

**RODENT DAMAGE CONTROL  
IN  
COMMERCIAL FORESTRY  
IN THE NATAL MIDLANDS,  
SOUTH AFRICA.**

**by**

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## ***PREFACE***

The work for, and the preparation of, this thesis were done while the author was a full time student in the Department of Zoology, University of Natal, Pietermaritzburg, from March 1994 to December 1995. Supervision was by Professor Michael R. Perrin.

These studies represent original work by the author and have not been submitted in any form to another University. Where use was made of the work of others it has been duly acknowledged in the text.

Signed: 

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It is unlikely that this work is without error and although I have acknowledged the parts played by other parties, any shortcomings as may exist in this work I fairly claim as my own.

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## ABSTRACT

Rodents cause damage in commercial forests by gnawing at the bark of the trees. It is currently estimated that rodent damage in commercial forestry costs the industry R50 million per annum. The species of rodents which cause the damage are not known, neither is the reason behind this behaviour. Through stomach analysis it has been established that 3 species are involved *Otomys irroratus*, *Rhabdomys pumilio* and *Mastomys natalensis*, however this behaviour is confined to the winter. Chemical analysis of the bark reveals that the percentage concentration of nitrogen varies seasonally. The period of high concentration correlates with periods when the natural food of the rodents is restricted and when bark gnawing is most prevalent. In the past the industry's response to the damage has been to treat the areas with rodenticides. Using standard CMR methods, the two commercially-licensed rodenticides and raptor perches were tested to examine their efficacy as rodent control strategies. It was found that at a lower application of 1 block of rodenticide every third tree there is little difference in the effectiveness of the rodenticide brands and there is also little reduction in the abundance of the rodents. At a higher application rate of 1 block per tree, the abundance of rodents is reduced but termination of the treatment results in the rodent numbers quickly recovering, indeed they surpassed their original population numbers within 4 months. Apart from the environmental dangers of applying such concentrations of poison, this is clearly an uneconomic solution. My results indicate that at first planting, the sites should be provisioned with raptor perches at a density of 16 ha<sup>-2</sup>. Contrary to accepted policy the perches do not require cross pieces, which add to the expense and offer no advantage in raptor residency time. In areas of very high rodent abundance the provisioning of tree collars provide physical protection to the trees. An additional benefit of the collars is that the collars cause a beneficial microclimate around the tree which enhances its growth rate. When the tree is around 2 years old it should be pruned to a height



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of 1 m, the slash being left in the inter-row. Results show that trees treated in such a way experience no further attack and the rodents browse on the prunings. As the cost of the perches is reduced and the cost of pruning is non-recurring the recommendations provide an economical and environmentally sympathetic alternative to rodenticide application.

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## **CHAPTER 1**

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# Chapter 1

## 1 --- Introduction

The origins of the commercial forestry of exotic species in South Africa is directly linked to the discovery of gold in the Sabie-Pilgrims Rest area of the North-Eastern Transvaal in 1895. The demand for pit-props in the mining industry quickly depleted the natural forests and in 1903 the first government plantations were established in the surrounding areas, with initial interest focusing on wattle (*Acacia mearnsii*), eucalyptus (*Eucalyptus* spp.) and pine (*Pinus* spp.) (Hechter-Schulz, 1953). Throughout the century, focus has shifted to coniferous species, in particular *Pinus patula*. By the latter part of the 20th century this species constitutes 56% of the area under softwood cultivation in Natal (Anon., 1988). Convergence on one species has occurred due to a growing consensus amongst silviculturalists that in the near future there will be a world shortage of softwood products, as a result of the "long growing times in northern European climates and increased depletion of the world's natural forests" (Trahar, 1994). The products derived from the timber include sawlogs and a wide variety of paper products, both for the home market and export to Australasia, South America and the Far East as well as other African countries.

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## **1.1 --- Rodent Damage: The Problem**

Shortly after the introduction of exotic tree species, damage by rodents was reported within the plantations (Hechter-Schulz, 1962) and by the early 1940's, the damage in pine plantations had become sufficiently extensive that research into possible methods of rodent control were recommended (Davis, 1942), a recommendation repeated in 1952 (Anon.), 1984 (Willan) and 1993 (ICFR).

Rodent damage takes place between April and December and two distinct types of damage occur depending on the age of the tree. Trees up to 2 years old are gnawed at the base of the trunk, breaching the cambial layer, which leads to the tree's death. In the past the forestry industry believed that trees surviving until their third year were clear of danger, however, Willan (1985) reported damage to trees up to 8 years old. Damage to older trees begins at the lower lateral branches which are stripped of their bark. The rodents then use these branches as "ladders" enabling them to attack the laterals further off the ground, they may then de-bark the trunk. This damage is rarely fatal but may lead to abnormal growth, especially if the higher trunk is attacked, severely reducing the commercial value of the tree at harvesting. Droomer (1985) has shown that bark stripping by samango monkeys (*Cercopithecus (mitis) albogularis*) causes resin staining and deformation on recovered boards, resulting in the loss of both volume and economic value. A similar conclusion was reached by Gill (1992a) in a review of damage by mammals in northern temperate forestry.

The benefit the rodents derive from this activity is unknown, however Bigalke and van Hensbergen (1990) have shown that starch levels in pine bark increase in winter and suggested this as a possible reason for baboons (*Papio ursinus*) switching to pine bark during that season. Atkinson

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(1993a) speculated that the same reason may prevail in the case of rodents, although he also suggests that lack of moisture in the winter may be the cause of the rodent's dietary change.

Apart from the seasonality of the damage no other pattern or factor has emerged which explains the behaviour. Atkinson (1993b) observed that the damage is principally associated with areas of first conversion from grassland to forest, yet Hechter-Schulz (1962) has suggested that plantings most affected are second rotation sites where the original vegetation was wattle. Willan (1992) has suggested that damage predominates on south or south-east facing slopes, whilst Hurd (1993) has argued that damage is greatest on west and east-facing slopes. Hechter-Schulz (1962) has suggested that the amount of damage is a function of the density and height of the understorey vegetation and that trees coexisting in areas with thick matted grass are most vulnerable to damage.

In economical terms it is difficult to evaluate the costs incurred by the industry from rodent damage, however, Willan (1992) estimated that it may be as much as R50 million or 7% of the gross forestry income. Three rodent species are suspected of causing the greatest proportion of this damage, the four-striped fieldmouse, *Rhabdomys pumilio* (Sparrman, 1784), the multimammate mouse, *Mastomys natalensis* (A. Smith, 1834)<sup>1</sup> and the vlei rat, *Otomys irroratus* (Brants, 1827) and many attempts have been made to control the number of these species within the forest environment.

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<sup>1</sup> The Multimammate mouse is classified by De Graaff (1981) as in the genus *Praomys* and sub-genus *Mastomys*. Meester et al. (1986) distinguishes two closely related species within the *Mastomys* complex *M. natalensis* and *M. coucha*. These species can only be identified by karyotypic or behavioural methods. Field identification is therefore impossible. For the purposes of this study the complex will be referred to as *M. natalensis*.

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## **1.2 --- Rodent Damage: A Brief History of Control Attempts**

Rodent damage control can be divided into two broad domains. The older and more established view is that damage control is best attempted through control of the rodent population within the forest plantation. An alternative perspective is to develop a method to ecologically isolate the prey, in this case the trees, from the predators.

The history of rodent control as a coherent policy began in 1962 when Hechter-Schulz recommended the use of rodenticides placed at bait stations within areas of optimum habitat. He argued that 22 bait stations per hectare should be maintained from January until late August and rodent deaths around the stations would cause a biotic vacuum. This would result in continuous rodent immigration to the stations, these animals being, in turn, killed by consuming the rodenticide. Thus the overall rodent density would be reduced as would the incidence of damage within the forest. The original proposed rodenticide was "Warfarin", an anticoagulant, and although this product has been replaced (See Chapter 3), rodenticides are still the principal means of rodent control in forestry. Apart from Wirminghaus and Schröder (1994), who tested the efficacy of a single rodenticide over six weeks, no published evidence exist on the effectiveness of rodenticides as a means of controlling rodents in South African forestry.

The second most widely used method of control is predation by both diurnal raptors and nocturnal owls. To this end most commercial forests are provisioned with raptor perches at first planting, in the hope that the birds will keep rodent numbers in check. Again no published data exist to support this supposition in South Africa and the practice seems to be based largely on inference or results from the Northern Hemisphere.

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The concept of the biotic vacuum has recently been resurrected by Willan (1984 and 1992). He suggests that, as an alternative to rodenticide, the vacuum could be formed by concentrated live trapping at permanent trapping stations followed by the selective removal of pest species.

Some rather esoteric control methods have also been implemented. Each of these methods share a common fate; subsequent to the trial, no results exist. Davis (1942) suggested that in the Natal Midlands, the understorey vegetation be controlled by cultivation of the inter-row with mealies (*Zea mays*), local women being employed for this purpose. In the Boston area of the Natal Midlands the forest manager distributed snaptraps to school children, who were encouraged to trap rodents as a food source (Pers. obs.). Cellarius (1993) released 79 pythons on the Entabeni State Forest in the Northern Transvaal between 1984 and 1989, while Parker (1993) released 8 domestic cats on the De Magtenburg Estate in the Natal Midlands.

Attempts at ecological isolation in South Africa are rare and consist exclusively of painting or spraying substances or mixtures directly onto the trees. The intention is that these applications will either provide a chemically noxious barrier or a physical barrier which the rodents are unable to breach (MacKellar, 1952). Substances which have been used on the trees include, eggs mixed with acrylic resin in water (Hurd, 1993), cow dung (after Jarman, 1992), pig manure (Hurd, 1993) and black bituminous paint (Parker, 1993). In the latter case the paint resulted in 20% mortality of the trees. Novellie et al. (1982) tested predator urine as a possible repellent but found no evidence to suggest that urine presence deterred rodents.



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### **1.3 --- Rodent Damage: A Perspective from World Forestry**

Rodent damage to trees within forestry plantations is not exclusive to South Africa and although the species of trees and rodents may differ, many incidents of damage have been reported worldwide depending on the planting method.

In Canada, broadcast sowing of seeds is the preferred planting method and seed predation by rodents is a major problem. Sullivan and Sullivan (1982) report that at sowing rates of 45000 lodgepole pine seeds  $\text{ha}^{-1}$  in British Columbia, 85% of the seeds had been destroyed by rodent predation within 3 weeks. The predation rate was significantly reduced by applying sunflower seeds at 90000 seeds  $\text{ha}^{-1}$  with the tree seeds.

Diet supplementation has also significantly reduced incidents of ring barking in China, where the most popular sowing method is the planting of seedlings (Sullivan et al., 1991). In New Mexico, protecting the trees from the rodents with tree collars proved to be unsuccessful (De Velice et al., 1981) and although severe burning of the organic layer initially reduced rodent abundance in Montana, abnormally large population increases occurred after two years (Halvorson, 1982). A similar trend is reported from Germany where weed control did not cause a prolonged reduction in the rodent population (Baumler, 1992a).

As in the South African experience, the principal control method on a world scale is the use of rodenticides and many studies exist in the literature, either reporting new toxic chemicals or their efficacy after short trials, e.g. in India (Srivastava, et al., 1989; Saxena, et al., 1990, 1991), Germany (Baumler, 1973; Schroder, 1990), Japan (Nakata et al., 1993) and Chile (Murua & Rodriguez, 1989). Whilst many of these studies report successful reductions in rodent populations, only the latter study considered the implications of stopping the treatment and showed that complete recovery of the population occurred within 4 months of termination. Additionally,



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Baumler et al. (1989) speculated that particular rodenticides may be species' specific and therefore *may* be ineffective against the target species.

### ***1.4 --- Aims of the Present Study***

The principal aim of this study was to develop a coordinated method of reducing the damage caused by rodent browsing on commercially grown trees in the Natal Midlands South Africa, which is both economically and ecologically sustainable. From this aim a number of specific objectives were addressed:

- 1 ... Establish which rodent species are responsible for the damage caused.
- 2 ... Establish the ecological reasons for the rodents' apparent dietary switch which results in damage to the trees.
- 3 ... Compare the relative efficacy of the commercially licensed rodenticides available in South African forestry.
- 4 ... Assess the use of raptor perches as a viable rodent control measure within the forestry environment in the Natal Midlands.
- 5 ... Investigate methods of isolating the rodents from the trees.
- 6 ... Compare each method of damage reduction and produce recommendations which will meet the criteria of economic and ecological sustainability.

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## ***1.5 --- Conclusion***

It is illustrated that rodent damage within South African forestry is a severe economic problem, has existed for most of this century and methods of controlling the damage either lack data retrieval or remain suggestions which have yet to be tested. For any pest control to be successful it must first target the pest species, and secondly, it must be both ecologically and economically viable. Therefore the aim of the present study was to devise a method of eradicating the damage caused by rodents within the forestry plantations which met these criteria. The first objective was to identify the species responsible for the damage.

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## **CHAPTER 2**

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## **Chapter 2**

### **Sites and Methodology**

#### ***2.1 --- Introduction***

Chapters 3 to 6 of this study deal with rodent control and cover objectives 1 to 4 of chapter 1. As this section of the study involves a long term experiment which contains common experimental sites and aspects of experimental approach, it is appropriate in this chapter to describe the common methods. Any additions or changes to the experimental design are given in the relevant chapters, where enhanced clarification of terms are also given as required.

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## 2.2 --- Experimental Sites

Two experimental plots at each of two study sites were identified as the areas have suffered similar and extensive rodent damage to commercially planted trees in the past. Both sites are planted with *P. patula* at a density of 1100 trees ha<sup>-1</sup> at regular spacing.

Goodhope Estate is situated at 29° 42'S and 29° 55'E, 5 Km. west of Boston and approximately half way between Howick and Bulwer in the Natal Midlands. The estate is owned and managed by Mondi Forests South. Of the two plots selected at Goodhope, one has an easterly aspect and is a conversion site from grassland to pine forestry. The second plot is generally flat and is a conversion site from wattle scrubland to plantation. The trees at both sites were 3 years old at the commencement of the study.

Briarmains Estate is situated at 29° 13'S and 29° 38'E, approximately 20 Km. west of the Natal Midlands town of Mooi River and east of the Southern Natal Drakensberg Mountains. Both plots are generally flat, however there is an age difference in the trees with one plot being planted in 1992 and the other plot a year later. Briarmains Estate is also owned and managed by Mondi Forests South, Natal.

Figure 2.1 gives the map locations of both sites in relation to major landmarks.

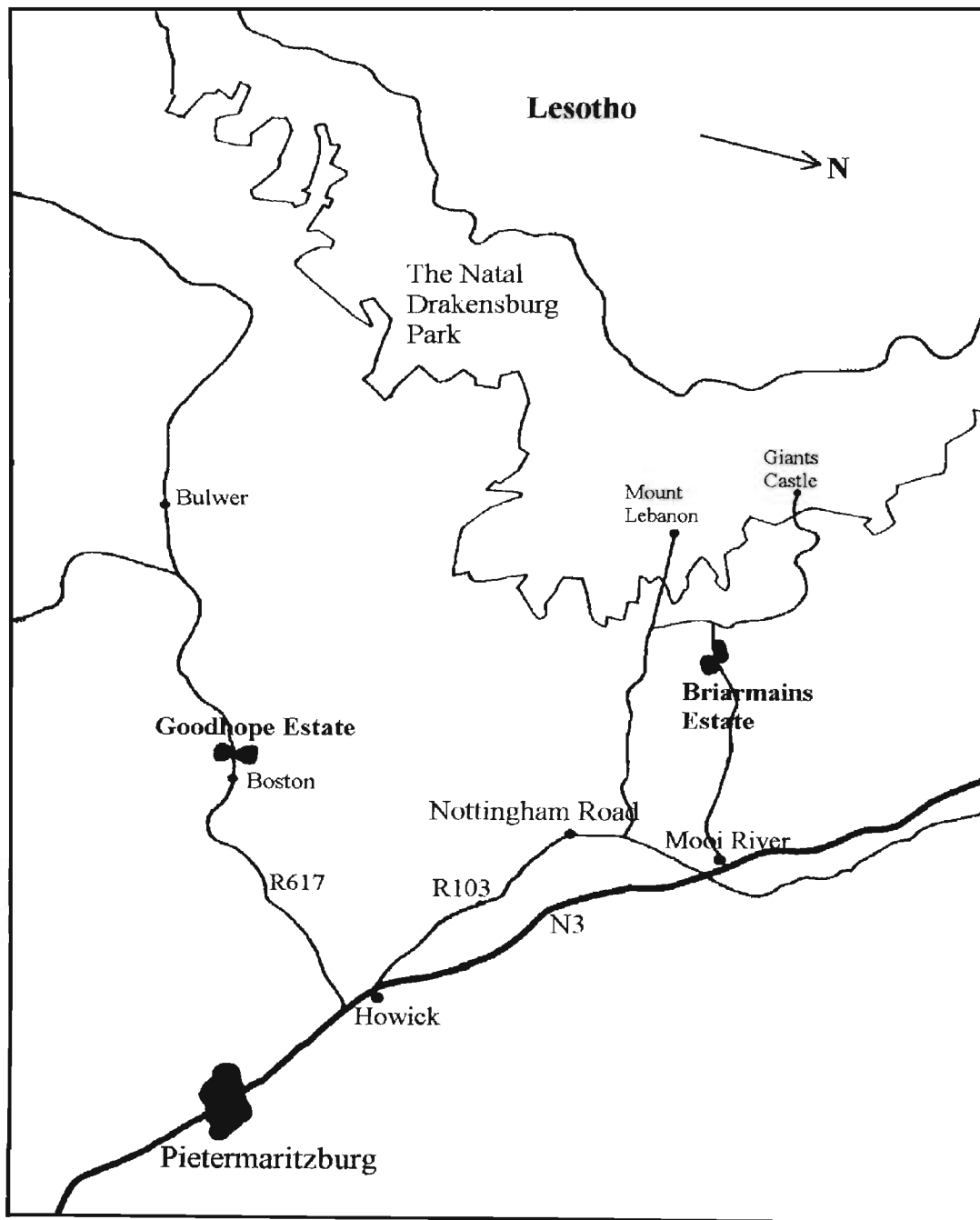


Figure 2.1: The Natal Midlands. Briarmains Estate lies to the west of Mooi River. Goodhope Estate lies on the R617 to the west of Pietermaritzburg.

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## **2.3 --- Control Methods**

The efficacy of rodenticide and raptor perches as forest rodent control methods were assessed using five trap lines at each of the four replicated plots. The trap lines were marked off following the hill gradient, if any, and assigned a different rodent control method. For the purposes of this study a trap line was defined as including the trap line plus the tree line on either side of it. Two types of commercially available multi-dose, anticoagulant rodenticides were used, “Racumin” and “Tornado”. The latter rodenticide being used at 2 different densities, 1 block per tree and 1 block per 3 trees. An untreated control line was then used to separate the chemical control lines from a trap line where raptor perches were erected at 25 m spacing along the length of the line. The spacing, general layout and method of rodenticide application on each plot is summarised in Figure 2.2.

Whilst it is recognised that it is usual to execute a Randomised Block Design for such treatments, the use of rodenticide necessitated that the areas where chemicals were being used be kept apart from areas where raptors and owls were being encouraged to hunt. The rodenticide blocks were placed within bamboo tubes, in an attempt to reduce the chances of non-target vertebrates consuming the blocks. With the exception of the trap line where rodenticide was applied at one block per tree, the rodenticide was replaced as necessary on a monthly basis.

