Investigating the impact of removing rabbit harbour on animal and vegetation dynamics

Cottonvale Project Report 2007-2013

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Report compiled by J C Scanlan and M Brennan.

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This publication has been compiled by J C Scanlan and M J Brennan of Biosecurity Queensland, Department of Agriculture and Fisheries.

Summary

The field study reported here documented differences between sites that were either side of the Darling Downs Moreton Rabbit Board fence: one side had a long history of rabbit exclusion with few rabbits present whereas the other side had higher rabbit numbers over time.

There were marked differences in the flora and fauna on either side of the fence, particularly rabbit abundance and pasture biomass. This difference reflected the long period of separation of the two areas by the DDMRB fence with differences in rabbit abundance as well as possible differences in general grazing management.

The control of rabbit numbers on the infested side of the fence did not improve pasture condition to a state similar to that in the rabbit free area during the relatively short period of this study. Recent reviews and simulation studies of the pasture response to changes in grazing management (including changing in grazing pressure) have shown that pastures may takes many years to respond to even quite large reductions in grazing pressure (Hunt et al. 2014, Scanlan et al. 2014). Any positive impact of reduced rabbit density on the infested side will require a much longer time frame for any measureable improvement could be recorded and will depend on the general grazing management of the area.

Small sample size precluded conclusively comparing rabbit survival on either side of the fence. This needs further investigation, particularly the effects on rabbit survival of those harbouring above ground compared with those living in warren systems. Similarly, reproductive output and recruitment appeared better where warrens were available, but this needs further testing in this environment with more data before more definitive conclusions can be made.

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Introduction

In 1950, the biological control agent, myxoma virus, reduced rabbit numbers dramatically across Australia. By the 1960s rabbit numbers had returned to extremely high levels in the best areas for rabbits while in other areas they did not recover at all.

In 1996, rabbit haemorrhagic disease virus (RHDV) spread across Queensland and reduced rabbit numbers by at least 70%. This, combined with myxomatosis, suppressed rabbit populations by over 90% below the pre-1950 levels (as at 2008). However, there are signs that rabbit populations are recovering now from RHDV as they did from myxoma virus. We have reports of rabbits in areas where a problem was not previously evident. Rabbits may be developing, or have developed, a genetically based resistance to RHDV and/or the virus may be developing less virulent strains.

Most disturbing is an increase in the number of rabbit outbreaks within the Darling Downs–Moreton Rabbit Board area. Historically, this is an area where rabbits have not been allowed to establish and where native plants and animals and agriculture have been protected from the impact of rabbits for over 100 years since rabbits arrived in Queensland. There is a need to stop the invasion of rabbits into this part of Australia.

The recovery from RHDV has not occurred in Queensland at sites where rabbit warrens were ripped. Rabbit control using biological control agents or poison, without destruction of warrens, generally provides only a short-term reduction in numbers. Areas where warrens were destroyed have remained virtually free of rabbits for up to at least 20 years (Berman et al. 2011). For long-term control, therefore, rabbit breeding places (e.g. warrens, holes under concrete slabs) must be removed.

An experiment was established in 2001 to measure the cost and effectiveness of warren ripping on Bulloo Downs in south-west Queensland. By 2002 we had demonstrated that warren ripping controlled rabbits and there were benefits to native plants and animals as well as cattle production. From 2002 to 2004 55 000 warrens were ripped on Bulloo Downs in areas considered to be drought refuge for rabbits. Targeting these key areas suppressed the rabbit population by over 99% for a fraction of the cost of ripping all warrens on the property.

The benefits of effective rabbit control to biodiversity and agriculture need to be properly measured also in south-east Queensland using techniques similar to those used at Bulloo Downs. Measuring these benefits and demonstrating methods used for control are essential to encourage landholders to control rabbits.

Warren ripping provides long-lasting control but often landholders claim that they have no warrens and that their rabbits live in logpiles or in other harbour. It is unclear if these rabbit populations are self-sustaining or depend on ‘source areas’ where there are warrens. Ripping of warrens in ‘source areas’ may reduce rabbit numbers in surrounding areas. This approach worked at Bulloo Downs and may also be applicable to other parts of Queensland.

This study comprised three components:

1. Description of differences in flora and fauna between rabbit free and rabbit infested areas
2. Estimating the potential impact of rabbits on livestock production through their consumption of pasture
3. Quantifying the influence of controlling rabbits on vegetation and fauna recovery towards that in the rabbit-free area.

Methods

Study site

After surveying a number of sites throughout south-east Queensland, a site at Cottonvale, on the southern edge of Warwick Shire (now Southern Downs Regional Council) was selected. This site has a high concentration of rabbit warrens in close proximity to the Darling Downs–Moreton Rabbit Board area (on the unprotected side of the rabbit proof fence). Breaches in the fence have allowed some rabbits into the rabbit-free area but they have not established warren systems there; these animals predominantly live in log piles. The study site was approximately 2.5 km south east of the town of Dalveen in south east Queensland. The site is 2 km due east of the New England Highway (see Fig. 1) between Warwick and Stanthorpe.

The site is located on the property ‘Forest Oak’, primarily a cattle grazing area situated in the granite belt region between Warwick and Stanthorpe. The site is divided into two areas that are separated by the Darling Downs-Moreton Rabbit Board (DDMRB) fence. For the purpose of this project, the areas are referred to as the ‘clean side’ and the ‘dirty side’ of the fence. The ‘clean’ side refers to the part of the site that is on the protected or rabbit-free side of the fence and is about 80 ha. The ‘dirty’ side refers to the area where rabbits are not excluded by any fencing and is about 120 ha.

The research site is generally dominated by perennial grass species such as blady grass (*Imperata cylindrica*), barbed wire grass (*Cymbopogon refractus*), love grass (*Eragrostis* spp.), white spear grass (*Aristida* spp.) and umbrella cane grass (*Leptochloa digitata*). Differences in cover existed across the site, due to differences in grazing pressure and also related to soils and landforms. All sites were non-saline, and hillslope soils were shallow (<0.5 m), and frequently stony. In the saddle, which runs perpendicular to the middle of the research area, soils are deeper, and colluvial in origin. Soil type, landform and land use are similar on both sides of the fence

Animal monitoring

All warrens and log piles were marked with steel posts and the number of active and inactive burrows was recorded for each warren system. Rabbit-proof and cattle-proof (with rabbit access) exclosures were established to separate the impact of rabbits on vegetation from impacts caused by cattle. Sand plots were also established to record rabbit tracks and predator tracks throughout the site as an index of their abundance.

Cattle movements

The two paddocks were managed together with cattle being moved from one to the other on a 3-6 monthly sequence, driven in part by forage availability and by a desire to provide some rest for the paddocks. Numbers of cattle varied between years but there was no information collected on actual numbers. Estimates of cattle numbers were based on informal discussions with the owner as well as inferences drawn from the forage availability in the vegetation assessment plots.

Rabbit harbour

Suitable rabbit harbour existed in both areas, with a combination of warrens and above-ground harbour (Fig. 3). On the dirty side, there were 72 warrens and 24 log piles while on the clean side, there were 77 log piles but no warrens.

Figure 1 General location of the Cottonvale project site, near Stanthorpe in southern Queensland.

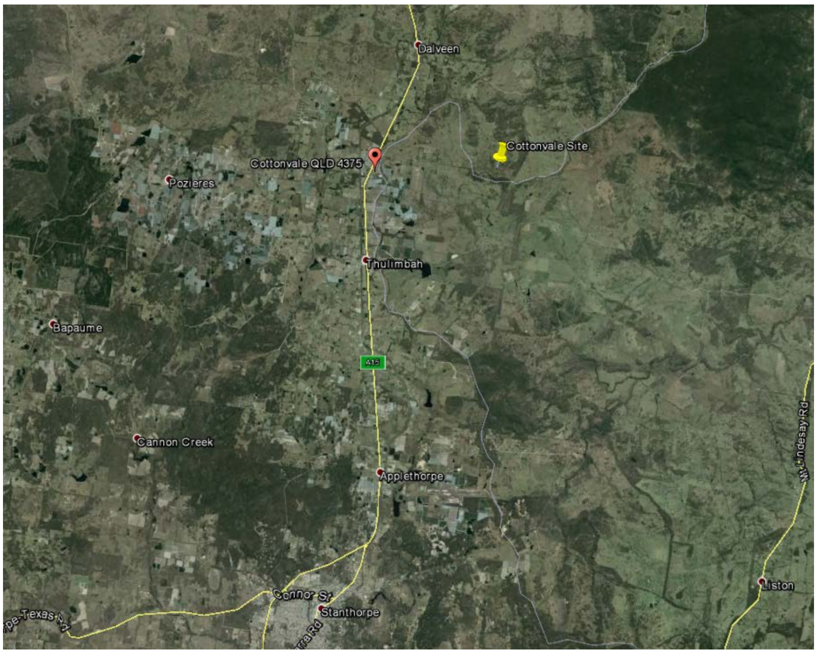


Figure 2 Cottonvale site showing the 'dirty' and 'clean' paddocks.

Figure 3. Examples of rabbit harbour at the research site. (a) warrens in rocks on dirty side (b) log piles on clean side, and (c) hole beneath log piles prior to clearing.

(a)

(b)

(c)

Rabbit Control

Rabbit habitat was mapped on both sides of the fence. On the dirty side of the fence, warrens and log piles were located and mapped with a hand held GPS while on the clean side only log piles were mapped as no warrens were located. Control commenced in April 2009 and took approximately 2 months to complete. Rabbits were controlled on the dirty side of the fence by ripping all warrens and burning the log piles. Vegetation surveys were conducted pre and post control and rabbit and other animal activity was measured using spotlight counts, track plots and remote cameras.

Remote Photography

Eight infra-red 'Moultrie Game Cameras' were set up in both treatments. Cameras were positioned on steel posts on the south east corner of each of the vegetation exclosures (see below). They were set above one of the five track plots that were also positioned around the perimeter of the exclosures. Cameras were set to capture images after 5-minute intervals between photos being taken.

Initially, cameras operated over an 18 month period, and photos were downloaded approximately every 6 weeks. Thereafter, use of cameras was opportunistic. Each camera marked each photo with temperature and time at moment of image capture. The number and species of animals seen in each of the photos were recorded. See Fig. 4 for some common animals photographed.

Track Plots

Sand track plots were used as a method of monitoring rabbit and predator activity across the site. Plots were circular and approximately one metre in diameter (Fig. 5). Five plots were evenly spaced around the perimeter of five warrens on the dirty side (total of 25 plots) and five log piles on the clean side (further 25 plots). Also, five plots were placed around each of the eight vegetation exclosures (40 plots), giving a total of ninety sand track plots for the whole site – 45 on each side.

Track plots were monitored for three consecutive mornings. All animal tracks were recorded and identified.

Spotlighting

A spotlight transect was established on both sides of the fence (see Fig 6). The transect started at the northern end of the site and ran south along the rabbit proof fence for 2.3 km. Rabbits were counted on both sides of the fence along this section of the transect, but those on the clean and dirty sides were distinguished. After the 2.3 km drive along the fence, the counts move into the middle of each site, away from the fence. The clean side spotlight transect is 4.2 km in length and the dirty side transect is 3.9 km. The spotlight counts were conducted at three monthly intervals for three consecutive nights over a two and a half year period from May 2007 till November 2009. Counts were conducted over three consecutive nights in May 2013.

Trapping, collaring and tracking

A total of 49 rabbits were trapped and fitted with VHF tracking collars between 15 Jan and 15 March 2009. Collars remained on rabbits from four days up until 308 days (one rabbit on the clean side was alive for 308 days and another on the dirty side for 307 days until we lost signals for both and could no longer track them). Thirty-five rabbits were collared on the dirty side and 14 were collared on the clean side. Each collar was fitted with mortality sensors that helped determine the number of hours since no movement on the collar (i.e. death).

Figure 4. Examples of the most common mammals observed by the remote cameras.

