National Rabbit Calicivirus Monitoring and Surveillance Program

Monitoring the impacts of changed rabbit numbers due to Rabbit Calicivirus Disease on native fauna and vegetation in the Stirling Range, Western Australia.

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

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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 South Stirlings in south-west Western Australia. One site was situated in the Stirling Range National Park and one on a patch of remnant vegetation off the park. Rabbit numbers decreased by about 65% on the remnant vegetation site after the initial outbreak of RCD in September 1996. Monitoring began on the sites in May 1997 and continued until September 1998. Rabbit numbers failed to show a sustained decrease. Most fluctuations recorded in small vertebrates could be attributable to seasonal conditions. Feral predators remained low throughout the study and the percentage cover and diversity of vegetation showed some fluctuations, but again these were related to seasonal factors, and possibly to seasonal variations in pasture availability, which in turn affected the amount of native vegetation grazed by rabbits.

The data collected however, does provide a good baseline for future work. If the virus does re-occur and cause a sustained decrease in rabbit numbers, the data presented here could be used to compare biodiversity under the influence of high and low rabbit numbers.

1. INTRODUCTION

The environmental 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 (M & S) Program. The program consists of work on 54 broadscale sites and 10 intensive sites across Australia. The intensive sites have been set up to closely monitor changes in rabbit populations, epidemiology of the virus, vegetation, native fauna, and predators. This paper documents the assessment of these changes at one intensive site, which was established in the Stirling Range National Park in south-west Western Australia. The site consists of two sub-sites; one located within the National Park and one on remnant vegetation within farmland outside the park (Remnanat Vegetation sub-site). This sub-site was co-located with a RCD M & S Program project carried out by Agriculture WA (AgWA) on the epidemiology of the virus.

Within the Stirling Ranges rabbits occur on the National Park boundary, adjacent to cleared farmland, and throughout remnant patches within surrounding farmland. They utilize the native vegetation for cover and the pasture for feed. In the south west of WA the damage that rabbits cause to crops can be measured in economic terms, however the critical level of unacceptable damage to biodiversty values on conservation reserves and other natural lands is unknown (Armstrong 1998). Control of rabbits on these natural lands is difficult due to inaccessibility, damage caused by harbour and warren destruction, the large size of many reserves and the intensive labour required. For these reasons, RCD may be of great benefit to the control of rabbits on natural lands.

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 (National Park site only; AgWA monitored these parameters on the Remnant Vegetation sub-site) 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 and iv) abundance and diversity of vegetation

2. MATERIALS AND METHODS

2.1 Sub-site locations and descriptions

The two Stirling Range monitoring sub-sites are approximately 80 kilometres north east of Albany, in south-west Western Australia (Figure 1). The average maximum monthly temperature ranges from 15° C in July to 27° C in January, with 460 mm average annual rainfall. About 75% falls between May and October. Soil type is white sand underlain by Cainozoic sediments.

1. National Park sub-site (SRNP sub-site) (118.25° E, 34.51° S, 150m elevation)

The National Park sub-site is a 1 km^2 located on the southern sand plain of the Stirling Range National Park in mallee-heath shrubland vegetation on deep sands (Figure 2a). The mallee-heath vegetation of SRNP compres about 1500 species, predominantly from the Proteceae and Myrtaceae families. This floristically diverse vegetation type has a dense scrub layer to about 1.5 metres with scattered mallee-form eucalypts less than 10 metres tall. At the sub-site the dominant overstorey vegetation is *Eucalyptus decipiens, E. tetragona, Banksia baxteri and Lambertia inermis*. The dense understorey is rich in proteaceous and myrtaceaous species, the more common being *Banksia nutans, Banksia repens, Dryandra plumosa* and *Beaufortia interstans* (Figure 2b). The study site is adjacent to crop/pastural land and is of two fire ages: a long unburnt (+ 40 years) patch directly adjacent to the pasture and a recently burnt (10 years) patch to the east of this. These are separated by a firebreak (Figure 3).

2. Agricultural/Remnant Vegetation sub-site (SRRV sub-site) (118.3°E, 34.5° S, 150m elevation)

The Agricultural/Remnant Vegetation sub-site consists of mallee-heath remnants on sand dunes surrounded by agricultural crops (barley and canola). When not carrying stock, sheep may be grazed in the paddocks. The remnant patch on which sampling was carried out is approximately 1 km wide at its widest and 3 km long, is surrounded by pasture, and dissected by a minor road (Figure 4a). A fence was installed around the remnant patch to exclude sheep. However, the effects of past sheep grazing could not be over-looked. The dominant overstorey species is *E. decipiens* with the dense understorey consisting primarily of proteaceous and myrtaceaous species with *Beaufortia interstans* being the most common (Figure 4b).

On this site, assessment of rabbit, large herbivore and feral predator numbers, and the epidemiology of RCD was carried out by AgWA. The results will be presented fully by AgWA, only preliminary unpublished data relevant to this study is presented here. This report documents changes in rabbit numbers (assessed by dung counts), small vertebrate fauna and vegetation for the Remnant Vegetation sub-site.

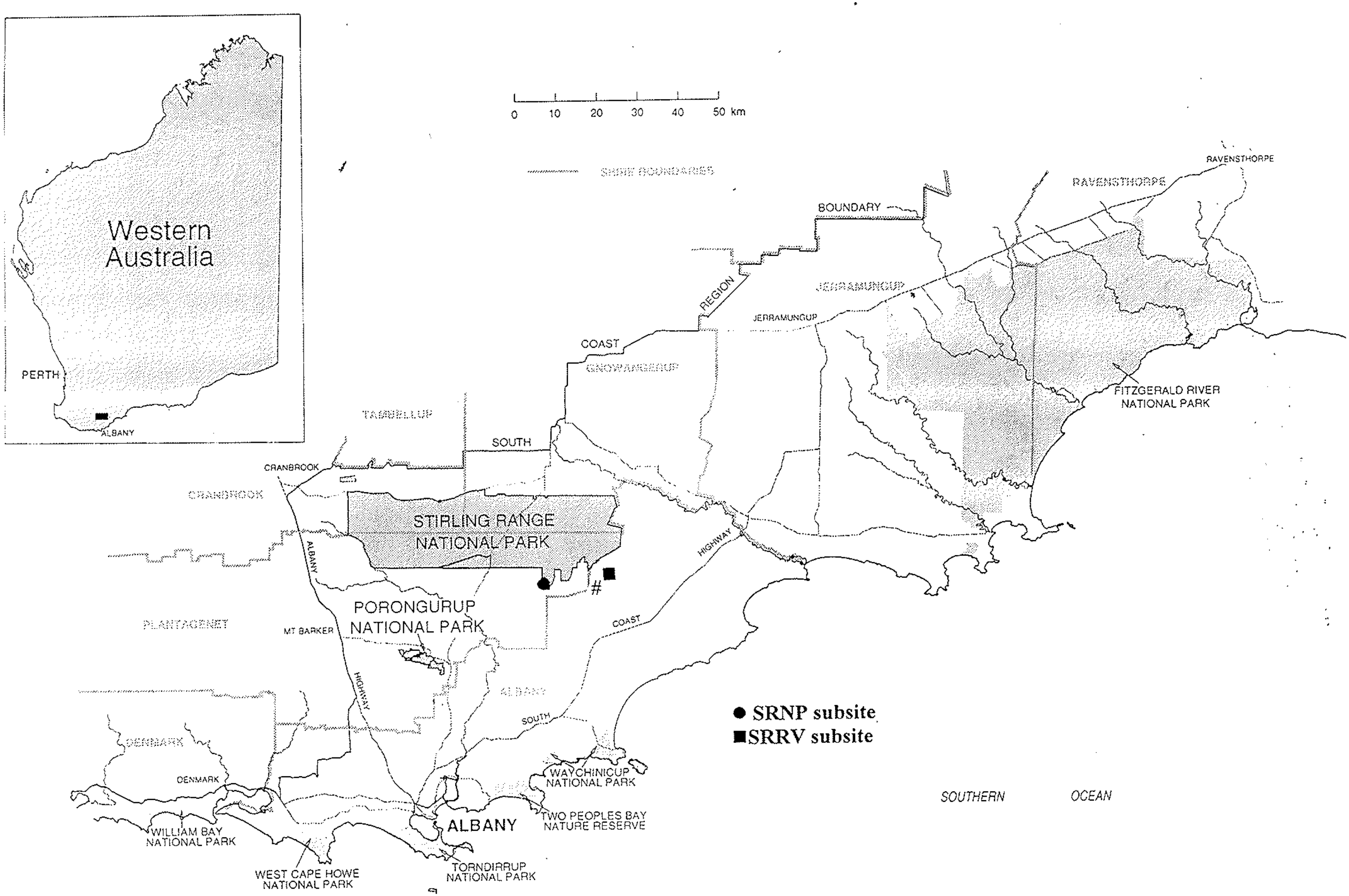
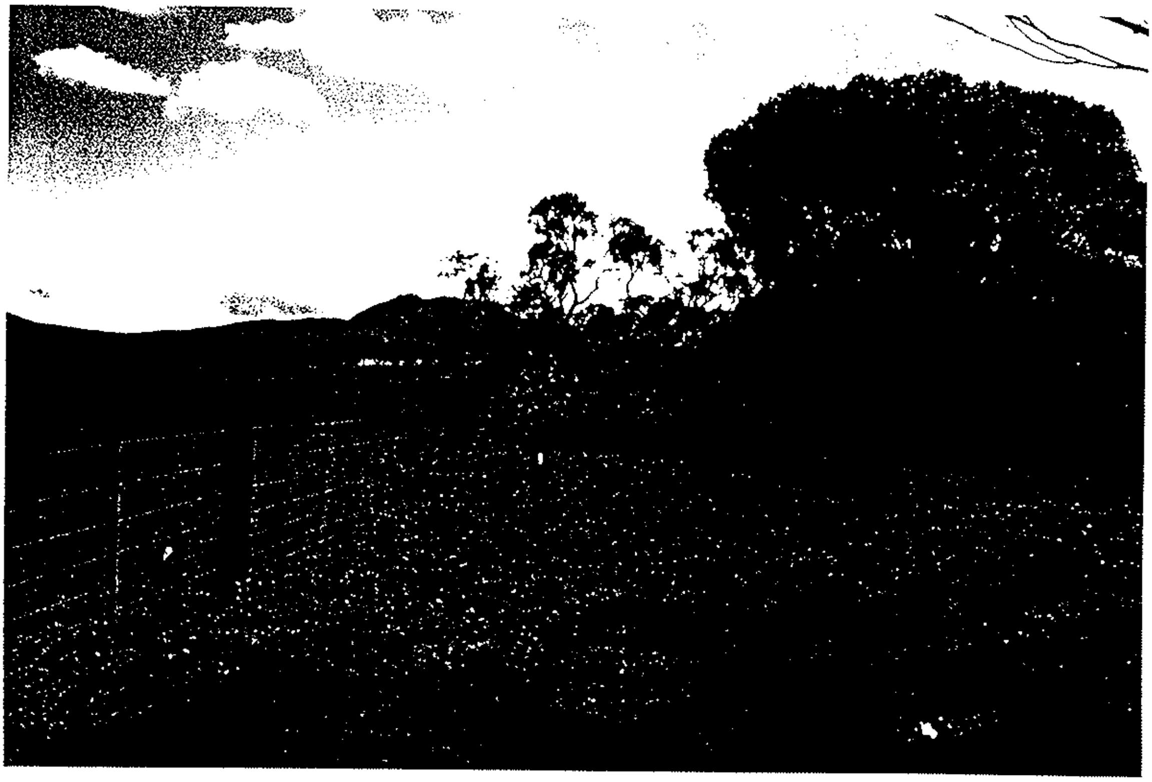


Figure 1: Location of the study sites (includes location of rainfall collection site, # Hall farm)

a)



b)

Figure 2. SRNP subsite a) The pasture / National Park interface. b) Mallee-heath vegetation formation.