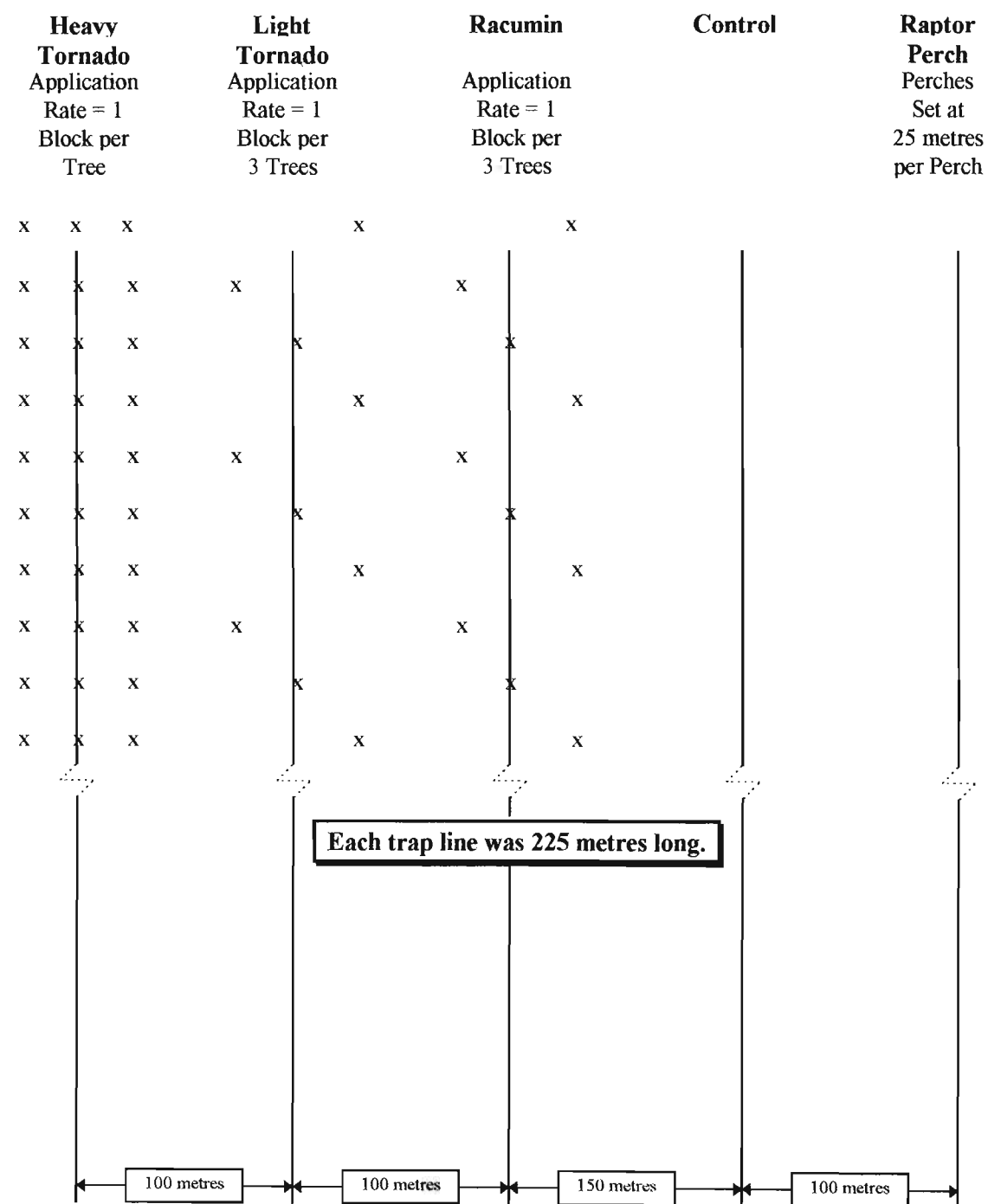


Figure 2.2: General Layout of the Treatments at each Site, where x represents the distribution of the rodenticide application. Note broken line signifies that the drawing is not to scale.



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## **2.4 --- Trapping Methods**

### **2.4.1 --- Trap Placement and Maintenance**

The relative abundance, species composition and intraspecific demography of rodents within the plantations was assessed using standard Capture-Mark-Recapture (CMR) methods. Trapping began in August 1994 and ended in August 1995.

On each trap line 15 trapping points were set at 15 m intervals. Each trapping point was assigned a reference number and permanently marked by way of barrier tape attached to trees, with the corresponding reference number written in indelible ink. Two traps were placed at each trapping point (Chitty and Kempson, 1949) resulting in 30 traps per line. Of these, 27 were live box traps and 3 were breakback snap traps, the latter being randomly distributed throughout the trapping points. All traps were provisioned with a mixture of rolled oats and peanut butter (Dippenaar, 1974). Traps were not prebaited as the effect of prebaiting is not known (Flowerdew, 1976) and were in place for four consecutive days per calendar month at each plot. The traps were examined each morning and if necessary, reprovisioned. Additionally, any debris or excreta was removed from the trap at this time. Both Rowe (1970) and Boonstra and Krebs (1976) suggest that a positive correlation exists between trapping success and conspecific odour and Willan (1982) suggests that this is the case with *R. pumilio*, although he also suggests that overall trap efficiency may be impaired by the odour of *M. natalensis*. Therefore, in the face of contradictory views it was decided that at no time during the study would the traps be washed, particularly as the traps were not in use at intervals of upto three weeks between trapping periods. During these times odours were minimised by leaving the traps under cover in the open air.

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### **2.4.2 --- Data Collection**

From each trapped individual the following information was noted:

- the date of capture
- the position on the trap line
- the species of the animal
- whether the animal was previously marked
- the body weight to the nearest gram, using a Pesola Spring Balance ( 2 PSBs were used, a 100 g and a 300 g)
- the tail and body length to the nearest mm
- Any remarks concerning the animal (presence of blue stained faeces from rodenticide, multiple captures in a single trap....)
- the animal's reproductive condition

Finally, if unmarked, the animal was marked and released at the point of capture. As most of the above points are straightforward they need no further explanation. However, decisions were taken concerning the measurement of body length, the marking method and the method of ascertaining the animal's reproductive condition, it is therefore appropriate that a fuller discussion of how these decisions were taken be presented.

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### **2.4.3 --- Body Length Measurement**

The body length was measured to facilitate mass to length ratios which give an indication of body condition. However, as a result of its flexible spine a live rodent is extremely plastic in body shape and difficulties therefore arise in definitively measuring body length. In this study the following method was used. Captured animals were emptied from the trap into a plastic bag. The bag was then rested on my left thigh and using my flattened left hand the animal was then gently pushed against the base of the bag. The body length was then taken using a 30 cm Rabone Steel Ruler to the nearest mm.

### **2.4.4 --- Body Condition**

An assessment of the body condition was made by the division of the body length by the body mass, giving units of  $\text{mm gm}^{-1}$ . This measurement was not calculated for females, due to the possibility of the female being pregnant resulting in bias of the estimation.

### **2.4.5 --- Marking Method**

Toe-clipping is the most common marking method for small mammals (Leirs, 1994), however, this method was not used in this study. Marking by tissue removal in the UK is now regulated under the Animals (Scientific Procedures) Act of 1986 and requires a licence from the relevant government authority and although this study was done outside the UK, a personal, ethical choice was made. Whilst, Korn (1987) has shown that toe-clipping has no detrimental effect on the subsequent weight gain of the clipped animal, Fairley (1982) has suggested that toe-clipping may reduce the probability of the marked animal re-entering the trap while Fullagar and Jewell (1965) suggested that the removal of more than one digit from any limb may impede an individual animal's ability to groom itself, thus exposing the animal to increased pest infestation. This could have important detrimental effects during a relatively long term recapture study.

Various other marking techniques were considered. Leg rings have been shown to be ill-suited to small mammal work (Fullagar and Jewell, 1965). Le Boulenge-Nguyen and Le Boulenge (1986) successfully used ear tags but Taylor (1993) found them to be difficult to use in the field and in preliminary observations of captive, laboratory *R. pumilio* the retention rate was very low. The presence of an ear tag seemed to promote aggressive behaviour on the part of cohabitees. The aggression centred on the tag with the result that the tag, in many cases was removed after a few hours.

Therefore the marking method employed was fur clipping (Gurnell & Flowerdew, 1990). The advantages of this method are that it is quickly applied in field conditions, the animals do not suffer undue stress and the mark is not permanent, the fur growing back at the conclusion of the study. Gurnell and Flowerdew (1990) claim that the clip remains visible for six months but it is a simple

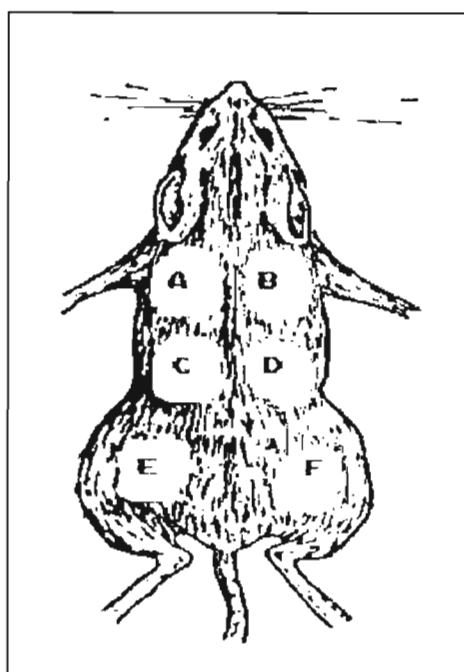


Figure 2.3: Fur Clip Marking Method  
(After Gurnell & Flowerdew, 1990)

matter to renew the clip upon recapture, thus extending the visibility time of the mark indefinitely. From the six basic marks (Fig. 2.3) it is possible by using combinations of up to five fur clips to individually identify 56 animals and through sexual discrimination the individual tally can be doubled. It should also be remembered that this allows for 112 marks for each species. A seventh fur clip is possible in the case of *R. pumilio*. Due to the morphology of the species it is possible to clip across the stripes, resulting in 90 possible combinations of 6 marks. It was however, realised that allowing 112 marks per species, or 180 in the case of *R. pumilio*, would be insufficient for the length of the study, even though the treatments were designed

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to reduce the populations. Therefore a complete set of marks was allocated to each line and the morphological dimensions and sex of any recaptured animals was closely compared with any animal bearing the same mark. Wide use was also made of any individual distinguishing marks, e.g. bald patches on the nose, blind in one eye etc. To further reduce the number of identification marks it was assumed that if an animal had not been recaptured for four months on any of the treated lines, it had succumbed to the rodenticide or been taken by a predator and the mark was reused. Although the system is rather cumbersome, it worked well and I am confident that no confusion arose in the identification of specific individuals.

#### **2.4.6 --- Recaptures**

An animal was considered a recapture if the same animal was recaptured in a second or subsequent trapping period. Animals captured more than once during the same trapping period were merely noted as such.

### 2.4.7 --- Ascertaining Sexual and Reproductive Condition

In his definitive study of the ecology of *O. irroratus*, *M. natalensis* and *R. pumilio*, Willan (1982) identified 6 castes of individuals. These and the physical determinants which distinguish them are summarised in Table 1.

Caste	Reproductive Condition	Mass of <i>O. irroratus</i>	Mass of <i>R. pumilio</i>	Mass of <i>M. natalensis</i>
Scrotal Male	Testes Fully Developed and Descended	≥ 90 g	≥ 35 g	≥ 35 g
Non-Scrotal Male	Testes Undescended, not Fully Developed	≥ 90 g	≥ 35 g	≥ 35 g
Perforate Female	Vaginal Orifice Open	≥ 90 g	≥ 35 g	≥ 35 g
Imperforate Female	Vaginal Orifice Sealed	≥ 90 g	≥ 35 g	≥ 35 g
Sub-Adult	Either Sex: Below Sexual Mass and Above Juvenile Mass	50 - 89.9 g	25 - 34.9 g	25 - 34.9 g
Juvenile	Either Sex: Below Sub-Adult Mass	< 50 g	< 25 g	< 25 g

Table 1.1: The Physical Determinants used by Willan (1982) to Ascertain Sex and Reproductive Castes.

With one exception, the same physical determinants to ascertain sex and reproductive condition were used. Reproductive males were distinguished from non-reproductives on the basis of whether the testes could be palpated into the scrotal sac, if this was the case then the animal was classified as reproductive (Brooks, 1974). It should be remembered however, that Brant (1962) has shown that temperature may vary the position of the testes. Everett (1961) and Marais (1974) have respectively demonstrated that ovulatory perforation or post-copulatory fusion can occur in female rodents, thus casting doubt on the condition of the vaginal orifice as a reliable indicator of reproductive condition. However I used the method outlined in Table 1 to distinguish between reproductive and non-reproductive females as it was generally reliable for *R. pumilio* (Brooks, 1974) and Willan (1982) used this method to identify the reproductive condition of *O. irroratus*, *M. natalensis* and *R. pumilio*. Many authors (e.g. Taylor & Green, 1976; Liers, 1994) have



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classified females as lactating or pregnant. Brooks (1974) proposed that expressing milk from the mammae is an unreliable field test of lactation and Macsroch (1954) suggested that palpation is an unreliable indicator of pregnancy, therefore classification of an animal as being pregnant was not used in this study, except when the animal was dissected and identified as such. In this study, whether an animal was classified as adult or juvenile was based purely on weight (See Table 1).

Willan (1982) employed a sixth classification of animal, the sub-adult. This classification was not used here as it is possible to sex sub-adults. Also, the classification is based on the individual falling within a prescribed weight range. It could therefore be possible for a well-fed sub-adult to be identified as an adult or an ill-fed adult as a sub-adult. This limitation can also be applied to the threshold between an adult and a juvenile, however it was felt that recognition of the juvenile stage was an important indicator of the species' breeding cycle.

## **2.5 --- Statistical Analysis**

In order that numbers of trapped animals could be compared over treatments, the absolute numbers of rodents caught were transformed into relative numbers by division of the total captures by the unit effort, in this case the sum of the number of traps and the numbers of nights they were in place each month, the trap night.

Although trapping continued from August 1994 until August 1995, no animals were captured at Briarmains Estate during August 1995. This was associated with a heavy infestation of the Black Pine Aphid (*Cinara cronartii*, Tissot & Pepper) on the trees. It is unimaginable that the animals had simply disappeared on this Estate and the results were inconsistent with previous months' captures, therefore, the trapping results from August 1995 at Briarmains were not considered in the analysis.

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## **CHAPTER 3**

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## Chapter 3

### ***Identification of the Rodent Species Involved in Damaging Trees.***

#### ***3.1 — Introduction***

Since the first recognition of rodent damage in South African forestry plantations two species have been suspected as being responsible, *R. pumilio* and *O. irroratus*, (Willan, 1984, 1985 and 1992). Davis (1942) reported observing these species gnawing *Pinus caribaea* and *Cupressus lusitancia* diurnally and suspected the same species were involved at night. Hechter-Schulz (1962) snap-trapped rodents after treating trees with a coloured dye. Of the *R. pumilio* caught and dissected, 21% contained stained material in the stomach, whilst no dye was found in the stomachs of *O. irroratus*. Nevertheless, he produced circumstantial evidence implicating *O. irroratus* in the damage to trees. Rowe-Rowe (1986) noted signs of *O. irroratus* feeding on the bark of the shrub, *Ouhout (Leucosidea sericea)* and also reported bark in the stomach of this species. Recently, it has been suggested that a third species, *M. natalensis* may also be a potential threat to trees (Wirminghaus and Schröder, 1994).

It is clear, that although rodents certainly cause damage within plantations of *Pinus patula*, there is a general paucity of evidence implicating any particular species. Therefore, a number of hypotheses were tested through stomach content analysis of animals taken from a short term removal study and the long term study.

The objective of the short term removal study was to identify which rodent species were present and to confirm their dietary preferences. This study also tested the hypothesis that all rodents in an area are involved in gnawing bark. If that hypothesis was rejected, a further hypothesis was

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considered, i.e. that there is a measurable physical characteristic which differentiates culprits from animals which do not eat bark. The existence of such a parameter would be a useful determinant in the control of rodents through selective removal after live trapping.

From stomach content analysis of snap trapped animals and "live trap deaths" during the long term study, an attempt was made to positively identify the target species. Additionally, evidence that gnawing trees is a seasonal behaviour was also investigated.

## **3.2 --- Study Area and Methods**

### **3.2.1 --- Short Term Removal Study**

The short term removal study was carried out between the 6th and 9th June 1994 on a 2.5 ha site at Goodhope Estate. The severity of rodent attack at this site forced the Estate forester to abandon the area as a commercial concern (Richardson, pers. comm.). A grid 35 m by 63 m was laid with 2 Elliot live traps at 7 m spacing. The traps were in place for three days. The grid contained 336 (21 x 16) tree plantings of *P. patula*, with extensive ground vegetation cover. Signs of fresh rodent activity were evident, i.e. runways, cut grass and droppings. Traps were baited with a peanut butter and oats mixture and checked every 2 h from dawn until dusk. On day four the Elliot live traps were replaced with one snap trap at each trapping point and checked every 2 hours.

### 3.2.2. — Stomach Content Analysis

All snap-trapped animals and live trap deaths from the long term study were collected in individually marked collecting bags and removed to the laboratory. The stomach was then dissected

out and weighed before being fixed in

10% formalin overnight. The contents were then removed and nine dietary categories were identified (Table 3.1).

The bait remnants, which in most cases provided the bulk of the

Dietary Category	
Senescent material	Brown grass stems and seed endosperm
Green material	Fresh, green grass stems
Pine needles	
Arthropods	Beetles, spiders etc.
Bark	
Hair	Single strands
Hair clumps	Clumps with skin still attached
Parasitic worms	Counted and fixed in formalin
Bait remnants	

Table 3.1: The dietary categories identified from stomach content analysis

stomach contents were easily recognised

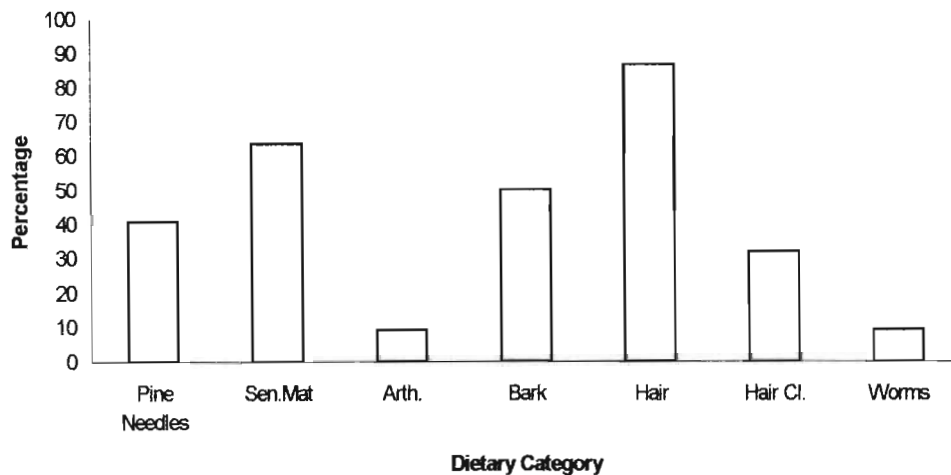
and discarded. The residual contents were rinsed through a 125  $\mu\text{m}$  sieve and stained with Ehrlich's hematoxylin (Culling, 1974) before being transferred to a standard Petri dish for examination under a dissecting or compound microscope when necessary. As the aim of this study was to identify whether the animals ate bark, no attempt was made to quantify the relative volumes of each dietary category. For the same reason the complete dietary contents, are not given, except in the case of the short term removal experiment. The presence of pine needles in stomachs indicates that the animal had recently browsed on the leaf litter which accumulates at the base of trees which have recently been gnawed. In some cases, after the removal of the bait material no other stomach contents were found and this *is* reported.

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### 3.3. --- Results

#### 3.3.1. --- Removal Trapping

Twenty-two animals were snap trapped on the 9th June 1994 all of which were *R. pumilio*, comprising 19 males, two females and one juvenile. Figure 3.1 shows the percentage of specimens which contained evidence of each dietary category.



**Figure 3.1: The frequency of occurrence of dietary material found by stomach content analysis as a percentage of the stomachs dissected,  $n = 22$ ; where Sen. Mat = senescent material, Arth. = arthropods and Hair Cl. = hair clumps.**

Of the total number of stomachs analysed, 50% contained bark. The physical parameters of bark consumers ( $n = 11$ ) was compared using a t-test with animals which showed no signs of tree browsing ( $n = 11$ ). No statistically significant difference was found in any of the comparisons ( $df = 20$ ) (Table 3.2).