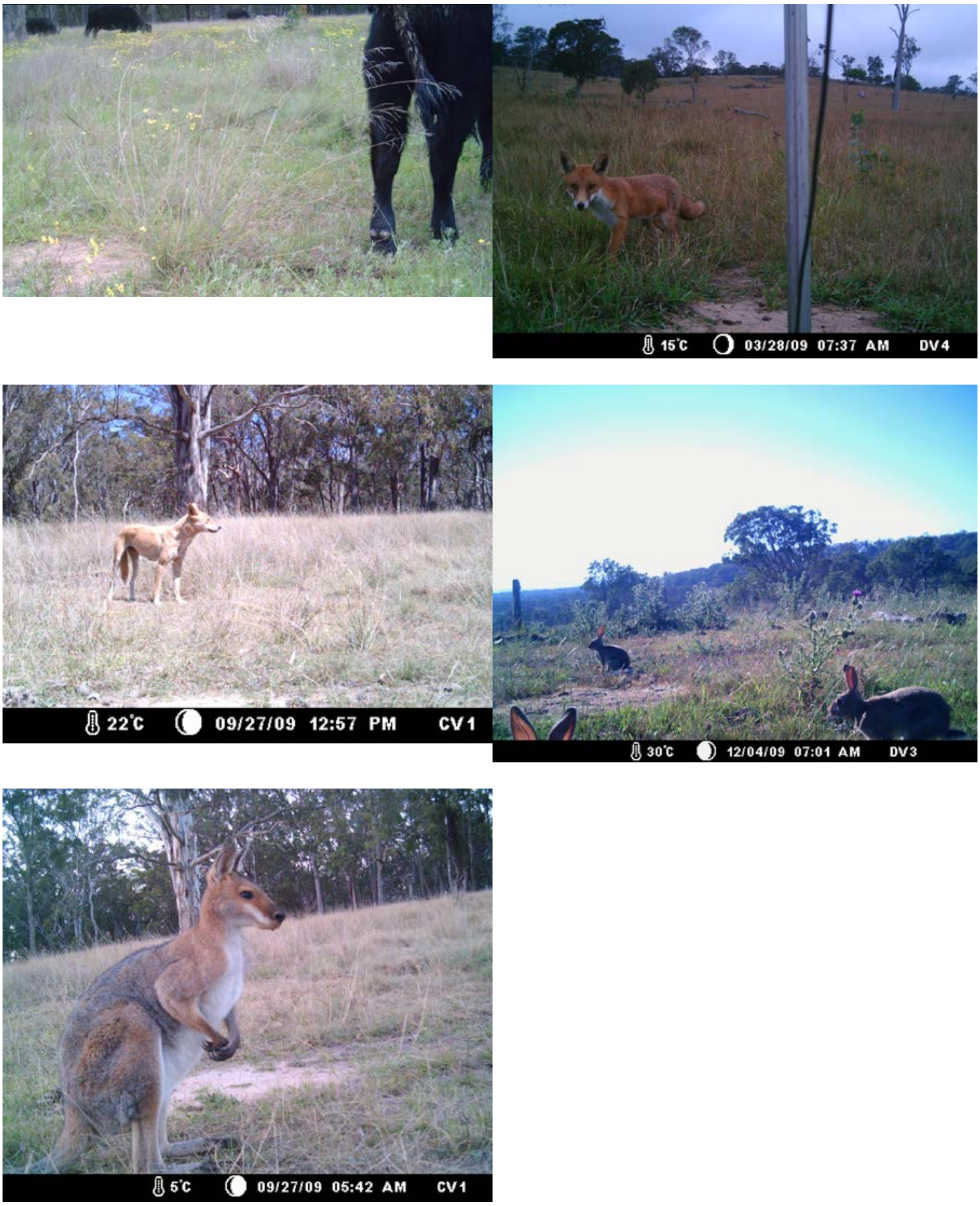


Figure 5. A sand plot being established near to a vegetation exclosure.

Figure 6. Spotlight transects on the dirty (western) side and the clean (eastern) side.

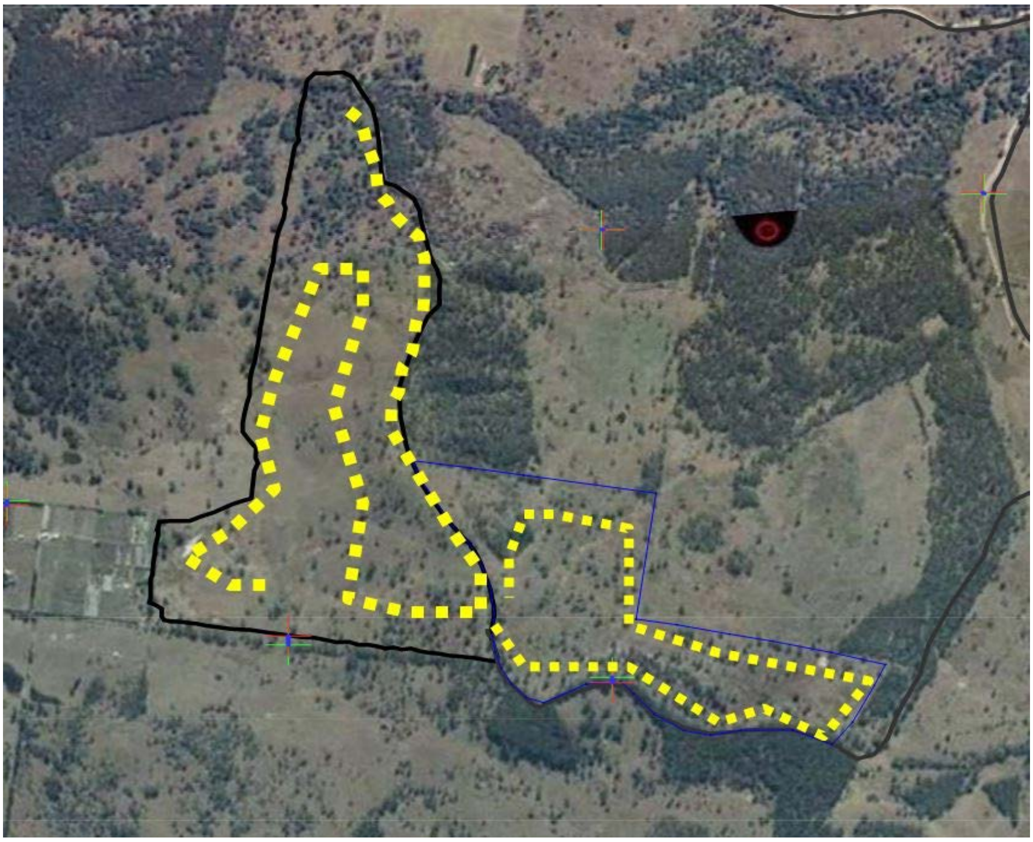


Figure 7. Tracking rabbits (a) rabbit with collar attached and (b) tracking a collared rabbit in a logpile.

(a)

(b)

Vegetation monitoring

Plot treatments

Four exclosures (fenced vegetation assessment plots) were constructed on each side of the rabbit proof fence as illustrated in Figure 8, giving a total of eight exclosures. Exclosures were located over the whole site and the range of soil types was represented. A soil analysis conducted at the site prior to any vegetation analysis revealed that the site comprises two major soil types - metamorphic and sandstone-derived soils.

Each exclosure comprised three 10 m X 10 m plots: one fenced to exclude cattle and rabbits (and other medium to large herbivores such as macropods) ‘rabbit (or full) exclosure’; one fenced to exclude cattle ‘cattle exclosure’; and the third was an unfenced control to allow all animals to access the vegetation - ‘open’.

Pasture biomass and species composition was determined by the BOTANAL technique (Tothill et al 1978). The BOTANAL procedure involves visual ratings of the amount of plant material in a 50 x 50 cm quadrat and comparing these to set standard quadrats. These standard quadrats are then cut, dried and weighed. All yield ratings are then converted to dry weights through a separate regression for each person. The three most dominant plant species in each quadrat are also recorded. In each of the 24 plots, 40 quadrats were examined. This provides an estimate of the yield of each plant species present.

Pasture species that could not be identified onsite were sampled and sent to the Queensland Herbarium for identification. Also, a Queensland Herbarium staff member visited the site in October 2007 to assist with species identification and determine species richness and diversity in the clean and dirty sides.

The first round of vegetation samples was conducted in early July 2007, approximately 2 weeks after the exclosures were erected. Pasture was sampled on six occasions up till October 2013.

Allocation to species groups

There were a large number of species recorded over the period of the trial. In order to examine vegetation change over time using the GRASP pasture production model, these were aggregated into six classes: 3P grasses; 2P grasses; annual grasses; forbs; native legumes; sedges. [3P grasses are the most desirable pasture species as they are perennial, palatable and productive grasses; 2P grasses have two of these characteristics].

GRASP simulations

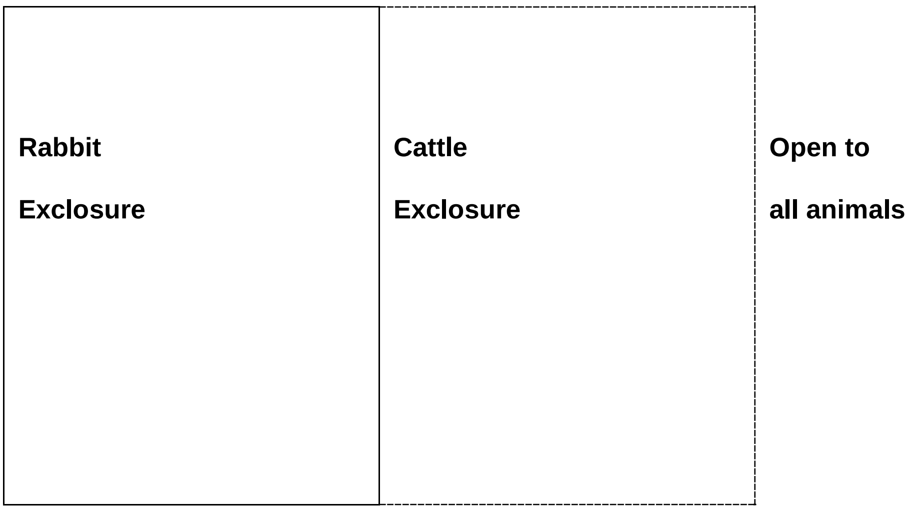
The data provided an opportunity to build a model of rabbit impact on pasture production at the site and so determine one cost of rabbits to the grazing industry in the region. The GRASP pasture production model is a well-validated, empirical model used extensively through northern Australia to estimate pasture production and pasture condition changes in addition to animal production (see Scanlan et al 2013 for an example of its use in a grazing trial).

Insufficient data were available for individual plots to compare observations with modelled estimates of pasture production. All plots within the same type of exclosure were therefore averaged for the clean side and the dirty side, giving three exclosure means for both the clean and dirty sides.

Figure 8 (a) Photograph of the exclosures and (b) diagram of the layout of the exclosures in the above photograph.

(a)

(b)



Data from the first year were used to develop an appropriate set of parameters for the GRASP model for the site as a whole (see Appendix 1). The GRASP model was then run for the length of the trial to predict total standing dry matter and the proportion of 3P grasses in each of the exclosure/treatment combinations. To do this required estimates of the numbers of herbivores in the paddocks over time. Data on the number of livestock and the timing of movements between the two treatments were not available. However, the total number of stock grazed on the two paddocks was about 50 adult equivalents (1AE = 450 kg dry beast) and were made up of varying proportions of cows, calves and steers. These were moved approximately every 3-6 months. These stock movements were included in the GRASP model to estimate changes in the OPEN plots. An additional base amount was estimated for the grazing due to rabbits and macropods. This was estimated from the difference between the full exclosure and the cattle exclosure. In general, these differences were small.

Results

Animal monitoring

Spotlight data

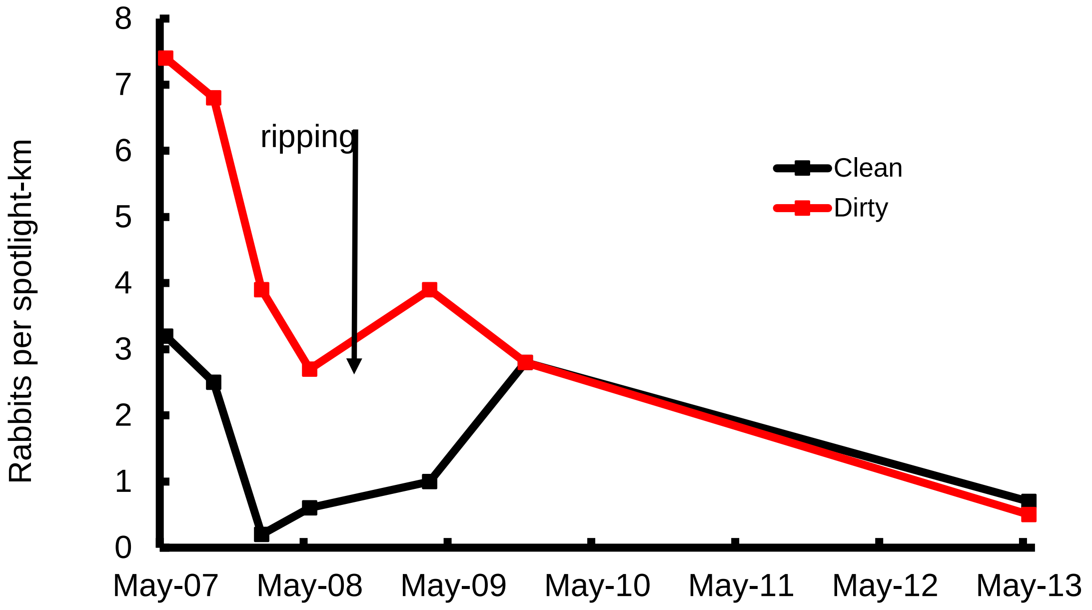
At the commencement of the study in May 2007, rabbit abundance in spotlight counts was 7.4 and 3.2 rabbits per spotlight kilometre on the dirty and clean sides of the fence respectively. Numbers declined steadily until late autumn of the following year (Fig. 9). There was evidence of myxomatosis at the study site and, while it was not confirmed if rabbit haemorrhagic disease virus (RHDV) was also present, two dead rabbits were found at the site that did not appear (from physical examination) to have died from myxomatosis. Generally rabbits stop breeding from summer through to early winter (particularly in southern Australia) – this is when rabbit numbers decline, or at least remain steady. Spring kittens also become susceptible to RHDV at this time. In January 2008 numbers should have been high as a result of spring breeding. There was a sharp decline from September 07 to January 08 – a time where numbers should have been increasing. The fact there was a decline on both sides of the fence suggests external pressures – more likely disease rather than predation because of timing and extent of mortality – were influencing densities.

