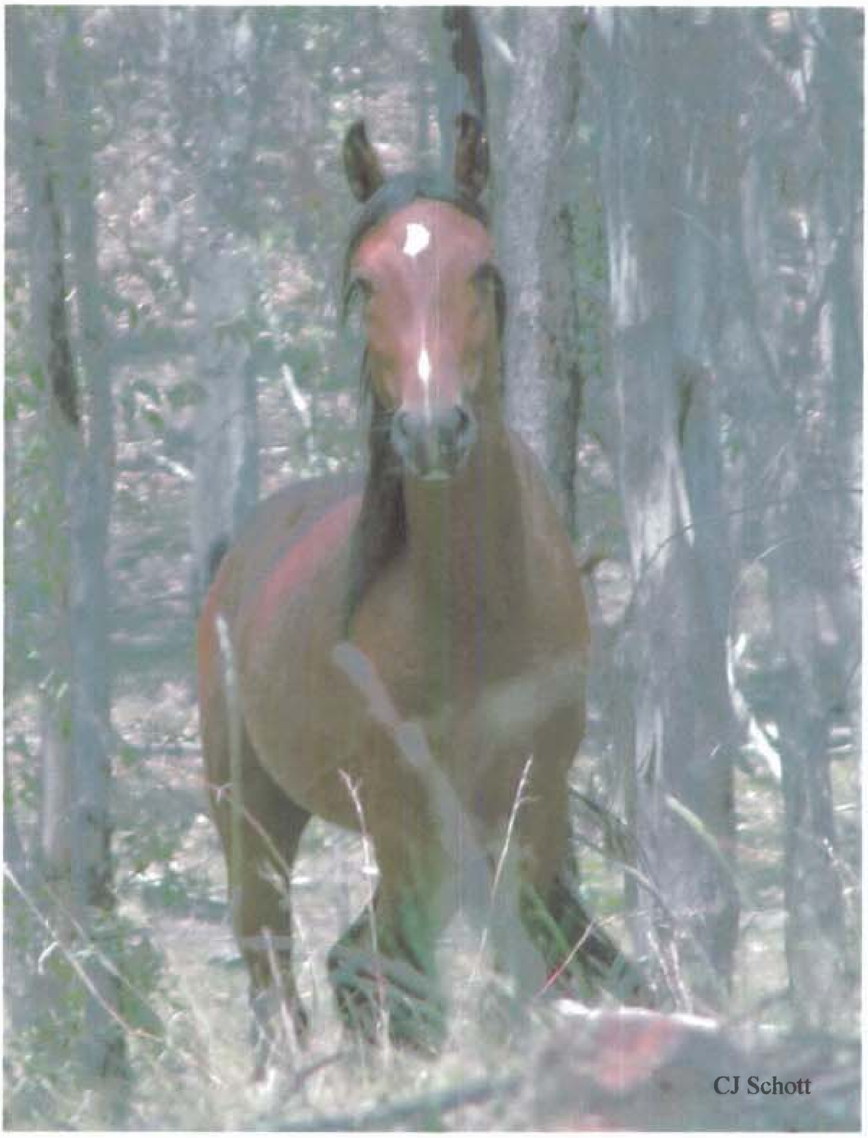
CHAPTER 5

EVALUATION OF EXCLOSURE METHODS



The Guy Fawkes River Brumby
~By Bruce Brislane

'His hooves beat out a thunder as he raced across the flat,
A wild thing, free and graceful in full flight.
And my heart in freedom, galloped with him through the dawn,
Long after he had disappeared from sight'...

5.1 Introduction & Research Links

The literature shows that, when measuring impacts of herbivores, it is particularly important to evaluate response of ecosystem elements to grazing removal (Table 5.1). Ungulates, such as free-ranging horses, cause disturbances that can directly influence ecosystems in various ways. They affect vegetation through biomass removal and through physical disturbance (Smit *et al.,* 2001).

Consumption of plants, redistribution of nitrogen and plant seeds by urination and defecations, trampling of vegetation and compaction of soils can result in changes to the vegetation (Hobbs, 1996 and Belsky & Blumenthal, 1997 in Beever *et al.*, 2003). Knowledge of such interactions is necessary to understand the consequences that free-ranging horses and other introduced herbivores can have on ecosystems.

Table 5.1 Some previous research on response of ecosystem components to the exclusion of grazers.

