THE INTERACTIONS BETWEEN POSSUMS, HABITAT TREES AND FIRE.

Thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Science with Honours at the Australian National University.

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Except where specific acknowledgment is given this thesis is my original work.

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ABSTRACT

This study in south-west Western Australia attempted to define the types of trees inhabited by the brushtail possum (Trichosurus vulpecula Kerr, 1792) and the ringtail possum (Pseudocheirus peregrinus Boddaerts, 1785) and how the ecology of these animals, and their host trees, are influenced by high intensity fire.

Any tree, regardless of species, condition, height or size is suitable for habitation by possums providing it contains a suitable hollow. Suitable hollows are defined by depth, with deeper hollows used significantly more frequently. Hollows of suitable size for habitation by possums first develop in jarrah trees at about 300 years of age and in marri trees at about 200 years. The average age of trees inhabited by possums was estimated at about 500 years for jarrah and 400 years for marri. In my study areas about 3 trees ha^{-1} were used by possums for diurnal refuge: the distribution of these trees was random.

Six brushtail and one ringtail possums were fitted with radiotelementry collars and tracked intensively. These animals utilized an area of about 3 ha each (range 2.6 - 5.9 ha). There was a high degree of overlap between the ranges, both spatially and temporally. Hollows in trees were the favoured sites of duirnal refuge but logs and dreys were also used.

Most animals were active for about 500 min. each night with most activity evident at the beginning and end of the active period. About 30% of the active period was devoted to terrestrial activities.

The animals spent significantly more time in parts of their habitat contiaining trees with significantly higher nutrient values in the foliage. This was particularly evident for P and K.

Fire of high intensity destroyed 37.8% of trees inhabited by possums: the degree of damage to such trees is related to their condition and the intensity of the fire. Fire also defoliates vegetation, removing the food source. The short-term effects are detrimental to populations of possums.

In the longer term, fire of high intensity increases the rate of formation of hollows by directly excavating hollows or by providing sites for fungal, and subsequently, termite infestation. The average age of trees which contained hollows and were used by possums 32 months after a fire, decreased by about 100 years from the average age before the fire. Fire also releases nutrients locked in the ecosystem. Because the quality of the habitat increases, due to the release of nutrients, and the quantity of hollows increases, the longer term effects of the fire of high intensity are beneficial to populations of possums.

Acknowledgments:

In any first attempt some guidance, advice and critisms are necessary. I was fortunate enough to have two competent and patient supervisors, in Dr. Mick Tanton and Mr Stuart Davey, to guide me in this first attempt at a thesis. Special thanks are due to Dr. Tanton who not only took on the role of supervisor but also as english tutor.

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CHAPTER ONE - INTRODUCTION

1.1. BASIS OF THE STUDY

The possible adverse effects of intensive, large scale forestry practices is a contentious issue. Some early concern was for the largely unknown effects of forest management on fauna which nested and roosted in hollows in trees (Tyndale-Biscoe and Calaby 1975). In a paper presented to A.N.Z.A.A.S. and to the Senate Woodchip Inquiry (1975), Tyndale-Biscoe and Calaby state "there is not enough information for any arboreal species of mammal to know what the minimum requirements for these are". The Senate Standing Committee on Science and the Environment in its report on "Woodchips and the Environment 1977", reiterates the concern expressed by Tyndale-Biscoe and Calaby when stating : "Much evidence was received concerning the need of many species of animals and birds for trees containing holes or hollows. Even so, this evidence revealed that very little is known about the size, number or kind of hole needed".

Before 1975, a defective tree which might contain a hollow(s), was termed a stag, cull, overmature, rogue or snag tree and possessed no commercial value, occupied valuable growing space and, in some situations, created a fire hazard. In the Eastern States of Australia, these trees were usually removed during silvicultural operations (Florence and Shepherd 1975). In Western Australia, intensive stand improvement operations from 1920 to 1940 used the surplus labour created by the Depression (Stoate 1923, Harris 1956). During stand improvement operations, large non-commercial trees were ringbarked (Anon 1927) to create growing space for the regenerating forest crop. By the mid-seventies, the term "habitat tree" crept into the forester's vocabulary, although this unfortunate terminology was intended to mean trees suitable for habitat for wildlife. At this time, few data were available on which to base decisions about management of fauna dependent on hollows. This is disturbing as about 23 percent of Australia's vertebrates, almost 350 species, are known to use hollows in some way (Ambrose 1982).

1.2 THE LITERATURE

Very little information has been published on the relationships between hollows in trees and fauna except in an incidental manner accompanying life-histories. Information that is available has been published recently, as the importance of this topic to wildlife management is realised. The papers on relationships between hollows in trees and fauna can be grouped into four categories :

(i) the value of the hollows in trees to wildlfe,

(ii) the formation of hollows in trees,

(iii) estimates of the number of hollows required per hectare for wildlife management, and

(iv) overseas parallels.

1.2.1. The value of hollows in trees to wildlife

Cowley (1971) was one of the first Australian authors to point out the high value to wildlife of overmature or defective eucalypts. He called for forest management which enhanced other values by retaining such trees and preserving habitat rather than a single emphasis on timber production. Tyndale-Biscoe and Calaby (1975), Sanderson (1975), Hampton and Seebeck (1970) and McIlroy (1978) all expressed concern that the removal of overmature or defective trees, during operations for improvement of forestry stands, decreased the wildlife values of the areas concerned. Meredith (1984) found a high correlation between the presence of standing dead timber and the presence of arboreal mammals. McIlroy (1978) lists areas of research needed into the role of hollows and their use by wildlife.

Recommendations have been made for the culling of suppressed or dying trees from a stand to reduce the losses of timber production caused by insect attack or competition. Incoll (1978) tested the effects of the retention of overstorey on regeneration of E. sieberi L. Johnson in Boola Boola State Forest and produced estimates of standing volume of regrowth lost due to suppression. His findings ranged from 8% of regrowth volume lost for 2 overwood trees ha^{-1} to 77% lost for 20 retained trees ha^{-1}.

Before the late 1970's, most information about hollows and wildlife was gathered during studies of life-histories. These included those at cockatoos (Saunders et al. 1982, Saunders 1979), possums (How 1978) and gliders (Tyndale-Biscoe and Smith 1969 a,b), however, few investigations have considered hollows in trees as a resource to be divided among the fauna of a community. Exceptions included Golding (1979) who examined the diurnal use by birds and mammals of artificial hollows attached to trees in the Wombat State Forest in Victoria. Particular reference was made to the timing,locality, breeding success and inferred function associated with use of hollows for each species. Working in conjunction with Goulding, Calder (1979) examined physical characteristics of natural hollows to establish interior temperature patterns. This information allowed the design of artificial hollows which provided similar temperature patterns. Using Goulding's data, Calder correlated an animal's choice of hollows with certain physical parameters and linked these to those affecting the interior temperature patterns. Also working in the Wombat State Forest,Manderson (1979) related the availability of natural hollows to forest-management operations in the past and discussed the relationships between vegetation, natural hollows and wildlife usage of those hollows. The 3 studies in the Wombat State Forest were combined to produce a management strategy for arboreal species in that forest (Calder et al. 1983).

Ambrose (1982) inspected artificial hollows and observed natural hollows in tall open forest and grassy woodlands in Victoria and examined the formation, distribution and abundance, structure and positioning of hollows used by vertebrate fauna. Man's effects on the availability of hollows were discussed and recommendations made for forest management.

The temperatures in hollows used by nesting Galahs, and the factors that influenced these temperatures, were investigated by Schmidt (1979). In addition, water-budgets of nestling Galahs were compared to those of adults and related to conditions occurring in the nest. Saunders (1979) related the parameters of hollows to the selection of hollows and the breeding success of white-tailed black cockatoos in remnant woodlands in the southwest of Western Australia. He suggested that the rate of destruction of the hollows was greater than the rate of creation and perceived a possible future shortage of hollows in the area.

The availability and dimensions of tree hollows that provide nest sites for 8 species of birds (6 Psittaciformes, 1 Anseriformes and 1 Falconiformes) in sympatry is provided by Saunders et al. (1982). The resource of hollows was partitioned among the bird species by the size of the hollows used, separable by the size of the entrance and the inside diameter of the cavity of a hollow. The authors commented on the dismal future for the availability of hollows in the study area.

The number of vertebrate species using hollows in standing trees in Australia is not clear, although Ambrose (1982) suggests that 350 species may do so, including 119 (17%) species of birds and 95 (42%) species of mammals. Fifty of the 250 species of land birds recorded in Victoria regularly use hollows in standing trees as do 6 species of bats, 5 species of possums, 5 species of gliders and 3 species of phascogale (Cowley 1971) and Disney and Stokes (1976) state that 19.7% of Australian land birds usually or always nest in holes in trees or stumps.

1.2.2. The formation of hollows in trees

Species of vertebrates in Australia which use hollows are almost completely dependent on processes of decay assisted by invertebrates (e.g. termites) for the provision of hollows, as primary vertebrate excavators such as woodpeckers (Piciformes) are absent from the Australian environment (Ashton 1975, Saunders et al. 1982). The dependence of non-excavating birds on excavating birds for the provision of hollows has been documented by Raphael and White (1984) for birds nesting in cavities in the Sierra-Nevada Mountains in the U.S.A. Processes for the formation of hollows are slower in Australia than the processes in the countries where Piciformes are found. Consequently, there may be an inadequate number of hollows available in some areas and this may limit the populations of certain species (McIlroy 1978, Tyndale-Biscoe and Calaby 1975.)

Little is known about the formation of hollows in eucalpyts. Hollows are only likely to form in plants if durable branches are present and limbs are large enough to support cavities (Ambrose 1982). There is no correlation between timber durability and resistance of living trees to decay (Manion and Zabel 1979). Marks et al. (1982) and Wilkes (1982 a) show that tree species and individual trees vary in their resistance to decay. Mackowski (1984) states that the formation and maintenance of hollows suitable for vertebrate fauna in blackbutt (E. pilularis Smith) is dependent on -

(i) excavation of hollow limbs by termites,

(ii) branch breakage to allow access to hollows,

(iii) drainage patterns within tree hollows, and

(iv) occlusion of hollows by continued branch growth until eventual total collapse of the large tree occurs.

Information about the role of fire in the formation of holes in trees is sparse. Ambrose (1982) believes fire creates "snag tops" and thus hollows, but destroys existing hollows during severe fires. Frequent burning is seen as one reason for the shortage of natural hollows in highly managed forests (Calder 1979) while Cowley (1971) and Ashton (1975) list fire, along with termites and fungi, as the major agents which form hollows. High intensity fires increase tree mortality and cause fire-scars in jarrah. (E. marginata Donn. ex Smith)

(Abbott and Loneragon 1983a) thus providing access to decay-causing organisms (Peace 1962). However, no published information is available in Australia about the effect of fire on the number and quality of hollows in a particular area.

The age at which a tree will develop hollows has been estimated as a minimum of 50 years for such species as E.fastigata Deane and Maiden, E. viminalis Labill, and E. dalrympeana Maiden, while estimates for dry sclerophyll species such as E.macrorhyncha F.Muell, E.dives Schauer and E.pauciflora Sieber was a minimum of 100 years (Disney and Stokes 1976). The first systematically-researched estimates of the age at which the hollowing processes occur and reach their maximum was provided by Ambrose (1982). He estimated that hollows first form in eucalypts in Victoria at over 100 years of age and increase to a maximum number of hollows per tree at about 400 to 700 years of age. The smallest E.salmonophloia F. Muell. capable of developing a hollow suitable for habitation by any cockatoo would be 130 years old (Saunders et al. 1982). Hollows suitable for larger wildlife, such as arboreal mammals, do not form in blackbutt trees less than about 200 years old, which is about two thirds the life span of the tree (Mackowski, 1984).

1.2.3. Estimates of the number of hollows required per hectare for wildlife management

Artifical hollows, such as nest boxes and adapted logs, have been used to examine the ecology and behaviour of wildlife using hollows (e.g. Calder et al. 1983, Ambrose 1982). Twelve vertebrate species used nest boxes placed in Gippsland forests (Menkhorst 1984), and indicated the demand for natural hollows. Suckling and MacFarlane (1983) used nest boxes to introduce the sugar glider (Petaurus breviceps) into the Tower Hill nature reserve in Victoria.

Estimates of the number of "habitat trees" or nest boxes required per hectare to maintain adequate levels of wildlife populations are available for management purposes. Between 10 to 15 hollows per hectare would be required to maintain populations for 8 of the species studied by Menkhorst (1984).

A minimum of 5 hollows per 15 ha was recommended by I.D.T.F. (1982) when proposing management prescriptions for a trial pulpwood harvesting operation in the Otway Ranges. In a blackbutt forest with an average d.b.h.o.b. of 40 cm and which had more than 3 trees with hollows per hectare, some factor other than hollows limited possum and glider populations (Mackowski 1984), though he considered that requirements for hollows were difficult to determine because of the inter-relationships between hollows and other habitat factors.

1.2.4. Overseas experience

Information about species which use hollows in the U.S.A. and Europe is relatively advanced. In the U.S.A., studies by survey (Conner and Adkisson 1974) or using nest boxes (Barkalow and Soots 1965) have yielded results with implications for forest management. In Europe, Von Haartman (1957) was the first to document that when large numbers of fauna which require hollows occur in areas with low numbers of available hollows, severe inter- and intra-specific competition exists for nest sites. Von Haartman (1957) also describes the adaptations involved with the use of hollows and the taxonomic levels at which usage of hollows occurs.

Research in the U.S.A. has been directed towards providing habitats containing adequate numbers of hollows in managed forests (McClelland et al. 1975, Raphael and White, 1984) and in some areas foresters are provided with tables to choose what populations of users of hollows they require for particular areas (see Thomas et al. 1979). In some areas, the processes that form hollows are assisted by the use of explosives and by inoculation of decay organisms into the resultant wound (Bull et al. 1981). The increasing demand for fuelwood with its threat to wildlife has been perceived in the U.S.A. Carey and Gill (1980) rated tree species or groups of species on the basis of their value for both firewood and to wildlife and used the ratings to decide how to manage a woodlot for fuel and wildlife objectives. Public awareness of the value to wildlife of "snags" (a term used in the U.S.A. for "habitat trees") is being promoted in the U.S.A. by information pamphlets (e.g. U.S.D.A. 1980)

1.3 THE STUDY

Different species have different physical requirements within a hollow, resulting in a partitioning of the resource within the community using hollows (Ambrose 1982, Calder 1979, Raphael and White 1984). An adequate account of the relationships between species and hollows, partitioning of the resource and the effect of fire on these interactive phenomena, on a community basis, is beyond the scope of an honours thesis. Two species of arboreal mammals, the common brushtail possum (Trichosurus vulpecula Kerr, 1792) and the common ringtail possums (Pseudocheirus peregrinus Boddaert, 1785) were selected for study. These species have several advantages for a research project :

(i) they are relatively common within the study areas and are easily trapped or caught by hand,

(ii) trees used as part of their habitat are easily identified by the characteristic scratch marks left on the bole (Scratch tracks) during the ascent and descent of the animal to and from a shelter hollow (See Plate 1),

(iii) they are large enough to wear the available radiotelemetry transmitters without undue discomfort to the animal and,

(iv) they have varieties unique to Western Australia. Trichosurus vulpecula vulpecula is common (Strahan 1983), but the Western Australian form of the common ringtail Pseudocheirus peregrinus occidentalis is listed in the Wildlife Conservation Act, 1950 as rare, or otherwise in need of special protection (Government Gazette 1983). It is also considered a separate sub-species with morphological and behavioural differences from the nominate race with a geographically isolated distribution (Winter 1978) and probably warrants species status (McKay 1984). Very few data are available concerning the Western Australian varieties of the two species, therefore the opportunity exists to supplement a limited data base (Plates 2 and 3).

In this thesis, the term "habitat tree" refers to a tree containing hollows which are used by the common brushtail or the common ringtail possum for roosting, sheltering, nesting and/or breeding and does not include any other species using hollows within the study areas, except in an incidental manner where co-habitation occurs.

Fire as a management tool is increasing in popularity despite the relatively limited knowledge of the effects of prescribed burning on the environment. The study of "habitat trees" evolved as a result of concern about lack of information about them.

Objectives of the study were :

(i) to quantitatively define a "habitat tree" and identify the important parameters which suited them to the two species of possum;

(ii) to observe and quantify the short term (three weeks) and longer term (two years) effects of fire on the availability and quality of these trees;

(iii) to observe and quantify how the two species utilize their habitat and determine reasons for the patterns of movements recorded; and

(iv) to assess the effects of some forestry practises on availability of habitat trees and on utilisation of habitat by possums and suggest procedures to forest management which,based on the information collected, will preserve or provide such habitats.

Preliminary work commenced in February 1981. The location, measurement and mapping of all habitat trees in two large plots was followed by burning of one plot while the other was maintained as a fire-free control. The short-term effects of fire on habitat trees was monitored.

Although the preliminary study yielded interesting results, it also left many unanswered questions about the longer term effects of fire on "habitat trees" and the relationships between fauna species and "habitat trees". In 1983, after a two year break the study was extended as part of an honours degree project and incorporated some behavioural aspects of the animals concerned.

Both plots assessed during 1981 were re-assessed during summer 1983/1984 and a radio-telemetry tracking programme with 3 common brushtail possums was completed. During the summer of 1984/1985, a radio-telemetry tracking programme with 2 common ringtail and 4 common brushtail possums was completed.

Some terminology used in this thesis has evolved from forester's jargon and may be obscure in meaning. Such terms have been defined in the Glossary (Appendix 1). Definitions are also provided for terms with specialised uses in this thesis.

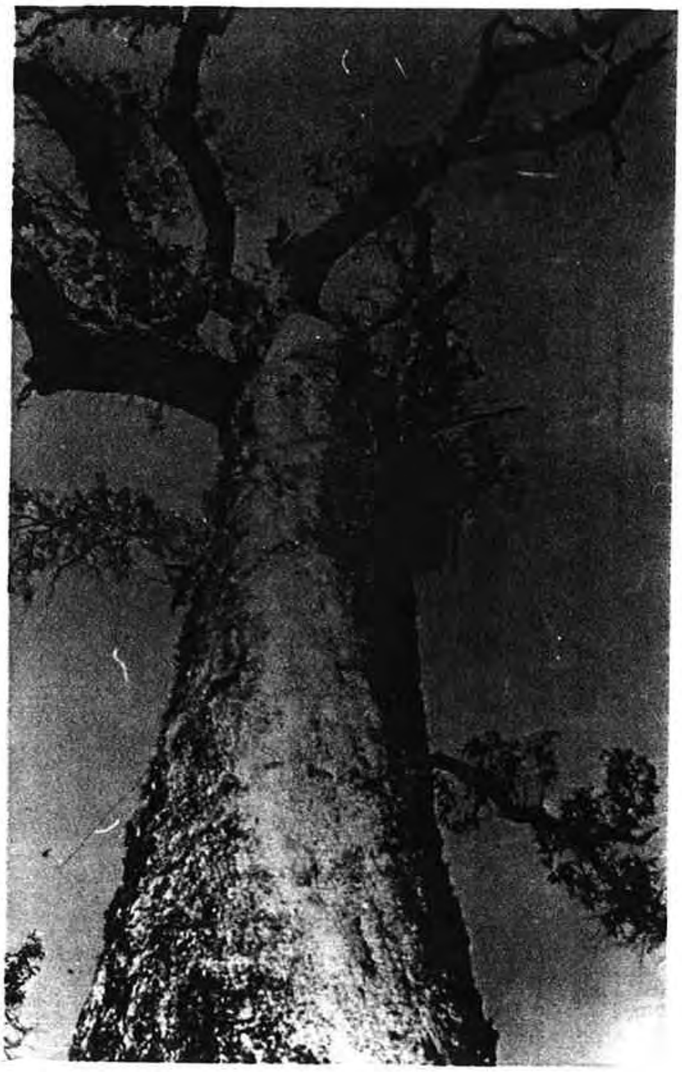


Plate 1. A typical "habitat tree" with a prominent scratchtrack along the bole. The hollow is in the broken branch, centre top.

Plate 2.   A western ringtail possum.

Plate 3. A common brushtail possum wearing a radiotelemetry collar and eartags.

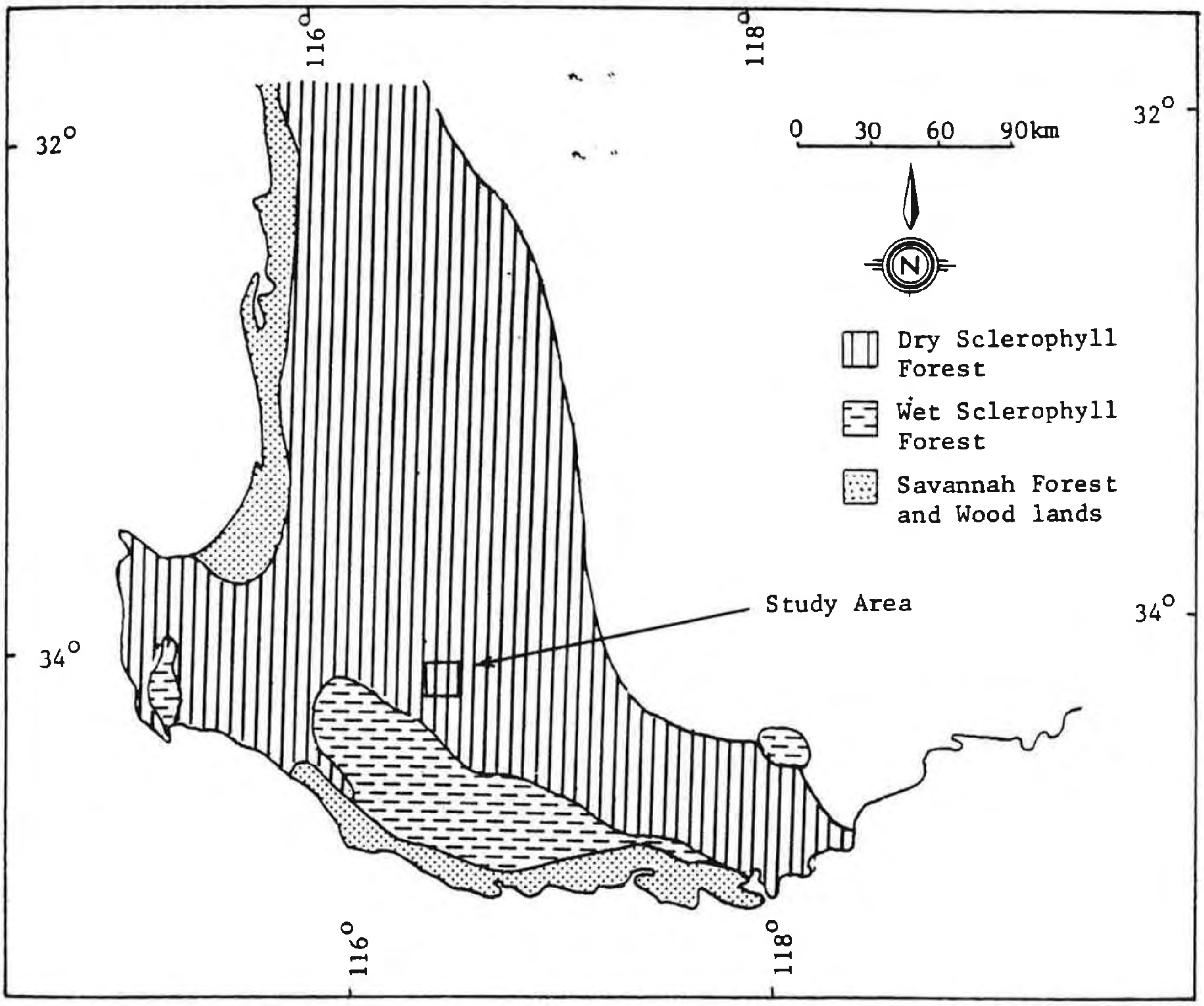
CHAPTER TWO - MATERIALS AND METHODS

2.1 THE REGION

The study areas are within the Perup Fauna Management Priority Area which occupies about 40 000 ha situated on the eastern edge of state forest, 50 km east of Manjimup in southwest Western Australia (Fig. 1). The area is managed by the Department of Conservation and Land Management (formally the Forests Department of Western Australia) as a Flora, Fauna and Landscape Reserve (Anon. 1977) and is used primarily for the conservation of fauna and flora and for ecological research (Christensen 1974). My project was in accord with research and investigation objectives of the Perup Fauna Priority Area Working Plan (Anon. 1976). The area includes the forest blocks of Chariup, Boyicup, Camelar, Yackelup, Moopinup, Yendicup and the southern parts of Dualgan and Balban. Only sections of the Yendicup and Boyicup blocks were used in my study.

The terrain is generally undulating with low ridges separated by wide, flat valleys. The tributaries of the Perup and Tone rivers drain the area but permanent water is scarce. Annual rainfall averages between 650 mm and 750 mm. Most of the eastern sector of the region is similar to the Perup association (McArthur and Clifton 1975) with yellow podzolic soils along drainage lines with sandy gravels and occasional boulders and sheets of laterite pavement along the ridges. The south-western sector is similar to the Nyamup association (McArthur and Clifton 1975), with yellow and red podzols and red earth predominating on the ridge and slopes, and terraces of loamy alluvium occupy the gullies.

Figure 1. Map of the south-west of Western Australia showing the location of the study area.



2.1.1 The Boyicup Study area

In this area a high intensity prescribed burn was scheduled for Autumn 1981, to regenerate heart-leaf (*Gastrolobium bilobum*) and thus enhance habitat for tammar wallabies (*Macropus eugerii* Desmarest) (Anon. 1984). Siting a plot containing "habitat trees" in this area guaranteed the plot would be burnt. The area lies at latitude 34°23'S and longitude 116°36'E and is bounded by Glendale Rd., Glendale 2 Rd., Boyicup 1 Rd. and Boyicup 2 Rd. (Fig. 2).

The area tends towards the more deeply dissected topography of the Nyamup association (McArthur and Clifton 1975) where the valley sides have slopes of about 5°. The main soils are yellow podzolics with red podzolics or red earths,with the main stream-lines containing terraces of loamy alluvium.

Smith (1972), using Specht's (1970) classification, defines the forest structure of the Boyicup study area as open forest, while Beadle (1981) categorises the characteristic tree species into his *Eucalyptus marginata - Eucalyptus calophylla* alliance. These 2 tree species are the sole components of the upper stratum except along drainage lines where they are occasionally joined by flooded gum (*Eucalyptus rudis* Endl.). Xeromorphic shrubs form an open understory along the ridge tops with typical species including *Bossiaea orinata* (Lindl.) Benth., *Hakea lissocarpha* R.Br., *Leucopogon capitellatus* Oc. and *Macrozamia riedlei*. Christensen (1980b) classifies this understorey as type F. Downslope, the xeromorphic shrubs give way to tall thickets of Gastrolobium with a ground cover of grasses and annuals and is classified as type R understorey by Christensen (1980b), (Plates 4 and 5).

2.1.2 The Yendicup Study Area

The Yendicup area provided an unburnt control for comparison between "habitat trees" from the south (Boyicup) and those from the north (Yendicup) of the Perup Fauna Management

Figure 2. Map of the Boyicup study area showing the location of the Boyicup habitat tree plot.

