National Rabbit Calicivirus Monitoring and Surveillance Program

Monitoring the impacts of reduced rabbit numbers due to Rabbit Calicivirus Disease on native fauna and vegetation in the Nullarbor Region, Western Australia.

Final report prepared by Department of Conservation and Land Management (WA) to the Management Committee of the Rabbit Calicivirus Monitoring and Surveillance Program

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SUMMARY

The impacts of any change in rabbit numbers due to Rabbit Calicivirus Disease on native fauna, feral predators and vegetation was monitored at two sites in the Nuallrbor Region, Western Australia. One site was situated in the Plumridge Lakes Nature Reserve in mulga (*Acacia anuera*) / western myall (*Acacia papyrocarpa*) woodland (PL sub-site) and one in the Great Victoria Desert Nature Reserve in chenopod shrubland (GVD sub-site). Monitoring began on the sites in March 1997, after RCD was detected at Eucla on the WA/ SA border in May 1996. The large number of inactive warrens compared to active warrens plus anecdotal evidence indicates a large reduction of rabbits on the sites in the recent past. On the GVD site this reduction was almost certainly the result of RCD. One outbreak of RCD occurred on the GVD site during the course of the monitoring program and caused a reduction in rabbits of about 50%.

Most fluctuations recorded in small vertebrates could be attributable to seasonal conditions. Feral predators, and large native herbivores remained low throughout the study and the percentage cover and diversity of vegetation showed some fluctuations, but again these were likely related to seasonal factors.

The most significant impact of a reduction in rabbit numbers was the successful establishment and subsequent recruitment of western myall seedlings. The present grazing regime resulting from a reduction in rabbits through RCD may be at a level to allow the continued successful recruitment of seedlings and hence the survival of the population in the long term.

1. INTRODUCTION

The environmental and economic impact of the European rabbit (*Oryctolagus cuniculus*) in Australia has been well documented (Williams *et al.* 1995 and references therein). Rabbit Calicivirus (RCV) is a naturally occurring virus, affecting only the European rabbit and causing an acute and fatal infectious disease. In September 1991 the virus was imported into Australia and trials commenced to determine the effects on native species at CSIRO's Australian Animal Health Laboratory. In October 1995 the virus escaped from quarantine field trials on Wardang Island South Australia, possibly with the aid of windborne vectors (Cooke 1996). It was not possible to control or eradicate the natural spread of the virus, and by December 1995 the virus was established in SA NSW and Queensland. RCD was accepted as a biological control agent under the Commonwealth *Biological Control Act* in September 1996, with the aim of reducing rabbit numbers to improve the integrated control of environmental and economic damage caused by rabbits. As the impact of Rabbit Calicivirus Disease (RCD) is yet unknown it is crucial to monitor the effectiveness of RCD and the ecological consequences of a reduction in rabbit numbers through the disease. These tasks are being undertaken by the National RCD Monitoring and Surveillence Program. The program consists of 54 broadscale sub-sites and 10 intensive sub-sites across Australia. This report documents the assessment of the impact of changes in rabbit numbers through RCD on biodiversity at two intensive sub-sites in the Nullarbor Region of Western Australia.

Rabbits first arrived in Eucla on the Nullarbor in 1894 and by the 1940's were so common as to support a commercial rabbit trade. Since then numbers have fluctuated with seasonal conditions and were reduced dramatically with the arrival of myxomotosis in 1954. However, numbers have increased since then, and in the 1980's, on the northern part of the treeless plain, they again supported a commercial trade (McKenzie and Robertson 1987).

The impacts of rabbits on the biodiversity of arid and semi-arid areas are numerous. Their foraging can: 1) suppress the regeneration by grazing of seedlings of arid zone perennial shrubs and trees such as the Acacias, *Acacia papyrocarp* (see below), *A. burkittii* and *A. oswaldii* (Crisp and Lange 1976; Lange and Graham 1983; Woodell 1990; Auld 1995). 2) decrease palatable and increase unpalatable herbs and grasses and thus change vegetation community structure and species composition, and 3) eliminate ground cover and hence increase run-off and erosion. Rabbits have both indirect and direct effects on native fauna. They directly effect native fauna through competition for shelter and food plants and indirectly through the maintenance of a food base for feral predator populations. This is thought to be particularly relevant to 'critical weight range' (CWR; 35 g to 5.5 kg) mammals. These CWR mammals are now extinct in the Nullarbor region (e.g. *Bettongia leseur*), and this is hypothesised to be the result of habitat change and loss of refugia in droughts and/or secondary predation by foxes whose primary prey are rabbits (Morton 1990, Pech and Hood, 1998). However, quantitative data on the density of rabbits at which biodiversity is adversely affect is sparse (Armstrong 1998).

Western myall (Acacia papyrocarpa)

Western myall (*Acacia papyrocarpa*) is a dominant tree of parts of the Nullarbor, Nyanga and Carlisle Plains of the Nullarbor Region (Eucla Botanical District, within the Eramaean Botanical Province) (Beard 1975). It is a long-lived tree that does not resprout and therefore is reliant on regeneration from seed alone (Ireland 1992). Seedling establishment occurs vary rarely and it has been suggested that successful germination and subsequent recruitment of seedlings requires specific conditions consisting of the co-occurrence of rare episodic events (Ireland 1992). In any plant population some recruitment is necessary to replace individuals that die in order to maintain a stable population. Examination of age/size structures of populations indicate that there are conspicuous age structure gaps, indicating periods of poor or non-existent recruitment (Crisp and Lange 1976, Chesterfied and Parsons 1985, Auld 1990). Exclosure experiments which selectively exclude certain herbivores have identified the rabbit as the primary agent of mortality of seedlings. Grazing pressure by the rabbit alone, even at densities as low as 0.5/ha, has been demonstrated to have a significant detrimental effect on successful seedling recruitment of *A. papyrocarpa* (Lange and Graham 1985).

On the initial visit to the sites, seedlings of western myall were observed, indicating a recent successful germination event. This provided an opportunity to study the effects of rabbit grazing on western myall seedlings.

Aims

The aims of this study were to monitor i) the incidence of RCD in rabbit populations ii) any changes in rabbit numbers resulting from RCD and, commensurate with these changes, to monitor changes in the i) abundance and diversity of small vertebrate species, ii) numbers of large native herbivores iii) numbers of feral predators, iv) abundance and diversity of vegetation and v) the fate of western myall seedlings under differing grazing exclosure treatments.

2. MATERIALS AND METHODS

2.1 Sub-site locations and descriptions

The study comprised two sub-sites, both within conservation reserves and corresponding to two sub-sites used in a biogeographical survey of the Nullarbor Region by a joint Western Australian and South Australian team in 1984 (McKenzie and Robinson 1987) (Figure 1). Sampling commenced in March 1997 and continued at 4 monthly intervals until April 1999.

1. Plumridge (PL) (125.17 E, 29.69 S, 198m)

This sub-site is located within the Plumridge Lakes Nature Reserve. It consists of two major community types; 1) woodland dominated by *Acacia papyrocarpa* (Western

Myall) with a bluebush (*Maireana sedifolia*) understorey (Figure 2a) and woodland dominated by *Acacia anuera* (Mulga) with a mixed understorey (Figure 2b).

2. Great Victoria Desert (GVD) (127.73 E, 30.02 S, 235m)

This sub-site is located at the southern fringe of the Great Victoria Desert Nature Reserve and at the northern edge of the 'treeless plain'. It consists predominantly of chenopod shrubland. Here perennial chenopods are interspersed with various herbs and grasses such as *Austrodanthonia caespitosa*, *Enneapogan* spp. and *Austrostipa* spp.(Figure 3a). Ridges are dominated by *Acacia papyrocarpa* (Figure 3b), and small depressions (dongas) consist of open woodland of trees such as *Acacia aneura, Myoporum platycarpum* and *Pittosporum phylliraeoides* (Figure 3c).

The climate of the Nullarbor Region is arid non-seasonal with an annual precipitation of 150-200mm.

2.2 Sampling design

Five 2 km x 2 km quadrats were set up by McKenzie and Robinson (1984) at each sub-site corresponding to the main plant sub-communities. Small vertebrate and vegetation sampling was carried out within each of these quadrats, centred on a line transect (vehicle track), 21 km long at the PL sub-site and 25 km long at the GVD sub-site.

2.3 Rabbit abundance

Rabbit numbers were estimated every four months by three methods :

i) Spotlighting was carried out over two consecutive nights at each sampling period. The spotlight route covered the length of the vehicle transect. The observer held the spotlight from a vehicle roof hatch. Vehicle speed was constant at 15-20 kms / hr and the same observer was used when possible.

ii) Active warren entrance counts were conducted on all warrens within 50 m either side of the vehicle transect at the PL sub-site (61 warrens), and 50 selected warrens along the vehicle transect at the GVD sub-site. All warrens present within 50m either side of the transect were scored for the number of active and inactive entrances. Criteria used to indicate an active entrance included fresh or recent disturbance of soil, fresh or recent dung at the entrance, or actual sighting of a rabbit. The total number of active entrances was used as a relative index of rabbit abundance. From June 1998, the number of warrens with fresh diggings was also recorded.

iii) Dung counts were conducted within fifty 3.6 m^2 plots. These were the same as the vegetation sampling plots described below (section 2.8). The plots were initially cleared of all dung and the number of pellets accumulated over a four month period were counted and removed from the plot.

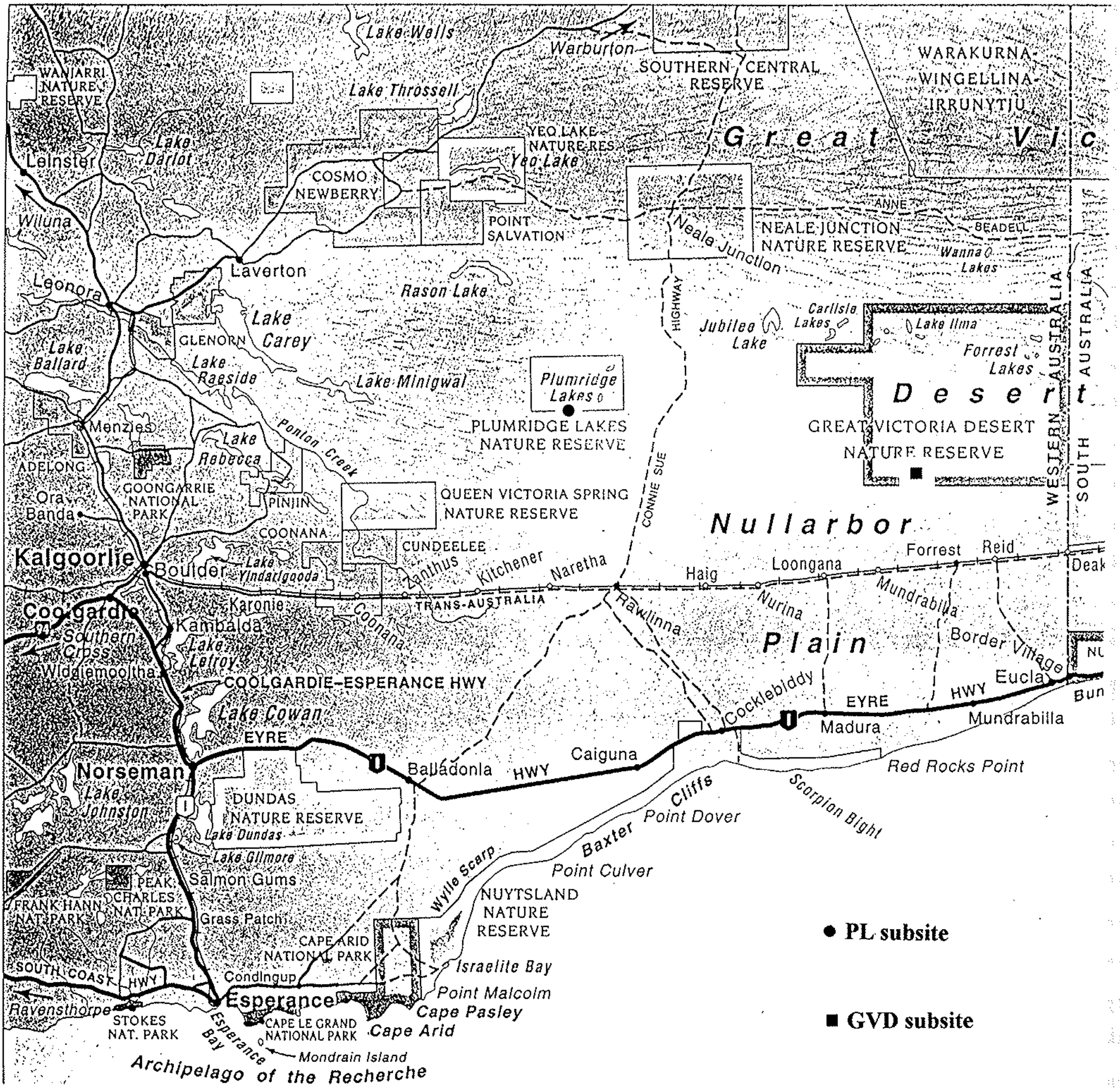

Figure 1: The location of the two subsites on the Nullarbor

a)