Response Variables Measured	Research on Exclusion of Grazers	Location	Source
Live mammal trapping, burrow counts, plant species richness, % cover, abundance of grasses and shrubs & vegetation height.	Ecological consequences of free-ranging horse grazing	W. Great Basin USA	Beever & Brussard (2000)
Plants, small mammals, ants & soil compaction	Characterising grazing disturbance in semi-arid ecosystems	W. Great Basin USA	Beever *et al.,* (2003)
Plant species composition, biomass, productivity & nitrogen cycling	Ecosystem level effects of mammalian herbivores	Wind Cave NP & Pryor Mtn. N. USA	Detling (1998)
Vegetation height, percent cover and vegetation replacement	Nutritional ecology of equids & their impact	N. Europe Camargue	Duncan (1992)
Species composition, biomass & available forage	Effects of free-ranging horses on vegetation	Pryor Mtn. N. USA	Fahnestock (1998 in Fahnestock & Detling (1999))
Plant cover, species composition & abundance	Influence of herbivory on plant cover & species composition	Pryor Mtn. N. USA	Fahnestock & Detling (1999)
Small rodent communities, seed predation & vegetation structural development	Effects of introduction & exclusion of large herbivores on small rodent communities	National Park 'De Hoge Valuare' Netherlands	Smit *et al.*, (2001)

Informed decision making, when it comes to free-ranging horse management in national parks, requires quantitative measures of responses of ecosystem components to the removal of grazing. Using exclosures allows manipulation of levels of herbivory across spatial scales and allows different response variables to be measured. Duncan (1992) used exclosures and reported a reduction in the disturbance to the plant community following the removal of grazing in the marshes of northern Europe. Increasing vegetation height and cover reduced opportunities for germination and led to a rapid decline in the numbers of annual plant species. There were documented changes in the short and long-term. Perennial monocotyledons were initially favored followed by woody plant replacement (Duncan, 1992).

In other herbivore-exclosure studies, increase in species richness, percent cover and biomass have been recorded in as little as 2 and 3 years (Beever & Brussard, 2000; Smit *et al.,* 2001). Striking differences in the structure, composition and character inside compared with that outside exclosures were reported by Beever and Brussard (2000). Additionally, Smit *et al.* (2001) suggested that large herbivores had significant effects on vegetation dynamics over 3 years by both altering plant composition and by reducing the quality of small rodent habitats.

Conversely, Detling (1998) and Fahnestock (1998) found differences in only vegetation biomass and percent cover of one or two dominant grass species after grazing had been removed for 2 years. They concluded that either the exclosures were not in place long enough for vegetative differences to accrue or horse density was low enough not to have imposed major changes (Detling, 1998; Fahnestock, 1998 in Beever & Brussard, 2000). They suggested that the effects of horse grazing might have been overshadowed by between-site or inter-annual variation and precipitation changes (Beever & Brussard, 2000). Differences over time were also found to be greater than differences attributed to grazing and were reported to be a bigger influence on plant features than grazing in Fahnestock and Detling's (1999) study.

Guy Fawkes River National Park is subjected to high environmental variability as illustrated in Chapter 2 and demonstrated by the recent drought of 2002/2003. The different results reviewed among studies lead to questions over the applicability of exclosure methods in GFRNP. Exclosure studies reported in the literature have provided valuable information, and could assist in management decisions regarding horse presence and impacts in the Park. The question of whether standard techniques hold up in the landscape needed to be answered before the implementation of a long-term vegetation study. For these reasons, exclosure methods were pilot tested for this study.

A collection of problems can arise when attempting to use exclosures to investigate effects of free-ranging horses when they are not the only grazers in the ecosystem. Guy Fawkes River National Park has a long history of grazing by horses and cattle, and the two herbivores occurred sympatrically on the plateau and in Bob's Creek during this research.

It is important to exercise caution when comparing effects of grazing by horses alone with effects of grazing by horses and cattle (Beever & Brussard, 2000), because researchers have found substantial dietary overlap between free-ranging horses and cattle in a variety of vegetation types (Olsen & Hansen, 1977; Salter & Hudson, 1979; Hanley & Hanley, 1982 in McInnis & Vavra, 1987).

The collective annual diets of free-ranging horses and cattle have been reported to share 81% similarity of plant species consumed and dietary overlap averaged 70% on an annual basis, Table 5.2 (McInnis & Vavra, 1987). The lack of dietary niche differentiation makes it nearly impossible to separate grazing effects of cattle and horses when both species forage in the same area (Beever & Brussard, 2000).

Cattle in arid regions often spend a disproportionate amount of time in riparian areas and researchers have long known that the magnitude of cattle impacts can be greatest closest to the water source (Roath & Krueger, 1982; VanVuren, 1982 in Beever & Brussard, 2000). Although research has shown that free-ranging horses also show a preference for riparian habitats (Berger, 1986, Crane *et al.,* 1997), they exhibit watering behavior noticeably different from that of domestic cattle. They travel greater distances from water and spend less time at watering areas (Berman & Jarman, 1988; Denniston *et al.,* 1982; McInnes, 1985; Meeker, 1979 in Beever & Brussard, 2000).