Prior to any control, trends in rabbit numbers were similar on both sides (i.e. both were in steady decline, regardless of density). After control measures were implemented in March 2009, rabbits seen in spotlight counts dropped significantly on the dirty side, while numbers seen in spotlight counts actually increased slightly on the clean side of the fence (Fig. 9). Some log piles were also burnt on the clean side of the fence at the same time as warrens were ripped on the dirty side, however this was sporadic and there was still harbour available for the clean side rabbits.

Predator numbers peaked in January 2008 at the site (Fig. 10), which is when rabbit numbers were declining. As noted previously, myxomatosis was active at the site and there were sick rabbits above ground on the site. This may have influenced predator activity, particularly on the dirty side of the fence.

Four years after ripping (May 2013), there was no evidence of an increase in rabbit numbers on the dirty side, compared to the clean side (Fig. 9). Rabbit numbers have remained low on both sides of the fence; 0.7 rabbits/km on the clean side and 0.5/km on the dirty side. It is likely that the combination of biocontrol (both RHDV and myxomatosis) and mechanical control has kept rabbit numbers low. Predators may have had a role in keeping rabbit numbers low, however without spotlight counts between November 2009 and May 2013 it is unknown if there was significant predator activity in the area (Fig. 10). Post ripping there was some predator activity recorded on the clean side in track plots, but not in spotlight counts.

Figure 9. Rabbit abundance from spotlight counts before and after ripping in the two treatments at Cottonvale.



Track Plots

Rabbit activity in track plots mirrored the results found in the spotlight results (Fig. 12). Both monitoring methods show the same trend in rabbit activity at the site over a two year period. There was a decrease in rabbit activity in the second half of 2007 and early 2008, followed by an increase in activity throughout 2008 and early 2009. Activity continued to increase on the clean side after warren ripping on the dirty side of the fence, while activity decreased on the dirty side after control was implemented.

Figure 10. Predator abundance from spotlight counts in the two treatments at Cottonvale

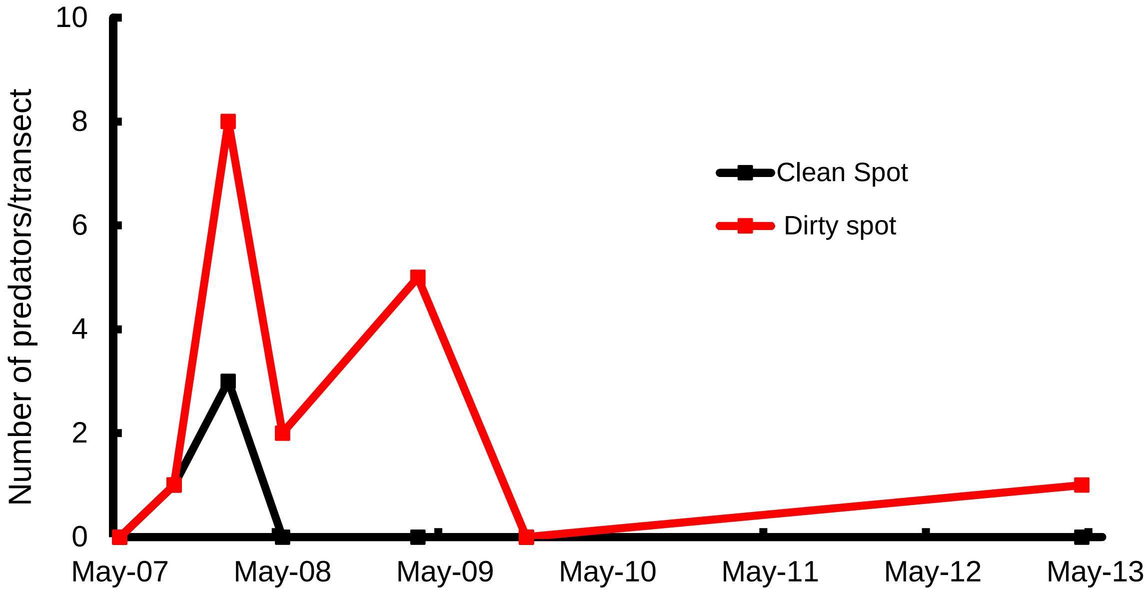


Figure 11 Predator activity in track plots in the two treatments at Cottonvale.

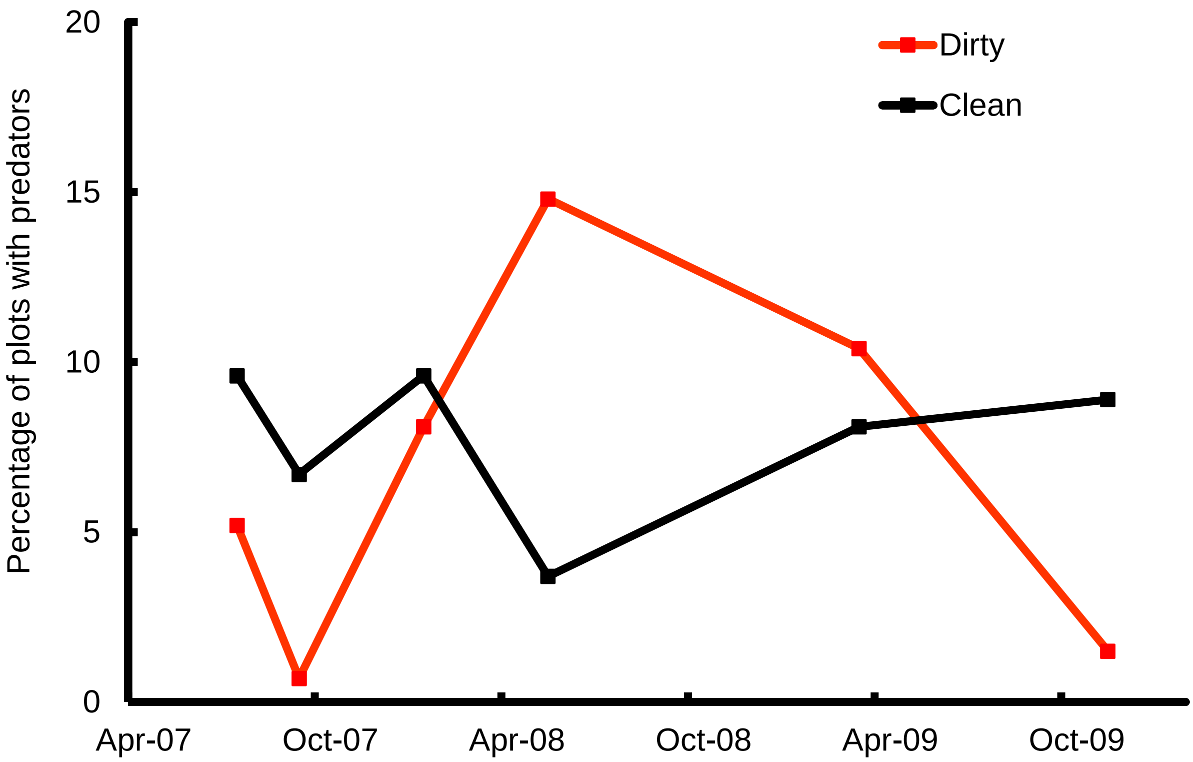
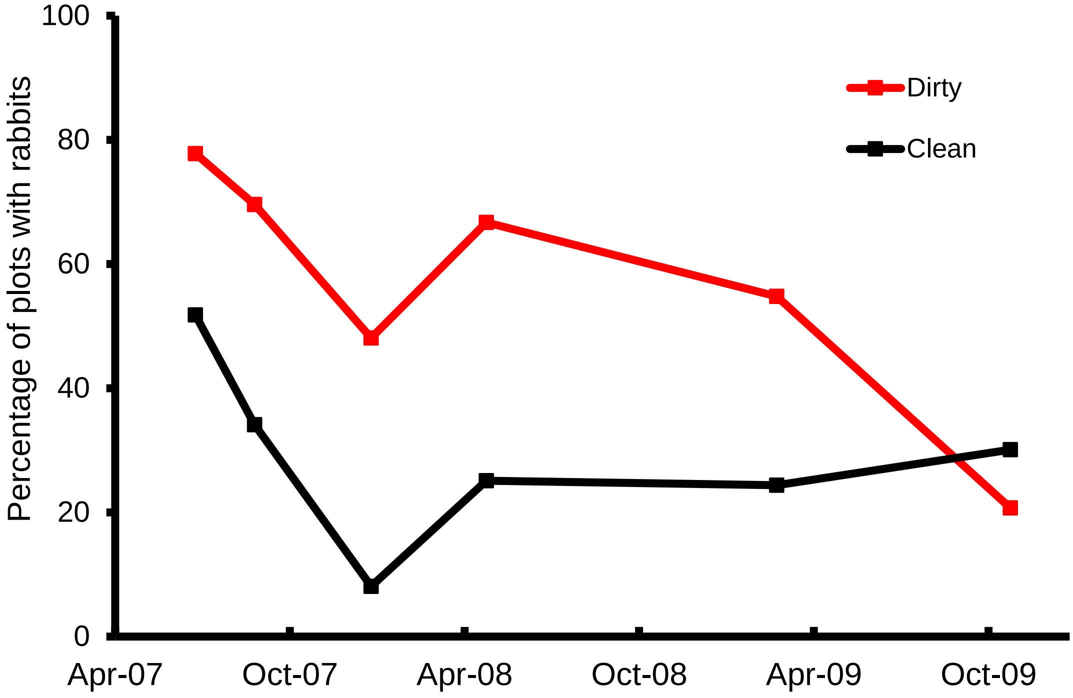


Figure 12 Rabbit track plot activity in the two treatments at Cottonvale



Predators were also recorded in track plots. The main predators were foxes and dogs, while there was also cat activity recorded on the site. Predator activity was closely aligned with rabbit activity. The percentage of track plots recording predators on the dirty side peaked in May 2008 (Fig. 11), corresponding with a peak in rabbit activity on the dirty side. (Fig.12). Track plots revealed predator activity on the clean side of the fence at times when spotlighting was not picking up any predator activity. From May 2008 there was no predator seen in spotlight counts on the clean side of the fence, whereas there was evidence in the track plots.

Remote cameras

The eight cameras set up at the site highlight the same trends in rabbit activity as the spotlighting and track plots. The cameras provided much more data on the presence and activity of rabbits at the site as they were left running continually between monitoring events. Fig.13 shows the decline in rabbit sightings post control on the dirty side (done in May 2009). It must be noted that the Y axis shows the 'number of rabbits photographed'. These are not individual rabbits, but just total number of photos taken with rabbits (i.e. not an indicator of density, but activity).

Trapping and collaring

The average survival time for rabbits on the clean side was 108 days compared with 64.5 days on the dirty side. Despite this apparently large difference, it was not statistically significant due to the relatively low number of animals (Fig. 14). Two relatively long-lived rabbits were responsible for the greater percentage survival on the clean side after 50 days. The pattern of survival was very similar for rabbits on both sides of the fence for the first two months.

Figure 13. The number of rabbits seen in remote cameras in the two treatments at Cottonvale.