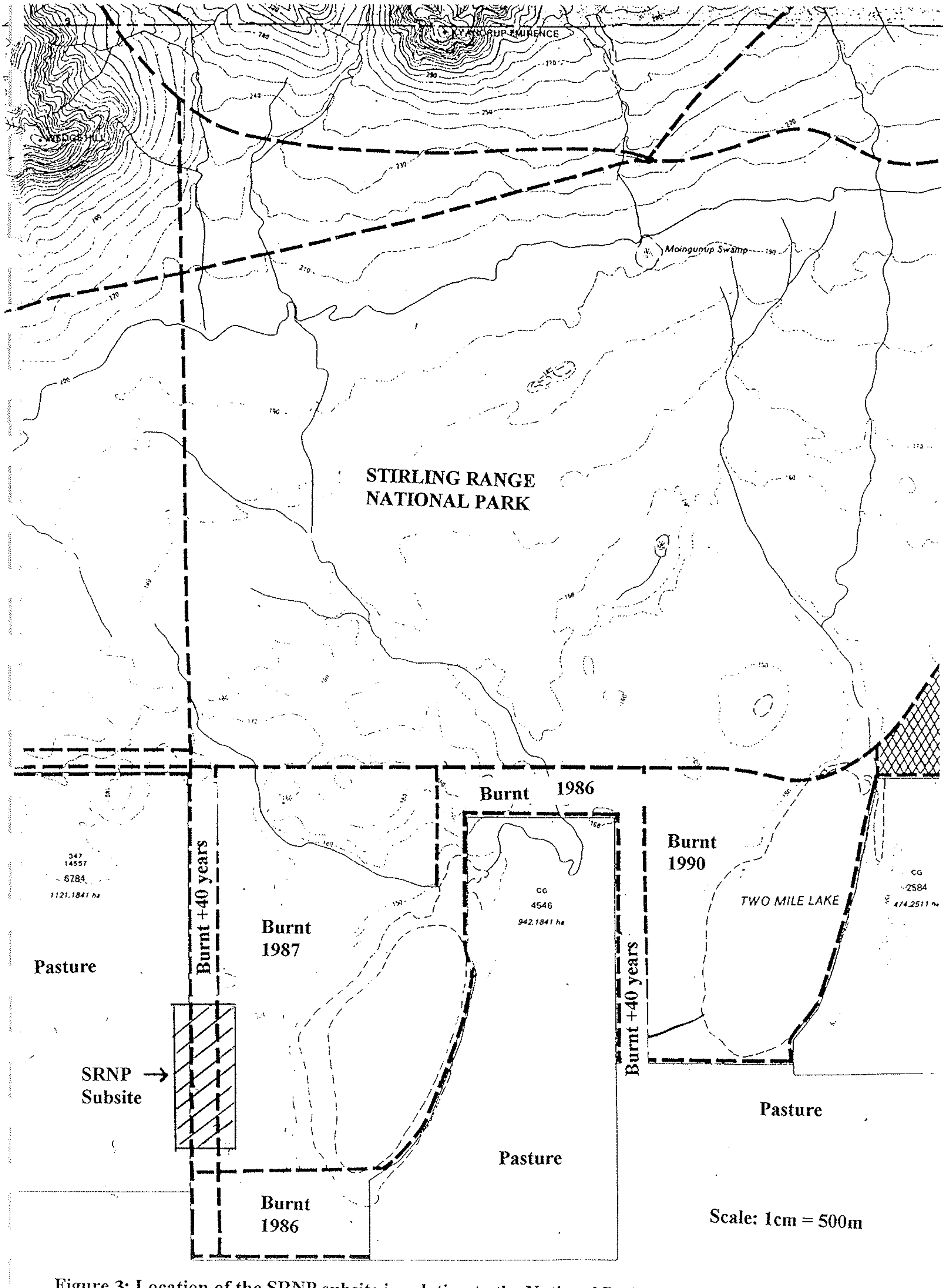
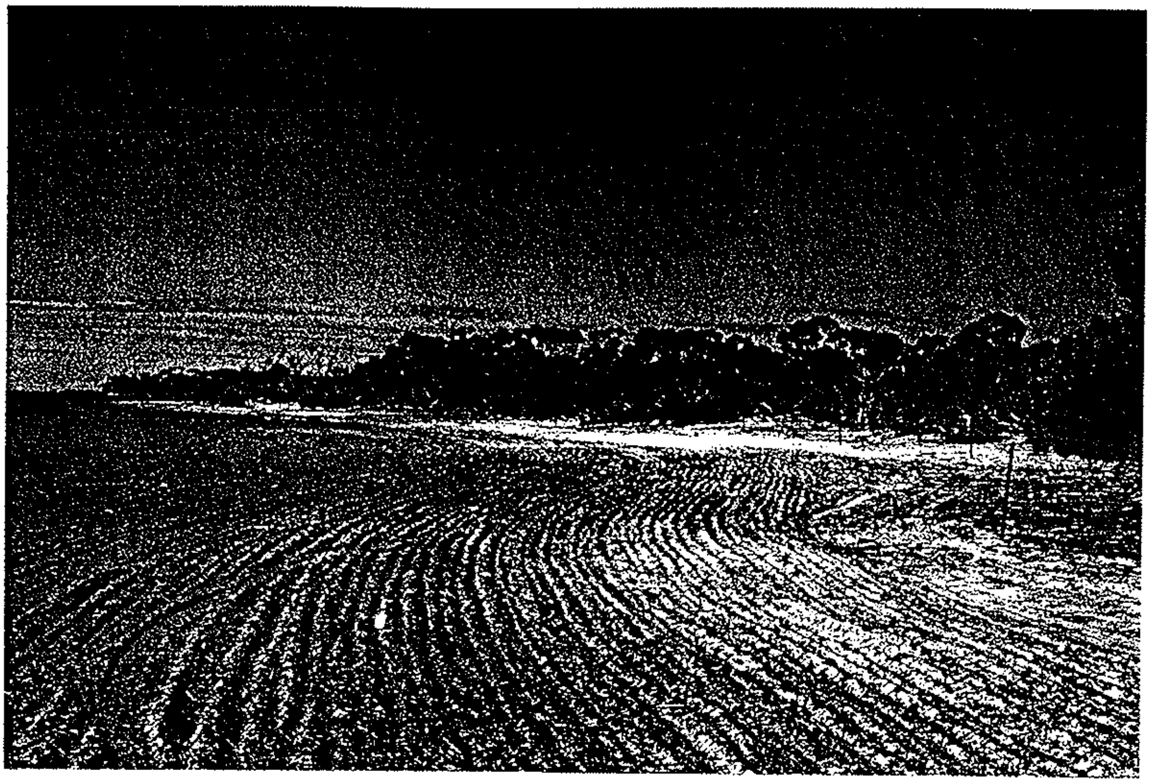


Figure 3: Location of the SRNP subsite in relation to the National Park / pasture boundary and the different fire ages of mallee-heath.

a)



b)

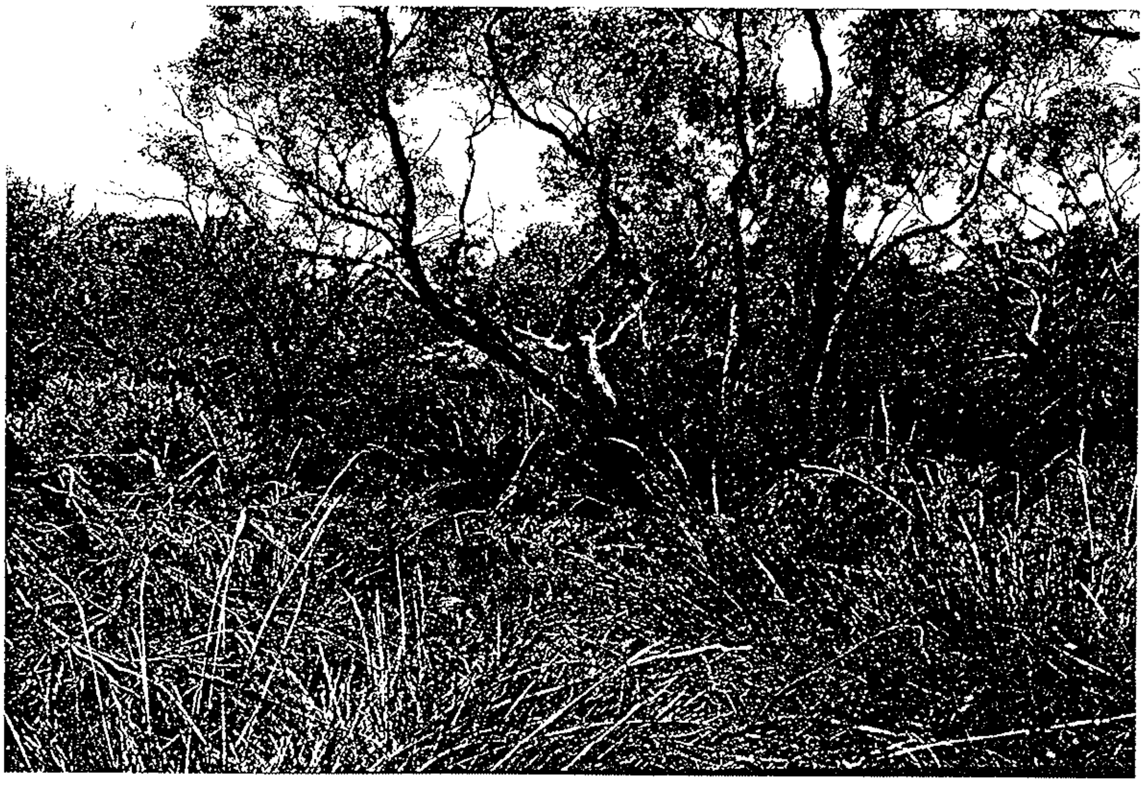


Figure 4. SRRV subsite a) The pasture / remnant vegetation interface.
b) Mallee-heath vegetation formation.

2.2 Sampling design

At both sites, three trap lines were set parallel, at 250 m apart. At the SRNP sub-site these commenced at the pasture / native vegetation interface, and extended through the long unburnt (+ 40 yrs) mallee-heath vegetation and into the recently burnt (10 yrs) mallee-heath vegetation (Figure 5). At the SRRV sub-site the remnant vegetation was of one fire age (approximately + 40 yrs) and the trap lines extended from one edge of the remnant vegetation to the other (Figure 6).