Table 5.2 Percent composition of diet by forage class and season for horses and cattle. (Adapted from Crane *et al.,*1997 in Bastain *et al.*, 1999)

Season	Species Category	Free-Ranging Horses	Cattle
Spring	Grass/forbs	99%	98%
Spring	Shrubs	1%	2%
Summer	Grass/forbs	98%	98%
Summer	Shrubs	2%	2%
Autumn	Grass/forbs	87%	84%
Autumn	Shrubs	13%	16%
Winter	Grass/forbs	76%	86%
Winter	Shrubs	24%	14%

It remains unclear to what extent horses may modify ecosystems around water sources because of their watering behaviour (Beever & Brussard, 2000). Mechanisms allowing the co-existence in tropical and temperate ecosystems of equids and grazing bovids have been debated. Janis (1976) noted that their very different digestive systems (hindgut vs. ruminant) could theoretically lead them to adopt different foraging strategies resulting in niche separation (Janis, 1976 in Menard *et al.,* 2002). This theory was not investigated in this research and cattle were included as large herbivores in Bob's Creek.

5.2 Methods

5.2.1 Exclosures

To test the applicability and usefulness of exclosure methods for evaluating impacts of stock grazing on herbaceous vegetation in GFRNP, a pilot experiment was developed. Grazing appeared to be concentrated along drainage-lines, so the experiment was designed for use in that catena level. The pilot study employed three different treatments at each of three sites for replication purposes.

One treatment was constructed with netted wire, and designed to exclude all large herbivorous mammals down to rabbit size. The second treatment was constructed with plain wire, and was designed to exclude horses and cattle but admit macropods and smaller herbivores. The last treatment excluded nothing and acted as the control.

The basis of the experiment had replicated measures of the differences between drainage-line vegetation exposed to no grazers, exposed to native grazers, and exposed to all grazers. Vegetation variables of biomass, seedbank and species richness were investigated. Bob's Creek was chosen for the pilot study because it was an area frequented by horses, and the remote location was thought to limit the possibility of public tampering. In addition, numerous sites along the creek flats showed ecological similarity and provided apparently similar sites from which to select three.

Three sites were considered the least amount necessary for replication purposes. Sites were selected based on adequate size for the three treatments plus a buffer zone between them. To measure chosen aspects of vegetation effectively, and to minimise edge effects, exclosure size was pre-determined to be 50 m x 50 m with at least 50 m between treatments (P. Jarman, UNE pers. comm., June 2002).

Once in the field, the sites along Bob's Creek were found to be not large enough for replication of 50 x 50m treatments. For this reason, exclosure size was scaled down to 20 m x 20 m with at least 20 m between treatments. Although exclosures were considerably reduced from the ideal size, they were still thought to be adequate to measure ecological similarity and test whether methods would hold up in the landscape.

Sites 3, 4 and 8 were chosen for the replicated exclosure pilot experiment because they were the largest sites (Table 5.3 & Figure 5.1). Three 20 m x 20m plots were marked out in each of the three sites and exclosures were constructed by the NSW NPWS staff on 18 July 2002. Exclosure plots were randomly assigned to the three different treatments at each site.

Table 5.3 GPS coordinates for selected exclosure sites in Bob's Creek (Adapted from S. Leathers, NSW NPWS May 2002).

Site	GPS coordinates
Site 1	30°00'25.7''S, 152°13'55.1''E
Site 2	30° 00' 9.3''S, 152° 14' 04.5''E
Site 3*	**30° 00' 03.3''S, 152° 14' 02.6''E**
Site 4*	**29° 59 49.1''S, 152° 14' 02.6''E**
Site 5	29° 59 45.1''S, 152° 14' 12.2''E
Site 6	29° 59 40''S, 152° 14' 09.7''E
Site 7	29° 59 40''S, 152° 14' 12.8''E
Site 8*	**29° 59 26.3''S, 152° 14' 22.4''E**

As suggested by Bhadresa (1986), exclosures were erected in areas that appeared homogeneous in terms of the vegetation, soil characteristics and topography (Figure 5.2). The three exclosures sites appeared equivalent because they were all located along the same creek and in the same habitat type; they were composed of the same soils; all sites had the same aspect, with less than 15° slope; and they did not differ in elevation. Confirming that the sites are similar ensures that future differences in the vegetation between grazed and ungrazed areas are mainly attributed to grazing (Bhadresa, 1986 in Moore, 1986).

To test for homogeneity of vegetation across the sites, three null hypotheses were developed. To test null hypotheses, sampling procedures were developed to collect and compare vegetation attributes between treatments and sites. There can be great variation in vegetation attributes over time, so sampling took place twice, 6 months apart.