Physical Parameter	Mean Browser	Mean Non-Browser	t-Statistic	Significance
Body Mass (gms)	38.45	41.45	-0.832	N/S
Body Length (mm)	87.55	92.18	-0.832	N/S
Tail Length (mm)	76.5	73.6	1.024	N/S

**Table 3.2: T-test comparison of measureable physical parameters of live non-browsing and browsing *R. pumilio*.**

Therefore the hypothesis that live browsing individuals can be distinguished from live non-browsing individuals by some measurable physical characteristic is rejected.

### **3.3.2. --- Long Term Trapping**

Five species were caught in sufficient abundance to facilitate investigation into whether they browsed on the plantation trees. The forest shrew, *Myosorex varius* (Smuts, 1832) was a common capture in live traps but frequently did not survive confinement. Analysis of the stomach contents of these live trap deaths showed no signs that the animals had been browsing.

The most common species captured was *R. pumilio* ( $n = 116$ ). The incidence of bark contained within stomachs is given as Figure 3.2. Polynomial trendlines were subsequently fitted to the time series and the coefficient of determination ( $r^2$ ) was determined. A very strong positive correlation existed between the incidence of browsing and the time of year (bark present,  $r = 0.860$ ,  $n = 11$ ,  $p < 0.01$ , no bark present,  $r = 0.923$ ,  $n = 11$ ,  $p < 0.01$ ) (Figure 3.3).

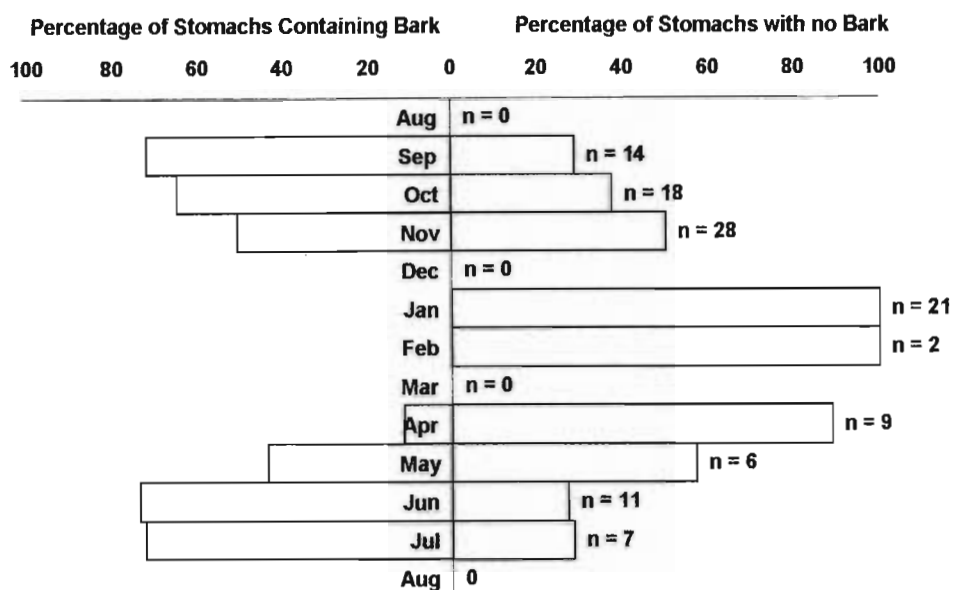


Figure 3.2: The incidence of bark within the stomachs of *R. pumilio* between August 1994 (top) and August 1995, expressed as a percentage of the total number of stomachs analysed per month for that species (n).

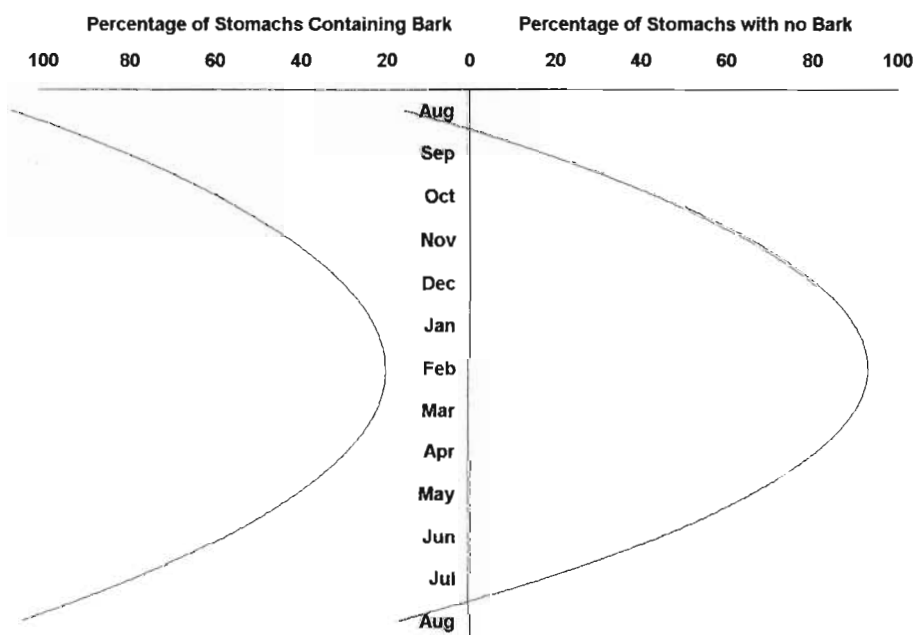


Figure 3.3: Second order polynomial trendline fitted to the data from figure 4. The lack of captures in March and December have not been included in the calculation. For the lefthand side, the coefficient of determination,  $r^2 = 0.739$  and for the righthand side  $r^2 = 0.852$ .

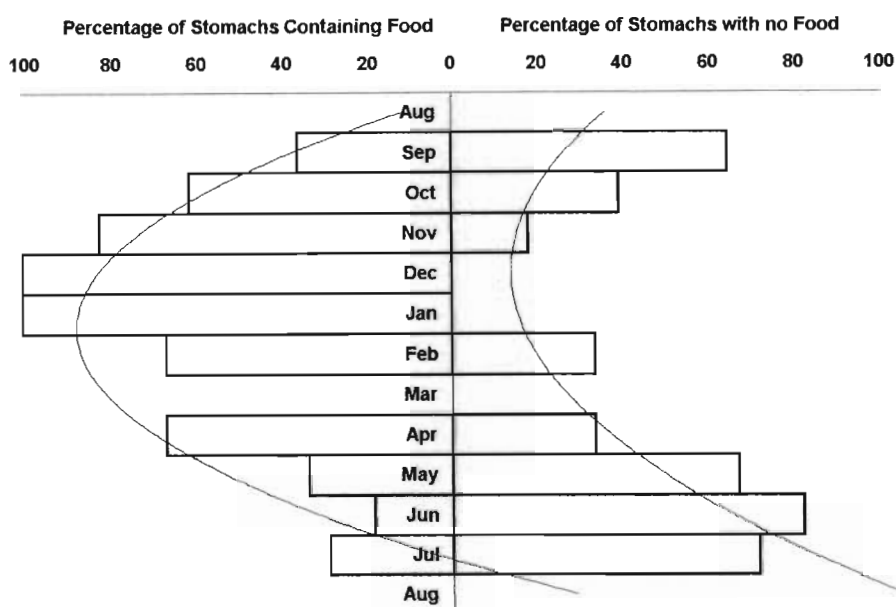


Figure 3.4: The occurrence of food (excluding bark and bait material) in the stomachs of *R. pumilio* between August 1994 (top) and August 1995, expressed as a percentage of the total number of stomachs analysed per month for those species ( $n$ ). The lack of captures in March has not been included in the calculation of the fitted second order polynomial trendline. For the lefthand side, the coefficient of determination,  $r^2 = 0.795$  and for the righthand side  $r^2 = 0.510$ .

After removal of the bark and bait material, the number of *R. pumilio* stomachs containing no food was counted (Figure 3.4). Again a strong positive correlation existed between the occurrence of food and the time of year (food present,  $r = 0.892$ ,  $n = 12$ ,  $p < 0.01$ ; no food present,  $r = 0.714$ ,  $n = 12$ ,  $p < 0.05$ ).

There was also a significant positive cross correlation between the incidence of bark and the absence of food ( $r = 0.839$ ,  $n = 12$ ,  $p < 0.01$ ). This is mirrored by a slightly less significant cross correlation between the non-occurrence of bark and the presence of food ( $r = 0.589$ ,  $n = 12$ ,  $p < 0.05$ ) indicating that in this species it is a lack of food which induces a seasonal dietary switch towards the bark of the trees.

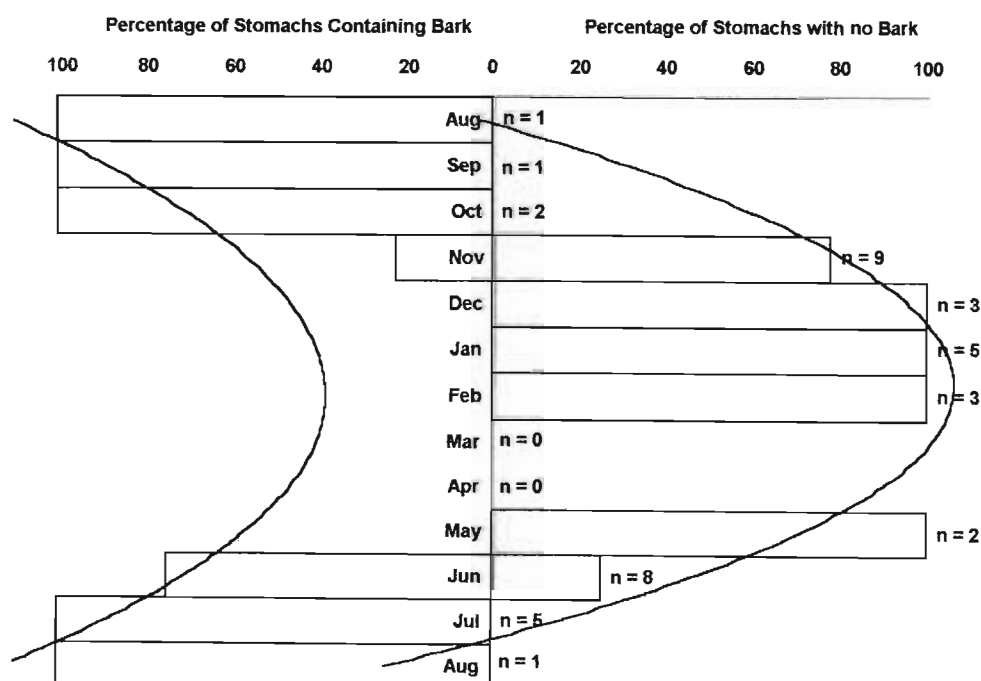


Three other species were commonly captured, although in relatively small numbers; *M. natalensis*, *O. irroratus* and the Highveld Gerbil, *Tatera brantsii* (A. Smith, 1836). No evidence of bark was

Species	n	Bark
<i>M. natalensis</i>	27	10
<i>O. irroratus</i>	12	8
<i>T. brantsii</i>	37	0
Total	76	18

**Table 3.3: The incidence of bark within the stomachs of *M. natalensis*, *O. irroratus* and *T. brantsii* during the duration of the study.**

found in the stomach of the latter species (Table 3.3), although 75.7% of all stomach's contained pine needles. To investigate the seasonal browsing trend of *M. natalensis* and *O. irroratus* the cumulative monthly captures were calculated (Figure 3.5).



**Figure 3.5: The incidence of bark within the stomachs of *M. natalensis* and *O. irroratus* between August 1994 (top) and August 1995, expressed as a percentage of the total number of stomachs analysed per month for those species (n). The lack of captures in March and April have not been included in the calculation of the fitted second order polynomial trendline. For the lefthand side, the coefficient of determination,  $r^2 = 0.506$  and for the righthand side  $r^2 = 0.870$ .**



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A strong positive correlation exists when comparing specimens with no bark in the stomachs to the month of the year ( $r = 0.933$ ,  $n = 11$ ,  $p < 0.01$ ). While a less, but still significant correlation is shown between the presence of bark and the time of year ( $r = 0.711$ ,  $n = 11$ ,  $p < 0.05$ ).

Much has been written on the difficulty of catching *O. irroratus* in traps (e.g. Willan, 1992) and although this will be discussed further in later chapters it is opportune to point out that only 12 individuals of this species were snap-trapped and 8 of them had been browsing on bark (Table 3.3).

It may be inferred that *R. pumilio*, *M. natalensis* and *O. irroratus* are all implicated in gnawing the bark of commercially planted trees and that this activity is significantly linked to season. Further, a significant positive cross correlation exists between this behaviour and the presence of other food items in the stomachs of *R. pumilio*.

### **3.4. --- Discussion**

Of the five species commonly captured, *M. varius* and *T. brantsii* are discounted as above ground forest pests. The former is an obligate insectivore (Skinner & Smithers, 1990), whilst the latter is entirely terrestrial and unable to climb. Indeed, many captured individuals were released onto the lower branches of a tree above the point of capture where they showed a complete inability to negotiate their position. Although they were able to cling to the branch, the first attempt at movement always resulted in a loss of balance and the animal immediately fell to the ground. Curtis and Perrin (1979) concluded that this species is a generalist omnivore and although over 75% of individual stomachs contained pine needles, no evidence was found that this species gnaws

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at the bark at the base of the trunk. Therefore, it is probable, given the species lack of climbing ability, that the needles were obtained from the leaf litter at the base of the trees.

Earlier studies have described *R. pumilio* as a granivore (Brooks, 1974), predominantly a granivore (Rowe-Rowe, 1986) and a herbivore (Kingdon, 1974). These views have been disputed by Curtis and Perrin (1979) and Perrin and Curtis (1980) pointed out that the species' digestive tract is typical of an omnivore. Perrin (1980b) described the species as a generalist omnivore which lives on high-energy and high-protein content diet when it is available, however in winter the species reverts to a low quality diet. At this time the species is relatively tolerant of periods of food shortage (Willan and Meester, 1987).

*M. natalensis* is a granivorous omnivore (De Graaff, 1981), which has not evolved mechanisms to survive periods of food shortage (Willan and Meester, 1987) and is adapted to disturbed habitats where it is subject to little interspecific competition (Meester et al., 1979). Nevertheless, Wirminghaus and Perrin (1992) found that *M. natalensis* and *R. pumilio* were the two most common rodent species within in a temperate forest of Natal and reported that *M. natalensis* had a significantly seasonal diet, which included stems and leaves during the autumn and spring. Although relatively few of this species was captured, the results confirm that both *M. natalensis* and *R. pumilio* undergo a seasonal dietary switch and that during times of food shortage, they supplement their diet by gnawing at tree bark.

The situation with regard to *O. irroratus* is slightly different, as in laboratory tests Curtis and Perrin (1979) showed that the preferred diet of this species was large quantities of grasses and stems. Perrin and Curtis (1980) confirmed that it is predominantly herbivorous and that the dentition and caecum are adaptations to a fibrous diet. The species is therefore more selective than *R. pumilio*, with which it coexists, specialising in permanently available low quality food (Perrin,

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1980b). It is perhaps not surprising then that *O. irroratus* gnaws at the bark of the plantation trees. However, again this behaviour was restricted to the winter months.

### **3.5. --- Conclusion**

It can be concluded that three species, *R. pumilio*, *M. natalensis* and *O. irroratus* are involved in the seasonal browsing of the bark of commercially planted trees. The browsing is correlated to season. No browsing seems to occur during the summer therefore, bark cannot be considered a preferred food item for any of these species. The browsing on bark seems to be prompted by other factors. Either the preferred dietary items are restricted or seasonal chemical changes in the bark renders it more nutritious in winter. From the stomach content analysis, the majority of individuals are involved in the behaviour, but there is no physical parameter to distinguish browsers from non-browsers.

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## **CHAPTER 4**

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## Chapter 4

### ***Why do Rodent Species Seasonally Damage Trees in Commercial Forestry in the Natal Midlands of South Africa?***

#### ***4.1 — Introduction***

Although *R. pumilio* and *O. irroratus* coexist and have superficially similar diets, sufficiently significant differences occur in food preferences that prevents direct competition (Perrin, 1980a). *R. pumilio* prefer high-protein and high-energy food when it is available whilst *O. irroratus* prefer a low quality diet which is abundant throughout the year. *M. natalensis* has also been shown to revert to a low quality diet in winter (Wirminghaus and Perrin, 1992). It would therefore seem that, certainly in the winter, in areas where all three species coexist some competition for food occurs.

In the previous chapter it has been shown that all of these species gnaw at the bark of commercially planted tree, *Pinus patula*. Further, as the behaviour is seasonal, either the bark cannot be considered a preferred dietary item or its palatability changes seasonally.

As this behaviour is correlated with the dry winter months, the question of whether the bark is a source of water when it is naturally limited is examined. The hypothesis that the nitrogen content of the bark varies seasonally, thus rendering the bark more nutritious to the rodents in winter is also tested.

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## **4.2 --- Methods**

One lateral branch was taken from a random tree on each of the trap lines per month (See Chapter 2). The bark of the resulting 20 samples was then stripped and a weighed sample was oven dried at 60°C until constant weight was achieved. The dried samples were reweighed and homogenised in an electric Moulinex Coffee Grinder before being stored in marked, airtight sample bottles. Two subsamples of each sample were then analysed using a Buchi 320 N<sub>2</sub> Distillation Unit, employing the Kjeldahl method (Allen et al., 1974). The resulting nitrogen was then expressed as the percentage nitrogen per dry matter. The expression of nitrogen content in terms of crude protein by multiplying the nitrogen content by 6.25 (Maynard et al., 1979) was avoided as the assumption is unsound (Kirkman, 1988).

## **4.3 --- Results**

### **4.3.1 --- Water**

There was no significant difference in the mean water content of the bark samples taken from Briarmains and Goodhope Estates over the length of the study period (ANOVA:  $f = 0.312$ ,  $df = 1$ ) and over monthly intervals (ANOVA:  $f = 0.103$ ,  $df = 11$ ). The mean water levels were therefore averaged (Figure 4.1).

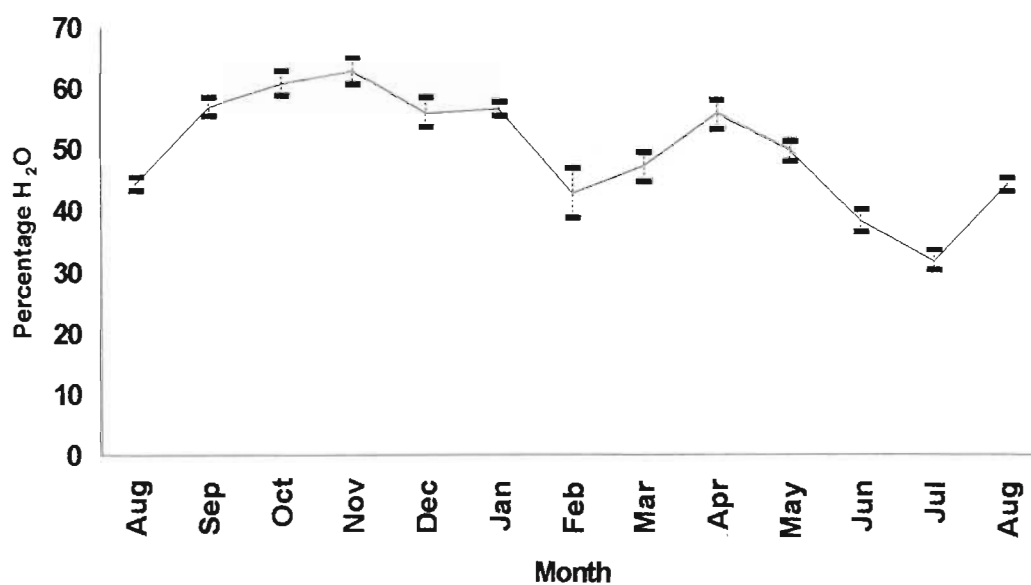


Figure 4.1: The mean water content of the bark samples taken from both Briarmains and Goodhope Estates, with 95% confidence limits.