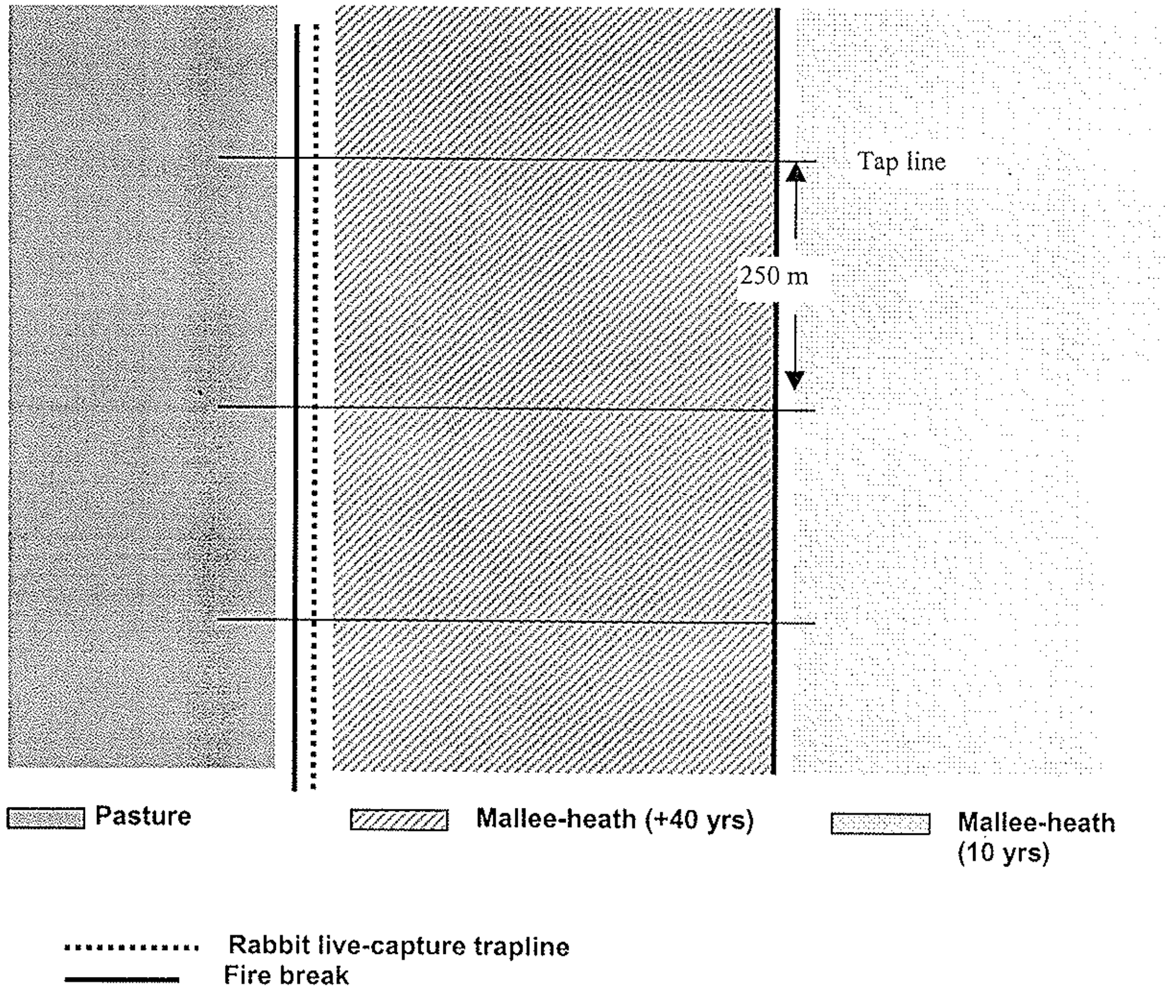


Figure 5: Sampling design (SRNP sub-site) (not to scale)

One trap site was placed at each 20 m interval along the trap line, commencing at the pasture / native vegetation interface. The number of trap sites at the SRNP sub site was such that three extended into the recently burnt (10 yrs) mallee-heath vegetation. This resulted in trap lines with 15, 14 and 16 trap sites respectively. The number of trap sites at the SRRV sub-site was such that the width of the native vegetation from

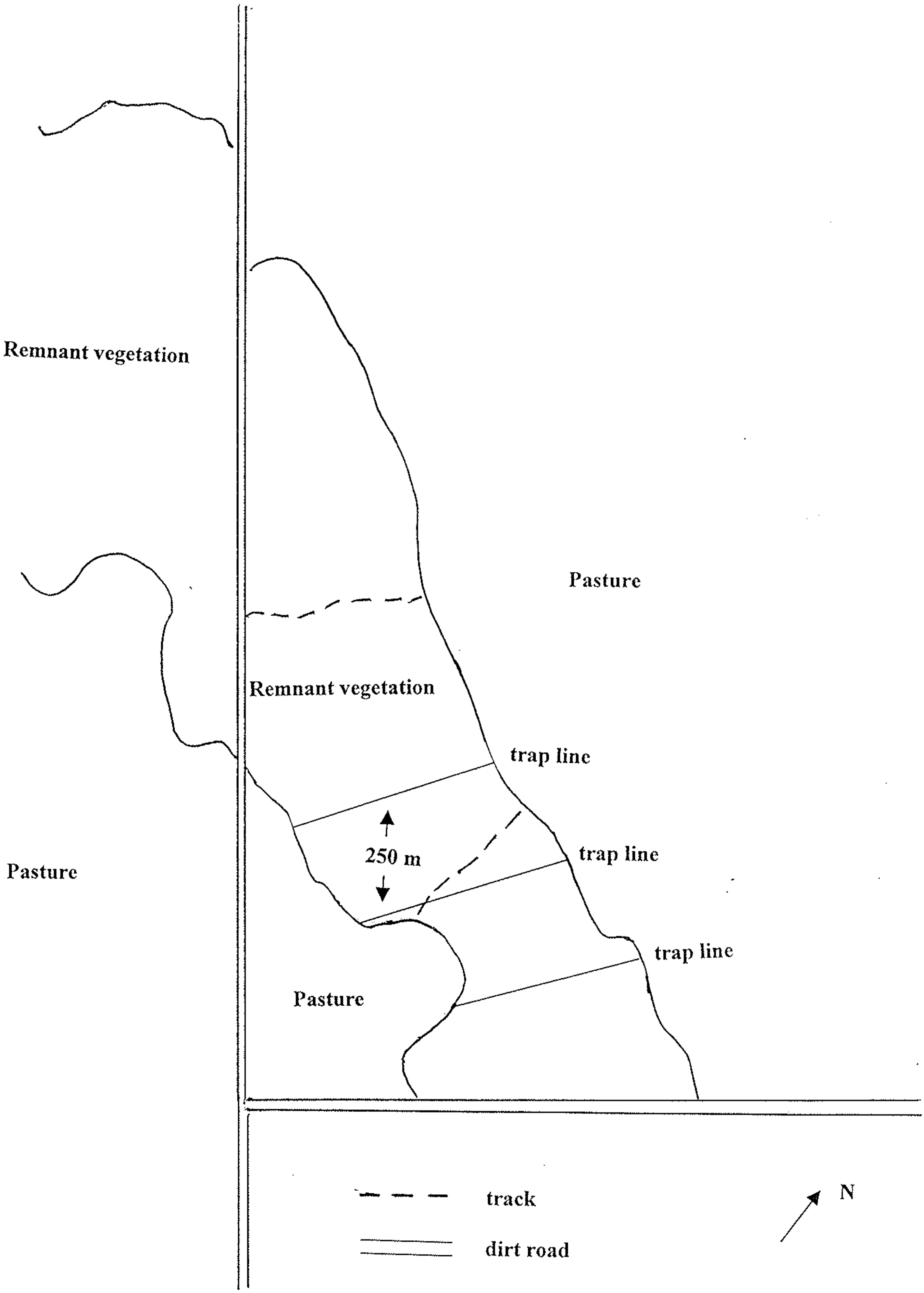


Figure 6: Location of traplines on the SRRV subsite in relation to pasture and remnant vegetation

pasture to pasture was sampled. This resulted in trap lines with 20, 18 and 15 trap sites respectively. A trap site consisted of two 20 litre buckets set flush with the ground and 10 m apart along a 20 m drift fence. Two Elliot traps were placed at each trap site, at either end of the drift fence. Five cage traps per trap line were set, spaced every 3-4 trap-sites. A $1m^2$ plot was placed at every trap site, at a distance of 20 m from the end of the drift fence. These plots were used to count rabbit dung and to assess the abundance and diversity of plant species. For the purpose of dung counts an extra five plots were extended into the pasture where possible.

At the SRNP sub site a line of 50 cage traps at 20 m intervals was set up along the fire break between the pasture and native vegetation to capture rabbits (Figure 5).

2.3 Rabbit abundance

SRNP sub-site

Two methods were used to determine indices of relative rabbit abundances.

1. Spotlight counts

Estimating rabbit numbers by spotlight counts is a rapid, simple method, which is suitable for large areas. However, results can be highly variable depending on weather conditions, vegetation type and patterns of rabbit emergence and activity. Variables, including those identified by Williams *et al.* 1995 (eg. distance, rate of travel, spotlight power, distance included either side of travel path, type of vehicle and position of observer), were standardised. A fixed 15 km route was used, divided into approximately 2 km sections. One section incorporated the pasture / National Park interface where the trap lines were located. It was necessary to extend the spotlight route beyond the area of the sub-site in order to get a sufficiently large per kilometre estimate of rabbit numbers. It was assumed that rabbit numbers would be similar over the route as it followed the pasture / vegetation interface and the vegetation and soil type was similar along the whole route. All rabbits seen either side of the vehicle were recorded using a constant speed (12-15km/hr). Counts were conducted over 2 consecutive nights, with the same observer using a 100 Watt (one million candle power) spotlight mounted on vehicle with access from the inside. Counts were carried out bi-monthly from May 1997 to May 1998.

1. Dung counts

Relative abundance of rabbits estimated from the spotlighting transect is assumed to have reflected numbers that lived in the mallee-heath scrub, as rabbits tend to shelter in the scrub and move onto the pasture to feed at night. In coastal habitat in the south-west of WA, Wheeler *et al.* (1981) found some rabbits use the scrub almost exclusively, as this habitat provides good cover and possibly food all year round (grass and herbs in the wet season and xerophytic native shrubs in the dry season). It was necessary, therefore, to obtain some measure of rabbit abundance in the mallee-heath scrub. As spotlighting can be unreliable in scrub vegetation due to limited visibility, an index of rabbit abundance was determined by dung counts. This method has the advantage of not being affected by wind and temperature, and sampling schedule can be flexible and counts can be made during the day. However, rain can wash dung into dung banks and therefore dung estimated to be older than the sampling period was excluded from counts. Warren counts were not used as rabbits in south-west Western Australia have been found to live above ground where there is suitable vegetation cover (Wheeler *et al.*1981, King *et al.*1984). All dung pellets were removed from dung plots on each occasion were counted to give an estimate of rabbit density along the transects. Care was taken not to include pellets that may have been washed in to the plot. Dung heeps were excluded from the counts. Dung counts were carried out bi-monthly from August 1997 till September 1998.

SRRV sub-site

1. Spotlight counts

Spotlighting was carried out along a 14.4 km transect, for one night every month. The transect was divided into sections; one section comprised the length of the remnant vegetation patch in which sampling of small native vertebrates and vegetation was carried out (2 km; SRRV sub-site section). Spotlighting commenced in December 1995 and continued until December 1998 (Henson and Bruce unpublished data).

2. Dung counts`

Dung counts were carried out by us, as above.

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

SRNP and SRRV sub-site (SRRV sub-site; Henson and Bruce unpublished data)

The reproductive status, age and incidence of RCD antibodies in individual rabbits was monitored from both live captured animals and shot samples. Fifty (SRNP sub-site) and 300 (SRRV sub-site) cage traps were set in pasture adjacent to mallee-heath vegetation and opened every 2 months (SRNP sub-site) or every month (SRRV sub-site). Captured animals were marked with a unique number, so individuals could be indentified. Sex, weight, reproductive status, presence of external parasites, and clinical signs of myxomatosis, were recorded. In addition to trapping, shot samples were taken from a matched location approximately 1 km from the study site. An attempt was made to obtain 20 (30 on the SRRV sub-site) samples per sampling period, but this was not always possible on the SRNP sub-site; capture rate was low at times and shooting was not always successful due to bad weather or rabbit behaviour.

Eyeballs were removed from shot samples. Eye-lens weight was used to determine age of animals (Wheeler and King 1980) and hence age structure of the population. Blood was taken from live animals via cardiac puncture and directly from the heart of shot animals. An estimate of the age of animals as assessed from eye-lens weight, body weight or from marked rabbits of known age was used in conjunction with serological analysis to determine the epidemiology of RCD. Live capture was carried out from May 1997 to September 1998 and shooting from June 1997 to June 1998 (SRNP sub-site). Both shooting and live capture was carried out from December 1995 to December 1998 on the SRRV sub-site.

