Crop And Pasture Protection From Rabbits In Native Bush Remnants

FINAL REPORT TO NFACP/BRS
November, 2002

By

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EXECUTIVE SUMMARY

Remnants of on-farm native vegetation have been left for conservation purposes on many farms in Western Australia. Although the main impetus for this practice is a reduction in the potential for soil erosion to occur in these sandy soils, many of these bush remnants have conservation value in their own right. However, unfortunately, these remnants also provide ideal habitat for rabbits, and when situated adjacent to crops and pastures, very high rabbit numbers can eventuate. These rabbits can have considerable impact on farm productivity. One approach for overcoming this problem, and which has received increasing attention of late, is to fence these bush remnants and thereby exclude most rabbits from this prime rabbit habitat. The effectiveness of this technique, and the effects of any residual rabbit populations on the bush remnants themselves, are not well documented.

This project examined both the short- and longer-term effects of confining wild rabbits within remnants of native vegetation on two different farming properties in southern Western Australia. A number of exclosure plots were constructed to totally exclude rabbits so that the relative abundance and biomass (percentage cover) of the remnant vegetation subjected to grazing by rabbits could be compared to the response of the vegetation where rabbits were excluded.

In the short-term (i.e. within the 14 month period after fencing the exclosures), it was difficult to demonstrate an obvious effect of rabbits except that the percentage cover of sedges and native grasses was clearly reduced in the presence of grazing by rabbits. Other negative impacts only become obvious during the longer-term trial (2 years). On this occasion, the percentage cover of sedges and grasses, and the abundance of seedlings and reshoots, were reduced as a result of grazing by rabbits. This effect was more pronounced in Year 2, suggesting that the impact of even a small number of rabbits would worsen with time. The impact of rabbits was greatest during periods of peak rabbit abundance (as indicated by a dung count abundance index). The greatest effect of rabbit grazing appears to be on the forb and herbaceous vegetation layer.

These findings strongly suggest that any residual rabbits within areas of fenced remnant vegetation must be removed prior to, or immediately after, fencing if the long-term viability of these bush remnants is to be maintained.

The effect of the fencing in reducing crop and pasture damage from rabbits was immediate and would provide a relatively permanent and long-term solution (> 15 y) provided the fences were adequately maintained. Based on crop damage estimates during the project, the cost of installing the rabbit-proof fences could be recouped within two growing seasons (i.e. years). This cost could then be further discounted over the ensuing years. However, the overall utility of this technique would depend upon the type of crop/pasture protected, the yields and returns generated, and the amount of fencing required. The use of rabbit-proof fencing, coupled with a rabbit eradication program within the fenced vegetation, would have considerable merit for protecting native vegetation remnants of high conservation value. Each situation would, however, need to be considered on a case by case basis.

RECOMMENDATIONS

- The use of rabbit-proof fencing was effective in preventing those rabbits residing in remnants of native vegetation from inflicting crop and pasture losses in the surrounding paddocks. However, these benefits would be even greater if landholders were encouraged to use a co-ordinated approach in each district. Such an approach may well 'remove' much of the prime habitat for rabbits.

- Because of the demonstrated impact of even low numbers of residual rabbits within the fenced vegetation on native plant biomass and diversity, we strongly recommend that a control program is undertaken to reduce (eradicate?) rabbit numbers within the bush remnants.

- The removal of residual rabbits would be best undertaken using a 1080-baiting program *before* the bush remnant is totally enclosed. This may need to be supplemented with a shooting program.

- Eradication of any residual rabbit population within the fenced remnants needs to be achieved. If this can not be done then routine control of rabbits should be undertaken if the conservation value of a bush remnant needs to be maintained.

- Where possible, the fencing of remnant vegetation should be accompanied by a reduction in other on-farm harbourage for rabbits, thereby further reducing the available rabbit-habitat.

- A suitable firebreak should be maintained immediately adjacent to the fence within the fenced vegetation. This would enable: i) the fence to be protected from fire, ii) provide a clean track area for monitoring the presence/entry of any rabbits, and iii) provide an area to undertake a future baiting program if required.

- The use of rabbit-proof fencing would be a valuable tool for providing relatively permanent protection from rabbit grazing to bush remnant vegetation of high conservation value. However, the appropriateness of this approach would depend upon the size of the area requiring protection.

- One negative aspect of fencing bush remnants is that the rabbit-proof fences will impact upon the movement and dispersal of some native animals (e.g. small wallabies, goannas, and larger skinks?). However, such impacts would require further study to gain an understanding of whether they would be significant, and whether any formal guidelines are needed to reduce such impacts.

INTRODUCTION, AIMS AND OBJECTIVES

Rabbit-proof fencing has been used to varying extents over many years in Australia to protect agricultural enterprises from rabbit damage, particularly where high-value horticultural crops are involved. However, rabbit-proof fencing has not been used much in recent times because of its perceived high cost, and the high labour component required for construction.

In Western Australia, areas of native vegetation on farms have been left uncleared, particularly where they are growing on ridges of light sandy soil which would otherwise be subject to wind erosion. This in turn has created a different problem, because such bush remnants provide ideal habitat for rabbits. Rabbits often attain relatively high numbers in these habitats, coming out to feed on, and often severely damaging, adjacent broad-acre crops and pastures. Annual poisoning programs have been used to control rabbit damage in these situations, but this approach does not solve the problem on a permanent long-term basis. Clearing the vegetation is not an option because of the potential soil erosion risk this would generate, and also because of the need for conserving the remnant vegetation.

Don and Val Tomlinson, on their farm "Pallinup Park" at Boxwood Hill (about 50 km west of Bremer Bay) have used rabbit-proof fencing as a solution for reducing the impact of rabbits on their broad-acre, dryland farming enterprises. They have surrounded each patch of remnant vegetation on their farm with a rabbit-proof fence to stop rabbits from feeding on their crops and pasture. Because the remnant vegetation (in this case mallee heath) does not have much herbage suitable as food for rabbits, the rabbits within the fenced areas generally declined to relatively low numbers after the rabbit-proof fencing was put in place. The fences provide complete protection for adjacent crops and pastures from rabbit damage on a long-term basis.

On the face of it, there appeared to be little effect of the remaining rabbits on the remnant bush itself. However, there was a reticence by landcare professionals to recommend the technique because of the assumption that the residual rabbit populations must be doing some damage that may be sufficient to alter the overall composition of the vegetation. This could happen either in the short term when rabbit numbers may be relatively high immediately following fence construction, or in the longer term, with continuous grazing by low numbers of rabbits.

In the event that the rabbits were causing significant effects on the vegetation, a carefully designed poisoning campaign inside the fence soon after construction could be used to eradicate the residual rabbits and ensure the ongoing conservation of the remnant vegetation.

This current project was carried out to demonstrate:

1. Whether there were any short-term initial effects of confined rabbits on the native vegetation over the first year following the enclosing of the remnant vegetation with rabbit-proof fencing.
2. Whether there were any long-term effects on the vegetation (over two years) of relatively low numbers of rabbits confined within the fenced vegetation, and
3. The benefits and costs of the construction of rabbit-proof fences for crop and pasture protection.

The results from this project enable some recommendations to be made on the suitability of the fencing technique for satisfying the need for crop and pasture protection while ensuring the conservation of the remnant native vegetation in the longer term.

LOCATION AND METHODS

The sites used in the study had not been burnt for at least 12 years, and probably for much longer than this. Climate is typical Mediterranean with an annual average rainfall of 514 mm. To aid in the interpretation of the results, monthly rainfall records were obtained from the closest official Bureau of Meteorology rainfall recording station (009865) at Warra Jarra, AMG reference: Zone 50, 673303E 6191882N. Warra Jarra is approximately 3.5 km from the Tomlinson's site and 8 km from Parsons'. Annual rainfall in 1999, 2000 and 2001 was 447 mm, 441 mm and 598 mm respectively.

