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# *Assessment of Impacts of Feral Horses (Equus caballus) in the Australian Alps*

Part 1.

Draft design of experimental monitoring programs for determining the environmental Impacts of feral horses in the Cobberas-Tingaringy Unit of the Alpine National Park.

**A report to the Australian Alps Liaison Committee.**
**K.R.Thiele & S.M.Prober**
**Ecological Interactions. Jan. 1999**

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## Introduction

### *Feral Horses in Australia*

Horses were first introduced into Australia in 1788 with the arrival of the first fleet, with irregular subsequent introductions from South Africa, India and England (Dobbie *et al.* 1993). Conditions in Australia were generally suitable for horses, and records of horses escaping to the bush date from as early as 1804. Feral horses were first recognized as pests during the late 1860s (Rolls 1969).

Australia now has an estimated 300 000 to 600 000 feral horses, the largest population in the world (Berman and Jarman 1987, Clement *et al.* 1990). Most occur in remote semi-arid areas, particularly the extensive cattle-raising districts of the Northern Territory, Queensland and Western Australia (Dobbie *et al.* 1993).

The greatest concentrations outside semi-arid regions occur in the montane to sub-alpine regions of New South Wales and Victoria. Feral horses have been recognised as a problem there since the nineteenth century (Sydney Morning Herald 1871, Helms 1890) and have been identified as a threat to montane environments in many studies including those of Byles (1932), Costin (1954), Anon (1977) and Alpine Planning Project Team (1989). Apart from a study by Dyring (1990), however, feral horse populations have not been well studied in the Australian Alps. *The aims of the present study are to review current knowledge of the extent and impact of high country feral horse populations, and to design a monitoring program to begin assessment of feral horse impacts in the Cobberas-Tingaringy Unit of the Alpine National Park.*

### *Feral Horses in the Australian Alps*

The first horses are believed to have arrived in the high country in 1843 when 70 mares and two sires were brought to Black Mountain on the eastern boundary of Victoria's highlands. The horses were released and never mustered, and the present populations of feral horses in the Cobberas region are thought to be descended from these animals (Allen pers. comm. in Dyring 1990). Similar introductions later occurred on the western fringe of the Monaro Tablelands.

Horse numbers in the high country generally fluctuate in response to drought and to bushfires (Rogers pers. comm., Byrne & Freebody pers. comm. in Dyring 1990), but numbers generally increased until the 1960s as a result of several factors, including the return of grazing leases to the Crown in some areas, a reduction in demand for horses in the Indian and Australian armies after the second world war, and a reduction in competition from rabbits after the introduction of myxomatosis in the late 1950s. Intensive culling by cattlemen in the 1960s reduced populations by up to 50% in some areas (Rodgers pers. comm. in Dyring 1990).

Today, feral horses in the high country of New South Wales are concentrated in the Kosciusko National Park. Several hundred horses are estimated to occur in the southern section, with scattered smaller mobs within and adjoining the Park (Dyring 1990). Small populations (totaling 33 animals) were eradicated from sub-alpine areas of the Australian Capital Territory in 1987.

Feral horse populations in Victoria are estimated at a total of 1000 to 3000 animals. Most (1200-1400 horses) occur within the Cobberas-Tingaringy unit of the Alpine National Park, with other smaller populations in Bogong National Park, the Gatturnurgh Creek area of the Snowy River-Byadbo Wilderness area, the Nunniong region south west of the Cobberas, and the Wonnongatta-Moroka National Park (Dyring 1990). The report of a small population in Errinundra National Park (Dyring 1990) appears to be mistaken (D. Ingram, DNRE Bendoc, pers. comm.). About 200 horses are also known in lowland areas in the Barmah State Forest near Echuca (Dobbie *et al.* 1993).

