involve an adjustment in peoples' views of rabbits and the damage they cause even at low levels. If rabbits were held below the level needed to conserve native vegetation, rabbit problems in wider rural landscapes would never reach levels where economic damage was sustained.

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Appendix I - Photos

Fig 1 - Rabbit faecal pellets showing relative size against a 5 cent piece.

Fig 2 – Large concentration of rabbit faeces in a typical 'buck-heap'.

Fig 3 – Typical rabbit scratch. Some faecal pellets are near the scratched out soil.

Fig 4 – Two roadside rabbit warrens showing freshly scratched out rubble and sand.

Fig 5 – A rabbit has gnawed bark from this *Bursaria spinosa* stem and severed twigs. Note the secateurs-like cut on twig on right.

Fig 6 – Kangaroo, wallaby and sheep browsing can be distinguished from rabbit browsing because leaves and growing tips are torn from stems rather than being 'cut'.

Fig 7 – Rabbit ‘browse-line’ about 50 cm above the ground on young native pine (*Callitris*) trees

Fig 8 – Rabbit ‘browse-line’ at 50 cm on the wattle *Acacia ligulata*. If rabbits were not present foliage would reach down to the ground.

Fig 9 a – Pine seedling showing slight rabbit damage (Damage score = 1)

Fig 9 b – Pine seedling completely defoliated by rabbits (Damage score = 5)

Appendix II - *Assessment tool*

The following simple steps will help assess the severity of rabbit damage in an area of native vegetation.

1. Assess rabbit abundance: Take 15 minutes to inspect a selected site, about 2 – 3 ha, on foot. Keep moving to cover as much of the area as possible, noting the patterns and distribution of any rabbit faeces or pellets you see. Score the abundance of rabbits according to the following scale:

Score

0 = none found in 15 minute search, 1 = small, isolated clumps 10 or more m apart; 2 = clumps <10 m apart; 3 = common, still patchy; 4 = abundant and widespread, 5 = very abundant, faeces always apparent.

☐

2. Seedling abundance: Are seedlings (less than 0.5 m high) of native shrubs and trees on the area present?

Score

0 = none, 1 = very few, 2 = present, not common, 3 = common, 4 = abundant, 5 = very abundant.

☐

Additional question: Is there a variety of native species regenerating or mainly unpalatable species such as *Eucalypts*? Tick one box.

☐ Variety of species ☐ Mainly one species

3. Rabbit damage:

Is there a conspicuous browse-line (at 50 cm above ground) on larger trees and shrubs with low foliage? Tick one box.

☐ Browse-line present ☐ No browse-line seen

Inspect the seedlings closely for evidence or rabbit damage including oblique secateurs-like cuts through smaller stems, defoliation and gnawing of bark. Score damage as follows:

Score

0 = no evidence of rabbit damage, 1 = slight damage to some seedlings, 2 = obvious damage confined to some seedlings, 3 = many seedlings moderately damaged, 4 = heavy general damage, some seedlings retain foliage, 5 = most foliage and small twigs and bark stripped from almost all seedlings. If you found no seedlings (**2 above**) and there is a **browse-line** on low foliage write score as 5.

☐

4. Weeds score: Consider the weediness of the area. This includes plants like blackberries and cacti as well as species such as Patterson's Curse and horehound. Remember that among natural vegetation escaped pasture species such as *Phalaris* and other grasses are also weeds.

Score

0 = none, 1 = small, isolated clumps; 2 = clumps commonly found; 3 = widely found; 4 = abundant, 5 = weeds dominate, e.g. more than 80% of ground cover.

☐

5. Estimate Biodiversity benefits:

Score

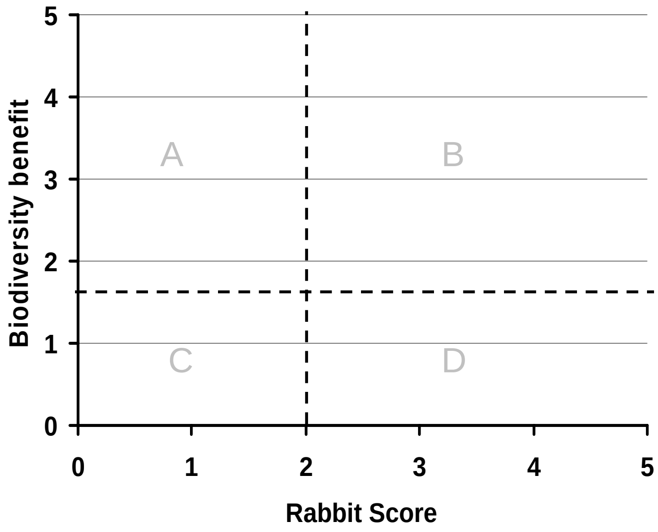
Use the **seedling abundance** score (**2** above) and the **rabbit damage** score (at **3** above) to estimate the recruitment prospects from **Table 1** below.

☐

Table 1. Biodiversity benefits for native plants. For a seedling abundance score of 3 and a damage score of 2 the likelihood, or prospect of successful regeneration is 1.0 on a scale of 1 – 5.

	Seedling abundance					
Damage	0	1	2	3	4	5
0	0.00	1.00	2.00	3.00	4.00	5.00
1	0.00	0.50	1.00	1.50	2.00	2.50
2	0.00	0.33	0.67	1.00	1.33	1.67
3	0.00	0.25	0.50	0.75	1.00	1.25
4	0.00	0.20	0.40	0.60	0.80	1.00
5	0.00	0.17	0.33	0.50	0.67	0.83

6. Data plot: Where does the site you are assessing lie on the following figure? Use **rabbit abundance** (from 1 above) and **biodiversity benefit** score (from 5 above).