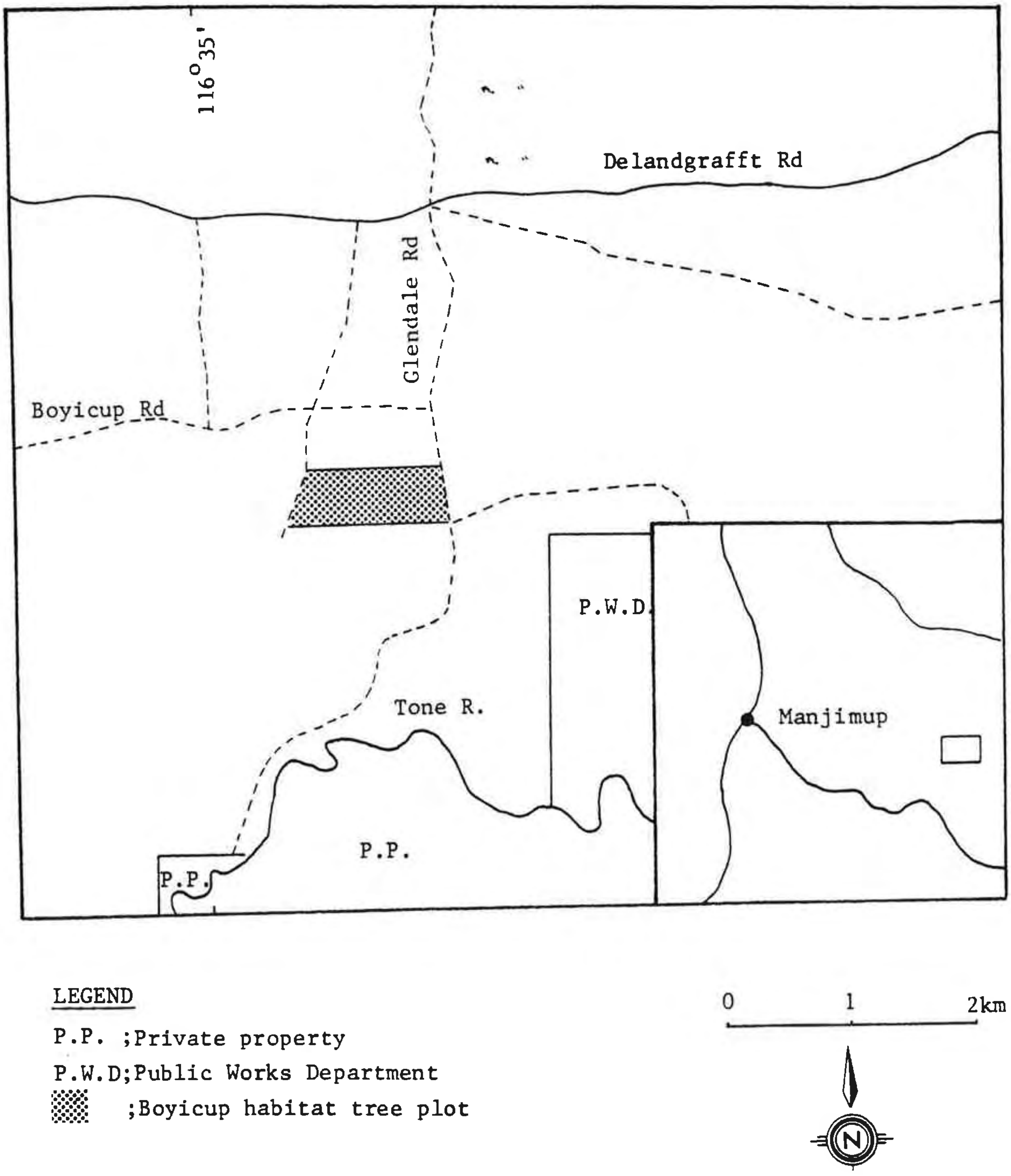


Plate 4. Vegetation on the ridge at the Boyicup study area.

Plate 5. Vegetation on the lower mid-slope at the Boyicup study area.

Plate 6. Vegetation at the Yendicup study site.

Priority Area. The site is about 18 km north of Boyicup at latitude 34°07'S and longitude 116°36'E and is bounded by Spencer and Bandicoot roads (Fig. 3).

The area lacks the dissected topography of the Boyicup site and tends towards the Perup association of McArthur and Clifton (1975), which is made up of broad flat drainage lines with narrow interfluves. The soils of the drainage lines are mainly yellow podsolic while those of the interfluves are generally very gravelly.

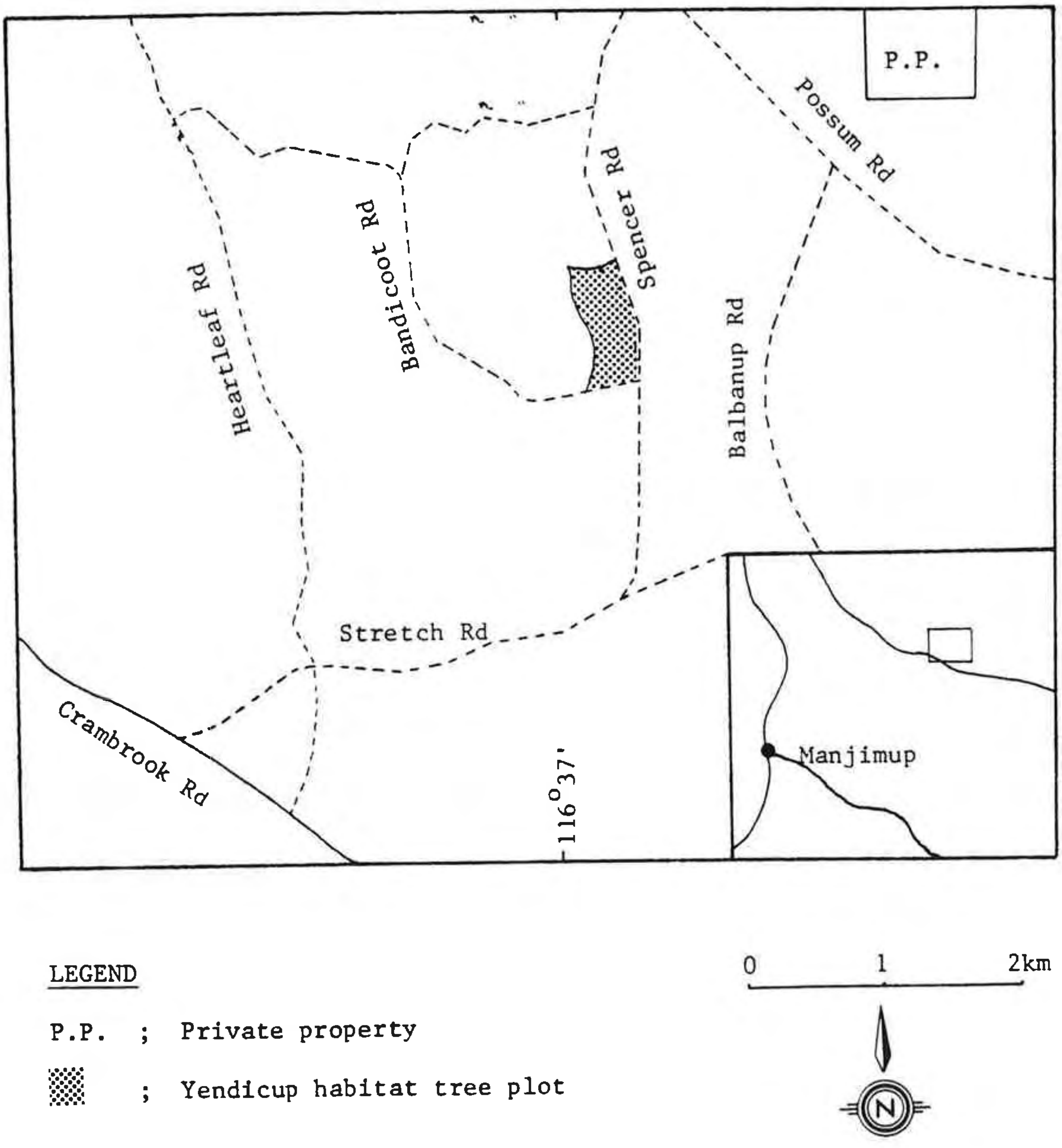
The area has similar forest structure and tree species to those described for the Boyicup area. The understorey is again composed of xeromorphic shrubs but it can not be assigned readily to any of the vegetation site types of Christensen (1980b). The low open understorey found on the ridges is composed mainly of *Hakea lissocarpha* R. Br., *Leucopogon capitellatus* F.V., *Acacia pulchella* R.Br. and *Hypocatymma argustifolium* Endl., which give way to small thickets of *Melaleuca viminea* Lindl. and scattered bushes of *Gastrolobium bilobum* around the drainage lines. The dense thickets of *Gastrolobium bilobum* evident in the gullies of the Boyicup area are absent from the Yendicup area (Plate 6).

2.1.3 Fire history

Eucalypts and their associated understorey species are adapted to survive fire; such adaptations have been reviewed by Gill (1975). Flora in the study areas show similar adaptations, which suggests that fire has been a long-time factor in the evolution of the flora in the region and a relatively frequent event. Churchill (1968), using carbon dating of charcoal deposits in the south-coast swamps confirms the frequency of fires before 1800.

The fire regime in the south-west has varied first with the arrival of aborigines and then of europeans (Underwood and Christensen 1981). Although fires have been frequent in the

Figure 3. Map of the Yendicup study area showing the location of the Yendicup habitat tree plot.



past, reliable records of fires on the study areas are only available for the period since 1938. Early records are incomplete, but leave little doubt that the area has been subject to fire at frequent intervals. The most severe recorded fires were in 1949-50 when the entire area appears to have been burnt by a wildfire.

As part of the forest estate, the study areas have been subject to regular prescribed burns, on a 5 to 7 year rotation, since 1955 (Peet 1967). The plan of prescribed burning for the areas was amended in the mid 1970's to conserve and enhance faunal, rather than timber values (Christensen 1974, 1983). Recently, as a result of studies by Christensen (1980b), the previous amended plan of burning was superseded by another more detailed plan which allows for alternate spring and autumn burning on longer rotations, ranging from a 6 to 7 year rotation to areas remaining free of fire. Consequently, the period of fuel accumulation for the 2 study areas was longer than for similar areas outside the Perup Fauna Management Priority Area. At the start of my study (1981), the period of fuel accumulation at the Boyicup site was 5 to 6 years on the ridges and about 27 to 28 years in the gully, while that at the Yendicup study site was about 27 to 28 years.

2.1.4 Logging history

Like most of the jarrah forests of the south-west, the Perup Fauna Management Priority Area has been harvested for commercial timber. Harvesting operations were based on a selective system with the intensity of operations varying greatly with forest quality. Most commercial stands in the areas were first harvested during the early 1940's with a second cut commenced in 1966 and continued sporadically until 1976 when the commercially viable sawlog resource was exhausted. No more than one third of the standing basal area of both merchantable and non-merchantable species were removed during the second harvesting operation (Anon.1976).

Logging operations were scant in the gully regions of the Boyicup study area because of the predominance of Marri (Eucalyptus calophylla R.Br.) and were mainly confined to the ridge tops where commercially viable stands of jarrah were found. An average of 8 trees ha^{-1} were removed from the ridge areas.

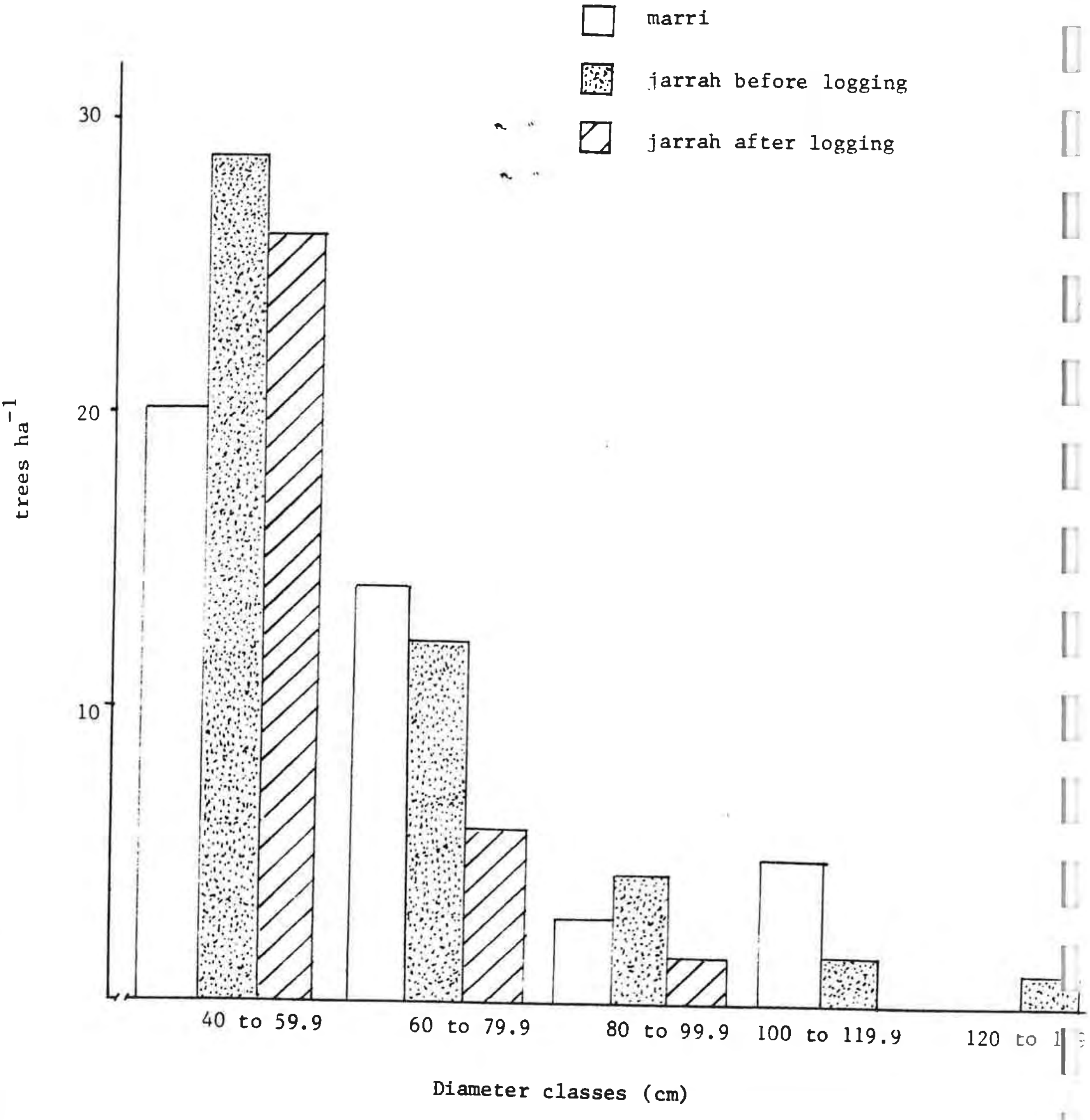
During 1975, areas around and including the Yendicup study area were harvested. Only jarrah with a diameter at breast height over the bark (d.b.h.o.b) above 40 cm was removed. These averaged 16 trees ha.$^{-1}$ (Inions 1981b) (Fig.4).

2.1.5 Fauna

The area containing the 2 study areas was designated a management priority area in 1971 because of the diversity of faunal species present. The area now contains more species of mammals than any other similarly sized area in the south-west of Western Australia. A total of 24 endemic and 5 exotic species of mammals, 86 bird species, 13 reptilian species and 7 species of frogs have been recorded in the area (Christensen et al. in press). Five of the mammalian species, including the ringtail possum, are listed as rare, or otherwise in need of special protection (Government Gazette 1983) (Appendix 2).

Eleven (45.8%) of the endemic mammal species and 21 (24.4%) of the bird species are known to use hollows in trees (Strahan 1983, Frith 1979). Such an abundance of species using hollows in a single area emphasises the importance of a previously neglected resource of hollows which we had not realised previously.

Figure 4. Frequency distribution of the number of trees per hectre at the Yendicup site, to show the effect of logging.



2.2 THE STUDY OF "HABITAT TREES"

2.2.1 Stand composition

Tables of stand composition were prepared from data collected in 37 (20 Boyicup, 17 Yendicup) randomly-selected square plots, each of 400 m^2. The tree species and d.b.h.o.b., for all trees with a d.b.h.o.b. > 2 cm, were recorded in each plot. Plot positions were located along a random transect at right angles to the contours, to incorporate any vegetation gradients.

2.2.2 Location of trees suitable for possum habitation

During summer 1981 and again in the summer of 1983/84 (see Section 2.2.6), a subjective search was made of 2 plots, the first of 35.6 ha in the Boyicup block, the other of 21.5 ha. in the Yendicup block, to locate, mark and plot the position of trees suitable for possum habitation (Figs. 2 and 3). The criteria for selection were that a hollow was visible and a scratchtrack was present, either on the bole of the tree in question or on a neighbouring tree, sufficiently close to enable the animal to transfer.

In both plots the area was searched 25 m either side of traverse lines spaced at 50 m intervals. Once located the "habitat tree" was marked with a numbered aluminium tag and its position surveyed by compass and pacing.

2.2.3 Characteristics of trees suitable for possum habitation

The following information was recorded for each tree suitable for possum habitation:

(i) species of the tree in which the hollow was situated,
(ii) condition of the tree,

(iii) d.b.h.o.b.,
(iv) height of the tree,
(v) height of the hollow above the ground,
(vi) position of the hollow,
(vii) intensity of the scratch track.

Diameters were measured with a diameter tape to the nearest millimetre while the heights of trees and of hollows were estimated to the nearest half metre, with a Hagameter. The positions of hollows were assigned to one of four groupings (i.e. in a broken branch, in the bole, in the fork at crown break, or in a broken top) (Plates 7, 8, 9). The tree was first classified as alive or dead. Dead trees were segregated further into old or recent deaths, using the presence of bark as the separating criterion. Living trees were subjectively classified, according to their crown conditions and overall vigour, into 3 groups (i.e. poor, fair or good). A tree classified as good or fair could be assigned to a lower condition class if a hollow butt or termite infestation was detected. A description of the subjective parameters is provided in Appendix 3 (Plates 9 and 10).

During ascent and descent of their "habitat trees" possums tend to use the same pathway along the bole. This pathway usually corresponds to the path with the least vertical gradient (pers.obs.). This habit leaves a tell-tale mark along the bole, the prominence of which will depend on the frequency of use of the trees concerned (a fact noted and exploited by fur traders up until the early 1960's). A stratchtrack was subjectively classed as either poor, fair, good or very good, depending on how far the scratchtrack had been worn into the cambium on living trees or the overall amount of disturbance to the bole on dead trees. The intensity of the scratchtracks was used as an index of "habitat tree" usage (Appendix 3 and Plates 11, 12 and 13).

Plate 7. A hollow positioned in the bole of a "habitat tree".

Plate 8. "Habitat tree" (P2TI) with its hollow in a broken top.

Plate 9. "Habitat tree" (T51), classified as in poor condition, with its hollow in the fork at crown break.

Plate 10. A "habitat tree", classified as in good condition. Its hollow is in the fork at crown break.

Plate 11. a brushtail possum begining ascent of a 'habitat tree'.

Plate 12. the same possum half way up the 'habitat tree'.The scratchtrack on the bole is classified as "good".

Plate 13. the possum entering its hollow,situated in a broken branch; Only the tail is visable.

2.2.3.1 Estimating the age of "habitat trees"

The age of a "habitat tree" was estimated from a growth curve of diameter which was derived from increment data obtained from 20 plots established by the Inventory and Planning Section of the Forests Department of Western Australia. Plots were chosen if they were in the bounds of the Manjimup Forests Division and were in low quality forest (i.e. east of the 1000 mm isohyet)(Abbott and Loneragan 1983b). Most plots were established in 1961 and were about 0.4 ha in area (Table 1).

Frequency distributions of diameter for a stand of jarrah trees are highly skewed to the left (Abbott and Loneragan 1983b)(Figs. 4 and 6), but the frequency of diameter increments is normal and is therefore convenient for analysis of tree growth. Diameter movement was calculated per tree per interval between measurements, averaged, and converted to increment per decade.

Curves of growth in diameter were calculated by regressing the diameter under bark (ub) of all trees in a plot, at the time of plot establishment, as the independent variable (X) against the diameter (ub) of all trees in the same plot, at the time of the next plot assessment, as the dependent variable (Y). The resulting model was used to calculate the final diameter after the time period between re-assessments of trees initially 10, 20...n cm diameter (ub). For example, using data from plot 557, containing 37 jarrah trees and 43 marri trees measured in 1964 and 1971, regression equations were calculated between diameter (ub) in 1971 as the dependent variable (y) and diameter (ub) in 1964 as the independent variable (x) for both tree species, namely -

$y = (X + 1.03)/0.97$ for jarrah trees
with $r^2 = 0.9922$
and $y = (X + 1.85)/0.98$ for marri trees
with $r^2 = 0.9860$

TABLE 1: THE DATA BASE FOR THE GROWTH PLOTS

Plot No.	Forest Black	Years Measured	Number of trees		Increment per decade (cm)					
			Jarrah	Marri	Jarrah			Marri		
					Mean	Std.Dev.	Std.Error	Mean	Std.Dev.	Std.Error
501	Dwalgan	1961,1971	20	11	1.79	2.42	0.54	5.69	6.83	2.05
503	Dwalgan	1961,1971	57	14	0.45	2.48	0.33	2.15	2.62	0.70
504	Dwalgan	1961,1971	54	16	1.30	1.76	0.24	2.43	2.85	0.71
505	Dwalgan	1961,1971	52	1	1.27	1.98	0.28	-	-	-
506	Keninup	1961,1971	34	0	1.03	1.43	0.24	-	-	-
557	Dunijup	1964,1971	37	43	1.78	1.73	0.28	2.15	1.78	0.27
558	Kingston	1964,1971	34	23	0.60	1.35	0.23	1.48	1.72	0.36
559	Winnejup	1961,1971	46	30	1.56	1.94	0.29	1.50	2.02	0.37
560	Kingston	1961,1971	36	26	1.57	1.92	0.32	2.14	2.42	0.48
561	Winnejup	1961,1971	67	39	1.76	2.22	0.27	2.06	2.47	0.39
562	Walcot	1961,1971	59	8	1.22	1.79	0.23	2.05	2.35	0.83
564	Kingston	1961,1971	27	65	2.35	2.77	0.53	3.50	4.00	0.49
565	Winnejup	1961,1971,1981	45	20	1.07	1.66	0.25	1.77	2.30	0.51
		1971→1981	38	19	1.31	1.85	0.30	1.46	1.87	0.43
566	Winnejup	1961,1971,1981	30	44	0.69	1.19	0.22	1.56	1.99	0.30
		1971→1981	33	42	1.63	2.12	0.37	1.18	1.98	0.30
567	Dudijup	1961,1971	61	10	1.59	1.82	0.23	1.99	2.20	0.70
568	Winnejup	1961,1971	27	27	0.35	1.29	0.25	2.05	2.40	0.46
569	Kingston	1961,1971	54	14	1.74	2.55	0.35	2.97	3.31	0.89
578	Yornup	1961,1971	73	17	1.41	1.75	0.20	1.70	2.61	0.63
618	Warrup	1964,1971,1981								
		1971→1981	21	43	0.77	1.69	0.37	2.20	2.84	0.43

This was used to calculate the final diameter after 7 years of trees initially 10, 20, ... 70 cm diameter (ub). The increment after 7 years was then standardised to that after 10 years growth as shown in Table 2.

Table 2 - Example of procedure used to calculate and standardise diameter increment after 10 years' growth for jarrah trees in plot 557.

Initial Diameter (cm)	10	20	30	40	50	60	70
Final Diameter (cm) (after 7 years growth)	11.4	21.7	32.0	42.3	52.6	62.9	72.9
Increment after 7 years (cm)	1.4	1.7	2.0	2.3	2.6	2.9	3.0
Increment after 10 years	2.0	2.4	2.8	3.3	3.7	4.2	4.2

This operation was repeated for each plot, then the increment in relation to each diameter class was averaged over all plots. The diameter growth curve was constructed assuming that it took 10 years for a dynamic advanced growth of jarrah (released after logging) to reach a diameter (ub) of 10 cm (Abbott and Loneragon 1983b) and a marri sapling 10 years to reach a similar diameter (Abbott pers. comm.) It is also assumed that the increment at initial diameter 10 cm would apply over the range 10-19 cm, and so on, for each 10 cm diameter class.

2.2.3.2 Pattern of distribution of "habitat trees"

Non-randomness or pattern of "habitat trees" is of interest as it provides an opportunity for identifying the factors, whether intrinsic or extrinsic, that control distribution.

Pattern is detected by examining the degree of departure of observed values from a Poisson distribution which assumes individuals are randomly distributed. Observed values were obtained by plotting data, as in Figs. 7, 8, 9 and 10, then counting the number of "habitat trees" in each of 20 randomly selected quadrants drawn on the originals of these figures. If the individuals are randomly distributed then the variance (σ) of the data equals the mean ($\bar{X}$)(i.e.$\sigma/\bar{x} = 1$). If there is a tendency towards clumping then $\sigma/\bar{X} > 1$ and if there is a tendency towards a regular pattern then $\sigma/\bar{X} < 1$ (Goldsmith and Harrison 1976). The variance : mean ratio was tested for departure from the expected (1) by a Student's t-test.

2.2.4 The 1981 fire at Boyicup

The main objective of the 1981 fire was to enhance fauna habitat by regenerating thickets of Gastrolobium. As high soil temperatures are required before seed of Gastrolobium will germinate (K. Maisey pers.comm.), the fire was of greater intensity than optimum for prescribed burns for hazard reduction (Burrows 1984).

The northern and eastern edges of the area to be burnt were separated from the main body by a bulldozed fire break and were subsequently burnt, with a low intensity buffer burn, a week before the ignition of the main areas. The study area containing the assessed "habitat trees" was ignited at 1400 on the 24 March, 1981.

The weather during the progress of the fire, measurements of fuel, observations of fire behaviour and fire intensities were provided by the fire research staff of the Manjimup Forests Department.

2.2.4.1 Conditions for burning

Fine fuels and soil moisture contents were measured at the start of fire-lighting. A weather station consisting of an

Asmann aspirated psychrometer and a cup anemometer, at 2 m above ground level, was positioned east of Glendale Road on the eastern side of the fire to monitor atmospheric conditions. The conditions are summarised in Appendix 4.

2.2.4.2 Measurements of fuel

Measurements to assess fuel were taken at 10 m intervals along 5 randomly spaced 100 m transect lines. At each sample point a visual estimate of trash height and density were made, along with a measurement of litter depth and a levy point sample. Available flash fuels were estimated using Forest fire behaviour tables for Western Australia (Sneeuwjagt and Peet 1976) and the parameters mentioned above. Fine fuels and scrub quantities were parameters required for predicting fire behaviour and were estimated by sampling 30 cm x 30 cm and 1 m x 1 m square quadrats taken every 50 m along the 5 transect lines. Quantities of logs were estimated using the Van Wagner line transect method (Van Wagner 1968).

2.2.4.3 Fire behaviour

Observations on the ground provided estimates of fire development, flame height and the rates of spread of the head fires (R.O.S.), and was obtained by placing observers around the perimeter of the fire. Observation from a light aircraft also provided estimates of flame heights and enabled the position of the head fires to be plotted at different time intervals.

2.2.4.4 Fire intensity

Fire intensities were calculated using Byran's (1959) formula where intensity is equal to the product of net heat of combustion, quantity of fuel consumed and rate of linear spread of the advancing fire., i.e. I = H.W.R.,
where,
I = fire intensity (kw m^{-1}),

H = fuel heat yield. 18 600 (kJ kg^{-1})
of fuel were used in this exercise (Burrows 1984),
W = fuel weight (kg m^{-2})
R = rate of spread (ms^{-1})

Fire intensity is rarely homogeneous over an area and usually fluctuates within an intensity range (Burrows pers.comm.) consequently, fire intensities within the study area were mapped in 4 classes;

1. Low intensity - 0 to 300 kW m^{-1}
2. Moderate intensity - 300 to 500 kW m^{-1}
3. Intermediate intensity - 500 to 1000 kW m^{-1}
4. High intensity - > 1000 kW m^{-1}

2.2.5 Assessment after the fire of "habitat trees"

Trees at Boyicup were re-assessed 3 weeks after the fire. This allowed sufficient time for the forest to stabilise (a safety precaution) and new scratchtracks to develop. "Habitat trees" assessed during the preliminary survey were located and, in cases where identification tags had melted, identification was confirmed by comparing the species of the tree and its height and d.b.h.o.b. with known but unlocated "habitat trees" in the vicinity. Each relocated tree was retagged and assessed for damage and usage by possums.