2.5 Feral Predators

SRNP sub-site only

The number of foxes (*Vulpes vulpes*) and cats (*Felis catus*) observed was recorded along the rabbit spotlight transect. This was carried out bi-monthly from May 1997 to May 1998.

2.6 Small Native Vertebrate Fauna

SRNP and SRRV sub-sites

Pit and Elliot trapping occurred for four consecutive nights every two months from May 1997 to September 1998. Cage traps were first set in July 1997 on the SRNP sub-site and in August 1997 on the SRRV sub-site. Species groups recorded included small mammals, reptiles and amphibians. Each individual was marked permanently and temporarily to identify animals recaptured within a trapping period. The total number of species and number of individuals caught per trapping period could therefore be determined.

Analysis

Correlation analysis was performed to test if the diversity or abundance of small vertebrate fauna was significantly correlated with i) rainfall in the previous 2 months to the sample or ii) rabbit numbers assessed by spotlight counts (SRNP sub-site) or dung counts (SRRV sub-site).

2.7 Large Native Herbivores

SRNP sub-site only

Western grey kangaroo (*Macropus fuliginosis*) and western brush wallaby (*Macropus irma*) were counted along the rabbit spotlight transect bi-monthly from May 1997 to May 1998.

2.8 Vegetation

SRNP and SRRV sub-site

A point quadrat method was used for assessing percentage cover and of ground layer vegetation within the $1m^2$ plots. A metal grid was divided into 20 cm quadrats giving a total of 36 points where the quadrats intersected. The grid was lowered onto the vegetation and any species touching a point was scored. Percentage cover was expressed as the number of crosses as a percentage of the total number points. All species present were also recorded, whether they intersected with the points or not. Small seedlings were given an abundance score: 1-5; 6-10; 11-20; 20-50; 50-100; >100 individuals. Vegetation was sampled every two months from June 1997 to September 1998 at the SRNP sub-site, and from July 1997 to September 1998 at the SRRV sub-site.

Analysis

Correlation analysis was performed to test if the diversity or abundance of plant species was significantly correlated with i) rainfall in the previous 2 months to the sample or ii) rabbit numbers assessed by spotlight counts (SRNP sub-site) or dung counts (SRRV sub-site). Correlation analysis was also performed after categorising plant species into floristic groups and life stage groups and correlating each category with the above variables.

3. RESULTS AND DISCUSSION

3.1 Rabbit abundance

RCD was first detected on the Remnant Vegetation sub-site in September 1996, and caused a reduction in rabbit numbers of about 65 % (Henson and Bruce unpubl. data). It is not known when the virus went through the National Park sub-site, but its close proximity to the Remnant Vegetation sub-site, and anecdotal evidence suggests that it was at a similar time. Monitoring on the National Park sub-site started five months later, but it was assumed that this sub-site had experienced a similar reduction in rabbit numbers as a result of RCD.

SRNP sub-site

i) spotlight counts

Rabbit numbers throughout the study, as assessed by spotlight counts likely reflect changes in abundance associated with the breeding season (Figure 6). The breeding season of rabbits in the south-west of Western Australia occurs predominantly from April, when pastures germinate with initial winter rains, to November when pasture begins to dry out (Wheeler and King 1985, Twigg *et al.* 1998), and numbers begin to increase in late spring with the emergence of young animals. However, numbers on this site were higher in May 1998 than in May 1997. This may be related to a greater winter rainfall, and correspondingly better breeding season, in 1998 compared to 1997 (Figure 8). The increase could also be the result of the failure of RCD to re-occur in the population (see section *3.2*). Rabbits numbers appear to have recovered to pre-RCD levels.

ii) dung counts

The relative abundance of rabbits as assessed by dung counts has remained at a similar level throughout the period of sampling (Figure 6). 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), and therefore, the error may have failed to demonstrate any changes.

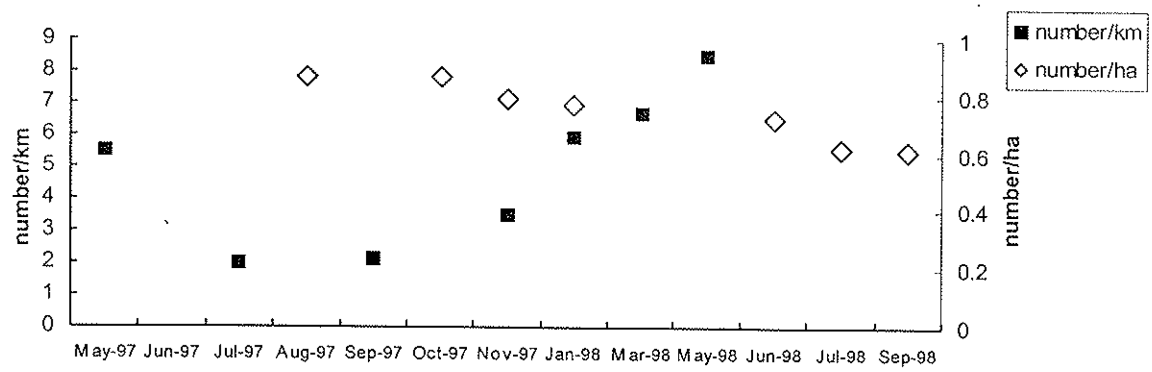


Figure 6: Relative abundance of rabbits on the SRNP site estimated by two methods: spotlighting (numbers / km) and dung pellet counts (numbers / ha). No spotlighting was carried out from May 1998 as the spotlighting route was made inaccessible by flooding.

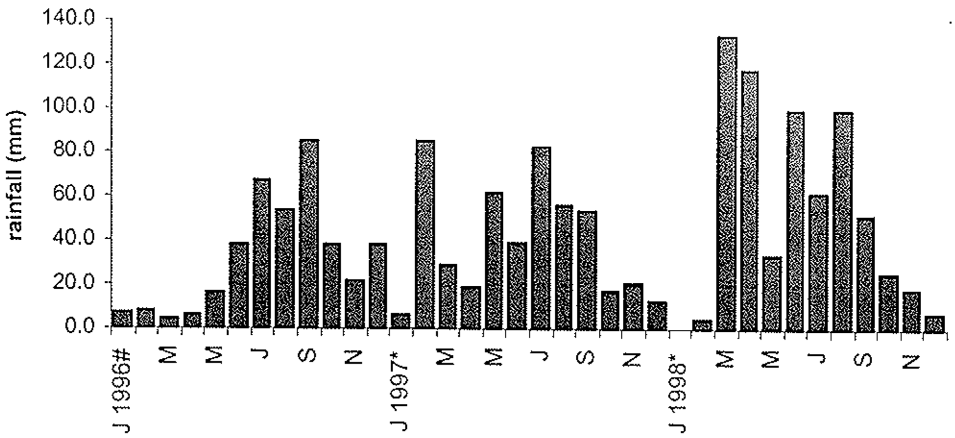


Figure 7: Monthly rainfall in the South Stirling area (# Hall farm, * SRNP sub-site. See Figure 1 for location in relation to study sites)

SRRV sub-site

i) spotlight counts

Rabbit spotlight counts on the SRRV sub-site section decreased by about 65% after the initial outbreak of RCD in September 1996 (see below, section *3.3 Epidemioloy*) (Figure 8). Numbers remained low (around 10 / km) until June 1997 and then began to increase steadily. At the end of this study (September 1998) numbers on the SRRV sub-site section increased to just below pre-RCD levels (Henson and Bruce unpubl. data).

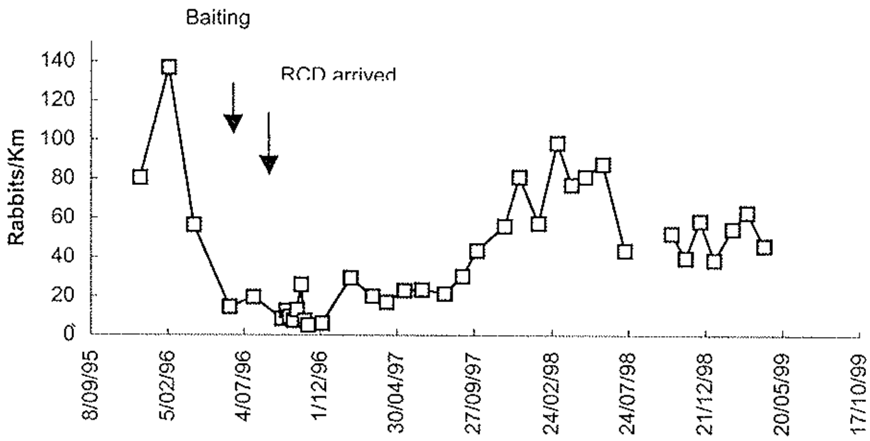


Figure 8: Relative abundance of rabbits on the SRRV sub-site section, estimated by spotlight counts (Henson and Bruce unpl. data.)

ii) dung counts

Dung counts did not commence on this site until May 1997, just before rabbit numbers had began to increase again. The data are too few to indicate any significant changes in relative abundance of rabbits (Figure 9).

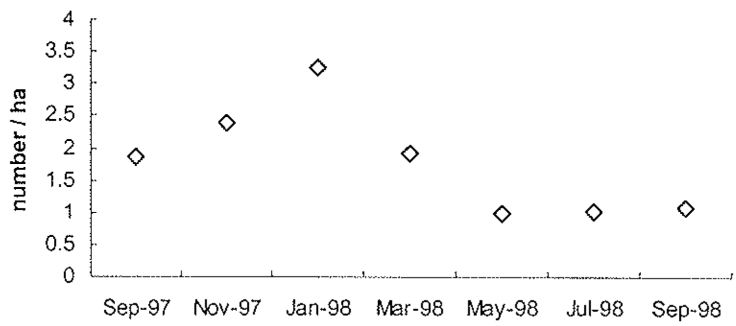


Figure 9: Relative abundance of rabbits estimated by dung counts on the SRRV site.

3.2 Rabbit age structure and reproductive status

SRNP sub-site

The low sample size of shot and live-captured rabbits makes any conclusions about age-structure or reproductive status of the population difficult. Young animals (>1000g, 51-100 days old) were recorded only in spring and summer (Figures 10 and 11). Pregnant and lactating females were present in all months of sampling (Table 1), however the low sample sizes make it impossible to draw any conclusions about the breeding season in this population. The presence of young animals in this population, corresponds well with the time of breeding in other populations of rabbits in the south-west of WA (Wheeler and King 1985, Twigg *et al.* 1998).

The low numbers of young rabbits in the population as a whole probably reflects a bias in sampling rather than a domination by older rabbits such that occurs during prolonged droughts (Williams *et al.* 1995)

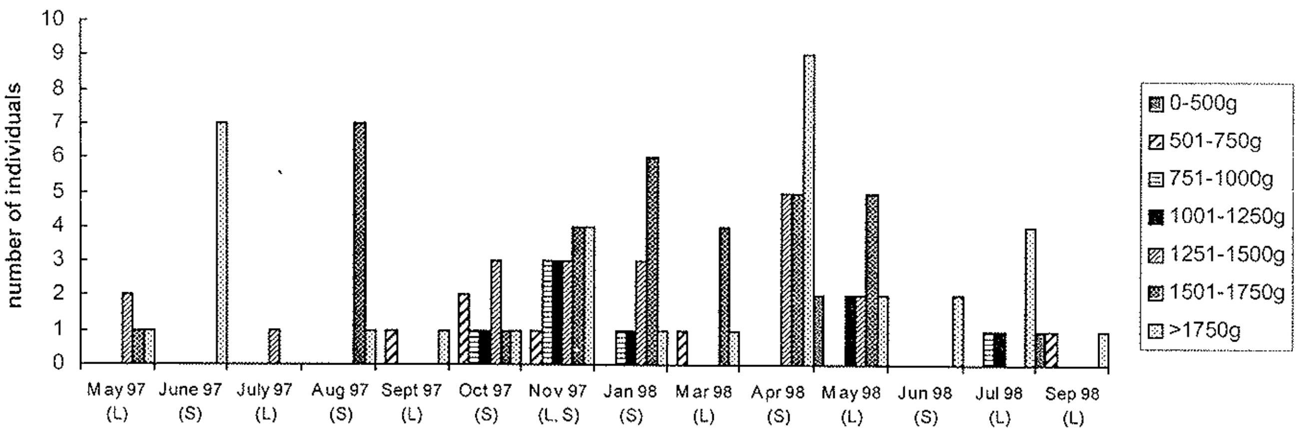


Figure 10: Number of rabbits recorded in each weight class (Live (L) and Shot (S) samples).