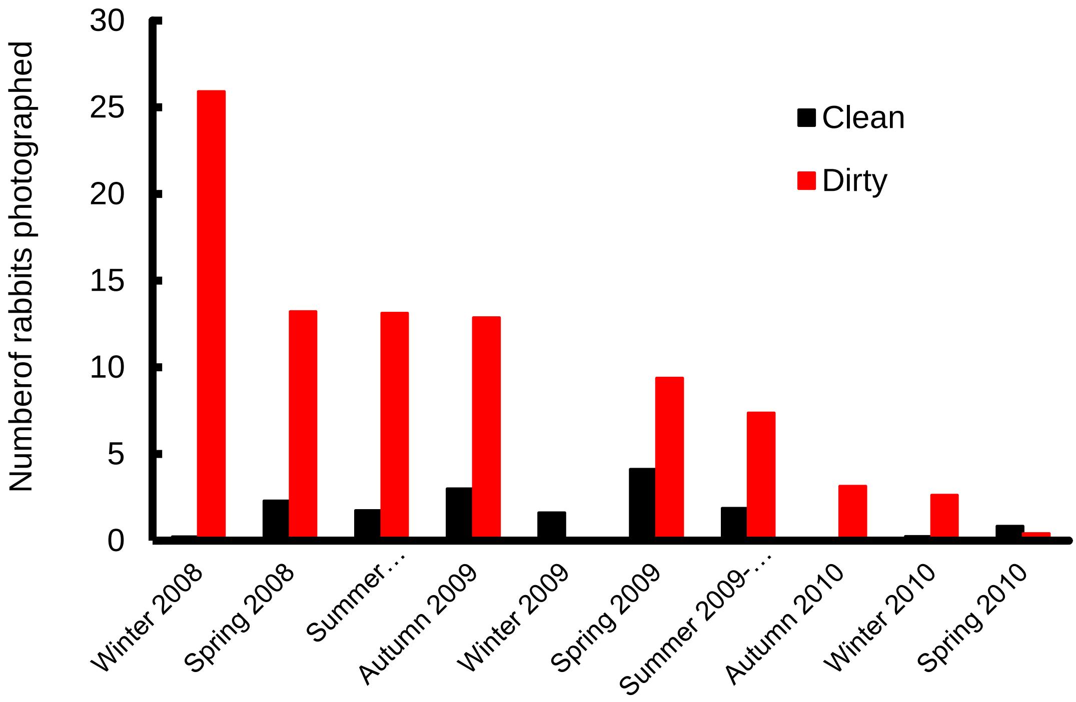
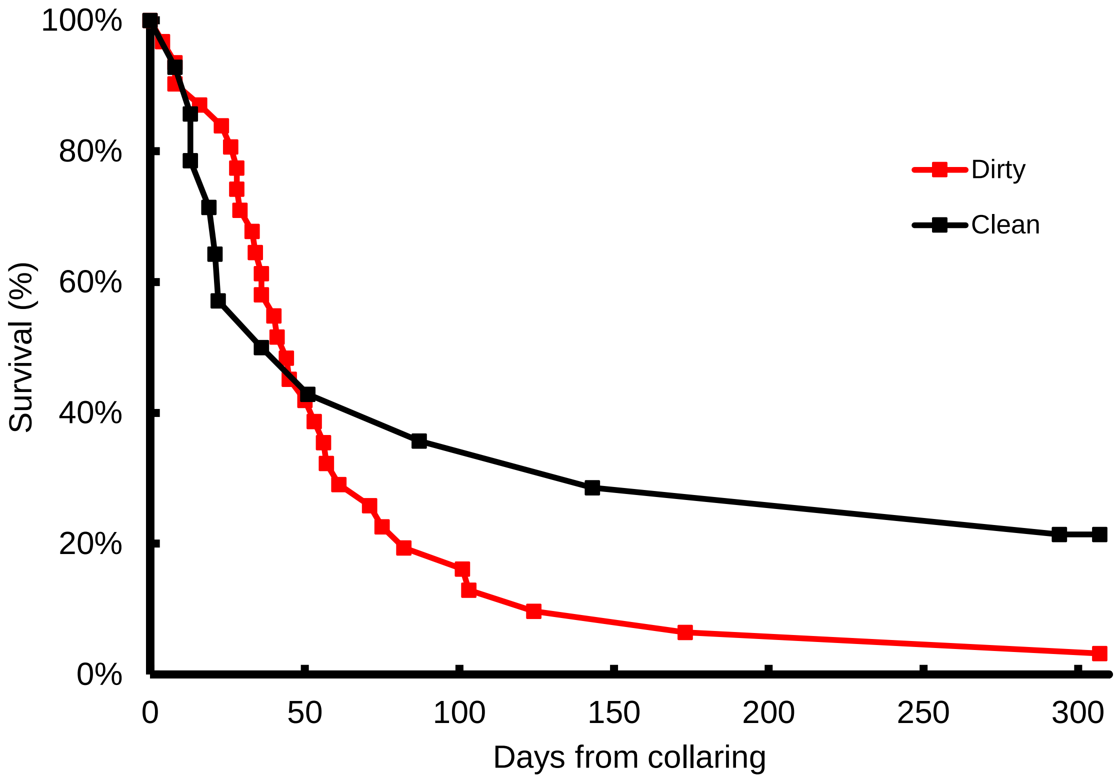


Figure 14. Survival curves for collared rabbits in both treatments at Cottonvale.



The longest surviving rabbit was on the clean side and was found to be living under log piles, in grass squats, and hiding in the long blady grass that dominated some areas of the site. This rabbit was collared and tracked for 308 days, until the signal was lost and the rabbit could no longer be located. Interestingly, the rabbit that survived the longest on the dirty side (307 days) was never located in a major warren and was found in logs, grass squats and above ground in long grass.

The cause of death was recorded (if known) for all rabbits that were fitted with collars (Table 1) Only rabbits that were confirmed dead are recorded in this table (the total rabbits collared on the dirty side was 35 and 14 on the clean side)

Table 1 Causes of death of collared rabbits at Cottonvale.

Cause of death	*Clean Side (n=11)*	*Dirty Side (n=32)*
Predator	55% (6)*	37% (12)
Ripped or log pile destruction	9% (1)	22% (7)
Unknown	36% (4)	41% (13)

*Numbers in brackets refer to the number of rabbits

Vegetation monitoring

Graphs of dry matter – Data

Initially, the standing dry matter was similar for each of the three treatments (rabbit, cattle and open) for the four replicate exclosures on both the dirty and clean sides, as would be expected as the assessments were done soon after the exclosures were erected (Figs 15 and 16). Not surprisingly, the highest total standing dry matter over the study period was observed in the rabbit exclosures, which had the least amount of grazing, with only invertebrates consuming the vegetation and the occasional macropod jumping the fences and grazing the area. As expected, the lowest standing dry matter was in the areas open to grazing by all animals.

There was a wide range of yields observed between replicates of the same treatments and at different sampling times, the rank order of the plots changed. In part, this is due to the different landscape positions of the four replicates. The Dirty3 replicate initially had the equal lowest standing dry matter, then in the cattle and the rabbit exclosures, this replicate had the highest standing dry matter until the last assessment. A possible contribution to the change during the last sampling interval is that the exclosures had been in place for almost six years by the last sampling and this could have resulted in the pasture becoming unproductive due to the high accumulation of dead material in the preceding intervals.

Graphs of dry matter - simulations

The GRASP model was calibrated to the mean standing dry matter in the rabbit exclosures on the clean side (Figs 17, 19). Those parameters were then used to run the model for the dirty side (Figs 18, 20). Estimates of the number of cattle on each side of the fence were available, but accurate numbers were not. These estimates were included in the model and gave a good representation of the standing dry matter in the open plots. The plots with cattle excluded but open to grazing by rabbits and macropods was best represented by using a grazing pressure equivalent to 0.02 Adult equivalent per hectare (2 AE/100 ha). There were inconsistent differences between the totally exclosed and the cattle exclosed plots to determine the equivalent grazing pressure due to rabbits and macropods. In broad terms, this is supported by remote camera observations and spotlight transects which showed a relatively small number of rabbits present at any time (even before any harbour removal was undertaken on the dirty side).

Graphs of species groups

One of the measures of the condition of pasture is the percentage of dry mater made up of 3P grasses. These productive, perennial and palatable grasses form the basis of a good pasture and are resilient. See Fig. 21 for fluctuations in the 3P grasses and other species components of the pasture. The pasture composition in all exclosure types on both sides of the fence showed an increase in the percentage of 3P grasses, indicating an improvement in the condition of pastures in all plots. Other grasses showed no consistent trend with time and there was a decline in the aggregation of other species as a percentage of the pasture (Fig. 21b, c).

The GRASP model was run to estimate the change in 3P grasses as a check of that model's application in southern Queensland. The overall agreement between the modelled 3P percentage and the measured composition is good (R^2 = 81% - Fig. 22).

Figure 15. Standing pasture dry matter in the three treatments (rabbit, cattle and open) for the four replicate exclosures on the clean side. The line is the mean of the replicates.

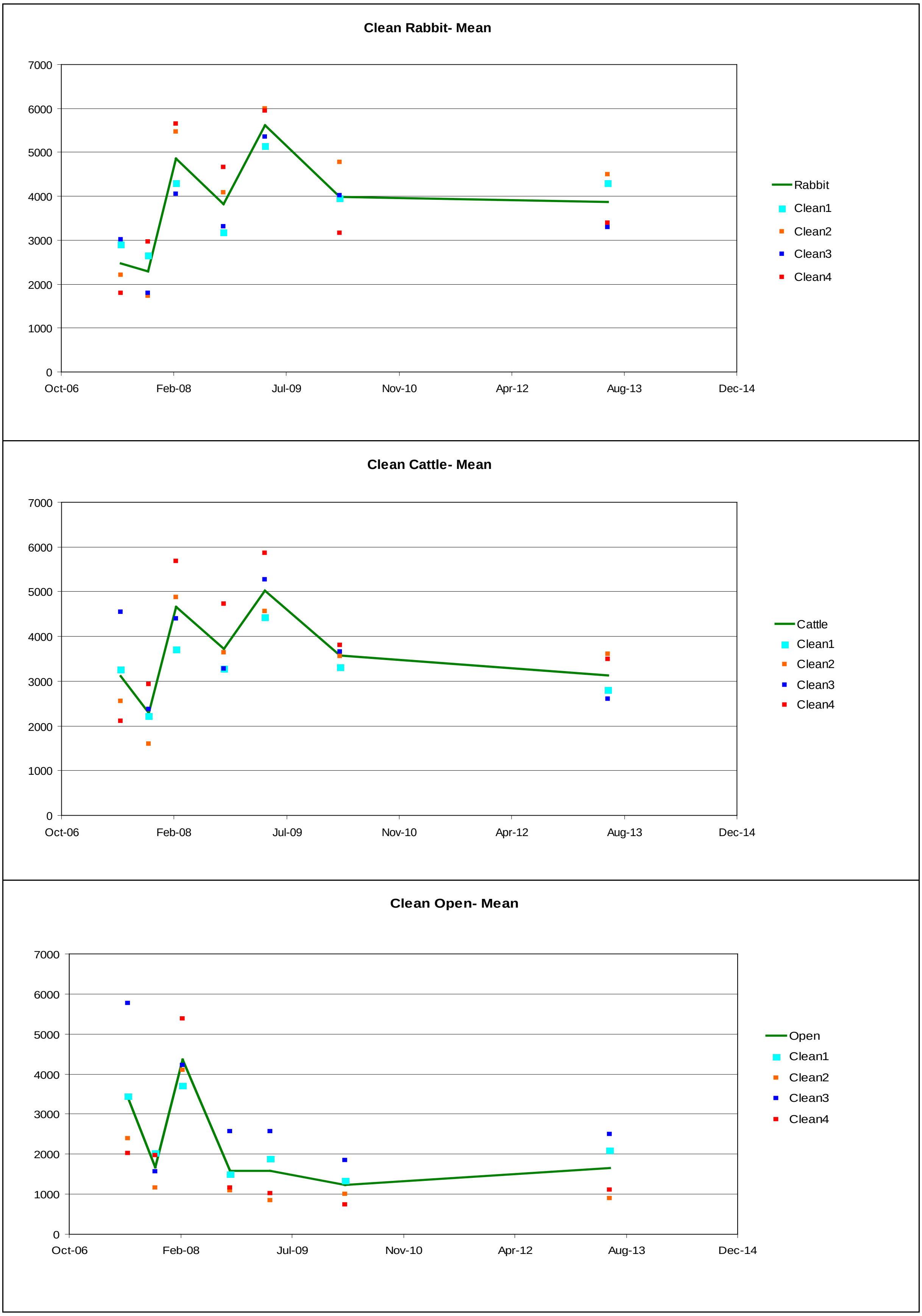


Figure 16. Standing pasture dry matter in the three treatments (rabbit, cattle and open) for the four replicate exclosures on the dirty side. The line is the mean of the replicates.

Figure 17. Predicted and observed standing dry matter over time for all treatments on the clean side (Rabbit Exclosure, Cattle Exclosure, Open)

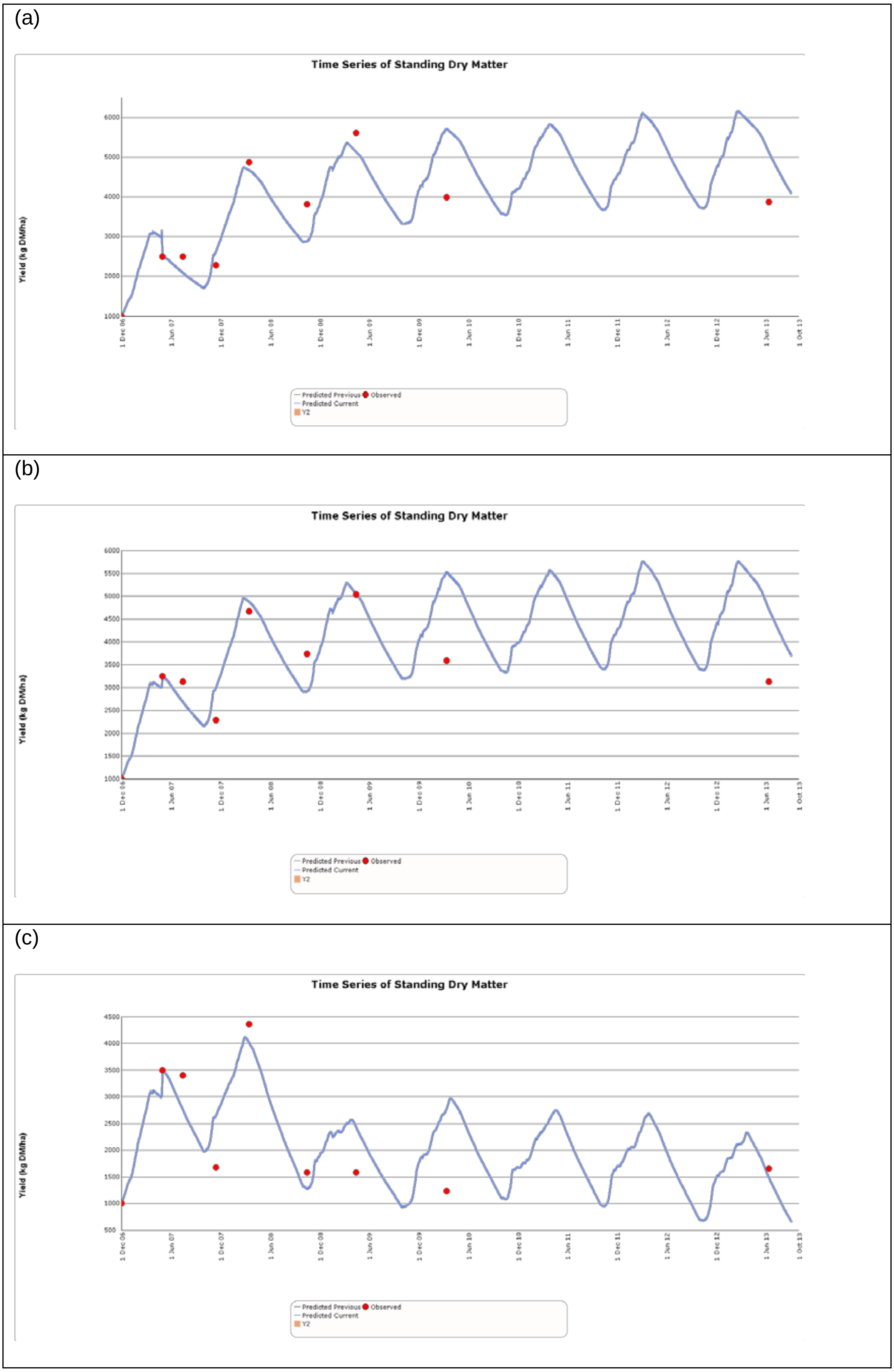


Figure 18. Predicted and observed standing dry matter over time for all treatments on the dirty side (Rabbit Exclosure, Cattle Exclosure, Open)