b)

Figure 2: The two dominant vegetation communities at the PL sub-site. a) Western myall (*Acacia papyrocarpa*) woodland with bluebush (*Maireana sedifolia*) understorey. b) Mulga (*Acacia annuera*) woodland with mixed understorey.

a)

b)

c)

Figure 3: The three dominant vegetation communities at the GVD sub-site. a) Chenopod shrubland, b) Western myall (*Acacia papyrocarpa*) on ridges and c) mixed woodland in depression.

2.4 Age structure and reproductive status of rabbits and epidemiology of RCD

1. Rabbit Shot Samples

A sample of 20 shot rabbits (when possible) were taken every four months to collect basic biological and epidemiological information (eye lens removed to estimate age structure of population; weight, sex, breeding condition, number of foetuses, kidney fat score, body condition, clinical symptoms of myxomatosis, and presence of fleas). Blood samples were taken and tested for rabbit calicivirus antibodies (competition ELISA) and myxoma virus antibodies (indirect ELISA). Although an attempt was made to obtain 20 samples per sampling period, this was not always possible; shooting was not always successful due to bad weather, rabbit behaviour, or simply low numbers.

2. Rabbit Mark Recapture

Cage traps baited with carrots were used to live-capture rabbits. All rabbits caught were individually marked. Weight, sex, reproductive condition, evidence of myxomatosis, and the number of fleas were recorded. Blood samples were also taken from live rabbits by cardiac puncture an tested as above.

2.5 Feral Predators

All foxes (*Vulpes vulpes*), cats (*Felis catus*) and dingoes (*Canis lupis dingo*) seen in the rabbit spotlight transect were recorded.

2.6 Small Vertebrate Fauna

Each of the 2 km x 2 km quadrats contained 2 or 3 50m fenced pitfall trap lines, at varying distances apart. These pitfall trap lines comprised 6 pits (approximately 60 cm deep) at 10 m intervals along a continuous drift fence. These pit trap lines were set up by McKenzie and Robinson (1987) and were re-opened and used to measure the diversity and abundance of small vertebrates at the sub-sites. There was a total of 12 pitfall trap lines at the PL sub-site and 11 pitfall trap lines at the GVD sub-site. Ten Elliott traps were also placed at 10 m intervals adjacent to each pitfall trap line. The pit and Elliott traps were opened for four consecutive nights every four months, from June 1997 to October 1998. All small mammals, reptiles, amphibians caught were recorded.

Analysis

Correlation analysis was performed to test if the diversity or abundance of small vertebrate species was significantly correlated with i) rainfall in the previous 4 months to the sample ii) rabbit numbers assessed by spotlight counts and iii) number of active warren entrances.

2.7 Large Native Herbivores

All Western grey kangaroo (*Macropus fuliginosis*) and red kangaroo (*Macropus rufus*) seen in the rabbit spotlight transect were recorded.

2.8 Vegetation

1. Herbs, grasses and small perennial shrubs

The species composition, abundance and height of herbaceous plants, grasses and small perennial shrubs were recorded within 3.6 m^2 circular plots. There were fifty plots at each sub-site; 2 on each pit trapline and the remaining placed along the transect, stratified into the 2 km x 2 km quadrats.

Species composition and abundance was scored by laying a dropper from a peg in the centre of the plot to a point on the search area perimeter nearest the transect to ensure random selection of the line direction *vis a vis* vegetation in the plot. The outer point was marked with a wire peg so that the count could be repeated. All plants that contacted or crossed above the dropper, were recorded, and identified where possible. This was repeated at 90°, 180°, 270° to the first line each perimeter point marked with a wire peg . The number of individual plants of each species coming in contact with the dropper was recorded. Abundance was expressed as the number of crosses recorded.

The average height of each species in the whole plot was assessed using the size classes; <5cm; 6-10 cm; 11-20cm; 21-30cm >30cm .The presence of any plant species not intersected by the dropper was also recorded and given an abundance score: 1-5 plants, 6-10 plants, > 10 plants.

Analysis

Both alpha diversity (average number of species per plot) and beta diversity (total number species recorded) were calculated. Correlation analysis was performed to test if the diversity or abundance of plant species was significantly correlated with i) rainfall in the previous 4 months to the sample ii) rabbit numbers assessed by spotlight counts or iii) number of active warren entrances. Correlation analysis was also performed after categorising plant species into floristic groups and life stage groups and correlating each category with the above variables.

2. Western Myall (*Acacia papyrocarpa*)

Population structure:

Ten 100 m^2 quadrats were set up within areas of western myall on the GVD sub-site only. Each individual within the quadrats was assigned to a life stage category as defined by Lange and Purdie (1976) and Ireland (1992) (Figure 4), see below. For

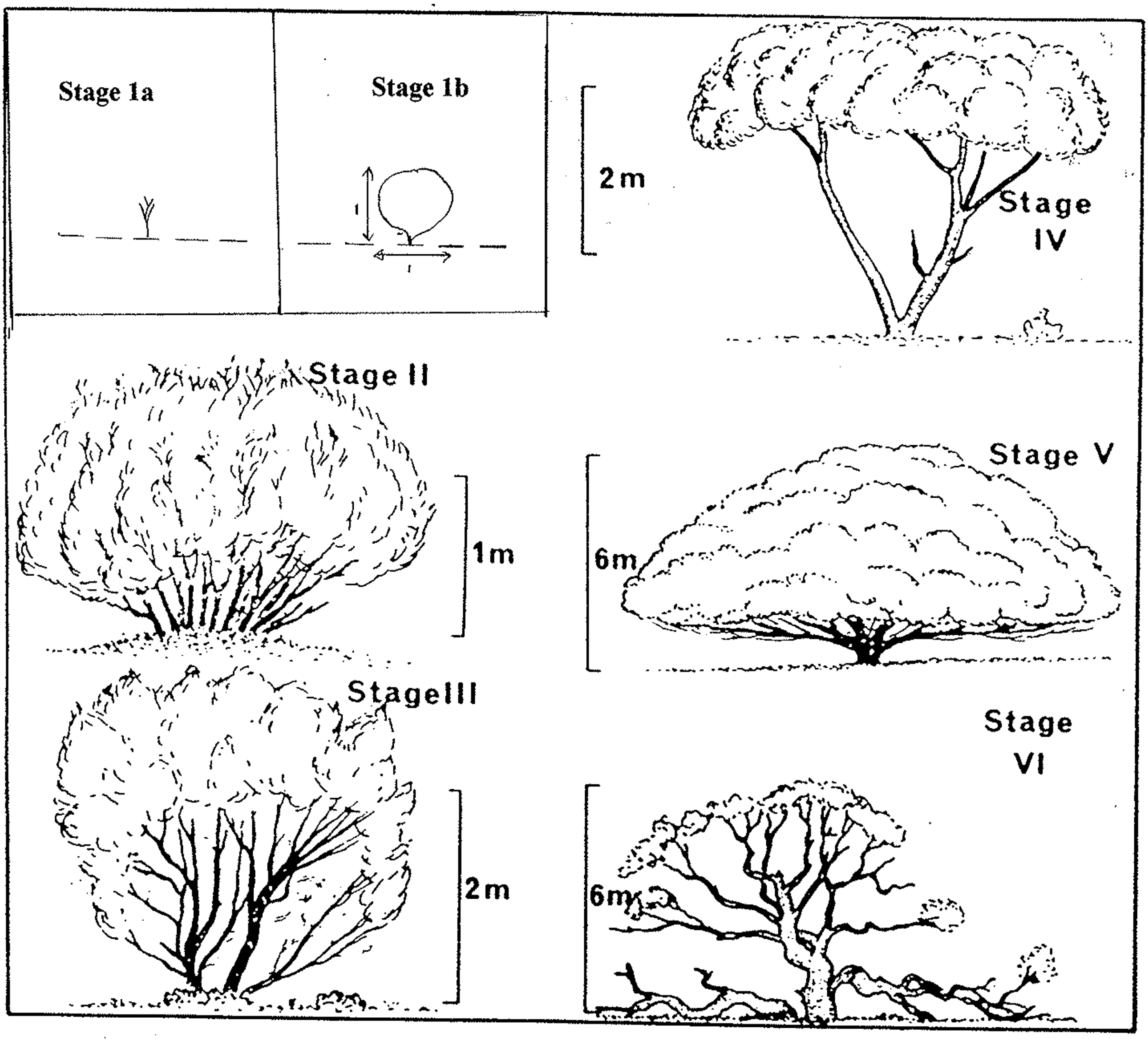

Figure 4: Growth stages of Western myall (*Acacia papyrocarpa*). Stages 1a and 1b are from Ireland (1992). Stage 2-6 are from Lange and Purdie (1976). See text for further explanation.

seedlings, four 10 m^2 quadrats were placed in each corner of the 100m^2 and all seedlings within these were counted and averaged over the four quadrats.

Stages of western myall:

Stage 1a seedling

Stage 1b juvenile – canopy spherical and close to the ground. Ratio of canopy width to height = 1/1.

Stage 2 juvenile – a small thicket of robust stems (their common junction buried under litter and sand), carrying a dense subspherical canopy to about 2-3 m, and clear of the ground.

Stage 3 juvenile – about 4 m high: stems thinned back to about 5 rough-barked trunks hedged in with persistent dead stems, branched to carry a dense subspherical canopy occupying the top half of plant height, but still "bushy" overall.

Stage 4 mature – a tree: stems thinned back to 1 or a few which will persist, free of other stems and foliage in their lower half: branched in the upper half of tree hieght to carry a dense canopy relatively shallower and with more lateral spread than stage 3.

Stage 5 mature – initially 1 or few rough-barked trunks from ground level, branched to carry and elevated parachute canopy; outer limbs reflexing with growth and age so that the canopy viewed in elevation forms a smooth arc down to ground level at its perimeter; finally with outer limbs procumbent at their distal branches.