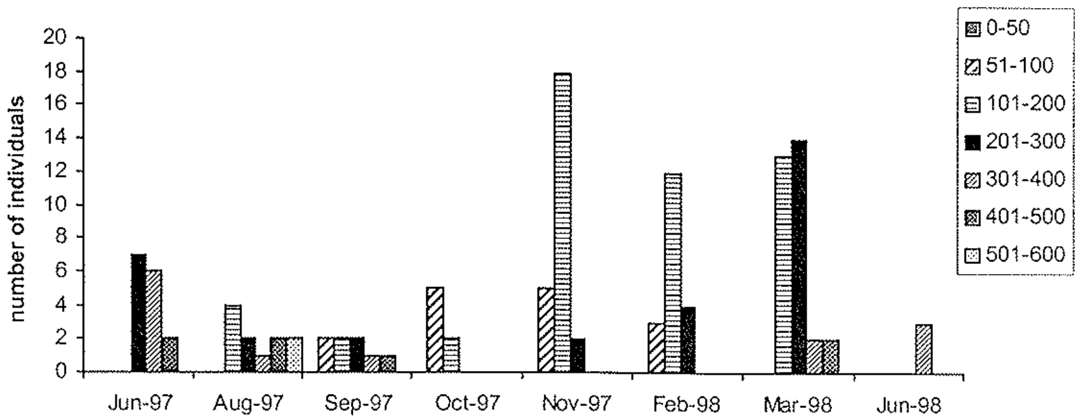


Figure 11: Number of rabbits in each age (days) class determined by eye-lens weight

Table 1: Numbers of females recorded in each reproductive category. Shot samples only. L= Lactating, NL = Not lactating, P = Pregnant, NP = Not pregnant.

Month	NP, NL	P, NL	L, NP	P,L
June 1997	0	0	0	**2**
Aug 1997	0	0	0	**1**
Sept 1997	0	0	0	**1**
Oct 1997	**3**	0	0	**1**
Nov 1997	**2**	0	0	**3**
Feb 1998	**3**	0	0	**1**
Mar 1998	**2**	**6**	0	**3**

SRRV sub-site

This data will be presented in an AgWA report

3.3 Epidemiology of RCD

SRNP sub-site

There have been no outbreaks of RCD on this site since the initial outbreak in this area in September 1996. The percentage of sero-positive animals on the site has been low since June 1997, and at the end of sampling in June 1998 the population was highly susceptible to RCD with 100% of the samples testing sero-negative (Figure 12).

The age structure of the rabbit population as determined eye-lens weight is shown in Figure 11. Low sample sizes early in the study do not give an accurate indication of age structure. However, a high percentage of sero-negative animals in November 1997, February 1998 and March 1998 corresponds to a high percentage of young (101-200 day old) rabbits in the population, indicating that these young rabbits had not been challenged by the virus and that the population was highly susceptible to an RCD outbreak at this time.

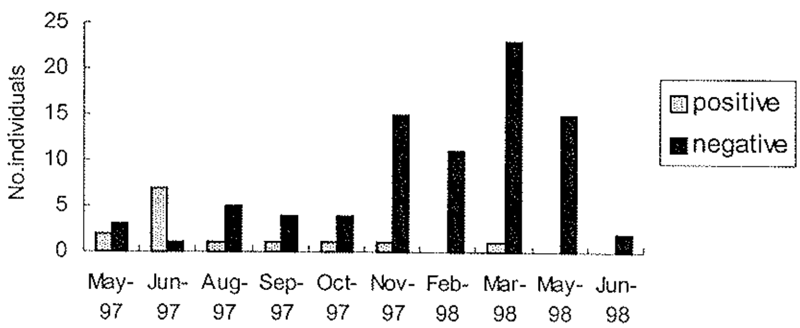


Figure 12: Number of rabbits per month testing sero-positive and sero-negative for RCD on the SRNP site

The incidence of myxoma virus antibodies in the population appears to follow a seasonal pattern with high numbers of individuals testing positive to the antibodies in summer (Figure 13). There was no correlation between numbers of individuals testing positive for RCD antibodies and numbers testing positive for myxoma virus antibodies ($r = 0.34$, df = 8, $P > 0.05$).

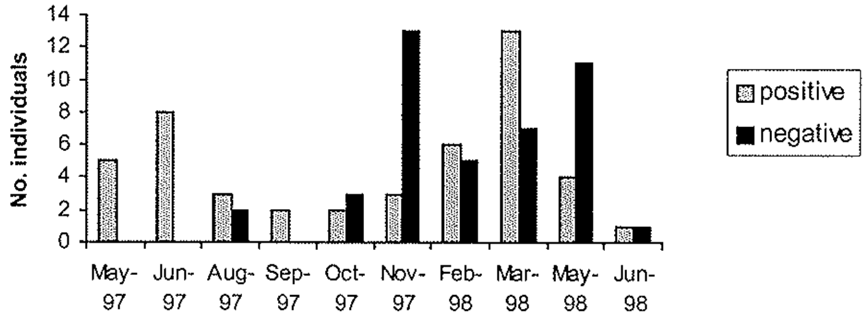


Figure 13: Number of rabbits per month testing sero-positive and sero-negative for myxoma virus on the SRNP site

SRRV sub-site

RCD was first detected in September 1996. There has been no re-occurrence of the virus on this site. This is supported by the fact that there was no obvious mortality (no significant reduction in spotlight counts) and no change in the sero-status of individual animals (Henson and Bruce unpl. data).

3.6 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).

SRNP sub-site

Fox baiting occurred in the Stirling Range National Park in the area of the SRNP site in March and September 1997, and March 1998. Fox numbers are very low in the area around the site. No cats have been observed spotlighting (Table 2).

Table 2: Number of feral predators seen per spotlight km on the SRNP site

	May 97	July 1997	Sept 97	Nov 97	Jan 98	Mar 98	May 98
Foxes	0.37 / km	0 / km	0 / km	0.13 / km	0.06 / km	0.06 / km	0 / km
Cats	0 / km	0 / km	0 / km	0 / km	0 / km	0 / km	0 / km

3.4 Small native 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*) and the numbat (*Myrmecobius fasciatus*); 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.

SRNP sub-site

Small mammals

There was no significant correlation of mammal abundance with either rainfall in the previous 2 months or rabbit numbers ($P > 0.05$ for both). The diversity of mammals was too low to perform any analysis.

Numbers of both *Tarsipes rostratus* (Honey Possum) and *Mus musculus* caught fluctuated widely, increasing substantially on the site in March 1998 (Figure 14). They continued to be high in May 1998 after which numbers began to drop off. The abundance of these two species in May of the previous year was substantially lower. Rainfall was substantially higher in winter 1998 (Figure 8) which may account for the higher numbers of *Mus musculus*, a species in which breeding occurs rapidly in response to rainfall. The abundance of *Tarsipes rostratus* has been found to be significantly, positively related to rainfall in the preceding year in a similar heathland habitat in the south coast of WA (Wooller *et al.* 1998). This relationship is mediated by changing nectar availability. The lag occurs possibly because the nectar producing plants such as *Banksia* and *Dryandra* respond more to subsurface water. Honey possums are highly fecund and can respond rapidly to changes in nectar levels. *Isoodon obesulus* (Southern Brown Bandicoot) and *Sminthopsis griseoventer* (Grey-bellied Dunnart) were caught for the first time on the site in March 1998, and the first capture of a Western Pygmy Possum *(Cercatetus concinnus*) occurred in May 1998. These three species were in very low abundance on the site at all times.

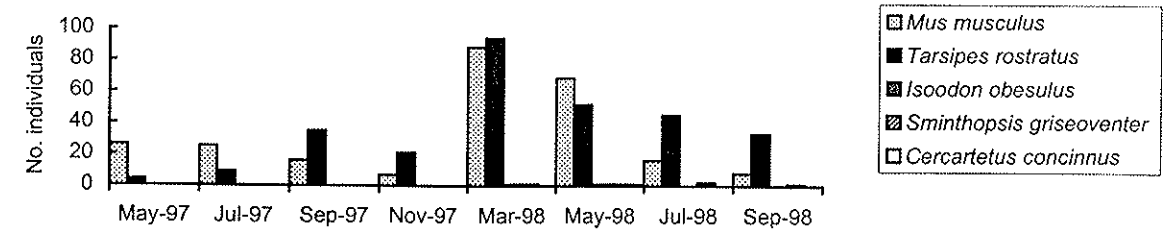
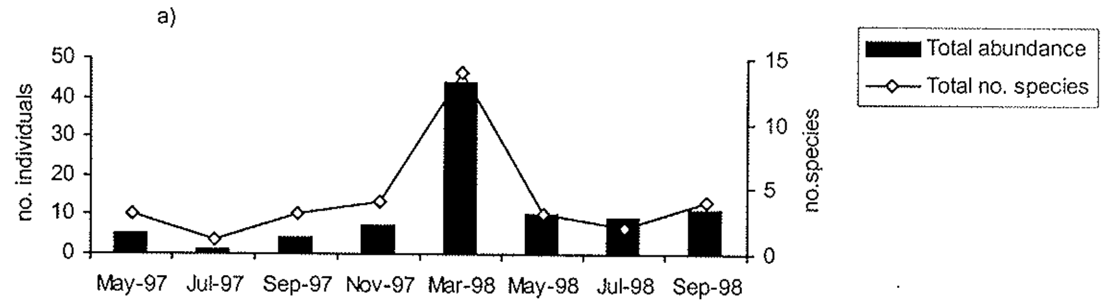


Figure 14: Species diversity and numbers of small mammals caught on the SRNP site. Trapping effort = 320 Elliott trapnights, 200 pitfall trapnights and 60 cage trapnights per month (except for Sept 1998 : 140 pitfall trapnights).

Reptiles and amphibians

There was no significant correlation of reptile an amphibian diversity and abundance with either rainfall in the previous 2 months or rabbit numbers ($P > 0.05$ for all).

The number and species diversity of reptiles and amphibians caught increased substantially in March 1998, as did the abundance of amphibians (Figure 15 a and b, Appendix 1) but had decreased again by May 1998 and continued to be low until September 1998. These fluctuations are likely the result of temperature, with high capture rates in the summer months, and low or zero in winter months. A species of skink (*Tiliqua occipitalis*) not previously recorded on the site was caught in September 1998.