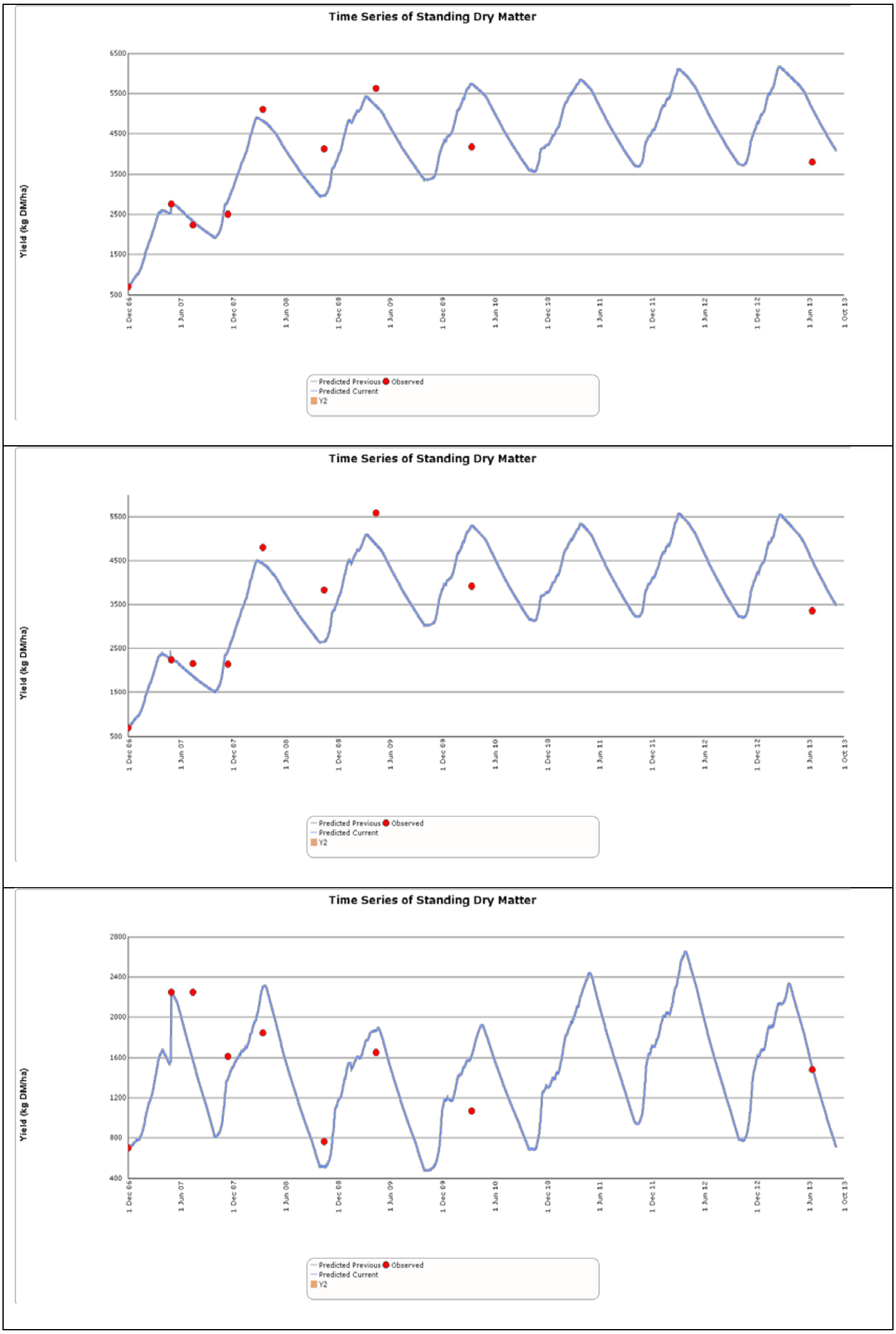


Figure 19. Predicted versus observed standing dry matter for all treatments on the clean side (Rabbit Exclosure, Cattle Exclosure, Open)

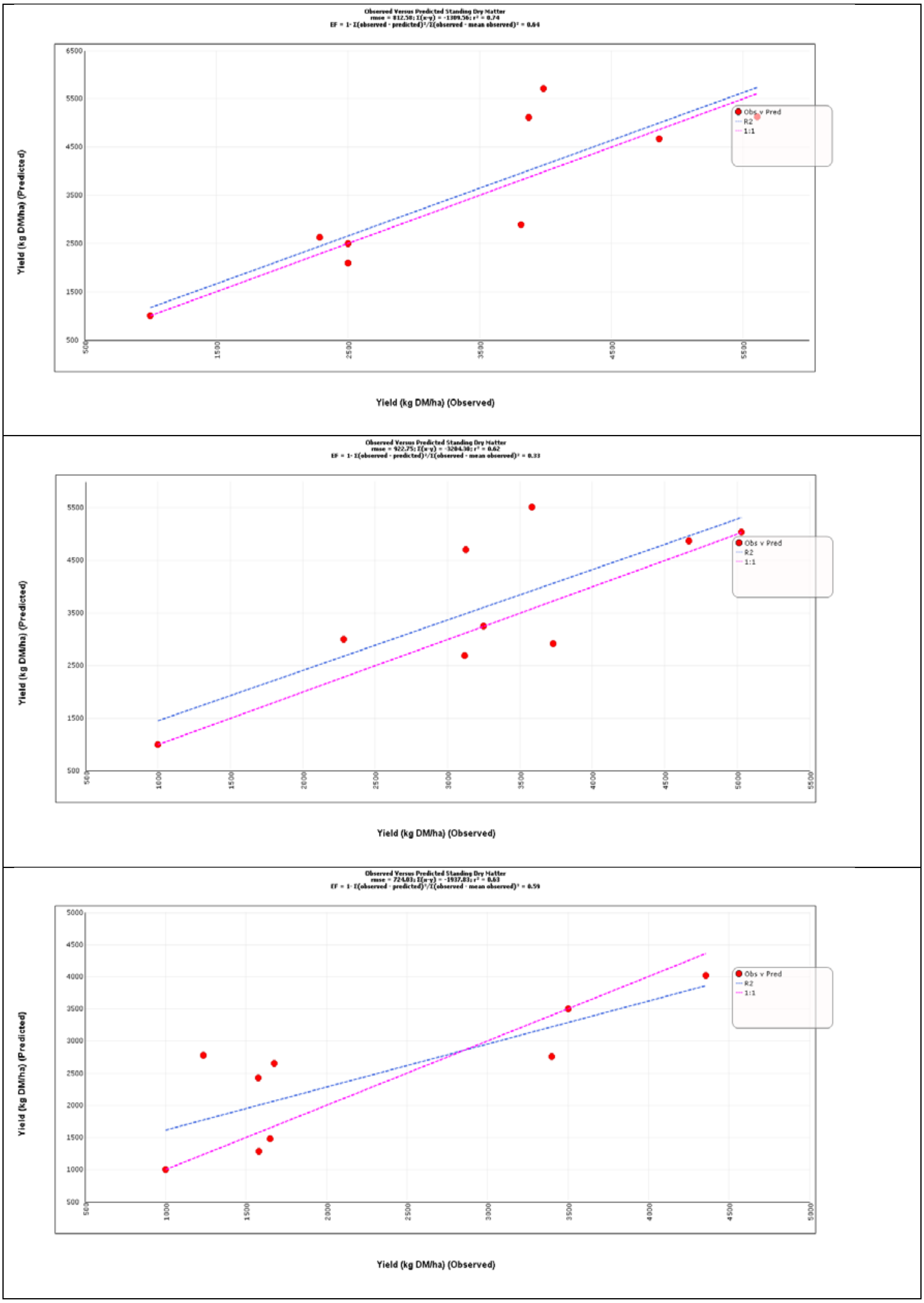


Figure 20. Predicted versus observed standing dry matter for all treatments on the clean side (Rabbit Exclosure, Cattle Exclosure, Open)

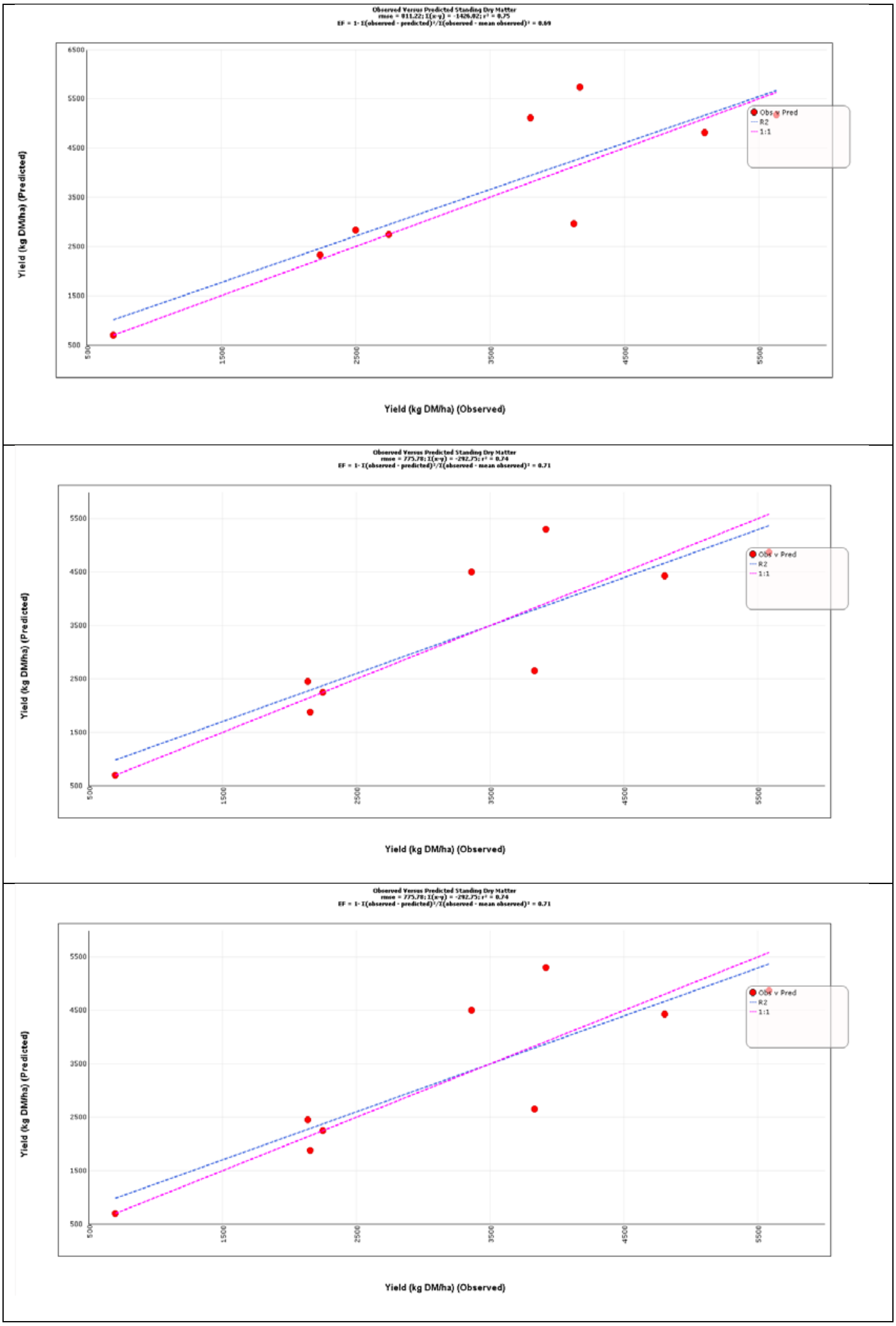


Figure 21. Percentage composition (% dry weight) of pasture that is 3P grasses, other grasses and pooled forbs (forbs, native legumes and sedges)