Relocated trees were subjectively assigned to one of five damage classes (unburnt, light damage, heavy damage, severe damage and destroyed). Trees in the unburnt, light and heavy damage groupings still possessed hollows which appeared to be habitable, while severely damaged trees had their hollows rendered uninhabitable. Destroyed trees were burnt to ground level. For descriptions of the damage classes see Appendix 3. Scratchtracks were not assigned to any prominence rating (see Section 2.2.3) though their presence was noted. Presence of a fresh scratchtrack was assumed to indicate an actively used "habitat tree".

The 1981 post-fire assessment was to determine what relation a habitat tree's condition, species and the fire intensity it experienced had on the damage it will sustain.

The Yendicup study area was not reassessed during 1981.

2.2.6 1983/1984 Re-assessment of the study area

During the summer of 1983/84, both plots were re-assessed to record the longer term effects of fire on "habitat trees" and observe changes in use of trees by possums. Trees recorded during the 1981 surveys but not used by possums during 1983/84 were not recorded in the later survey.

2.2.7 Measurements of physical parameters of the hollows

The tree assessments mentioned in Sections 2.2.3, 2.2.5 and 2.2.6 recorded only the presence and position of hollows. Dimensions of hollows significantly influence which species will inhabit a tree and how successfully (Calder _et al_. 1983, Saunders _et al._ 1982, Ambrose 1982).

An assessment of hollows during May 1984 measured and determined the important parameters of hollows which affect use by possums. Only trees with hollows that could safely be reached with ropes and an 8 m extension ladder were assessed. These trees were not confined to the Boyicup plot (see Section 2.1.1), but included trees from the vicinity. Twenty-nine trees contained 32 hollows, 16 of which were in the Boyicup plot while 13 were from the surrounding area. A further 6 trees from within the Boyicup plot were climbed to confirm or refute their status as trees that could be used by possums, but for safety reasons their hollows were not assessed.

Parameters noted for each tree were :

(1)	Tag Number	(See Fig. 5)
(2)	Species	
(3)	Height	(A)
(4)	d.b.h.o.b.	(B)
(5)	intensity of the scratchtrack	(C)

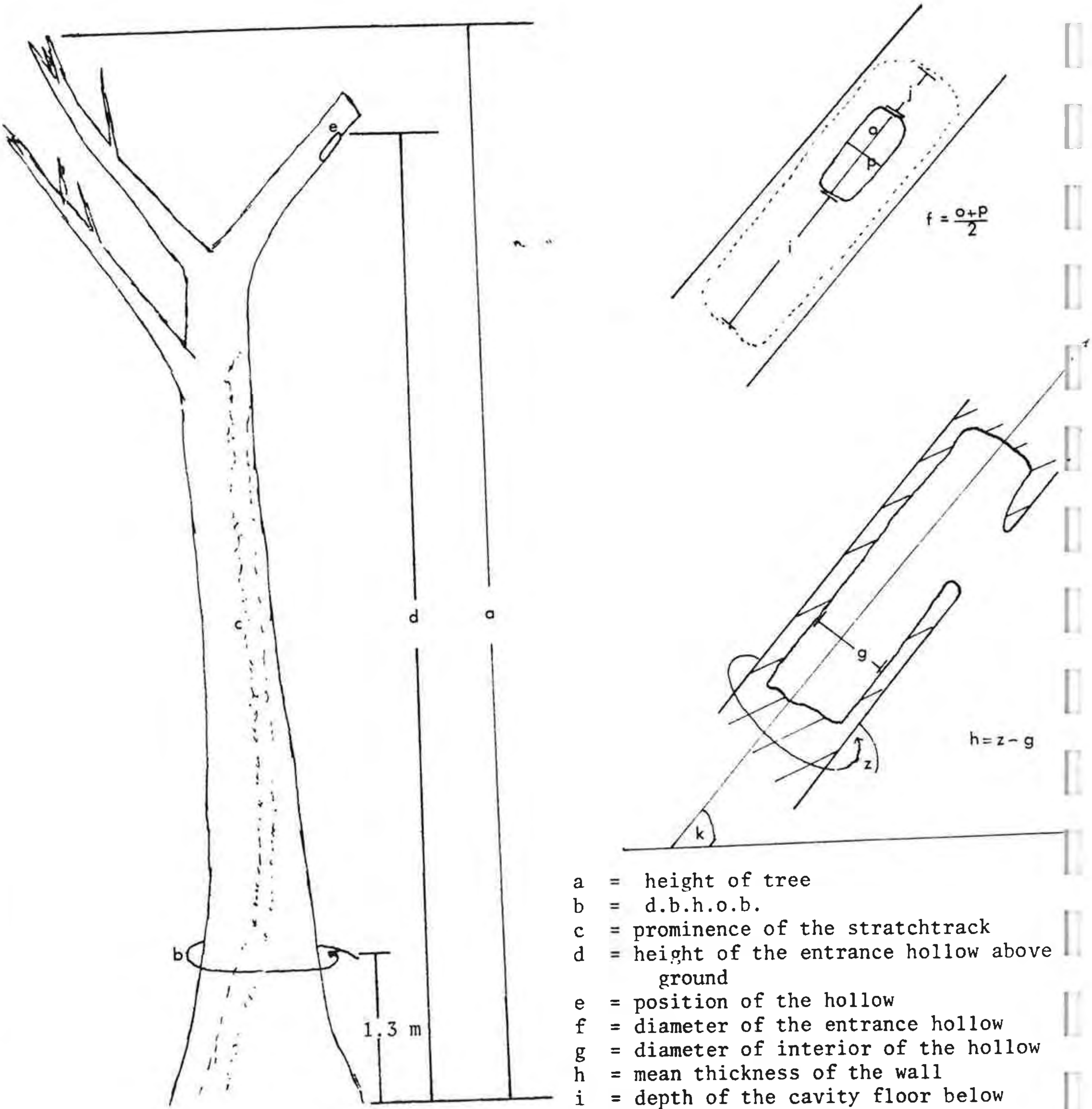
For each hollow :

(6)	Height above ground (m)	(D)
(7)	Position of hollow	(E)
(8)	Diameter of entry hole (cm)	(F)
(9)	Diameter of the cavity interior (cm)	(G)
(10)	Mean thickness of wall (cm)	(H)
(11)	Wall material alive or dead	
(12)	Depth of cavity floor below entry hole (cm)	(I)
(13)	Height of cavity roof above entry hole (cm)	(J)
(14)	Planar orientation (degrees)	(K)
(15)	Aspect (degrees)	
(16)	Evidence of occupation and nest materials	

Tree height, d.b.h.o.b., intensity of the scratchtrack, position of the hollow and height of the hollow above ground, were measured or described using the same methods employed during the surveys of "habitat trees" (see Section 2.2.3). The diameters of the entry hole and interior of the cavity were determined by averaging the lengths of the long and short axes, measured to the nearest centimetre with a flexible metal tape. Mean thickness of the walls was estimated by subtracting the diameter of the interior of the cavity from the diameter of the branch or bole housing the hollow. The diameter of the housing material was estimated with a diameter tape. If the hollow resulted from a snapped bole or branch and was thus cross-sectioned, direct measurements of the wall thickness was possible. Planar orientation was the angle formed by the centre axis of the cavity interior to the horizontal and was measured, to the nearest 5° with a Suunto clinometer. Aspect was the direction faced by the entrance hole and was measured, to the nearest 5°, with a Suunto compass (Fig. 5).

Evidence of occupation included the presence of an animal during inspection, scratches on the interior of the cavity, the presence of fur, faeces and/or nest materials, such as leaves, bark or twigs.

Figure 5: Parameters measured during the survey of habitat trees and hollows



a = height of tree
b = d.b.h.o.b.
c = prominence of the stratchtrack
d = height of the entrance hollow above ground
e = position of the hollow
f = diameter of the entrance hollow
g = diameter of interior of the hollow
h = mean thickness of the wall
i = depth of the cavity floor below the entrance hollow
j = height of the cavity roof above the entrance hollow
k = planar orientation

2.3 RADIOTELEMETRY STUDIES

2.3.1 Introduction

The study of trees suitable for occupation by possums identified the important parameters of a "habitat tree" and its hollow(s) but gave no indication as to which habitat variables influenced the microdistribution and movements of a species. The secretive, nocturnal habits of possums presents obvious problems for observing their movements. Radiotelemetry techniques provided an efficient way of getting data.

Two radiotelemetry studies, during the summer months of 1983 and 1984, tracked intensively a total of 7 animals (6 brushtail possums and 1 ringtail possum). Two (1 brushtail possum and 1 ringtail possum) were located regularly but were not tracked during their active period. All telemetry work was sited in and around the western half of the Boyicup plot.

2.3.2 Choice of animals

2.3.2.1 Brushtail possums

The brushtail possum is readily caught with a cage trap and universal bait, which is a mixture of rolled oats, honey, peanut paste and flour. Variations in trappability were reported by Dunnet (1964), but all brushtail possums in my study could be caught easily by positioning cage traps at the base of their home trees. Trap shyness was discouraged by feeding trapped animals as much universal bait as the animal desired. Only selected individuals were fitted with transmitters with selection based on trap positions and the sex of the animal.

To complement the study of trees occupied by possums, only animals trapped in the western half of the Boyicup plot were used in the telemetry studies. As well as position, the distance of each animal from other radiotagged possums was considered, so that as many possums as possible were sited close together for easier collection of data.

Although Crawley (1973) and Ward (1978) reported no evidence of territoriality in populations of brushtail possums in New Zealand, Dunnet (1964) and How (1978) both suggest that territorial behaviour is practised among males in Australian populations. Consequently, only female brushtail possums were selected for intensive tracking, thus reducing the effect that territorial behaviour may have on the activity of an animal. Movements influenced by territoriality would detract from the explanatory value of any habitat variable chosen to explain possum activity.

Gouges from the incisor teeth of possums, made to the bases of saplings around "habitat trees" ("totem poles"), were common in the area. Such marks were also evident on branches surrounding the entrance to a hollow.

2.3.2.2 Ringtail possums

Ringtail possums could not be trapped in cage traps and were caught by "shinning" up small saplings and seizing the animals by hand while they were "held" in the beam of a 100 w spotlight. Because of the poor success rate (<50%) of this method, I could not be too selective when choosing animals for tracking and based selection on capture position rather than sex. As the ringtail possum is a gregarious species (How 1978, Thomson and Owen 1964), the effect that territoriality might have on animal movements is assumed to be minor. Attempts to catch ringtail possums by climbing "habitat trees" and inspecting hollows was futile.

2.3.3 Equipment

Each animal selected was fitted with a radio transmitter powered by a lithium battery. Both the transmitter and battery were housed in a waterproof moulding and attached to the neck of the possum by a brass strap, acting as an aerial, encased in a protective rubber tube. All brushtail possums were fitted with A.V.M. SB2 transmitters with "2/3 A" batteries while the ringtails wore the smaller A.V.M. SB2 transmitters powered by "1/2 A" batteries (Plates 3, 14 and 15).

To locate the animals, a 12 channel A.V.M., LA12 portable receiver, operating on the 150.180 - 151.150 $\mathrm{MH_z}$ band, and a hand-held yagi antenna were used (Plate 16).

A constant record of possum activity was obtained by connecting an LA12 portable receiver to a Y.E.W. 3057 portable recorder, which converted radio signals into electrical impulses to produce a graphical representation of variation in signal strength with time. The LA12 portable receiver was attached to a multidirectional aerial positioned about 8 m above the ground.

A total of 21 traces was obtained.

Power flow was regulated by a timing clock which prevented the system operating during daylight hours, thus extending the operating life of the 12V battery. (See Plates 17 and 18).

Signal strength fluctuations resulting from the movements of the animals was not as prominent when using the elevated multidirectional aerial. However, signal strength did vary considerably when the animals moved from the tree crown to the ground and vice versa, consequently, analysis of the traces provided the following information -

(a) duration of active period,
(b) times when activity was greatest, and
(c) estimates of the proportion of time allocated to activity in the trees and on the ground.

2.3.4 Tracking routine

The onset and cessation of animal activity was determined by listening for variations in signal strength caused by the movement of the transmitter. After the onset of activity,the positions of animals were obtained at 20 or 30 minute intervals until activity ceased at about sunrise. On occasions when rapid activity occurred, bearings of positions were taken at more frequent intervals.

Positions of animals were determined by the intersection of 2 compass bearings taken from 2 of the 5 recording stations along Boyicup 2 Road and Glendale 2 Road. The direction of the bearings was obtained by positioning the yagi antenna so that maximum signal strength was received. A bearing was taken along the main shaft of the antenna using a Suunto compass.

Very weak signals could be improved by changing the polarity of the antenna to either horizontal or vertical. At times when the animals were close to the recording station, reduction of the receiver gain prevented an overloading effect which could cancel directivity. Loss of directivity resulted from rapid movement by an animal, thus causing considerable signal fluctuations. This was overcome by offsetting the fine tuning on the receiver so that the sound produced was a dull thud rather than the characteristic high pitched beep.

2.3.5. Observations from a hide

Animals were observed from hides to provide data of exit times from hollows, the number of possums per tree and descent

Plate 14. An A.V.M. SB2 transmitter.

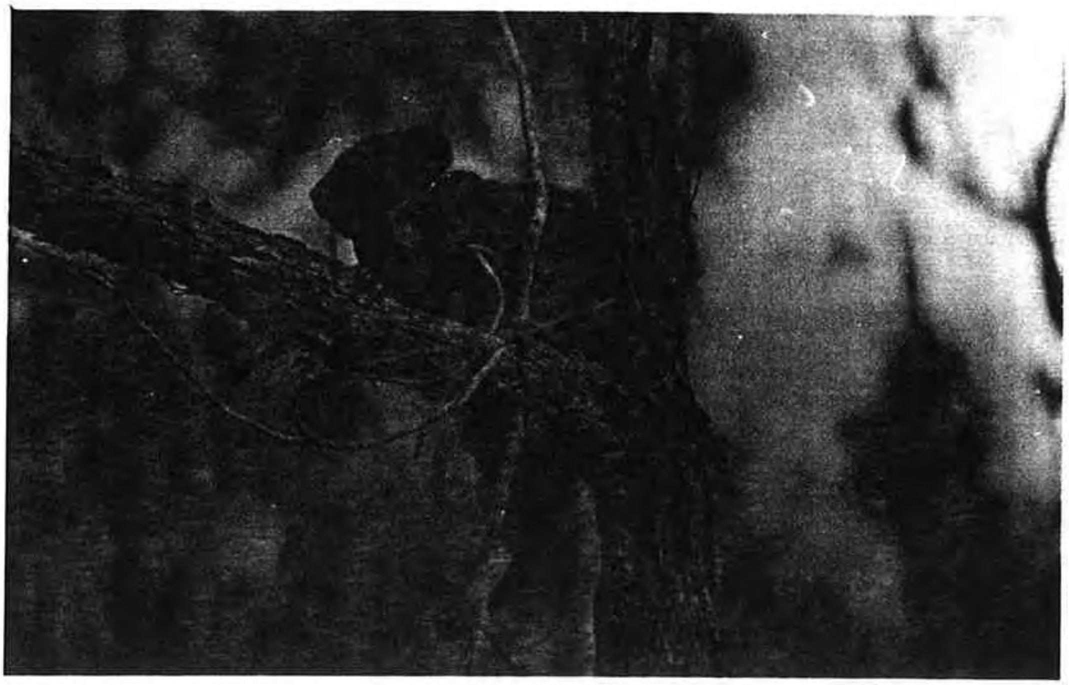


Plate 15. A transmitter fitted to the neck of a young ringtail possum (RTP10).

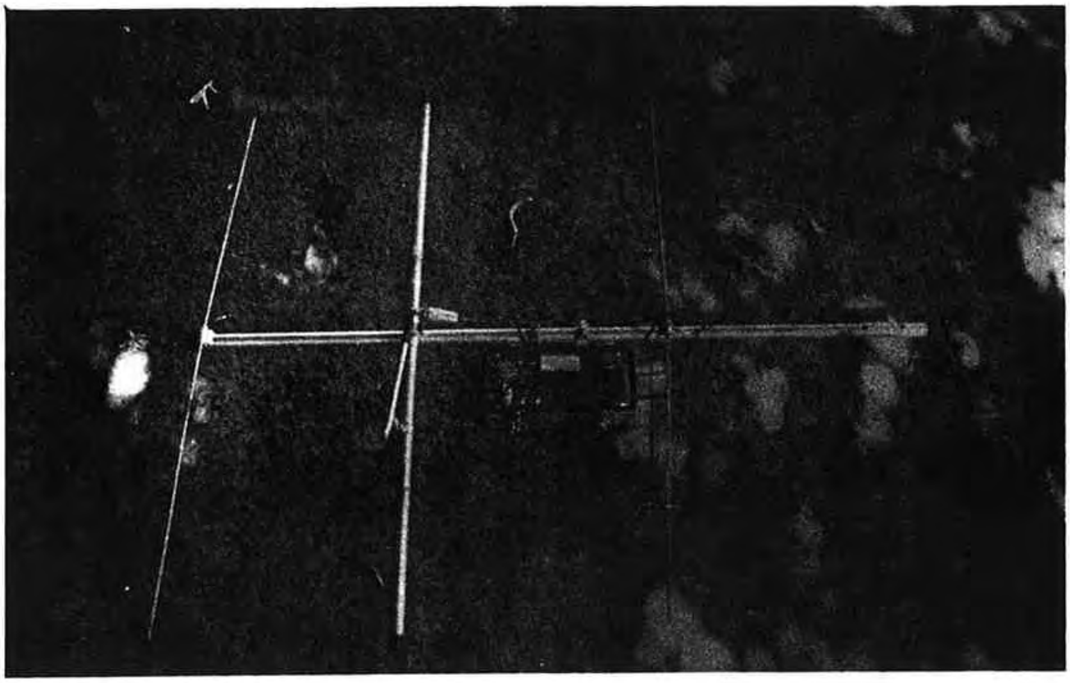


Plate 16. A 12 channel A.V.M., LA12 portable receiver and hand-held yagi antenna.

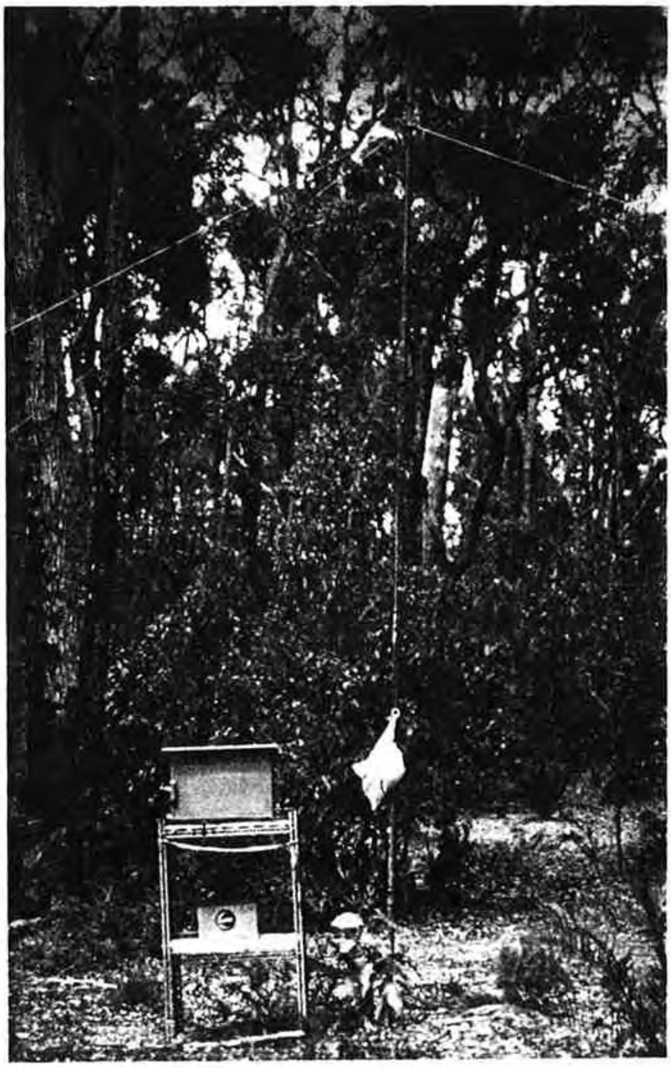
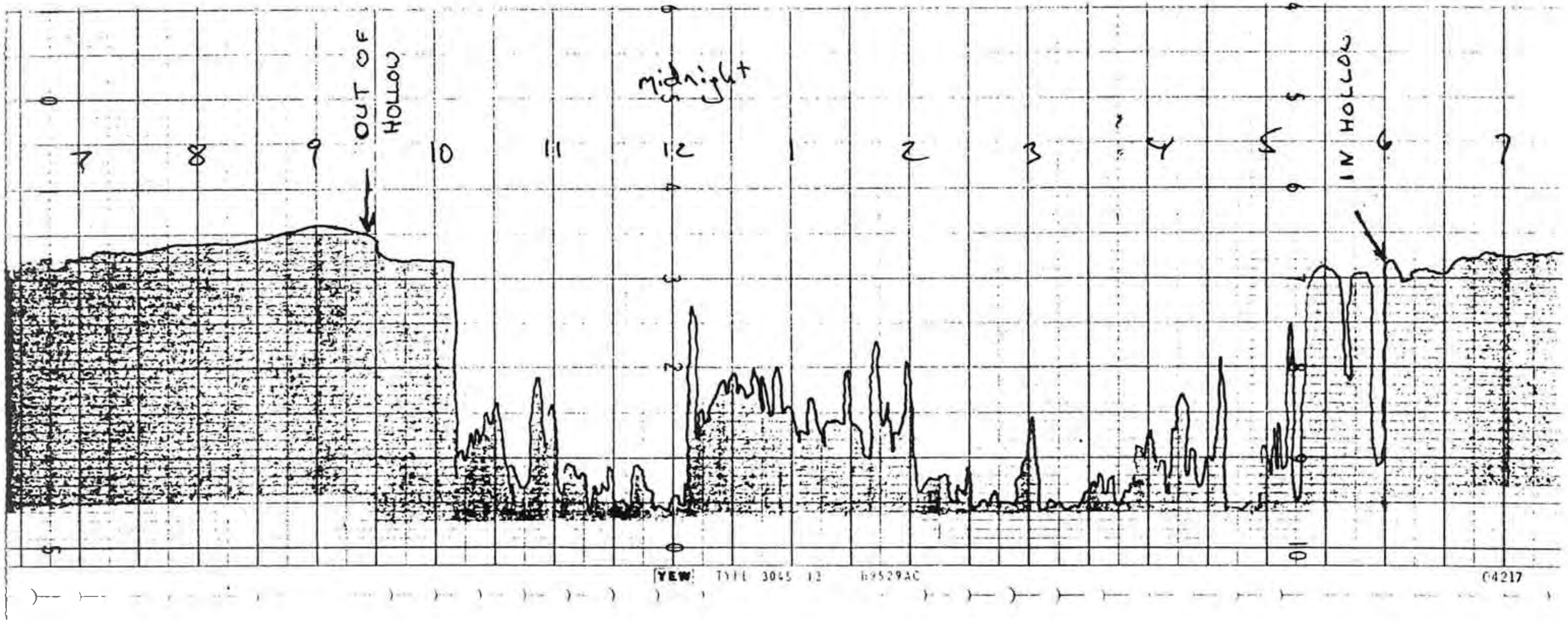


Plate 17. The Y.E.W. recorder housing and multidirectional aerial positioned about 8m above the ground.

Plate 18. The Y.E.W. recorder, A.V.M. receiver, battery and timing clock.

Plate 19: An example of the Y.E.W. recorder output.



routes. The data also allowed calibration of the traces from the Y.E.W. recorder to known possum activities. Hides were positioned about 40 m from the base of selected "habitat trees" and were constructed from eucalypt branches and understorey shrub species. Only the onset of the evening's activities were observed due to the poor visibility later.

2.3.6 Analysis of data

Variations in movement patterns occur with season and weather (Ward 1978). For uniformity, data were collected for this study over the summer months and on fine nights only. If rain occurred during the night's tracking, the data were discarded. All observations were recorded in the field on a small portable tape recorder. Locations for each night were plotted on separate sheets of translucent drafting foil. The identification numbers of the possums and the species were colour coded and locations for each night were superimposed onto a single master plan.

2.3.6.1 Active period

The "active period" was the period from when the signal strength fluctuations started, to when they ceased. The active period was divided into -

(i) active while in a hollow, and
(ii) active while out of a hollow.

The active period in and out of the hollow was determined using the hand-held equipment and observations from hides. The active period after exit also was checked by analysis of the traces from the Y.E.W. recorder. When an animal left the hollow, signal strength would suddenly increase as the wood around the hollow no longer absorbed the signal. This resulted in a characteristic lump on the recorder trace (Plate 19). Likewise, entry into a hollow would suppress signal strength resulting in a sudden depression.

2.3.6.2 Time spent on the ground

The proportion of time allocated to activities on the ground was measured off the Y.E.W. recorder traces. Signal strength varied markedly with the animal's vertical position and thus deep troughs were produced on the trace when the animal was on the ground (Plate 19).

2.3.6.3. Rates of movement

The distance moved between 2 consecutive locations was assumed to be a straight line; the rate of movement between such points was assumed to be constant. Rates of movement were calculated by dividing the distance between 2 consecutive points, measured off a plot of each night's data (scale = 1:1000), by the time lapsed between locations -

i.e.,
$$R = \frac{D}{t_2 - t_1}$$

where R = rate of movement ($m\ hr^{-1}$)
D = distance between 2 consecutive locations (m)
t_2 = time when last location was determined
t_1 = time when previous location was determined

2.3.6.4 Habitat utilized

Beginning with Seton (1909) home ranges have been included in natural histories of mammals. Burt (1943) defines home range as that area traversed by the individual in its normal activities of food gathering, mating and caring for the young". Burt goes on to distinguish between home range and territory while Blair (1953) defines the home range to include the area covered in normal daily activities of an animal which may include exploratory sorties excluded by Burt's definition.

Generally, clusters of points of capture or locations are considered to represent home range, but the correctness of this assumption will depend on the time over which the data are collected and on the species studied.

The activities of arboreal mammals are never 2-dimensional, yet the usual concept of home range considers all activity to have persisted in a single plane. The concept of home range for a species which uses a 3-dimensional habitat is misleading, therefore, the term "utilized area" will be adopted. My data were too limited to allow the use of a 3-dimensional model of home range such as that proposed by Koeppl *et al*. (1977).

Utilized area is defined as the area enclosed by a polygon obtained by projecting 3 dimension on to two. The concept should not be confused with either home range or territory:it is an index for comparisons between animals. Utilized area was calculated with a compensating polar planimeter. Perimeters were determined by measuring the distance between two outer points of location. Any point which lay between these two with a distance to the starting location point less than half of the original was included. This procedure was followed until the boundary was complete.

2.3.7 Habitat variables chosen to explain patterns of movement

2.3.7.1 Variables in the habitat of brushtail possums

After the completion of the first radiotelemetry program in 1984, a master plan of the locations of all brushtail possums was produced (Fig.18) and divided into ninety 40mm x 40mm sections by placing a randomly positioned grid over the plan. Each section represented 40 m x 40 m in the field. The centres of each grid square were located in the field and the following parameters were measured from 61 of the squares -

(i) basal area of jarrah (m^2 ha^{-1}),
(ii) basal area of marri (m^2 ha^{-1}),
(iii) foliar nutrient content (%) of a sample from the nearest pole-sized jarrah tree. Analysed for N,P,K and Ca, and
(iv) foliar nutrient content (%) of a sample from the nearest pole sized marri tree. Analysed for N,P,K and Ca.