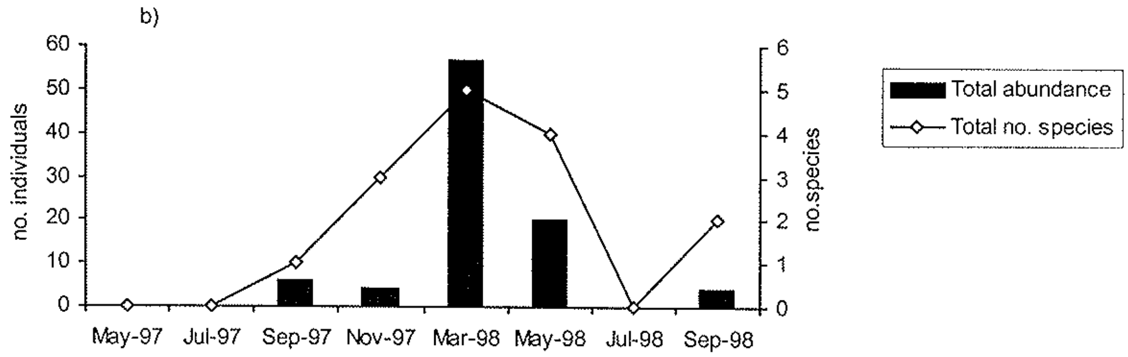


Figure 15: Species diversity and numbers of a) reptiles and b) amphibians caught on the SRNP site. Trapping effort = 400 Elliot trapnights, 200 pitfall trapnights and 60 cage trapnights per month.

SRRV sub-site

Small mammals

There was no significant correlation of mammal abundance with either rainfall in the previous 2 months or rabbit numbers ($P > 0.05$ for both). The diversity of mammals was too low to perform any analysis.

Numbers of *Tarsipes rostratus* are quite low on this site and *Sminthopsis* sp.was only recorded twice (Figure 16). Southern brown bandicoot (*Isoodon obesulus*) numbers remain steady despite the high rabbit numbers on this site. The numbers of *Mus musculus* fluctuated widely. High numbers occurred in March 1998 but had decreased substantially by the next sampling period (May 1998).

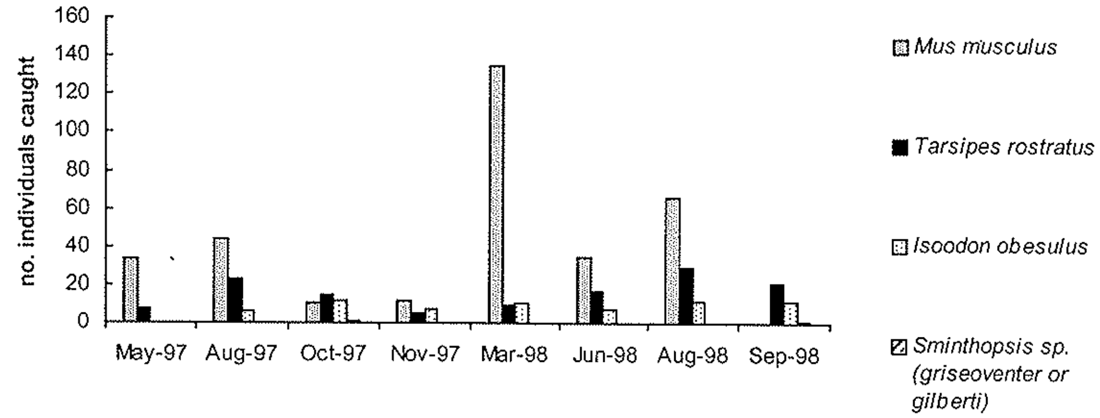


Figure 16: Species diversity and number of small mammals caught on the SRRV site. Trapping effort = 400 Elliot trapnights, 200 pitfall trapnights and 60 cage trapnights per month (except for Oct 97; 300 Elliot trapnights, 150 pitfall trapnights and 45 cage trapnights)

Reptiles and amphibians

There was no significant correlation of reptile an amphibian diversity and abundance with either rainfall in the previous 2 months or rabbit numbers ($P > 0.05$ for all).

Reptile abundance and diversity fluctuated, probably in response to seasonal temperatures (Figure 17a, Appendix 2). Amphibian abundance and diversity increased substantially in March 1998 (Figure 17b, Appendix 2). There was high rainfall in this month, which would have stimulated activity and breeding. After March 1998 diversity and abundance of both reptiles and amphibians decreased and remained low until the end of sampling in September 1998, apart from an increase in the abundance of *Tiliqua rugosa* in this month (Appendix 2)

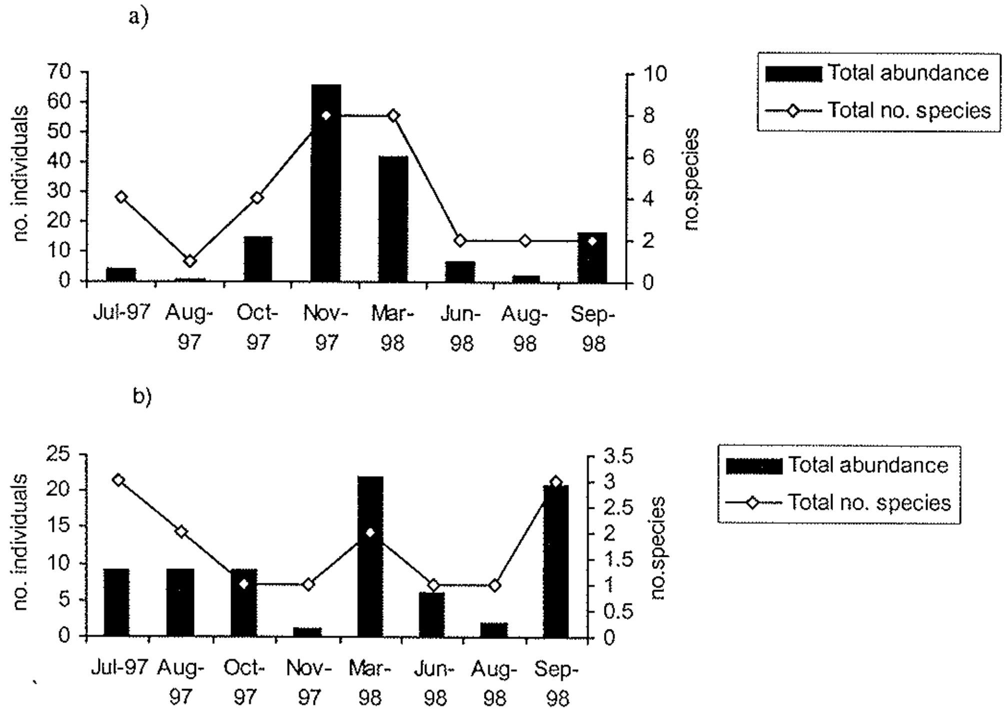


Figure 17: Species diversity and numbers of a) reptiles and b)amphibians caught on the SRRV site. Trapping effort = 400 Elliot trapnights, 200 pitfall trapnights and 60 cage trapnights per month (except for Oct 97; 300 Elliot trapnights, 150 pitfall trapnights and 45 cage trapnights).

3.5 Large native herbivores

Any reduction in the abundance of rabbits will directly affect other herbivores and stocking rates on farming and pastoral 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 from grazing competition by rabbits may lead to increase in numbers of kangaroos such that the total grazing pressure remains relatively unchanged.

SRNP sub-site

Two species of medium to large native herbivores occur at the SRNP site, *Macropus fuliginosis* and *Macropus irma* . Numbers of *M. fuliginosis* have remained quite steady since the beginning of sampling in May 1997 (Figure 18). *M. irma* numbers have been low since first recorded in November 1997.

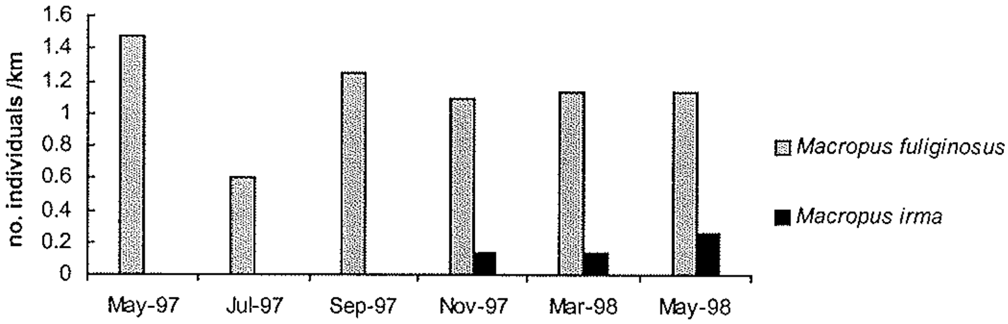


Figure 18: Number of *Macropus fuliginosus* and *Macropus irma* seen per spotlight km. Spotlighting was carried out on the site from May 1998 due to flooding of the spotlight route.

3.6 Vegetation

SRNP sub-site

There was no significant correlations between plant diversity or abundance with rainfall in the previous 2 months or rabbit numbers ($P < 0.05$ for all correlations).

The average diversity of plant species increased between the first and last sampling period (Figure 19) ($t = 6.45$, df$= 52$, $P < 0.001$). However, due to the short period of sampling the effects of seasonal conditions will be an overiding factor in this increase.

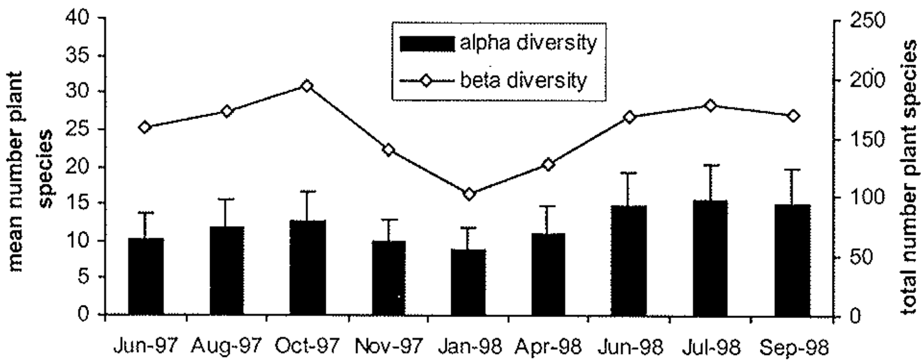


Figure 19: Mean number of plant species per plot (alpha diversity) (mean and SD), and total number plant species (beta diversity). SRNP sub-site.

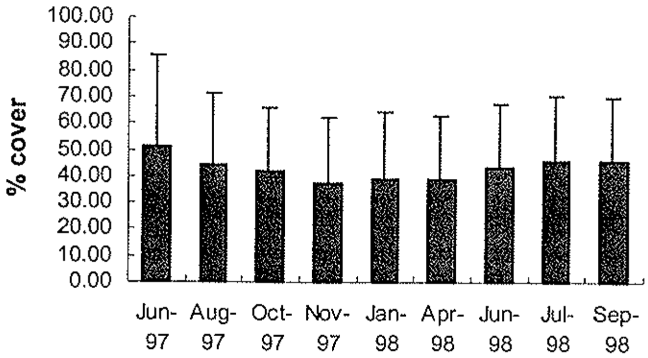


Figure 20: Percentage cover of all plants. Mean and SD. SRNP sub-site.

The percentage cover of all plants changed little over the period of sampling; there was no difference in cover between the first and last sampling period (Figure 20) (t = 0.49, df = 52, $P > 0.05$). When plant species are categorised into floristic groups it can be seen that sedges dominate in terms of cover (Figure 21) and there was a significant increase in their cover between the first and last sampling periods (t = 6.72, df = 50, $P < 0.05$). However, again, due to the short period of sampling the effects of seasonal conditions will be an overiding factor in this increase. The two other florsitic groups which showed the most cover ('other dicots' and 'grasses') did not change in cover between the first and last sampling period (t = 0.41, df = 50, $P > 0.05$, t = 0.37, df = 50, $P > 0.05$ respectively).