1. Short-term effects of rabbits following fence construction. (Parsons' site; Experiment 1)

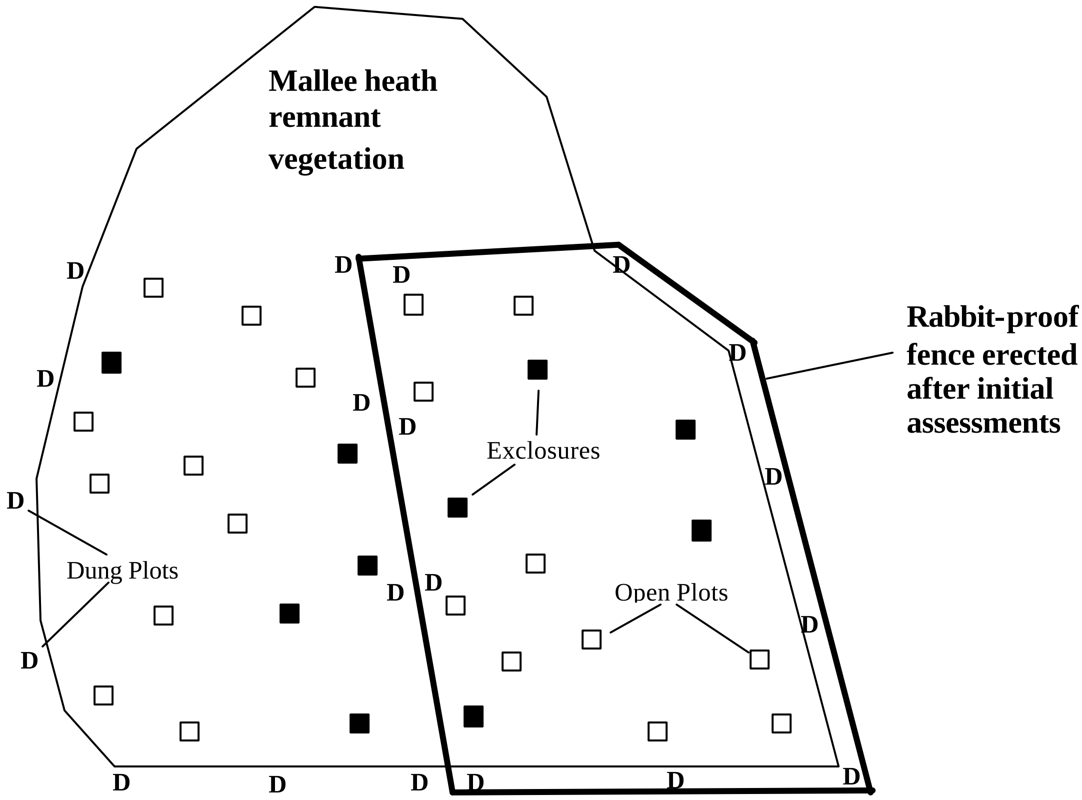
This study was carried out within a 10.5 ha (350 x 300 m) patch of native mallee-heath vegetation at Boxwood Hill, Western Australia (site approximately 50 km due west of Bremer Bay, AMG reference: Zone 50, 665610E, 6189450N). This study site was established to determine the short-term effects of rabbit grazing on remnant vegetation where the effects of confining rabbits within the bush remnants were compared with those areas with unconfined rabbit populations. A schematic diagram of the experimental design is given in Figure 1.

This site was ultimately divided into two parts: one with (treatment) and the other without (experimental control), rabbit-proof fencing. Initially, the impact of rabbits on the remnant vegetation was assessed, as described below, in 5 one-metre square quadrats within each of thirty 10 x 10 m plots, 15 in each half of the site. One quadrat was located near each corner of the plots and the fifth was situated in the middle of each plot. A point quadrat method (36 points) was used for assessing percentage cover within the 1 m^2 quadrats (S. Gillfillan 1999). Following this assessment, the site was then divided into two halves and we surrounded one half with a rabbit-proof fence (see Figure 1). At the same time, we also surrounded five of the 10 x 10 m areas (chosen at random) in the treatment and experimental control areas with rabbit-proof fencing, making them rabbit-proof exclosures. These exclosures were equivalent to removing the effect of rabbits on the vegetation completely, and thus enabled comparison with and without the effects of rabbit grazing. The remaining open (i.e. subject to 'normal' rabbit grazing) 10 x 10 m plots (10 in each of the fenced and unfenced areas) enabled the comparison to be made between the areas where rabbits were confined and where they had ready access to surrounding pastures and crops (i.e. 'rabbits free to move out'). Vegetation assessments, at fixed marked positions, were repeated at two-monthly intervals for the 14 months immediately after the treatment vegetation was fenced.

The following vegetation measures were taken at all plots:-
Height and percentage cover of dominant (overstorey) shrub layer, percent cover of small (<0.5 m high) understorey shrubs (SS), percent cover of sedges and grasses (SG), percent cover of other monocotyledonous plants (OM), number of quadrats in which seedlings or reshoots of rootstocks were visible (SR Quadrats), and the abundance index of seedlings and reshoots (SR Score:- 1 = 1-5 seedlings/reshoots, 2 = 6-10, 3 = 11-20, 4 = 21-30, 5 = 31-50, 6 = 51-100, 7 = >100).

Because the treatment in the comparison 'rabbits confined' versus 'rabbits free to move out' was the erection of the external rabbit-proof fence, the open plots (vegetation assessment areas) did not provide true replication, and so the experiment was not suitable for strict statistical analysis. However, this experiment was carried out because information about the initial effect of rabbits is critical in the decision making process about the overall effects of the rabbit-proof fencing, and the documentation of the process was valid, even without rigorous statistics. Means (± Standard Error, SE) for each vegetation parameter were calculated and plotted for each monitoring period.

Figure 1: *Schematic representation of the experimental design for the short-term study undertaken at the Parsons' site.*



2. Long-term effects on vegetation of rabbits confined to bush remnants (Tomlinson's site; Experiment 2)

This experiment was undertaken on two sites (i.e. patches of native vegetation), both situated on the Tomlinson's "Pallinup Park" property, about 50 km west of Bremer Bay, Western Australia (AMG references: Zone 50, 670762E 6189255N, and 671875E 6189255N). One site ("Site 2"; 8.5 ha; 500 x 170 m) had been recently rabbit-proof fenced (less than a year), and the other ("Site 1"; 11 ha; 550 x 200 m) had been similarly fenced 4-5 years previously. Within each of these sites, 10 locations were randomly selected. At each location, an area of visually uniform vegetation was chosen, and in each of these a 10 x 10 m exclosure was constructed (preventing rabbit access) and a 10 x 10 m open plot, where rabbit access was unimpeded, was marked. In all exclosures and open plots, the vegetation was assessed within 5 one-metre square quadrats, at the beginning of the experiment (when the exclosures were constructed in 1999) and again at the same time of year in 2000 and 2001. This design was similar to that shown in Figure 1.

The same measures of vegetation were taken as in Experiment 1.

In Experiment 2, the exclosures constituted the treatment, so on each site there were 10 replicates, and the data were analysed by analysis of variance (Zar 1984). The analysis of variance for each measurement compared the grazed and ungrazed plots in 2000 and 2001 using the measurements from 1999 as a covariate. A split plot analysis of variance was used with the year as the sub-treatment. Residual plots were used to check that the assumptions underlying the analysis of variance were valid. Analysis of variance was also used to compare grazed and ungrazed plots in 1999, prior to any treatment effects.

3. Index of rabbit abundance

Indications of the numbers of rabbits, and changes in rabbit abundance, were obtained by counting rabbit dung on permanently marked quadrats. The dung quadrats were located near each open plot within the fenced and unfenced areas of the remnant vegetation in both experiments. In addition to these, dung quadrats were also positioned around the perimeter of each experimental area (see Figure 1). The number of dung pellets was counted on these quadrats every time that the associated vegetation plots were surveyed. There were 20 dung quadrats in each area of Experiment 1 and 30 quadrats in each area used in Experiment 2. The quadrats comprised 1 m^2 of bare soil (sand), and they were brushed clean after each count.

4. Documentation of the benefits and costs of rabbit-proof fencing

Examples of rabbit damage to adjacent crops were documented photographically. Areas of crop lost were estimated by physically measuring the area affected on foot and/or by vehicle. The dollar values of the losses were calculated from the paddock yield per hectare and the current price at the relevant harvest. Examples of these losses are presented.

On the Tomlinson's farm, a substantial area of canola seedlings was lost to rabbits, and they decided to fence the affected area to keep rabbits out, and to reseed the affected area. The benefits and costs of this practice are also presented as a case study.

Pasture exposed to rabbit grazing, and pasture protected by rabbit-proof fencing were photographed, and examples of these treatments with and without rabbit damage are provided (see Plates 1-12).

RESULTS

1. Short-term effects of rabbits on remnant vegetation after fence construction (Parsons' site)

Figure 2 shows the changes in the mean rabbit dung pellets on the quadrats over the 14-month experimental period. It is clear that the number of rabbits in the fenced and unfenced areas were similar, and low, at the time the fence was constructed. In the fenced vegetation, rabbit numbers stayed more or less constantly low throughout the experiment. However, in the unfenced area there was a dramatic rise in the dung counts in November which corresponds with the end of the breeding season and the beginning of the recruitment period. The rabbit dung abundance index suggests that rabbit numbers outside the fence ultimately rose to about five times those within the fenced vegetation. From then, until the end of the experiment in July 2001, rabbit density in the unfenced area, as indicated by the dung index, was always considerably higher than in the fenced vegetation with the confined rabbits (Figure 2).