Basal areas were estimated by basal area sweeps using a 2 dioptre basal area prism. Foliar samples were collected from branches shot from the tree using a Vixen .222 calibre rifle. For uniformity, only the leaves from the first 3 whorls of a leaf spray were sampled as it is these younger leaves that brushtail possums seem to prefer when feeding (Plate 22).

Hingston _et_._al_. (1980/81) working in jarrah-marri forest and Lamb (1976) studying _Eucalyptus deglupta_ Blume., found that there are small but constant differences in nutrient concentrations between foliar samples taken from the upper, middle and lower crown positions. Although the sampling position does not seem to be critical for some elements such as P and K (Hingston _et_. _al_. 1980/81), it was taken into account during foliage sampling in this study and only branches from the middle crown position were removed.

Each sample was stored in a paper bag, labelled and dried in a drying kiln for 24 hrs. at 100°C. Nitrogen analysis was by the Micro Kjeldahl method (McKenzie and Wallace 1954). For measurements of phosphorus, potassium and calcium, each sample of ground-up leaves was digested in a mixture of nitric, sulphuric and perchloric acids. Phosphorus was determined spectrophotometrically using the molybdo-vanadate procedure (Kitson and Mellon 1944), potassium was detected on an E.E.L flame photometer (Hutton and Bond 1954) and calcium was measured using a Perkin-Elmer atomic absorption spectrophotometer (David 1959).

The 10 habitat variables (i.e. % jarrah foliar nutrient values for N,P,K, and Ca, % marri foliar nutrient values for N,P,K and Ca, basal area of jarrah and basal area of marri) were used to group the 61 grid squares into 4 distinct cluster groups using cluster analysis (Section 2.5.3). A 1-way ANOVA, with the cluster groups as the covariables and the total recorded time the animals spent in each grid square as the dependent variable, tested if any cluster group was preferred.

Principal coordinate and canonical variate analysis identified which of the habitat variables were prominent in discriminating between clusters.

After the completion of the second radio-telemetry program in 1985, foliar samples were taken from 20 of the original 61 sample points and analysed for percentage N,P,K and Ca, using the methods outlined above. The 2 sets of data were tested with a 1-way ANOVA for any shift in the values of foliar nutrients. Data relating habitat variables and possum activity were treated in the same manner as data collected in 1983/84.

2.3.7.2 Variables in the habitat of ringtail possums

After the completion of the radiotelemetry program for ringtail possums in 1985, a master plan showing the points of location of ringtail possum RTP8 was produced (Fig. 20). The master plan was divided into 37 sections, each 40mm x 40mm, by extending the grid used during the brushtail possum surveys (Section 2.3.7.1.). These sections represent 40m x 40m in the field. The centres of each square were located in the field and a 10m x 10m plot was established whose sides ran north-south and east-west. The top north-west corner of the plot was the centre of the larger grid square. The following parameters were measured from each plot,

(i) foliar nutrient content (%) of a sample from the nearest pole-sized jarrah tree. Analysed for N,P,K and Ca,

(ii) foliar nutrient content (%) of a sample from the nearest pole-sized marri tree. Analysed for N,P,K and Ca,

(iii) the tree species and d.b.h.o.b. for all trees with a d.b.h.o.b. > 2 cm.,

(iv) the number of "habitat trees" per plot,

(v) the percentage of the plot covered by *Gastrolobium bilobum*, and,

(vi) the species and diameter of any stump left from logging operations.

Foliar nutrient analysis, d.b.h.o.b. and the identification of "habitat trees" were done using the materials and methods already defined in Sections 2.3.7.1, 2.2.3 and 2.2.2 respectively, while the percentage of the plot covered by *Gastrolobium bilobum* was estimated by eye.

The data were used to group the grid squares into similar groups using cluster analysis (Section 2.4.3). A 1-way ANOVA with cluster groups as the co-variables and the total recorded time the animal spent in each grid square as the dependent variable, tested if any cluster grup was preferred. Principal co-ordinate and canonical variate analysis (Section 2.4.4) identified which of the habitat variables were prominent in discriminating between clusters.

2.4 STATISTICAL ANALYSIS

2.4.1. Introduction

Correlation and regression, analysis of variance, cluster analysis, principle co-ordinate analysis and canonical variate analysis were from the Rothamsted statistical package GENSTAT on the Univac 1100/42 computer system at the Australian National University, Canberra. I outline briefly the methods of data analysis used and to which data they were applied.

2.4.2. Linear statistical models

The simple and multiple regression used are comprehensively reviewed by Neter and Wasserman (1974) and GENSTAT (1977). Output from GENSTAT included:

(i) for each regression co-efficient b(1), b(2),..,b(n), its estimate b(i), i = 1,2,...,n, the standard error of estimate, and the t value used to test Ho:bi = 0, and

(ii) the analysis of variance in which the total sums of squares is split into regression and residual sums. Change is shown for the residual degrees of freedom, sums of squares and mean square since the last model was fitted. To test for the significance of the change the mean square divided by residual mean square, from the full model, provides an F-statistic.

The following data were analysed using regression models -

(i) determining diameter growth curves (see Section 2.2.3.1) and,

(ii) deriving the relationship between the condition of a "habitat tree", the intensity of fire it experiences and its susceptibility to fire damage (see Section 3.1.5.4).

Analysis of variance tested the relationship between selected dependent variables and one or more co-variables. The co-variables may be qualitative and if the co-variables are qualitative no assumption is made about the nature of the statistical relationship between them and the dependent variable.

A comprehensive review of analysis of variance is given by Neter and Wasserman (1974) and GENSTAT (1977). The following data were analysed using analysis of variance -

(i) differences between the mean diameters of each study site (Section 3.1.4.1),

(ii) differences between the mean heights of "habitat trees" of each study area (Section 3.1.4.2),

(iii) differences between the mean height of hollows of each study area (3.1.4.3),

(iv) differences between the mean depth of the hollow for each intensity of use class (Section 3.1.7),

(v) differences in the mean active period between individual possums (Section 3.2.3.1),

(vi) comparison between two methods of obtaining data pertaining to the active period (Section 3.2.3.1),

(vii) comparison of proportion of time devoted to terrestrial activity between individuals (Section 3.2.3.2),

(viii) detection of any shift in mean nutrient values of the foliage between years (Section 3.2.4.1), and

(ix) difference in total time spent active by possums in each cluster group (Sections 3.2.4.1, 3.2.4.2)

2.4.3. Cluster analysis

Cluster analysis was used to separate a set of objects into constituent groups or clusters so that the members of any one group differ from one another as little as possible, according to a chosen criterion (Spath 1980, GENSTAT 1977).

Mathematically, cluster analysis assigns 1 axis per variable and aligns the sites or objects being described along the axis according to their particular variable values. The number of dimensions involved will be determined by the number of variables used.

Difficulty arises in deciding if 2 sites or objects are sufficiently close or distant, in multi-dimensional space, to be grouped into a cluster or segregated. The algorithms in GENSTAT start with all sites in separate clusters. The 2 clusters with the highest similarity are merged, and similarities between the new cluster and all other sites redefined according to the options available. These include -

(a) single linkage cluster analysis,
(b) furthest neighbours cluster analysis,
(c) centroid cluster analysis,
(d) average linkage cluster analysis, and
(e) median cluster analysis

The centroid cluster analysis proved most effective for processing of my data. Centroid clusters are determined when the re-calculated similarities are resolved by weighted means of similarities between each of the 2 merged clusters and any third cluster.

The furthest neighbour cluster analysis (i.e., the similarity between 2 clusters is the least similarities between any 2 units, 1 in each cluster) gave similar results to that of the centroid clusters but was not as clear in the results obtained using centroid analysis.

The following data were analysed using cluster analysis -

(i) grouping the grid squares, placed over the utilized area of the brushtail possums, into like entities, and

(ii) grouping the grid squares placed over the utilized area of the ringtail possums into like entities

2.4.4. Multivariate techniques

Multidimensional scaling, or ordination techniques include principal components, factor analysis, canonical variate analysis and principal co-ordinate analysis (GENSTAT, 1977).

The clustering methods (Section 2.4.3) describe relationships at the level of pairs of objects and allow the identification of fine relationships. Used with clustering techniques, ordinations are useful in that they treat the total variability of an association matrix which enables the most important general relationships to be extracted.

Gower (1966) termed one such method "principal co-ordinate analysis".

Principal co-ordinate analysis summarises, in a few important dimensions or principal axes, the larger part of the variation found in a dispersion matrix for a large number of measured parameters or values of a site or object.

It replaces a set of variables by a smaller set of new variables or co-ordinates without losing significant explanation of the variability. Its advantage over the more common principal component analysis is that a greater range of data types is acceptable (i.e. quantitative and qualitative).

The GENSTAT program output includes the percentage variance explained by each principal axis, a list of latent vectors and a scattergram of points in 2-dimensions for defined principal axes. This technique enables the analyst to determine if groupings are discrete or if vectors represent recognisable gradients of some parameter.

The technique of dividing blocks or objects into clusters or groups using clustering or ordination techniques is essentially descriptive and will remain as such until the clusters or simplified multidimensional space is interpreted. It could be possible to examine each descriptor one after another and those discriminating between groups or clusters may be noted. However, as so often happens when dealing with environmental parameters, no single descriptor manages to separate groups completely.

Canonical variate analysis overcomes this problem by finding linear combinations of the discriminate descriptors which maximise the differences between the groups while minimising the variance within each group (Legendre and Legendre, 1983). Since the descriptors are to be linearly combined they must be quantitative and as the condition of multinormality is assumed the descriptors must be transformed. Such computations are done on matrices of sums of squares and cross products in the GENSTAT program "CVA" (GENSTAT 1977).

After a series of algebraic manipulations of matrices, a matrix of normalised eigenvectors which define the canonical spaces of the discriminent analysis is derived. Canonical axes describe the dispersion between groups with the first axis indicating the direction of the greatest variance between the centroids of the groups and so on for consecutive canonical axes.

An asymptotic, approximate chi-squared significance test, based on the normal theory, tests for the homogeneity of the canonical variates. If the condition of homogeneity is fulfilled, the conclusion that the canonical axis describes the dispersion between groups is valid (Legendre and Legendre 1983).

The 'KEY' directive in GENSTAT examines each variate in the data matrix to test which groups, if any, are distinguished by the variate under examination. The output from the 'KEY' directive is a frequency table for the number of units in each group at each level and provides a quick indication as to the importance of each variable in segregating groups or clusters by providing a pseudo t-test.

It is easy to misuse or misinterpret multivariate analysis when using powerful packages such as GENSTAT. To avoid spurious results, Mr. R. Cunningham gave detailed advice during analysis of the data used to identify variables instrumental in clustering grid squares.

CHAPTER THREE - RESULTS

3.1 THE STUDY OF 'HABITAT TREES'

3.1.1 Stand composition and structure

Stand composition and structure for Yendicup and Boyicup are illustrated in Figure 6. Abbott (1984b), working in virgin and cut-over jarrah forest in Western Australia, demonstrated that the diameter class frequencies of the structural components showed little uniformity between sites, however this was not the case for either of my sites, which showed a typical negative exponential relationship. The most numerous components at both sites were found in the lignotuberous or advanced growth stages (Jacobs 1955).

Pooled data from both localities gave 276 (50.7%) marri trees ha^{-1}, 179 (32.9%) jarrah trees ha^{-1} and 89 (16.4%) flooded gum trees ha^{-1}.

At Boyicup, not all trees were suitable for possums to live in, and no tree with a d.b.h.o.b. less than 40 cm contained a hollow that was adequate in size (see Section 3.1.4.1).

The portion of the forest stand with a d.b.h.o.b. greater than 40 cm averaged 37.5 (56.6%) marri and 29.0 (43.3%) jarrah trees ha^{-1} but no flooded gum. These two species made up 12.3% (7.0% marri, 5.3% jarrah) of the total forest stand (Fig. 6, Table 3)

At Yendicup no tree with a d.b.h.o.b. less than 50 cm contained a hollow of suitable size for a possum to live in (see Section 3.1.4.1). The portion of the forest stand with a d.b.h.o.b. greater than 50 cm included 33.7 (71.7%) marri and 13.3 (28.3%) jarrah trees ha^{-1}, but no flooded gum. These two species made up 8.2% (5.9% marri, 2.3% jarrah) of the total forest stand (Fig.6, Table 3).

3.1.2 Tree species used as "habitat trees" and number per hectare

A total of 82 "habitat trees" (35 jarrah (42.7%) and 47 marri (57.3%)) were located at Boyicup and gave about 2.3 such trees ha^{-1}, only 0.004% of the total forest stand (Fig.7, Table 3). The proportions of the two species were not significantly different ($p>0.05$) from their proportions in the total stand with a d.b.h.o.b. greater than 40 cm. (see Section 3.1.1), (i.e. 43.4% jarrah and 56.6% marri), so possums do not appear to give preference to a particular tree species when choosing a "habitat tree".

At Yendicup the distribution of 73 "habitat trees" (22 (30.1%) jarrah, 51 (69.9%) marri) amounted to 3.4 trees ha^{-1}, about 0.006% of the total forest stand (Fig. 8, Table 3). There was no significant difference ($p> 0.05$) between proportions of these habitat trees and the proportions of the same species in the stand with a d.b.h.o.b. > 50 cm. (i.e. 28.3% jarrah and 71.7% marri). Again, no preference was shown by the possums for either tree species.

Lack of a relationship between species of tree and usage by White-tailed black cockatoos was recorded by Saunders (1979), while Raphael and White (1984) reported variation between cavity-nesting birds in their selection of suitable tree species.

Thirty two months after the fire at Boyicup, a total of 254 "habitat trees" were recorded at the Boyicup site giving 7.0 such trees ha^{-1}. This was a marked and significant ($p > 0.05$) increase from the total of 82 "habitat trees" present before the fire (Figs. 7 and 9). Of the "habitat trees", 128 were jarrah (50.4%), 124 (48.8%) marri and 2 (0.8%) flooded gum. The proportion of jarrah and marri "habitat trees" did not

Figure 6. Distribution of diameter classes in the forest stands at the Yendicup and Boyicup sites.

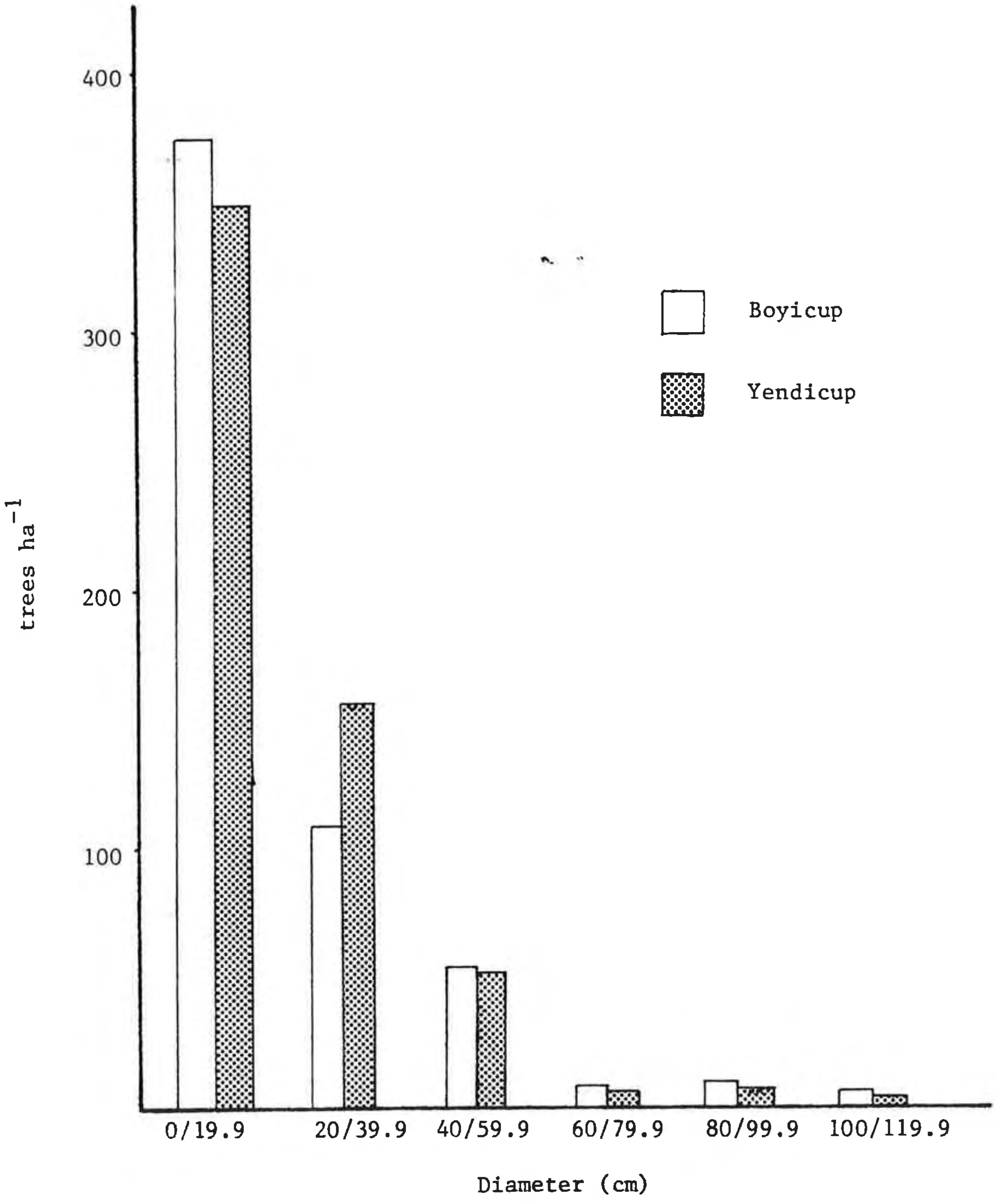


TABLE 3 : STAND STRUCTURE AND COMPOSITION IN THE BOYICUP AND YENDICUP STUDY AREAS

Site and tree species	Total stand		Trees of suitable d.b.h.o.b.		Habitat trees used before fire		Habitat trees used after fire	
	trees ha^{-1}	% Total Stand	trees ha^{-1}	% Total Stand	Trees ha^{-1}	% Total stand	Trees ha^{-1}	% total stan
BOYICUP								
Marri	276.0	50.7	37.5	7.0	1.3	0.002	3.4	-
Jarrah	179.0	32.9	29.0	5.3	1.0	0.002	3.6	-
Flooded Gum	89.0	16.4	-	-	-	-	0.06	-
YENDICUP								
Marri	276.9	48.5	33.7	5.9	2.5	0.004	2.2	-
Jarrah	293.5	51.5	13.3	2.3	1.1	0.002	0.9	-
Flooded gum	-	-	-	-	-	-	-	-

differ significantly ($p > 0.05$) between the successive assessments despite the increase in numbers, so possums were still indifferent to tree species.

After the fire 67 "habitat trees" were identified at Yendicup giving 3.2 such trees ha^{-1} (Figs. 8 and 10). This decrease from 73 before the fire at Boyicup was not significant ($p > 0.05$). Of these trees, 20 (29.8%) were jarrah while 47 (70.2%) were marri. No flooded gum trees were identified as "habitat trees". Again, the proportion of jarrah and marri "habitat trees" was not significantly ($p > 0.05$) different between the 2 assessments so selection by possums is independent of tree species.

3.1.3 Pattern of distribution

The variance : mean ratio of data for "habitat trees" per quadrant, when checked for departure from the expected 1:1 ratio using student's t-test showed no significant deviation towards clumping or regularity at either study area before or after the fire at Boyicup ($p>0.05$). Distribution appears to be random and independent of the influence of fire (Figs. 7, 8, 9 and 10).

This contrasts with the contagious distributions observed for trees containing hollows in open-forest and grassy woodlands in Victoria (Ambrose 1982). The degree of contagion varied from highly clumped in modified sites to slightly clustered in relatively unmodified environments.

3.1.4 Parameters of "habitat trees"

3.1.4.1 Diameters

D.b.h.o.b. of "habitat trees" at Boyicup ranged between 45 cm and 132 cm ($\bar{x}$ = 82.5cm, S.D. = 18.9 cm, n = 82), while those at Yendicup ranged between 53.5 cm and 143 cm ($\bar{x}$ = 94.8 cm,

Figure 8. The position of "habitat trees" located in the Yendicup plot during the 1981 survey.

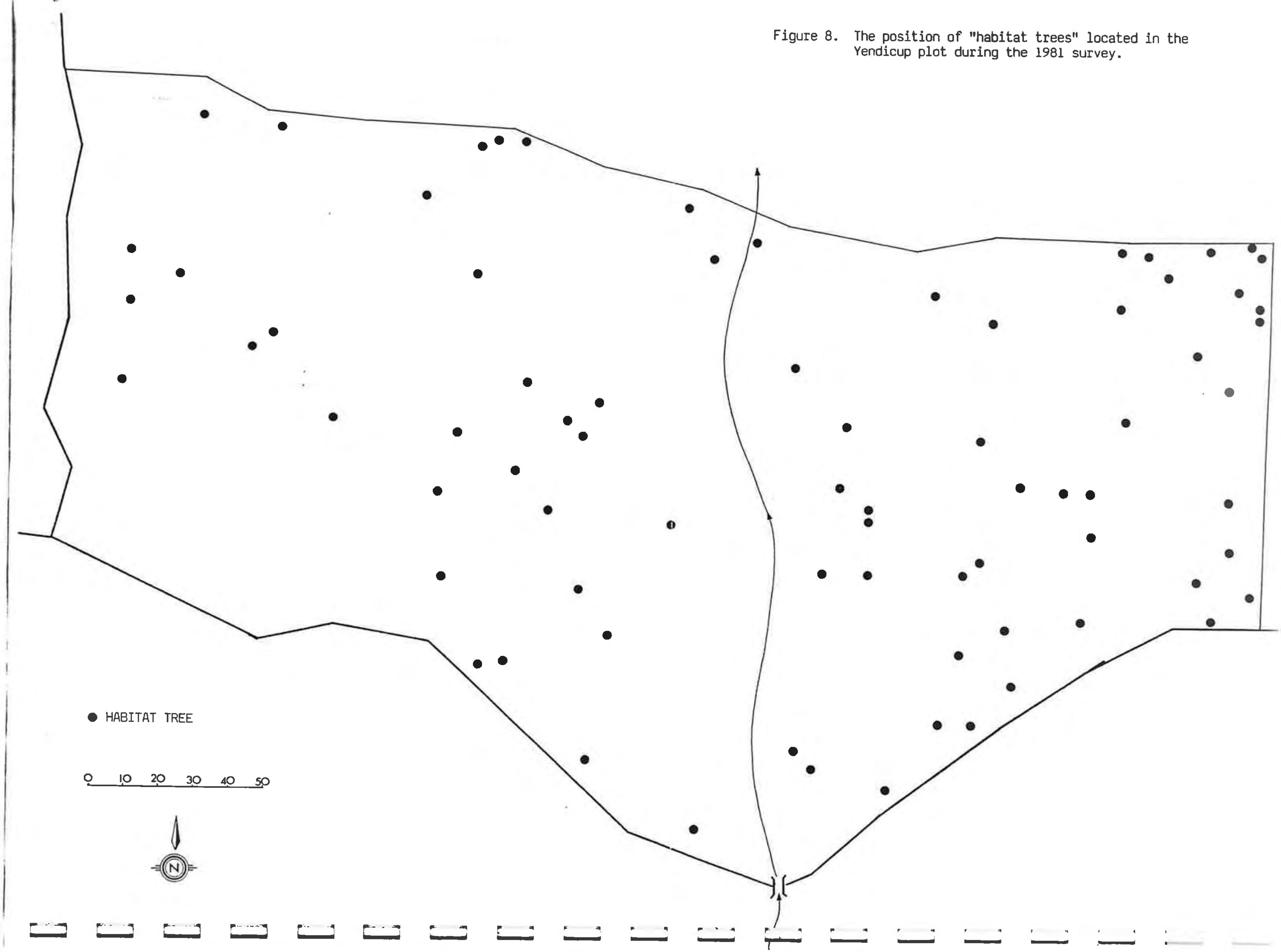


Figure 7. The position of "Habitat Trees" located in the Boyicup plot during the 1983 survey.

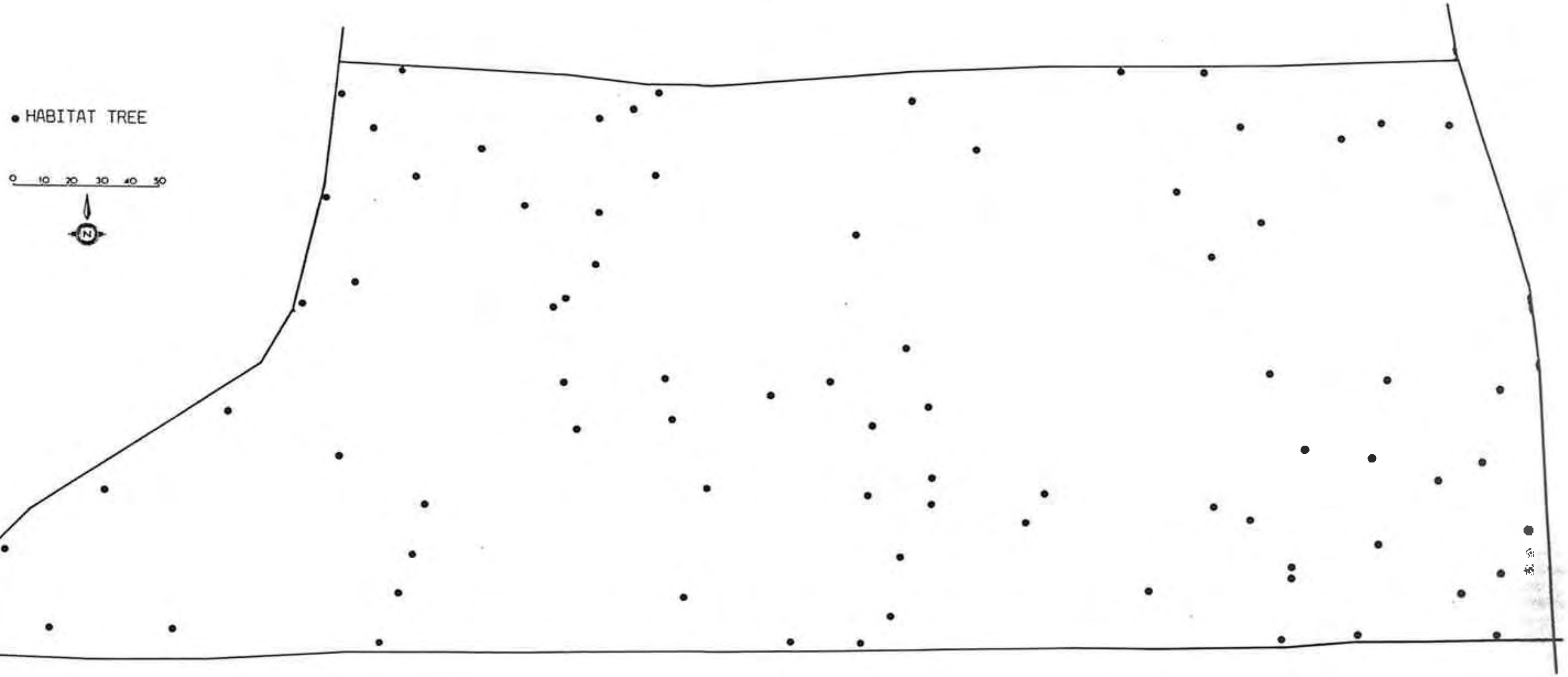


Figure 9. The position of "Habitat Trees" located in the Boyicup plot during the 1984 survey.