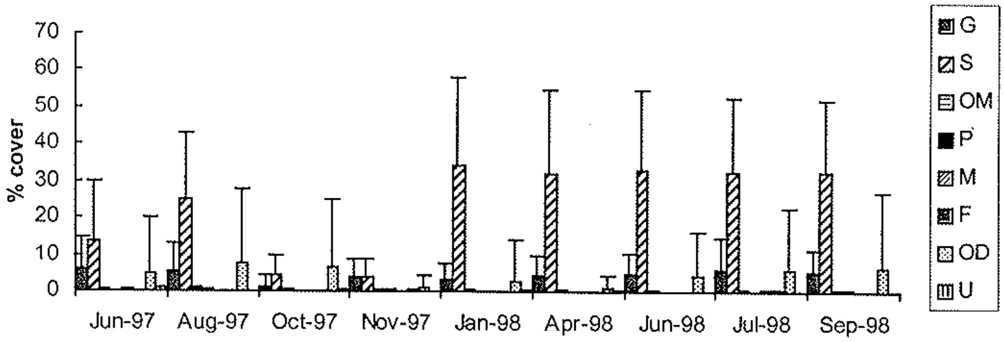


Figure 21: Percentage cover of floristic groups (SRNP site) G=Grasses, S=Sedges, OM=Other Monocots, P=Proteaceae, M=Myrtaceae, F=Fabaceae, OD=Other Dicot, U=Unidentified. Standard deviations shown only for G, S and OD.

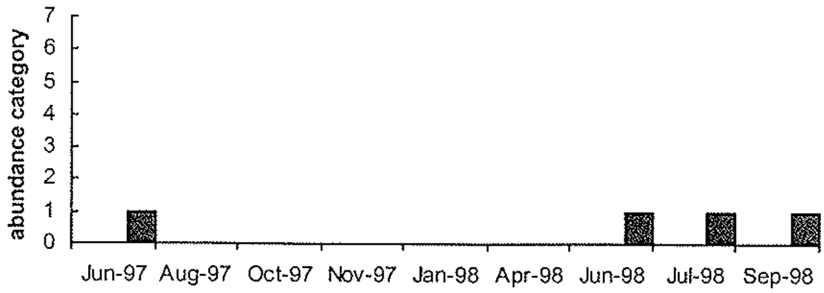


Figure 22: Abundance of seedlings. Abundance category: 1= 1-5, 2=6-10, 3=11-20, 4=21-30, 5=31-50, 6=51-100, 7= >100.

Seedlings were scarce throughout the period of sampling (Figure 22) and the percentage cover of adult plants remained fairly constant and the incidence of re-shooting was very low (Figure 23). As adult plant cover comprised a very high percentage of the total plant cover no separate analysis was performed.

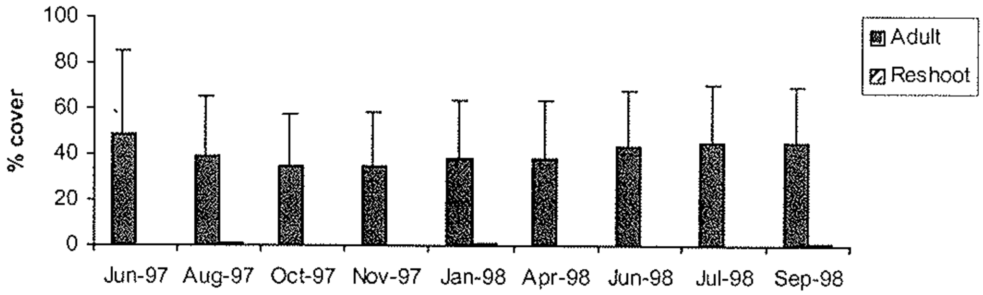


Figure 23: Percentage cover of adult plants and re-shoots. Mean and SD. (SRNP sub-site)

SRRV sub-site

The only significant correlation was between alpha diversity and rainfall in the previous 2 months ($r = 0.74$, df $= 6$, $P < 0.05$).

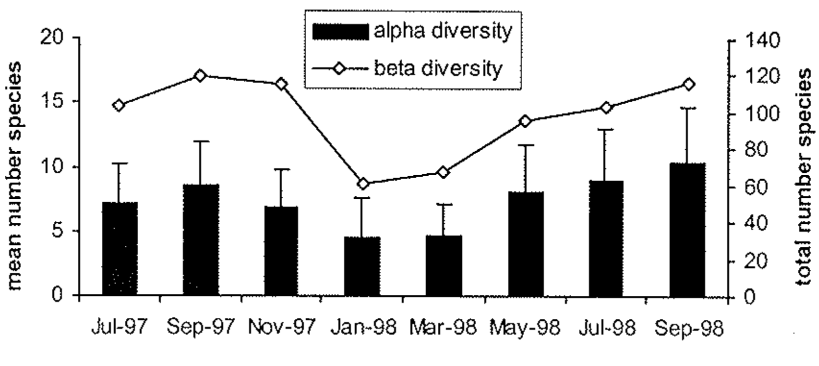


Figure 24 : Mean number of plant species per plot (alpha diversity), and total number plant species (beta diversity), SRRV sub-site.

The average diversity of plant species did not change significantly between the first and last sampling period (Figure 24) (t = 1.49, df = 54, $P > 0.05$).

The percentage cover of all plants decreased in the summer months but there was no difference in cover between the first and last sampling period (Figure 25) (t = 0.14, df = 52, $P > 0.05$). When plant species are categorised into floristic groups it can be seen that 'sedges', 'grasses' and 'other dicots' dominate in terms of cover (Figure 26). There was a significant decrease in cover of sedges between the first and last sampling periods (t = 2.11, df = 49, $P < 0.05$). However, again, due to the short period of sampling the effects of seasonal conditions will be an overiding factor in this decrease. The other florsitic groups ('other dicots' and 'grasses') did not change significantly in cover between the first and last sampling period (t = 0.23, df = 49, $P > 0.05$; t = 0.37, df = 49, $P > 0.05$ respectively).

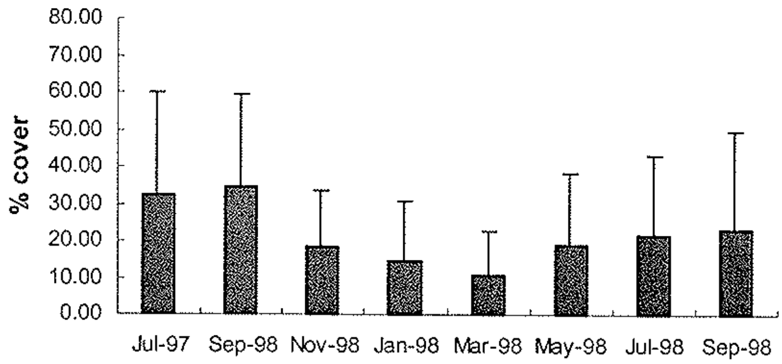


Figure25 : Percentage cover of all plants. Mean and SD. SRRV sub-site.

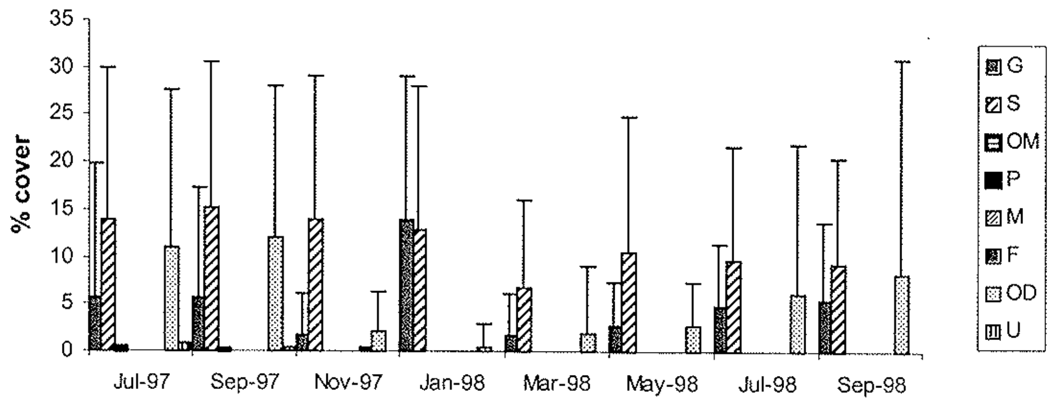


Figure 26: Percentage cover of floristic groups (SRRV site). Mean and SD. G=Grasses, S=Sedges, OM=Other Monocots, P=Proteaceae, M=Myrtaceae, F=Fabaceae, OD=Other Dicot, U=Unidentified

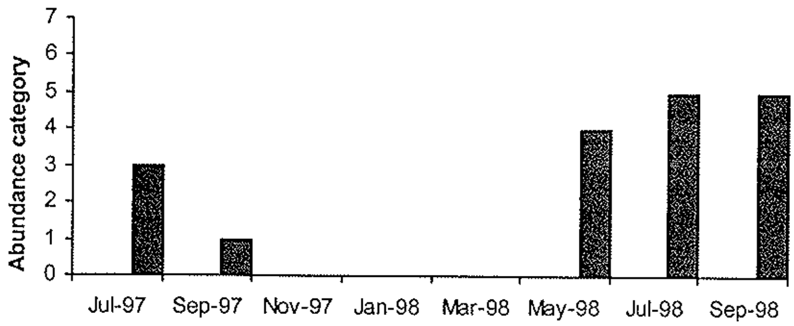


Figure 27: Abundance of seedlings (SRRV site). Abundance category: 1= 1-5, 2=6-10, 3=11-20, 4=21-30, 5=31-50, 6=51-100, 7= >100.

Seedlings were more numerous on this sub-site than on the SRNP sub-site, and were absent in the summer months (Figure 27). As adult plant cover (Figure 28) comprised a very high percentage of the total plant cover no separate analysis was performed.

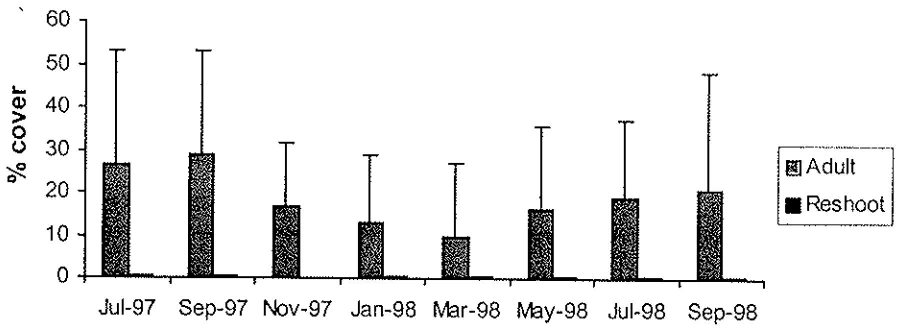


Figure 28: Percentage cover of adult plants and reshoots. Mean and SD. (SRRV site)

Observations

Some species of perennial grasses (eg. *Amphipogan strictus*) were heavily grazed in January and April when pasture feed was absent. This grazing was particularly evident on the SRRV site where rabbit numbers have increased markedly (see AgWA report). There was some grazing of perennial re-shoots evident in January, and the loss of some perennial seedlings, though it is not known if this was due to death or grazing.

4. CONCLUSION

After the initial spread of RCD through this area in September 1996 and the reduction of rabbits by about 65%, the virus has not re-ocurred and rabbits numbers have recovered. It is therefore impossible to make any conclusions about the impacts of reduced rabbit numbers through RCD on biodiversity on these sites. The changes in the abundance and diversity of flora and fauna observed are almost certainly related to seasonal factors.

The data collected however, does provide a good baseline for future work. If the virus does re-occur and cause a sustained decrease in rabbit numbers, the data presented here could be used to compare biodiversity under the influence of high and low rabbit numbers. There is a re-release of the virus planned for the Remnant Vegetation sub-site in the near future and this may provide a good opportunity for measuring impacts by comparing data collected in this study to that post virus release. The reasons why RCD is not reinfecting populations in this area is being investigated at present by Agriculture Western Australia.