Stage 6 senescent – as for Stage 5 but main limbs broken out or procumbent – detached, canopy fragmented or sparse.

A Chi-square test was performed on the frequency distribution to determine if the observed distribution differed significantly from a flat distribution (ie. all stages of equal frequency).

Seedling exclosure experiments

To establish whether rabbits were responsible for grazing of western myall seedlings, and at what densities they failed to have a significant impact survival of seedlings, an exclosure experiment was undertaken.

Eighty individual seedlings or juvenile plants at the PL sub-site, and 52 individual seedlings at the GVD sub-site were identified in June 1997 to give 20 and 13 replicates respectively of each of the following treatments.**1: no cage** – seedlings accessible to rabbits and kangaroos (control), **2: rabbit entry cage** - rabbits in, kangaroos excluded, **3: rabbit exclusion cage** - kangaroos in, rabbits excluded, **4: total exclosure** - both kangaroos and rabbits excluded.

The **rabbit entry cage** consisted of a cylinder sheep ring-lock fencing 1.5 m in diameter and 75 cm high with a 15 cm collar dug into the ground to prevent animals digging underneath the cage. It was assumed that the mesh was large enough for rabbits to fit through but not kangaroos and was tall enough and wide enough to prevent kangaroos from reaching the seedling (Figure 5a)

The **rabbit exclusion cage** consisted of a square of rabbit proof fencing with 47 cm long sides and a height of 40 cm. A collar of 20 cm was dug into ground and another of the same dimensions was bent over at the top at a 45^0 downward angle to prevent rabbits from climbing over the top. Kangaroos had easy access over the top of exclosure (Figure 5b)

The **total exclosure** was identical to the rabbit entry cage but was made rabbit proof fencing. Rabbits, therefore, could not fit through the mesh and the mesh was tall enough and wide enough to prevent kangaroos from reaching the seedling (Figure 5c)

Multi-stemmed myall plants with new growth re-shooting from large basal stem were assumed to have been grazed in the past. Single-stemmed seedlings, or juvenile plants with multi stems and no re-shooting, were presumed to be ungrazed.

Initially each seedling was measured for maximum height, mean canopy spread (or length of longest phyllode for single-stem seedlings), maximum stem diameter, basal stem diameter (multi-stemmed seedlings only) and evidence of past grazing. These measurements were carried out a further five times at four monthly intervals, as well as noting any new grazing by herbivorous mammals.

3. RESULTS AND DISCUSSION

3.1 Rabbit abundance

History of rabbit numbers on the Nullarbor

Rabbit numbers have fluctuated widely on the Nullarbor since their arrival in the 1890's as a result of rainfall and myxomotosis. They had reached plague proportions before myxomotosis reduced numbers dramatically in the 1950's, and by 1966 no rabbits were observed in one transverse of the Nullarbor (Figure 6, Beard 1975). Brooker (1977) documents changes in rabbit numbers from 1968 to 1976 in the area around Rawlinna. Rabbit numbers were very low from 1969 to 1971, probably due to drought conditions. They then steadily increased and reached plague proportions again during 1975 due to three consecutive years of above average rainfall. Numbers then declined dramatically from February 1976, but there was no signs of myxomotosis associated with this decline. After the detection of RCD at Eucla, near the SA border, in May 1996, rabbit numbers declined by about 90% of pre-RCD numbers in some areas (Garry Gray pers. com.). Many residents of the Nullarbor observed many rabbit deaths and vast reductions in rabbit numbers in the months that followed the initial detection of RCD. Residents from some areas estimate a reduction from 10-50 / km to 1-10 / km, or from "thick" to "extremely scarce".

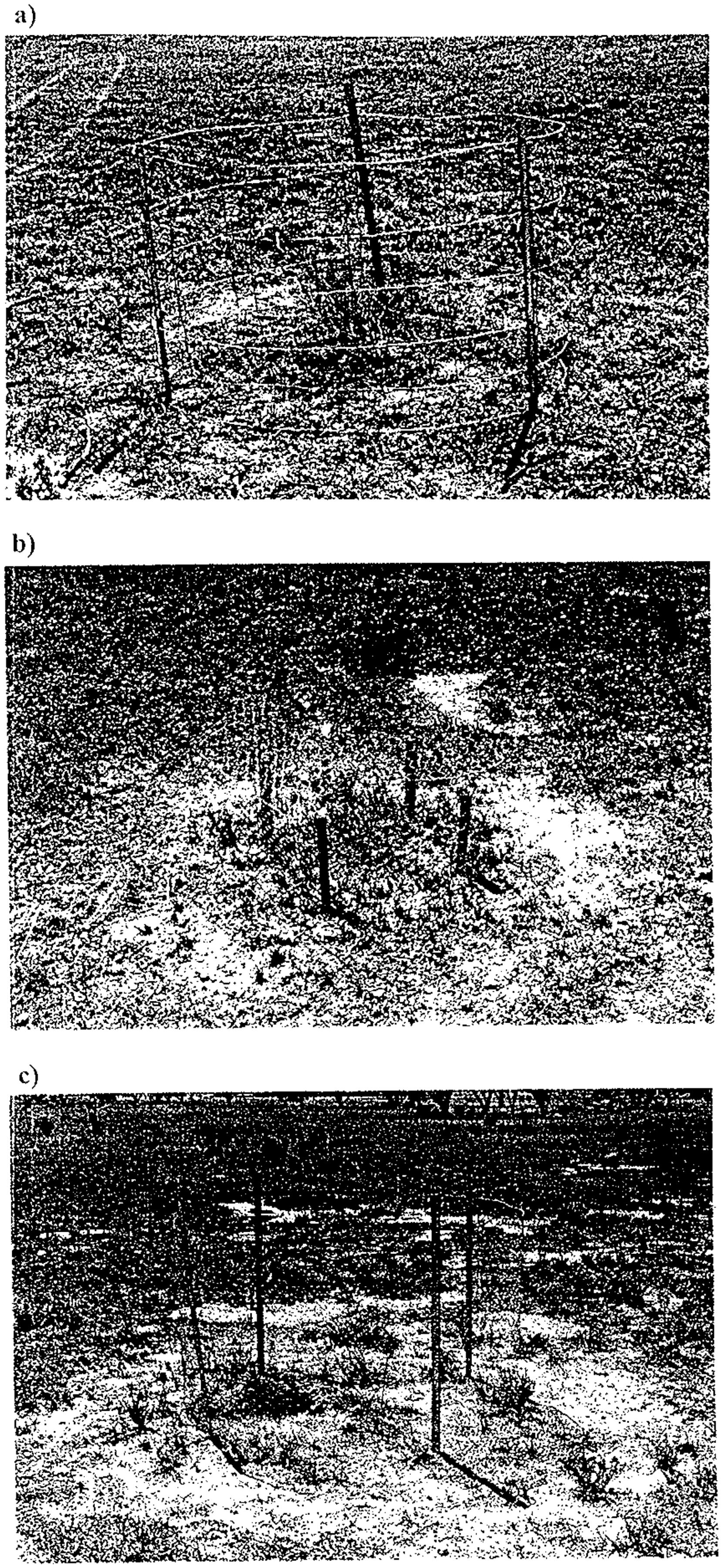

Figure 5: Seedling exclosures. a) rabbit entry cage, b) rabbit exclusion cage and c) total exclusion (rabbits and kangaroos).

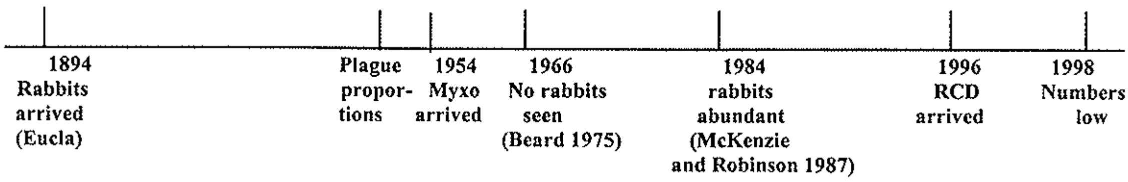

Figure 6 : Some estimates of rabbit abundance from various sources in the Nullarbor Region since their arrival in 1894

At both sub-sites on the initial visit in March 1997 large numbers of rabbit skeletons were observed, and warrens contained many inactive entrances which appeared to be recently active, indicating a recent large reduction in rabbit numbers.

PL sub-site

i) spotlight counts

Rabbits were observed in the spotlight transects at the PL sub-site in only one sampling period (June 1998;Table 1), but there was some indirect evidence of rabbit activity ie. fresh dung and fresh diggings on the sub-site in June and October 1998. In these months there was also evidence of recent activity in an area approximately 1 km north of the sub-site on the edge of a salt lake system.

Table 1: Rabbit density estimates via three methods for the PL sub-site. N/S = not sampled

Method	March 1997	June 1997	October 1997	February 1998	June 1998	October 1998	April 1999
spotlighting	0 / km	0 / km	0 / km	0 / km	0.05 / km	0 / km	0 / km
total number active (inactive) warren entrances in 61 warrens	N/S	0 (268)	0 (264)	0 (67)	11 (232)	0 (174)	8 (133)
% of warrens with fresh diggings	N/S	N/S	N/S	N/S	1.6	0.0	5.0
dung pellet counts	N/S	Plots cleared	0.3 / ha	0.3 / ha	0.3 / ha	0.3 / ha	N/S

ii) warren entrance counts
Active entrances were present only in June 1998 and April 1999. The high number of inactive entrances compared to the number of active entrances indicates that rabbit numbers have been high on this sub-site previously but have reduced to almost zero at present. The low number of inactive entrances recorded in February 1998 was likely due to observer differences.

iii) dung counts
Rabbit density estimates using dung counts remained below 0.5 / ha. However, the low numbers of dung pellets counted in this study is at or near the *y*-intercept in the regression used to estimate rabbit density by dung counts (Wood 1988). Therefore, density estimates via dung counts may be inaccurate at this level and fail to detect any changes. Dung counts will include some that have blown or washed into the plot, therefore, even though rabbit may not be present, this method will indicate a low density.

GVD sub-site

i) spotlight counts
Estimates of rabbit numbers by spotlight counts on the GVD sub-site remained below 2.0 / km, until March 1999 when numbers more than doubled this value.

ii) warren entrance counts
The high number of inactive entrances compared to the number of active entrances indicates that rabbit numbers have been high on this sub-site previously but have reduced considerably at some time in the recent past. The number of active warren entrance counts increased significantly in June 1998 compared to the previous sampling period. However, although all 50 warrens examined at the GVD sub-site were considered recently active, only 23 (46%) showed evidence of fresh diggings indicating that rabbit numbers had recently dropped. This was supported by estimates via spotlight counts, which decreased by approximately half from February 1998 to June 1998 (Table 2). In October 1998, numbers of active warren entrances decreased, however 42 out of 50 warrens (84%) had fresh diggings, indicating a possible increase in numbers from June 1998. This is supported by the increase in numbers observed in spotlight counts. In March 1999 the number of active entrances were similar to June 1998 values, however the spotlight count had increased 7 fold over this period. There were 46 warrens out of 50 (92%) that had fresh diggings in March 1999 compared with 46% in June 1998. This suggests that, in arid areas the percentage of warrens with fresh diggings may give a more accurate assessment of rabbit abundance than the number of active entrances. The observation that individual rabbits use more than one warren (pers. obs.) supports this suggestion.

iii) dung counts
Rabbit density estimates using dung counts remained below 1.0 / ha and are subject to the same error as stated above for PL sub-site dung counts.