7. Decision time:

Depending on where the plotted point lies, in zone A, B, C or D, the impact of rabbits on native biodiversity is as follows:

'A' - Rabbits are having little impact on common shrub species but may still reduce biodiversity by removing very rare or highly palatable plants (e.g. orchids).

'B' - There is little rabbit damage seen despite relatively high rabbit numbers. It would be worth asking: Is the vegetation mainly tough coastal scrub or unpalatable like *Eucalypt* seedlings? This was an additional question at **2** above.

'C' – Regeneration of very palatable native species, such as sheoaks, can be hampered even by a few rabbits. If the few shrub or tree seedlings present were undamaged by rabbits, check whether other factors such as excessive weeds (high weed score at **4** above) may be preventing regeneration. If rabbit damage to seedlings is obvious and widespread (a high rabbit damage score at **3** above), you should begin rabbit control.

'D' - Rabbits are having a high impact on biodiversity. This often goes together with a conspicuous rabbit grazing line, low seedling abundance, high levels of damage by rabbits and abundant weeds. Action needs to be taken to control rabbits to prevent severe decline of native vegetation.

8. Removing rabbits

Where rabbits are clearly reducing biodiversity and action needs to be taken to reduce their impact it is important to remember that the '*cure should not be worse than the disease*'. Obviously, if rabbits are living amongst remnant native vegetation, the control methods chosen should not irreparably damage trees, shrubs and native herbage.

Several different methods of control will need to be used together to achieve adequate results:

- poison during summer and autumn to eliminate most rabbits
- destroy readily accessible warrens in openings among vegetation by ripping
- fumigate the remaining rabbit holes under trees and bushes.

Although a combination of rabbit control techniques means more work and more initial expense, the low costs of keeping rabbits down in subsequent years quickly brings accumulated costs below those of repeated annual treatments. Treating re-opened rabbit holes by fumigation 'on the spot' during inspections every few months will ensure that rabbits do not regain damaging numbers. Consult your local Catchment Management Authority or Resource Management Board for advice on the best rabbits control methods and equipment available for completing the three steps above.

9. Measuring achievements

These methods can be useful for measuring progress in rabbit control if records are kept and assessments are repeated over time. Remember, success should not be measured in terms of reduced rabbit numbers alone. Improved shrub and tree regeneration is the main aim.

Appendix III - Rabbit and biodiversity survey data sheet

1. Site details

Site Name or reference: (e.g. local name, owner's name details)	
Name of assessor:	
Date:	
Inspection time: am/pm	
Location: (e.g. nearest town)	
Latitude: (from GPS) º S	Longitude: º E
Altitude: (from GPS) metres	
Approximate area inspected: ha. Total area of land if known: ha.	
Land use(s): (e.g. grazing, cropping, rail reserve):	
General description of site: (e.g. remnant native vegetation adjacent to cropland)	

2. Rabbit abundance

Indications of Rabbits:	**Score**
Faeces: 0 = none found in 15 minute search, 1 = small, isolated clumps 10 + m apart; 2 = clumps <10 m apart; 3 = common, widely found; 4 = abundant overall but still patchy, 5 = very abundant, faeces always apparent.	
Buck heaps: 0 = none found,1 = occasionally seen; 2 = seen frequently; 3 = common; 4 = very common, 5 = abundant	
Scratches: 0 = none seen in 15 minute search 1 = very few; 2 = common seen every few metres; 3 = very common, every metre or so, 4 = abundant small areas of soil bared; 5 = very abundant widely damaging top soil.	
Number of rabbits seen on site visit:	
Warren density: if possible count the number of warrens in the area surveyed (calculate the approximate number of warrens/ha)	Total:
Average number of active entrances/warren: count the number of active entrances in 3 or 4 typical warrens and note the average. Use this space to record active entrances: Warren 1: , Warren 2: , Warren 3: , Warren 4 .	Average:
Nearest adjoining patch of rabbit warrens: 0 = none known, 1 = >1 km away, 2 = < 1 km away, 3 = continuous population	

3. Biodiversity impacts

Are there typical oblique cuts on stems of weeds, seedling trees indicating presence of rabbits?	Notes:
Is there a rabbit 'browse line' 40 cm above ground on shrubs?	
Evidence of past damage: (e.g. shrubs with dead severed stems and re-sprouting from base).	
Bark gnawed from stems and roots of some shrubs?	
Native grasses: (e.g. kangaroo grass). Score: 0 = no native grasses, 1 = few, 2 = common, 3 = very common, 4 = abundant	
Introduced grasses: (e.g. wild oats). Score: 0 = no introduced grasses, 1 = few, 2 = common, 3 = very common, 4 = abundant	
Weeds: (e.g. thistles, horehound) Score: 0 = no weeds, 1 = few, 2 = common, 3 = very common, 4 = abundant	
Is there a vegetation gradient associated with rabbit density? (e.g. Are weeds more common and native grasses and tree seedlings less common where rabbits are present?)	
Tree/shrub population structure: Are seedlings of common native shrub and trees species apparent? Score: 0 = none, 1 = very few, 2 = present, not common, 3 = common, 4 = abundant, 5 = very abundant.	
Rabbit damage to seedlings: Is damage likely to prevent establishment of those seedlings within reach of the rabbits? 0 = no evidence of rabbit damage, 1 = some damage but not restricting growth, 2 = obvious, though small proportion of seedlings, 3 = moderate, over 50% of seedlings damaged, 4 = heavy damage, some foliage remains, 5 = complete stripping of all seedlings.	