Figure 3 shows the trends in numbers of seedlings and reshoots observed in the exclosures and open plots at the Parsons' site. The overall seasonal pattern is similar between the fenced and unfenced areas. There was a rise in the abundance of this vegetation class in July, followed by a decline to extremely low levels in summer (January to March), and a sharp rise between May and July following the late break of season. There are, however, some differences in the fine details of this response that are worthy of note. The most marked decline in numbers of seedlings and reshoots occurred in the open plots in the unfenced vegetation between September and

November. This corresponds with the considerable rise in rabbit density between the same sampling times (Figure 2). In January, when the numbers of seedlings and reshoots were declining to low levels, the open plots on both the fenced and unfenced areas showed significantly lower numbers of seedlings and reshoots than in the fenced exclosures, where the rabbits had no access at all to the remnant vegetation. It is interesting to note that on the unfenced area, the rise between May and July was similar to the rises in the fenced area, and to that which occurred within the exclosures. This was in spite of the continuing higher levels of rabbit density as indicated by dung counts (Figure 2). It must be remembered, though, that the rabbits in the unfenced area also had access to annual species growing in the open paddock surrounding the site.

Figure 2: *Changes in the rabbit dung abundance index for the fenced and unfenced areas of remnant vegetation at the Parsons' site investigating the possible short-term effects of rabbits being confined within this vegetation. Data are means of the number of pellets per plot (n = 20).*

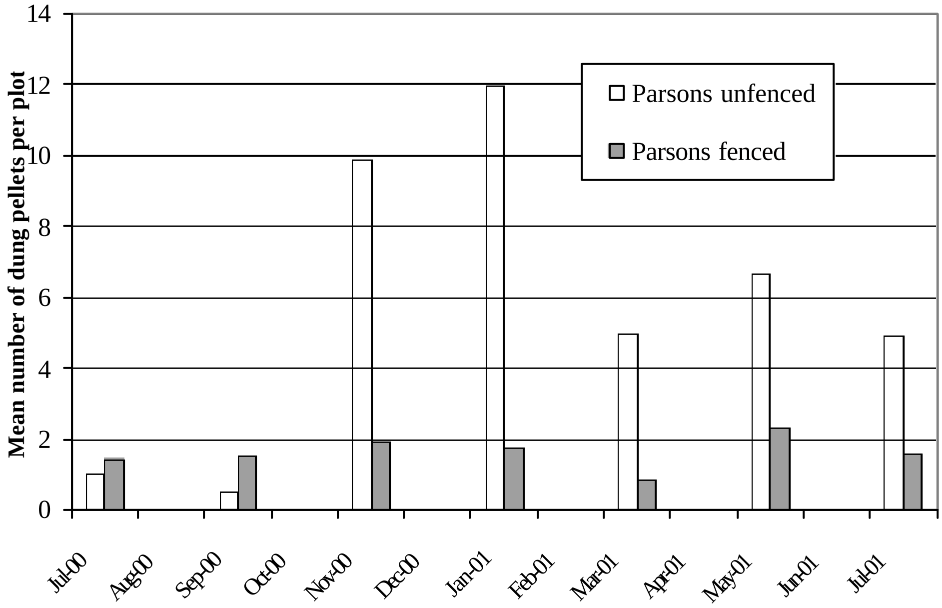


Figure 3: *Changes in the abundance index of seedlings and reshoots, combined, as a result of rabbit grazing within the fenced and unfenced areas of remnant vegetation at the Parsons' site. An abundance index scale of 1 to 7 was used (1 = 1-5 seedlings/reshoots, 2 = 6-10, 3 = 11-20, 4 = 21-30, 5 = 31-50, 6 = 51-100, 7 = >100). Data are means and standard errors of the abundance index of these plants per plot.*

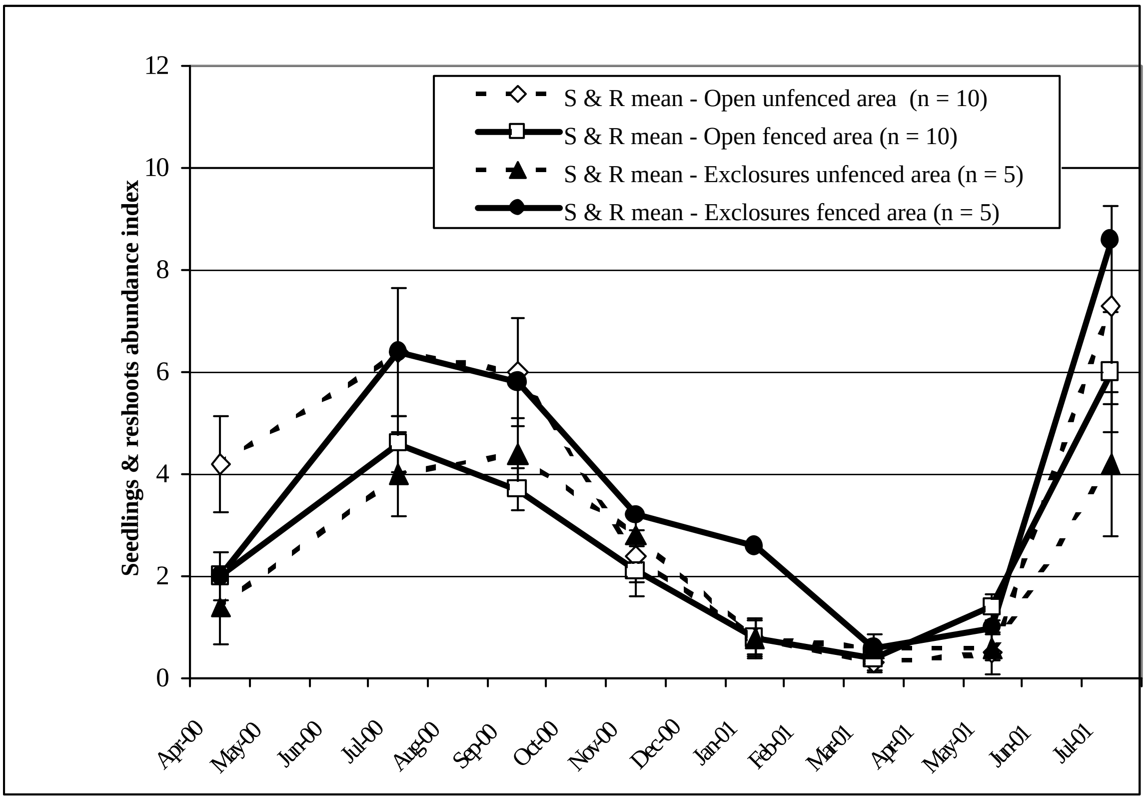
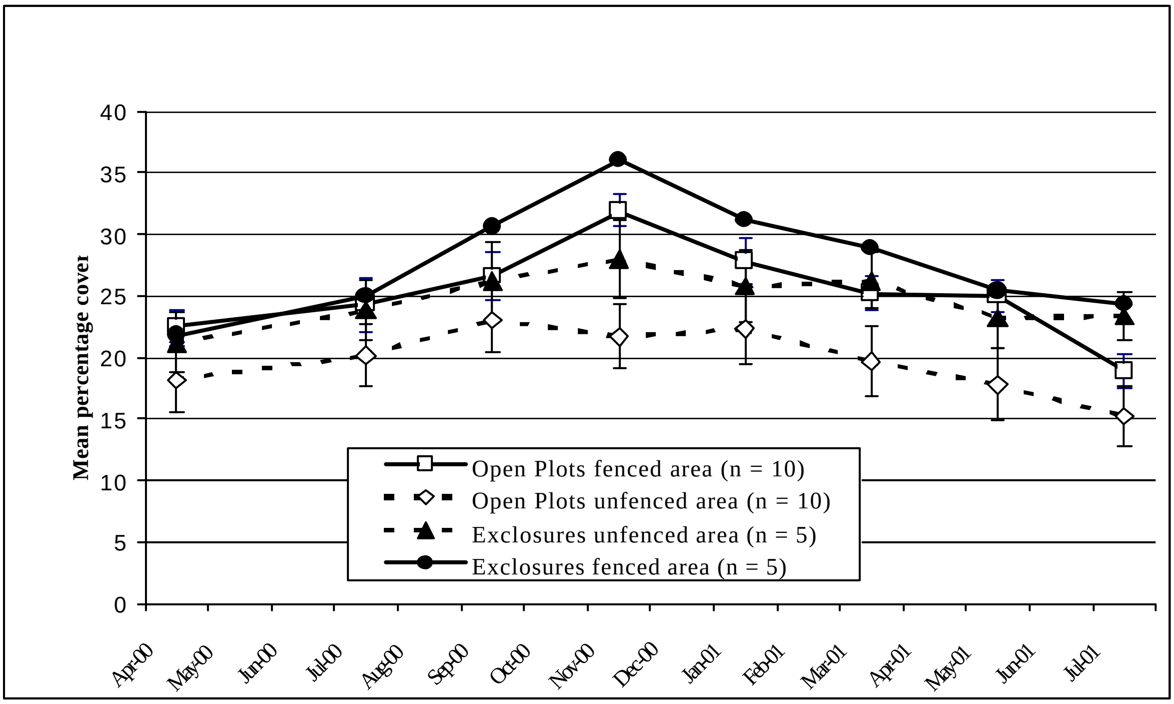


Figure 4 shows the percentage of vegetation cover that was sedges and grasses, and the changes in this vegetation class over time, with and without confined rabbits. Again, the basic trends were similar through the experiment, with one exception. The increase in the amount of sedges and grasses seen between September and November (Spring growth) in the exclosures and in the open plots on the fenced area, was not seen in the open plots on the unfenced remnant vegetation where grazing by rabbits was unrestricted. A large increase in rabbit numbers also occurred at this time (Figure 2). As noted above, there was also a coincident decline in numbers of seedlings and reshoots over the same period. Interestingly though, the effect on the sedges and grasses did not appear to continue through January although the number of rabbits on the unfenced area remained relatively high during this period.