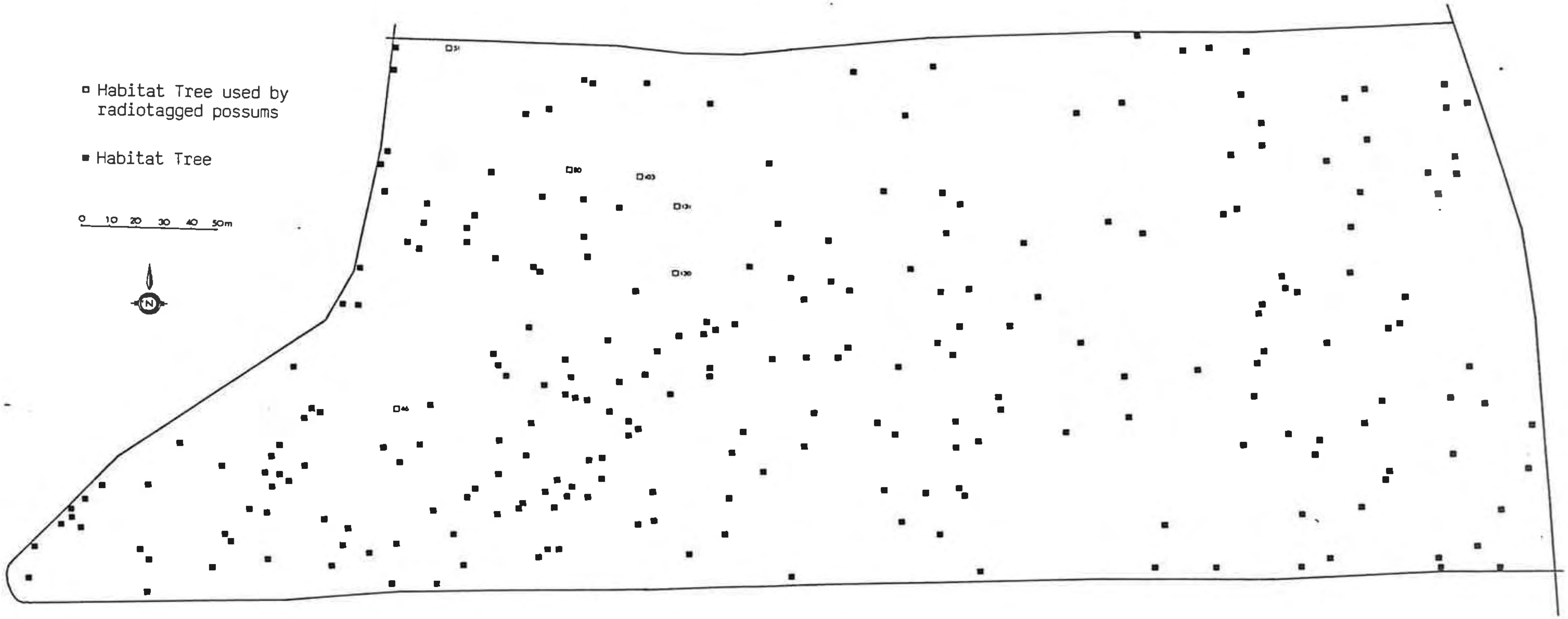


Figure 10. The position of "habitat trees" located in the Yendicup plot during the 1984 survey.

S.D. = 23.2 cm, n = 73). The mean d.b.h.o.b. of "habitat trees" from the Boyicup site was significantly less than that from Yendicup ($p < 0.05$).

Diameters of "habitat trees" at Boyicup after the fire ranged between 20 cm and 115 cm ($\bar{x}$ = 68.8 cm, S.D. = 18.9 cm, n = 254) while those at Yendicup ranged between 42 cm and 140 cm ($\bar{x}$ = 90.1 cm., S.D. = 23.8 cm, n = 67). The mean diameter of "habitat trees" at Boyicup was significantly ($p < 0.05$) less than that for trees at Yendicup, after the fire. No significant ($p > 0.05$) difference exists between the mean diameters of the pre- and post-fire data for trees at Yendicup.

Table 4 summarises the relationships between the 4 sets of data.

3.1.4.2 Heights of "habitat trees"

Heights of "habitat trees" at Boyicup ranged betweeen 7 m and 33 m ($\bar{x}$ = 19.4 m, S.D. = 6.1 m, n= 82), while at Yendicup heights ranged between 11 m and 29 m ($\bar{x}$ = 18.8 m, S.D. = 4.5 m, n = 73). The 2 means were not significantly different ($p > 0.05$).

Heights of "habitat trees" at Boyicup, after the fire, ranged between 2 m and 31 m ($\bar{x}$ = 18.6 m, S.D. = 5.6 m, n = 254) while those at Yendicup ranged between 8 m and 25 m ($\bar{x}$ = 18.3 m, S.D. = 4.6 m, n = 67). No significant difference ($p < 0.1$) exists between mean heights for any pre- or post-fire site (Table 5).

3.1.4.3 Heights above ground of hollows

The heights of entrances to hollows ranged from 6 m to 25 m ($\bar{x}$ = 14.2 m, S.D. = 5.4 m, n = 87) at Boyicup and from 8 m to 22

TABLE 4 : ANALYSIS OF VARIANCE TABLE FROM A 1-WAY ANOVA ON DIAMETERS OF HABITAT TREES WITH MEANS AND STANDARD ERROR

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	SUMS OF SQUARES PERCENTAGE	MEAN SQUARE	VARIANCE RATIO (F)
Diameters (cm)	3	5365	21.7	17885	43.1
Residual	467	193646	78.4	414	
Total	470	247302	100.2	526	

TABLE OF MEANS (cm)

Boyicup Preburn	Boyicup After Fire	Yendicup Preburn	Yendicup
82.5 ± 2.1	68.8 ± 1.2	94.8 ± 2.07	90.1 ± 2.9

m ($\bar{x}$ = 14.0 m, S.D. = 3.7 m, n = 79) at Yendicup. The 2 means were not significantly different ($p < 0.05$).

Heights of holes in "habitat trees" at Boyicup after burning ranged between 2 m and 26 m ($\bar{x}$ = 13.5 m, S.D. = 4.7 m, n = 299), while those at Yendicup ranged between 7 m and 25 m ($\bar{x}$ = 14.2 m, S.D. = 3.5 m, n =77). The mean height of holes from Boyicup, after the fire, was significantly lower than that measured before the fire. No other significant differences were detected (Table 6).

3.1.4.4 Position of the hollows

Hollows in broken branches were the most commonly used refuge in both study areas, before and after the fire (Table 7). No significant ($p > 0.05$) differences exist, in the distribution of proportions, between the positions of hollows between any of the sites, whether before or after the fire. Despite the increase in the absolute number of available hollows at Boyicup after the fire, their positional distribution appears to remain constant even after such a catastrophic event.

3.1.4.5 Condition of the "habitat trees"

Within Boyicup a significantly greater ($p< 0.05$) percentage (72%) of "habitat trees" was in the dead or poor condition categories. This was not the case at Yendicup where none of the 4 condition categories deviated significantly ($p > 0.05$) from their expected values (25%) (Table 8).

The condition of a "habitat tree" was a critical factor affecting the chances of the tree surviving fire (Section 3.1.5.2).

A significant proportion (67.7%) ($p < 0.05$) of "habitat trees" at Boyicup was either dead or in poor condition after the fire. Despite the increase in the numbers of "habitat trees" at Boyicup, no significant difference exists between the

TABLE 5 : ANALYSIS OF VARIANCE TABLE FROM A 1-WAY ANOVA ON HEIGHTS OF HABITAT TREES WITH MEANS AND STANDARD ERRORS.

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	SUMS OF SQUARES PERCENTAGE	MEAN SQUARE	VARIANCE RATIO (F)
Heights (m)	3	56	0.4	18.6	0.641
Residual	470	13617	99.6	29.0	
Total	473	13672	100.0	29.0	

TABLE OF MEANS (m) + STANDARD ERRORS

BOYICUP PREBURN	BOYICUP POST BURN	YENDICUP PREBURN	YENDICUP POST BURN
19.4 ±0.7	18.6 ± 0.3	18.8 ± 0.5	18.3 ± 0.6

TABLE 6. ANALYSIS OF VARIANCE TABLE FROM A 1-WAY ANOVA ON THE HOLE HEIGHTS IN HABITAT TREES WITH MEANS AND STANDARD ERROR.

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	SUMS OF SQUARES PERCENTAGE	MEAN SQUARE	VARIANCE RATIO (F)
Hole height	3	162	1.5	54.0	2.656
Residual	536	10907	98.5	20.3	
Total	539	11070	100.0	20.5	

TABLE OF MEANS (m) ± STANDAR ERROR

BOYICUP BEFORE-FIRE	BOYICUP AFTER-FIRE	YENDICUP BEFORE-FIRE	YENDICUP AFTER-FIRE
15.0 ± 0.6	13.5 ± 0.3	14.0 ± 0.4	14.2 ± 0.4

TABLE 7. DISTRIBUTION OF THE POSITIONS OF HOLLOWS.

HOLLOW POSITION	BOYICUP				YENDICUP			
	Before the fire		After the fire		Before the Boyicup fire		After the Boyicup fire	
	No. of hollows	Percentage	No. of hollows	Percentage	No. of hollows	Percentage	No. of hollows	Percentage
In broken branch	53	61.6	181	60.7	45	57.7	44	57.1
In bole due to broken top	16	18.6	53	17.8	21	26.9	17	22.1
In bole due to broken branch	13	15.1	52	17.5	8	10.3	10	13.0
In fork at crown break	4	4.7	12	4.0	4	5.1	6	7.8
Total	86	100	298	100	80	100	77	100

TABLE 8. CONDITION OF "HABITAT TREES"

CONDITION	BOYICUP				YENDICUP			
	Before the fire		After the fire		Before Boyicup fire		After Boyicup fire	
	No. of trees	Percentage	No. of trees	Percentage	No. of trees	Percentage	No. of trees	Percentage
Dead	28	34.2	79	31.1	16	21.9	13	19.4
Poor	31	37.8	93	36.6	22	30.1	23	34.3
Fair	12	14.6	30	11.8	14	19.2	12	17.9
Good	11	13.4	52	20.5	21	28.8	19	28.4
Total	82	100	254	100	73	100	67	100

distribution of proportions between condition classes before and 32 months after the fire (Table 8).

No significant difference ($p > 0.05$) was detected between data for Yendicup before and after the fire on the distribution of proportions between condition classes remained about equal (Table 8).

3.1.4.6 Scratchtracks on "Habitat trees"

Only a small percentage of "habitat trees" had scratchtracks classed as "very good" before the fire (i.e. 11.0% at Boyicup and 9.6% at Yendicup)(Table 9). It appears that :

(i) only a small proportion of "habitat trees" was used, by possums, on a consistent basis; and/or

(ii) these trees were inhabited by more than one individual, as was the case for tree T51 at Boyicup (Section 3.2.4).

No significant difference ($p > 0.05$) exists between proportions for each class of scratchtrack intensity recorded for before and after the fire at Boyicup. The intensity of use of the "habitat tree" resource has remained about the same despite the increase in the number of trees. Although the evidence is circumstantial, it may indicate that a larger possum population existed at the time of the second survey (1983/84).

The Yendicup study area contained more "habitat trees" before the fire, and these were more intensively used than after the fire, so the population of possums at Yendicup may have decreased slightly during the period between the 2 surveys (Table 9).

3.1.5 The effect of autumn fire at Boyicup on "habitat trees"

TABLE 9 : INTENSITY OF SCRATCHTRACKS

INTENSITY	BOYICUP				YENDICUP			
	Before the fire		After the fire		Before Boyicup fire		After Boyicup fire	
	No. of trees	Percentage	No. of trees	Percentage	No. of trees	Percentage	No. of trees	Percentage
Poor	13	15.8	33	13.0	8	11.0	11	16.9
Fair	31	37.8	86	33.8	20	27.4	25	38.5
Good	29	35.4	96	37.8	38	52.0	21	32.3
Very Good	9	11.0	39	15.4	7	9.6	8	12.3
Total	82	100	254	100	73	100	67	100

The Boyicup study area was burnt in harsh weather on 24 March, 1981. (Environmental conditions for that day are summarised in Appendix 4). An assessment of the original habitat trees at Boyicup 3 weeks after the fire revealed that a large percentage (37.8%) of the trees had been rendered uninhabitable by the fire (Table 10, Fig. 11).

3.1.5.1 Relationship between the species of "habitat trees" and the fire damage

Fire damage was not species-specific as 37.2% of jarrah "habitat trees" were rendered uninhabitable compared to 36.2% destruction of marri "habitat trees". The difference was not significant ($p > 0.05$) (Table 11).

3.1.5.2 Fire damage and the condition of the "habitat tree"

The damage a "habitat tree" sustained during the fire was influenced by the condition of the tree just before the fire. "Habitat trees" which were dead or in poor condition were more likely to be rendered uninhabitable (44% of these trees) than were trees in the fair or good categories (13% of these trees)(Fig.12). Of the total trees rendered uninhabitable, 89.6% were classified as either dead or in poor condition.

A map of fire intensity classes was produced using Byram's (1959) equation to estimate fire intensities (Fig. 11). Distribution of "habitat trees" was examined in relation to fire intensity classes. The greatest degree of damage occurred to trees in the higher fire intensity classes (Table 11).

Five habitat trees became uninhabitable in the low and moderate intensity classes; 2 of these were dead, 2 in poor condition and 1 was in good condition before the fire.

The relationship between my data for fire intensity, condition of the habitat tree and the expected damage a tree will sustain in a fire are best described by the equation ;

$$Y = 0.559 + 2.038\,I - 1.07C - 0.293I^2 + 0.230C^2$$

where, Y = the expected damage class,
i.e., 0 to 1 - undamaged
1 to 2 - light damage
2 to 3 - heavy damage
3 to 4 - severe damage
> 4 - destroyed

I = intensity class,
i.e., 1 = low
2 = moderate
3 = intermediate
4 = high

and, C = condition of "habitat tree"
i.e., 0 = dead
1 = poor
2 = fair
3 = good

Thirty three of the remaining 51 (64.7%) "habitat trees" at Boyicup were still in use at the time of the surveys 32 months after the fire. At Yendicup, only 34 (46.6%) of the original 73 "habitat trees" were still in use.

The condition of the original "habitat trees" still in use remained mainly unaltered except in the Boyicup site where a signficantly ($p < 0.05$) higher proportion of dead trees occurred after the fire. This resulted from 4 of the "habitat trees", classified as in poor condition in the survey before the fire, dying presumably as a result of the fire (Table 12).

Figure 11.

Map of the boyicup site (post burn) showing the relationship between fire intensity and habitat tree destruction

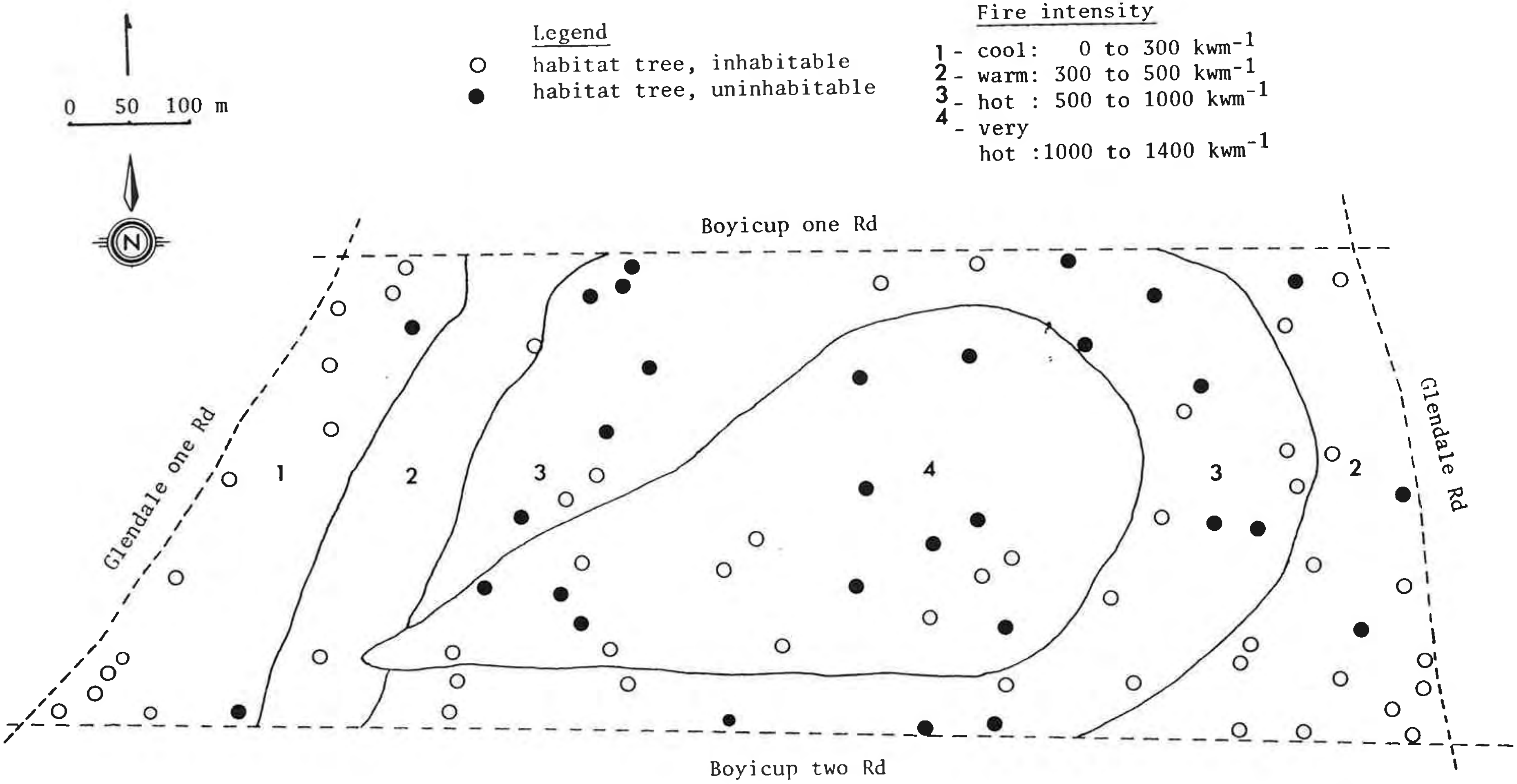


TABLE 10. FIRE DAMAGE TO "HABITAT TREES" OF JARRAH AND MARRI AT BOYICUP.

DAMAGE		JARRAH		MARRI		TOTAL	
		No.of trees	Percentage	No.of trees	Percentage	No.of trees	Percentage
Inhabitable	Undamaged	9	25.7	11	23.4	20	24.4
	Light damage	9	25.7	17	36.2	26	31.7
	Heavy damage	4	11.4	2	4.2	5	6.1
Uninhabitable	Severe damage	5	14.3	3	6.4	9	11.0
	Destroyed	8	22.9	14	29.8	22	26.8

TABLE 11. FIRE DAMAGE AND INTENSITY CLASSES

DAMAGE CLASSES		FIRE INTENSITIES							
		LOW		MODERATE		INTERMEDIATE		HIGH	
		No. of trees	Percentage	No.of trees	Percentage	No. of trees	Percentage	No. of trees	Percentage
Inhabitable	Unburnt	14	70	3	16.7	2	8.7	2	9.5
	Light	4	20	8	44.4	6	26.1	7	33.3
	Heavy	-	-	4	22.2	1	4.3	1	4.8
Uninhabitable	Severe	-	-	1	5.6	2	8.7	4	19.1
	Destroyed	2	10	2	11.1	12	52.2	7	33.3

Figure 12. Fire damage to habitat trees compared with the condition of the tree.

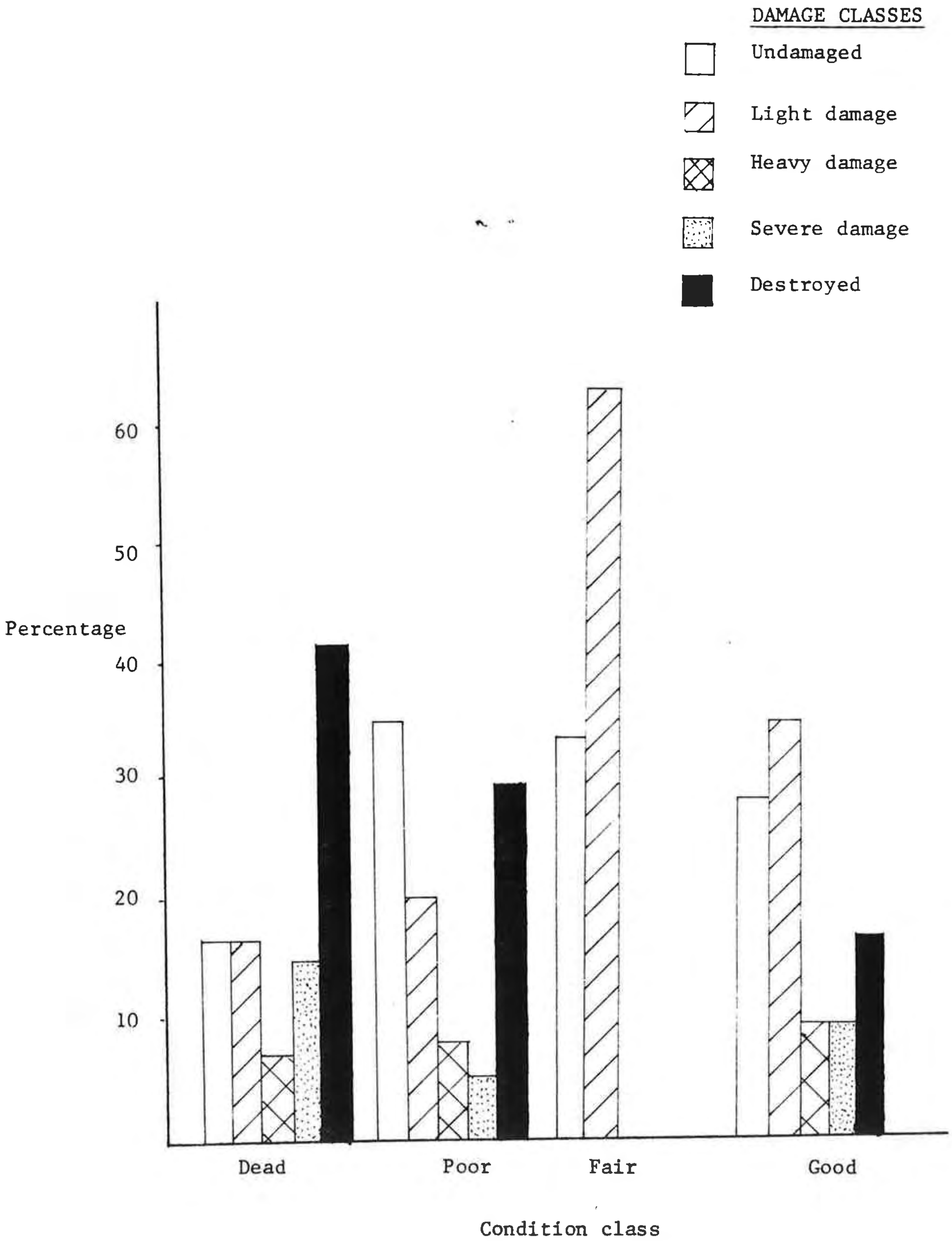


TABLE 12 : THE CONDITION OF "HABITAT TREES" STILL IN USE 32 MONTHS AFTER THE FIRE.

CONDITION	BOYICUP				YENDICUP			
	Before the fire		After the fire		Before the fire		After the fire	
	No. of trees	Percentage	No. of trees	Percentage	No. of trees	Percentage	No. of trees	Percentage
DEAD	13	39.4	17	51.6	6	17.6	5	14.7
POOR	9	27.3	5	15.1	12	35.3	14	41.2
FAIR	5	15.1	5	15.1	6	17.6	6	17.6
GOOD	6	18.2	6	18.2	10	29.5	9	26.5
TOTAL	33	100	33	100	34	100	34	100

3.1.6. Age of "habitat trees"

The growth rates of marri and jarrah are relatively constant with time and a plot of d.b.h.u.b. against age does not show the characteristic sigmoidal growth curve usually associated with tree growth (see Pienarr and Turnbull 1973)(Fig.13). The mean diameter increment for each 10 cm diameter class, was significantly greater for marri than for jarrah ($p < 0.001$) (Table 13): for example, it would take a marri tree about 230 years to reach a d.b.h.u.b. of 60 cm while a jarrah tree would take about 385 years to reach this size.

The mean age of jarrah "habitat trees" at Boyicup, before the fire, was 507± 21 years while the mean age of marri "habitat trees" was significantly younger at 334± 13 years ($p < 0.001$). After the fire the mean age of jarrah "habitat trees" decreased significantly ($p < 0.001$) to 403± 12 years as did the mean age of marri "habitat trees" (i.e. 277 ± 8 years)($p < 0.05$)(Table 14, Figs. 14 and 15).

The mean age of jarrah "habitat trees" at Yendicup, before the fire at Boyicup, was 538± 30 years while the mean age of marri "habitat trees" was significantly ($p < 0.05$) younger at 399 ± 15 years. After the fire at Boyicup, the estimated mean age of jarrah "habitat trees" decreased significantly ($p < 0.05$) to 485± 29 years, while the mean age of marri "habitat trees" did not ($p < 0.05$) and was 378± 16 years (Table 14, Fig.18). The 53.5 year deficit in the mean age of jarrah "habitat trees" experienced between the two surveys at Yendicup may not be attributed to the effects of fire. Rather it is a result of the dynamics involved with "habitat trees" selection by possums and should be considered a chance result (Table 14, Figs. 16 and 17).

Before the fire the mean age of jarrah "habitat trees" did not differ significantly between Boyicup and Yendicup, but the marri "habitat trees" at Yendicup were significantly older ($p > 0.05$) than those at Boyicup. After the fire the mean ages

TABLE 13. MEAN DIAMETER INCREMENTS PER DECADE PER PLOT OF JARRAH AND MARRI IN RELATION TO INITIAL DIAMETER (cm).