Table 2: Rabbit density estimates via three methods for the GVD sub-site. N/S = Not sampled

Method	March 1997	June 1997	October 1997	February 1998	June 1998	October 1998	March 1999
spotlighting	0.5 / km	0.7/km	1.7 / km	1.2 / km	0.56/km	1.18 / km	4.2 / km
total number of active warren entrances in 50 warrens	N/S	133 (1370)	167 (1275)	235 (994)	386 (710)	277 (741)	391 (608)
% of warrens with fresh diggings	N/S	N/S	N/S	N/S	46	84	92
dung pellet counts	Plots cleared	0.6 / ha	0.3 / ha	0.4 / ha	0.3 / ha	0.3 / ha	NS

3.2 Rabbit age structure and reproductive status

In arid populations rabbits have an endogenous reproductive cycle, however rainfall largely determines reproductive rate and juvenile survival and hence numbers. The age structure of the population alternates between being dominated by old rabbits during prolonged droughts to being dominated by young animals during periods of rapid population increase (Williams *et al.* 1995). There was no above average rainfalls recorded during the study period (Table 3, figure 7) and therefore large increases in rabbit numbers through a subsequent high reproductive rate and juvenile survival would not be expected.

PL sub-site

The low sample size of shot and live-captured rabbits at this sub-site makes any conclusions about age-structure and reproductive status of the populations impossible.

GVD sub-site

The number of pregnant females recorded was low on this sub-site, but lactating females were more numerous (Table 4), and young animals were recorded in all sampling periods except June 1997 (low sample size) and June 1998 (Figures 8 and 9).

Table 3: Rainfall recorded at each sub-site over 4 monthly periods

	Rainfall (mm)	
	GVD sub-site	PL sub-site
June - Oct 1997	48	49
Oct 1997 -Feb 1998	49	104.5
Feb - June 1998	77.75	70.5
June-Oct 1998	44	49
Oct 1998 – March 1999	49	155

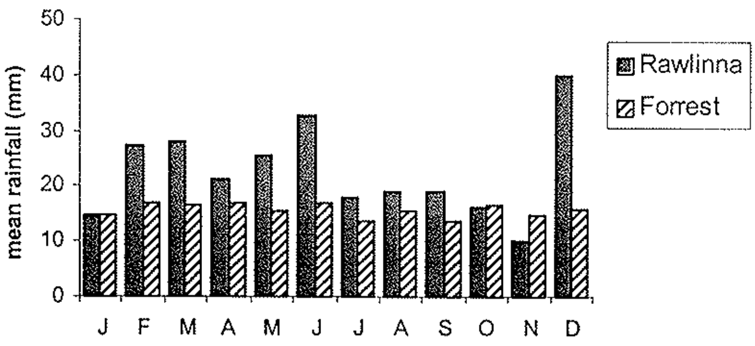

Figure 7: Mean monthly rainfall for the closest recording stations to the PL sub-site (Rawlinna) and the GVD sub-site (Forrest)

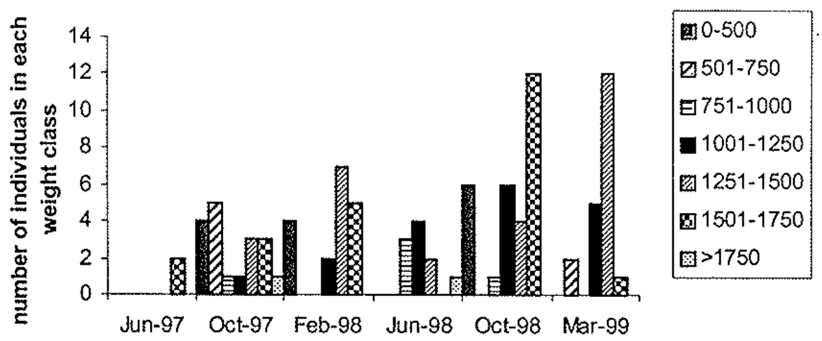

Figure 8: Number of rabbits live-caught or shot in 7 weight classes. GVD sub-site

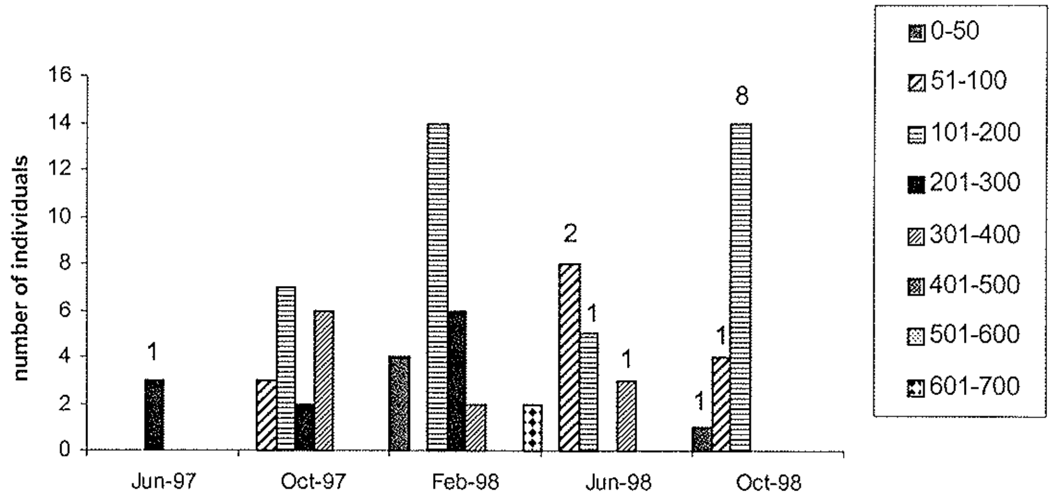

Figure 9: Number of rabbits in each age category (days) based on eye-lens weights. GVD sub-site. Number of rabbits testing sero-positive for RCD in each age category are also shown.

Table 4: Numbers of females in each reproductive category in each month of sampling. GVD sub-site. Shot samples only. L= Lactating, NL = Not lactating, P = Pregnant, NP = Not pregnant.

	NP, NL	NP, L	P, NL	P, L
June '97			1	1
Oct '97	3			2
Feb '98	4	5	2	
Jun '98	2	2		
Oct '98	2	7		1
Mar '99	7	1		1

3.3 Epidemiology of RCD

PL sub-site

Due to the very low numbers of rabbits at this sub-site, no blood samples were obtained until October 1998. Four samples for this month all tested negative for RCD and myxoma virus. It is therefore inconclusive from blood samples as to whether RCD has occurred on this sub-site.

GVD sub-site

At the start of sampling the assessment of the epidemiological status of this population was hindered by low sample numbers (Figure 10). In October 1997 and February 1998 a large percentage of the population was sero-negative and therefore highly susceptible to RCD infection. In June 1998 greater than 50% of blood samples tested were sero-positive for RCD. In addition, the following observations strongly suggest that a very recent outbreak of RCD had occurred on the GVD sub-site:

- 5 rabbit carcasses, all of a similar state of decay (estimated at no more than 2 weeks old), were found on top of 5 separate warrens, close to entrances. This equates to 10% of the warrens examined.
- The numbers of rabbits observed in spotlight counts in June 1998 was about half that observed in February 1998.
- The estimated time of rabbit deaths likely corresponded to a rainfall event, which may have increased vector activity.
- Flies of two species (*Chrysomia varipes* and *Chrysomia rufifacies)* collected off the carcass of dead rabbits tested sero-positive for rabbit calicivirus, using reverse transcriptase polymerase chain reaction (RT-PCR) analyses.

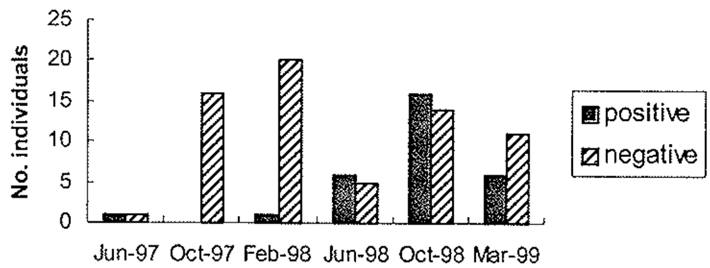

Figure 10: Number of rabbits per month testing sero-positive and sero- negative for RCD on the GVD sub-site.

From shot samples it was possible to relate age (via eye-lens weight) and serological status of rabbits. It has been shown that a large percent of rabbits less than 8 weeks (56 days) old that are challenged with RCD survive the infection and become immune for life. Also, progeny of adult rabbits that have been exposed to the virus and survived, are temporarily protected from RCD (up until about 8-11 weeks) by antibodies acquired from their mothers (maternal immunity). (Cooke 1996)

Of the 15 rabbits that tested sero-positive for RCD antibodies, 2 were < 50 days old, and therefore may have had maternal antibodies only. The greatest number of sero-positive animals were 100-200 days old in October 1998. These animals were probably young (< 8 weeks) when RCD was suspected to have gone through the population in June 1998, and hence not susceptible and therefore survived and became immune.

There was a high percentage of animals testing sero-positive for the myxoma virus on the GVD sub-site throughout the period of sampling (Figure 11). There was no signifcant correlation between the number of rabbits testing sero-positive for myxomotosis antibodies and sero-positive for RCD antibodies (r = -0.12, df = 4, $P >$ .05).

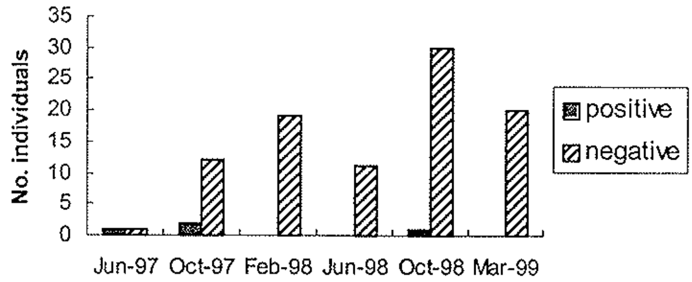

Figure 11: Number of rabbits per month testing sero-positive and sero-negative for Myxoma virus on the GVD sub-site.

3.4 Feral predators

Rabbits are the primary prey of foxes (Catling 1988) and cats (Catling 1988, Martin *et al.* 1996) in many parts of Australia where rabbits are common. Dingoes also prey on rabbits, although the importance of rabbits in their diet varies greatly (Newsome *et al.* 1983). It is expected that a sustained reduction in rabbits would cause a decline in the abundance of foxes and cats, after an initial increase with increased supply of carcases (feast effect) (Pech and Hood 1998).

Fox numbers fluctuate on the Nullarbor, probably in response to rabbit numbers. In early 1969 foxes were numerous and rabbit numbers were high. By August 1969 foxes had declined and rabbit numbers were already low but in September 1976 foxes were numerous despite low rabbit numbers (Brooker 1977).

PL and GVD sub-sites

On the first RCD monitoring trip, March 1997, soon after RCD had passed through, several fox and cat skeletal remains were found.

Fox numbers were extremely low throughout the sampling period. Only one fox was sighted at the PL sub-site, in April 1999 (in 21 km). On the GVD sub-site only two foxes were sighted (in 25 km) in October 1997 and March 1999, one in October 1998, and two in March 1999. There has been indirect evidence of the presence of feral predators (fresh tracks, calls) at both sub-sites on all trips. No cats or dingoes were observed.

It appears that feral predators have reduced on the sites in response to a reduction in rabbit numbers.