**Biology**

*Habitat*

Feral horses occur in a range of habitats in Australia, from semi-arid plains to tropical grasslands and swamps, temperate ranges, small islands and subalpine mountains (Dobbie *et al.* 1993). Most studies of Australian feral horses have been in semi-arid areas, with the exception of a study by Dyring (1990), which examined habitat preferences in the Kosciusko National Park and northern Victoria. Dyring (1990) found that horses concentrate in grassland and heath communities for feeding throughout the year, although they also utilize forests for shade and relief from horseflies on hot summer days. This is consistent with findings for horses in France (Duncan 1980, 1983, 1985, Mayes & Duncan 1986), New Zealand (Rogers, 1991) and England (Pratt *et al.* 1986), although Ganskopp and Vavra (1986) found no habitat preferences in feral horses of Oregon. In arid Australia horses also prefer grassy flats, but often retreat to hill country during drought or mustering activities (Dobbie *et al.* 1993).

Dyring (1990) estimated population densities as high as 53 animals per square kilometre in catchments of the Kosciusko National Park, although these figures are likely to be inflated by concentration of horses in the relatively small grassland feeding areas. Rogers (1991), after a census of horse numbers for whole catchments in the Kaimanawa Mountains, recorded a maximum of 3 animals per square kilometre for some catchments.

Habitat patchiness across catchments means that average density figures such as these give little indication of actual impacts at grazing sites.

*Social Organisation*

Feral horses live in small social units known as harems and bachelor groups (Salter & Hudson 1978). Harems are relatively stable breeding units consisting of a dominant stallion, one or more mares, and their offspring. Bachelor groups are more unstable units comprising up to four two- to four-year old males that have been forced out of their harems (Dyring 1990, Dobbie *et al.* 1993). Dyring (1990) found that harem sizes ranged from two to eleven animals in the catchments that she studied in the Kosciusko region, with a mean group size of three to four animals, including on average one stallion, 2 females and one foal. This compares with a typical group size of five to seven individuals in central Australia (Berman & Jarman 1987), and four to 14 individuals in the United States (Keiper 1986).

The home range of feral horses has not been determined for the Australian Alps. It has been estimated at 100 $km^2$ (Mitchell *et al.* 1982) in Queensland and 70 $km^2$ in central Australia (Dobbie & Berman 1990), which is comparable with estimates for North American deserts. These estimates are much larger than for wetter parts of the world (Dobbie *et al.* 1993) that are likely to be more comparable with the Australian sub-alpine environment. Ganskopp and Vavra (1986), for example, estimated home ranges of between 12 and 27 $km^2$ in sagebrush steppe in Oregon.

*Population Dynamics*

Feral horse populations can increase by 20% in favourable years (Eberhardt *et al.* 1982; Rogers, 1991), implying a population doubling time of 3.4 years. Horses foal mostly over spring and summer (Dobbie & Bermann 1990), and while they are capable of foaling annually, they usually only successfully raise one foal every two years. Mares in poor condition rarely foal (Berman & Jarmann 1987). Several physical defects prevalent in Victorian populations of feral horses have been attributed to inbreeding (Dobbie *et al.* 1993).

An average of 20% of a horse population, mostly juveniles and subadults, dies each year. Apart from human culling and harvesting, the main causes of death are associated with drought (thirst, starvation and poisonous plants, Dobbie *et al.* 1993), although bushfires may also cause dramatic local reductions in feral horse numbers in Victoria (Dyring 1990). Major horse diseases that contribute significantly to mortality overseas are absent from Australia (Kennedy 1986, Dobbie *et al.* 1993), although some such as worm or tick burdens can cause ill-thrift.

*Diet*

Horses are selective grazers, mainly of grasses and palatable herbs. A diet study in Central Australia (Berman & Jarman, 1987) showed that the grass *Enneapogon avenaceus* was favoured, and that horses would forage over large distances to graze favourable sites. In New Zealand, favoured species included the grasses *Chionochloa pallens* and *Festuca tenuifolia*, and herbaceous species such as *Helichrysum bellidioides*, *Stackhousia minima* and *Galium propinquum* (Rogers, 1991). Low-growing and prostrate species often escaped significant grazing pressure, and sometimes increased in grazed sites as competition from taller plants decreased.