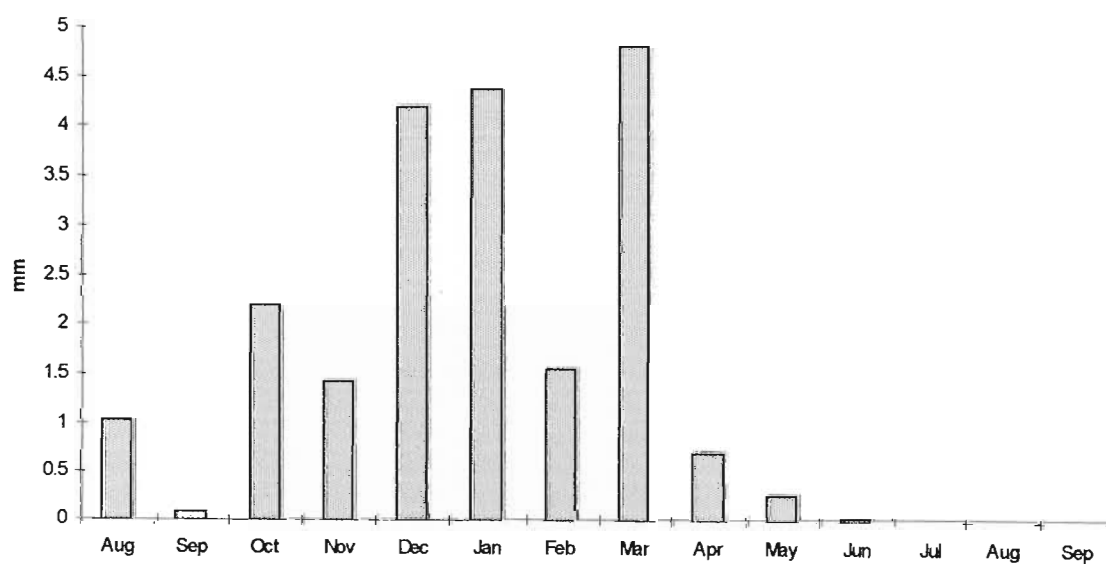


Figure 4.2: The averaged daily rainfall at the Briarmains and Goodhope Estates between August 1994 and September 1995.

The water content of the bark followed closely the trend of the average daily rainfall pattern (Fig. 4.2), with the low rainfall in February being mirrored by a reduction in mean water content of the bark in both that month and March. Although a peak in bark water occurs in the spring and early summer, rodents begin to gnaw the bark around April/May which coincides with a decline in the water content of the bark. In fact as the incidence of damage reaches its peak in July the water content of the bark is at its lowest.

**4.3.2 --- Nitrogen**

The mean nitrogen level of the bark samples taken from Briarmains (Fig. 4.2) and Goodhope Estates (Fig. 4.3) were significantly different when compared over the length of the study period

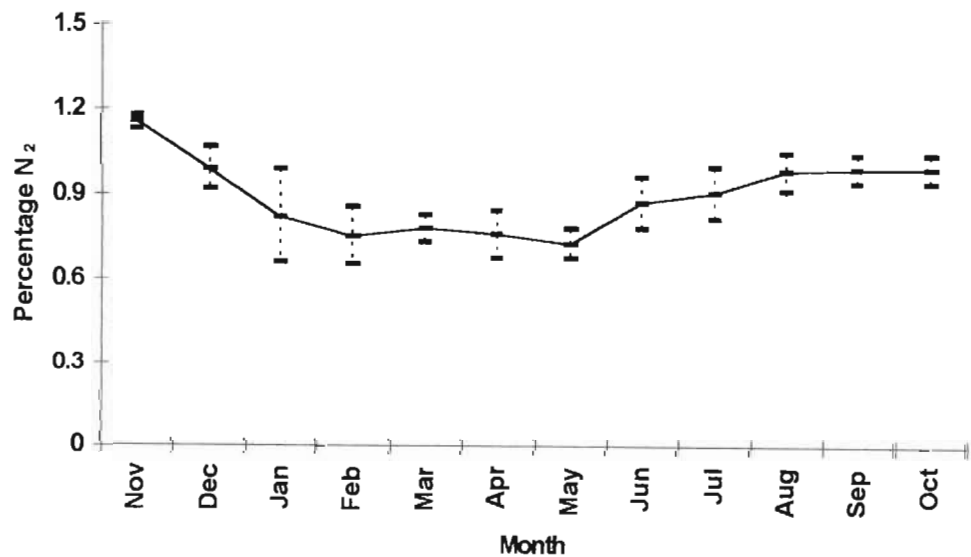


Figure 4.3: The monthly mean percentage nitrogen of the bark samples of *Pinus patula* collected from Briarmains Estate, with 95% confidence limits.



(ANOVA:  $f = 11.757$ ,  $p < 0.001$ ,  $df = 1$ ) and over monthly intervals (ANOVA:  $f = 8.951$ ,  $p < 0.001$ ,  $df = 11$ ). However, both follow a similar seasonal trend, with a minima reached in summer

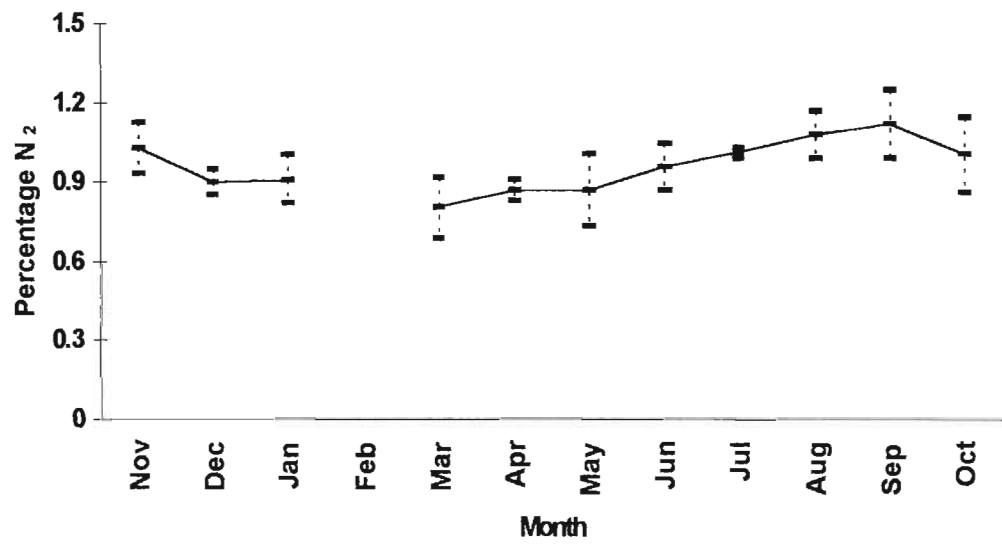


Figure 4.4: The monthly mean percentage nitrogen of the bark samples of *Pinus patula* collected from Goodhope Estate, with 95% confidence limits. Note the missing value in February 1995.

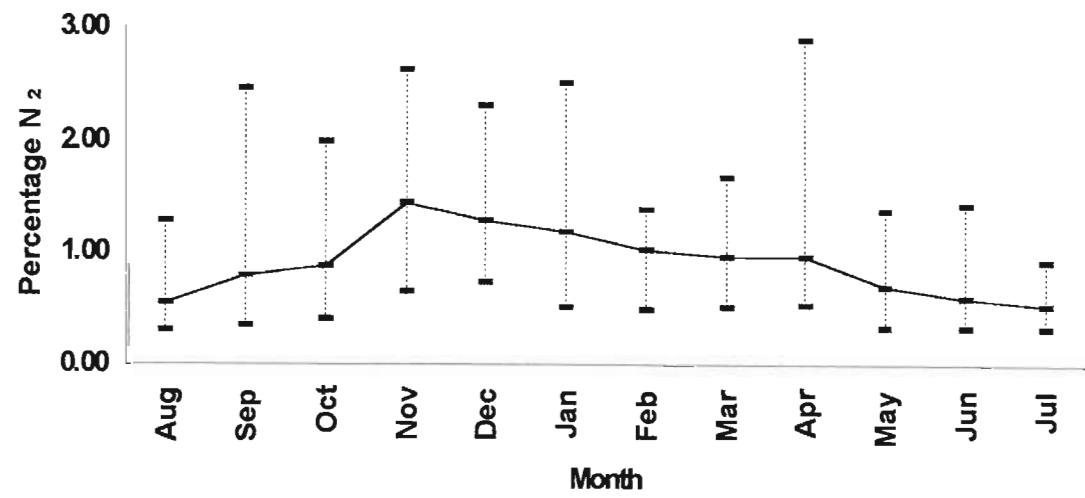


Figure 4.5: The monthly mean percentage nitrogen content of pasture samples collected from the Natal Midlands over 3 years, with maximum and minimum values. Adapted from Du Toit et al. (1940) by dividing the Crude Protein levels reported by 6.25.

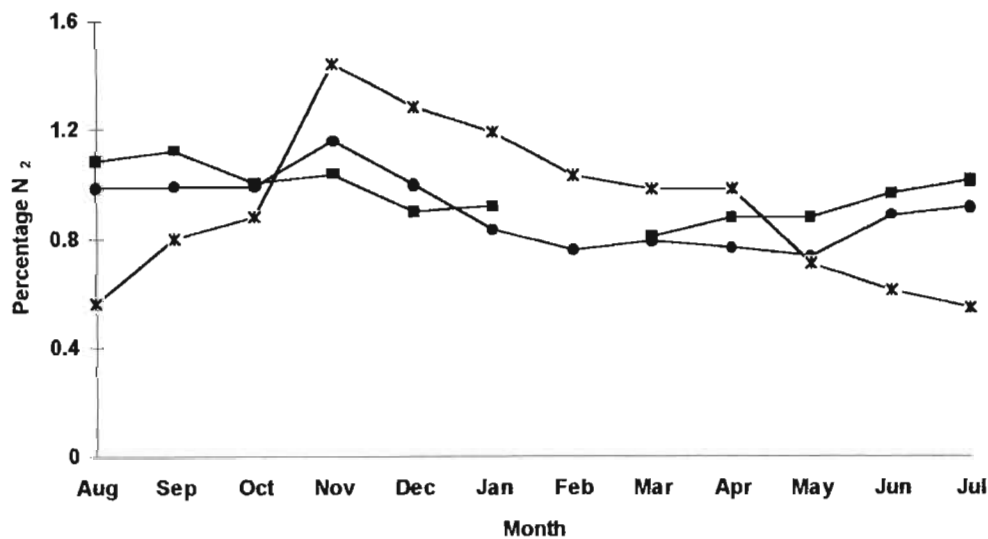


Figure 4.6: The monthly mean percentage nitrogen of pasture samples ( x ) compared to those at Briarmains ( • ) and Goodhope ( ■ ) Estates. The pasture data is adapted from Du Toit et al. (1940) by dividing the Crude Protein levels reported by 6.25. Spearman Rank Correlation coefficient values, Goodhope and pasture - 0.3363, Briarmains and pasture 0.1965.

and the maximum value reached in winter. This is in direct contrast to the nitrogen levels of the pasture (Fig. 4.4), where a significant rise in percentage nitrogen content in October/November was followed by a decline in April/May. There was no significant correlation between the pasture nitrogen levels and either of the Estates (Fig. 4.5). It has already been demonstrated that gnawing on bark begins around April/May (Chapter 3). This coincided with the time when the nitrogen content of the bark rose above that of the pasture and the gnawing ceases around September/October when the nitrogen of the pasture rose above that of the bark. It is also noticeable that the nitrogen content of the bark did not fluctuate appreciably over the year, the difference between the maximum and minimum levels being less than 0.32%, whilst the pasture fluctuated by almost 0.90%.

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## 4.4 --- Discussion

Both Atkinson (1993a) and Baxter (1995, pers. comm) have suggested that the seasonal gnawing of bark by rodents is a result of a lack of moisture availability in the dry winter. My results do not bear out that conclusion. The mean water content of the bark is constrained by the average rainfall, however as shall be pointed out in Chapter 5, bark damage is not and continues throughout the season. Both Schutz et. al (1978) and Novellie and Bigalke (1981) suggested that seasonal damage to *Pinus radiata* by antelope is related to seasonal fluctuations in natural vegetation availability. I would suggest that this is also the case with the gnawing behaviour of rodents and that it is related to seasonal nitrogen fluctuations in the natural diet. Such fluctuations have been noted many times. Karue (1974) showed how the mean nitrogen levels of selected East African grasses fluctuated from a high of 1.008% in the wet season to a dry season low of 0.656%. Rethman and de Witt (1988) noted "the relatively poor protein content of pasture grasses in Autumn", whilst White (1983) demonstrated a similar seasonal shift in American grasses. Of course, the rodents causing the damage do not rely on grasses alone as a staple diet and Kinyamario and Macharia (1992) demonstrated a similar seasonal fluctuation in the levels of nitrogen in a standing crop of mixed monocot and dicot species.

Many animals exhibit a seasonal dietary switch. Grassman (1962) suggested that the Ca/P ratio may be related to seasonal bark damage by Roe Deer (*Capreolus capreolus*). Perhaps the best studied is the African Elephant (*Loxodonta africana*, Blumenbach, 1797) (reviewed in Laws, 1970). Jachmann and Bell (1985) reported significant correlations between both the protein and sodium contents of leaf material and the tree species' utilisation by elephants. However, Croze

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(1974) hypothesised that “there is something in the trees which accounts for their attraction to elephants”. Whilst, Jachmann and Bell (1985) were equally vague in concluding that the seasonal utilisation of trees was part of a feeding strategy which improved the elephant’s food availability. Radwan (1969) has also suggested that chemical analysis is insufficient to explain the problem of feeding by bears on the sapwood of trees. Indeed, both Beeson (1985) and Bigalke and van Hensbergen (1990) have suggested that samango monkeys and baboons, respectively may strip bark from trees because the abundance of “identical potential victims” may stimulate prolonged stripping bouts. The latter authors have also proposed that, at least with baboons, the reason for bark stripping, is not because of a nutritional deficiency but because the fresh cambial layer and sap tasted sweet.

#### **4.5 --- Conclusion**

The reason that rodents damage trees by seasonally gnawing at the bark of exotic tree species is probably not a result of water deficiencies in their diet but a lack of protein in the form of digestible nitrogen. Gnawing behaviour begins when the nitrogen content of the bark rises above that of the natural vegetation and ceases when the nitrogen content of the bark falls below that of the natural vegetation. Although chemical analysis points to nitrogen rather than moisture as the causal factor, this conclusion remains tentative as many authors have pointed out that the underlying reasons behind other animals seasonally switching their diet may be other chemicals or simply hedonism.

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## **CHAPTER 5**

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## Chapter 5

### ***The Efficacy of Rodenticides in Controlling Rodent Damage in Commercial Forestry***

#### ***5.1 --- Introduction***

The current dependence on rodenticide to control rodent damage in commercial forestry in South Africa stems from recommendations made by Hechter-Schulz (1953). He concluded that “Warfarin”, an anticoagulant, could be used at bait stations which would destroy the rodents in the immediate vicinity and create a vacuum into which other animals would migrate. In this way the rodent density of a large area would be reduced as would the incidence of damage. However, this strategy was not embraced, instead rodenticides were broadcast over the affected plantations.

The possibility of “Warfarin”-resistance, as occurred in the brown rat (*Rattus norvegicus*) (Bishop & Hartley, 1976) and the accumulation of toxins in rodent predators (Willan, 1984) led to the replacement of “Warfarin” with “Storm” whose active ingredient is flocoumafen. Because of secondary poisoning of raptorial birds (Hurd, 1993) the product was replaced by “Finale”. In this product the toxic chemical is brodifacoum and for the same reasons of non-target species poisoning, the product was finally replaced by “Tornado”, a multiple-dose anticoagulant (manufactured by RT Chemicals, ). This product is available as a 20g wax block, containing the anticoagulant difenacoum, vitamin K (an antidote to the poison in non-target animals) and a substance to repel non-target animals. The product has been used extensively since 1990 (Atkinson, 1993a) and until recently was the only poison bait registered for use in forestry in South Africa. Some evidence of poisoning of non-target animals was given by Atkinson (1993b) and it has since been recommended that the blocks be placed in bamboo tubes to ensure that the

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rodenticide is not available to non-target species. The same recommendations have been given for “Racumin” (manufactured by Bayer (Pty) Ltd), a multiple-dose anticoagulant based on coumatetralyl which was licensed for use in forests in South Africa in 1994. Again this product is wax-based and contains  $0.375 \text{ g kg}^{-1}$  of toxin. The main advantage of multiple-dose anticoagulants is that bait shyness is avoided and the target animals will return to the bait. Multiple ingestions decrease the mean lethal rodenticide dosage. In the case of “Racumin” the acute dosage declines from  $16.5 \text{ mg kg}^{-1}$  body weight to  $5 \times 0.3 \text{ mg kg}^{-1}$  body weight if the bait is consumed over 5 consecutive days (Bayer, 1993).

Given the routine use of rodenticides in controlling rodent numbers it is surprising that little published literature exists on its effectiveness in commercial forestry. Whilst no published data exists on “Tornado”, Wirminghaus and Schröder (1994) assessed the efficacy of “Racumin”. They concluded that rodenticide densities of up to 25% (1 block per 4 trees) effectively reduce potential rodent pests and that rodenticide densities above that are excessive. However, their conclusions were based on a 7 week trial.

Standard CMR methods were used to test three hypotheses. At the same density of rodenticide application there is no significant difference between the “Racumin” and “Tornado” and second that rodenticides are not a biologically effective method of controlling the abundance of forest rodents. This was tested by comparing the treated lines with the control. By discontinuing treatment after excessive dosages it was also possible to examine the recovery rates of the rodents.



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## 5.2 --- Study Area and Methods

The study areas and trapping methods were those outlined in Chapter 2. Additionally, the number of rodenticide blocks put down on each treatment line was noted as was the subsequent number of blocks which were replaced. The blocks were replaced once per month and only when the block had completely disappeared.

The total numbers of *Rhabdomys pumilio*, *Otomys irroratus* and *Mastomys natalensis* were expressed as rodent numbers captured per trap night and these were compared using (M)ANOVA or repeated measures ANOVA. The same statistical tests were used to compare rodenticide replacement and bait taken at the snap traps across the treatment lines.

Homogeneity of the variances were tested using Bartlett's  $\chi^2$ , Hartley's  $F_{\max}$ , and Cochran's C statistics. Normal probability plots were used to test for the normality of the residuals and the group means were compared by calculation of the minimum significant difference using the Tukey-Kramer method for pairs of means (Fry, 1993). As the data proved to be heterogeneous, Taylor's power law was used to find suitable transformations. The rodent numbers caught per trap night were subjected to a transformation of  $X' = \sqrt{X}$  and the proportions of bait and rodenticide blocks replaced to  $X' = \arcsin \sqrt{X}$ . 95% confidence limits of means were calculated using the standard error times the  $t$  statistic or where  $n$  was small, the Bonferroni adjustment. This adjustment, though less conservative than the Scheffe adjustment (Iles, 1993), can give negative lower intervals where the variates are small numbers. Where this occurs, zero was taken as the minima. The Student's  $t$ -test was used to compare mean values at time  $t$  and multiple regression analysis to compare interrelationships between variables.



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## **5.3 --- Results**

### **5.3.1 --- Rodent Captures**

It was stated in Chapter 2 that 2 plots were chosen at each Estate, resulting in 4 replicate experimental sites. The assumption of replication was tested using a (M)ANOVA to compare number of rodents captured per trap night at similar treatment lines at Briarmains and Goodhope respectively (within Estate) and similar treatment lines at Briarmains with those at Goodhope (between Estate). The number of rodents captured per trap night were statistically different across the treatments within the two estates ( $f = 3.712$ ,  $p = 0.0122$ ,  $df = 3$ ). A multiple range analysis showed that a difference existed between the Heavy Tornado treatments (ANOVA:  $f = 7.378$ ,  $p = 0.012$ ,  $df = 1$ ) and the Racumin treatments (ANOVA:  $f = 14.844$ ,  $p < 0.001$ ,  $df = 1$ ) at Briarmains. No significant difference in this factor exists in the “within Estate” comparison at Goodhope.

Although a significant difference occurs between the two Estates ((M)ANOVA:  $f = 2.417$ ,  $p < 0.001$ ,  $df = 7$ ), a multiple range analysis shows that the differences occur over dissimilar treatments and that no statistically significant “between Estate” difference exists in the number of rodents captured per trap night when comparing similar treatment lines.