3.5 Small Vertebrate Fauna

In addition to rabbits as their primary prey, foxes and cats have been shown to prey on a large variety of native species (eg. western quoll (*Dasyurus geoffroii*), numbat (*Myrmecobius fasciatus*) and Nullarbor quail-thrush (*Cinclosoma cinnamomeum*); Saunders *et al.* 1995 and references therein). When foxes are removed from an area the number of native species have been shown to increase (eg. *Petrogale lateralis*, Kinnear *et al.* 1988). It is expected that an initial reduction in these native prey species may occur as foxes and cats switch to other prey, but then a reduction in feral predators may see and increase in native species preyed upon by them (Pech and Hood 1998). Therefore, by reducing the primary prey of foxes, RCD has the potential to improve the conservation prospects of native prey species.

PL sub-site

Overall, 5 species of mammal, 28 species of reptiles and 1 species of amphibian were recorded at the PL sub-site (Appendix 1).Comparisons in the diversity and abundance of small vertebrates can be made with pre-RCD data at this sub-site provided by McKenzie and Robertson (1987) (Table 5).

i) Mammals

Mammals other than *Mus musculus* occurred in very low abundance. *Mus musculus* comprised 89% of the individuals caught over the period of the study (Figure 12), and increased in abundance over this time. All mammal species were recorded previously on this sub-site by McKenzie and Robinson (1987), however, two species, *Ningaui ridei* and *Sminthopsis dolichura*, recorded by McKenzie and Robinson (1987), were not recorded in this study (Table 5).

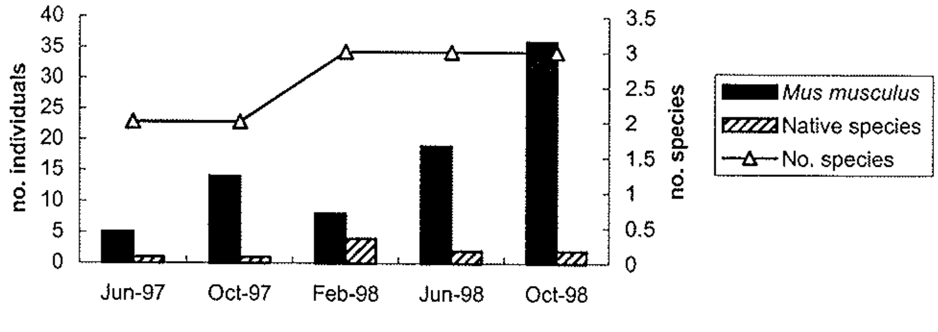

Figure 12: Abundance and diversity of small mammals (PL sub-site).

i) Reptiles

Reptile diversity and abundance fluctuated greatly, most likely as a result of seasonal temperature fluctuations (Figure 13). The total number of species recorded was greater than the number recorded by McKenzie and Robinson (1987), however, not all species recorded by McKenzie and Robinson (1987) were recorded in this study. This is likely due to the fact that McKenzie and Robinson (1997) did not sample in summer, a time when we caught the largest number of reptiles, both individuals and species.

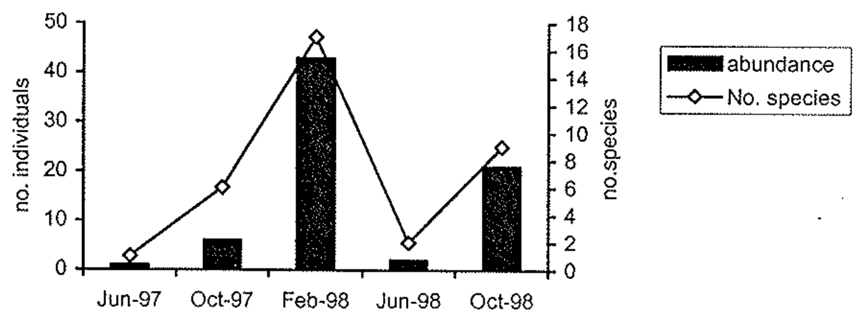

Figure 13: Abundance and diversity of reptiles (PL subsite).

ii) Amphibians

One species of frog (*Neobatrachus kunapalari*) was recorded (Appendix 1). No amphibians were recorded on this sub-site by McKenzie and Robinson (1987). This species was only described in 1986 (Mahoney and Roberts 1986) and previous to this was misidentified as *N. centralis*. *Neobatrachus kunapalari* has been recorded on this sub-site previously as *N. centralis* (Burbidge *et al.* 1976).

Correlation of faunal species diversity and abundance with rainfall and rabbit numbers

Due to the very low rabbit numbers on this sub-site, only 'rainfall in the previous 4 months' was used as a variable in the correlation analyses. In addition, due to the very low diversity of mammals, only the abundance of mammals was used, and, due to their low abundance, amphibians were excluded from the analyses.

There was no significant correlations of either the abundance of mammals, the diversity of reptiles or the abundance of reptiles with 'rainfall in the previous 4 months'.

Table 5: Comparison of the number of faunal species recorded in this study and that by McKenzie and Robinson (1987), PL sub-site.

	Mammals	Reptiles	Amphibians
No. species recorded			
This study	5	28	1
McKenzie and Robertson (1987)	7	21	0
No. different species			
This study	0	9	1
McKenzie and Robertson (1987)	1	7	0

GVD sub-site

Overall, 4 species of mammals and 14 species of reptiles were recorded at the GVD sub-site (Appendix 2). No amphibians were recorded. Again, comparisons in the diversity and abundance of small vertebrates can be made with pre-RCD data at this sub-site provided by McKenzie and Robertson (1987) (Table 6).

i) Mammals

Mammals showed an increase in abundance over the period of sampling, however, 84% of individuals caught were *Mus musculus,* and the large increase in abundance observed in October 1998 comprised 86 % *Mus musculus* individuals.

Two species of *Peudomys* (*P. hermansburgensis* and *P. bolami*) were caught for the first time in October 1998 (Appendix 2). These species were not recorded previously on this site by McKenzie and Robinson (1987), nor are there any previous records from the area. *Pseudomys hermansburgensis* has a wide distribution over much of central and western Australia, and is restricted to sandhill country associated with spinifex and loamy soil with mulga scrub (Breed 1995). This latter vegetation type is found in depressions of the GVD sub-site, but the one animal recorded was caught in open chenopod grassland. Little is known of the ecology of *P. bolami* other than it is usually found on loamy to clay soils in sparse mallee or acacia woodland with scattered dwarf shrubs (Watts 1995). No such vegetation type occurs on the GVD sub-site, the one animal recorded was also caught in open chenopod grassland.

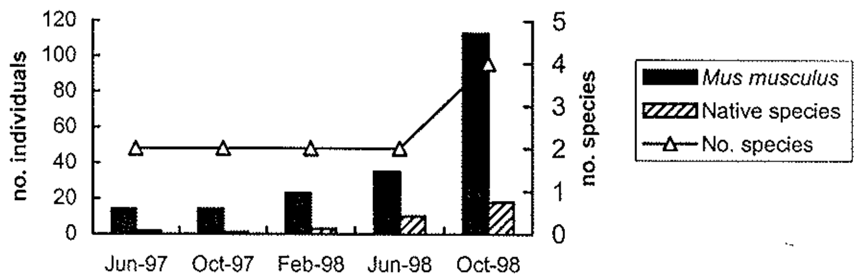

Figure 14: Abundance and diversity of mammals (GVD sub-site).

ii) Reptiles

Diversity and abundance (Figure 15) fluctuated widely, again likely in response to seasonal temperature fluctuations; numbers caught were near zero in the winter months. Eight species of reptiles recorded in this study that were not recorded by McKenzie and Robinson (1987) (Table 6). Again, this is likely due to the differing time of sampling in the two studies.

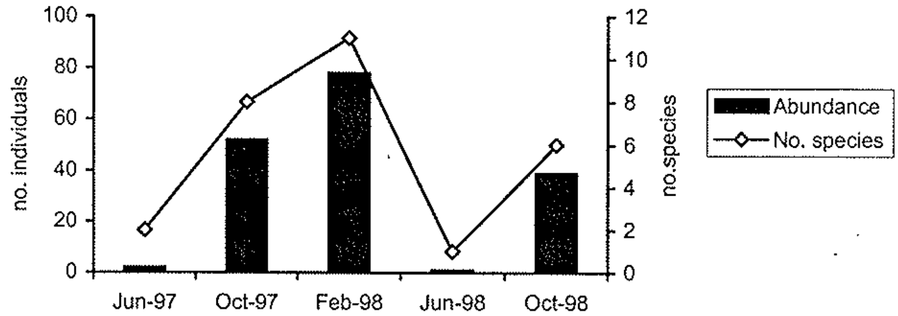

Figure 15 : Abundance and diversity of reptiles (GVD sub-site)

Correlation of faunal species diversity and abundance with rainfall and rabbit numbers

Due to the very low diversity of mammals, only the abundance of mammals was used as a variable in the correlation analyses.

There was no significant correlation of either the abundance of mammals, the diversity of reptiles or the abundance of reptiles with rainfall in the previous 4 months, number of rabbits per kilometre or number of active warren entrance counts.

Table 6: Comparison of the number of faunal species recorded in this study and that by McKenzie and Robinson (1987), GVD sub-site.

	Mammals	Reptiles	Amphibians
No. species recorded			
This study	4	14	0
McKenzie and Robertson (1987)	2	10	0
No. different species			
This study	2	8	0
McKenzie and Robertson (1987)	0	4	0

3.5 Large Native Herbivores

PL and GVD sub-sites

Any reduction in the abundance of rabbits will directly affect other herbivores (primarily red and grey kangaroos in arid areas), through competition for food. The response in herbivore numbers will be expected to be long term because there will be a lag in the vegetation response. Release form grazing competition from rabbits may lead to increase in numbers of kangaroos such that the total grazing pressure remains relatively unchanged. This may still be beneficial for sheep production as kangaroos mainly compete with sheep only for the less nutritious perennial grasses (Wilson 1991a and b in Williams), but the effect on biodiversity will likely be as detrimental.

Numbers of large herbivores were very low at both sub-sites, with no measurable increase. Only one western grey kangaroo (*Macropus fuliginosis*) was sighted along the 21 km spotlight transect at the PL sub-site in October 1997, and none were sighted in February and June 1998. No red kangaroos (*Macropus rufus*) have been sighted at the PL sub-site. Numbers of both western grey kangaroos and red kangaroos observed spotlighting on the GVD sub-site were 0.28 / km in June 1997 and 0.0 / km in October 1997, February 1998, June 1998 and October 1998. In March 1999 red kangaroo numbers were 0.1 / km and grey kangaroos 0.0 / km.

It would appear that, to date, large native herbivores have not increased substantially on the sites, and that therefore, total grazing pressure has reduced.

3.6 Vegetation

1. Herbs, grasses and small perennial shrubs

PL sub-site

Both the total and average diversity of plants was fairly constant over the period of sampling (Figure 16); there was no significant difference between the average diversity of plants between the first and last sampling period ($t = 1.8$, df = 49, $P > 0.05$).

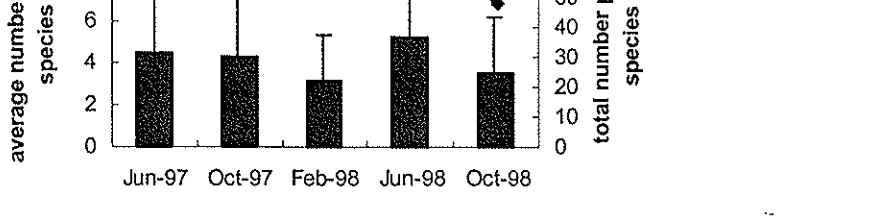

Figure 16: Average (alpha diversity) and total (beta diversity) number of plant species recorded per month (PL sub-site)

The total abundance of plants varied over the sampling period (Figure 17); there was a significant difference in total plant abundance between the first and last sampling period ($t = 2.42$, df = 49, $P < 0.05$).