No direct studies on feral horse diet preferences have been published for the Australian high country. However, inferences may be made from the detailed studies of effects of cattle-grazing in Kosciusko and the Alpine National Parks (Williams *et al.* 1997), as horse and cattle preferences are probably broadly similar. Cattle on the Bogong High Plains graze extensively on the dominant snow grasses (especially *Poa hiemata*), but also strongly targeted species of the tall, herbaceous daisy genera *Celmisia*, *Craspedia* and *Podolepis*. Grazing selectivity in cattle is indicated by a strong preference for *Celmisia spp.* over another common daisy, *Leptorhynchos squamatus* (van Rees 1984).

**Impacts**

Apart from studies by Berman and Jarmann (1988) and Dyring (1990), the environmental impacts of feral horses in Australia have not been well studied, and existing information is largely anecdotal. Overseas studies of impacts are also limited, except for a study of population dynamics and impacts of feral horses in subalpine grasslands of the Kaimanawa Mountains on the North Island of New Zealand (Rogers 1991). By comparison with horse impacts, a large body of literature is available regarding the impacts of cattle grazing in the Australian Alps. Some of this may be generalizable to horses.

*Impacts of grazing on soils and landscape*

Intensive summer grazing by cattle and sheep in the Australian high country between around 1850 and 1960 resulted in widespread soil erosion associated with direct effects of trampling as well as loss of plant cover. Bare areas are normally non-existent or negligible in sod-tussock or herbfield communities of the high country, thus under any circumstances, bare soil surface is an indicator of unsatisfactory catchment condition with threat of accelerated erosion (Durham 1959). Sheet erosion is the predominant form of erosion, followed by rilling and gullying if allowed to advance unchecked.

Another significant impact of grazing by hard-hoofed animals has been stream incision and increased drainage in the originally broad, boggy valleys, resulting in drying and erosion of peats and subsequent vegetation changes (Byles 1932, Costin *et al.* 1959, Durham 1959). These impacts were exacerbated by practices of frequent burning of vegetation to encourage greenpick for animals. Burning followed by grazing was able to completely remove the overstorey of snow gums (*Eucalyptus niphophila*) in some areas of the high country. Owing to this widespread damage to sub-alpine environments, grazing by livestock in the Kosciusko National Park was prohibited in 1958, and grazing by sheep was prohibited in 1947 on the Victorian High Plains (cattle grazing continues today). There has been considerable recovery in areas where grazing was prohibited, although some changes appear to be irreversible (Costin *et al.* 1959, Durham 1959, Williams *et al.* 1997).

Owing to their more localized distribution and lower economic significance, the effects of feral horses in the Australian Alps have been less well documented. Given the widespread effects of past cattle and sheep grazing in the regions, the effects of horses may not always be distinguishable from the legacy of an already modified system. However, the more localized distribution and lower density of horses, combined with the lower incidence of burning-off since the removal of livestock and greater control of leases, are likely to result in more localized and less severe impacts on the high country environments. Nevertheless, significant environmental impacts have been noted in most areas populated by feral horses.

Dyring (1990) found that horses produced an extensive network of tracks in the Kosciusko region. Soils on tracks were significantly compacted compared with off-track areas. Compaction was most severe on dry soils, with 20 to 50 passes by horses being sufficient to increase compaction on dry soils, while structural damage was more important on wet soils. Soils on tracks were often finer and more loamy than off tracks, were significantly drier, and showed marginal but not significant loss of organic matter. Fewer plants grew on and adjacent to tracks, with a resultant lower native species richness, but a higher exotic species abundance. General soil loss from tracks averaged 40 to 156 $cm^3$ per $m^2$. Wallowing caused more local damage than tracks, with greater exposed surface and greater loss of organic matter.

Dyring (1990) noted up to 83% stream bank disturbance resulting from drinking and crossing by feral horses. Damage included bank slumping and breakdown and vegetation disturbance. Most damage occurred in herbaceous communities compared with shrub and *Sphagnum* communities, probably owing to greater accessibility and palatability. Dyring (1990) also noted that hydrologically unstable conditions such as stream incision and increased drainage of broad, boggy valleys caused by earlier livestock grazing may be perpetuated by feral horses, and suggested that elimination of grazing may see these eroding catchments restored to the more swampy pre-European situation.