H_{01} = Biomass production is equal among sites and treatments

H_{02} = Seedbank density is equal among sites and treatments

H_{o3} = Species richness is equal among sites and treatments

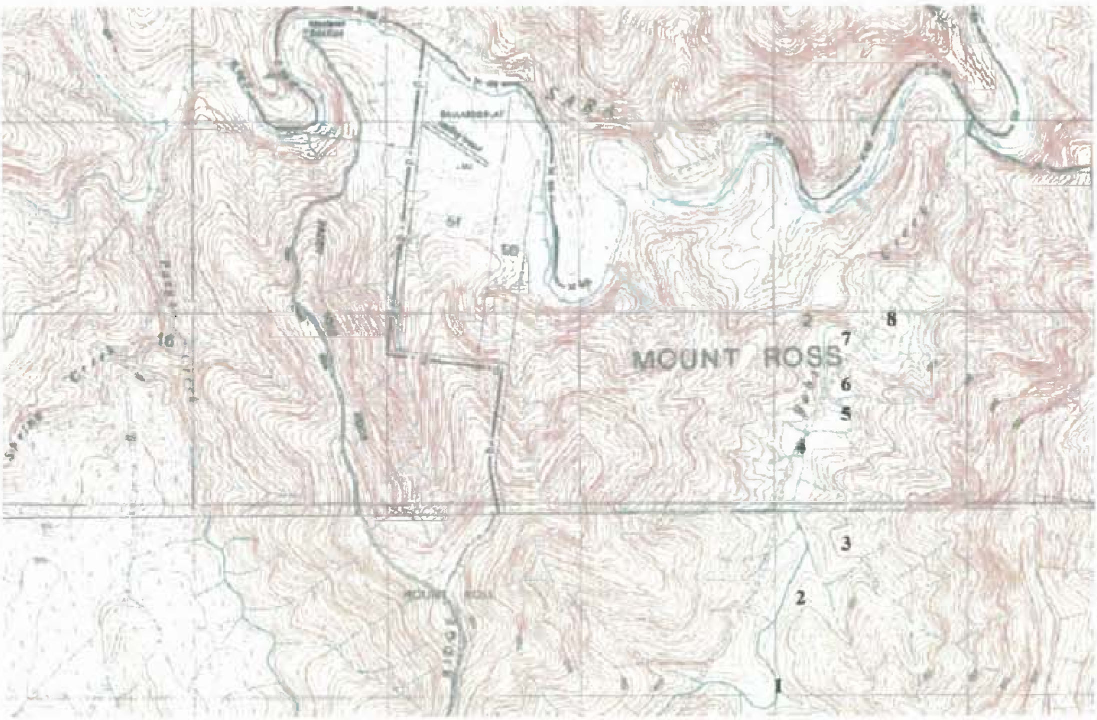


Figure 5.1 Sara River Topographic Map with possible exclosure sites (Source: 1:25 000 Sara River Topographic Map).

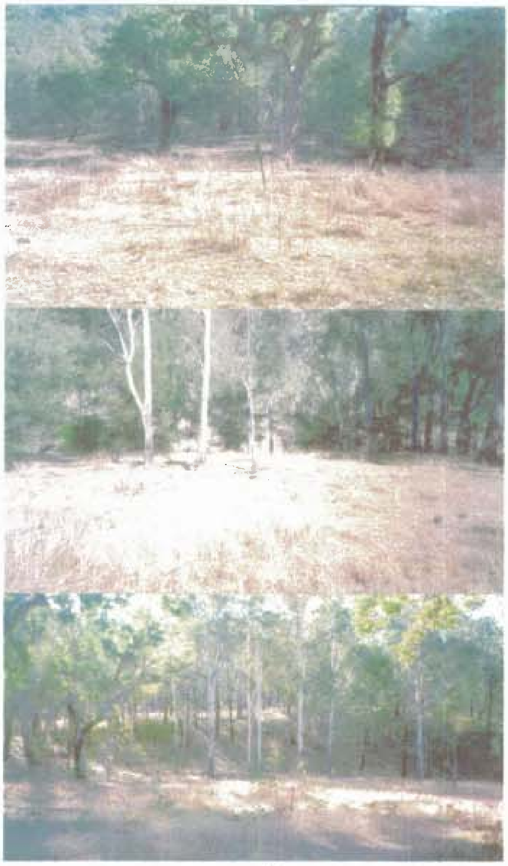


Figure 5.2 Exclosure sites 3 (top), 4 (middle) and 8 (bottom).

5.2.2 Vegetation Attributes

5.2.2.1 Vegetation Biomass Collection

For sampling vegetation biomass, treatment plots were considered as independent replicates and 1 m x 1 m quadrats were used as sub-samples within plots. All three treatments together were treated as an experimental unit. Standing crop (above ground) biomass was clipped from three randomly selected 1 m x 1 m quadrats within each of the nine 20 m x 20 m treatment plots (Figure 5.3). The sampling was conducted late winter, August 2002, and was repeated in late summer, February 2003. The standing crop materials were oven dried at 45 degrees Celsius for 24 h then the samples were sorted, weighed and documented.