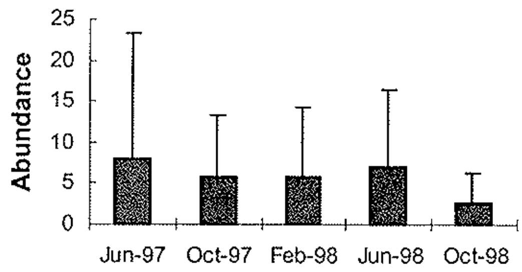

Figure 17: Abundance of all plants per month (PL sub-site). Mean and SD.

These changes in abundance are reflected in changes of particular floristic and life stage groups; there was a significant difference in the abundance of 'other dicots' between the first and last sampling period ($t = 2.41$, df = 49, $P < 0.05$), and in the abundance of seedlings ($t = 2.87$, df = 50, $P < 0.01$). In June 1997, there was early emergence of mainly annual seedlings (Figure 18). By October 1997 most of the annual herbs ('other dicots') had disappeared and ground cover was dominated native perennial grasses such as *Stipa* sp., *Eragrostis* sp. and *Aristida* sp. (Figure 19). Grasses were high in abundance in February 1998 (Figure 19). In June 1998 there were both annual herbs ('other dicots') and native perennial grasses present. There was evidence of grazing of a small percentage of the grasses (mostly *Stipa* sp.). In June 1998, the high abundance of "undetertimed" plants (Figure 19) was due to a high numbers of seedlings which could not be identified (Figure 18). In October 1998, most annual species were dead and vegetation was dominated mostly by grasses and chenopods (Figure 20).

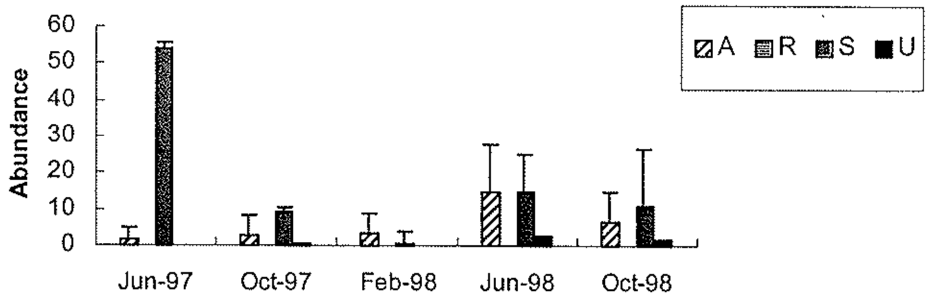

Figure 18: Average abundance per life stage group (PL sub-site). Mean and SD. A = Adult; R = Reshoot; S = Seedling; U = Undetermined

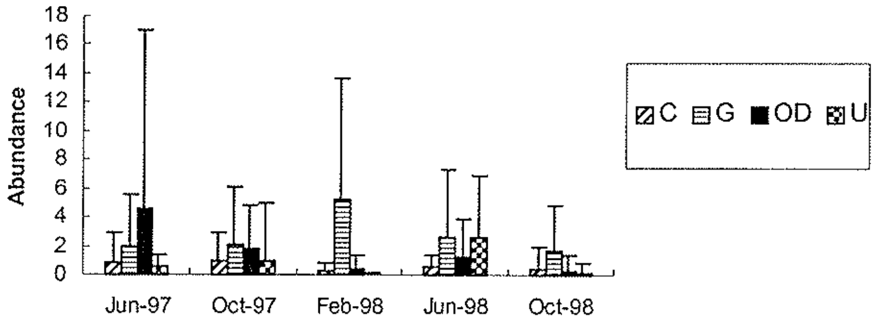

Figure 19: Abundance per floristic group (PL sub-site). Mean and SD. C = Chenopod; G = Grass; OD = Other Dicot; U = Undetermined

Correlations

Due to the very low rabbit numbers on this sub-site, only 'rainfall in the previous 4 months' was used as a variable in the correlation analyses. There was a strong positive correlation between 'rainfall in the previous 4 months' and the abundance of grasses ($r = 0.89$, $P < 0.05$). A large amount of rain (104.5 mm) fell between October 1997 and February 1998 (Table 3) which stimulated grass germination and growth. In arid areas grass germination is stimulated by a combination of rainfall and high summer temperatures (Mott and Groves 1981).

GVD sub-site

Both the total and average diversity of plants increased towards the end of the period of sampling (Figure 20); there was a significant difference in the average diversity of plants between the first and last sampling period ($t = 9.38$, df $= 49$, $P < 0.001$).

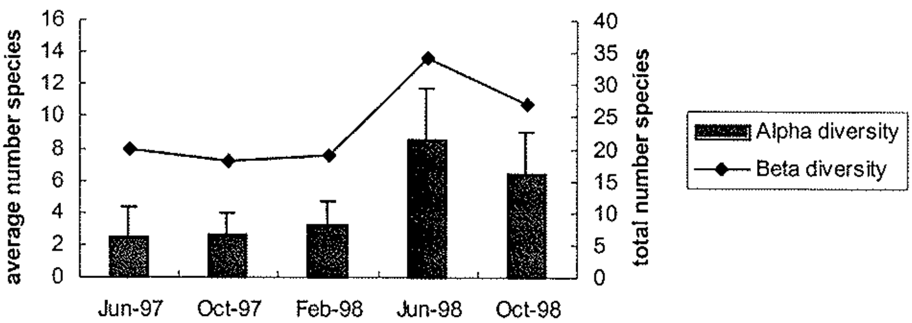

Figure 20: Average (alpha diversity) (mean and SD) and total (beta diversity) number of plant species recorded per month (GVD sub-site)

The total abundance of plants varied over the sampling period (Figure 21), but there was no significant difference in total plant abundance between the first and last sampling period ($t = 1.71$, df = 49, $P < 0.05$). However, when plants were categorised into floristic groups, there was a significant increase in the abundance of 'chenopods' and 'other dicots' between the first and last sampling periods (Figure 22; $t = 4.74$ ('chenopods') and $t = 4.08$ ('other dicots'), df = 49, $P < 0.001$). Wards weed (*Carrichtera annua)* an annual weed was very abundant on this site and therefore was analysed seperately. There was a significant decrease in the abundance of *C. annua* between the first and last sampling periods ($t = 2.53$, df = 49, $P < 0.01$). When plants were catergorised into life stage groups, both adult plants and seedlings showed a significant difference in abundance between the first and last sampling periods (t = 4.76 and 4.29 respectively, df = 49, $P < 0.001$).

Initially (June 1997) there was early emergence of mainly annual seedlings (dominated by wards weed) (Figure 22). By October 1997 most of the annual herbs had disappeared and ground cover was dominated by wards weed and native perennial grasses such as *Stipa* sp., *Eragrostis* sp. and *Aristida* sp. ('grasses', Figure 23). Wards weed was ungrazed as were most of the grasses. In June 1998 there were both annual herbs and native perennial grasses present, and new growth of wards weed, which had been mostly dead in the previous sampling period. There was evidence of grazing of a small percentage of the grasses (mostly *Stipa* sp.). In October 1998, most annual species and wards weed were dead and vegetation was dominated mostly by grasses and chenopods (Figure 23).

Correlations

There was a significant positive correlation of both average (alpha) and total (beta) plant species diversity with number of active warren entrances ($r = 0.91$, $P < 0.05$ for both). It is known that rabbit grazing can change the composition of vegetation communities by decreasing the number of perennial grasses and shrubs and increasing the number of unpalatable species. The correlation was investigated further by correlating the diversity of plants within floristic groups. There was a significant positive correlation of number of active warren entrances with the number of chenopod species ($r = 0.92$, df = 3, $P < 0.05$). As an increase in chenopod species would be expected with a decrease in grazing pressure, clearly this may be the start of a response in vegetation to the large reduction in rabbits through RCD, and the correlation is either an artefact or due to undetermined factors.

There was no significant correlation of total plant abundance with either of the rabbit number estimates or rainfall. However, when plants were categorised into floristic groups, there was a significant positive correlation of 'other dicots' with rainfall in the previous 4 months (r = 0.96, $P < 0.05$). The high value in June 1998 for the 'other dicots' category was comprised of 21% annual herbs from the Asteraceae family. The germination of many species of this family in the arid zone is stimulated mainly by winter rainfall (Mott and Groves 1981).

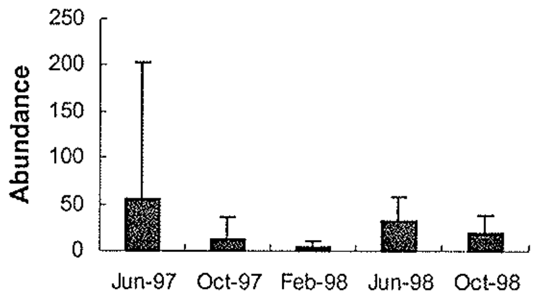

Figure 21: Abundance of all plants (GVD sub-site). Mean and SD

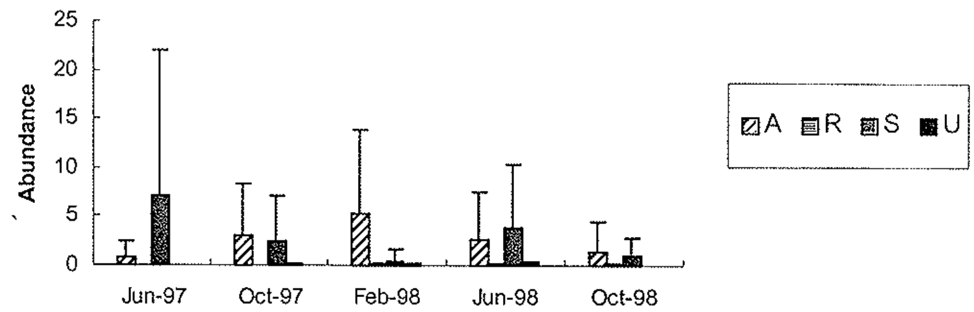

Figure 22: Average abundance per life stage group (GVD sub-site). Mean and SD. A = Adult; R = Reshoot; S = Seedling; U = Undetermined

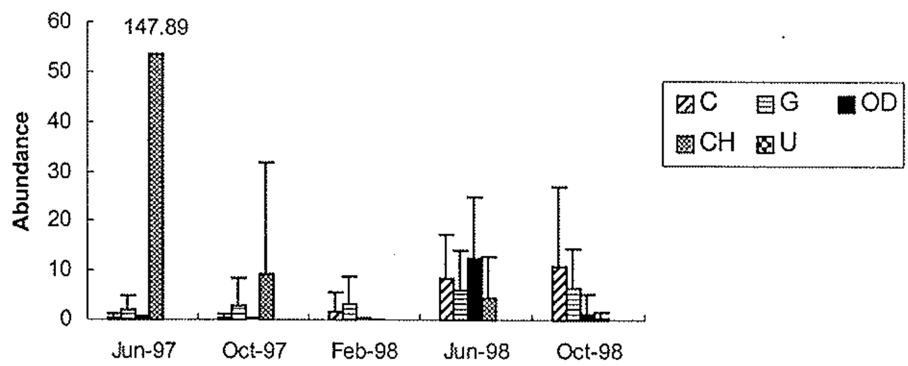

Figure 23: Abundance per floristic group (GVD sub-site). Mean and SD. C = Chenopod; G = Grass; OD = Other Dicot; CH = *Carrichtera annua* (Wards weed); U = Undetermined. For clarity, SD for CH in June 1997 shown as number not bar.