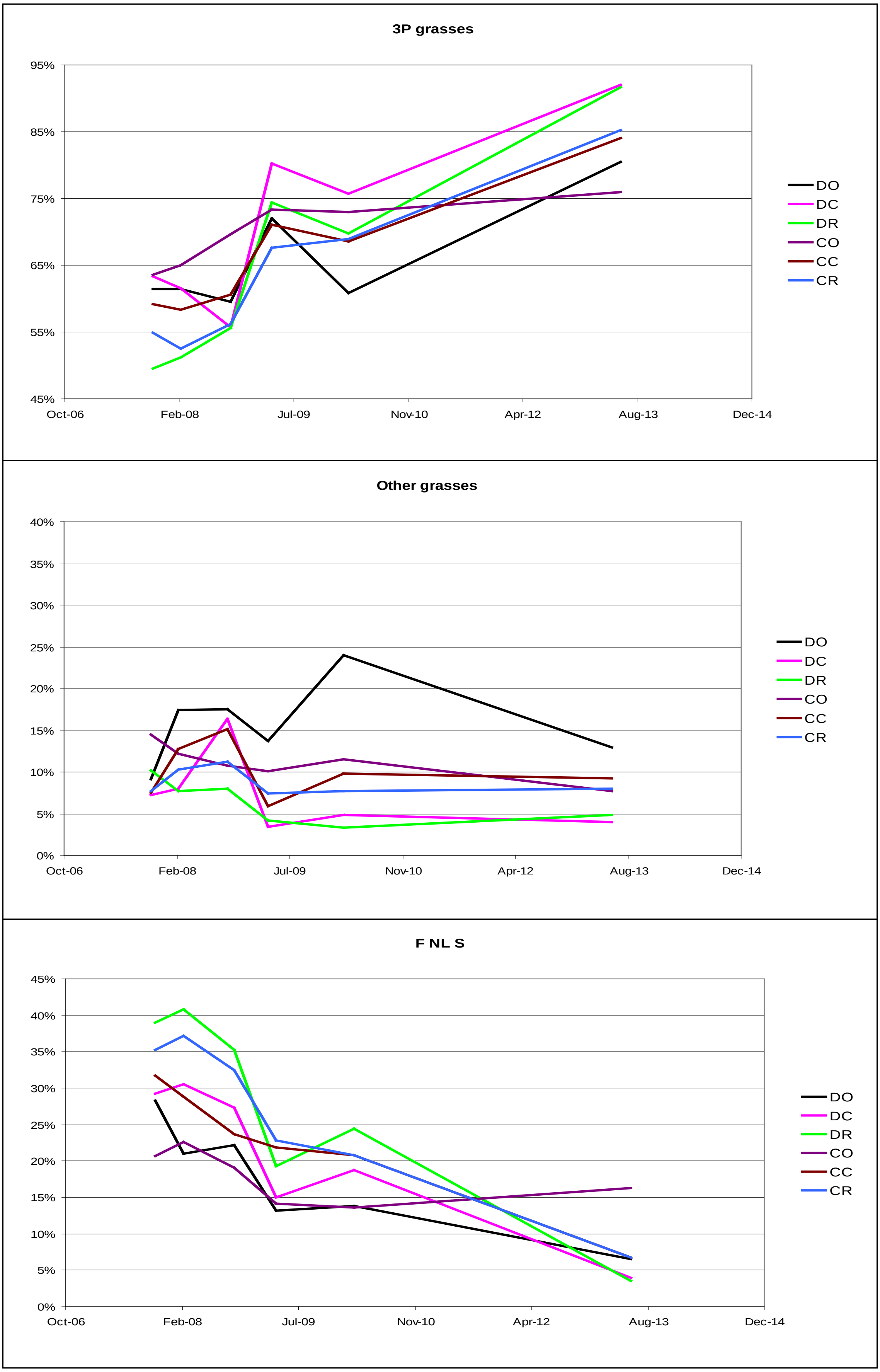
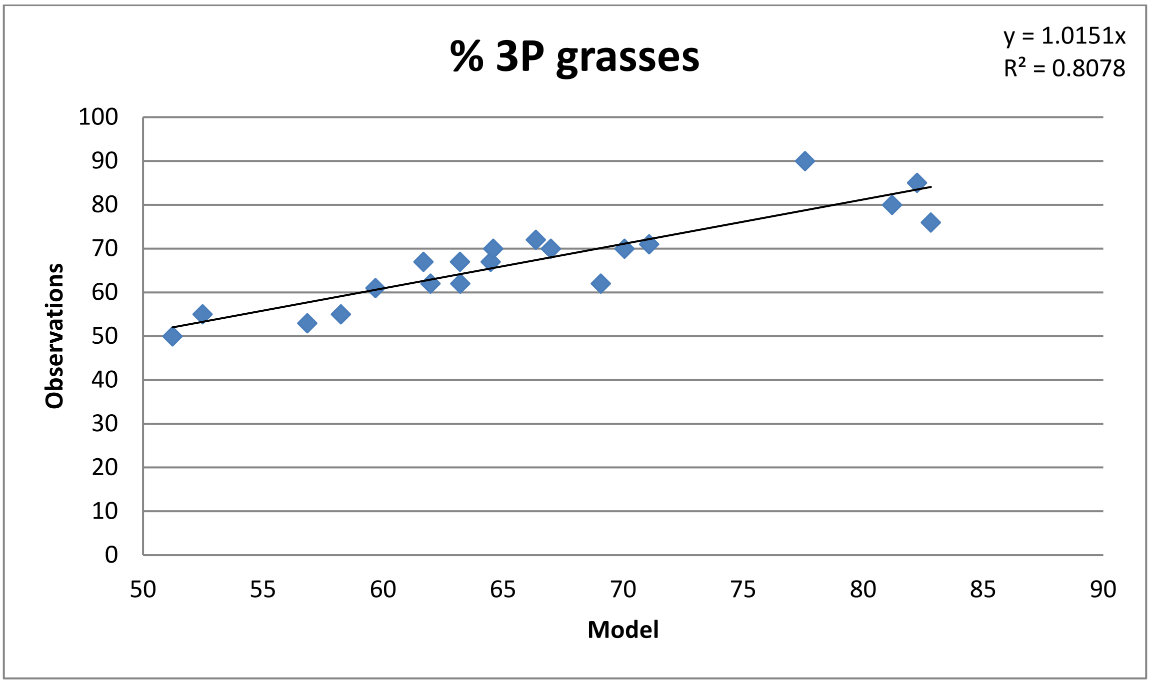


Figure 22. Observations and model predictions for % 3P grasses in the open grazing and rabbit grazing areas of both clean and dirty sides of the fence.



Discussion

Animal monitoring

All indices of abundance showed that predator activity (foxes and dogs) was higher on the dirty side of the fence pre rabbit control. This reflected the higher prey (rabbit) abundance on the dirty side of the fence. Post control the activity was shown to be higher on the clean side with remote cameras and track plots. Spotlighting did not pick up any predator activity on the clean side of the fence post control.

Track plots in particular are a good measure of activity when densities of animals are low. This was also evident with other work we have done – the RHDV bait delivery trial at Kingaroy (2002) showed that after a control operation when we couldn't find a single rabbit in spotlight counts we still had activity on sand track plots. Figure 3 shows that predators were being recorded at the site in track plots but not in spotlight counts.

Table 2 compares the total number of mammal and reptile species recorded with the three activity indices. Birds were not included as species could not be identified on track plots. Remote cameras recorded more species than spotlighting and track plots.

Activity indices

All three activity indices recorded similar rabbit activity at the study site, highlighting a decrease in rabbit activity on the dirty side after warrens had been ripped (dirty side) and log piles destroyed (clean side). Rabbit activity increased slightly on the clean side post control. One possibility for the increase in activity on the clean side is the burning of log piles and rabbit harbour on a neighbouring property, adjacent to the clean side of the study site. The owner of this property reported seeing rabbits running out of log piles as they were being burnt, and these rabbits could have moved onto the study site, a distance of no more than five hundred metres.

Table 2 Combined number of mammal and reptile species recorded using three methods of detection[1]

Method	***Total Species (exc. birds)***
Spotlight Counts	7
Sand track plots	10
Remote Cameras	14

Remote cameras picked up a greater diversity of species than spotlighting and track plots. Animals such as bandicoots, bearded dragons and echidnas were all detected with remote cameras but not in track plots or spotlight counts. These three native species were only detected on the clean side of the fence with the cameras. Birds were detected in track plots but identification of species was difficult, however birds that were recorded on cameras could be easily identified. This is one advantage of using cameras; they are a good tool for species identification and for doing an inventory of what species are present in an environment. The cameras also recorded an increase in fox activity on the clean side of the fence post control, which was not detected with track plots or spotlight counts. This increase in fox activity on the clean side could be attributed to the increase in rabbit activity on the clean side of the fence after control.

Vegetation monitoring

The GRASP model was successfully calibrated for the Cottonvale site. A good match between the observed and modelled total standing dry matter and percentage of 3P grasses was obtained after calibration. This will enable simulations to be done for this site under a range of different seasonal conditions as well as under a wider range of grazing conditions. Although no detectable differences due to rabbit grazing was observed, we can use the equivalence between rabbit and domestic livestock to determine the possible impact of various combinations of rabbit populations and domestic livestock. This could be extended to determine the potential economic impact of rabbit grazing using either the ENTERPRISE model (see Scanlan et al 2013 for example use for livestock) or the BREEDCOW model (Holmes 2000).

There are a number of contributing factors to the lack of any detectable differences due to rabbit (and macropod) grazing at this site. A major factor was the relatively low densities of rabbits and macropods in both the clean and the dirty sides of the fence. In addition, the grazing pressure imposed by the cattle at the site was also relatively light as indicated by the increase in the perennial grass percentage over the life of the experiment. The actual number of livestock (in terms of adult equivalents) was not recorded during the trial. General information on the numbers of cattle grazed

[1] These are not directly comparable as the detection probabilities of the different methods depend on several factors including sample size.

and the general timing of grazing of the two paddocks enabled an estimate of grazing pressure and enabled model calibration, but this was insufficient to determine actual grazing pressure. In particular, the liveweight of the animals was unknown but could be estimated sufficiently to enable the GRASP calibration.

The observed rate of increase in perennial grasses was quite low and lower than the rate observed for a major grazing trial in northern Australia (Scanlan et al. 2013). This has implications for future modelling work done using the GRASP model to evaluate grazing management strategies e.g. the impact of pasture resting as recently examined by Scanlan et al. (2014).

Another factor contributing to the lack of a detectable overall impact of rabbit grazing was the variability in aspects of the environment (e.g. soils, vegetation, aspect) between the four replicates on each side of the fence (clean and dirty). These replicates were deliberately chosen to cover the range of land types within the site. This resulted in a large variation in yields between replicates and also inconsistent trends in total standing dry matter between replicates. Another impact of this environmental variation was the variability in grazing pressure by both rabbits and domestic livestock. High background variability coupled with a relatively low and variable grazing pressure combined to prevent any detection of differences due to rabbits.

This trial exemplifies the difficulties in experimentally determining the impact of rabbits, or indeed any feral pest. Small plot experiments have very limited applicability to the real world; trials covering commercially-sized experimental units necessarily encompass a great deal of variability (making detection of treatment impact challenging) and are inherently expensive to replicate. This trial at a commercial scale was unable to detect any differences due to rabbits; to do so would have required a greatly increased effort in terms of replicated sites and a number of plots per treatment to overcome the potentially confounding responses due to the variability within the sites. Higher rabbit numbers would have helped by creating a large enough impact to possibly swamp the background variation.

One cross-fence comparison is of limited use when there is little or no pre-treatment data as differences could be due to pre-existing site differences. However, the data collected here would be useful in simulation studies which are based on models calibrated for this site.

Concluding remarks

There were marked differences in the flora and fauna on either side of the fence, particularly rabbit abundance and pasture biomass. This difference reflected the long period of separation of the two areas by the DDMRB fence with differences in rabbit abundance as well as possible differences in general grazing management.

The control of rabbit numbers on the infested side of the fence did not improve pasture condition to a state similar to that in the rabbit free area during the relatively short period of this study. Recent reviews and simulation studies of the pasture response to changes in grazing management (including changing in grazing pressure) have shown that pastures may takes many years to respond to even quite large reductions in grazing pressure (Hunt et al. 2014, Scanlan et al. 2014). Any positive impact of reduced rabbit density on the infested side will require a much longer time frame for any measureable improvement could be recorded and will depend on the general grazing management of the area.

Small sample size precluded conclusively comparing rabbit survival on either side of the fence. This needs further investigation, particularly the effects on rabbit survival of those harbouring above ground compared with those living in warren systems. Similarly, reproductive output and recruitment appeared better where warrens were available, but this needs further testing in this environment with more data before more definitive conclusions can be made.