Also of interest is that there was decline in the percentage sedges and grasses cover on all open plots and in most exclosures between May and July 2001 (Figure 4). In the previous year, sedges and grasses had been increasing at this time of year. However, the break of season was later in 2001 than in 2000. The biggest decline was in the open plots with unrestricted rabbit access within the fenced area.

Figure 4: *Changes in the percentage cover of sedges and grasses, combined, as a result of rabbit grazing in the fenced and unfenced areas of remnant vegetation at the Parsons' site. The results from rabbit exclosure plots are included for comparison. Data are means and standard errors of the percentage cover of these plants per plot.*



The graphs of the percentage cover of small shrub and the tall (overstorey) shrub categories are not presented because they show the same seasonal trends as reported above for the other vegetation classes. You would not generally expect rabbits to have a severe short-term impact on small and tall shrubs unless rabbit densities were very high.

2. Long-term effects on vegetation of rabbits confined in remnant vegetation (Tomlinson's site)

In 1999, at the start of this experiment, there were no significant differences in the vegetation parameters measured between the exclosure (ungrazed) and the open (grazed) plots (Table 1). This indicates that the variety and abundance of the plants were similar in these plots before the rabbit-proof fence was erected to exclude rabbits from the exclosure plots.

As there was no detectable differences in shrub height or density between the ungrazed and grazed plots over the two years of measurement after the erection of the rabbit-proof fences to exclude rabbits from the ungrazed plots, no further analyses of these two parameters were carried out.

However, there were some interesting differences for many of the other vegetation measurements taken. The ANOVA used to examine these data was a split plot design with a blocking factor (the two sites, d.f. = 1), and with the corresponding 1999 pre-treatment levels used as a covariate. The approach used did not test for differences between sites as the main interest was in the response of the remnant vegetation with and without rabbit grazing (i.e. the treatment). However, the analyses did remove any differences between sites (block stratum), and between the 20 locations (plots) at each individual site (block.pair stratum) before examining the effects of treatment (ungrazed vs. grazed) and year (2000 vs. 2001). These analyses were run using Genstat. The covariate, (i.e. the 1999 pre-treatment levels) was significant ($p < 0.05$) for all of the plant parameters tested. This indicates that the response of the vegetation in 2000 and 2001 was related to the amount and species diversity of the remnant vegetation at the start of the experiment in 1999. Thus, the use of the covariate 'compensates' for this relationship so that only the treatment effects are compared.

***Table 1**: The results of an ANOVA showing that the vegetation parameters were not significantly different between the ungrazed (exclosure) and grazed (open) plots when they were measured at the start of the experiment in 1999.*

Measurement	Probability
Shrub height	0.144
Shrub Density	0.206
Cover – Small Shrubs (SS)	0.977
Cover – Sedges and Grasses (SG)	0.917
Other Monocotyledonous Plants (OM)	0.353
Seedlings and Reshoots - Quadrats	0.154
Seedlings and Reshoots – Score (Square root transformation)	0.204

Rabbit grazing had a significant impact upon the sedges and grasses, and on the abundance of seedlings and reshoots (treatment effect, Table 2). This effect was also greater in Year 2 as the year effect was significant for these two vegetation parameters (Table 2). However, although the magnitude of this change varied between years, the overall trends were the same in both years as none of the interactive terms (treatment x year) were significant (Table 2).

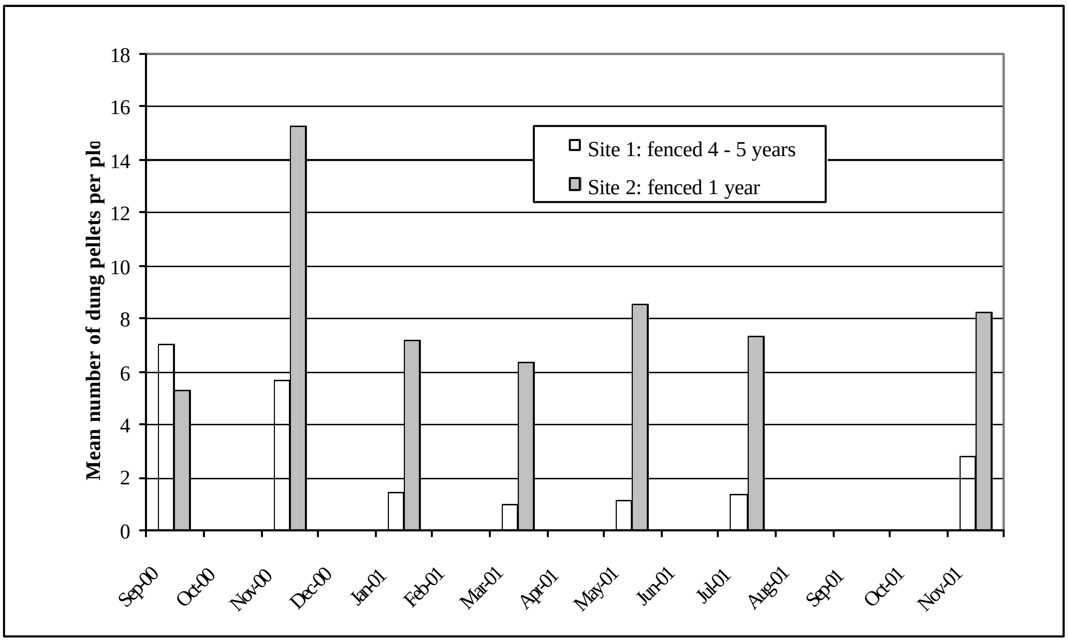
***Table 2**: The results of an ANOVA showing the differences between the ungrazed (exclosure) and grazed (open) plots over the two year 'experimental' period.*

	Probability			**Treatment means**			**Year means**		
Measurement	*Treatment*	*Year*	*Treatment X Year*	*Exclosure*	*Open*	*5%LSD critical values*[A]	*2000*	*2001*	*5%LSD critical values*[A]
SS	0.460	**0.035**	0.802	0.1769	0.1844	0.0209	0.1885	0.1728	0.0145
SG	**<0.001**	**<0.001**	0.094	0.4276	0.3542	0.0241	0.4354	0.3464	0.0185
OM	0.811	0.440	0.699	0.0088	0.0082	0.0057	0.0079	0.0090	0.0029
SR Quadrats	0.060	**0.004**	0.468	3.55	3.03	0.541	2.93	3.65	0.484
SR Score (No transform)	**<0.001**	**<0.001**	0.507	6.05	4.35	0.726	4.45	5.95	0.755

[A] *The difference between each 'pair' of means needs to greater than this value for this to be significant at the 5% level.*

Changes in rabbit abundance throughout the long-term trial, as indicated by the rabbit dung index, are given in Figure 5. Rabbit numbers on Site 2, the area that had been fenced approximately 1 year prior to the experiment, were moderate and generally constant throughout, apart from the higher numbers seen during the breeding season (spring/November). In contrast, rabbit numbers were lower on Site 1, the area that had been fenced for approximately 4-5 years. Although rabbit numbers were similar between the two sites at the commencement of the trials, the seasonal breeding peak in numbers (i.e. dung deposits) was almost absent on Site 1 in subsequent years (Figure 5).