Western Myall (*Acacia papyrocarpa*)

Population structure (GVD sub-site only)

A total of 258 individual myall were sampled and assigned to one of six stages. The frequency distribution (Figure 24) differs significantly from a flat distribution (ie. all stages of equal frequency) ($X^2 = 481.5$, df = 3, $P < 0.001$). There is a complete absence of Stage 2 individuals, and low numbers of Stage 3. Stage 4 plants dominate and seedlings (Stage 1a) and young juveniles (Stage 1b) are present in the population. Lange and Purdie (1976) estimate that Stage 2 corresponds to an age of about 30 years and Stage 3 to about 50 years. Individuals probably take about 75 years to reach Stage 4, and Stage 5 plants can be up to 250 years old. What this frequency distribution illustrates is a gap in the stages of western myall present in the population, such that successful germination and recruitment of individuals has not occurred, or occurred in low numbers, for the last 50 –75 years, and that there has been a recent germination event which has, so far, been successful in recruiting individuals into the population.

Rabbits probably arrived in the area in the 1890's and reached plague proportions before myxomotosis reduced numbers dramatically in the 1950's (Beard 1975). It is possible that; all the Stage 4 plants were recruited before rabbits arrived; the few Stage 3 individuals may have been respite from rabbits through the initial vast reduction by myxo about 40 years ago; and the recent recruitment may be respite from rabbit grazing due to a reduction in numbers caused by RCD.

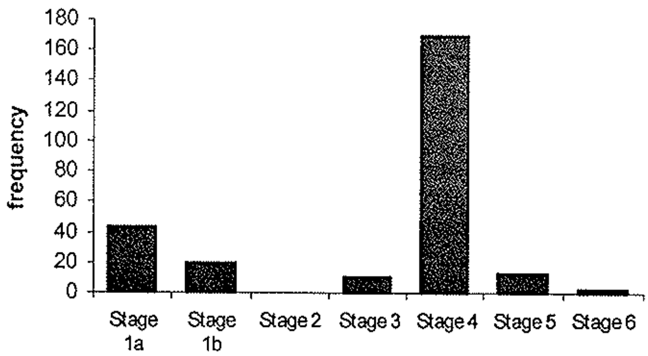

Figure 24: Frequency distribution of stages of western myall *(Acacia papyrocarpa)*, GVD sub-site.

Seedling exclosures

Initially (in June 1997), past grazing was assumed to have occurred in young myall plants that were multi-stemmed with regrowth occurring from a large basal stem. Plants that were single-stemmed were assumed to be ungrazed.

PL sub-site

No seedlings were grazed at the PL sub-site at the completion of the study (Table 9a). There was some mortality of seedlings by other means (trampled or withered) towards the end of the study (Table 10).The average height of seedlings changed little over the period of sampling (Figure 22). There was no significant increase in height in treatment 1 and 2 between the first sampling period (June 1997) and the last (April 1999). (t = 1.80, treatment 1; t = 1.39, treatment 2; t = df = 19, $P > 0.05$ for all). Plants in treatment 3 and 4 increased significantly in height (t = 2.14, df = 17, $P < 0.05$, treatment 3; t = 2.11, df = 19, $P < 0.05$, treatment 4). There was no significant difference in heights between treatment at the end of sampling (April 1999) (F = 1.18, df = 3, p > 0.05).

Table 7: Grazing of western myall (*Acacia papyrocarpa*) plants placed under differing exclosure treatments. PL sub-site.

[1]Treatment	No. replicates	[2]Initial no. (and %) replicates showing evidence of passed grazing	No. (and %) replicates showing evidence of grazing since exclosures were put in place				
			October 1997	February 1998	June 1998	October 1998	April 1999
1	20	20 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2	20	20 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
3	20	19 (95)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
4	20	19 (95)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

[1]**1:** no cage - rabbits and kangaroos present ,**2:** rabbit entry cage - rabbits in, kangaroos excluded, **3:** rabbit exclusion cage - kangaroos in, rabbits excluded, **4:** total exclosure - both kangaroos and rabbits excluded (control).
[2] Multi-stemmed plants with new growth reshooting from a large basal stem. Plants without evidence of passed grazing are single-stemmed seedlings.
[3] This plant was dead and may or may not have been grazed before death.

Table 8: Mortality of *Acacia papyrocarpa* seedlings on the PL sub-site.

Treatment	No. plants	Mortality Eaten	Disappeared	Withered	Buried	Trampled	% dead after 2 years
1	20	0	0	0	0	0	0
2	20	0	0	0	0	1	5
3	20	0	0	1	0	0	5
4	20	0	0	0	0	1	5

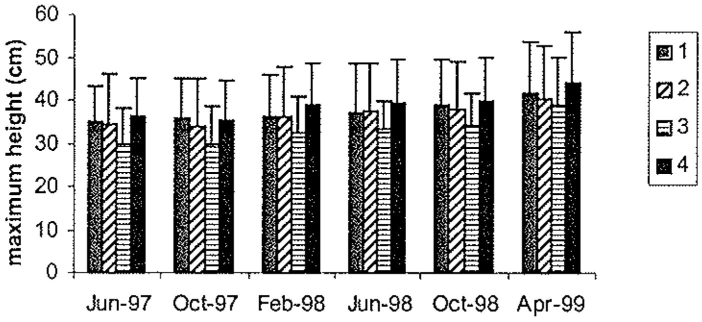

Figure 25: Average height per month of *Acacia papyrocarpa* seedlings on the PL sub-site. 1: no cage - rabbits and kangaroos present ,2: rabbit entry cage - rabbits in, kangaroos excluded, 3: rabbit exclusion cage - kangaroos in, rabbits excluded, 4: total exclosure - both kangaroos and rabbits excluded (control).

GVD sub-site

No grazing of seedlings was observed until eight months after the exclosures were erected (Table 9b). Most (84.6%) deaths occurred as the result of being eaten (Table 7). In February 1998 there was evidence of new grazing in 5 plants (38.5%). Three of these plants were with no exclosure and two were rabbit entry cages, which were exposed to rabbit grazing but excluded kangaroos, indicating that rabbits were the cause of the damage. Two plants were dead and may or may not have been grazed. One of these plants was inside a rabbit only exclosure, however it appeared that an animal had dug under the cage and therefore the plant may have been grazed by a rabbit. The increase in rabbit numbers on the GVD sub-site (determined by active warren entrance counts) in February 1998 may account for this observed grazing. Two of these occurred in exlosures where both rabbits and kangaroos were assumed to be excluded, and therefore could have been grazed by some other herbivore. This increased grazing corresponded to an increase in the number of rabbits observed in spotlight counts form 1.18 / km to 4.2 / km in March 1999 (Table 2). Lange and Graham (1983) found that rabbit grazing had detrimental effect on *A. papyrocarpa* seedlings at 0.5 / ha, which equates approximately to 5.0 / km.

The exclosure experiments, therefore, indicate that it is rabbits that are the prime grazers of the seedlings and that at the level of rabbits on the site (< 5.0 / km) at least a proportion of seedlings are able to escape grazing pressure and survive.

The average height of seedlings changed little over the period of sampling (Figure 23). There was no significant increase in height, in any treatment, between the first sampling period (June 1997) and the last (April 1999). ($P > 0.05$ for all). There was no significant difference in heights between treatments at the end of sampling (April 1999) ($F = 0.79$, $df = 3$, $P > 0.05$).

Table 8: Grazing of western myall (*Acacia papyrocarpa*) plants placed under differing exclosure treatments. GVD sub-site.

[1]Treatment	No. replicates	[2]Initial no. (and %) replicates showing evidence of passed grazing	No. (and %) replicates showing evidence of grazing since exclosures were put in place				
			October '97	February '98	June '98	October '98	March '99
1	13	3 (23.1)	0 (0)	2 (15.4)	3 (23.1)	3 (23.1)	4 (30)
2	13	3 (23.1)	0 (0)	2 (15.4)	2 (15.4)	2 (15.4)	5 (38.5)
3	13	3 (23.1)	0 (0)	[3]1 (7.7)	[3]1 (7.7)	[3]1 (7.7)	[3]1 (7.7)
4	13	3 (23.1)	0 (0)	0 (0)	0 (0)	0 (0)	2 (15.4)

[1]**1**: no cage - rabbits and kangaroos present ,**2**: rabbit entry cage - rabbits in, kangaroos excluded, **3**: rabbit exclusion cage - kangaroos in, rabbits excluded, **4**: total exclosure - both kangaroos and rabbits excluded (control).
[2] Multi-stemmed plants with new growth reshooting from a large basal stem. Plants without evidence of passed grazing are single-stemmed seedlings.
[3] This plant was dead and may or may not have been grazed before death.

Table10: Mortality of *Acacia papyrocarpa* seedlings on the GVD sub-site.

Treatment	No. plants	Mortality Eaten	Disappeared	Withered	Buried	Trampled	% dead after 2 years
1	13	4	0	0	0	0	30.7
2	13	5	0	1	0	0	46.2
3	13	0	0	1	0	0	7.7
4	13	2	0	0	0	0	15.4

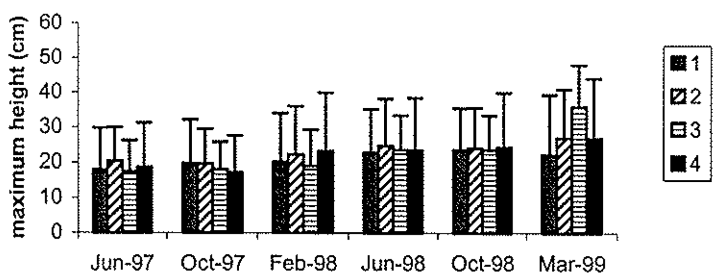

Figure 23: Average height per month of *Acacia papyrocarpa* seedlings on the GVD sub-site. 1: no cage - rabbits and kangaroos present ,2: rabbit entry cage - rabbits in, kangaroos excluded, 3: rabbit exclusion cage - kangaroos in, rabbits excluded, 4: total exclosure - both kangaroos and rabbits excluded (control).

4. CONCLUSION

The evidence presented indicates that rabbit numbers were reduced dramatically on both sub-sites prior to the commencement of sampling. On the GVD sub-site this was almost certainly as a result of RCD. Rabbit numbers remained low throughout period of sampling and one outbreak of RCD was observed on the GVD sub-site, which reduced rabbit numbers by about 50%.

The significant changes observed in some biodiversity measures, eg. an increase in the diversity of plants on the GVD sub-site over the period of sampling, could not be attributed solely to a sustained reduction in rabbits due to the confounding effects of seasonal conditions and the constraints of the short duration of the study, a factor which is particularly limiting for the semi-arid and arid zone sites where pulses in biodiversity are triggered by infrequent rainfall events (Sandell and Start 1999). Nevertheless, the data do provide a good baseline for future work. Whether rabbit numbers increase or continue to be kept at a sustained low level through RCD, the data can be used to compare biodiversity at present with that at a future date.