Rogers (1991) found that impacts on bogs depended on their nutrient status. Low nutrient bogs on summits and valley floors were not favoured by feral horses and the hydrological status and vegetation of these communities remained largely intact. However, high nutrient flushes were severely damaged by trampling and grazing, leading to disrupted water flow, increased downstream siltation and weed invasion.

In central Australia, it has been difficult to separate impacts of feral horses from impacts of other animals, including cattle and kangaroos (Dobbie *et al.* 1993). Recognized short term effects include creation of horse tracks and paths, damage, depletion and fouling of waterholes, collapse of wildlife burrows and damage to vegetation through trampling and grazing. Potentially serious long term effects include increased erosion through soil disturbance and denuding areas of vegetation, reduced fire frequency owing to loss of ground fuel, increased seed dispersal of natives and weeds in manure, changes in pasture composition and restriction of the distribution of native fauna (Berman & Jarman 1988, Berman 1991).

*Impacts on Vegetation*

Detailed information regarding the effects of feral horses on vegetation of the Australian Alps is not available. However, the following summary of known impacts of cattle grazing in the high alps and subalpine feral horses in New Zealand gives some indication as to likely effects (see Williams *et al.* 1997 for a detailed review of impacts of livestock grazing in alpine and subalpine communities in Australia).

Rogers (1991) used a series of permanent monitoring and exclosure plots to study effects of the feral horse population in New Zealand's Kaimanawa Mountains. The most extensive community, *Chionochloa rubra* tussock grassland, was severely affected by grazing only on more mesic sites, where the tussocks were often eliminated. The more restricted *Chionochloa pallens* tussock grassland, however, was rapidly being eliminated throughout the area by preferential grazing. The habitats of a number of rare and threatened species were also being adversely affected. Exclosure of horses from semi-degraded *Festuca novae-zelandiae* grassland (previously grazed by sheep and cattle), led to proliferation of introduced weedy species at the expense of the native, low-stature inter-tussock flora. Rogers (1991) speculated that this weed flush may be short-term, but his experimental data could not address this.

The impact of cattle grazing on the vegetation of the Australian Alps has been studied since the 1940s (Carr & Turner 1959, Wahren *et al.* 1994). Permanent monitoring plots set up at that time are still maintained today, and numerous additional monitoring studies have been established to cover many types of alpine and subalpine vegetation (Williams *et al.* 1997). These studies have shown that trampling and selective grazing by stock greatly alters the composition and structure of many alpine plant communities, and can lead to invasion by exotics.

In grasslands and open heathlands, the abundance and seed production of many taller herb species, such as silver snow daisy (*Celmisia spp.*), is markedly reduced by grazing. Invasion of grassy areas by shrubs can also occur as a result of increased bare ground. This can result in temporary increases of shrub cover if grazing is subsequently removed, but there is a return to more grassy vegetation as the shrubs begin to senesce (Carr & Turner 1959, Wahren *et al.* 1994).

Wetlands or bogs in areas of impeded drainage are not preferred for cattle grazing, but they do contain palatable species as well as drinking water, and are highly sensitive to damage by trampling. This may eventually lead to their drying out, with subsequent vegetation changes and creation of bare stony pavements. Regeneration of stony pavements is extremely slow, but has occurred in some exclosures (Williams *et al.* 1997).

Relatively rare snowpatch herbfields are favoured by stock, and are highly sensitive to grazing because they occur on steep slopes. Most snowpatch communities on the Bogong High Plains are now in degraded condition, with 20-50% bare ground, and no recovery has been observed in one 16 year exclosure study (Williams *et al.* 1997).

Impacts of cattle on closed heathlands are low as they are relatively non-palatable to stock (Williams *et al.* 1997).

## Monitoring

*Horse Populations*

Monitoring of horse populations is beyond the scope of this study. A study currently proposed (M.Walter pers comm.) seeks to study population dynamics and biology of feral horses in Kosciusko National Park. We recommend that part of that study be undertaken in parallel with the exclosure experiments, as this is likely to provide benefit to both parties.