Figure 5: *Changes in the rabbit dung abundance index for the fenced and unfenced areas of remnant vegetation at the Tomlinson's site investigating the possible longer-term effects of rabbits being confined within this vegetation. Data are means of the number of pellets per plot (n = 30). Site 1 and Site 2 had been fenced for approximately 4-5 years and 1 year, respectively prior to the experimental plots being established (i.e. the 10 m x 10 m exclosures were fenced).*



The main effects of rabbit grazing on remnant vegetation when rabbits were confined within this vegetation are shown in Figures 6 and 7. The analysis of variance presented in Table 2 shows that both rabbit grazing and time (i.e. years) had a significant effect on the percentage vegetation cover for the sedges and grasses (Figure 6). Although the percentage sedges and grasses cover in the open plots and exclosures on each site were similar when the experiments were commenced in 1999, there was a consistent divergence over time between the ungrazed and grazed plots on both sites. This was presumably due to the effects of rabbit grazing, as the percentage cover on the open plots was markedly reduced compared with the amount of vegetation within the ungrazed exclosures. This effect appeared to become more pronounced over time as there was a clear difference between the years (Table 2). However, initially, there was little overall change in the percentage sedges and grasses cover between 1999 and 2000, but there was a marked decline in this vegetation parameter between 2000 and 2001. This change may well have been 'driven', at least partially, by rainfall events. Figure 8 shows that the period between November 2000 and November 2001 had much less rain than the corresponding period in 1999-2000. In fact, rainfall over the 10 months between September 2000 and June 2001 was also considerably less than the long-term average for this period.

The presence of seedlings and reshoots, or the seedling and reshoots score (= abundance index), also showed a significant effect of both year and exposure to grazing (Table 2 and Figure 7). The yearly measurements provided a snapshot of what was germinating or reshooting at the time these parameters were measured (November). Like sedges and grasses, changes in this parameter almost certainly reflected recent preceding rainfall (Figure 8). However, in the absence of grazing by rabbits (i.e. in the exclosure plots; Figure 7) there was an increase in the percentage cover of the seedlings and reshoots from year to year. Again, grazing by rabbits diminished the numbers of seedlings and reshoots with the biggest effect being seen in November 2000 after two months of very low rainfall. As indicated by the dung index, this period also corresponds with the observed peak in rabbit abundance (Figure 5).

Figure 6: *Changes in the percentage cover of sedges and grasses, combined, as a result of rabbit grazing in the fenced and unfenced areas of remnant vegetation at the Tomlinson's site. The results from rabbit exclosure plots are included for comparison. Data are means and standard errors of the percentage cover of these plants per plot (n = 10). Site 1 and Site 2 had been fenced for approximately 4-5 years and 1 year, respectively prior to the experimental plots being established.*

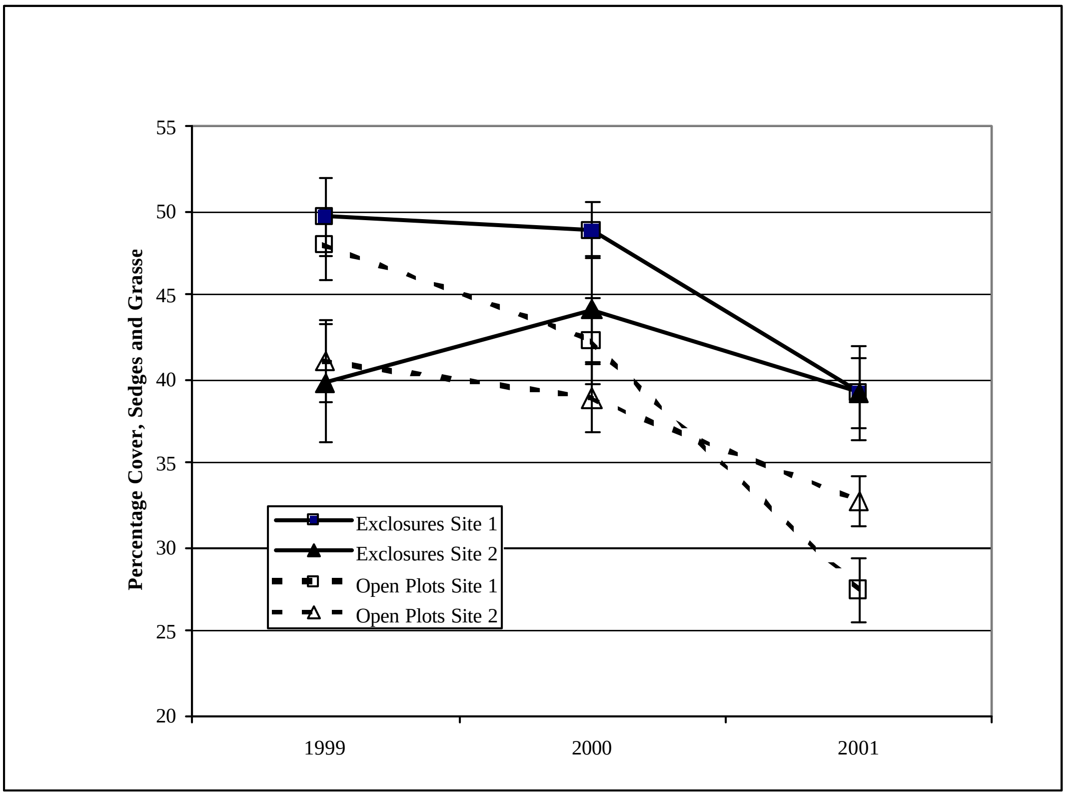


Figure 7: *Changes in the abundance index of seedlings and reshoots, combined, as a result of rabbit grazing in the fenced and unfenced areas of remnant vegetation at the Tomlinson's site. The results from rabbit exclosure plots are included for comparison. An abundance index scale of 1 to 7 was used (1 = 1-5 seedlings/reshoots, 2 = 6-10, 3 = 11-20, 4 = 21-30, 5 = 31-50, 6 = 51-100, 7 = >100). Data are means and standard errors of the abundance index of these plants per plot (n =10). Site 1 and Site 2 had been fenced for approximately 4-5 years and 1 year, respectively prior to the experimental plots being established.*