Therefore, although a “within Estate” difference is demonstrated over the Heavy Tornado and Racumin treatments at Briarmains, this is somewhat ameliorated by the lack of a “between Estate” difference over these treatments. The assumption of replication is accepted and the analysis will proceed on that basis.

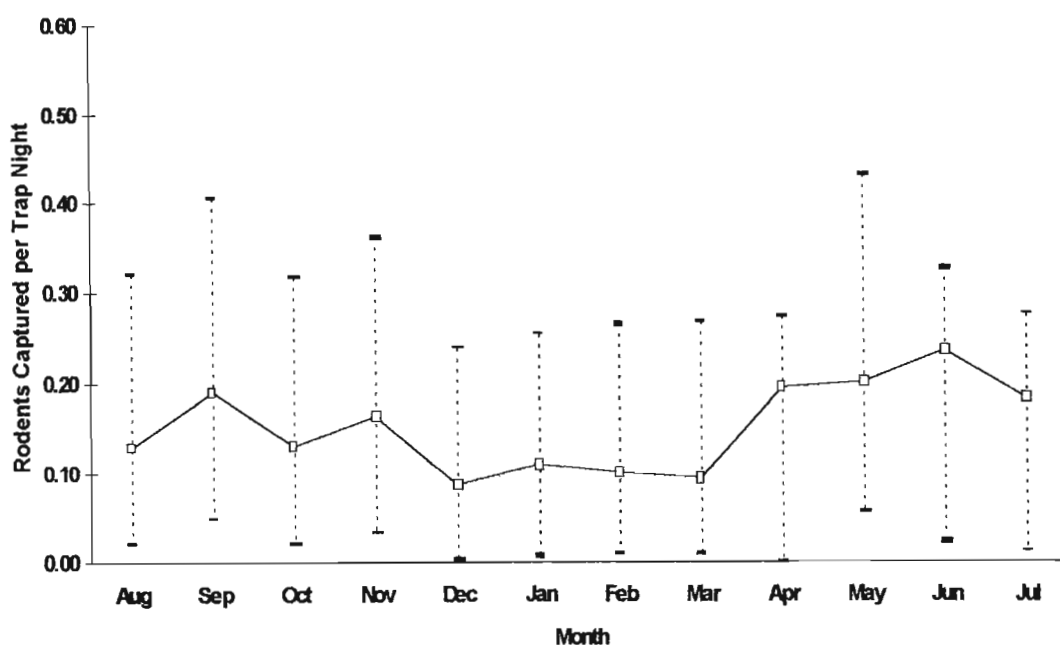


Figure 5.1: Arithmetic mean and 95% Bonferroni confidence intervals (dotted lines) of the number of rodents (*Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*) captured per trap night over the length of the study period on the control treatment at the four replicate sites.

A total of 1424 animals were captured at least once. Of these 82.5% were *R. pumilio* and 12.8% *M. natalensis*, the remainder being *O. irroratus*. A capture rate of 0.1 rodents per trap night is roughly equivalent to the capture of 36 animals or 9 animals per treatment line. This also equates to the approximate basal capture rate of the control lines. However, *O. irroratus* is notoriously trap shy and as a result of the same neophobia in some individuals of other species the basal capture rate almost certainly did not represent the true number of animals inhabiting the trap line area. Figure 5.1 shows a seasonal difference in the mean number of rodents captured per trap night for the control treatment, with summer captures (December to March) being significantly lower than winter captures ( $t$ -test:  $t = 4.336$ ,  $p < 0.001$ ,  $df = 10$ ). The mean number of rodents captured

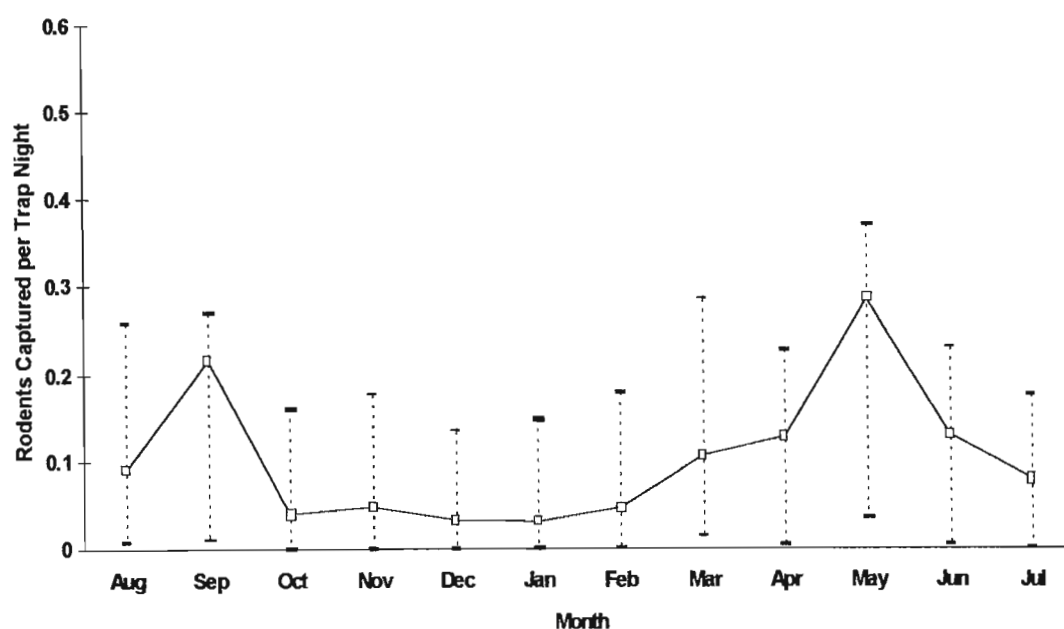


Figure 5.2: Arithmetic mean and 95% Bonferroni confidence intervals (dotted lines) for the number of rodents (*Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*) captured per trap night over the length of the study period on the Heavy Tornado treatment at the four replicate sites.

per trap night steadily increased from March until June. A similar seasonal trend existed on the Heavy Tornado treatment (Fig. 5.2). Rodenticide treatment began there in September 1994 and accounts for the sharp decline in rodent captures in October. Rodenticide application was discontinued after December. Between February and March numbers rose sharply until the numbers exceeded the control in May. Although the difference between the Heavy Tornado and control captures in May was not significant ( $t$ -test:  $t = 2.356$ ,  $df = 6$ ), the rodenticide application was resumed and numbers immediately declined. As a result of the fluctuation in treatment, there was no significant difference in rodent captures between the Heavy Tornado treatment and the control treatment over the length of the study (repeated measures ANOVA:  $f = 1.457$ ,  $df = 11$ ).

Both the Light Tornado treatment (Fig. 5.3) and the Racumin treatment (Fig. 5.4) also showed seasonal differences in the numbers of rodents captured. Both treatments began in September 1994

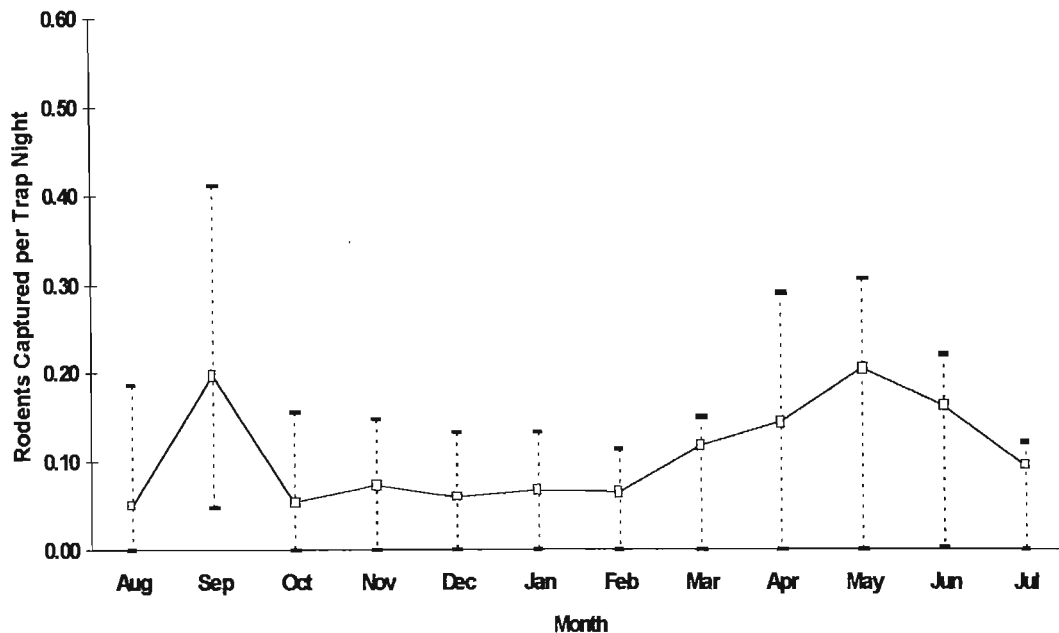


Figure 5.3: Arithmetic mean and 95% Bonferroni confidence intervals (dotted lines) for the number of rodents (*Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*) captured per trap night over the length of the study period on the Light Tornado treatment at the four replicate sites.

and captures declined the following month. Although the rodenticide was continuously applied, rodent captures on both treatment lines steadily increased from February, reaching a peak in May. Again there was no statistically significant difference in the mean number of rodents captured when comparing either of these treatments with the control (repeated measures ANOVA: Light Tornado,  $f = 2.012$ ,  $df = 11$ , Racumin,  $f = 2.226$ ,  $df = 11$ ).

During the period November to March there was no statistical difference between the mean number of rodent captures between any of the treated lines and the control (ANOVA:  $f = 3.800$ ,  $df = 3$ ).

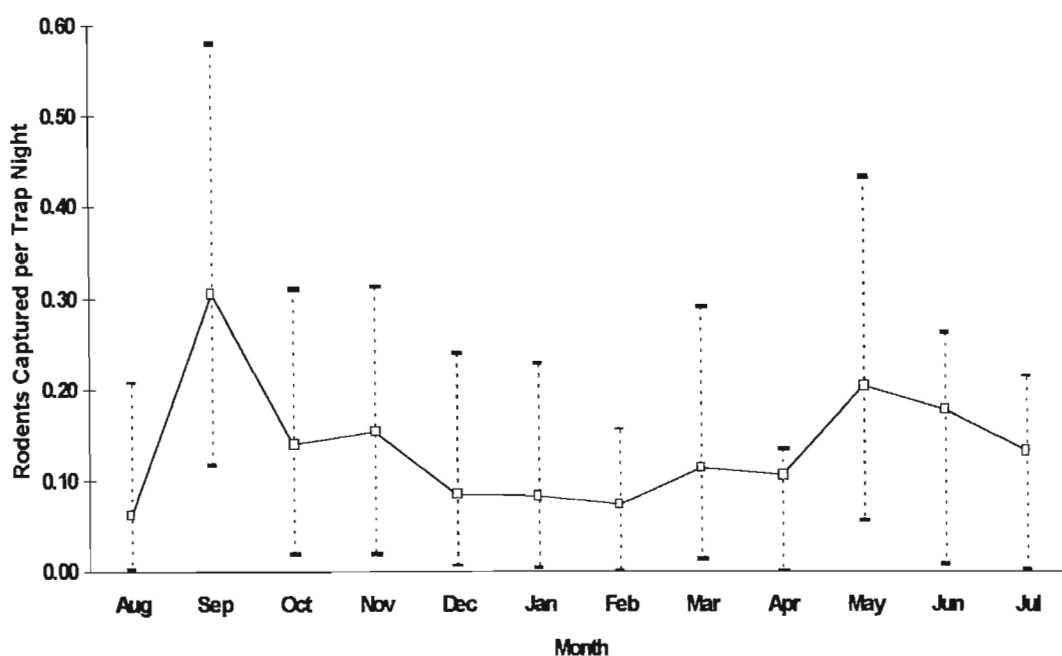


Figure 5.4: Arithmetic mean and 95% Bonferroni confidence intervals (dotted lines) for the number of rodents (*Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*) captured per trap night over the length of the study period on the Racumin treatment at the four replicate sites.

Fig. 5.5 compares the slopes of the late summer/autumn increases. There was no significant difference between the rate of increase on the Light Tornado and Racumin lines where rodenticide was continually replaced and the increase on the control lines (multiple regression:  $t = 0.579$ ,  $df = 6$ ). Comparison of the same parameter across the control and Heavy Tornado lines where application ceased for 5 months revealed a greater rate of increase on the rodenticide treated line than on the control, though not significantly so (regression:  $t = 0.458$ ,  $df = 4$ ). In all 3 rodenticide-treated lines the number of rodent captures per trap night declined after the peak in May, however, although the peak of rodent captures on the control line was reached a month later, a decline also occurred.

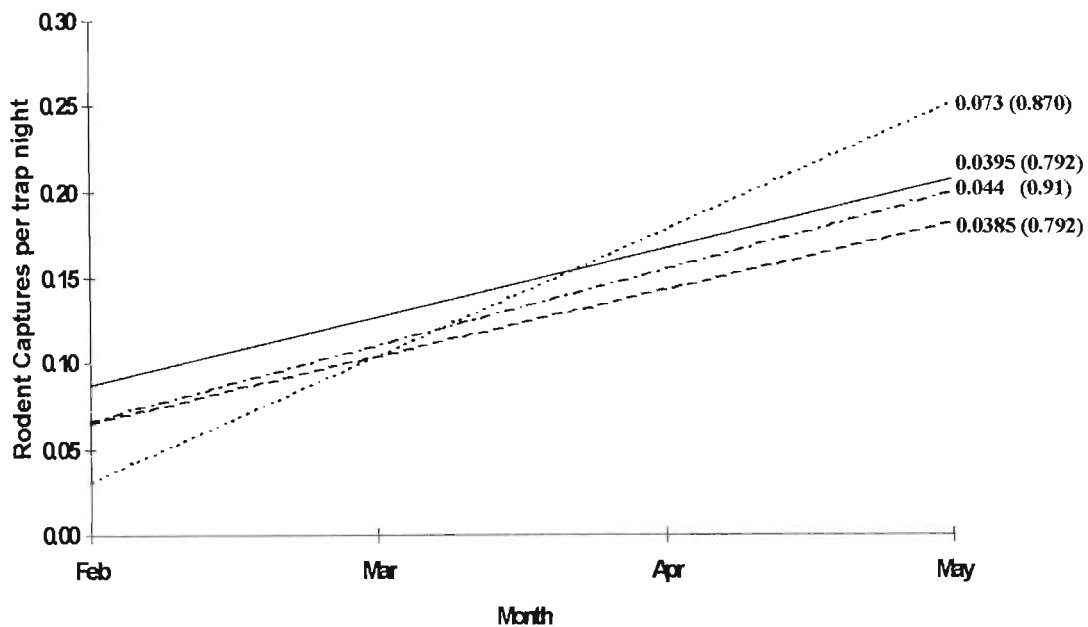


Figure 5.5: Comparison of the slopes of the mean rate of increase of trapping success between February 1995 and May 1995 over the Control ( — ), Light Tornado ( - . - . - . ), Racumin ( ..... ), and Heavy Tornado ( ..... ). The coefficients of determination  $r^2$  of the slopes are given in parenthesis.

As the aim of the rodenticide treatment was to reduce the numbers of rodents the mean abundance of rodents for each treatment for the length of the study was also examined (Fig. 5.6) and again no significant difference in rodent abundance were deduced between the rodenticide-treated lines and the control (ANOVA:  $f = 2.163$ ,  $df = 3$ ). A significant difference existed between the treatment lines and the control in terms of the numbers of animals recaptured (Fig. 5.7) (ANOVA:  $f = 4.452$ ,  $p < 0.05$ ,  $df = 3$ ). A multiple range test showed that the difference was between the Light Tornado treatment and the control.

There is therefore a high population turnover on the treated lines with the vast majority of animals

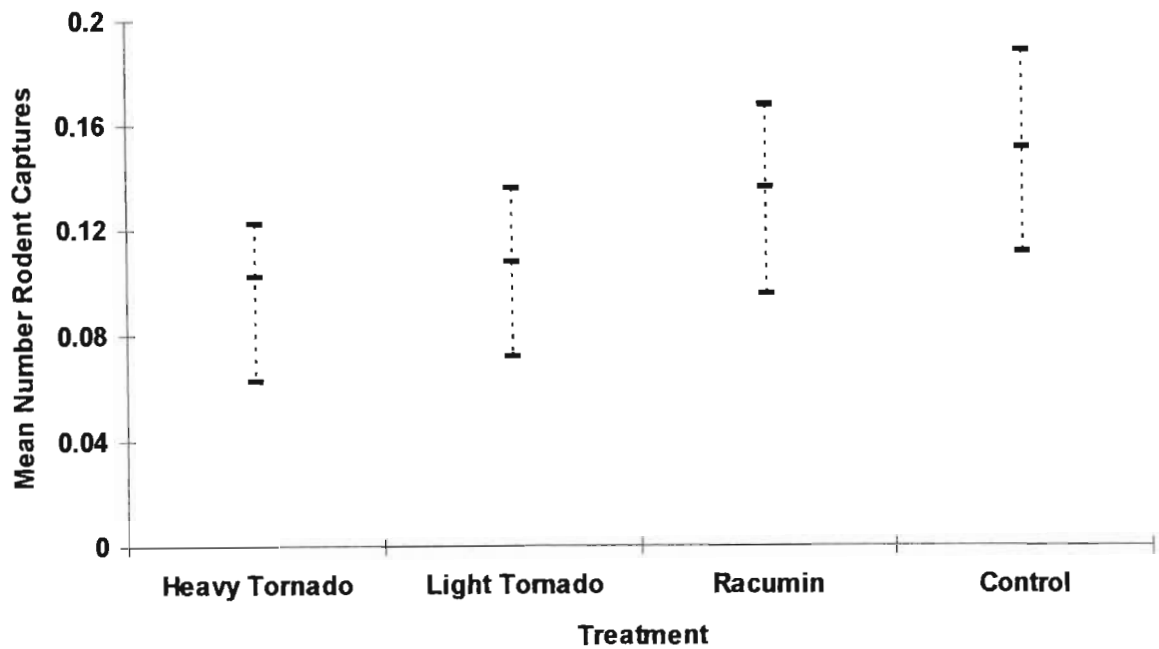


Figure 5.6: Comparison of mean total rodent abundance over the duration of the study, with 95% Bonferroni confidence intervals.