Acknowledgements

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APPENDIX 1 – GRASP parameter file for the Cottonvale site:

```
Cottonvale Rabbit Trial
created using MRX_tidy Ver: 2.1
12:20 13Aug2014

SOIL PARAMETERS
20  100.000  Thickness (mm) of soil layer 1 (surface 100mm approx)
21  400.000  Thickness (mm) of soil layer 2 (main zone of root activity)
22  500.000  Thickness (mm) of soil layer 3 (limit of pasture root penetration)
26   25.000  Layer 1 maximum soil moisture (mm).
27  100.000  Layer 2 maximum soil moisture (mm).
28  100.000  Layer 3 maximum soil moisture (mm).
19   10.000  Layer 1 air dry soil moisture content (mm).
29   10.000  Layer 1 wilting point soil moisture (mm).
30   40.000  Layer 2 minimum soil moisture (mm).
31   50.000  Layer 3 minimum soil moisture (mm).

TREE WATER USE
291      0.0  MATURE TREE BASAL AREA  square metres/ha
292   10.000  Layer 1 minimum soil moisture (mm) with trees
293   40.000  Layer 2 minimum soil moisture (mm) with trees.
294   50.000  Layer 3 minimum soil moisture (mm) with trees.
295      0.0  Layer 4 available water (trees only)
296  250.000  Maximum rooting depth of trees in cm
168   20.000  Tree basal area at which potential tree transpiration=pan

SOIL EVAPORATION
33    5.000  EPLIM   Upper limit to daily BARE soil evaporation (mm/day)

RUNOFF AND SOIL LOSS
270    1.000  0 for free draining soils,
271    1150.  Tsdm yield at 50% cover for run-off calculation
272  0.95000  k value in cover=y**k / (y**k + p271**k)
273    1.000  Maximum  runoff of rainfall  at zero cover, wet soil
104    1.016  Constant in I15 equation I15=p104+p105*cos(dayno+15)
105  0.46500  Co-effic in I15 equation I15=p104+p105*cos(dayno+15)
278    1.000  % slope of land 0-20%
245    3.000  Soil loss If=1 use Rose model, 2=Bob Miles, 3=Joe Scanlan
375    1095.  No of days before soil loss accumulators and soil loss occurs

PLANT COVER
45    1000.  Green yield (kg/ha) when green cover for transpiration is 50%

PLANT TEMPERATURE INDEX selection parameters.
209    4.000  TIX 1=FSS, 2=GP , 3= NP ,4= use p61 and p62 ,5= tix=1.0
```

```
61    5.000  If temp is less than P61, temperature index (TIX) is zero.
62   18.000  As temp increases from P61 to P62, TIX increases from 0 to 1.
63   30.000  As temp increases from P62 to P63, TIX remains at 1.
64   40.000  As temp increases from P63 to P64, TIX decreases from 1 to 0.0

CLIMATE CHANGE or PAN CALCULATION
3  0.75000  If >0.0 <1.0  use .p51 met files & calc mean daytime VPD

PLANT SOLAR RADIATION INDEX & INTERCEPTION
46    1000.  Green yield (kg/ha) when  radiation interception is 50%
8   12.000  Radiation use efficiency kg/ha per MJ/sqm of solar radiation

PLANT GROWTH
5    4.000  Initial plant density e.g. % basal area
6    3.500  Potential daily regrowth rate (kg/ha/day/unit of density)
7   18.000  Transpiration efficiency (kg/ha/mm of transpired at vpd 20hPa
96   20.000  Height (cm) of 1000 kg/ha

SOIL MOISTURE SUPPLY EFFECT ON PLANT GROWTH
149  0.30000  Soil water index at which above-ground growth stops.

NEW SWARD MODEL
123  0.50000  Proportion of leaf of total growth (L/(L+S))
11      0.0  Minimum screen temperature (c) at which green cover = 0%
125    2.000  Minimum screen temperature (c) at which green cover =100%=no deat
53    2.000  Daily minimum screen temperature for frost effect on quality
9  0.30000  Soil water index.  Maximum green cover = amin1(0.99,swix/p(9))
47  0.50000  Scale (0-1) for effectiveness of tree litter in runoff
132   85.000  Percentage of leaf/(leaf+stem) in diet at 50% leaf in sward

PLANT SENESCENCE AND LITTER BREAKDOWN
10 0.002000  Death constant ) DEATH = (P51*(1-swix) + P10) * green pool
51  0.01300  Death slope    )            where swix = soil water index
133    1.000  Multiplier on total death for DM death of leaf
134    1.000  Multiplier on total death for DM death of stem

DETACHMENT
128 0.002000  Prop of Dead leaf detached per day from 1Dec to 30 April
129 0.002000  Prop of Dead stem detached per day from 1Dec to 30 April
130 0.002500  Prop of Dead leaf detached per day from 1May to 30 November
131 0.003000  Prop of Dead stem detached per day from 1May to 30 November
15  0.75000  Proportion of pasture which can be eaten by stock. The rest is

NITROGEN UPTAKE
90      0.0  N kg/ha per 1000 mm of rain
97    5.000  N uptake (kg/ha) at zero transpiration, N=p(97)+p(98)*(trans/100
```

```
98    6.000  N uptake per 100 mm of GRASS transpiration
167    1.000  Prop of p98 for N uptake in TREE transpiration from layers 1&2&3
99   25.000  Maximum N uptake (kg/ha)
100    2.500  Maximum % N in growth
101  0.70000  % N at zero growth   Nitrogen index = (%N-p101)/(p102-p101)
102  0.80000  % N at maximum growth   Nitrogen index = (%N-p101)/(p102-p101)
103    2.000  N uptake per 100 mm of soil water
108      0.0  Proportional decline per day in % N for green material
109  0.01500  Proportional decline per day in % N for dead material
110    1.000  Minimum % N in green & maximum in dead
111  0.40000  Minimum % N in  dead
112    1001.  Date for resetting Nitrogen uptake
```

GRAZING

```
214   50.000  Pasture yield limiting lwg in annual lwg calculation
215   15.000  LWG advantage due to burning used in lwgyear1 sub
216  0.30400  Slope in LWG maximum possible for given dry matter intake
217-0.800000  Intercept in LWG maximum possible for given dry matter intake
228  0.06029  Intercept in annual lwg regression
229-0.002061  Coeff for %utilisation in annual lwg regression
230 0.004833  Coeff for %green days in annual lwg regression
231      0.0  Coeff for THI(temperature-humidity) in annual lwg regression
120    9.000  Animal model; 0 =0.0,or 1 for utilization model,
56  0.05000  Growth index for greenday/frost & wool climatic index
142    1.050  Intercept in equation of reln between intake and utilisation
143-0.300000  Slope in equation of reln between intake and utilisation
144   50.000  Yield (kg/ha) at which intake restriction no longer operates
145   70.000  Expected live weight gain (kg/hd) in summer at low stocking rate
146   25.000  Expected live weight gain (kg/hd) in autumn at low stocking rate
147   10.000  Expected live weight gain (kg/hd) in winter at low stocking rate
148   35.000  Expected live weight gain (kg/hd) in spring at low stocking rate
```

SIMULATION CONTROL

```
203    2000.  Starting year of simulation; 1800 to begin at start of metfile.
204    1.000  Starting month of simulation
206  201309.  Number of days in simuln run,last date : 1st Mar 1986=198603
```

CLIMATE STATIONS

```
250    1.000  If=1 full daily met data, if=3  weekly austclm
264  -99.000  ron8697.dr2
269      0.0  cottonvale.p51
```

OUTPUT CONTROL

```
246  132.000  Output type: 80=80 column output, 132= 132 output  0=132 col
374    1095.  No of days spin up before probabilty distribution data collected
247  999.000  Output of totals:365 - 999=yr - obs.If=mndy & P249=0,print prob
```

248	30.000	Output of model:365=yr,91=seas,30=mthly,7=wkly,1=daily,999=obs
249	0.0	if=1,totals are summed;if=0 and P247=mndy then probs are printed
262	979.000	Output to screen:365=yr,91=seas,30=mthly,7=wkly,1=daily,999=obs
259	0.0	Output to screen: 1= stop screen scrolling
283	0.0	If=1 ET output to file s18.ogp, p246 must be 132
284	13.000	If=1 TE output to file p9.ogp, p246 must be 132
211	0.0	If=1-365 gives output of observed & predicted , and
285	0.0	If=1 monthly growth output to file m15.ogp, p211 must be 0
286	0.0	If=1 rainfall use efficiency to r17.ogp, p246 must be 132
287	0.0	If=1 runoff output to p19.ogp, only days with rain GE p287
289	0.0	Output options for unit 21
236	9.000	For storing simulation output from probability array XO
227	194.000	Parameter no for output when p289=0
208	99.000	Parameter no for output when p289=0

ANNUAL CROP MANAGEMENT

PASTURE BURNING MANAGEMENT

265	0.0	If=1 call pasture burning subroutine and use options 266-7
52	33.300	Percentage of pasture burnt
266	1001.	First date of burning; month day 1001 = 1st Oct
267	800.000	Threshold yield required for burn; total standing DM kg/ha

DYNAMIC PASTURE BASAL AREA

268	2.000	if=0 CONSTANT basal area(p5) & reset when mrx=11
288	4.000	Water (ET) use efficiency for basal area change 268=1
166	0.0	Slope on ET for 100% green utilisation, basal area change,268=10
164	0.50000	Proportion of this year's growth affecting sward basal area
157	430.000	Date (monthday) for annual change in tussock grass basal area
158	0.10000	Minimum tussock grass %BA, TGBA=p158+p159*(growth or yield430)
159	1.300	Slope , TGBA=p158+p159*(average growth year1+2 /1000 or yield430)
165	0.0	Coefficient(-ve) on green utilisation in basal area change,268=4,5
160	2.500	Maximimum possible increase per year in TGBA e.g. 2.5 %units
161	9.000	Maximimum possible tussock grass basal area
162	0.30000	Swix 2+3 <threshold for counting drought days
163	0.50000	Swix 2+3 >threshold for turning off drought

RESET STOCKING RATE, LIVEWEIGHT, BREED

4	0.0	Average growth for use in wingrasp when 082=1 on 1st simulation
81	601.000	Date for resetting stocking rate & shearing, 930 is 30th Sept
82	13.000	1=Constant %of AveGR, 2=%Use of TSDM for next year,
83	0.0	%Utilisation of average growth, pasture yield, forecast growth
84	400.000	Liveweight kg
85	3.000	Breed 1=XBRED 2=BRITISH 3=G2 XBRED, =11 for dry sheep equivalents
86	30.000	Age in months

RESET POOLS TO SAME YIELD on a date each year

```
140      0.0  Date for resetting DRY MATTER,  930 is 30th Sept
```

HEAVY UTILISATION PARAMETERS

```
180    3.000  If=1 change parameters as a function of utilisation 30th April
191  0.50000  proportion green_eaten/growth at which pasture has
194    2.500  Initial pasture condition 0=90% perennials,11=heavily grazed
195    1.000  Resilience rate %util<22.5 1= 1 year equivalent on AA scale
196    1.000  Degradation rate %util>34 1= 1 year equivalent on AA scale
197    1.000  If=0 resource cannot return from heavily grazed state
198   15.000  % DM Utilisation for increase in %perennials to occur. %UGrn if p18
199   50.000  % DM Utilisation for decrease in %perennials to occur. %UGrn if p18
181   18.000  p99 Maximum N uptake (kg/ha)
182  750.000  p45 Green yield (kg/ha) when green cover for transpiration is 50%
183   15.000  p96 Height (cm) of 1000 kg/ha
184  0.88000  p101 % N at zero growth   Nitrogen index = (%N-p101)/(p102-p101)
185  0.98000  p102 % N at maximum growth   Nitrogen index = (%N-p101)/(p102-p101)
186 0.002000  p128 Prop of Dead leaf detached per day from 1Dec to 30 April
187 0.002000  p129 Prop of Dead stem detached per day from 1Dec to 30 April
188 0.005000  p130 Prop of Dead leaf detached per day from 1May to 30 November
189 0.005000  p131 Prop of Dead stem detached per day from 1May to 30 November
190  0.90000  p149 Soil water index at which above-ground growth stops.
192   50.000  p144 Yield (kg/ha) at which intake restriction no longer operates
193  0.90000  p009 Soil water index. Maximum green cover = amin1(0.99,swix/p(9))
200  0.05000  p056 Growth index for greenday/frost & wool climatic index
```

DYNAMIC TREE MODEL

```
462      0.0  If=1 use dynamic tree model
459    1.000  % annual increase in tree basal area
460    5.000  % death in tree basal area with fire (p437*% pasture burnt p52)
461   20.000  Maximum tree basal area for dynamic tree model
601    1.000  If=1 use ramp function for fire impact in dynamic tree model
602    2000.  Length of fire ramp function in dynamic tree model (kg/ha of TSDM)
603    3.000  Height of fire ramp function in dynamic tree model (% death of tree
```