5.2.2.2 Soil Seedbank Collection

For seedbank density and species richness analyses soil samples were taken from each treatment in August 2002 and February 2003. Soil samples were taken using a soil tube, which is the most desirable tool for collecting soil samples because it gives a continuous core with minimal disturbance of the soil (IANR, 1998). Moreover, viable seeds are strongly concentrated in the top 2 to 3 cm of the soil (Sutherland, 1996). In order to achieve an acceptable degree of accuracy when analysing seedbank, sample size depends on the spatial distribution pattern of the seeds in the soil (Ambrosio *et al.*, 1997).

There was a degree of uncertainty about the spatial distribution of seeds, so large amounts of samples were collected at randomly located points, as suggested by Gross (1990). Gross (1990) determined that 15 to 20 sampling locations were sufficient to determine the numbers of species present in the seedbank and she covered 0.016% within a 30 by 50 m area. For Bob's Creek exclosures, sampling was designed to cover 0.014% of the 20 m x 20 m area within exclosures.

Using a hierarchical sampling scheme, soil was sampled within a systematic grid. In each 20 m x 20 m treatment, a grid was set out with four rows each way. Five soil-cores with a 3.5 cm diameter were randomly collected to a depth of 5 cm in each 5 m x 5 m grid square, with 80 taken from each treatment plot. In total, there were 720 soil-core samples taken from the replicated sites (Figure 5.3).