DIAMETER INCREMENT(cm)	10	20	30	40	50	60	70	80	90	100
MARRI										
Mean	2.19	2.36	2.53	2.82	2.12	2.12	2.19	2.11	2.09	2.40
S.E.	0.17	0.32	0.49	0.73	0.19	0.24	0.29	0.34	0.51	0.53
No. of Plots	19	19	19	17	16	15	14	13	4	3
JARRAH										
Mean	1.33	1.33	1.34	1.34	1.34	1.34	1.42	1.63	1.45	2.20
S.E.	0.13	0.12	0.12	0.13	0.15	0.19	0.22	0.28	0.33	0.62
No. of Plots	20	20	20	20	20	20	18	15	10	3

TABLE 14 : ESTIMATED MEAN AGE OF "HABITAT TREES" (YEARS)

	MEAN	STANDARD ERROR	STANDARD DEVELOPMENT	NO. OF TREES	RANGE
Boyicup before the fire					
Jarrah	507	21	122	33	280-730
Marri	334	13	90	49	160-550
Boyicup after the fire					
Jarrah	403	12	132	123	85-680
Marri	277	8	88	123	100-550
Yendicup before the fire					
Jarrah	538	30	139	22	310-790
Marri	399	15	107	51	206-610
Yendicup after the fire					
Jarrah	485	29	128	20	235-790
Marri	378	16	108	47	160-610

Figure 13 : Diameter growth measured for jarrah and marri in low quality forest east of Manjimup

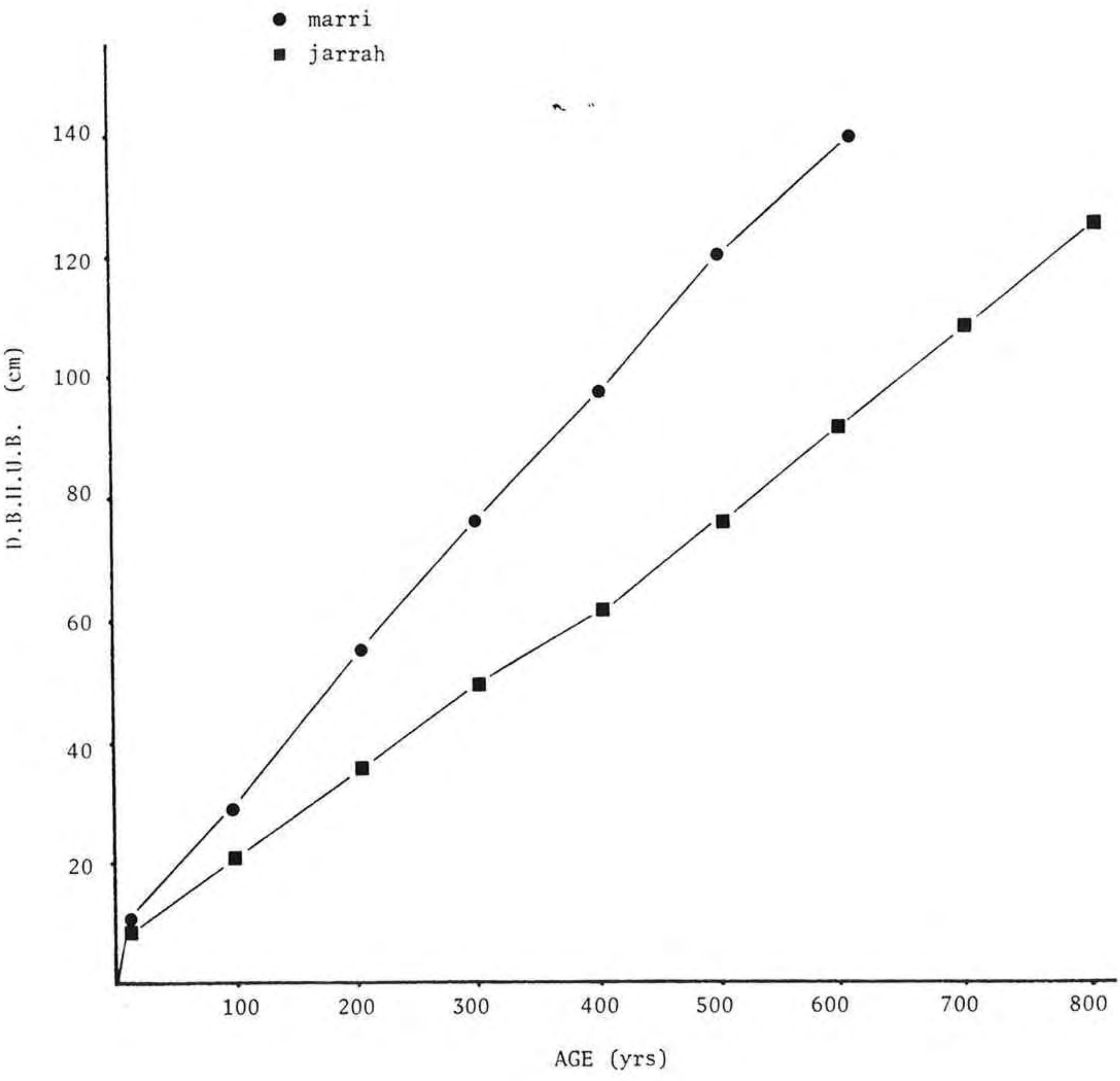


Figure 14. Percentage distribution of the ages of habitat trees in Boyicup before the fire.

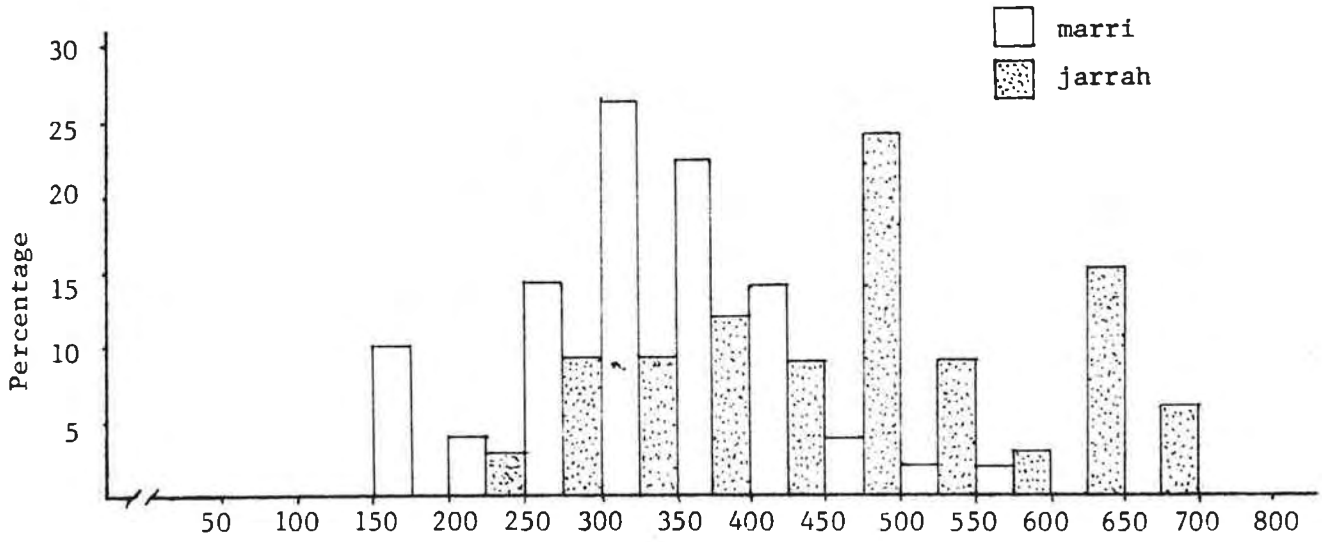


Figure 15. Percentage distribution of the ages of habitat trees in Boyicup after the fire.

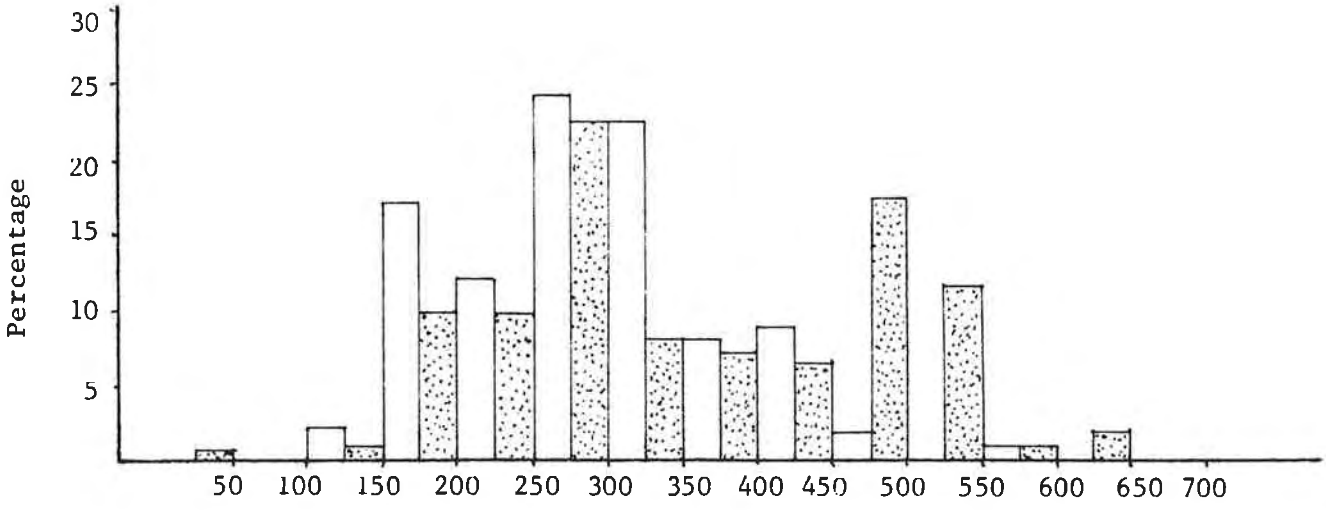
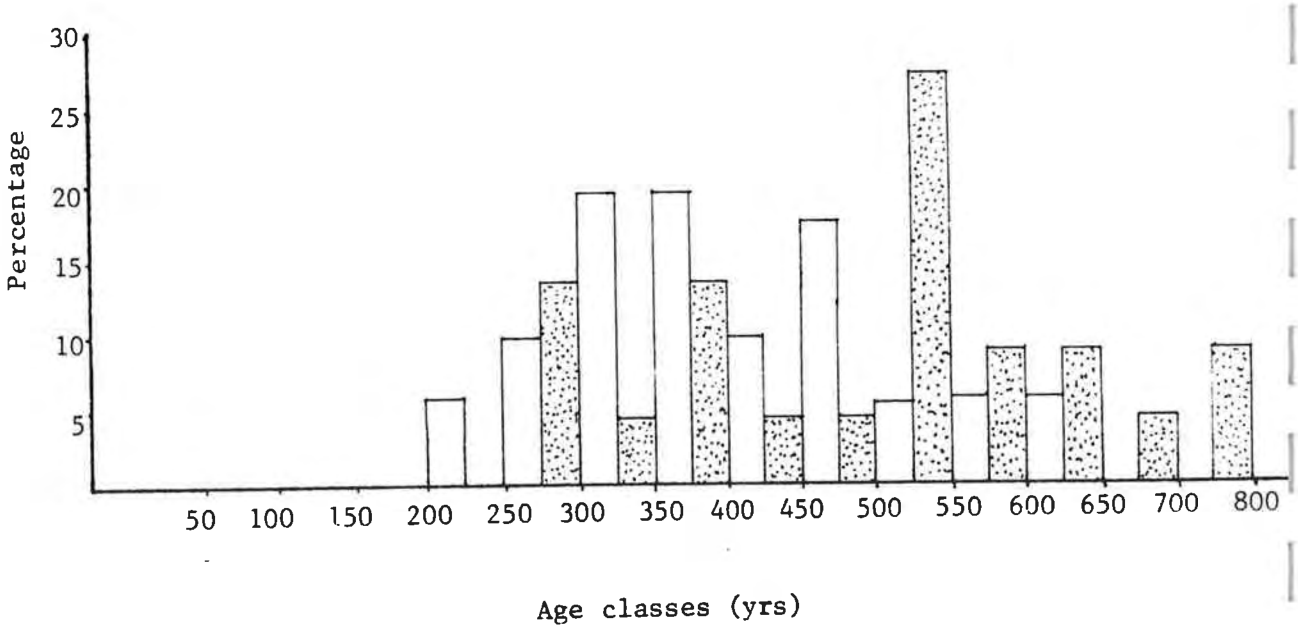


Figure 16. Percentage distribution of the ages of habitat trees in Yendicup before the fire.

Figure 17. Percentage distribution of the ages of habitat trees in Yendicup after the fire.



of both marri and jarrah "habitat trees" at Boyicup were significantly younger than those at Yendicup ($p > 0.005$).

Although the mean age for marri and jarrah "habitat trees" at Boyicup decreases significantly after the fire, it is invalid to suggest this is solely in reaction to the fire as the mean age of jarrah "habitat trees" at Yendicup also decreased after the fire. However, it is probable that a major portion of the decrease is attributable to the fire as the mean age of jarrah "habitat trees" at Boyicup decreased by 103.8 years between assessments compared to 53.3 years at Yendicup. Also the decrease in mean age of marri "habitat trees" at Boyicup was significant while it was not at Yendicup.

3.1.7 Physical paramaters of the hollows

The dimensions of hollows measured for all 32 hollows surveyed are summarised in Tables 15, 16, 17, 18 and 19.

To identify which parameters were important in determining if a hollow was suitable for habitation by possums, the data were converted to binary data. Hollows in trees which possessed no scratchtrack or one classified as "poor" were assumed not to be used as shelter sites, while hollows in trees possessing "fair", "good" or "very good" scratchtracks were. A logistic regression analysis showed that the depth of the cavity floor below the entry hole was the only significant ($p < 0.01$) parameter determining if a hollow is used or not. No significant ($p > 0.05$) interaction between the depth of the cavity floor below the entry hole and other parameters was detected, although this is probably due to the small sample size.

A 1-way ANOVA using the intensity of the scratchtracks as the treatments showed that hollows in trees with scratchtracks classified as "fair, "good", or "very good" were significantly ($p < 0.01$) deeper than the others (Table 20). This agrees with the study by Menkhorst (1984a) who found, while studying the patterns of nest-box usage by possums and gliders, that the brushtail possum preferred deep nest-boxes but the ringtail possum used a broad range of nest boxes. Calder <u>et al</u> (1983) showed that the ringtail possum had distinct preferences for particular dimensions which influenced the use of artificial hollows by the species. These dimensions included the interior diameter of the box, the wall thickness, the depth, orientation of the opening and of the box.

TABLE 15 : DIMENSIONS OF 32 HOLLOWS SURVEYED FOR THEIR SUITABILITY FOR USE BY POSSUMS.

Parameter	Mean	Standard Error	Range
Height of the tree above (m)	12.8	0.9	3.5 - 23.0
Height of the hollow above ground (m)	6.7	0.4	0.5 - 10.0
Diameter of the entry hole (cm)	17.6	1.7	6.0 - 49.0
Diameter of the cavity interior (cm)	17.8	1.7	8.0 - 48.0
Mean thickness of the wall (cm)	14.3	1.6	3.0 - 44.0
Depth of the cavity floor below entry hole (cm)	77.7	18.0	0.0 - 390.0
Height of cavity roof above entry hole (cm)	6.0	2.0	0.0 - 40.0
Planar orientation (degrees)	60.9	6.7	-65.0 - 90.0

TABLE 16 : ASPECTS OF 32 HOLLOWS SURVEYED FOR THEIR SUITABILITY FOR USE BY POSSUMS.

Aspect of Entrance	No. of hollows	Percentage
North north east	8	25.0
North north west	2	6.2
East north east	6	18.8
East south east	1	3.2
South south east	5	15.6
South south west	0	0.0
West south west	5	15.6
West north west	2	6.2
Vertical	3	9.4
TOTAL	32	100.0

TABLE 17 : THE SPECIES OF TREES CONTAINING HOLLOWS WHICH WERE SURVEYED FOR THEIR SUITABILITY FOR USE BY POSSUMS

Tree Species	No. of hollows	Percentage
Jarrah	13	41.9
Marri	16	51.6
Flooded gum	2	6.5
Total	31*	100.)

* One piece of data missing.

TABLE 18 : THE INTENSITIES OF SCRATCHTRACKS ON TREES CONTAINING HOLLOWS WHICH WERE SURVEYED FOR THEIR SUITABILITY FOR USE BY POSSUMS

Scratchtrack	No. of hollows	Percentage
Nil	7	21.9
Poor	11	34.4
Fair	6	18.8
Good	5	15.6
Very Good	3	9.3
Total	32	100.)

TABLE 19 : THE POSITION OF 32 HOLLOWS WHICH WERE SURVEYED FOR THEIR SUITABILITY FOR USE BY POSSUMS

Position	No. of hollows	Percentage
In a broken branch	7	21.9
In the bole	9	28.1
In the fork at crown break	1	3.1
In a broken top	15	46.9
Total	32	100.)

TABLE 20: THE MEAN DEPTH (cm) OF THE CAVITY FLOOR BELOW THE ENTRY HOLE FOR HOLLOWS IN TREES WITH DIFFERENT SCRATCHTRACK INTENSITIES.

Scratchtrack Intensity	Mean	Standard error	n
Nil	15a	2.0	7
Poor	28b	4.4	11
Fair	107c	15.2	6
Good	176d	26.0	5
Very good	185d	27.0	3

Different letters indicate significant differences ($p<0.05$).

3.2 RADIOTELEMETRY STUDIES

3.2.1 The Animals

Information about animals fitted with radio transmitters is summarised in Table 21. Some of the animals used during this study were captured by Christensen (1980b) and records for these animals were available. BTP3 (see Table 21) was caught and tracked for both years (i.e., 1983/84 and 1984/85). The radio transmitters signal for BTP9 and RTP8 stopped before the radiotelemetry program was completed, due either to transmitter failure or preation of the animal (Christensen 1978).

3.2.2. Utilised area

On the basis of 154 locations identified in 1983/84, possum BTP1 utilised an area of about 5.9 ha, while BTP2 (139 locations) and BTP3 (127 locations) both used 3.0 ha (Fig.18). These areas include any area enclosed by the polygons, but possibly not visited by the possums. About 1.9 ha were common to all 3 possums, and comprised about 31% of BTP1's area, 61% of BTP2's area and 63% of BTP3's area. BTP2 and BTP3 shared 2.3 ha (77%) of their total areas and this area was that most intensively used by both animals (i.e., BTP3 spent 87% of its active period there compared to 80% of BTP2's active time). About 3.4 ha (57.6%) of BTP1's area was exclusive and it was this area which was most intensively used, with BTP1 spending 86.4% of its active period there.

BTP1 often made sorties into the southern end of her utilized habitat, which was common to BTP2 and BTP3,but rarely spent long periods of time there. Because of the high average speed of movement (See Section 3.2.5.2) involved, these expeditions were probably exploratory in nature.

TABLE 21 :INFORMATION ABOUT ANIMALS FITTED WITH RADIOTRANSMITTERS

Animal Code	Species	Tag No.	Sex	Capture Method	Capture Point	Date of Capture	Weight (g)	History (Other captures)	Age Yrs.	Information gathered			Year information was gathered	Comments
										No. of YEW traces	No. of days divrnal refuge sites were located	No. of nights animal tracked intensively		
BTP1	Brushtail	1363/ 1370	♀	Cagetrap	Below T51	9.11.83	-	28.3.79 (1120g) 16.4.80 (1240g) 4.11.81 (1440g)	6	3	24	6	1983/84	Pouch empty
BTP2	Brushtail	3107/ 3106	♀	Cagetrap	Below T80	10.12.83	1300	Nil	1	6	25	6	1983/84	-
BTP3	Brushtail	2200/ 2199	♀	Cagetrap	Below T51	7.12.83	-	3.11.81 (1600g) 6.10.81 (-)	≥ 4	3	27	6	1983/84	-
BTP3	Brushtail	2200/ 2199	♀	Cagetrap	Below T51	27.11.84	1670	As above	≥ 5	6	21	5	1984/85	Young in pouch-330g-♀
BTP4	Brushtail	Nil	♀	Cagetrap	Below T80	6.12.84	1800	Nil	1	1	22	5	1984/85	Daughter of BTP9
BTP9	Brushtail	Nil	♀	Cagetrap	Below T80	6.12.84	2500	Nil	≥ 2	0	10	4	1984/85	Mother of BTP4
BTP6	Brushtail	2804/ 2803	♂	Cagetrap	Below T87	26.10.82	1930	26.10.82	≥ 3	0	9	0	1984/85	-
RTP8	Ringtail	Nil	♂	Hand	Cnr.Boyicup 1 Rd/Glendale 2 Rd	4.12.84	-	Nil	≥ 1	1	14	4	1984/85	-
RTP10	Ringtail	Nil	♂	Hand	Cnr.Boyicup Rd./Glendale Rd.	4.12.84	-	Nil	≤ 1	1	18	0	1984/85	-

During the 1984/1985 summer BTP3 was recaptured and radiotracked. Her utilized area was extended to 3.9 ha, derived from 57 locations, an increase of 23.1% on the previous year. Based on 55 locations, identified in 1984/85, BTP4 utilized an area of about 2.8 ha, while BTP (40 locations) utilized an area of 2.5 ha (Fig.19). About 1.5 ha were common to all 3 possums and comprised 38.5% of BTP3's area, 53.4% of BTP4's area and 60% of BTP9's area. From 62 locations, RTP8 utilized an area of 2.6 ha and this area was not common with the area utilized by any other radiotagged possums (Fig.20)(Table 22).

The mean utilized area for female brushtail possums tracked during 1983/1984 was 4.0 ± 1.0 ha, while the mean utilized area of female brushtail possums tracked during 1984/1985 was 3.1 ± 0.4 ha. These areas are larger than the 2.4 ha mean home range of female brushtail possums in Australia given by Green (1984). Allen (1982) and Vellios (1981), both of whom worked in the eucalypt forest in Western Australia, give the mean home range of female brushtail possums as 1.8 ha and 2.05 ha respectively.

3.2.3 Intensity of use of the utilized area

All possums used "core" areas of their utilized areas more intensively than other areas. For example in 1983/84 BTP2 used 65% of its area 89% of the time, BTP3 used 70% of its area 91% of the time and BTP1 used 36% of its area 84% of the time. During 1984/85, BTP3 used 33.1% of its area 55.5% of the time, BTP4 used 67.8% of its area 92.7% of the time and BTP9 used 67.0% of its area 85% of the time. RTP8 also exhibited this pattern using only 40.3% of its area 74.2% of the time.

The percentage of the total recorded time spent in each section of an animal's utilized area is represented in figures 21, 22, 23, 24, 25, 26 and 27.

TABLE 22 : THE UTILISED AREAS (ha) OF 6 RADIOTRACKED POSSUMS

	YEAR			
	1983/1984		1984/1985	
Animal	Area (ha)	Locations	Area (ha)	Locations
BTP 1	5.9	154	-	-
BTP 2	3.0	139	-	-
BTP 3	3.0	127	3.9	57
BTP 4	-	-	2.8	55
BTP 9	-	-	2.5	40
RTP 8	-	-	2.6	62

Figure 18. Utilized areas of 3 brushtail possums determined by radiotelemetry during 1983/1984.

Figure 19. Utilized areas of 3 brushtail possums determined by radiotelemetry studies during 1984/1985.

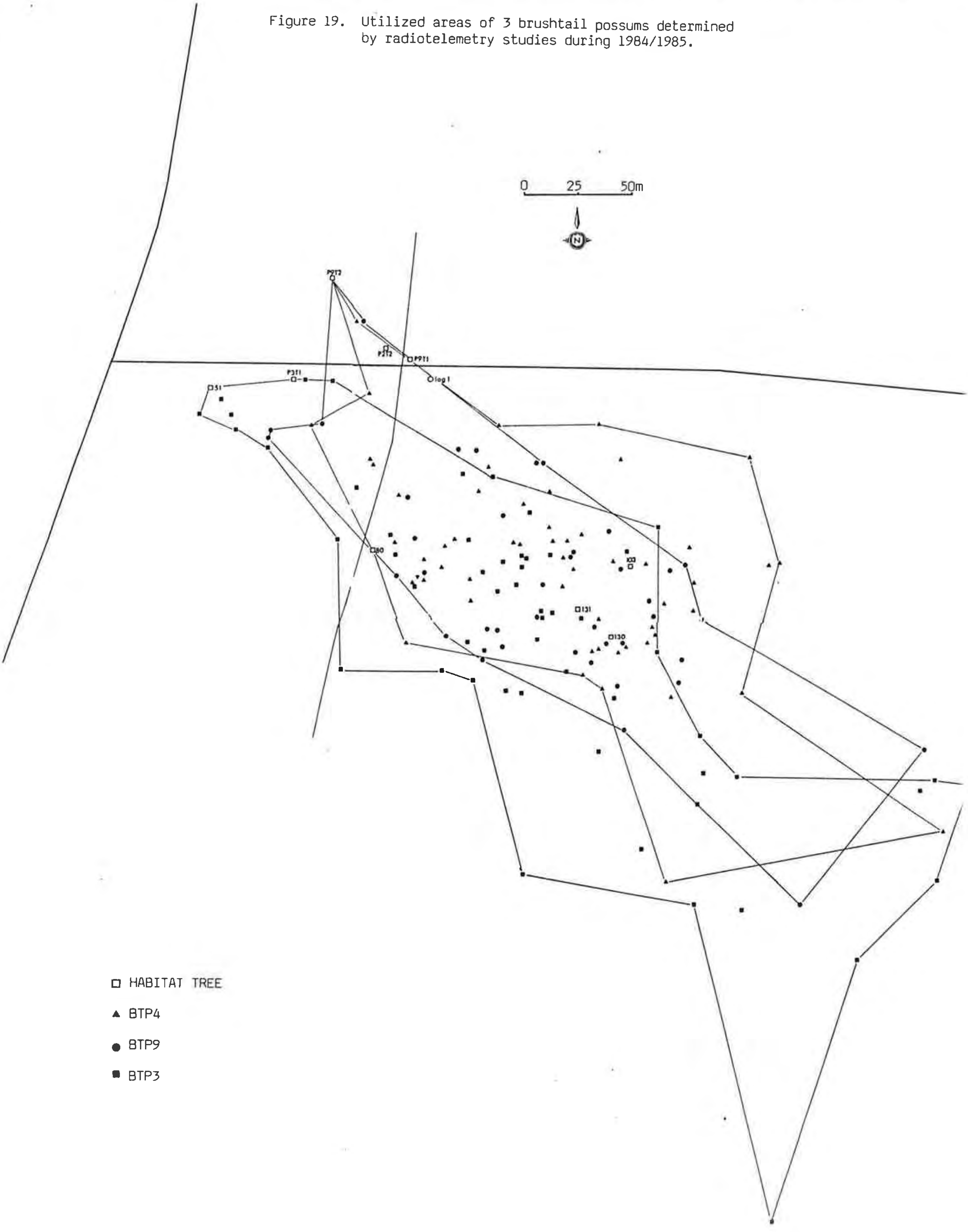


Figure 20. The utilized area of a ringtail possum, (RTP8) determined by radiotelemetry studies during 1984/1985.

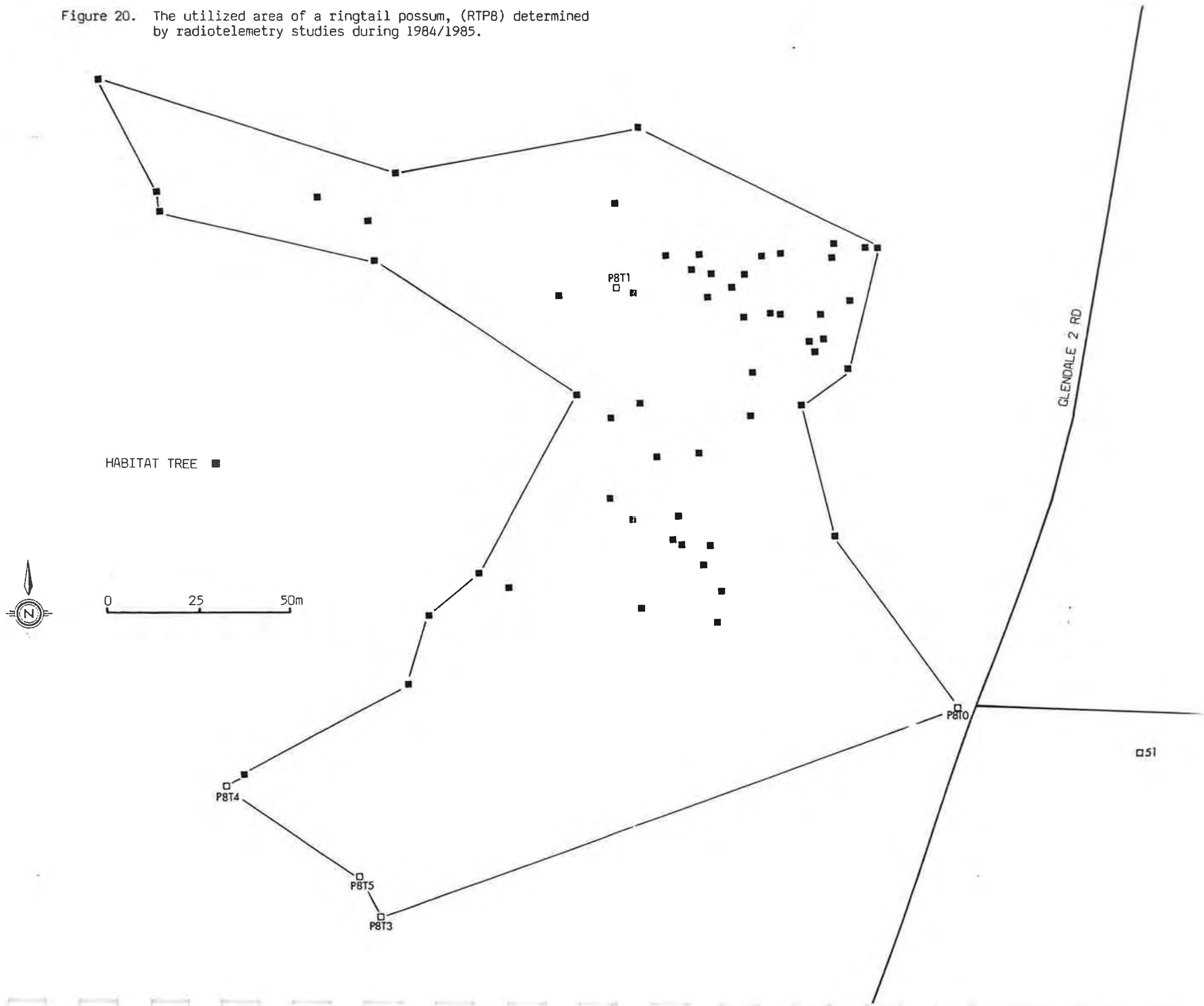


Figure 21. Contour map of the utilized area of BTP1 showing the different intensity of use of the utilized area. Contours based on the number of locations per grid cell.