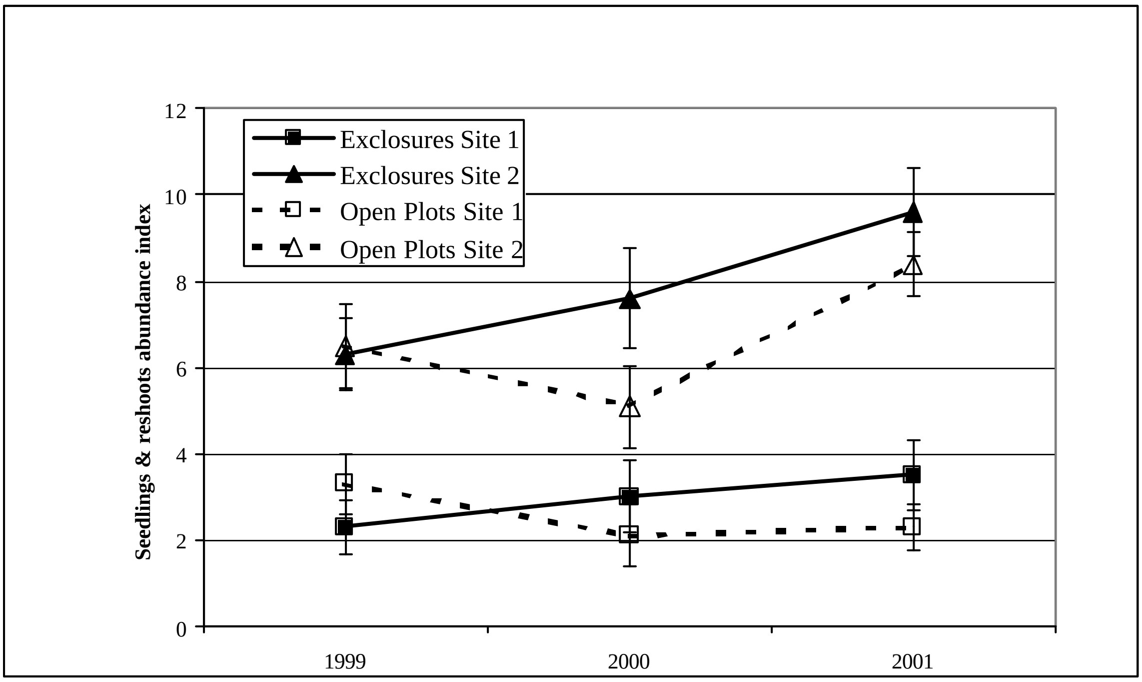
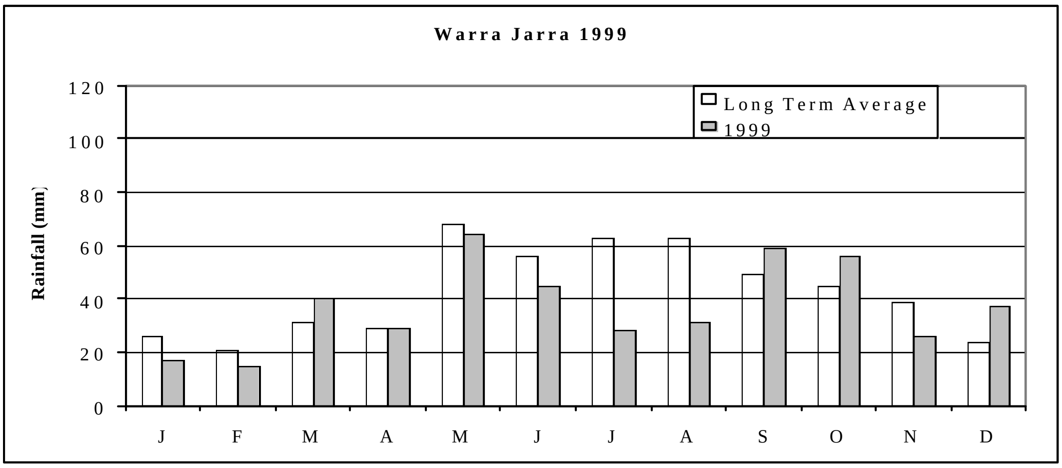
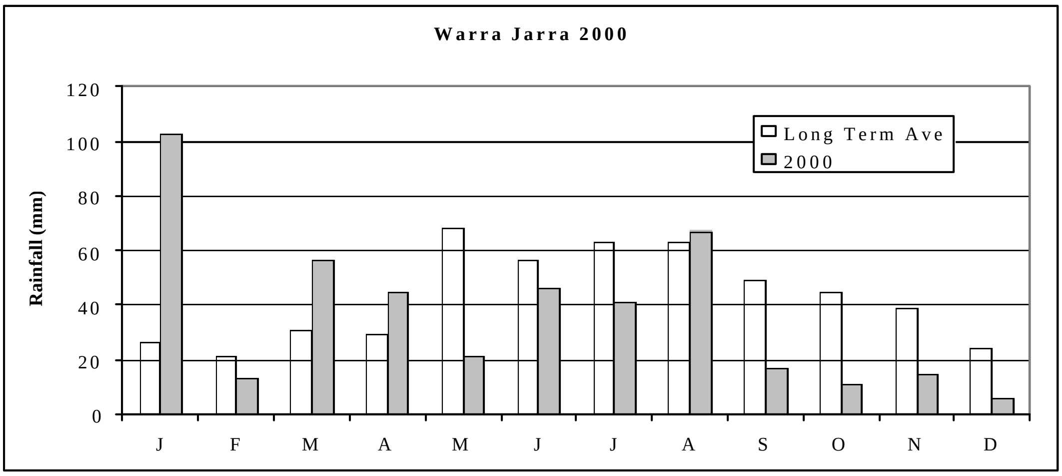
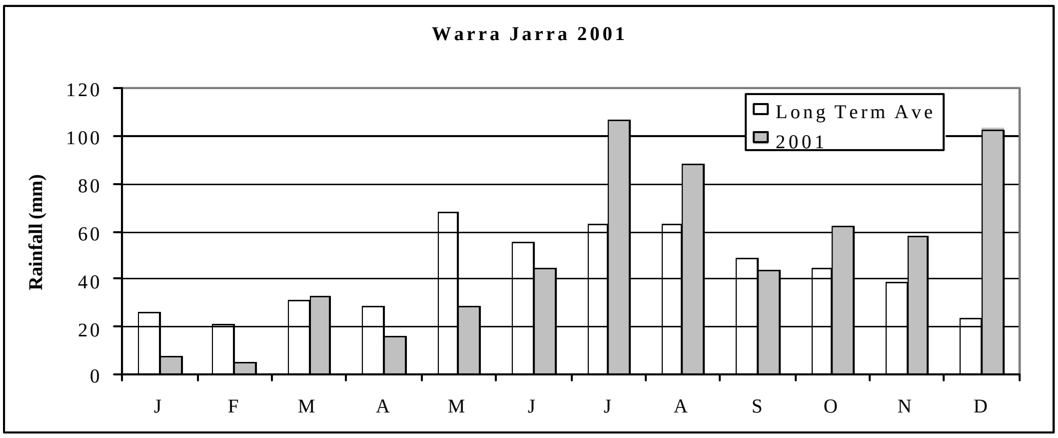


Figure 8: *Rainfall (mm) for each of the years during the short- and long-term studies. The recording station was within 8 km of the study sites.*







3. ***Documentation of the costs associated with rabbit-proof fencing***

Examples of rabbit damage, and the visual benefits of erecting rabbit-proof fencing to prevent the impacts of rabbit grazing, are provided in Plates 1-12. Although the overall area affected was often small, there was usually a total loss of the crops or pasture in the affected areas. In canola crops, these losses ranged from $288 to $1296 (mean $972, n = 4) with 0.5 ha to 3 ha (mean 1.75 ha) of crop lost. Losses were lower in lupin crops during the study, and ranged from $50 to $297 (mean $195, n = 3) or 0.25 ha to 1.5 ha (mean 0.98 ha) of affected crop. Obviously, rabbit-proof fencing is relatively permanent, and if properly maintained, is likely to last for at least 15 years. Thus the associated costs would need to be discounted against the benefits obtained over such a time period. There are also tax benefits (e.g. depreciation) to landholders.

The following case study documenting the benefits and costs of using rabbit-proof fencing to exclude rabbits has been taken *directly from the information generously provided by Don and Val Tomlinson and Son.* A photograph of the main area of concern is provided in Plate 12.

D. & V. J. TOMLINSON & SON
RABBIT CONTROL ON MILLAR'S POINT ROAD

COSTINGS ($)

Clearing of old fence and dig trench for wire	300.00
17 rolls Rabbit netting @ $182 roll	3094.00
116 steel star pickets – galvanised @ $4.98	577.68
12 Strainers @ $25.00	300.00
5 struts @ $25.00	125.00
6 rolls Tyeasy plain wire @ $95.50 roll	573.00
Netting clips & sundries	100.00
Contract erection	1200.00
Reseeding 10 ha. @ 5 kg. ha. x $2.50 kg.	12.50
Seeding at contract rates $12.00 per ha.	120.00
Total outlay	**6402.18**
This paddock yielded 1.4 ton ha. @ $300 per ton	
10 ha. x 1.4 ton @ $300	
Total income	**4200.00**

"On these figures we lost $2202.18 but we did all the work ourselves and we saved $1620.00 in labour. If the rabbits were not fenced out when they were they would have done more damage and the bare area would have not repaired, and it would have blown away and caused a lot of erosion. 1.7 km of fencing was done along a roadway that is deep sand banksia country and full of rabbits.

All our fencing materials were purchased at a heavily discounted rate in a bulk buy purchase order. These figures are what we paid, and not the going market rate.

We consider this an outstanding result."

DISCUSSION AND IMPLICATIONS FOR RABBIT MANAGEMENT

Short-term effects of confining rabbits

Some of the provisional effects we observed from fencing in the short-term (Parsons' site) were the opposite of what might have been expected. The dung counts in November 2000, for example, indicated a relatively large increase in rabbit numbers in the unfenced remnant vegetation compared to the fenced area. This could imply that the rabbits within the fenced vegetation only had access to less palatable/nutritious native vegetation that hence restricted the reproductive output of these rabbits. Conversely, rabbits in the unfenced remnant vegetation had ready access to a canola crop of higher nutritional value thereby enhancing their reproductive output. Significant breeding by rabbits depends upon the provision of green feed of adequate nutritional quality (King & Wheeler 1985; Williams *et al.* 1995; Twigg *et al.* 1998). In the unfenced remnant vegetation, where the increase in rabbit numbers occurred, there was a suggestion of a greater decline in the abundance of seedlings and reshoots. This was accompanied by a decline in the percentage cover of sedges and grasses which was in contrast to the fenced area, where the percentage cover of sedges and grasses had increased.

The number of seedlings and reshoots was similar between the open (grazed) and exclosure (ungrazed) plots within fenced and unfenced remnant vegetation after the 14-month monitoring period (Figure 3). There are four possible causes for this similarity, and these are not necessarily mutually exclusive. Firstly, rabbit numbers within the fenced vegetation were low and may have been below the threshold level required to cause obvious environmental damage. Conversely, because the rabbits in the unfenced remnant vegetation had ready access to other foods (e.g. crops and pasture), there may not have been a great demand for these rabbits to feed within the remnant vegetation as they always had access to an adequate feed supply within the surrounding paddocks. Hence their impact on the remnant vegetation was minimal. This may occur irrespective of rabbit density. Thirdly, the seed bank/species richness of the remnant vegetation was depauperate, and hence the vegetation was unable to respond. We do not favour this option as the study sites used had a diverse range of plant species present, and we did get a difference in the response between the exclosures and the open plots in the long-term experiment. Finally, because the numbers of rabbits ultimately confined within the fenced remnant vegetation were relatively low, it could take several years before any detrimental impacts become obvious. We believe the latter is an important consideration and that the fencing of remnant vegetation should include a strategy (e.g. 1080-baiting) to reduce rabbit numbers prior to totally enclosing a bush remnant.