It is clear that more work is needed to determine the level of unacceptable damage caused by rabbits to biodiversty values on conservation reserves and other natural lands (Armstrong 1998).

REFERENCES

Armstrong, R. (1998). Government Rabbits and Their Control on Crown Reserves. South Coast Regional Initiative Fox and Rabbit Control Workshop Proceedings. Agriculture WA, Albany.

Catling, P.C. (1988). Similarities and contrasts in the diet of foxes (*Vulpes vulpes*) and cats (*Felis catus*) relative to fluctuating prey populations and drought. *Australian Wildlife Research* 15: 307-317

Cooke, B.D.(1996). Analysis of the Spread of Rabbit Calicivrus from Wardang Island through Mainland Australia. A report prepared for the Meat research Corporation. Project CS.236.

Kinnear, J.E., Onus, M.L. and Bromilow, R.N. (1988). Fox control and rock-wallaby population dynamics. *Australian Wildlife Research*. 15:435-450.

Martin, G.R., Twigg, L.E., and Robinson, D.J.(1996). Comparisons of the diet of feral cats from rural and pastoral Western Australia. *Wildlife. Research* 23: 475-484.

Pech, R.P. and Hood, G.M. (1998). Foxes, rabbits, alternative prey and rabbit calicivirus disease: consequences of a new biological control agent for an outbreaking species in Australia. *Journal of Applied Ecology*. 35:434-453.

Saunders, G., Coman, B., Kinnear, J. and Braysher, M. (1995) Managing Vertebrate Pests: Foxes. Australian Government Publishing Service, Canberra.

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

Wheeler, S.H and King, D.R. (1980). The use of eyelens weights for aging wild rabbits, *Oryctolagus cuniculus* (L.) in Australia. *Aust. Wild. Res.* 7: 79-84.

Wheeler, S.H. and King, D.R. (1985). The European Rabbit in South-western Australia II Reproduction. *Aust. Wildl. Res.* 12:197-212.

Wood, D.H. (1988). Estimating rabbit density by counting dung pellets. *Aust. Wildl. Res.* 15:665-71

APPENDIX 1: Species of reptiles and amphibians recorded on the SRNP site

Species	No. individuals May 1997	July 1997	Sept 1997	Nov 1997
Reptiles				
Ctenotus gemmula	0	0	0	0
Ctenotus impar	0	0	0	0
Hemiergis peronii	0	0	**1**	0
H. initialis initialis	0	0	**1**	0
Leilolopisma trilineatum	**1**	**1**	0	**1**
Morethia obscura	**3**	0	**1**	**2**
Morethia adelaidensis	0	0	0	0
Tiliqua occipitalis	0	0	0	0
Tiliqua rugosa	**2**	0	**1**	**3**
Pygopus lepidopodus	0	0	0	0
Tympanocryptus adelaidensis	0	0	0	0
Notechis coronatus	0	0	0	0
Rinoplocephalus bicolor	0	0	0	0
Aprasia repens	0	0	0	0
Delma australis	0	0	0	**1**
Delma fraseri				
Total abundance	*6*	*1*	*4*	*7*
Total no. species	*3*	*1*	*4*	*4*
Amphibians:				
Myobratrachus gouldi	0	0	0	1
Neobatrachus albipes	0	0	0	0
Neobatrachus pelobatoides	0	0	0	0
Crinia sp.	0	0	0	2
Heleioporus psammophila	0	0	6	1
Total abundance	***0***	***0***	***6***	***4***
Total no. species	***0***	***0***	***1***	***3***

APPENDIX 1 cont.

Species	No. individuals March '98	May '98	Jul '98	Sep '98
Reptiles				
Ctenotus gemmula	3	0	0	0
Ctenotus impar	1	0	0	0
Ctenotus sp.	1	0	0	0
Hemiergis initialis initialis	1	2	1	0
Leilolopisma trilineatum	0	1	0	2
Morethia obscura	14	7	8	7
Morethia adelaidensis	4	0	0	0
Tiliqua occipitalis	0	0	0	1
Tiliqua rugosa	2	0	0	1
Pygopus lepidopodus	1	0	0	0
Tympanocryptus adelaidensis	1	0	0	0
Notechis coronatus	1	0	0	0
Rinoplocephalus bicolor	1	0	0	0
Aprasia repens	2	0	0	0
Delma australis	2	0	0	0
Total abundance	*44*	*10*	*9*	*11*
Total no. species	*14*	*3*	*2*	*4*
Amphibians:				
Myobratrachus gouldi	11	4	0	0
Neobatrachus albipes	7	8	0	3
Neobatrachus sp.	3	0	0	0
Crinia glauerti	8	0	0	0
Heleioporus psammophila	0	0	0	0
Limnodynastes dorsalis	21	1	0	0
Pseudophryne guentheri	22	7	0	1
Total abundance	*72*	*21*	*0*	*4*
Total no. species	*6*	*4*	*0*	*2*

APPENDIX 2: **Species of reptiles and amphibians recorded on the SRRV site.**

Species	No. individuals May 97	Aug 97	Oct 97	Nov 97
Reptiles:				
Leiolopisma trilineatum	**1**	0	**1**	**2**
Morethia obsura	0	0	**2**	**13**
Ctenotus gemmula	0	0	0	**4**
Lerista distinguenda	0	0	0	**21**
Aprasia repens	0	0	0	**3**
Tiliqua rugosa	0	**1**	**11**	**20**
Notechis curtus	**1**	0	0	0
Notechis scutatus	**1**	0	**1**	**1**
Rhinoplocephalus bicolor	**1**	0	0	0
Varanus rosenbergi	0	0	0	2
Total abundance	*4*	*1*	*15*	***66***
Total no. species	*4*	*1*	*4*	***8***
Amphibians:				
Litoria cyclorhynchus	**1**	0	0	0
Myobatrachus gouldii	**3**	0	0	0
Neobratrachus albipes	0	0	0	1
Heleioporus psammophilis	**4**	**1**	0	0
Crinia glauerti	**1**	**1**	0	0
Total abundance	*9*	*2*	***0***	*1*
Total no. species	*4*	*2*	***0***	*1*

APPENDIX 2 cont.

Species	No. individuals Mar 98	June 98	Aug 98	Sept 98
Reptiles:				
Leiolopisma trilineatum	**1**	**3**	**1**	0
Morethia obsura	**5**	0	**1**	**2**
Ctenotus gemmula	**0**	0	0	0
Lerista distinguenda	7	0	0	0
Hemiergis peroni	**1**	0	0	0
Aprasia repens	0	0	0	0
Tiliqua rugosa	**25**	**4**	0	**15**
Notechis curtus	0	0	0	0
Notechis scutatus	**1**	0	0	0
Rhinoplocephalus bicolor	**1**	0	0	0
Varanus rosenbergi	0	0	0	0
Varanus gouldii	**1**	0	0	0
Total abundance	*42*	*7*	*2*	*17*
Total no. species	*8*	*2*	*2*	*2*
Amphibians:				
Litoria cyclorhynchus	0	0	0	0
Myobatrachus gouldii	0	0	0	0
Limnodynastes dorsalis	**17**	**6**	**2**	**15**
Neobratrachus albipes	**4**	0	0	**4**
Pseudophryne guentheri	0	0	0	**2**
Heleioporus psammophilis	0	0	0	0
Crinia glauerti	**1**	0	0	0
Total abundance	*22*	*6*	*2*	*21*
Total no. species	*3*	*1*	*1*	*3*

APPENDIX 3: Plant species recorded in 1 m^2 plots, SRNP sub-site (identifiable).
* exotic species

Family	Genus	Species
MONOCOTYLEDON		
Anthericaceae	Chamaescilla	spiralis
Cyperaceae	Lepidosperma	sp.
	Mesomelaena	stygia
	?Schoenus	sp.
	S.	subbarbatus
Dasypoganaceae	Lomandra	sp.
Haemodoraceae	Anigozanthos	humilis
	Conostylis	setigera
Orchidaceae	Elythranthera	brunonis
	Leporella	fimbriata
	?Pterostylis	sp.
Poaceae	Amphipogan	strictus
	A.	turbinatus
	Avellinia	michelli
	*Bromus	rubens
	*Lolium	rigidum
	Neurachne	alopercuroidea
	*Vulpia	myuros
Restionaceae	Anarthria	gracilis
	A.	sp.
	Loxocarya	fasiculata
	L.	flexuosa
	Lyginia	barbata
	Onychospalum	laxiflorum
	Restio	confertispiculatus
DICOTYLEDONS		
Apiaceae	Xanthosia	pusilla
Asteraceae	*Arctotheca	calendula
	*Hypochaeris	sp.
	Millotia	tenuifolia
	?Podetheca	sp.
Casuarinaceae	Allocasuarina	thuyoides
Crassulaceae	*Crassula	alata
	C.	exserta
	*C.	glomerata
Dilleniaceae	Hibbertia	
Droseraceae	Drosera	glanduligera
	D.	sp.
	D.	subhirlella
Fabaceae	Daviesia	sp.
	Kennedia	sp.
	*Ornithopus	compressus
	*Trifolium	arvense
Goodeniaceae	Dampiera	juncea
	Goodenia	caerulea
	G.	incana

	Lechenaultia	?formosa
Mimosaceae	Acacia	biflora
Myrtaceae	Calothamnus	gracilis
	Darwinnia	vestita
	Eucalyptus	pachyloma
Protaceae	Banksia	sphaerocarpa var.
	B.	sp.
	Hakea	?lissocarpha
	Synaphea	sp.
	S.	favosa
Rubiaceae	Opercularia	vaginata
Rutaceae	Boronia	spathulata
Santalaceae	Leptomeria	aureum
Stylidiaceae	Levenhookia	pauciflora
	Stylidium	repens

APPENDIX 4: Plant species recorded in 1 m^2 plots, SRRV sub-site (identifiable). * exotic species

Family	Genus	Species
MONOCOTYLEDON		
Anthericaceae	Burchardia	umbellata
	Thysanotus	sp
Cyperaceae	Caustis	dioca
	Cyathochaeta	avenaceae
	Lepidosperma	sp.
	Mesomelaena	stygia
	Schoenus	sp..
	S.	subbarbatus
Dasypoganaceae	Lomandra	sp.
Haemodoraceae	Anigozanthos	humilis
	Conostylis	setigera
Orchidaceae	Caladenia	cairnsiana
	Elythranthera	brunonis
	*Monadenia	bracteata
	Pterostylis	sp.
	P.	aspera
Poaceae	Amphipogan	strictus
	A.	turbinatus
	*Avellinia	michelii
	*Bromus	rubens
	*Hordeum	sp.
	*Ehrharta	brevifolia
	*Lolium	rigidum
	Stipa	sp.
	*Vulpia	myuros
Ploygonaceae	Rumex	pulcher
Restionaceae	Hypolaena	exsulca
	Loxocarya	fasiculata
	L.	flexuosa
	Lyginia	barbata
	Restio	confertospiculatus
DICOTYLEDONS		
Asteraceae	*Arctotheca	calendula
	*Gamochaeta	falcata
	*Hypochaeris	sp.
	Millotia	tenuifolia
	?Podetheca	sp.
	Sonchus	oleraceus
Casuarinaceae	Allocasuarina	thuyoides
Crassulaceae	*Crassula	alata
	C.	exserta
	*C.	glomerata
Droseraceae	Drosera	sp.
	D.	subhirlella

Epacridaceae	Andersonia	simplex
Fabaceae	Kennedia	sp.
	*Trifolium	arvense
Goodeniaceae	Dampiera	juncea
	Goodenia	incana
Myrtaceae	Calytrix	flavescens
	Conothamnus	aureus
	Melaleuca	striata
Proteaceae	Synaphea	sp.
Santalaceae	Leptomeria	aureum
Stylidiaceae	Levenhookia	pauciflora
	Stylidium	repens