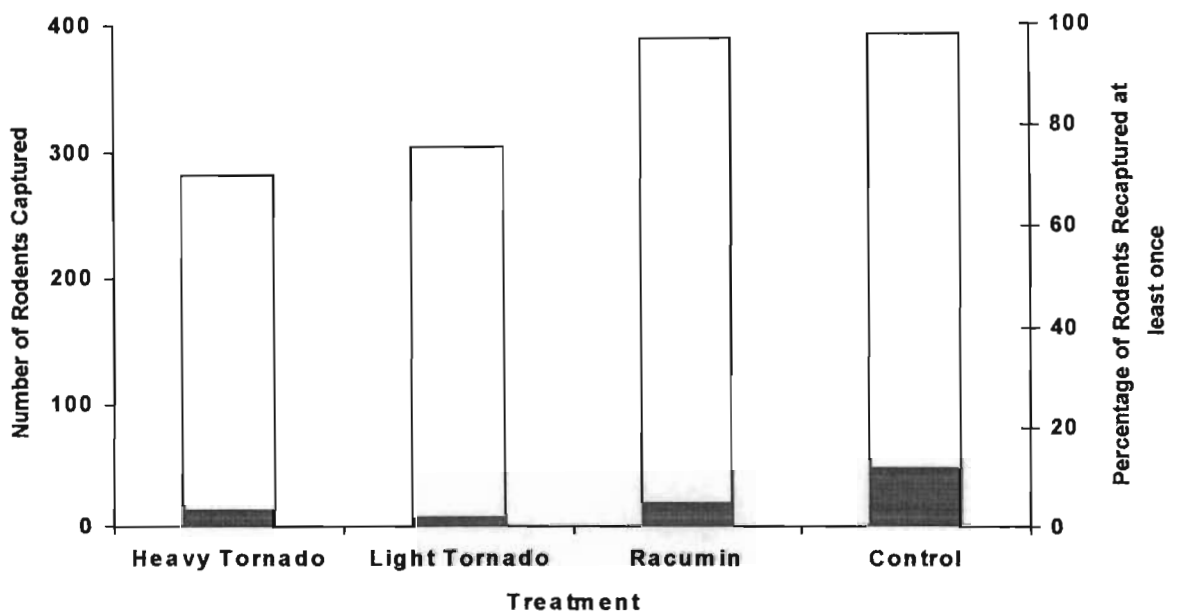


Figure 5.7: The total number of animals caught per replicate treatment line and the total percentage of recaptures per treatment line (shaded). The figures do not include snap-trapped animals or deaths in live traps. Rodents refer to the assemblage of *Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*.

captured being new to the area. Analysis of the body condition of the newly captured males showed

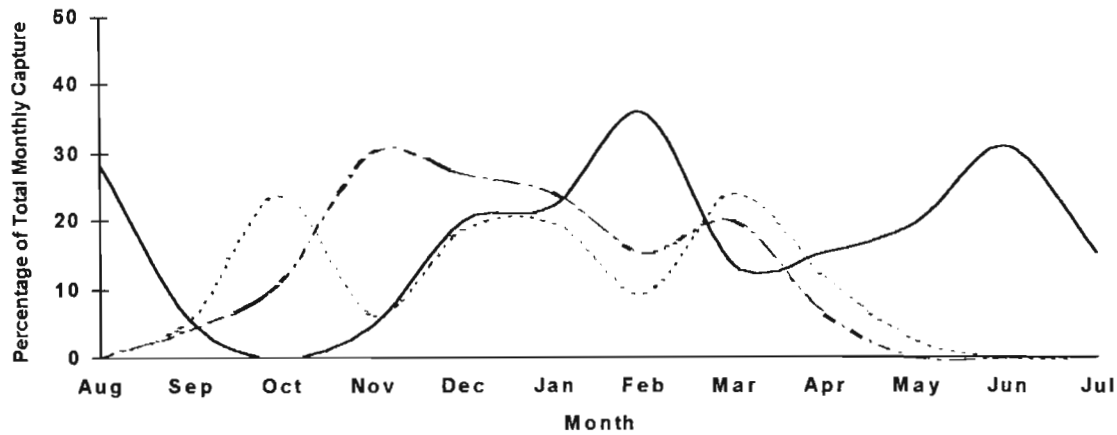


Figure 5.8: The mean percentage of total monthly rodent captures of sexually active adults and juveniles on the rodenticide treated lines. Breeding males ( \_ \_ \_ ), breeding females ( ..... ) and juveniles ( \_\_\_\_\_ ) Rodents refer to the assemblage of *Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*.

there was no significant difference in the body condition of the individuals over time for any of the treatments ((M)ANOVA:  $f = 0.661$ ,  $df = 56$ ). Figure 5.8 shows how the percentage of breeding

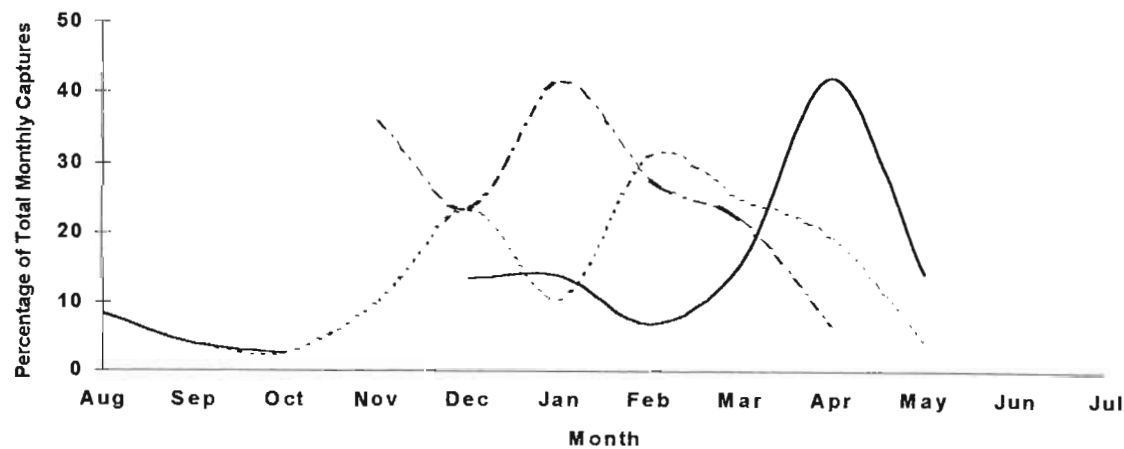


Figure 5.9: The mean percentage of total monthly rodent captures of sexually active adults and juveniles on the replicate control lines. Breeding males ( - - - - - ), breeding females ( ..... ) and juveniles ( \_\_\_\_\_ ) Rodents refer to the assemblage of *Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*.



males and females fluctuated throughout the year on the treated lines. Of particular interest was the bimodality of captures of juveniles. The first peak occurred in February, two months after the peak of sexual condition in adults. The second peak in June was not evident in the control line (Figure 5.9).

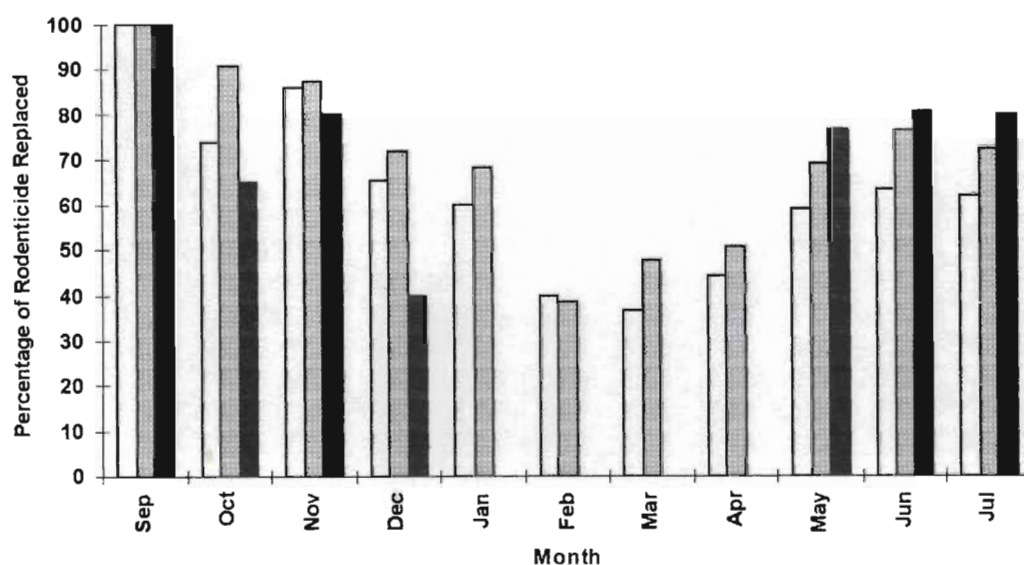
### 5.1.2 --- Rodenticide Replacement

The initial numbers of rodenticide blocks put down at each site are given in Table 5.1 and

<i>Site</i>	<i>Heavy Tornado</i>	<i>Light Tornado</i>	<i>Racumin</i>
Goodhope 1	120	47	43
Goodhope 2	146	43	44
<i>Goodhope Mean</i>	<i>133</i>	<i>45</i>	<i>43.5</i>
Briarmains 1	162	51	44
Briarmains 2	175	50	48
<i>Briarmains Mean</i>	<i>168.5</i>	<i>50.5</i>	<i>46</i>
<b>Total Mean</b>	<b>150.75</b>	<b>47.75</b>	<b>44.75</b>

**Table 5.1:** The initial number of rodenticide blocks laid down at each treatment line, the mean for each Estate and the total mean for each treatment.

greater numbers of rodenticide blocks were laid down at Briarmains than at Goodhope. This was the result of differing planting spaces at the two Estates. There is no significant difference in the block replacement between Estate for either the Racumin (ANOVA:  $f = 1.711$ ,  $df = 9$ ) or the Light Tornado (ANOVA:  $f = 1.899$ ,  $df = 9$ ), but the mean block replacement of Racumin (67.2%) was



**Figure 5.9: Comparison of mean rodenticide replacement per month over the Light Tornado treatment (unshaded), Racumin treatment (shaded) and Heavy Tornado treatment (black) replicated sites.**

significantly greater than the replacement of Tornado (59%) at the Light Tornado treatment line over the 4 replicates (ANOVA:  $f = 3.652$ ,  $p < 0.001$ ,  $df = 9$ ) (Fig. 5.9). It should also be noted that after the initial October decline in rodent captures at the Light Tornado and Racumin lines, rodenticide replacement was still over 70% and continued at or slightly below this figure until January. When the rodent captures were at their lowest points, replacement continued to be above 40%. The percentage of rodenticide taken by the rodents increased steeply from February until May, however the treatment did not prevent the sharp increase in rodent abundance at this time (Fig. 5.5). The mean block replacement on the Heavy Tornado line was 61.6 % between October and December, rising to 78.7% when the application resumed in May.

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## 5.4 --- Discussion

Despite continuous rodenticide application no significant difference in rodent abundance existed between the lightly treated areas and the areas where no rodenticide was used, although "Tornado" was generally more effective than "Racumin" both on a month to month comparison and the mean annual abundance. Neither rodenticide reduced the rate of increase that took place between February and May compared to the control.

It could easily be argued that the experimental design utilised in this study is a modification of the bait station principle where each line is a station. However this could be argued for any open environment. Whether the animal population is poisoned or removed by intensive trapping, without a physical barrier the area will certainly be reinvaded. This was demonstrated as early as 1955 when Mehl found that repetition of poisoning was necessary after re-immigration into a forest of *Microtus agrestis* after the original population had been killed out. Barnes et al. (1970) have shown that rodenticide treatment against pocket gophers was greater than 90% effective but the area was soon reinvaded whilst, rodenticide treatment of *Peromyscus maniculatus* destroyed the local population but the animal reappeared in 15-19 days with complete population recovery in 5-7 months (Gashwiler, 1969). Obrazcov (1961) showed that after a heavy removal trapping regime of forest Muridae the population had completely recovered in 10 days. Similarly, Murua and Rodriquez (1989) reported that after successfully eradicating rodents from within forests in central Chile, rodents reappeared "after 5 months of treatment". Holmes (1955) reported that no chemical repellent remained effective in protecting young plants against damage by rabbits for longer than 6 months.

The length of time until reinvasion will be determined by the ecological and reproductive strategy of the species involved. By far the commonest species captured was *R. pumilio*. This has been

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shown to be an *r*-selected species (Perrin, 1980a, 1986) characterised by rapid and intense summertime recruitment (Perrin, 1979). Brooks (1974) showed that in a *R. pumilio* population studied near Pretoria, the breeding season extended from September to April and this is in general agreement with this study (Fig. 5.7) although, Delany (1972) suggested that this pattern may not apply throughout the species' range and that reproduction is affected by numerous environmental factors. For instance, Choate (1971) in Zimbabwe, and Brooks (1974) determined the mean gestation period as 22 days and 25.4 days, respectively. Brooks (1974) also suggested that breeding maturity was reached at 3 months, whilst David and Jarvis (1985) suggested a mean age of sexual maturity of 6 to 7 weeks in females on the Cape Flats, with the males maturing 5 weeks later. Perrin (1980c) estimates the mean litter size to be between 4.75 and 7.15, whilst Taylor and Green (1976) gives a mean litter size range of between 2 and 10. Willan and Meester (1989) have suggested that the species is generally mobile with a two-phase dispersal of weaned young. Perrin (1986) noted a similar pattern of recruitment of *R. pumilio* juveniles in the Eastern Cape Province and this was also noted in this study (Figure 5.7). Brooks (1974) reported monthly immigration of all age classes of up to 30% into his study area and this study (Fig. 5.6) shows that this rate of immigration is greatly enhanced where an area is treated with rodenticide.

*M. natalensis* is even more fecund than *R. pumilio*. Taylor and Green (1976) reported a mean litter size of between 5 and 24. Meester (1960) reported a female giving her first litter at 77 days and an average time between litters of 33.1 days. Willan (1982) has proposed that *M. natalensis* has evolved ecological strategies to promote dispersal and that dispersal is through adults, with the young staying in the natal area.

*O. irroratus* is predominantly a K-selected species (Perrin, 1980a) producing relatively small litters. According to Davis (1973) the mean litter size is 2.33, ranging between 1 and 4. However, Perrin (1980c) suggested that the species was capable of breeding at any time throughout the year

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if conditions were favourable and as the species is polyoestrous the female may produce up-to 7 litters per annum (Skinner and Smithers, 1990).

Although the rodenticide was replaced each month the practice of the forest managers is to saturate the affected areas for a limited period only. Figure 5.5 indicates that this practice promotes increased dispersal into the previously treated areas and this was also observed by Gashweiler (1969) who noted increased breeding activity in *Peromyscus maniculatus* after poisoning of areas to reduce damage in the Oregon Cascades.

It is clear that the limited control offered by rodenticide is only effective with repeated application, however, Martell & Radvanyi (1977) found that even at low densities *Microtus pennsylvanicus* still caused severe damage in a broadleaf stand in Ontario. Additionally,

Baumler (1973) reported both specific and seasonal variations in rodent acceptance of commonly used poison baits. Seasonal variation in bait acceptance was also noted by Kulicke and Ritter (1968) when used against *Arvicola terrestris* in a poplar plantation in Germany.

Further it is clear from Figure 5.9 that during the winter months with continuous replacement the rodent population had reached its basal limit, yet the replacement level was at least 40% and this doubled during the summer.

## **5.5 --- Conclusion**

The practice of broadcasting of rodenticide intermittently seems to have little long term effect on rodent numbers, except to stimulate greater breeding activity. Continuous application seems to reduce rodent abundance but not significantly, although "Tornado" is marginally more effective

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than “Racumin”. Continuous application in any area has the effect of reducing the resident population but this area is quickly reinvaded by dispersing individuals from nearby habitats. Such dispersal is impossible to stop unless effective physical barriers were erected. Even when the rodent population of the forest environment is naturally at its lowest, rodenticide replacement was still around 40%. The economics of this strategy are discussed in Chapter 8, however, it will suffice to say here that continuous rodenticide application binds the forestry companies to the rodenticide manufacturers and for reasons of stock replenishment and the risk of rodent resistance the cycle is never ending.

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**CHAPTER 6**

**5. THE EFFICACY OF RAPTOR PERCHES IN CONTROLLING RODENT  
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## Chapter 6

### ***THE EFFICACY OF RAPTOR PERCHES IN CONTROLLING RODENT DAMAGE IN COMMERCIAL FORESTRY***

#### ***6.1 --- Introduction***

Optimal foraging theory predicts that for any individual there should be a trade-off between the energy expended foraging and the rate of energy intake. For raptorial birds feeding on rodents this would mean that the bird maximises the number of rodents captured whilst spending as little energy as possible in searching and handling prey. This ecological principle has been utilised within commercial forestry and many forest managers in South Africa routinely provide raptor perches in new plantations at a density of 2 ha<sup>-1</sup> in the hope that the birds will control the rodent abundance and thus control the damage to the trees.

The object of this part of the study was to test the hypothesis that the provision of raptor perches is not an efficient method of controlling rodent abundance.

#### ***6.2 --- Study Area and Methods***

Details of the perch placement and rodent capture methods are given in Chapter 2. Three perch designs were used and distributed at random throughout the raptor perch treatment lines. The perch most commonly used in Natal is commercially made and is about 2 m tall (Figure 6.1a). The second design is one proposed by Willan (1992) who suggested that diurnal raptors may have



different crossbeam height preferences from owls which prefer a lower beam (Figure 6.1b). The top crossbeam was approximately 3.5 m above ground and the bottom crossbeam 1 m below.

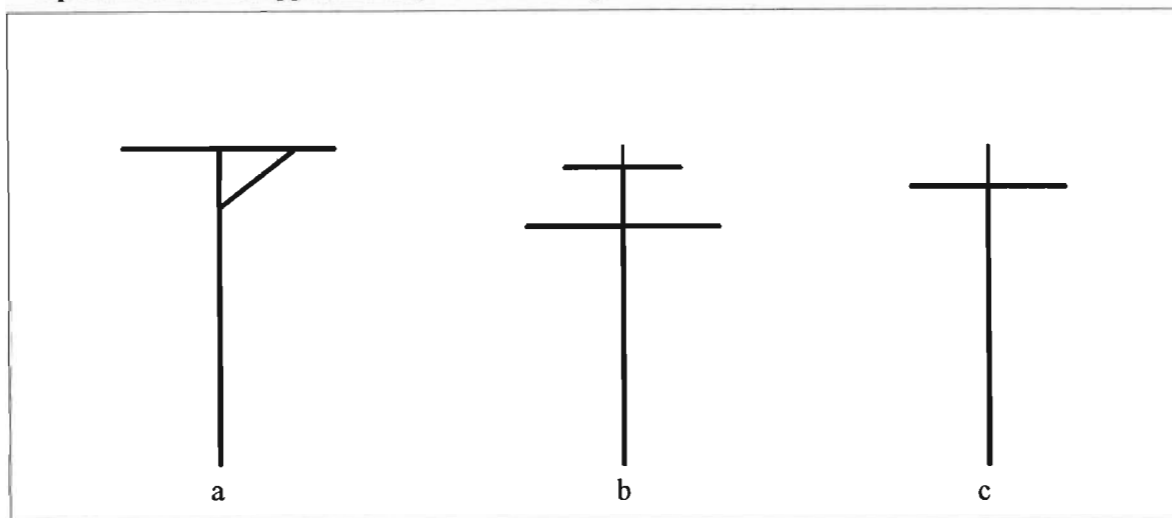


Figure 6.1: Design of raptor perches used showing the position of the crossbeams (drawing not to scale).

A third design was utilised in which the vertical crossbeam was lowered to distance of around 0.25 m from the top of the pole (Figure 6.1c). Tarboton (1978) has pointed out that black-shouldered kites (*Elanus caeruleus*), the most common of the diurnal raptors, are more likely to hunt at around midday, therefore after the trap maintenance was completed the perches were observed from a car through binoculars and the length of occupancy of any kite landing on a perch was monitored. In addition any raptor pellets found at the base of perches were inspected for rodent skulls. These were identified using the molar alveoli formula (Bowland and Bowland, 1989).

The same statistical tests and transformations as detailed in chapter 5 were used in the present analysis. The  $\chi^2$  test was applied to analyse the length of occupancy on perches and as there was only one degree of freedom, Yates correction for continuity was incorporated (Fowler and Cohen, 1990).

## 6.3 --- Results

### 6.3.1 --- Rodent Captures

There was no significant difference comparing the monthly captures at the control treatment (Fig. 6.2) with those at the raptor perch (Fig. 6.3) treatments (repeated measures ANOVA:  $f= 1.988$   $df = 11$ ). Neither was there a significant difference when comparing the mean total rodent abundance over the duration of the study for these two treatments (ANOVA:  $f= 0.236$ ,  $df = 1$ ).