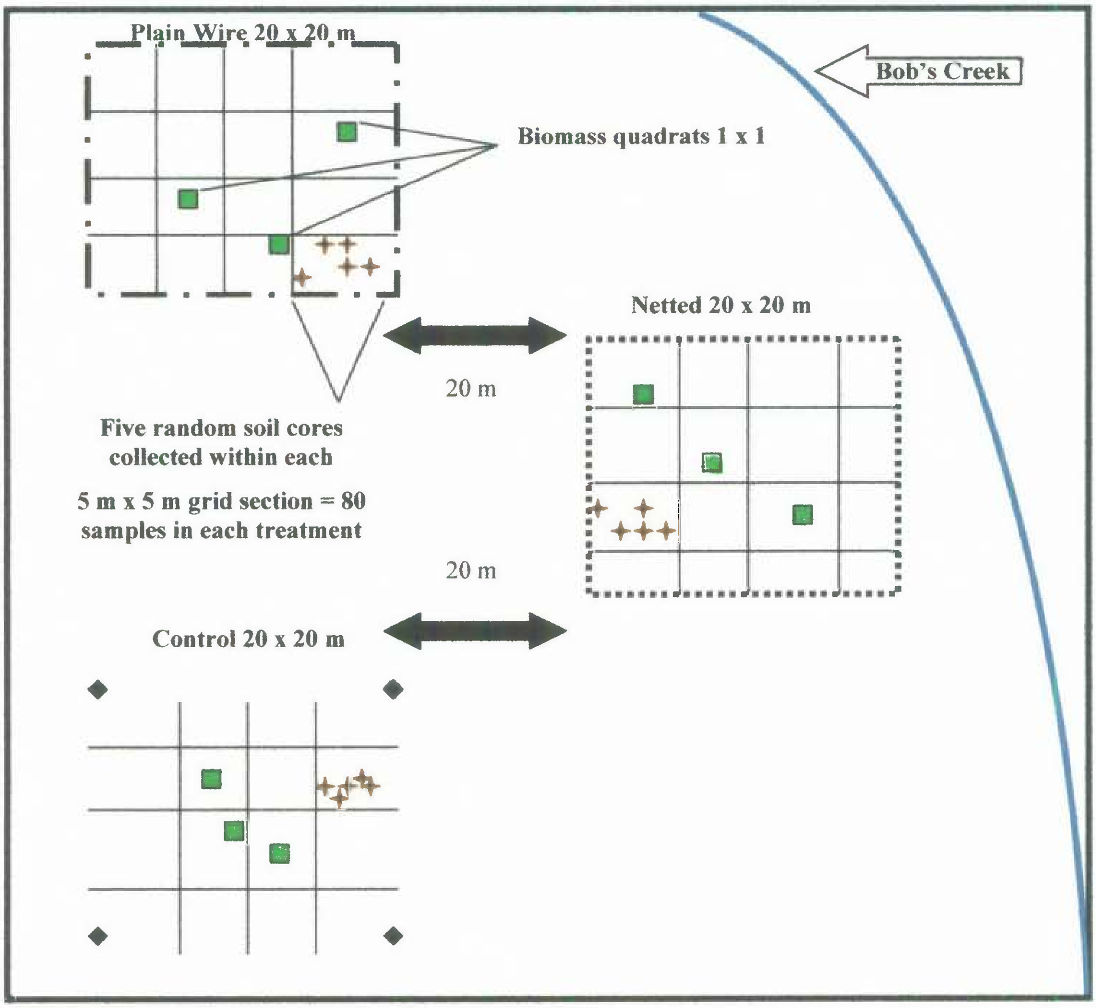


Figure 5.3 Bob's Creek exclosure study design: Replicated at three sites

Soil cores were taken back to the University of New England. Fifteen random soil samples were selected out of the 80 samples from each of the nine treatment plots for both sampling trials. In total, 135 of the 720 soil samples were potted in vermiculite and placed in the UNE glasshouse, first in mid-September 2002 and again in February 2003, where they had a twice-daily watering regime.

Sprouts were monitored over an 8-week period with sprout numbers in each sample documented weekly. These numbers assisted in comparisons of seedbank density among treatments and sites. When seedlings had established, and sprout numbers leveled out, the number of different species in each sample were counted and used to compare species richness.

Figure 5.4 Glasshouse experiment design to analyse seedbank and species richness.

5.3 Results

5.3.1 Exclosures

The replicated exclosures were intended to be used to measure the differences between Bob's Creek vegetation exposed to the different treatments over a 6-month period. It was anticipated that animals would see exclosures and ignore them. However, over the course of the experiment, the majority of exclosures were breached by stock.

All plain wire exclosure treatments were penetrated with the star pickets bent nearly to the ground (Figure 5.5). Two netted exclosures remained intact. The third netted exclosure had been breached by a free-ranging horse, which is assumed to have died upon entry (Figure 5.5).

This unfortunate incident illustrates the complications of exclosure methods in remote locations with limited access and hence, infrequent maintenance. Recently constructed exclosures that have not had uninterrupted span of no grazing are difficult to extrapolate results from.

Breached exclosures made it impossible to employ inferential statistics. Comparisons did not test for treatment effects, but rather described variability in, and the difference between treatments and sites.

Figure 5.5 Breached exclosures. Clockwise from top right, netted exclosure, plain wire exclosure, netted exclosure, plain wire exclosure.

5.3.2 Vegetation Attributes

To test for homogeneity of vegetation in each site and time-period, statistical comparisons were undertaken using Statgraphics Plus (Version 2.0, 1996). One-way analysis of variance was initially applied to all variables of biomass, seedbank and species richness, using Cochran's C test. If assumptions underlying the analysis of variance were violated, non-parametric Kruskal-Wallis ANOVA was used, which compares medians instead of means. If normality assumptions underlying ANOVA were not violated, a parametric test was run, which compared the mean values of vegetation for the three different treatments.

Comparisons of each vegetation variable between treatments in each site revealed differences in between treatments. The majority of treatments in sites 3 and 4 were similar but treatments in site 8 differed significantly from each other in seedbank (Feb. 2003), and species richness (Aug. 2002 & Feb. 2003) (Appendix 5.1). Variation in treatment measurements led to speculation over similarity of sites. Average measurements for each vegetation variable, +/- the standard error, in each treatment are illustrated in Figure 5.6.