MONTHLY GRASS BASAL AREA MODEL

```
604   80.000  Benchmark for monthly pasture growth eg = 80 kg/ha/mth per unit of
605  0.05000  Maximum monthly decrease in gba per unit of gba due to season & gro
606  0.20000  Maximum monthly increase in gba per unit of gba due to season & gro
607    2.000  GBA season ndx when p268=12: Month that ndx starts to fall      (eg 2=
608    5.000  GBA season ndx when p268=12: Month that ndx reaches its minimum (eg 5=
609    9.000  GBA season ndx when p268=12: Month that ndx starts to rise      (eg 9=
610   12.000  GBA season ndx when p268=12: Month that ndx reaches its maximum (eg 12
611  0.40000  GBA season ndx when p268=12: Minimum value of index
612    3.000  GBA grazing ndx when p268=12: Month that ndx starts to fall (eg 3=Mar)
613    6.000  GBA grazing ndx when p268=12: months that ndx is falling    (eg 6=Jun)
```

```
614   10.000  GBA grazing ndx when p268=12: Month that ndx starts to rise (eg 10=Oct
615   12.000  GBA grazing ndx when p268=12: months that ndx is rising     (eg 12=Dec
616  0.10000  GBA grazing ndx when p268=12: Minimum value of index
617  0.30000  Maximum proportional monthly decrease in gba due to very high utilisat
618      0.0  Minimum value of utiln index (ie when % utiln is very low)
619    1.000  Range in utiln index
620   20.000  Utiln at which utiln index is increased 5% above its min value
621   36.500  Range in %Utiln to where utiln index is reduced 5% below its max value
622  0.05000  standard curve parameter for ramp functions
623  0.10000  Absolute maximum monthly increase in GBA
624    2.000  Absolute maximum monthly decrease in GBA
625      0.0  Date (mmdd) when p268=12 for accum pasture eaten and growth for GBA %U

PASTURE CONDITION MODIFICATION
626      0.0  Switch ; off=default=0.0 , use p198 and p199 step function
627   20.000  if p626=1 then = % Utilisation when zero change in pasture condn (eg h
628    1.000  if p626=1 then = increase in pasture condition at zero % utilisation e
629    1.000  if p626=1 then = decrease in pasture condition at 100 % utilisation eg

PERCENT PERENNIALS MODIFICATION
630  0.10000  corner parameter
631    1.800  Pasture condition when % peren is reduced by 10% (ie % peren=81%)
632    6.800  Pasture condition when % peren is reduced by 90% (ie % peren=9%)
633   93.000  maximum value of % perennials curve (percperennials max=90)
634    2.000  minimum value of % perennials curve (when Past condn=11.0, then %peren

STOCKING RATE OPTION 2 - HYBRID
635      0.0  SR switch; default=0,  If 1 then limit changes to srwean
636    5.000  maximum % increase in stocking rate in any one year when stocked above
637    5.000  maximum % decrease in stocking rate in any one year when stocked above
638   40.000  initial SR for weaners per 100ha
639    5.000  maximum % increase in stocking rate in any one year when below above p
640    5.000  maximum % decrease in stocking rate in any one year when below above p
641   10.000  maximum % increase in SR above p638 for the whole simulation period
642   10.000  maximum % decrease in SR above p638 for the whole simulation period

WEIGHTINGS TO CHANGE GRAZING SENSITIVITY (FOR SPELLING)
300     0.0  End of parameters
300     0.0  Indicates end of parameter file
Cottonvale Base
file end  99990000  for GRASP
```

Appendix 2 Species list for plants located within the trial site.

Family	Species	Growth form	Status (* non-native)	Common name
Amaranthaceae				
	Alternanthera nana	h		
Apiaceae				
	Torilis nodosa	h	*	
Araliaceae				
	Hydrocotyle acutiloba	h	*	
Asteraceae				
	Bidens pilosa	h	*	Cobbler's pegs
	Chrysocephalum apiculatum	h		Yellow daisy buttons
	Calotis cuneifolia	h		
	Carduus pycnocephalus	h	*	
	Circium vulgare	h	*	Scotch Thistle
	Conyza canadensis	h	*	
	Conyza primulifolia	h	*	
	Conyza sumatrensis	h	*	Fleabane
	Cotula australis	h		
	Cyanthilium cinereum	h		
	Cymbonotus lawsonianus	h		
	Euchiton sphaericus	h	*	Cudweed
	Facelis retusa	h	*	
	Gamochaeta calviceps	h	*	
	Gamochaeta coarctata	h	*	
	Glossocardia bidens	h		
	Hypochaeris glabra	h	*	
	Hypochaeris microcephalus var. albiflora	h	*	
	Hypochaeris radicata	h	*	
	Leucochrysum albicans	h		
	Senecio madagascariensis	h	*	Fireweed
	Senecio pinnatifolius var*. pinnatifolius*	h	*	Fireweed
	Sigesbeckia orientalis	h	*	
	Soliva sessilis	h	*	Bindy-eye
	Sonchus aspera	h	*	Milk Thistle

	Sonchus oleracea	h	*	Milk Thistle
	Tagetes minuta	h	*	Stinking Roger
	Taraxacum officionale	h	*	Dandelion
	Triptilodiscus pygmaeus	h		
	Vittadinia dissecta var. *dissecta*	h	*	
	Vittadinia muelleri	h		
	Xerochrysum bracteatum	h		Paper daisy
Boraginaceae				
	Heliotropium amplexicaule	h	*	Blue heliotrope
Brassicaceae				
	Capsella bursa-pastoris	h	*	Shepherds purse
	Cyclospermum leptophyllum	h	*	
	Lepidium africanum	h	*	Common Peppercress
	Lepidium didymus	h	*	Bittercress
	Lepidium bonariense	h	*	Argentine Peppercress
Campanulaceae				
	Lobelia purpurascens	h		
	Wahlenbergia communis	h		
	Wahlenbergia tumidifructa	h		
Caryophyllaceae				
	Cerastium glomeratum	h	*	Mouse-eared chickweed
	Paronychia brasiliana	h	*	Brasilian Whitlow
	Petrorhagia dubia	h	*	Velvet pink
	Polycarpon tetraphyllum	h	*	
Chenopodiaceae				
	Chenopodium carinatum	h		
	Einadia trigonos	h		
Clusiaceae				
	Hypericum gramineum	h		
Commelinaceae				
	Murdannia graminea	h		
Convolvulaceae				
	Dichondra repens	h		

Crassulaceae				
	Crassula tetramera	h		
Cyperaceae				
	Carex breviculmis	g		
	Carex inversa	g		
	Cypeus gracilis	g		
	Cyperus brevifolius	g		
	Cyperus sanguinolentus	g		
	Fimbristylis dichotoma	g		
	Gahnia aspera	g		
	Schoenus apogon	g		
Dilleniaceae				
	Hibbertia linearis subsp. obtusifolia	b		
	Hibbertia vestita	b		
Droseraceae				
	Drosera peltata	h		
Euphorbiaceace				
	Tragia novae-hollandiae	h		
Fabaceae				
	Desmodium varians			
	Glycine clandestina var. *sericea*	h		
	Glycine tabacina	h		
	Medicago polymorpha	h	*	Burr medic
	Medicago	h	*	Burr medic
	Swainsona brachycarpa	s		
	Trifolium dupium	h	*	Yellow suckling clover
	Trifolium glomeratum	h	*	
	Trifolium repens	h	*	
	Vicia monantha	h	*	
	Zornia dyctiocarpa var. dyctiocarpa	h		
Gentianaceae				
	Centaurium tenuiflorum	h	*	Spike Centaury
Geraniaceae				
	Erodium cicutarium	h	*	
	Geranium solanderi	h		
Goodeniaceae				

	Goodenia glabra	h		
	Goodenia hederacea	h		
	Velleia paradoxa	h		
Halagoraceae				
	Haloragis heterophylla	h		
Hemerocallidaceae				
	Dianella longifolia var. stenophylla	h		
Hypoxidcaeae				
	Hypoxis hygrometrica	h		
Iridaceae				
	Sisyrinchium sp. (Peregian P.R.Sharpe 4970)	h		
Johnsoniaceae				
	Tricoryne elatior	h		
Juncaceae				
	Juncus bufonius	g		
	Juncus continuus	g		
	Juncus usitatus	g		
Lamiaceae				
	Marrubium vulgare	h	*	White Horehound
	Mentha diemenica	h		
	Salvia verbenaca	h	*	Wild Sage
Laxmanniaceae				
	Arthropodium fimbriatum	h		
	Eustrephus latifolius	s		
	Lomandra filiformis	g		
Malvaceae				
	Malva parviflora	h		
Mimosaceae				
	Acacia deanei	t		
Myrtaceae				
	Angophora floribunda	T		Rough barked apple
	Eucalyptus moluccana	T		Gum topped box
	Eucalyptus caliginosa	T		Broad-leaved stringbark
	Eucalyptus biturbinata	T		grey gum

Onagaraceae				
	Epilobium billardierianum subsp. cinereum	h		
Orchidaceae				
	Spiranthes sinensis	h		
Oxalidaceae				
	Oxalis exilis	h		
Poaceae				
	Andropogon virginicus	g	*	Whisky grass
	Anthoxanthum odoratum	g	*	Scented Vernal Grass
	Aristida personata	g		Three-awned speargrass
	Aristida vagans	g		Three-awned speargrass
	Austrodanthonia racemosa var. racemosa	g		Wallaby grass
	Austrodanthonia tenuir	g		Wallaby grass
	Austrostipa aristiglumis	g		Plains grass
	Austrostipa verticillata	g		Slender bamboo grass
	Axonopus compressus	g	*	Broadleaf carpet grass
	Axonopus filiformis	g	*	Narrowleaf carpet grass
	Bothriochloa macra	g		Redleg grass
	Briza minor	g	*	Shivery grass
	Bromus catharticus	g	*	Prairie grass
	Capillepedium spicigerum	g		Scented top
	Chloris truncata	g		Windmill grass
	Cymbopogon refractus	g		Barbed wire grass
	Cynodon dactylon	g		Couch grass
	Dactylis glomerata	g		Orchard grass
	Dichelachne inaequiglumis	g		
	Dichelachne micrantha	g		Shorthair plumegrass
	Dichelachne rara	g		
	Digitaria ciliaris	g	*	Summer grass

	Digitaria ramularis	g		
	Digitaria violascens	g	*	Violet crab grass
	Echinopogon caespitosus var caespitosus	g		Hedgehog Grass
	Echinopogon intermedius	g		Hedgehog Grass
	Echinopogon nutans var. nutans	g		Hedgehog Grass
	Echinopogon ovatus var. ovatus	g		Hedgehog Grass
	Eleusine indica	g	*	Crow's-foot grass
	Eleusine tristachya	g	*	Goosegrass
	Elymus scabrus var. scabrus	g		Common Wheatgrass
	Eragrostis brownii	g		Love grass
	Eragrostis curvula	g	*	African lovegrass
	Eragrostis leptostachya	g		Paddock lovegrass
	Eragrostis longipedicellata	g		Love grass
	Hordeum glaucum	g	*	Northern barley grass
	Imperata cylindrica	g		Blady grass
	Lachnagrostis filiformis	g	*	Blown grass
	Lolium perenne	g	*	Perennial ryegrass
	Lolium rigidum	g	*	Annual ryegrass
	Microlaena stipoides	g		Weeping ricegrass
	Panicum effusum	g		Hairy panic
	Panicum simile	g		Two coloured panic
	Paspalidium distans	g		
	Paspalum dilatatum	g	*	Paspalum
	Pennisetum alopecuroides	g		Swamp foxtail
	Pennisetum clandestina	g	*	Kikuyu
	Poa annua	g	*	Winter grass
	Poa sieberiana var. *hirsuta*	g		Fineleaf tussock grass
	Poa sieberiana var. *sieberiana*	g		Fineleaf tussock grass
	Sacciolepis indica	g		Indian cupscale grass
	Sarga leiocladum	g		Wild sorghum

	Setaria pumila subsp. pallida-fusca	g		Cattail grass
	Setaria surgens	g		Pigeon grass
	Sporobolus africanus	g	*	Paramatta Grass
	Sporobolus creber	g		Slender rat's tail grass
	Sporobolus elongatus	g		Slender rat's tail grass
	Sporobolus fertilis	g	*	Giant Paramatta Grass
	Themeda triandra	g		Kangaroo grass
	Vulpia bromoides	g	*	Squirrel tail fescue
Phyllanthaceae				
	Phyllanthus virgatus	h		
	Poranthera microphylla	h		
Plantaginaceae				
	Plantago debilis	h		
	Plantago lanceolata	h	*	Snake plantain
Polygalaceae				
	Polygala japonica	h		
Polgonaceae				
	Acetosella vulgaris	h	*	Sheep sorrel
	Rumex brownii	h		Swamp dock
Primulaceae				
	Anagallis arvensis	h	*	Scarlet pimpernel
Scrophulariaceae				
	Linaria peisseriana	h	*	
	Scleranthus biflorus	h		
	Veronica arvensis	h		
	Veronica pleibia	h		
Solonacaeae				
	Solanum ambymerum	h		
	Solanum opacum	h		
Ranunculuaceae				
	Ranunculus sessiliflorus subsp. sessiliflorus	h		
Rosaceae				
	Acaena agnipila	h		Sheeps burr
	Rubus anglocandicans		*	Rasberry
Rubiaceae				

	Asperula conferta	h		
	Galium migrans	h		
	Richardia stellaris	h	*	
Thymaliaceae				
	Pimelea linifolia	s		
Verbenaceae				
	Verbena bonariensis	h	*	
Violaceae				
	Viola betonicifolia			
Adiantaceae				
	Cheilanthes sieberi	f		
Dennstaedtiaceae				
	Pteridium esculentum	f		Bracken fern