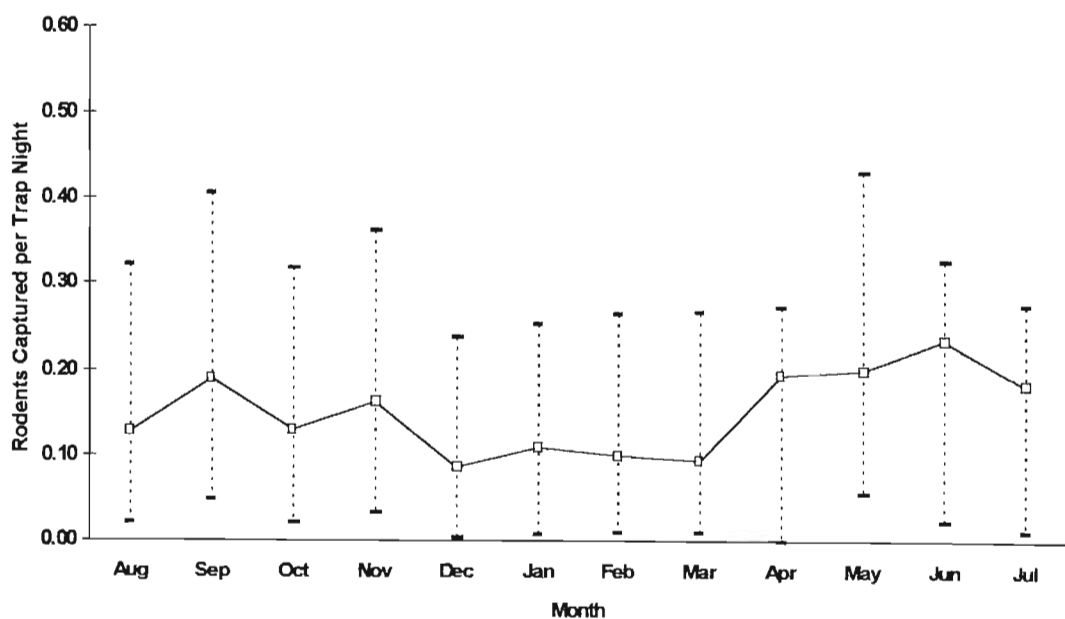


Figure 6.2: Arithmetic mean and 95% Bonferroni confidence intervals (dotted lines) for the number of rodents (*Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*) captured per trap night over the length of the study period on the control treatment at the four replicate sites.

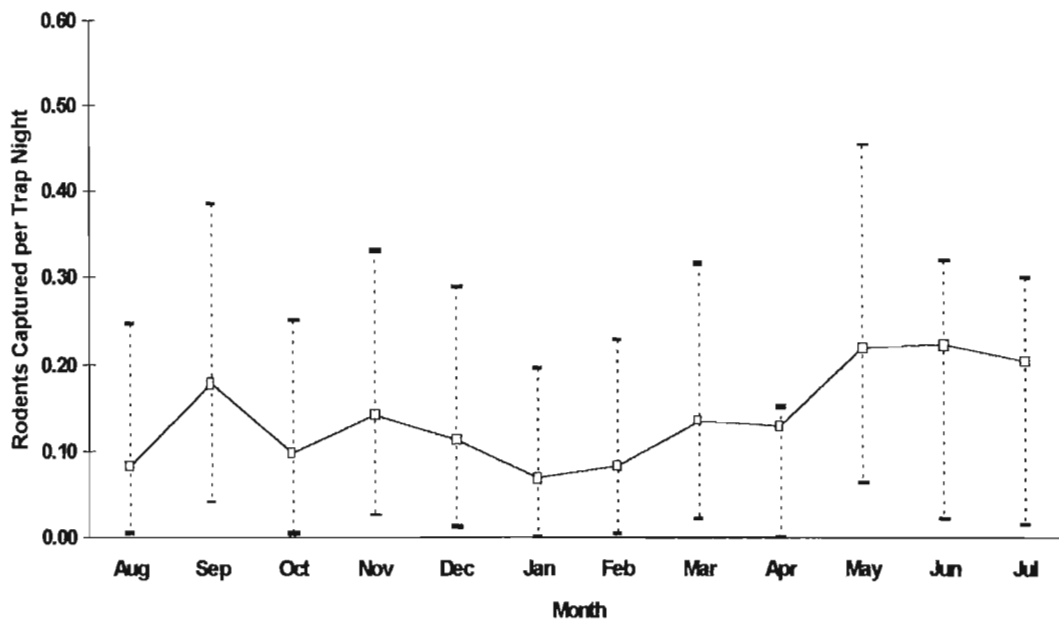


Figure 6.3: Arithmetic mean and 95% Bonferroni confidence intervals (dotted lines) for the number of rodents (*Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*) captured per trap night over the length of the study period on the raptor perch treatment at the four replicate sites.

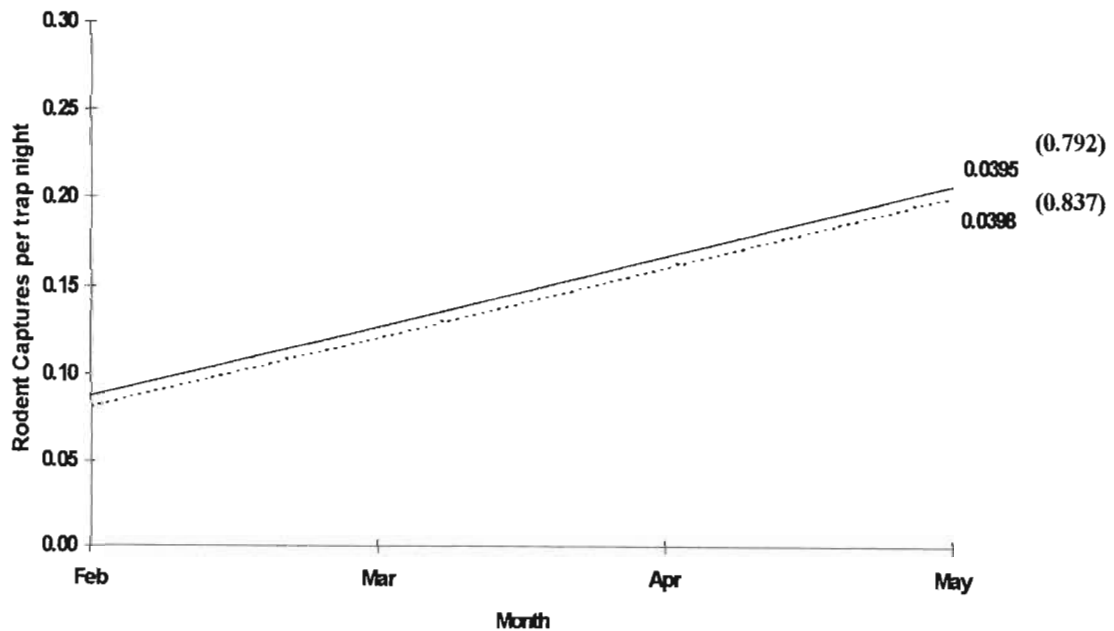


Figure 6.4: Comparison of the slopes of the mean rate of increase of trapping success between February 1995 and May 1995 over the Control (————), and raptor perch treatment(.....). The coefficients of determination  $r^2$  of the slopes are given in parenthesis.

Fig. 6.4 compares the slopes of the late summer/autumn increase in rodent abundance. There is no significant difference between the rate of increase on the raptor perch treatment and the increase on the control lines (regression:  $t = 0.017$ ,  $df = 4$ ). Neither is there a significant difference between the raptor perch treatment lines and the control in terms of the numbers of animals recaptured (Fig. 6.5) (ANOVA:  $f = 0.026$ ,  $df = 1$ ).

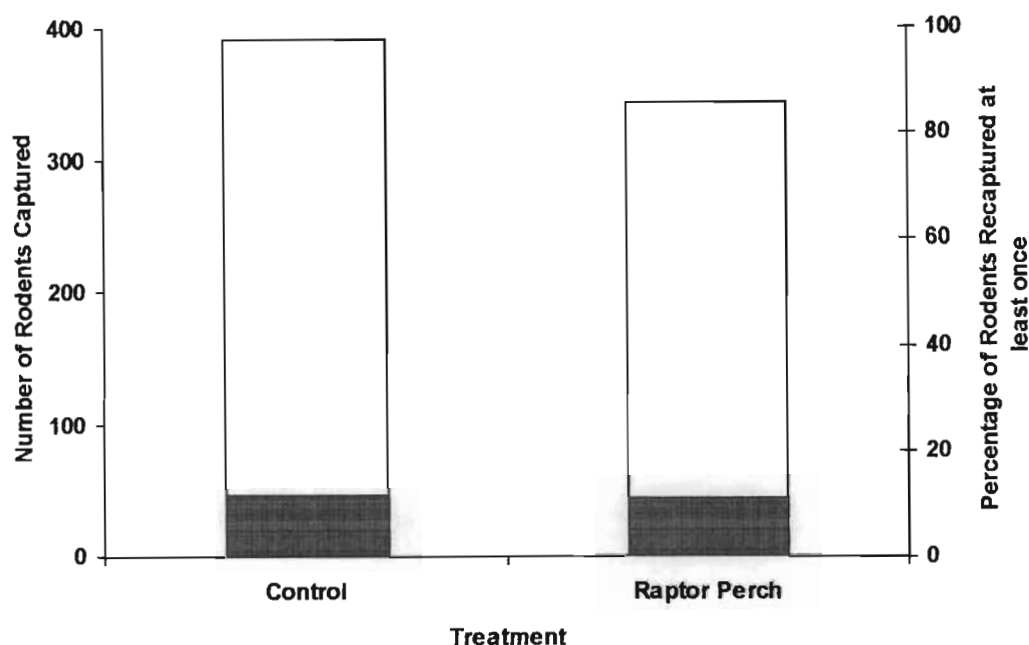


Figure 6.5: The total number of animals caught per replicate treatment line and the total percentage of recaptures per treatment line (shaded). The figures do not include snap-trapped animals or deaths in live traps. Rodents refer to the guild of *Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*.

### 6.3.2 --- Perch Utilisation

Black-shouldered kites were observed hunting from perches for a total of 387 minutes, periods of preening or inactivity i.e. sleeping or eyes closed were ignored. Active hunting from perch design (a) in Figure 6.1 was observed for 118 minutes. However, no birds were observed actively hunting from the crossbeams of perch design b or c in Figure 6.1. Instead all birds hunted from the point of

the pole and this was observed for 269 minutes. The difference in occupancy is highly significant ( $\chi^2 = 56.60$ ,  $p < 0.0001$ ,  $df = 1$ ). On 3 separate occasions black-shouldered kites were seen catching and consuming the prey. All of these successful kills were launched from the top of the pole where the bird returned to consume the prey. Table 6.1 details the results of analyse of regurgitated pellets found at the bottom of perches. It is interesting that pellets were only found in

Month	No. of Skulls	Species
October	4	2 x <i>R. pumilio</i> , <i>M. natalensis</i> and <i>O. irroratus</i>
November	3	1 x <i>R. pumilio</i> , 2 x <i>O. irroratus</i>
December	4	2 x <i>R. pumilio</i> and 2 x <i>O. irroratus</i>
January	4	2 x <i>R. pumilio</i> and 2 x <i>O. irroratus</i>

**Table 6.1: The number of regurgitated black-shouldered kite pellets retrieved from the base of raptor perches. No pellets were retrieved with no skull and no pellet contained more than one.**

the early part of the study. The cultivated trees on both estates were around 3 m tall and 2 m wide at the lowest lateral branches. It is probable that the perches had an initial “novelty value” for the birds but as a result of the comparatively large trees impairing the birds’ searching pattern and decreasing in the bird’s manoeuvrability, the catch rate was not sufficiently beneficial for the birds to continue hunting on these sites.

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## 6.4 --- Discussion

It is obvious from the results that the provisioning of raptor perches in older age stands does little to control rodent numbers within the plantations. This does not mean however, that the encouragement of raptors into an area to hunt is an inefficient measure *per se*.

The black-shouldered kite is “probably” the most common raptor in Southern Africa (Maclean, 1988) and an important rodent predator (Siegfried, 1965). Both Tarboton (1977) and Slotow et. al (1988) estimated that greater than 98% of their diet comprised rodent species. The former suggested that *R. pumilio* or *Otomys* sp. was the most important component whilst the latter author also added *M. natalensis* as a common dietary component. In terms of bulk intake a single bird consumes the equivalent of “2 *Rhabdomys*-sized rodents day<sup>-1</sup>” (Tarboton, 1977), whilst a nesting pair may consume 6 rodents per day through the breeding cycle (Willan, 1992) of up to 90 days (Maclean, 1988). The species is a typical saltatory hunter, where a stationary perched mode is followed by a period of locomotion to a new search area (Tye, 1989). The species also wind-hovers (Tarboton, 1978), which is described by Videler et al. (1983) as “flight against the wind resulting in zero ground speed”. But the alteration of rest and movement is more energy efficient than continuous movement even when the continuous movement is at a lower speed than the movement phase of the stop-go pattern (Andersson, 1981). Widen (1994) reported that given the choice raptors forage in areas with perches to the exclusion of areas without perches and that if the perches are moved so do the raptors. He also suggested that this preference is not influenced by prey density or vegetation cover. Willan (1992) listed long-crested (*Lophaetus occipitalis*) and lesser spotted eagles (*Aquila pomarina*), forest (*Buteo oreophilus*), long-legged (*Buteo rufinus*) and jackal buzzards (*Buteo rufofuscus*) and African marsh harriers (*Circus ranivorus*) as diurnal South African raptors whose diet composition is greater than 50% rodent species. The same author

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lists another 14 diurnal species where rodents make up between 10 and 50% of the diet. Almost all of these species are saltatory hunters, whose breeding season coincides with the breeding season of the rodent species they hunt.

Of the nocturnal avian predators the barn owl (*Tyto alba*) is widespread in South Africa and Maclean (1988) suggested that their diet may comprise 75 to 97% rodents. Hanney (1962) concluded that in Malawi barn owls ingested 32% of their body mass daily, whilst Dean (1973) suggested a lower figure of 14% in the Transvaal area. Given the average mass of a barn owl of 346 g, (Perrin, 1982), this amounts to between 48 and 111 g of food per day. Willan (1992) suggested that a breeding pair of birds may require 1700 rodents to successfully complete one breeding cycle. It has been suggested, however, that barn owls in the Eastern Cape may underutilise diurnal species such as *R. pumilio* and *O. irroratus* and concentrate more on species which are active at night, for instance *M. natalensis* (Perrin, 1982). A second common nocturnal rodent specialist is the marsh owl (*Asio capensis*) which feeds almost exclusively on rodents (Willan, 1992). Both of these species are saltatory and again the breeding season is in synchrony with the rodent breeding season (Maclean, 1988).

In order that the bird maximise both its energy budget and the area searched, the provisioning of 2 perches ha<sup>-1</sup> is clearly not enough. Sonerud (1992) showed that parts of a clear-cut with perches were preferred by hawk owls (*Surnia ulula*) to areas where no perches were provided and recommended perches be spaced at 15 ha<sup>-1</sup>. Similar spacing was recommended by Murúa and Rodriguez (1989) in central Chilean forests. They concluded that the erection of perches coupled with improved habitat conditions were effective long-term control measures against rodent pests, a conclusion confirmed by Muñoz and Murúa (1990). The costs involved in providing raptor perches can be severely reduced by merely erecting single poles, which the birds seem to prefer to the more elaborate designs.



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One of the most convincing arguments for the control of rodent species by natural predators is the experience of the Le Valois forest in the Paris basin as reported by Debreyne (1959). Despite good mast years during the second world war, natural regeneration continued within the forest as a result of the protection of carnivores and birds of prey during German occupation. At the culmination of the war these species were persecuted by gamekeepers and sportsmen. Debreyne reported little natural regeneration from 1952 onwards and concluded that rising populations of small mammals within the forest were the main reason for this depredation.

## **6.5 --- Conclusion**

South Africa has an abundance of predatory birds which either specialise in rodent predation or where rodents make up at least half of their diet. Most of these birds need to catch at least 2 rodents per day to sustain their metabolism above basal levels and this rises significantly during their breeding season. Their habit of saltatory hunting may be profitably used by forest managers to reduce rodent abundance within young plantations by providing raptor perches. However, to maximise the hunting success of the birds perches should be spaced at  $16 \text{ ha}^{-1}$ . The costs of these perches can be dramatically reduced by not having crossbeams. The efficacy of the perches reduces as tree height increases. When the trees are around 2 years old the perches may be removed and different methods of reducing rodent damage must be employed.



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## CHAPTER 7

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## **Chapter 7**

### ***Methods of Isolating Trees from Rodents***

#### ***7.1 --- Introduction***

The forestry industry in South Africa, has made the association that if rodents cause damage to the trees then to control the damage to trees the rodents must be controlled. Although, this has been the emphasis of the preceding chapters, it is not the rodents that are the problem but the damage that they cause. Therefore in this section I focus on controlling the damage.

Damage control can be attempted by mechanical or chemical protection. Mechanical protection involves isolating the vulnerable parts of the tree from the predators. Gill (1992b) in a review of deer browsing reported that bark thickening deters all species of deer present in the UK from bark stripping. The thickness of the bark and its relationship to rodent damage was also pointed out by Pudden (1959) who discussed early pruning as a method of isolating the new tree growth from small mammals in Kenya.

A second possible method of mechanical protection is the use of stem guards, where the young seedlings are planted and enclosed by a sleeve, which effectively causes a physical barrier separating the predator and the prey.

The theory behind chemical protection is that a noxious, non-lethal chemical is either painted onto the tree trunk or left in a receptacle beside it. The chemical then exudes an odour or taste which repels the rodents from the immediate vicinity of the tree. Selenium is a possible repellent because of the strong odour of the compounds exuded by selenized foliage (Reamer and Zoller, 1980; Zieve

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and Peterson, 1981). Synthesised organoselenium compounds give of a characteristically garlic odour (Vokal-Borek, 1979) and Radwan (1978) has shown that browsing animals react strongly to compounds volatilized from foliage.

In this study I test the hypotheses that neither early pruning and stem guards (Treemate, Pavini Tiles c.c., P.O. Box 1072, Four Ways 2055, S.A.) are effective protection against damage. I also test the efficacy of a slow release device which releases a garlic odour over 1+ years ( Plant Pro-Tec, Inc, P.O. Box 902, Palo Cedro, CA 96073, USA). The manufacturers claim that this device effectively repels both deer (*Odocoileus* spp.), elk (*Alces* spp.) and rabbits (*Oryctolagus* spp.).

## **7.2 --- Study Area and Methods**

### **7.2.1 --- Pruning**

Pruning began in late March on a plot of trees at Briarmains Estate. Two out of every third row of trees were pruned, resulting in 421 pruned trees and 217 trees left unpruned. The lateral branches were removed to a height of at least 1 m and the branch was taken off flush with the trunk. The trees were approximately 3 years old and the prunings were left in the inter-row areas. Any signs of fresh damage to the trees was noted each month and following Murua and Rodriguez (1989) the instantaneous rate of damage was calculated from  $D_i = \log (D_i/D_0)$ , where  $D_0$  is the initial number of trees showing damage and  $D_i$  is the number of trees showing fresh damage in that month.

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### **7.2.2 --- Stem Guards**

The study area was Linwood Estate which lies at 29°34'S and 30°04'E to the south-west of Midmar Dam in the Natal Midlands. It is owned and managed by Mondi Forests South. From 1000 trees, 500 were chosen at random and stem guards were put into place around them. The operation began on the 15th May 1995 and the trees had been planted in February 1995. The height of each tree was measured before the guards were in place and they were also inspected for recent rodent damage. The trees were measured and inspected at approximately 3 monthly intervals.

### **7.2.3 --- Chemical Repellent**

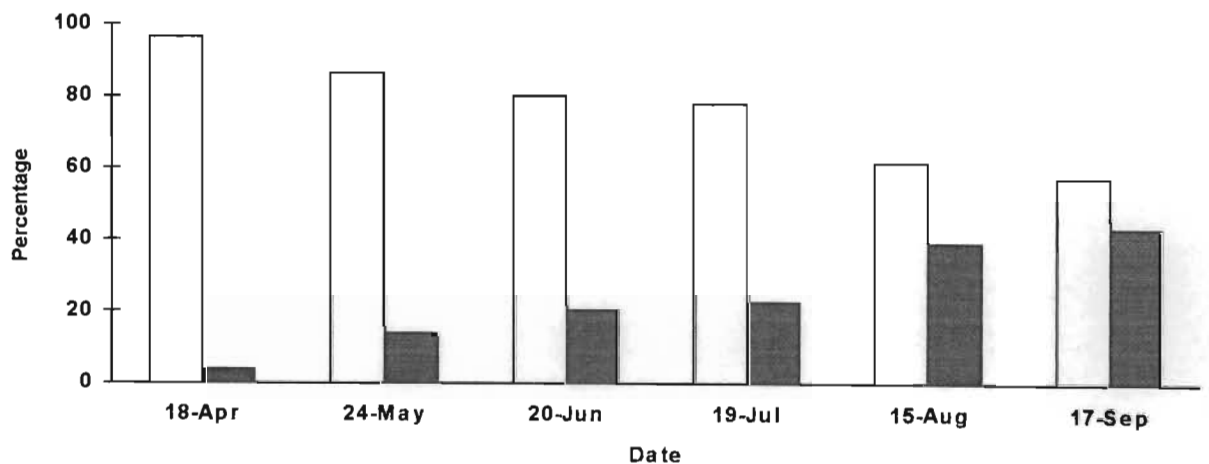
Twelve blocks of trees, 8 x 8 were marked of at random on the Linwood Estate and the trial began on the 22nd May. The trees were planted in February 1995. Six of the blocks were selected at random and a garlic repellent was placed at the base of each tree. The other 6 blocks were left as controls. The number of trees which showed any damage was counted as the repellent was being put out, and again in late December.