*Measurement of Impacts*

No long term monitoring of the impacts of feral horses on Australian alpine environments has been undertaken to date. Two important aspects of such an assessment are an estimation of the extent and nature of impacts, and an assessment of the degree and speed at which impacted areas can recover. Direct assessment of impacts is difficult since horses are already established in most subalpine areas, and experimentally introducing horses into areas that are currently horse-free would be environmentally unacceptable. Estimates may also be complicated by a history of grazing by sheep or cattle in many areas. Hence, estimation of impacts suffers from the lack of a formal control. However, some estimation of impact may be gained by experimental removal of horses from exclosures with subsequent monitoring of enclosed and control (grazed) plots. Exclosure experiments would also provide valuable data to estimate the rate and extent of recovery of impacted sites.

The long term impacts of cattle grazing in the Australian Alps, and grazing by feral horses in New Zealand, have generally been assessed through the monitoring of permanent plots, usually including both grazed and exclosed plots, but sometimes simply monitoring changes after cessation of grazing in a larger area. Many studies of cattle grazing in the Alps, as well as studies of feral horses in New Zealand (Rogers 1991), have been limited by a lack of true replication (Wahren *et al.* 1994).

Monitoring usually involves an estimate of the abundance of each species within the plot at each monitoring period, although it is also possible to measure pooled classes of species (e.g. grasses, forbs, shrubs) rather than individual species. Subjective visual estimates of abundance can be made using a recognised scale; the most commonly used in general vegetation survey is the Braun-Blanquet scale. Visual estimates are relatively rapid and are well accepted for use in vegetation surveys, although being subjective they may be unreliable and can vary significantly between recorders. Objective estimates of abundance (cover) can be made using point quadrat or line intercept techniques (Levy & Madden 1933, Goodall 1952, Mueller-Dombois & Ellenberg 1974). These methods are more time-consuming than subjective measures but are more reliable, can increase the number of species detected within a plot, and are less biased towards visually striking (e.g. flowering) species.

For studies of impacts of cattle grazing in the Victorian Alps (Carr & Turner 1959, Williams & Ashton 1987, Wahren *et al.* 1994, Williams *et al.* 1997) and in the Kosciusko region (Costin *et al.* 1959, Wimbush & Costin 1979, Leigh *et al.* 1987), point quadrat or line intercept techniques have most commonly been used for monitoring. Application of these technique varies considerably, with the main considerations being the arrangement of points (systematic, grouped or random), use of permanent points, the diameter of the pin used, total number of points scored, and whether the number of hits per species at each point is counted or simply recorded as presence or absence. A typical application of the point quadrat technique to cattle grazing studies in the Victorian Alps is as follows:

- at each site a number of permanent line transects of at least 10 m long are established
- along each transect a pin is placed vertically into the vegetation at 20 cm intervals, and the number of times each species contacts the pin is recorded
- overlapping cover for each species is then estimated according to the number of times it was recorded as a proportion of total number of points
- ground cover at the base of the pin (generally litter or bare ground) is also recorded, as this provides an indication of susceptibility to erosion (Durham 1959, Williams *et al.* 1997).

Studies of grazing exclosures in the Australian high country have also included more detailed measurements such as biomass/standing crop (an important measure of available feed and combustible fuel loads, e.g. Wimbush & Costin 1979, Leigh *et al.* 1987), plant height (Gibson & Kirkpatrick 1989), seedling establishment (Williams & Ashton 1987), scat density to indicate grazing pressure (Leigh *et al.* 1987, Gibson & Kirkpatrick 1989), and soil properties including moisture, bulk density and organic matter (Carr & Turner 1959, Wimbush & Costin 1979).

Permanent photo points have also been used to assess vegetation changes. Wimbush and Costin (1979) and Rogers (1991) used stereo pairs of colour photographs to assess changes in top cover of vegetation resulting from exclusion of livestock and feral horse grazing. Photo points were established to record recovery after culling of feral horses in the ACT (D. Fletcher, ACT Parks and Conservation, pers comm.) Photo points are also likely to be a valuable tool for assessing gross effects such as recovery of tracks and wallows, and for illustrating major vegetation effects.