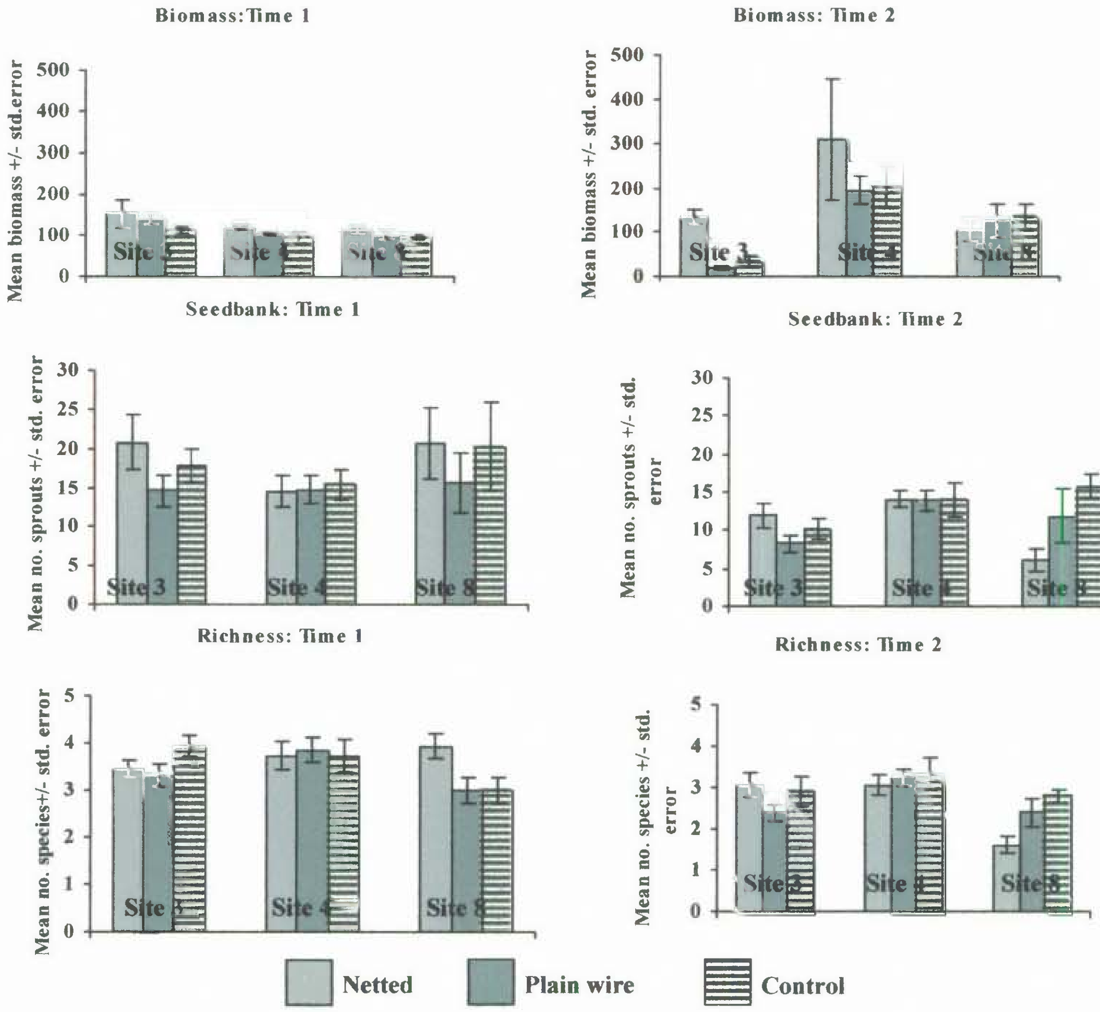


Figure 5.6 Average measurements in grams +/- standard errors of biomass, seedbank and species richness collected from each exclosure treatment (Netted, Plain Wire, and Control) in each site.

5.3.2.1 Biomass

It was attempted to test the similarity of biomass values among sites and treatments over time by multiple factor ANOVA followed by Fishers' least significant difference (LSD) tests. Results were flawed because of the lack of independence of measurements at the same site at different times. Because complications were raised by time, the two different time frames were tested independently (One-way ANOVAs) to test for similarity of sites, and not time. Using biomass weight as the dependant variable and treatments (Netted, plain wire, and control) as factors, a one-way analysis of variance for weight was carried out. The ANOVA table for weight by treatment is presented in Table 5.2a for August and Table 5.2b for February.

Results for the August timeframe revealed that there was not a statistically significant difference between the mean weight from one level of treatment to another (P-Value= 0.163, df=2, F-Ratio=1.96, P≥ 0.05). Results for the February timeframe also revealed that there was not a statistically significant difference between the mean weight from one level of treatment to another (P-Value= 0.4047, df=2, F-Ratio=0.94, P≥ 0.05)

Table 5.4a ANOVA table for weight of biomass between treatments (Netted, Plain Wire and Control), and between three sites in August.

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-Value
Between groups	3200.54	2	1600.27	1.96	0.1632
Within groups	19625.9	24	817.748		
Total (Corr.)	22826.5	26			

Table 5.4b ANOVA table for weight of biomass between exclosure treatments (Netted, Plain Wire and Control), and between three sites in February.

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-Value
Between groups	24400.9	2	12200.4	0.94	0.4047
Within groups	311626.0	24	12984.4		
Total (Corr.)	336027.0	26			

5.3.2.2 Seedbank

Similarity of the seedbank density values among sites and treatments over time was tested using multiple factor ANOVA followed by Fishers' least significant difference (LSD) tests. Type I sum of squares was used in analysis of variance. Main effects tests revealed that time had a statistically significant effect on seedbank density (P-value $_{1, 0.001} \leq 0.0001$, F-ratio = 17.49). Interactions showed that site and time affected seedbank density and sites were not similar (P-value $_{2, 0.05}$ = 0.047, F-ratio = 3.09) (Appendix 5.3a). Fisher's least significant difference test revealed no significant differences for seedbank density between sites (Appendix 5.3b).