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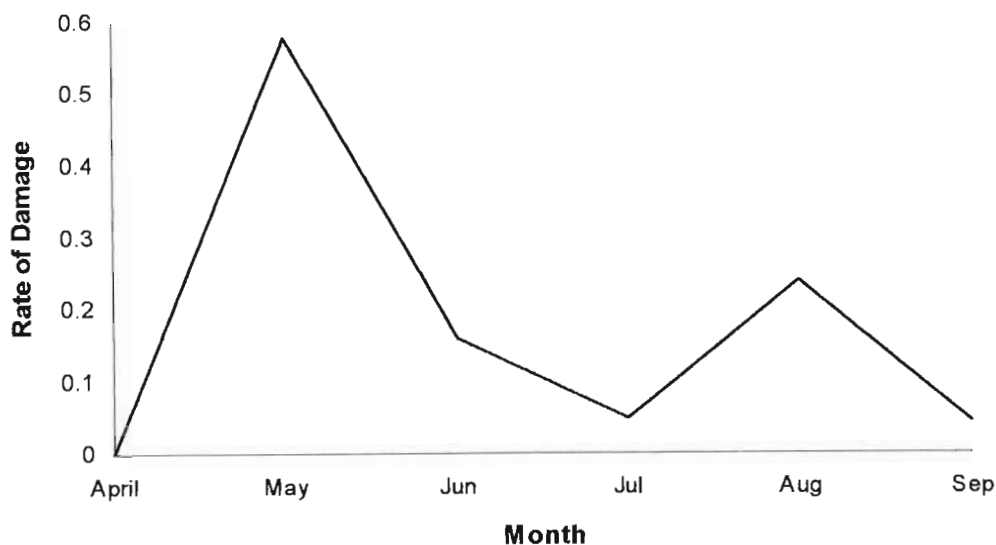
## 7.3 --- Results

### 7.3.1 --- Pruning

Very few trees showed any signs of damage in April, however by May, 13.8% of the trees were damaged and by the 17th September this figure had risen to 42.7% (Figure 7.1). No pruned trees showed any signs of damage at any time. The prunings that were left in the inter-row areas were gnawed, however, and some were completely stripped of bark.



**Figure 7.1:** The percentage of trees that were not pruned which showed rodent damage (shaded) or were not browsed.



**Figure 7.2: The instantaneous rate of damage of unpruned trees based on the formula given in Murua and Rodriguez (1989).**

The instantaneous rate of damage (Fig. 7.2) gives an indication of how the rodents turn to new trees as the season progresses through June to September.

### 7.3.2 --- Stem Guards

During the time that the guards had been applied no rodent damage was noted on any of the trees by end of the trial. No trees with guards had been attacked whilst 15% of the trees without guards had suffered damage ( $\chi^2 = 73.013$ ,  $p < 0.001$ ,  $df = 1$ , yates correction for continuity applied). Although these trees were still alive at that time, it is probable, given the nature of the damage, that rodents will return to these trees and they will eventually be ring-barked and die. The tree heights were measured to give an indication of whether the guards had a detrimental effect on tree growth, however the opposite was found (Table 7.1). The mean tree height of the treated and untreated

Date		Mean Height (mm)	95% Confidence Limit	t - Statistic	Significance
15-20 May 1995	With Guard	294.84	9.03	0.417	N/S
	Without Guard	291.98	9.90		
29th Aug. 1995	With Guard	392.25	11.84	5.305	< 0.001
	Without Guard	347.94	11.30		
29th Dec. 1995	With Guard	512.72	14.62	9.631	< 0.001
	Without Guard	396.17	14.78		

Table 7.1: The incremental growth rate of the trees with and without stem guards, the 95% confidence limits of the mean, the t-test statistic and its significance.

trees was not significantly different in May. By August the incremental growth of the guarded trees was double that of the unguarded trees and this growth enhancement continued until the end of the trial in December.

### 7.3.3 --- Chemical Repellent

There was no significant difference in the damage experienced on the chemically-treated blocks when compared with the untreated blocks ( $\chi^2 = 7.635$ ,  $df = 11$ ). It should be pointed out that during the trial, it was suspected that the area was broadcast with rodenticide on more than one occasion and this would obviously have influenced the results.

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## 7.4 --- Discussion

From direct observations, damage always begins on the lowest lateral branches and continues vertically over time. It would seem that given the lack of damage to the pruned trees, that the laterals serve as a ladder. With the removal of the “ladder” the animals are unable to climb to any significant height up the trunk. By far the most common and therefore the most destructive of the rodents that attack the trees is *R. pumilio*. It has noted in a laboratory study of the climbing ability of 11 species of muroid rodents that this species showed no tendency to climb (Dewsbury et al., 1980). They concluded that the species was adapted to a terrestrial habit. Earl and Nel (1976) concluded that *M. natalensis* had a propensity to utilise the vertical component of a habitat but whether they did so or not was inconclusive. The climbing ability of *O. irroratus* has not been studied but Earl and Nel (1976) showed that the pouched mouse (*Saccostomus campestris*) had a very low ability to climb and they concluded that this was due to its low tail to body ratio. As the tail to body ratio of *O. irroratus* is also low (De Graaff, 1981) this probably precludes it as a proficient climber.

The stem guards also seem to provide 100% protection against rodent damage and offered enhanced growth of the trees. Both of these effects have been noted before. Myllymäki (1977) reported that over the period 1969 to 1976 in Finnish seed orchards the principal control method against rodent damage to the trees shifted from poisoning to stem guards. During that period the incidence of damage reduced “markedly despite a doubling of the seed orchard area”. Similarly, Mason and Davidson (1964) found a significant reduction in damage to *Pinus taeda* by rabbits. Jolly (1980) noted that stem guards protected poplar and willow species from brush-tailed possums (*Trichosurus vulpecula*) in New Zealand. In Germany a polythene sleeve encasing the apical bud



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gave complete protection against deer browsing and improved growth, “presumably through a greenhouse effect” (Anon. 1963).

Chemical repellents have been tested before in South Africa as a means of protecting *Pinus radiata* against antelope damage (Novellie and Bigalke, 1981). They tested 3 chemicals, 2 commercially-produced repellents, plus synthetic fermented egg. The authors concluded that both commercial products were potentially effective, however, their effect lasted less than 14 days. The advantage of the “garlic devices” is that they release the odour slowly. Allan et al. (1984) demonstrated that deer browsing on Douglas Fir (*Pseudotsuga menziesii*) seedlings was significantly reduced when these devices were used.

## **7.5 --- Conclusion**

Of the 3 methods, both early pruning and stem guards seem to offer complete protection against rodent attack. Pruning at an early age, if it does not interfere with the incremental growth of the tree, offers a viable one-off method of protecting the trees against rodent attack. The stem guards offer the added advantage of enhanced growth. The results from the chemical repellent is inconclusive as the result of suspected interference during the trial.

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## **CHAPTER 8**

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## 8.1 --- INTRODUCTION

In the past the forestry companies have dealt with a clear-cut problem. Rodents in the forests cause damage to the trees that is economically significant, therefore the rodent population must be obliterated or at least controlled to a level until no economical damage occurs. For various reasons I believe that this view is an oversimplification of the problem and for successful rodent damage control it must be recognised that solving the problem is more complex.

Murua and Rodriguez (1989) have stated that “the goal for any control programme of wild fauna is to obtain the effect wanted by man with a minimum of risk to himself and a minimum of perturbation to the ecosystem”. Myllymäki (1979) pointed out that all programmes directed towards minimising damage involved the reduction of the numbers of the target species. This is preferable to habitat manipulation, being less disruptive and affecting the whole ecosystem to a lesser extent. He saw the first step of any control programme as the positive identification of the species responsible for the damage. The second step was the determination of the control threshold. The estimation of the pest population and the potential damage without control. Thirdly, the control measure must be selected for its technical and economic feasibility. Finally, to follow-up the efficacy of the control operation. He suggested that rodent populations reduced to say 20% of their original numbers may only need 6 months to fully recover. South African foresters do not appear to be aware of the need to follow up pest control programmes (Bigalke, 1980).

The principal aim of this study was to develop a co-ordinated method of reducing the damage caused by rodent browsing on commercially grown trees in the Natal Midlands, which is both economically and ecologically sustainable. From this aim a number of objectives emanated. It has been shown that 3 rodent species are involved in causing the damage *Rhabdomys pumilio*, *Mastomys natalensis* and *Otomys irroratus*, with the first species probably causing the most

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damage as a result of its relative prevalence in the forest environment. The reason behind this behaviour seems to be a seasonal protein deficiency. The nitrogen content of the trees is relatively stable over the year and the rodents turn to gnawing bark at a time when the nitrogen content of vegetation which comprises their natural diet falls below that of the bark. In the succeeding chapters I have discussed the relative efficacy of the control methods already used and other methods which may offer a solution. The purpose of this section then is to compare the economic and ecological viability of these methods.

## **8.2 --- THE ECONOMICS OF RODENT CONTROL**

Mondi Forests plant *Pinus patula* at a density of 1100 trees ha<sup>-1</sup>. The average time taken to plant a hectare is 3.5 mandays with a total cost of R1200 inclusive of labour and cost of seedling production. Although there are some other costs involved, such as the labour cost of weed control, these costs are negligible and will not be considered.

### **8.2.1 --- RODENTICIDE APPLICATION**

It has been pointed out in chapter 5 that rodenticide at a density of 1 block per 3 trees reduces the numbers of rodents in the forest but not significantly. The current cost of 1 kg of "Tornado" is R19.95 and although I am unable to find a costing for "Racumin" I will assume that both products are equitable. The weight of one block of "Tornado" is  $\pm 20$  g, whilst 1 block of "Racumin" weighs  $\pm 30$  g. To treat 1 ha of plantings with "Tornado" at a rodenticide density of 1 block per 3

trees, would involve an initial application cost of R146. The average replacement rate of “Tornado” was 59% per month, representing a monthly cost of R86. Therefore the first year costs R1092 ha<sup>-1</sup>, with the second year and subsequent years costing R1032 ha<sup>-1</sup>.

“Racumin” weighing 30 g per block is more expensive at the same application density. The monthly replacement rate of this product was also higher at 67%. Therefore “Racumin” application costs R1672 ha<sup>-1</sup> for the first year and R1584 ha<sup>-1</sup> for the second and subsequent years.

The additional costs are the same for both products. An average of 367 bamboo tubes are required to hold the rodenticide to safeguard against poisoning of non-target species. The cost of these are unknown. As a result of being subjected to extreme temperatures the tubes tend to split and it is estimated that 50% of the tubes need to be replaced each year. It requires 1 manday per month to check each tube and replace the rodenticide. Table 8.1 summarises the relative costs of the 2 products for 5 years of treatment. These costs could be cut by one third by not treating the areas between December and March, when the rodents are not browsing on the trees.

	First Year	Following Years	Labour	Tubes	Total
<b>Racumin</b>	<b>R1672</b>	<b>R1584</b>	<b>R1413</b>	<b>Unknown</b>	<b>R9421</b>
<b>Tornado</b>	<b>R1092</b>	<b>R1032</b>	<b>R1413</b>	<b>Unknown</b>	<b>R6633</b>

**Table 8.1: The total comparative costs involved in applying rodenticide to 1 hectare at a density of 1 block per 3 trees assuming that the tree is no longer in danger after 5 years.**

As the “Racumin” is comparatively more expensive I will only analyse the costs of application of “Tornado” at the higher density of 1 block per tree. Excluding the period when no rodenticide was replaced the average replacement was 69%. The following costs assume that the rodenticide is not applied during December and March and that it takes 3 mandays to replace and check 1 ha of

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tubes. The first year cost is R3124 ha<sup>-1</sup> and the second and subsequent years cost R2685 ha<sup>-1</sup>. Over 5 years this amounts to R13864 ha<sup>-1</sup> inclusive of labour but not including the cost of the bamboo tubes.

### **8.2.2 --- RAPTOR PERCHES**

The favoured design of perch in the Natal Midlands is one with a cross beam. The cost of this design is R6, however it has been pointed out in Chapter 6 that raptorial birds show a preference for perches with no cross beam, they only require that the top of the pole should have a diameter of about 10 cms. With no crossbeam the cost of a pole about 4 m long reduces to  $\pm$  R2. Assuming the poles are dug in at a density of 16 ha<sup>-1</sup> and that 1 manday would be required for their erection then the cost is R55 ha<sup>-1</sup> inclusive of labour. This cost is non-recurring, however, and the perches are not a viable control method 2 years after planting. They could be removed and stored for future use or left in place, the economics of either strategy is not significantly distinct.

### **8.2.3 --- PRUNING**

At about 2 years old the trees can be pruned to a height of approx. 1 m from the ground. Again this cost is non-recurring and as can be seen from Chapter 7 offers a reliable and effective method of controlling damage caused by rodents. The only cost involved is labour and  $\pm$  6 mandays are required to prune 1 ha of trees, representing a cost of R141.3 ha<sup>-1</sup>.

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### **8.2.4 --- STEM GUARDS**

It was indicated in Chapter 7 that stem guards also provide effective damage control. The stem guards which were used in this trial cost R3 each. For 1 ha of tree cover the cost is R3300. The sleeves themselves were not quite what the manufacturer had promised. The sleeves came in flat packs of twenty and each sleeve had to be assembled in the field. This was done by first opening them out around a metal shaft. An aluminium collar was placed over the top and crimped using another tool. Both tools were supplied with the sleeves. The sleeve was then positioned over the plant and the sleeve stake was driven into the ground. The overall construction was rather flimsy and on many occasions the aluminium collar fell off when taking the sleeves through grass. The sleeve stake was also made of aluminium and it was impossible to drive the stake into the ground without a mallet. Using the mallet almost always displaced the aluminium collar. Also because the sleeve had to be hammered into the ground, the sleeve could not be re-used as the manufacturers claimed. If the sleeves were field tested it was done in compost and not in upland forestry.

With two people working, one box of 20 sleeves took 45 minutes to construct and put in place. This represented  $\pm 4$  mandays  $\text{ha}^{-1}$  at an additional cost of R94. Therefore the total cost was R3394  $\text{ha}^{-1}$ .

### **8.2.5 --- GARLIC CHEMICAL REPELLENTS**

The cost of the garlic chemical repellents was \$0.55, which at current exchange rates is about R2. The manufacturers estimate that the devices are viable for 1 year, therefore coverage of 1 hectare for 5 years cost would cost R11000. There would be no labour costs involved in the first year as



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the devices can be stuck into the ground as the trees are planted. Subsequent labour costs would be R329.7, making a total of R11329.7.

### **8.3 --- ECOLOGICAL CONSIDERATIONS**

Having discussed the costs involved in each strategy I now turn to the ecological considerations of the control methods. It was pointed out in Chapter 5 that rodenticides at low densities do not significantly affect rodent populations, therefore if rodenticide is to be used then effective control is only possible at a density of 1 block per tree, with almost continuous monthly application. If the application is suspended then it has been shown in Chapter 5 that re-immigration of rodents into the area will quickly occur. In African ecosystems, many authors have shown that after a drastic decrease in the numbers of individuals captured, for instance after a fire, there follows a fairly rapid recovery to pre-fire densities in 6 to 15 months (Neal, 1970; Cheeseman and Delany, 1979; Mentis and Rowe-Rowe, 1979; Kern, 1981 and Rowe-Rowe and Lowry, 1982). It has also been pointed out that there will be increased breeding activity in the area.

A further difficulty involved in using rodenticide is the danger of secondary poisoning of non-target species, especially considering the amount of rodenticide used. In the Natal Midlands in 1994, 52 tonnes of rodenticide was used (Leibnitz, Pers. Comm.). Both the manufacturers of "Tornado" and "Racumin" have stated that the danger of secondary poisoning is negligible, however this claim was also made about toxaphene (e.g. Krump, 1956; Meyl, 1956; Schindler, 1957; Holmes et al., 1959; Dodge, 1959). Newton et al. (1986) reviewed the disastrous effects that continued usage of these chemicals had on Britain's sparrowhawk (*Accipiter nisus*) population. As recently as 1993, "Storm" was withdrawn from the South African market because of suspected secondary poisoning of non-target species.



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Two further points should be addressed concerning the use of rodenticides. Is it actually advisable to try to make the rodents locally extinct? Maser et al. (1978) concluded that the role of each species of mammal in an ecosystem must be examined and that small mammals were important distributors of mycorrhizal fungal spores and that without them the fungi would become limited.

Second, it is not the rodents *per se* that are the problem but the damage they cause.

The strategy of early pruning of the trees at 2 years old, is the most viable control method of non-lethal control, however that does not address the safety of the seedlings. The stem guards offer an expensive but viable solution. Myllymäki (1977) concluded that, although the installation of the guards amounted to 90% of the control costs in Finnish seed orchards, these costs had been recovered in 7 years through increased survival of the trees. Similarly, Mason and Davidson (1964) found the cost of polyethylene stem guards was justified because of the significant reduction in damage to *Pinus taeda* by rabbits. Given the success of the guards and the unsuitability of the present design it would be profitable to investigate a better designed guard. However, even the extra cost of the guards may be justified because of the growth enhancement offered.

The low cost of providing raptor perches with no crossbeam also seems to offer a control strategy in newly planted areas.

## **8.4 --- RECOMMENDATIONS**

1 ... It is clear from the preceeding chapters that the most suitable method of controlling rodent damage depends on the age class of the tree.

2 ... Before any new plantings are attempted the rodent abundance of the area should be assessed between March and September. There is little point in trying to assess the population at other times

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as it will be naturally low. The lowest cost method of assessment is trap lines using snap traps baited with peanut butter and oats.

3 ... A central database should be kept which records the locality and the rodent abundance in terms of unit effort.

4 ... All new plantings should be provisioned with raptor poles, with no crossbeams, at a density of  $16 \text{ ha}^{-1}$  as a first line of defence. If possible the poles should be erected in advance of the planting to encourage birds to the area or acclimate an existing population to using the poles. This will also reduce the rodent population before planting begins. Obviously, more significant reductions will occur as a function of the time period between pole erection and planting.

5 ... New plantings should be inspected at weekly intervals beginning in April until December for signs of rodent browsing. **If** the rate of rodent attack becomes economically significant, then the trees should be fitted with stem guards.

6 ... Stem guards should also be used to bring under cultivation areas which forest managers have previously abandoned as a result of severe rodent activity.

7 ... All trees should be pruned to a height of at least 1 m as early as this is feasible. The pruning of the lateral branches should be done flush with the trunk and the prunings left in the interrows. After this pruning the trees can be regarded as safe from browsing rodents.

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8 ... The forest companies should tender for a better design of stem guard. The guard should be made from opaque plastic and be removable. It need be as simple as two pieces of guttering pipe wired together, which can be forced into the newly dug soil round the seedling. Simplicity of design and the capability to be reused will significantly reduce the cost.

## **8.5 --- CONCLUSION**

The use of rodenticides is neither economically or ecologically defensible. Because of reimmigration and increased rodent breeding effort, the rodenticide must be reapplied each month except for a 4 month break. The provisioning of raptor perches at a high density provides a first line of defence in new plantings, however the most efficient method of damage control is the use of stem guards. Unfortunately, these are too expensive to justify their use. A new design should be promulgated which is both suited to the rigours of forestry and which is reuseable. When the trees are able to sustain it then they should be pruned to a height of at least one metre.

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**CHAPTER 9**

**9. REFERENCES.....91**

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## Chapter 9

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