**Proposed Feral Horse Exclusion Project**

*Aims*

1. To compare the effects of removal of grazing with continued grazing by feral horses on:

    a. Floristic composition and structure of favoured grazing areas (grasslands)
    b. Streambank condition

2. To monitor recovery of soils and vegetation on tracks, camps, pugged areas and wallows

*Proposed Methods*

We propose:

1. a replicated exclosure experiment to assess effects of grazing on floristic composition of intensively grazed sites
2. a replicated exclosure experiment to assess impacts on stream bank and bed condition, and
3. an unreplicated set of photopoint monitoring points to qualitatively record recovery of wallows and trackways.

*Sites*: The experiment will be conducted at two grassland sites, previously selected by the Australian Alps Liaison Committee and Friends of the Cobberas, at Cowombat Flat and Native Cat Flat. These sites are not currently grazed by cattle (although they have been historically).

*Experimental plots*: At each site, eight plots will be established in pair-wise fashion (4 replicate pairs) either side of a small stream line (see Fig. 1). Each plot will measure 10m x 10m. Plots will be sited so that each is relatively uniform, both plots of the pair (either side of the creek) are visually similar, and both are dominated by grazed grassland (shrubby or heathy vegetation and areas under tree canopy will not be included). Plots will be adjacent to the streamline but beyond the zone of direct riparian influence.

At each pair of plots, one of the pair will be randomly assigned to one of two treatments i.e. fenced to exclude horses but not other grazers (rabbits, wombats, macropods), and unfenced so that grazing is unrestricted. In addition, the fence for each fenced plot will extend over the creekline to the far edge of the riparian zone. Fences around the fenced plots will be located at least 1 m outside the edge of the plot boundaries, to reduce edge effects and to allow space for any future destructive sampling such as biomass or soil samples.

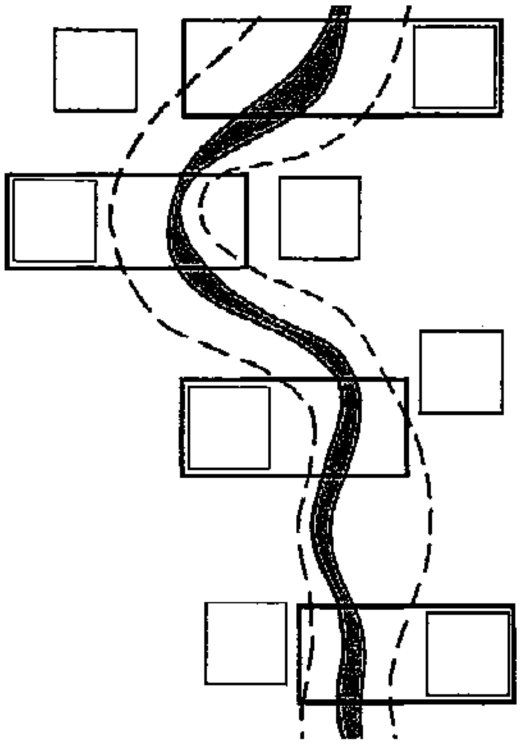

Fig. 1. Layout of experimental plots along a small streamline. Squares are monitoring plots, bold lines are fences, the dashed line is the limit of direct riparian (streamside) influence.

Fences will be constructed using treated pine or steel posts with corner assemblies and 3 or 4 plain wire strands. Wires may be fixed so that there is enough space below the bottom wire (or between the bottom and second wires) for unrestricted access by wombats and rabbits. It may be possible (on advice from a fencing contractor) to leave one end assembly unwired to allow access to wallabies.

Unfenced plots and the boundaries of the plots within fences will be permanently marked using steel star posts.

In addition to the above paired plots, at each site an adjacent larger area (up to 1ha) should be fenced, sited to include several wallows and trackways. Recovery of these will be monitored qualitatively, using permanent photopoints. There will be no formal replication or controls for these.

*Replication*: Vegetation at the two sites (Native Cat Flat and Cowombat Flat) is different. This precludes replication across the sites – all replication will be internal, and the two sites will be considered independent experiments. Each experiment will thus have four replicates and three degrees of freedom. While greater replication would be statistically desirable, it would greatly increase the work involved in establishment and monitoring. Important effects on vegetation should still be detectable with four replicates.