5.3.2.3 Species Richness

Similarity of the species richness values among sites and treatments was tested over time using multiple factor ANOVA followed by Fishers' least significant difference (LSD) tests. Type I sum of squares was used in analysis of variance. Tests revealed that site and time had statistically significant effects on species richness (P-value $_{1, 0.01}$ = 0.0001, F-ratio = 9.30 and P-value $_{1, 0.001} \leq$ 0.0001, F-ratio = 35.45). Interactions revealed that site, treatment and time affected species richness (P-value $_{4, 0.01}$ = 0.0044, F-ratio = 3.88) (Appendix 5.4a). Fisher's least significant difference test revealed significant differences between sites 3 and 8 and between sites 4 and 8 (Appendix 5.4b).

5.4 Discussion, Implications & Future Research

This chapter has identified the need for rigid standardisation of technique that must encompass several factors. Remote location was the major difficulty that limited usefulness of the exclosure experiment. Remote location of the sites was intended to limit public tampering. However, it restricted access for maintenance. Monitoring and maintenance was infrequent, and as a result, exclosures were breached by stock.

Exclosures being breached by stock made it impossible to extrapolate results on the effects of grazing. On the other hand, one of the aims of the study was to test whether the methods would hold up in the landscape. The methods employed in this study did not hold up in the landscape because the fencing designs of exclosures were not suitable to keep out large herbivores. Installing strands of barbed wire could have possibly prevented the damage, as well as tightly strained wiring. The unfortunate incident leading to the death of a horse during this research accentuates these recommendations.

The 20 m x 20 m exclosures in this research were, in reality, all edge-affected, as 15 m is the recommended distance for a buffer zone (Smit *et al.*, (2001). Larger plots correspond with scales at which large-bodied herbivores such as free-ranging horses and cattle afflict ecosystems (Beever *et al.,* 2003), and would have been more beneficial to employ in this study. This study also could have achieved greater experimental rigour through increased replication. Use by free-ranging horses appeared to be concentrated along the drainage-lines, which led to priority of measuring impacts in that catena level. It would be ideal if similar sets of exclosures could be erected amongst a matrix of habitats and landscape positions so that the impact of herbivores in different catena levels could be examined.

Although exclosures were erected in sites showing ecological similarity, as suggested by Bhadresa (1986), statistical comparisons of seedbank and species richness revealed significant differences. The question that remains is; what the acceptable degree of difference for this type of study is. Before-After Control-Impact (BACI) experimental designs were developed in the 1980's to overcome the problem of natural site variation (N. Reid, UNE pers. comm., April 2004), and would be useful to apply in future designs. Even if the BACI experimental design is employed to account for natural variation, confirming the sites are initially similar in biological composition ensures that future differences in the vegetation between grazed and ungrazed sites are attributed to herbivory.

Both temporal and environmental variation must be considered when designing exclosure studies. Inter-year variations in precipitation have been shown to sometimes have a bigger influence on plant features than grazing, so scientists suggest collection of data across seasons and years (Beever & Brussard, 2000). Long periods are also necessary because some vegetation differences require time to emerge or accumulate following the removal of grazing. Comparisons between drought years and between periods of high rainfall could increase understanding of free-ranging horse ecology in GFRNP.

Quantitative investigations into the ecological consequences of stock grazing in northern GFRNP, and relationships that horses maintain with ecosystem elements, could increase our understanding of some of the impacts of free-ranging horses in Australia. In addition to biomass, seedbank and species richness, more detailed assessments of plant diversity, relative abundance and phenology could be implemented. Beever and Brussard (2003) suggest also incorporating disturbance-sensitive variables such as soil surface hardness. Future exclosure studies could examine these variables.

Exclosures may be more useful on Paddy's Land plateau, which has greater accessibility making their maintenance and plant sampling more feasible; and, in collaboration with UNE could be monitored over a longer time period. Paddy's Land plateau also provides larger homogenous sites and accessibility for regular monitoring of sites as well. Regardless where future exclosure studies are implemented, complications can be avoided by adhering to several basic guidelines.

5.4.1 Guidelines for a "Best-Bet" design:

- **Accessibility**: An easily accessible location is important in making sampling and maintenance feasible.
- **Exclosure design**: Construction of exclosures must be strong enough and location-appropriate, to prevent penetration by free-ranging horses and cattle.
- **Exclosure size**: Fifty by 50 m is the adequate size determined for exclosures but could be scaled down to 40 m x 40 m if selected sites are restricted (P. Jarman, UNE pers. comm., June 2002).
- **Experimental Design**: Ideal experimental design would employ replicated exclosures located amongst a matrix of habitats (Beever & Brussard, 2000).
- **Current science**: Implementing the Before-After Control-Impact (BACI) experimental design can assist with accounting for natural variation of sites.
- **Timeframes**: Comparisons between drought years and between periods of high rainfall could increase understanding of free-ranging horse ecology in GFRNP.