The most significant and positive impact of a reduction in rabbit numbers was the successful establishment and subsequent recruitment of western myall seedlings. The seedling exclosure experiments indicated that rabbits were the prime grazers of seedlings and a large percentage of seedlings survived under a grazing regime resulting from rabbit numbers of less than 5.0 / km on the GVD sub-site and less than 0.1 / km on the PL sub-site. If RCD maintains rabbit numbers at these levels or lower, successful recruitment of seedlings should continue, ensuring survival of the populations in the long term.

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APPENDIX 1: Faunal species diversity and abundance on the PL sub-site.
Trapping effort = 440 Elliott trapnights and 44 pit fence nights (6x pitfall traps per fence).

Species	June 1997	October 1997	February 1998	June 1998	October 1998
Mammals:					
Pseudomys bolami	1	0	1	0	1
Pseudomys hermansburgensis	0	0	0	0	1
Notomys alexis	0	1	0	1	0
Mus musculus	5	14	8	19	36
Sminthopsis ooldea	0	0	3	1	0
Total abundance	**6**	**15**	**12**	**21**	**38**
Total no. species	**2**	**2**	**3**	**3**	**3**
Reptiles:					
Cryptoblepharus plagiocephalus	0	0	2	0	1
Ctenotus schrombergkii	0	1	1	0	8
C. leonhardii	0	0	1	0	0
Egernia innornata	0	0	8	0	0
Egernia sp.	0	0	0	0	1
Eramiascincus richardsonni	0	0	0	0	1
Lersita bipes	0	0	0	1	1
L. desertorum	0	0	0	1	0
Menetia greyi	1	0	4	0	0
Morethia boulengeri	0	0	1	0	0
Diplodactylus granariensis	0	1	0	0	0
D. damaeus	0	1	0	0	0
D. maini	0	1	0	0	3
Underwoodisaurus milii	0	1	0	0	0
Gehyra variegata	0	0	7	0	0
Heternotia binoei	0	0	1	0	0
Nephrurus levis	0	0	6	0	1
N. sp.	0	0	1	0	0
Rhynochoedura ornata	0	0	2	0	0
Pygopus lepidopodus	0	1	0	0	0
Ctenophorus cristatus	0	0	1	0	0
C. inermis	0	0	1	0	0
C. pictus	0	0	1	0	0
C. sp.	0	0	1	0	0
Varanus gouldii	0	0	3	0	4
Ramphotyphlops sp.	0	0	1	0	0
Simoselaps betholdii	0	0	1	0	0
Vermicella semifasciata	0	0	0	0	1
Total abundance	**1**	**6**	**43**	**2**	**21**
Total no. species	**1**	**6**	**17**	**2**	**9**
Amphibians:					
Neobatrachus kunapalari	0	0	0	2	1
Total abundance	**0**	**0**	**0**	**2**	**1**
Total no. species	**0**	**0**	**0**	**2**	**1**

APPENDIX 2: Faunal species diversity and abundance on the GVD sub-site.
Trapping effort = 440 Elliott trapnights and 44 pit fence nights (6x pitfall traps per fence)

Species	June 1997	October 1997	February 1998	June 1998	October 1998
Mammals:					
Pseudomys hermansburgensis	0	0	0	0	2
Pseudomys bolami	0	0	0	0	2
Sminthopsis crassicaudata	2	1	6	10	14
Mus musculus	14	14	23	35	113
Total abundance	**16**	**15**	**29**	**45**	**131**
Total no. species	**2**	**2**	**2**	**2**	**4**
Reptiles:					
Ctenotus schrombergkii	0	31	12	0	23
Menetia greyii	0	0	5	0	0
Morethia adelaidensis	0	1	3	0	2
Diplodactylus granariensis	0	2	6	0	2
D. mainii	0	0	0	0	1
D. pulcher	0	2	0	0	0
Gehyra variegata	0	0	2	0	0
Rhynchoedura ornata	0	0	2	0	0
Underwoodisaurus milii	1	4	9	0	0
Tympanocryptis lineata	1	8	26	1	10
Aprasia sp.	0	0	2	0	0
Ramphotyphlops waiti	0	3	5	0	0
Ramphotyphlops bituberulatus	0	0	4	0	0
Varanus gouldii	0	1	0	0	1
Total abundance	**2**	**52**	**78**	**1**	**39**
Total no. species	**2**	**8**	**11**	**1**	**6**
Amphibians:	0	0	0	0	0
Total abundance	**0**	**0**	**0**	**0**	**0**
Total no. species	**0**	**0**	**0**	**0**	**0**

APPENDIX 3: Plants identified at the PL sub-site

Oppotunistic / Recorded from plots

Family	Genus	Species	Family	Genus	Species
Amaranthaceae	Ptilotus	?polystachyus	Amaranthacea	Ptilotis	obovatus
	P.	obovatus		P.	gaudichaudii
Asteraceae	Brachyscome	sp.		P.	sp
	Cephalipterum	drummondii	Asclepiadacea	Leichhardtia	australis
	Cratystylis	concephala	Asclepiadacea	Rhyncharrhen	?linearis
	C.	subspinescens	Asteraceae	Actinobole	uliginosum
	Erymophyllum	ramosum ssp.		Angianthus	tomentosus
	E.	ramosum		Brachyscome	?ciliaris
	Leuchochrysu	fitzgibbonii		B.	sp.
	Rodanthe	floribunda		Calotis	multicaulis
Boraginaceae	Halgania	cyaneae var.		Chrysocephal	puteale
Caesalpinaceae	Senna	artemisioides		Podolepis	capillaris
Casurinaceae	Casurina	cristata		Rhodanthe	floribunda
Chenopodiaceae	Atriplex	?vesicaria		Senecio	sp
	A.	vesicaria ssp.		S.	lautus
	Chenopodium	curvispicatum		S.	lautus subsp.
	Einadia	nutans ssp.	?	Schoenia	ayersii
	Enchylaena	tomentosa var.		Vittadinia	eremaea
	Maireana	georgei		V.	nullarborensis
	M.	pyramidata		Waitzia	acuminata var.
	M.	trichoptera	Brassicaceae	Carrichtera	annua
	M.	sp.		Lepidium	rotundum
	Rhagodia	drummondii		Stenopetalum	sp.
Frankeniaceae	Frankenia	puncata	Caesalpinacea	Senna	artemisioides
	F.	setosa		S.	nemophila
Goodeniaceae	Goodenia	occidentalis	Chenopodiace	Atriplex	sp.
	G.	pinnatifida		A.	vesicaria
	Scaevola	spinescens		Enchylaena	tomentosa var.
	Velleia	rosea		Eriochiton	sclerolaenoides
Haloragaceae	Haloragis	trigonocarpa		Maireana	integra
Loranthaceae	Amyema	maidenii		M.	sedifolia
	Lysiana	exopcarpi		M.	sp
Malvaceae	Sida	calyxhymenia		M.	trichoptera
Mimosaceae	Acacia	anuera		Salsola	kali
	A.	burkittii		Sclerolaena	diacantha
	A.	kempeana		S.	obliquicuspis
	A.	nyssophylla	Convulvulacea	?Convolvulus?	?erubescens
	A.	oswaldii	Euphorbiacea	Euphorbia	boophthona
	A.	tetragonophyll	Fabaceae	Clianthus	formosus
Myoporaceae	Eremophila	alternifolia	Geraneaceae	Erodium	crinitum
	E.	clarkei	Goodeniaceae	Goodenia	pinnatifida
	E.	falcata	Malvaceae	Sida	currugata
	E.	georgei		S.	sp.
	E.	latrobei ssp.		S.	?spodochroma
	E.	miniata	Poaceae	Aristida	contorta

	Myoporum	platycarpum		Austrodanthon	sp.
Poaceae	Aristida	contorta		Austrostipa	scabra
	Austrostipa	plumigera		A.	sp
	Eragrostis	dielsii		A.	trichophylla
	E.	eriopoda		Enneapogan	avenaceus
	E.	laniflora		E.	caerulescens
	Eriachne	scleranthoides		E.	cylindricus
	Monachather	paradoxus		E.	sp.
	Neurachne	munroi		Eragrostis	dielsii
	Triraphis	mollis		E.	eriopoda
Santalaceae	Santalum	acuminatum		E.	laniflora
Sapindaceae	Dodonaea	lobulata		Monacanther	paradoxus
Solanaceae	Solanum	ellipticum		Stipa	sp.
	S.	lasiophyllum		Triraphis	mollis
	S.	orbiculatum	Portulacaceae	Calandrinia	calyptrata
Zygophyllaceae	Zygophyllum	iodocarpum	Tetragoniacea	Tetrogonia	eremaea
	Z.	ovatum	Zygophyllacea	Zygophyllum	eremaeum
				Z.	ovatum

APPENDIX 4: Plants identified on the GVD sub-site

Opportunistic / Recorded from plots

Family	Genus	Species	Family	Genus	Species
Asteraceae	*Sonchus	oleraceus	Asteraceae	Angianthus	tomentosus
	?Senecio	sp		Vittadinia	eremaea
	Senecio	lautus		Rhodanthe	floribunda
	Rhodanthe	floribunda	Brassicaceae	Carrichtera	annua
	Vittadinia	?virgata		Lepidium	rotundum
	V.	nullarborensi	Chenopodiaceae	Atriplex	acutibractea
Brassicaceae	Phlegmatosperm	?cochlearinu		Atriplex	sp.
Chenopodiaceae	Atriplex	nummularia		Dissocarpus	paradoxus
	Chenopodium	curvispicatu		Eriochiton	sclerolaenoides
	Dissocarpus	paradoxus		Maireana	sp.
	Enchylaena	tomentosa		Salsola	kali
	Maireana	sedifolia		Sclerolaena	Diacantha
	Sclerolaena	?brevifolia		Sclerolaena	obliquicuspis
Convolvulaceae	Convolvulus?	erubescens?		Sclerolaena	sp
Fabaceae	Cullen	cinereum	Euphorbiaceae	Euphorbia	drummondii
Goodeniaceae	Goodenia	concinna	Fabaceae	Inigofera	australis?
	Goodenia	pinnatifida	Geraneaceae	Erodium	crinitum
Loranthaceae	Amyema	hilliana	Goodeniaceae	Goodenia	pinnatifida
	Amyema	preissii	Malvaceae	Sida	currugata
	Lysiana	exocarpi	Poaceae	Austrodantho	caespitosa
Malvaceae	Lavatera	plebeia		Austrostipa	

	*Malvastrum	americanum		Enneapogan	acenaceus
	Sida	spodochrom		Enneapogan	cylindricus
Mimosaceae	Acacia	annuera		Eragrostis	laniflora
	A.	burkittii (accuminata)	Tetragoniaceae	Tetrogonia	eremaea
	Acacia	oswaldii	Zygophyllaceae	Zygophyllum	ovatum
	A.	papyrocarpa			
	A.	tetragonophy			
Myoporaceae	Eremophila	latrobei ssp.			
	Eremophila	longifolia			
Oxalidaceae	Oxalis	corniculata			
Pittosporaceae	Pittosporum	phylliraeoide s var. microcarpa			
Poaceae	Aristida	contorta			
	Enneapogon	avenaceus			
	Enneapogon	cylindricus			
	Eragrostis	dielsii			
	Eragrostis	?setifolia			
Polygonaceae	Muehlenbeckia	floruleata			
Proteaceae	Grevillia	nematophylla			
Rubiaceae	Marsdinia	australis			
Sapindaceae	Dodonaea	stenozyga			
Solanaceae	Lycium	australe			
	Nicitinana	rotundifolia			
Tetragoniaceae	Tetragonia	eremaea			
Zygophyllaceae	Zygophyllum	idiocarpum			
	Zygophyllum	ovatum			