Scale = 1:2000

JAM652*BTP1 PLOTLIB-3.0
8JAM 111585 150349

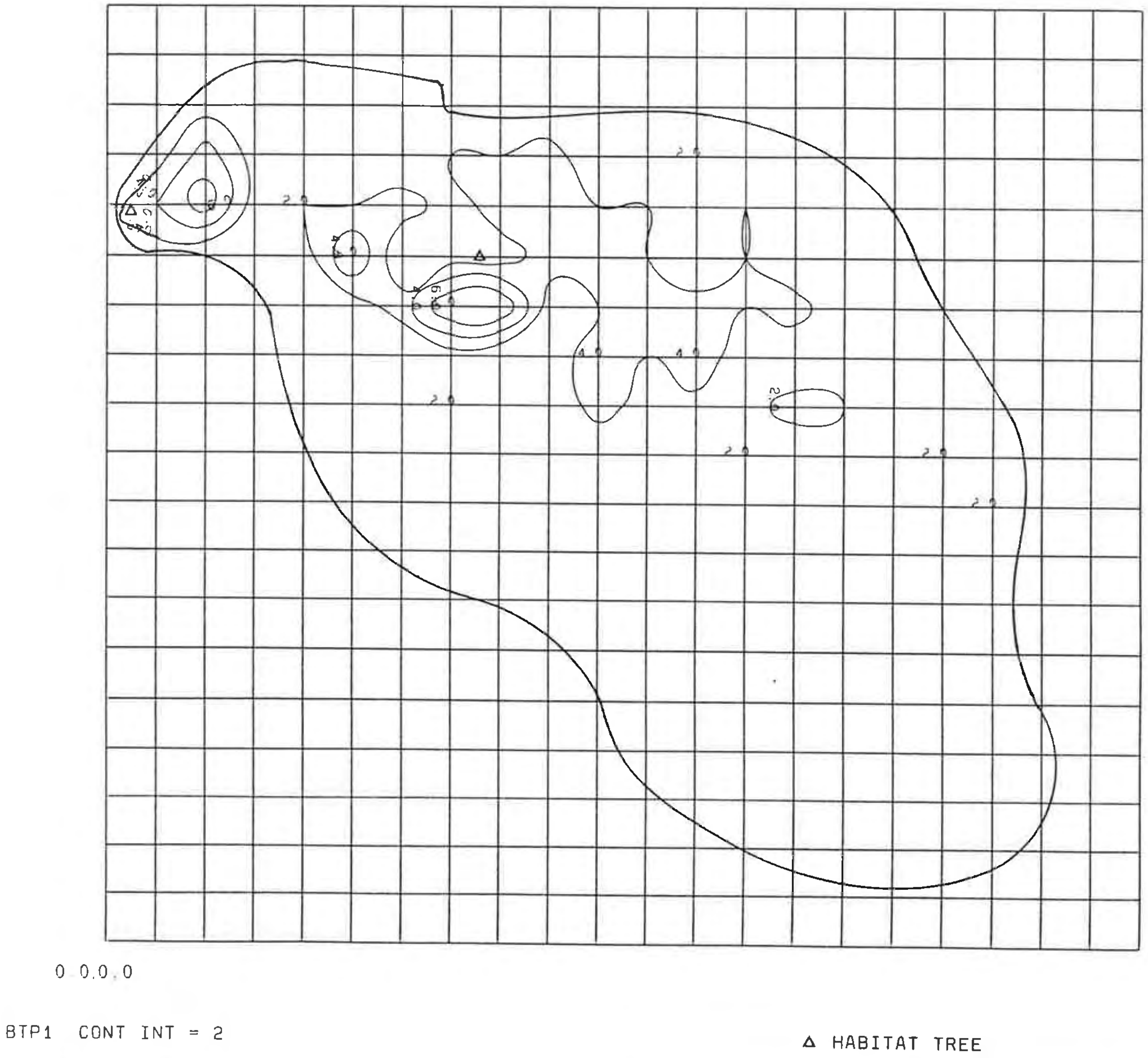
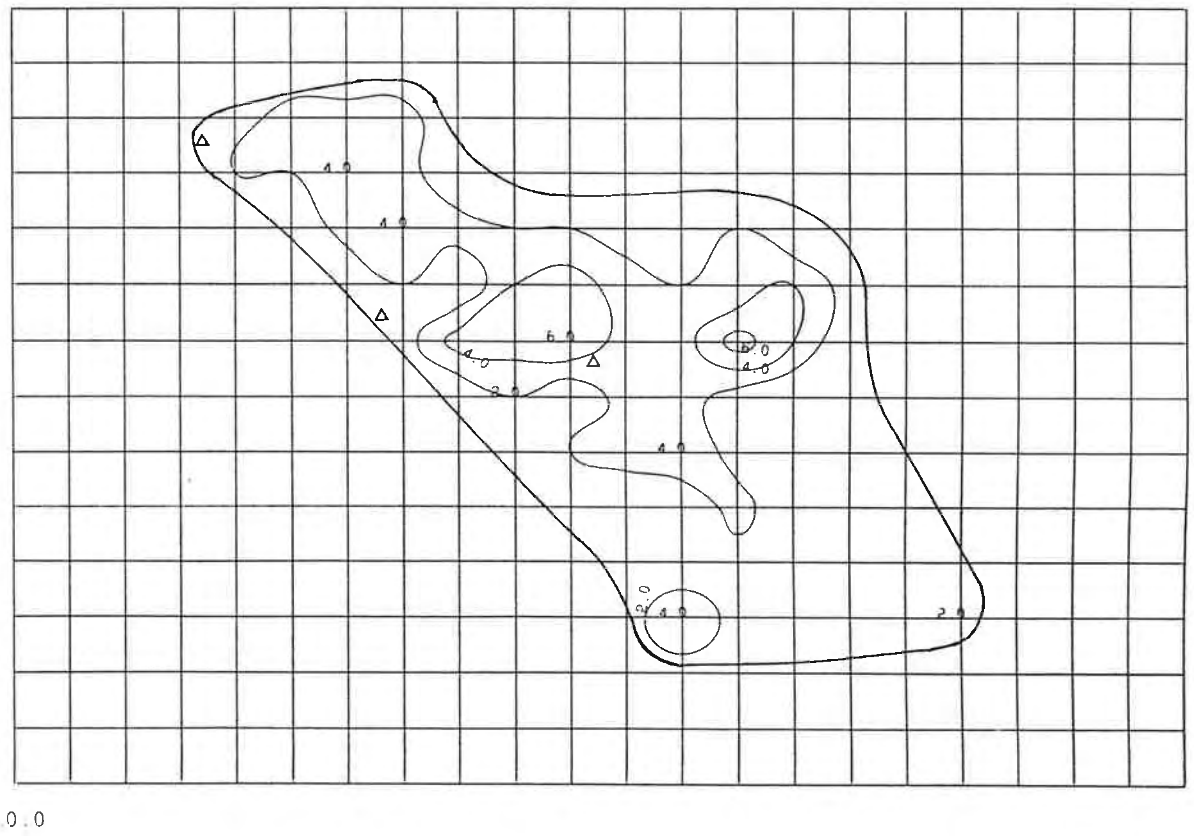


Figure 22. Contour map of the utilized area of BTP2 showing the different intensity of use of the utilized area. Contours based on the number of locations per grid cell.

Scale = 1:2000

JAM652*BTP2
8JAM 111585 150724 PLOTLIB-3.0



BTP2 CONT INT = 2.0

△ HABITAT TREE

Figure 23. Contour map of the utilized area of BTP3 during 1983/1984, showing the different intensity of use of the utilized area. Contours based on the number of locations per grid cell.

Scale = 1:2000

JAM652*BTP31 PLOTLIB-3.0

8JAM 111585 152756

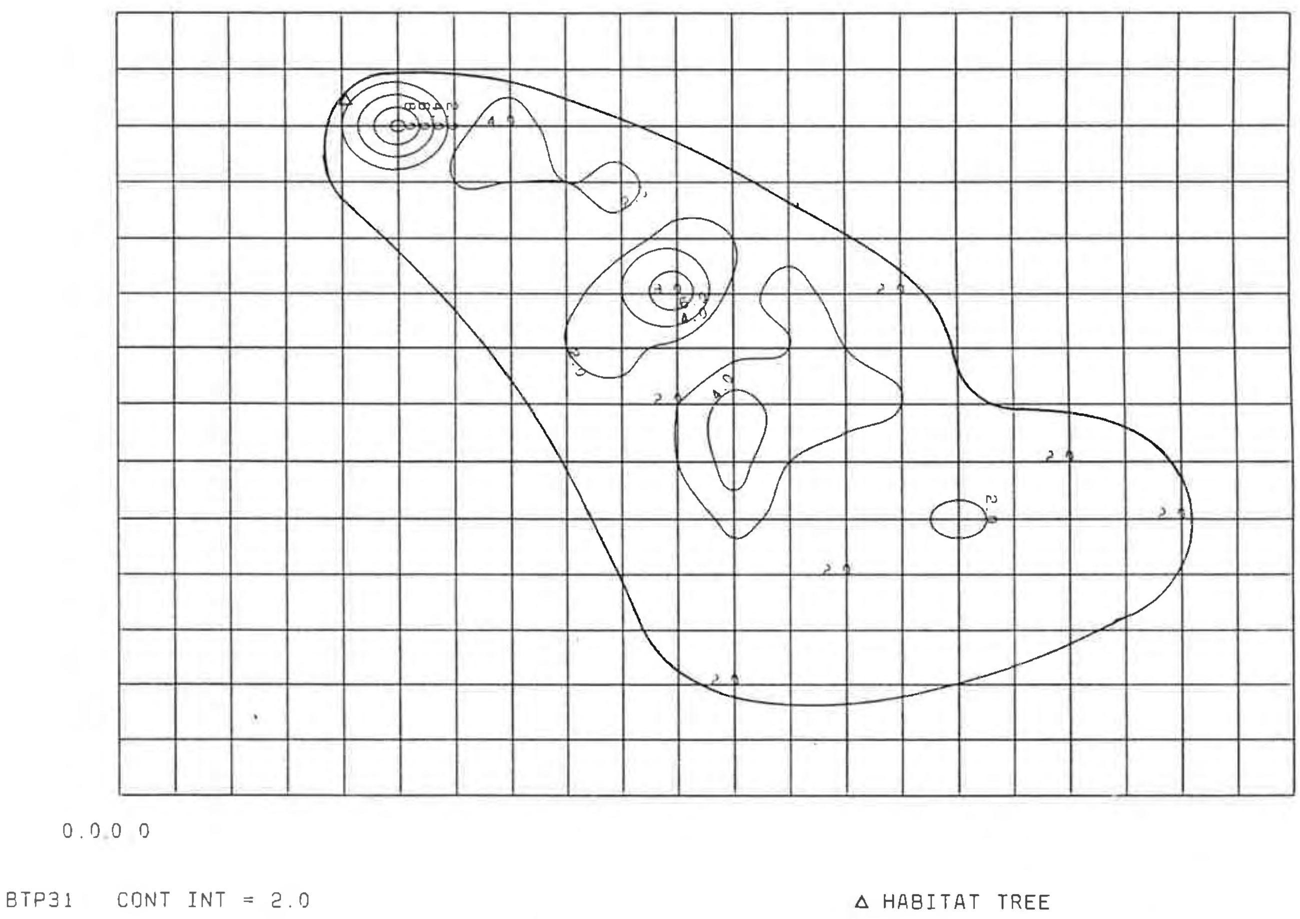
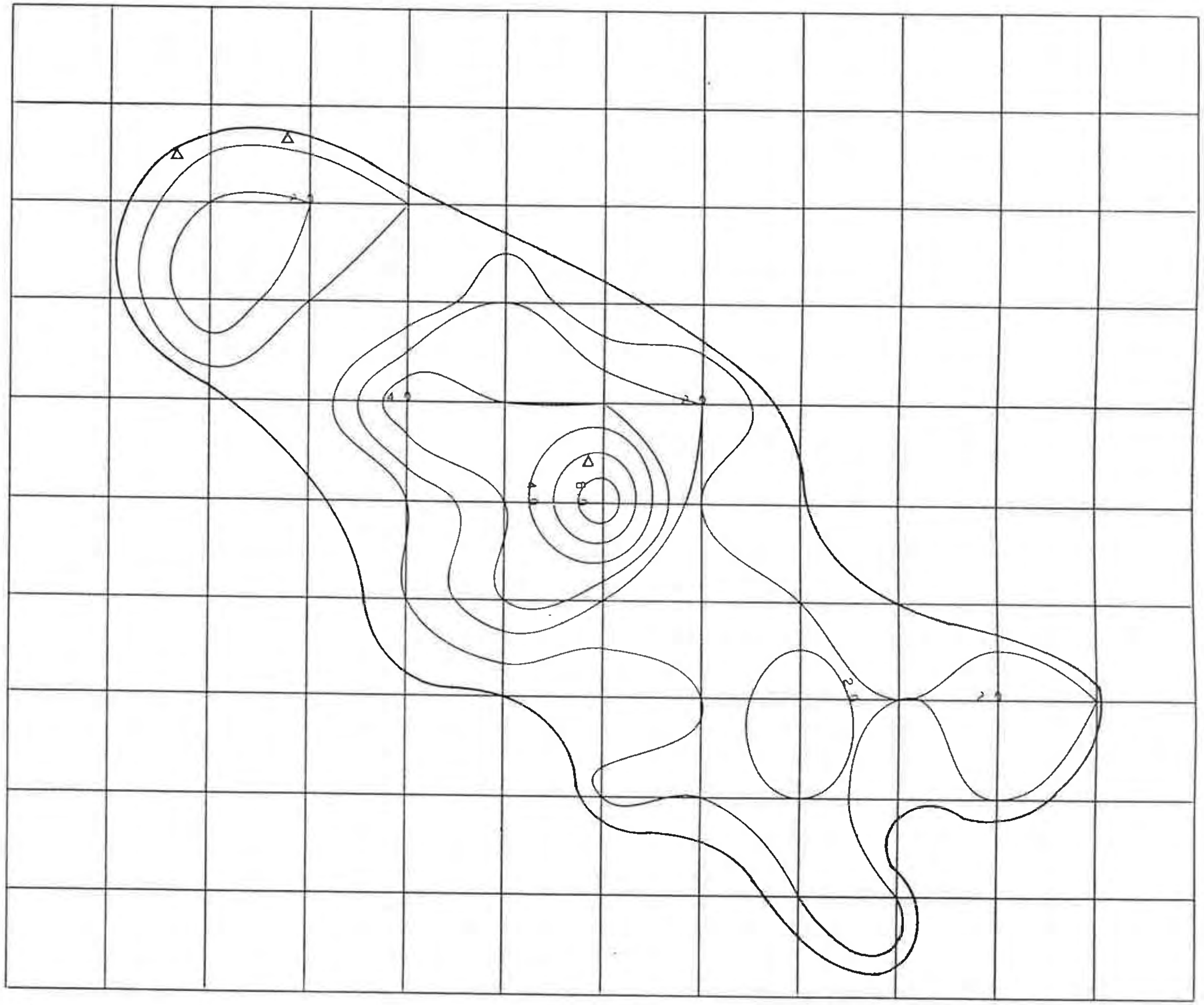


Figure 24. Contour map of the utilized area of BTP3 during 1984/1985, showing the different intensity of use of the utilized area. Contours based on the number of locations per grid cell.

Scale = 1:1000



JAM652*BTP32
8JAM 111585 152350
PLOTLIB-3.0

Figure 25. Contour map of the utilized area of BTP4 showing the different intensity of use of the utilized area. Contours based on the number of locations per grid cell.

Scale = 1:1000

JAM652*BTP4 PLOTLIB-3.0
8JAM 111585 151706

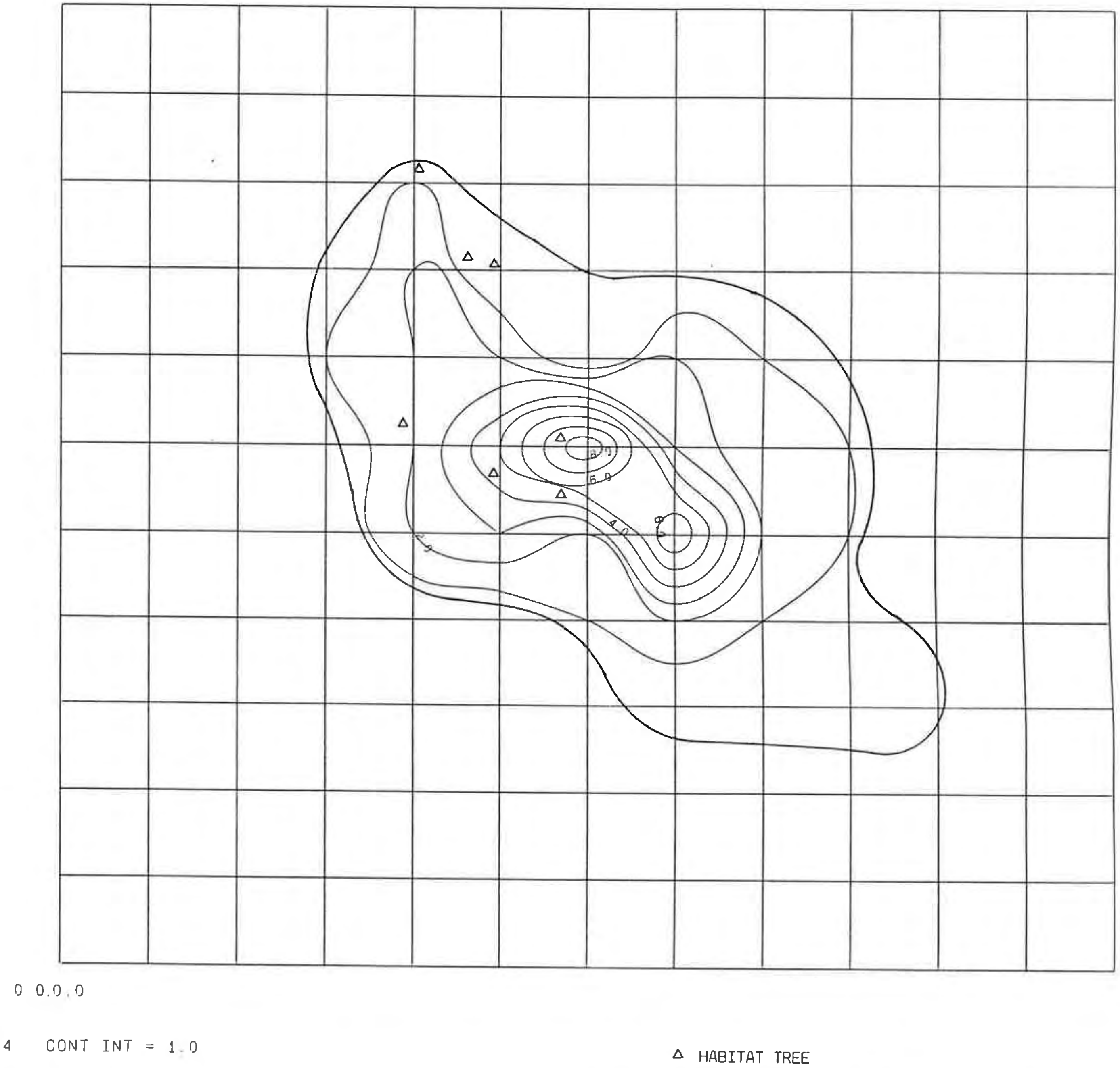
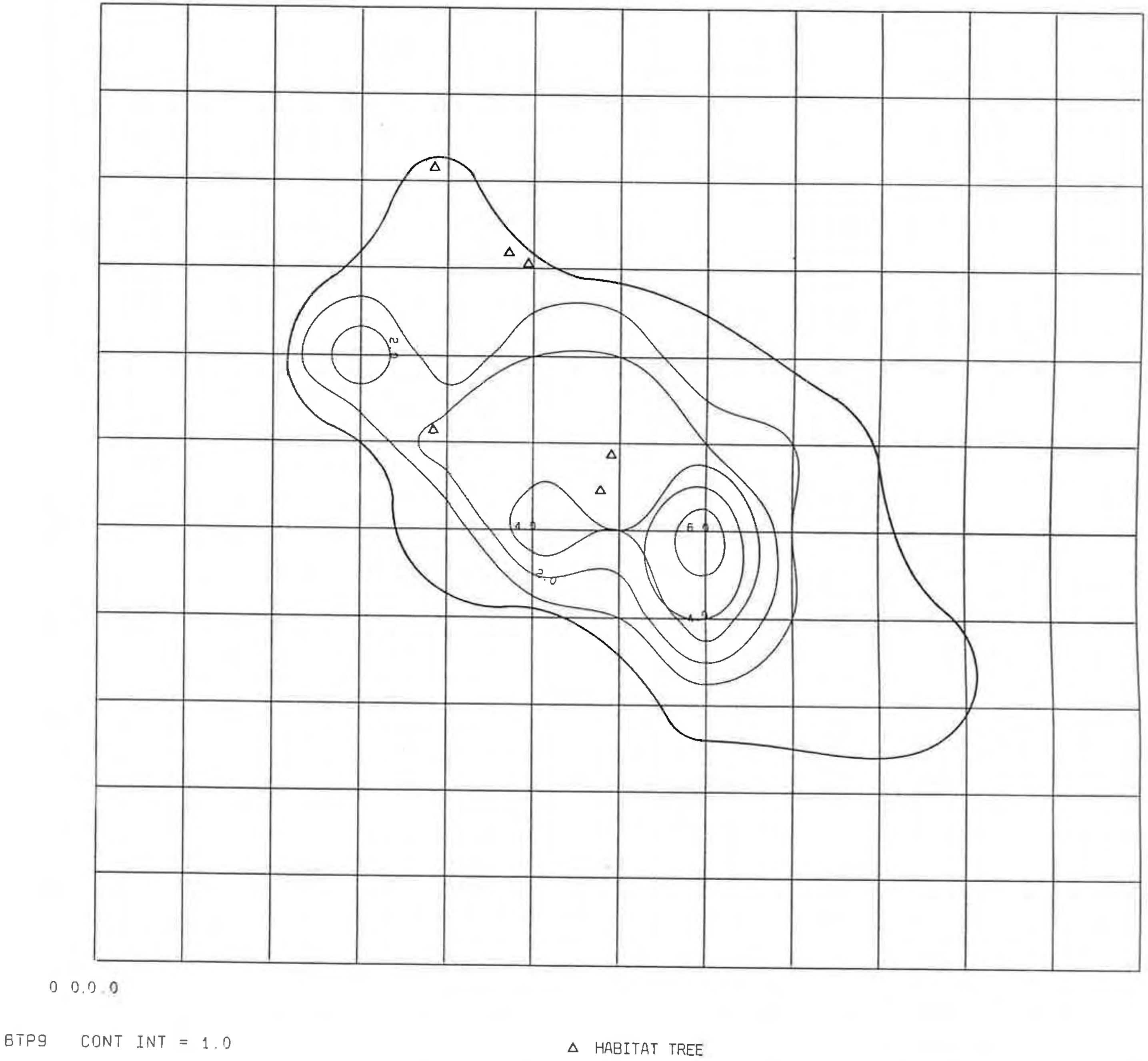


Figure 26. Contour map of the utilized area of BTP9 showing the different intensity of use of the utilized area. Contours based on the number of locations per grid cell.

Scale = 1:1000

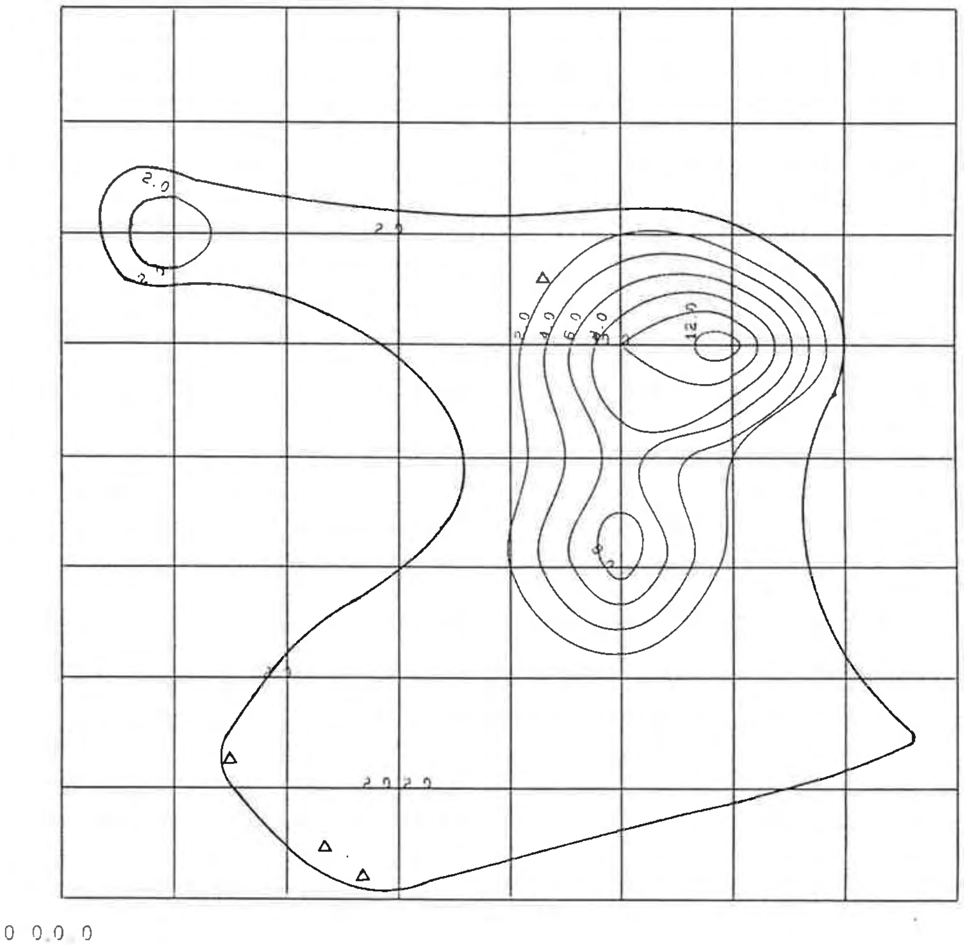


JAM652*BTP9
8JAM 111585 152043
PLOTLIB-3.0

Figure 27. Contour map of the utilized area of RTP8 showing the different intensity of use of the utilized area. Contours based on the number of locations per grid cell.