*Monitoring*

a. Vegetation plots.

Two types of monitoring will be used for the vegetation plots. An initial monitoring (1999) will record all species present in each plot, together with visual (Braun-Blanquet) estimates of cover and point-quadrat cover estimates using 100 evenly spread, non-permanent points (5 mm diameter pin) and presence/absence scores for species at points. This monitoring may be repeated after several years have elapsed, once significant differences are qualitatively observable. Analyses can then compare treatments at year x, using year 0 (1999) to factor out initial differences where appropriate.

Annual monitoring will need to be simpler than the initial and year x monitoring, since funds are not available for full annual floristic monitoring. We recommend that annual monitoring, conducted by members of the Friends of the Cobberas group and/or staff of DNRE, should begin in 1999 and visually estimate the following in each plot:

1. Average height of grass cover
2. Proportion of bare ground
3. Cover (%) of
    a. pooled grasses
    b. pooled forbs
    c. pooled shrubs
    d. Yorkshire Fog (*Holcus lanatus*)
    e. pooled clovers and medics (*Trifolium spp., Medicago spp.*)
    f. cats ear (*Hypochoeris radicata*)
    g. any other species that initial or subsequent observation suggests is changing significantly

In addition, permanent photopoints will be established at one corner of each plot, for annual photographic recording.

b. Streambank plots

The design of the experimental plots creates a paired series of fenced and unfenced streambank segments. Initially, positions of stream banks at five paired points along each segment will be marked permanently using steel posts, and the width of the stream channel, nature of the bank (vegetated, bare, undercut etc) and depth of the stream at the midline between each pair measured. These measurements will be repeated annually.

c. Wallows and trackways

One or more wallows and sections of trackway will be permanently marked in the larger exclosure at each site. Permanent photopoints will be established at each site, to record recovery of these features after exclosure.

*Data analysis*

A number of techniques may be used to explore and analyze the experimental data, including analysis of variance, analysis of covariance and ordination.

Analysis of variance (randomized complete block design with four replicate blocks) will be appropriate to assess the statistical significance of experimental effects on individual attributes measured for each plot for any given year. Attributes may include derived attributes such as native and introduced species richness and abundance, abundance of different species groups (e.g. tall herbs, rosetted herbs, unpalatable grasses), and direct abundance estimates of individual species that appear to change markedly. Attribute measures may require transformation (e.g. square root, $\log_{10}$, arcsin) before analysis, depending on the distribution of variance in the data set for each attribute. As discussed above, separate analysis of data from each of the two sites is likely to be most appropriate, with subjective comparison of results from each site.

If necessary, depending on any differences between plots found in the first year's monitoring, initial variation in attributes may be factored out using analysis of covariance.

Floristic data, when collected, may be analyzed using the exploratory technique of ordination. This technique arranges sites in two or more dimensions according to their floristic similarity, and correlations of this arrangement with external variables such as grazing level are then possible. While not allowing precise statements as with analysis of variance, an understanding of trends in floristic data, and species responsible for these trends, is best obtained by this method. Non-metric multi-dimensional scaling (Kruskal 1964 a & b) using the Bray-Curtis measure for calculating distance between plots, is a well accepted method for such analyses. These procedures are available in a number of commercial computer packages, including DECODA (Minchin 1989) and PATN (Belbin 1988).

Photographs from permanent photopoints should be compared visually each year to allow subjective assessment of recovery from grazing.

*Potential Limitations*

The following limitations may need to be considered when interpreting data from the proposed experiments:

1. Landscape scale effects that might occur if feral horses are excluded from the entire region, such as changes in hydrology and changes to populations of other grazers, will not occur under the conditions of the experiment.

2. Unusually high levels of grazing by other herbivores may occur on the exclosed plots, leading to a smaller effect than might be expected if horses were controlled over a larger area. Comparison with adjoining larger exclosures established for monitoring of wallows and trackways should help to determine the magnitude of this problem.

3. The ecosystem may already be modified by past sheep and cattle grazing.

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