It would appear that, over the short term, in the year that the short-term study was undertaken, there were some positives and some negatives resulting from the rabbit-proof fencing of the patch of remnant vegetation. The positives mainly resulted from keeping rabbits out, which helped to maintain the confined rabbit population at low levels. However, there did appear to be some deleterious effects inflicted by the confined rabbits, such as a decrease in the percentage cover of the sedges and grasses (see Figure 4).

Longer term effects of confining rabbits

Although there was a significant effect between years (the two years were markedly different in rainfall during the growing season), there is no doubt that low numbers of confined rabbits had a significant impact on the fenced remnant vegetation. In particular, the abundance of seedlings and reshoots was reduced, and the sedge and grass cover was diminished, relative to the exclosures in the corresponding 1-year and 5 to 6-year fenced remnant vegetation. Given that this effect occurred within 3-7 years from when the fences were originally erected (e.g. for 1 year plus 2 years of experimentation), then the longer term implication is that a substantial change in the biomass and composition of bush remnants is a likely consequence of confining even low numbers of rabbits within these remnants. It is possible that some of the deleterious effects of rabbit-grazing may be exacerbated by environmental stress. That is, such effects may not become obvious until the fenced remnant vegetation undergoes an additional source of abiotic stress, such as below average rainfall. Rabbit damage within the bush remnants mainly occurred in the forb and herbaceous vegetation layer.

It is also noteworthy that our findings are consistent with those of other studies, and some examples of this are presented below.

- Rabbits will often selectively browse seedlings of certain shrubs and trees. In fact, there may be no 'safe' rabbit density for some tree and shrub seedlings (Morris 1939, Lange and Graham 1983). For example, with free-ranging, unconfined populations, even rabbit densities of around 4 rabbits ha^{-1} can prevent the regeneration/replacement of some plant species, particularly in arid Australia, and this can lead to significant soil erosion (Cooke 1981, 1987; Foran, *et al.* 1985).

- Rabbit-grazing can also impact on native grasses, and when rabbits are excluded, native perennial grasses will regenerate and rapidly replace many of the introduced annual grass species (Mallet and Cooke 1986).

- In some subalpine areas, the effects of rabbit-grazing resulted in the loss of nine palatable forbs within seven years. However, where rabbits were excluded there was a net overall gain of two species (Leigh *et al.* 1987). The presence of rabbits led to a substantial reduction in the cover, biomass and species diversity of the forbs in this habitat.

- In the Victorian mallee district, seventeen native species of ground-layer plants were recorded where rabbits had been excluded for two years but none of these plant species were found where rabbits had ready access to such areas (Cochrane and McDonald 1966).

These findings, and the results of our study, strongly support the need for a strategy for reducing the numbers of rabbits present in bush remnants prior to the remnant vegetation being totally enclosed with rabbit-proof fencing. This could be achieved by a well conducted baiting program, preferably with 1080, which may or may not need to be integrated with a shooting program to mop up any remaining rabbits.

Benefits and costs of rabbit-proof fencing
It is clear from the benefits and costs associated with our trials that, in a cropping situation, rabbit-proof fencing is worthwhile, and the associated erection costs can be recovered in a relatively short time. The protection gained is also relatively long-term. The Tomlinson's case study showed that, with a high value crop such as canola, costs can be recovered within two seasons, depending on the amount of fencing required, and the crop yields and returns obtained. The benefit cost ratio of rabbit-proof fencing to eliminate rabbit damage is likely to be even more favourable for high return horticultural crops/market garden enterprises. There is an ongoing cost to maintain these fences which has not been accounted for in our costings. However, the associated cost of this maintenance would be relatively low over the lifetime of the fence, and would certainly be less expensive than the alternative technique of needing to undertake a poisoning campaign on a regular basis. This is especially so when it is remembered that a poisoning program does not provide the same absolute protection compared to that achieved with rabbit-proof fencing. Small crop losses may well continue to occur following a baiting program unless some technique is used to remove any remaining rabbits.

It is also clear that decisions on the value of fencing must be taken on a case by case basis. The lower value crops (lupins and barley) have less returns per hectare, but the costs of fencing can be discounted over the life of the fence (i.e. > 15 years?). However, the benefits from rabbit-proof fencing are likely to increase if such undertakings are co-ordinated between neighbouring properties. That is, a co-ordinated approach is best as this would 'remove' much of the habitat available to rabbits. This is particularly so if other on-farm habourage (e.g. rock piles, fallen trees) is also removed, or at least kept to a minimum. If the native vegetation has conservation value, then this should also be factored into any considerations. Provided some means are used to reduce the residual rabbits, then rabbit-proof fencing of remnant vegetation of high conservation value would be well worthwhile. Obviously the benefits and costs of this would depend upon the size of the area which needs to be protected.

What is clear, however, is that a well maintained rabbit-proof fence will provide absolute long-term protection, which even the best conducted poisoning campaign can not do.

Implications for the management of rabbits by fencing native vegetation remnants
Rabbit-proof fencing of those native vegetation remnants that provide refuge for rabbits is a technique which effectively removes 'prime rabbit habitat'. If conducted at a sufficient scale, then this in turn reduces the number of rabbits which can potentially inflict damage to the surrounding crops and pastures. The benefits of rabbit-proof fencing can outweigh the associated costs and become cost-neutral in the medium term (2+ years).

However, with respect to the conservation of the remnant vegetation, we have some caveats. In the short term (one year) the effect of confining rabbits within remnant vegetation, and thereby reducing the available rabbit habitat, may be both positive or negative. Such effects were not always easy to define. However, based on the results of our longer term experiment, the effect of confining the rabbits within bush remnants over a much longer term (say, 15 years) will almost certainly be negative, unless steps are taken to remove the residual rabbits completely (i.e. eradication is achieved). This would be quite possible using a combination of poison baiting and shooting, particularly if control efforts were undertaken when other food is in relative short supply (e.g. summer). If the long-term viability of the remnant bush is to be maintained, then every effort needs to be made to ensure that the residual rabbits are completely eradicated. If this is not achieved, then the bush remnants themselves may need to be subjected to regular poisoning campaigns, in addition to the cost of the fence, to prevent the deleterious effects caused by the residual rabbits. Such a situation may well be little better (or possibly worse) than employing a regular poisoning program, without the fence, undertaken to reduce the impacts of rabbits.

Another factor which needs to be considered is that the rabbit-proof fence may interfere with the movement of native animals, particularly kangaroos and wallabies. The conservation issues potentially associated with this may be important if species of high conservation value, or species which are under threat, are involved. How important this is may need to be balanced against the losses inflicted to crops and pasture, the potential loss of native vegetation, and the conservation value of the vegetation of concern. Such issues will need to be considered carefully on a case by case basis.

Consideration of extension work within the project
Most of the extension objectives for this project have been met. A well attended field-day, which was supported by the Department of Agriculture, Western Australia, was undertaken at the Tomlinson's site prior to commencing the associated experimental trials, to explain the potential benefits and costs associated with the use of rabbit-proof fencing to reduce the impact of rabbits on farm productivity. Since then, numerous, less formal visits to the Tomlinson's site by

interested landholders have taken place. A draft Farmnote has been prepared, and a copy of this is provided in Appendix 1. However, at the time of writing, the final poster display is yet to be prepared but photographs and the content of this display will be provided once the display preparation is complete.

Acknowledgements

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References

Cochrane, G.R. and McDonald, N.H.E. (1966) A regeneration study in the Victorian mallee. *Victorian Naturalist* 83, 220-226.

Cooke, B.D. (1981) Food and dynamics of rabbit populations in inland Australia. *Proceedings of the World Lagomorph Conference Guelph, Ontario 1979*. Eds. K. Myers & C.D. MacInnes. pp. 633-636. IUCN, Switzerland.

Cooke, B.D. (1987) The effects of rabbit grazing on regeneration of sheoaks, *Allocasuarina verticillata*, and saltwater ti-tree, *Melaleuca balmaturorum*, in Coorong National Park South Australia. *Australian Journal of Ecology*, **13,** 11-20.

Foran, B.D., Low, W.A. and Strong, B.W. (1985) The response of rabbit populations and vegetation to rabbit control on a calcareous shrubby grassland in central Australia. *Australian Wildlife Research,* **12,** 237-247.

Gilfillan, S (1999) Monitoring the impacts of reduced rabbit numbers due to rabbit calicivirus disease on native fauna and vegetation in the Nullarbor region, Western Australia: Final report prepared by the Department of Conservation and Land Management, WA to the Management Committee of the Rabbit Calicivirus Monitoring and Surveillance Program.

King, D.R. and Wheeler, S.H. (1985) The European rabbit in south-western Australia I. Study sites and population dynamics. *Australian Wildlife Research,* **12,** 183-196.

Lange, R.T. and Graham, C.R. (1983) Rabbits and the failure of regeneration in Australian arid zone Acacia. *Australian Journal of Ecology* 8, 377-381.

Leigh, J.H., Wimbush, D.J., Wood, D.H., Holgate, M.D., Slee, A.V., Stanger, M.G. and Forrester, R.I. (1987) Effects of rabbit grazing and fire in a subalpine environment. I. Herbaceous and shrubby vegetation. *Australian Journal of Botany* 35, 433-464.

Mallet, K.J. and Cooke, B.D. (1986) *The Ecology of the Common Wombat in South Australia.* Nature Conservation Society of South Australia, Adelaide.

Morris, M. (1939) Plant regeneration in Broken Hill district. *Australian Journal of Science* 2, 43-48.

Twigg, L.E., Lowe, T.J., Martin, G.R., Wheeler, A.G., Gray, G.S., Griffin, S.L., O'Reilly, C.M., Robinson, D.J. and Hubach, P.H. (1998) The ecology of the European rabbit *(Oryctolagus cuniculus)* in coastal southern western Australia. *Wildlife Research*, **25,** 97-111.

Williams, C.J., Parer, I., Coman, B.J., Burley, J. and Braysher, M.L. (1995) *Managing Vertebrate Pests: Rabbits.* Bureau of Rural Resources/CSIRO Wildlife & Ecology, Australia Government Printing Service, Canberra.

Zar, J.H. (1984) 'Biostatistical Analysis'. (Prentice-Hall: Inglewood Cliffs, New Jersey, USA.) 718 pp.

PLATES

Plate 1. Pasture with no rabbit-proof fence – Tomlinson's

Plate 2. Pasture protected by rabbit-proof fence Tomlinson's – site 1, fenced 4-5 years previously

Plate 3. Canola protected by rabbit-proof fence – Tomlinson's site 1

The following photos show crop losses caused by rabbits. The value of the losses is given for each photograph.

Plate 4. Parsons'. Canola 2.25ha, 1.6t/ha, 3.6t at $360, = **$1296**

Plate 5. Parsons'. Canola, 0.5ha, 1.6t/ha, 0.8t at $360/t, **$288**

Plate 6. Parsons'. Canola, 1ha, 1.6t/ha, 1.6t at $360/t, **$576**

Plate 7. Griffiths (a neighbouring property of Parsons'). Canola, 3ha, 1.6t/ha (estimate from Parsons' yields), 4.8t at $360/t, **$1728**

This area of crop (centre) was damaged by the high density of rabbits from the roadside reserve (right of photo).

Plate 8. Tomlinson. Lupins, 0.25ha, 0.9t/ha, 0.225t at $220/t, **$50**

Plate 9. Parsons'. Lupins, 1.5ha, 0.9t/ha,1.35t at $220/t, **$297**

Plate 10. Parsons'. Lupins, 1.2ha, 0.9t/ha, 1.08t at $220/t, **$238**

Plate 11. Parsons'. Barley, 0.3ha, 2.0t/ha, 0.6t at $165, **$99**

Plate 12. The photo shows the damage to canola which led the Tomlinson's to reseed part of a paddock following construction of rabbit-proof fencing (see case study on page 16).

APPENDIX 1 **DRAFT**

FARMNOTE XX/2002
Agdex xxx

Use of rabbit-proof fencing to protect crops and pasture from rabbits in bush remnants

By Tim Lowe, Stuart Wheeler and Laurie Twigg, Vertebrate Pest Research Section, Forrestfield.

Background

Rabbits are estimated to cost Australia at least $600 million annually in lost agricultural production and they also have a well-documented history for causing environmental damage.

In Western Australia, some areas of native vegetation on farms have been left uncleared, particularly on sandy ridges that would otherwise be subject to wind erosion. These bush remnants are also recognised as a major refuge habitat for rabbits. Rabbits living these areas can subsequently cause considerable damage to the adjacent pastures and crops (Figs. 1 & 3).

Some measure of rabbit-control can be achieved by poisoning around these bush remnants in late summer or autumn, prior to seeding. However, rabbit densities and consequent crop and pasture losses can still be unacceptably high using this approach unless any residual rabbits are removed. To be effective, this approach usually requires an annual control effort.

Because of their conservation value, clearing these bush remnants (some of which are along protected road reserves) in order to eliminate the resident rabbit populations is not an acceptable option. So what can be done in these situations?

Rabbit-proof fencing

The use of rabbit-proof fencing is not a new approach but nowadays tends to be overlooked as a viable option by the majority of landholders due to its relatively high initial cost. Landcare professionals are also concerned that any rabbits remaining in native bush remnants that have been fenced-off could have a damaging effect on the long-term viability of these remnants.

A recent study in the south coastal region of Western Australia investigated the benefits and costs of fencing off areas of remnant vegetation to prevent rabbit damage to surrounding crops and pastures. It also examined the effects of "fenced-in" rabbits on the native vegetation itself. Crop losses caused by rabbits in areas adjacent to unfenced areas were also evaluated.

To be effective, the fence should be approximately 900 mm high, with the bottom 150 mm bent to lay on the ground facing away from the bush remnant. This 'apron' can be secured with rocks and/or soil. Alternatively the netting can be buried vertically 150 mm below ground level. If necessary the height of the fence can be increased by attaching additional 'repair' netting (300 mm wide) to the top of the fence.

Fig 1. Barley crop damaged by rabbits living in the adjacent remnant bush.

Benefits

Rabbit-proof fences can provide complete protection for crops and pastures adjacent to a fenced bush remnant on a long-term basis (Figs. 2 & 3). Even the most efficient poisoning campaign cannot achieve such a result. Nevertheless, these fences need to be checked regularly, to make sure there are no breaches, if they are to be totally effective.

If all rabbits are completely removed from within the fenced bush refuge, then no further control action is required. However, if rabbits persist, even at low numbers, remedial action will be required to ensure that the residual rabbits do not effect the viability of a bush remnant.

Another advantage of fencing-off a bush remnant is that stock are excluded thereby reducing any damage to the native vegetation, and hence preventing any future soil erosion.

Fig 2. This canola crop is protected from rabbits in the bush refuge (right of photo) by a well-constructed rabbit-proof fence

Costs

Rabbit-proof fencing may not be cheap. A 1 kilometre long rabbit-proof fence would cost approximately $5,000 to erect ($4,000 for materials plus $1,000 for labour). However, for high value crops such as canola, these costs could be recovered within two seasons depending on the amount of fencing needed, and on crop returns. For crops of a lesser value (e.g. lupins, barley) the costs of fencing can be defrayed over the life of the fence. There are also tax benefits to landholders (e.g. depreciation). If well maintained, most fences should last for at least 15 years.

Fig 3. Remnant bush has been fenced to protect the newly sown crop in the adjoining paddock

Effects on remnant vegetation

Even low numbers of residual rabbits in the fenced-off bush will have a negative impact on the abundance of seedlings and regenerating plants, and the sedges and native grasses are also affected. The effect of confining rabbits over the medium to long term will ultimately be detrimental to the overall 'health' of the native vegetation, affecting both the abundance and mass of many plant species. Thus, measures need to be taken to remove all residual rabbits.

Poison baiting with 1080 would be a suitable technique for removing residual rabbits. This may be easier because the rabbits are confined within the bush remnant, particularly if they are targeted when available food is in short supply (summer/autumn). However, the best approach is to remove all rabbits prior to totally enclosing a bush remnant. This may require a combination of 1080-baiting, shooting and live cage-trapping.

Other considerations

If all rabbits are not totally removed from the fenced-off area, a regular poisoning program will be required to prevent long-term damage to the bush remnants. If this becomes necessary it may well create a situation which may be no better than the use of routine rabbit control techniques without a fence.

The use of bait stations may help with controlling the rabbits within the bush refuge, where stock access is prevented by the rabbit-proof fencing. Bait stations can reduce the potential risks to non-target species. However, bait stations should not be left permanently loaded with poison bait, as this is likely to increase the development of resistance to the poison being used.

The fence may also interfere with the movement of other animals (e.g. kangaroos, wallabies) whose welfare and conservation could be an issue for consideration in some situations. Thus, the merits of each case will need to be assessed on an individual basis.

Further information

For further information contact the Vertebrate Pest Research Section, Department of Agriculture, Forrestfield, telephone (08) 9366 2300.

See also Farmnotes:

- *Options for rabbit control* (Agdex 671).
- *Landholder use of 1080 One shot rabbit bait* (Agdex 671)
- *Rabbit warren and harbourage destruction* (Agdex 671)
- *Bait stations and rabbit control* (Agdex 671)

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