Scale = 1:2000

JAM652*RTP8
8JAM 111585 154225
PLOTLIB-3.0



3.2.4 Usage of shelter sites

Periodic locations of the possums, during the inactive diurnal period, showed that hollows in "habitat trees" were the most commonly used form of shelter. Other sites used included hollow logs, dreys and logging debris. (Table 23).

Variability of usage of shelter site was evident between individuals and species of possum. Variability was also recorded by Vellios (1981) who radiotracked 4 brushtail possums which used from 4 to 11 "habitat trees". The number of dens used per possum, in New Zealand, ranged from 6 to 11 (F.R.I 1980). Of the 59 possums radiotracked in New Zealand, the majority were at or below ground level during the diurnal period, in tree root systems, hollow logs and stumps and even down crevices in stream banks, with each possum normally having a number of dens spread over a relatively small area of is home range (F.R.I 1980). The difference between the chosen sites of diurnal refuge shown between the F.R.I. (1980) study and this study may be due to behaviour aimed at avoidance of predators, a view supported by MacLennan (1984). Both Christensen (1980b) and Inions (1981c) suggest that predatory pressure exerted by the European fox (Vulpes vulpes L.) is extensive in the study area, therefore, arboreal sites of refuges would be advantageous to the individual.

With the exception of RTP8 and BTP3 (during 1983/1984) the site of refuge favoured by an animal was positioned towards the extremities of the intensively used portion of the individual's utilized area (Figs. 21, 22, 23, 24, 25, 26 and 27). Possibly, due to the quality of the "habitat trees" used by RTP8 and BTP3, these animals adopted a strategy of travelling longer distances to their desired feeding areas in contrast to the other possums. Minimizing travelling distance by selecting refuge sites close to a desired area may be an adaptation to conserve energy, otherwise spent in travelling, which has evolved as a response to energy balance problems imposed by the high toxin levels in their eucalypt diet

TABLE 23 : Shelter site usage by 8 possums

ANIMAL	1983/1984											
	tree	n	%	Log	n	%	Drey	n	%	Debris	n	%
BTP1	P1T1	14	58.3		-			-			-	
	P212	10	45.8		-			-			-	
BTP2	T51	13	52.0		-			-			-	
	T131	11	44.0		-			-			-	
	T80	1	4.0		-			-			-	
BTP3	T51	27	100.0		-			-			-	
					1984/1985							
BTP3	T51	11	44.0		-			-			-	
	P3T1	13	52.0		-			-			-	
	T131	1	4.0		-			-			-	
BTP4	T80	7	33.3	1	1	48%		-			-	
	T103	2	9.5		-			-			-	
	T130	2	9.5		-			-			-	
	T131	2	9.5		-			-			-	
	P9T1	2	9.5		-			-			-	
	P9T2	4	19.1		-			-			-	
	P2T2	1	4.8		-			-			-	
BTP9	T80	3	30.0		-			-			-	
	T131	1	10.0		-			-			-	
	P9T1	3	30.0		-			-			-	
	P9T2	3	30.0		-			-			-	
BTP6	T46	2	25.0		-			-			-	
		1	12.5		-			-			-	
	P6T1	5	62.5		-			-			-	
RTP8	P8T1	2	16.7		-			-			-	
	P8T3	6	50.0		-			-			-	
	P8T4	3	25.0		-			-			-	
	P8T5	1	8.3		-			-			-	
RTP10		-			-		1	12	70.6	1	3	17.6
		-			-		2	2	11.8		-	

(Freeland and Winter 1975). This adaptation may equally be associated with predator avoidance (MacLennan 1984).

The co-occupation of "habitat trees" was uncommon except for adult/offspring relationships such as BTP9 and BTP4 and BTP3 and BTP2 (Table 23). Although BTP3 and BTP4 used Tree T131 during the 1984/85 tracking period, they were not recorded in tree T131 at the same time. "Habitat tree" co-occupation has been recorded by Vellios (1981), but this was for one night only and possibly for mating purposes.

Although co-occupation of "habitat trees" is uncommon, the ownership of the tree seems to be dynamic. For example, tree T80 was used by 2 different radiotagged brushtail possums on 2 separate occasions in May 1981 (Vellios 1981). In the summer of 1983/84 the same tree was frequently inhabited by BTP2 while during 1984/85 the same tree was occupied by BTP4 and BTP9. Tree P2T2 was occupied by BTP1 during 1983/84 and by BTP4 and one other unidentified untagged brushtail possum during 1984/85. Dreys also appear to be "recycled" by ringtail possums. During 1983/84 a drey (D2) was located but remained unoccupied until 1984/85 when RTP10 began occupation.

The number of sites of diurnal refuge used per possum varies with the age of the individual. For example, BTP4 used 8 different refuge sites while its parent BTP9 used only 4 (Table 23). Inions (1981c) found the same pattern while radiotracking 3 brushtail possums in similar habitat. This phenonemom may be a behavioural adaptation evolved to prepare the offspring for independence.

3.2.5 The pattern of possum activity

3.2.5.1. The active period

The active period refers to the time the animal first becomes active, usually just after sunset, to when activity stops, usually just before sunrise and includes any periods of inactivity which occurred during the night. The active period may be divided into -

(i) active while in a shelter hollow, and
(ii) active while out of a shelter hollow.

The time spent active while in a shelter hollow varied between individuals (Table 24). During the 1983/1984 tracking period BTP1's active period while in a shelter hollow was significantly longer ($p < 0.05$) than that for BTP2 or BTP3 whose active period while in a shelter hollow was similar, particularly when they co-occupied a hollow.

Possums varied in their tolerance to my presence during observationbs from the hides. In some cases my presence prevented emergence of the animal from its hollow. In such cases the data were discarded. In other cases such as when observing BTP3, the possum grew accustomed to my presence and on one occasion she and her juvenile offspring moved to the hide entrance to grunt at the observer.

The conditioning of brushtail possums to become tolerant of human observation was also noticed by Ward (1978) and may prove useful for future studies.

The lack of reliable data from observations made from hides for 1984/85 prevents a detailed comparison between years, however, 2 reliable observations were obtained for BTP3 and these varied little from the 1983/84 data (Table 24).

During 1983/84, all brushtail possums were observed leaving their shelter hollows. Rarely was feeding activity observed in the "habitat tree" containing the shelter hollow, although feeding in adjacent trees was observed regularly. After emergence from their shelter hollow in a "habitat tree", T51, BTP2 and BTP3 would remain in the crown for about 4 minutes (range 1-5 min). Occasionally, one of the possums would browse the leaves surrounding the roost branch, but this was the exception rather than the rule.

Descent from T51 was by 2 routes -

(i) down the bole onto the ground. If this pathway was used, the possums would, on reaching the ground, move off rapidly to a desired area (See Section 3.2.6.1). This pathway was used for 65% of observed descents, and

(ii) transfer from the crown of T51 to the crowns of adjacent trees. This required a leap of about 2 metres. If this pathway was chosen,the possums would feed in trees around T51 for up to 1 hour before descending and moving off rapidly, along the ground, to a desired area.

The choice of the pathway for descent did not seem to be influenced by the weather, as both pathways were used on stormy as well as fine nights.

BTP1 did not remain in the crown of its "habitat trees" after emergence. Descent was usually rapid but unlike BTP2 or BTP3, BTP1 did not move off rapidly to a desired area on reaching the ground but usually ascended a neighbouring tree and commenced feeding activity.

TABLE 24 : MEAN NIGHTLY TIME SPENT ACTIVE WHILE IN A SHELTER HOLLOW.

ANIMAL	1983/84			1983/84		
	Mean (min)	n	Range	Mean (min)	n	Range
BTP 1	35 ± 15 [a]	2	20-50	-	-	-
BTP 2	8 ± 3 [b]	4	3-18	-	-	-
BTP 3	9 ± 3 [b]	5	4-18	8 ± 2	2	6-11

Letters after means, indicate significant subsets (p>0-05).

During 1984/85 only BTP3 was observed. Only one descent route (i.e., down the bole) was used. This may be due to the small size of the offspring accompanying her and the hazard associated with the 2 metre leap required for the second route.

Table 25 shows the mean period of time each possum was active per night as determined by 2 methods. No significant difference was detected ($p > 0.05$) between data derived off the YEW recordings and for that collected with the hand-held receiver. No significant difference exists between the total mean time spent active nightly for each year and no significant change in the mean time BTP3 spent active between years was found ($p > 0.05$). The grand mean for all observations was 501±5 min. which was somewhat less than that of brushtail possums in open eucalypt woodlands in southern

TABLE 25. MEAN TIME (min) ACTIVE EACH NIGHT FOR EACH POSSUM

METHOD	YEW RECORDER						HANDHELD RECEIVER					
YEAR	1983/84			1984/85			1983/84			1984/85		
ANIMAL	Mean (min)	n	Range	Mean (min)	n	Range	Mean (m)	n	Range	Mean (min)	n	Range
BTP1	543.7±1.2	3	542-546	-	-	-	516.7±7.6	6	500-540	-	-	-
BTP2	498.5±11.3	6	456-531	-	-	-	502.5±1.7	6	500-510	-	-	-
BTP3	516.0±0.8	3	501-527	488±10.7	6	458-520	469.2±11.2	6	420-500	495.0±3.8	4	487-505
BTP4	-	-	-	-	-	-	-	-	-	496.8±3.7	4	487-505
BTP9	-	-	-	-	-	-	-	-	-	489.7±10.1	3	470-497
RPT9	-	-	-	-	-	-	-	-	-	500.3±3.0	4	495-507

Queensland, found by MacLennan (1984) to be 537.6± 57.6 min. However, the quoted errors indicate that probably there was no significant difference between these means. MacLennan (1984) also found that brushtail possums spent most of the first two hours after sunset in the den tree, grooming, moving around or sitting. Feeding did not commence until the second hour after sunset and then it was usually restricted to the den tree. These findings are in contrast to mine but agree with Ward (1978) and Winter (1963). Significant differences did occur ($p < 0.005$) between the individuals with BTP1 spending significantly more time active ($p < 0.1$) than any other possum. The ringtail possum RTP8 exhibited a similar length of time spent active as the brushtail possums.

3.2.5.2 Terrestrial activity

The proportions of time each possum spent on the ground are shown for each year in Table 26. Results are given as the mean percent of the total "reliable" time spent on the ground and was read off the YEW recorder traces. This enabled any section of the trace which was considered suspect to be omitted.

No significant ($p > 0.05$) difference exists between the animals or between the years for BTP3 ($p > 0.05$). Most terrestrial activity was at the beginning or at the end of the active period. MacLennan (1984) observed the same pattern for brushtail possums in open eucalypt woodland in southeast Queensland.

My estimates of terrestrial activity are larger than both MacLennan (1984), who estimated brushtails spent 9.9% of the time on the ground and Ward (1978) who gave estimates ranging from 4% to 21%.

TABLE 26 - MEAN PROPORTIONS (%) AND STANDARD ERRORS OF TIME DEVOTED TO TERRESTRIAL ACTIVITY.

	1983/4			1984/5		
Animal	%-ground	Range	n	%-ground	Range	n
BTP1	41.1 ± 8	32.7-49.5	2	-	-	-
BTP2	27.5 ± 1	24.0-30.2	5	-	-	-
BTP3	35.1 ± 1	32.9-36.1	3	30.3 ± 3.5	17.0-36.9	5

3.2.5.3. - Temporal variations of possum activity

With the exception of BTP1, the animals were most active soon after emergence for the night, least active towards the second half of the period for which they remained out and increased activity before returning to the next site of diurnal refuge at the end of the night's activity (Fig. 28, 29, 30, 31, 32, 33 and 34). MacLennan (1984) found that brushtail possums in open eucalypt woodland in southeast Queensland spent the highest proportions of each hour travelling at the beginning and end of the night's activities. This agrees with my findings and suggests that the animals are travelling from the "habitat tree" used during the day to and from the preferred feeding area at the beginning and end of each active period out of the hollow. An example of typical movement during a night is shown in Figure 35. This is a general case and variability was high; often an animal did not follow this pattern.

3.2.6 - Habitat variables influencing the pattern of movement

3.2.6.1 - Habitat variables influencing the pattern of movement of brushtail possums

Cluster analysis of the data for nutrient content and basal area obtained during 1983/84, from 61 grid squares (see Section 2.~~4~~3.7.1), grouped the squares into 4 distinct clusters at the 75% similarity level (Fig. 28). The mean value of each habitat variable is shown, for each cluster group, in Table 27. Twenty of the original 61 sample points were re-sampled in 1984/1985 to detect any shift in the mean nutrient values between years. Only the percentage concentration of nitrogen in jarrah tree foliage was significantly different ($p < 0.05$), as the 1984 sample showed higher concentrations. It is, therefore, valid to assume that the cluster groups derived from 1984 data holds true for the habitat in 1984/1985.

Figure 28. Mean rate of movement (mhr^{-1}) for each hour after the start of the active period for BTP1 (1983/84).

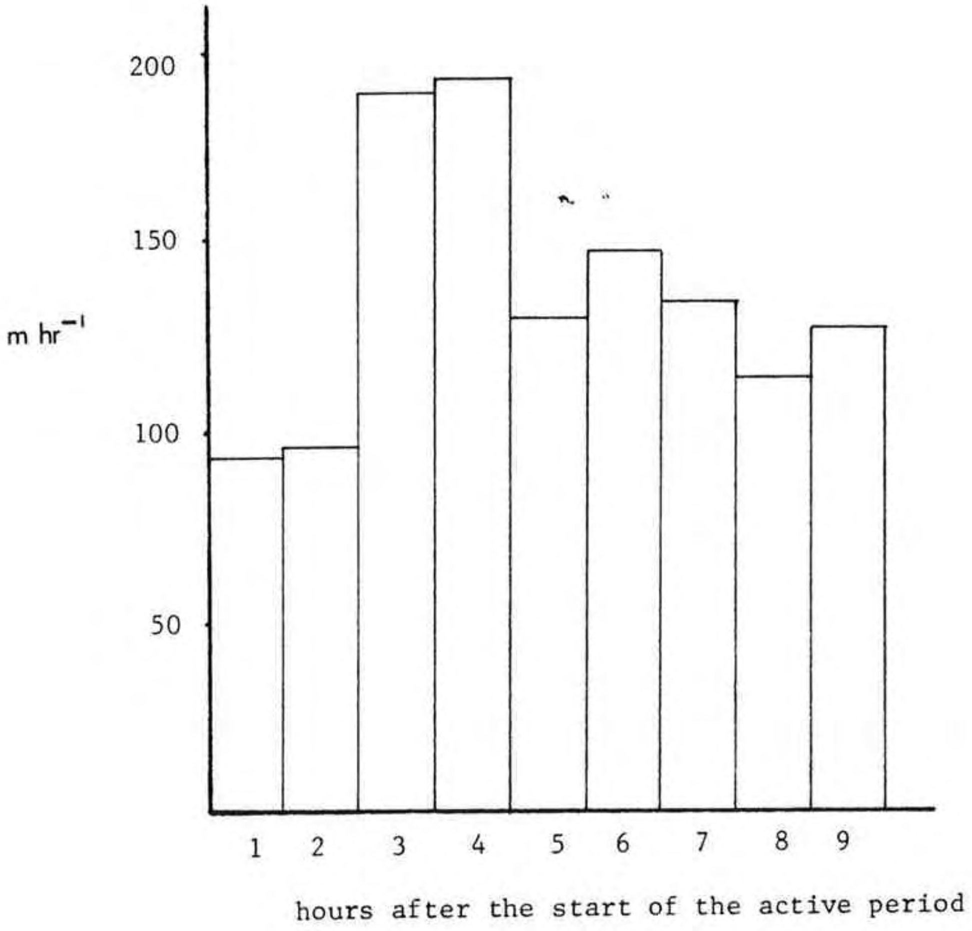


Figure 29. Mean rate of movement (mhr^{-1}) for each hour after the start of the active period for BTP2 (1983/84).

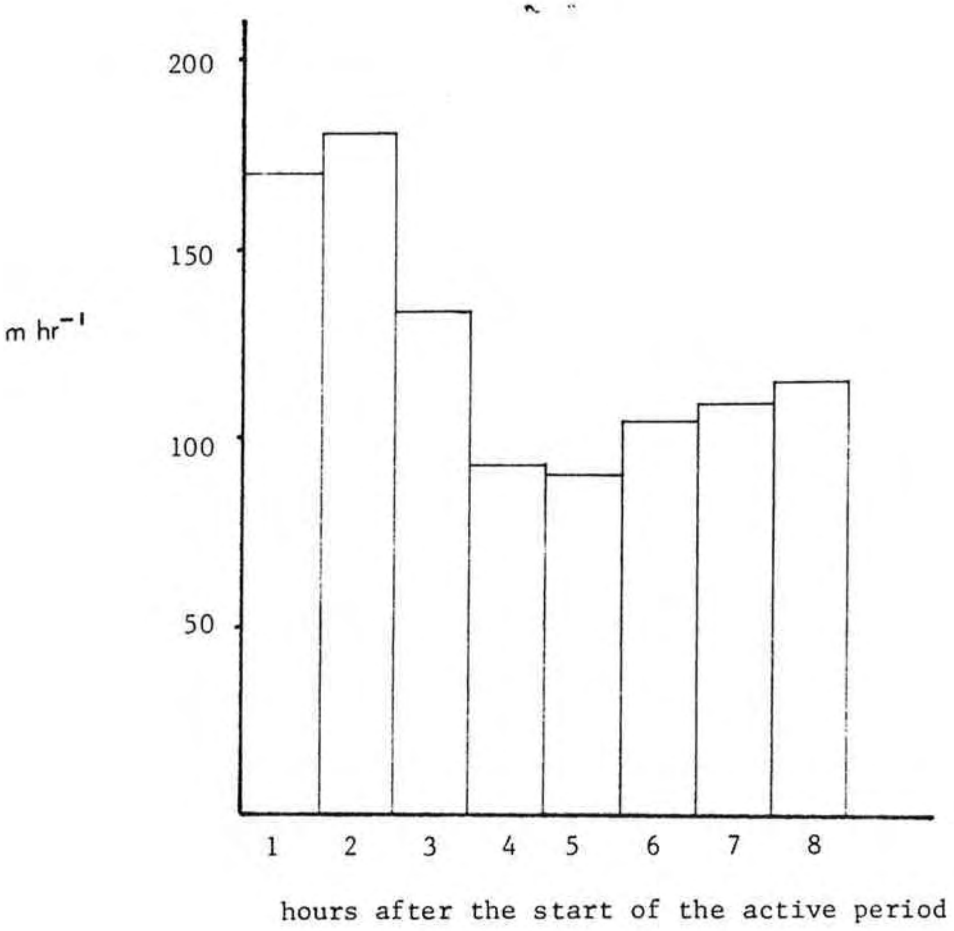


Figure 30. Mean rate of movement (mhr^{-1}) for each hour after the start of the active period for BTP3 (1983/84).

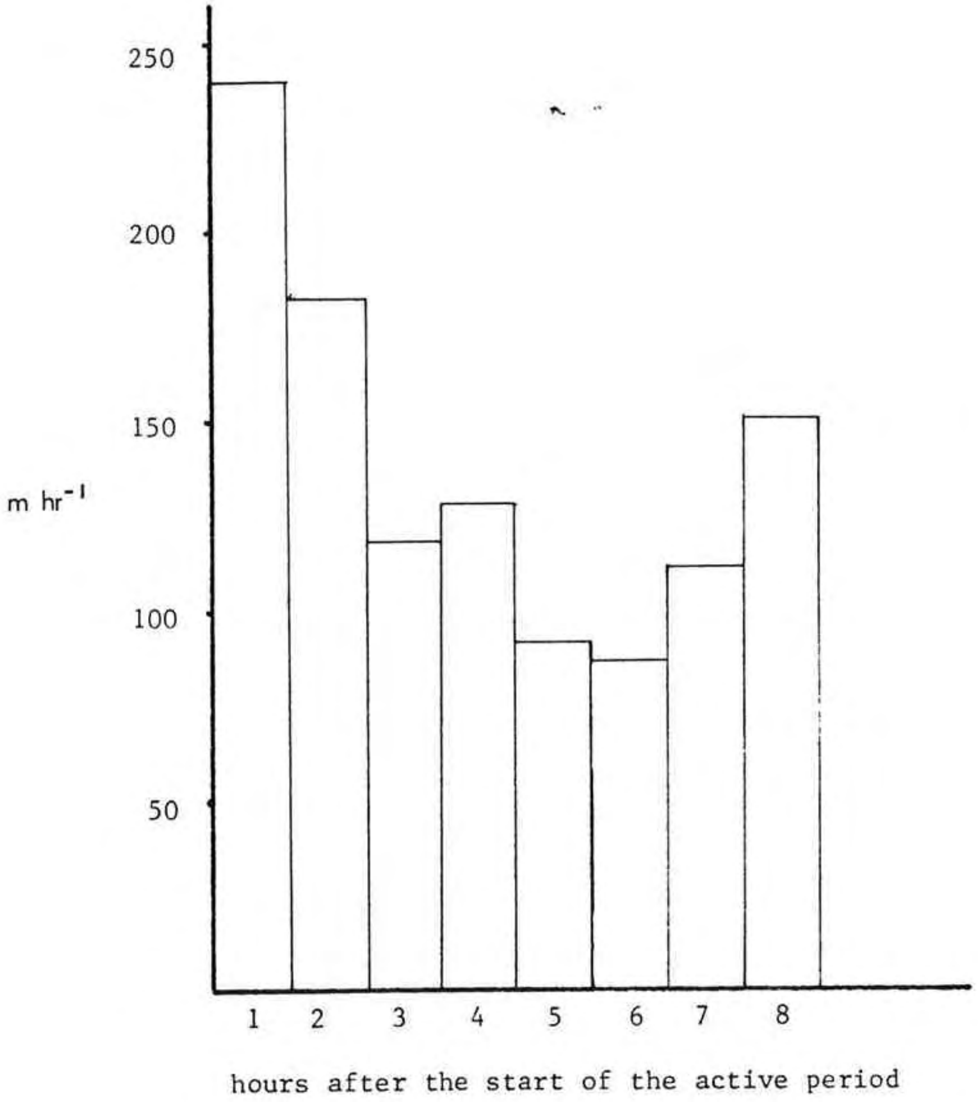


Figure 31. Mean rate of movement (mhr^{-1}) for each hour after the start of the active period for BTP3 (1984/85).

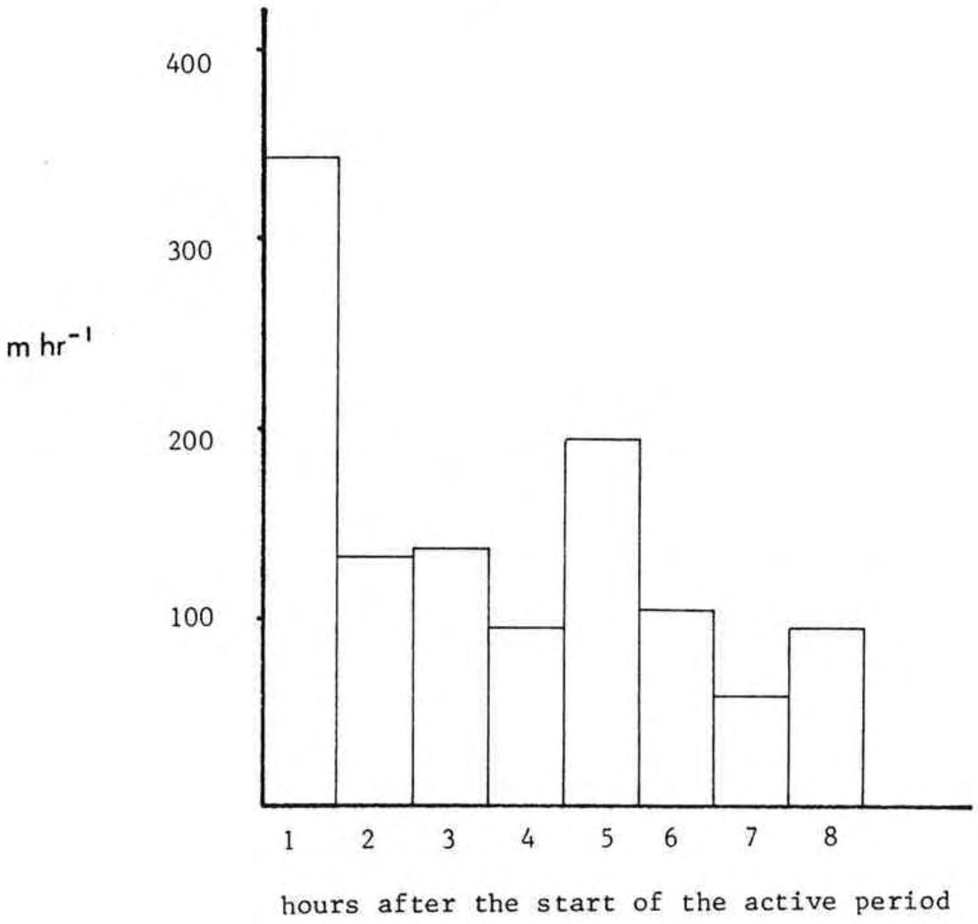


Figure 32. Mean rate of movement (mhr^{-1}) for each hour after the start of the active period for BTP4 (1984/85).

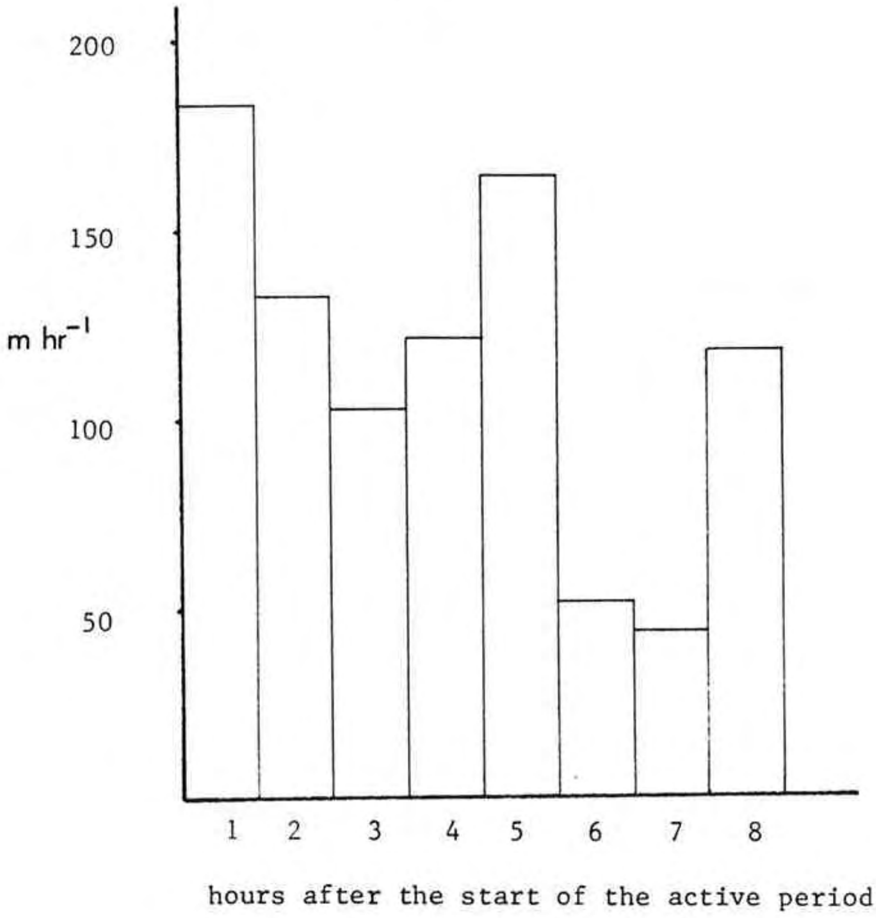


Figure 33. Mean rate of movement (mhr^{-1}) for each hour after the start of the active period for BTP9 (1984/85).

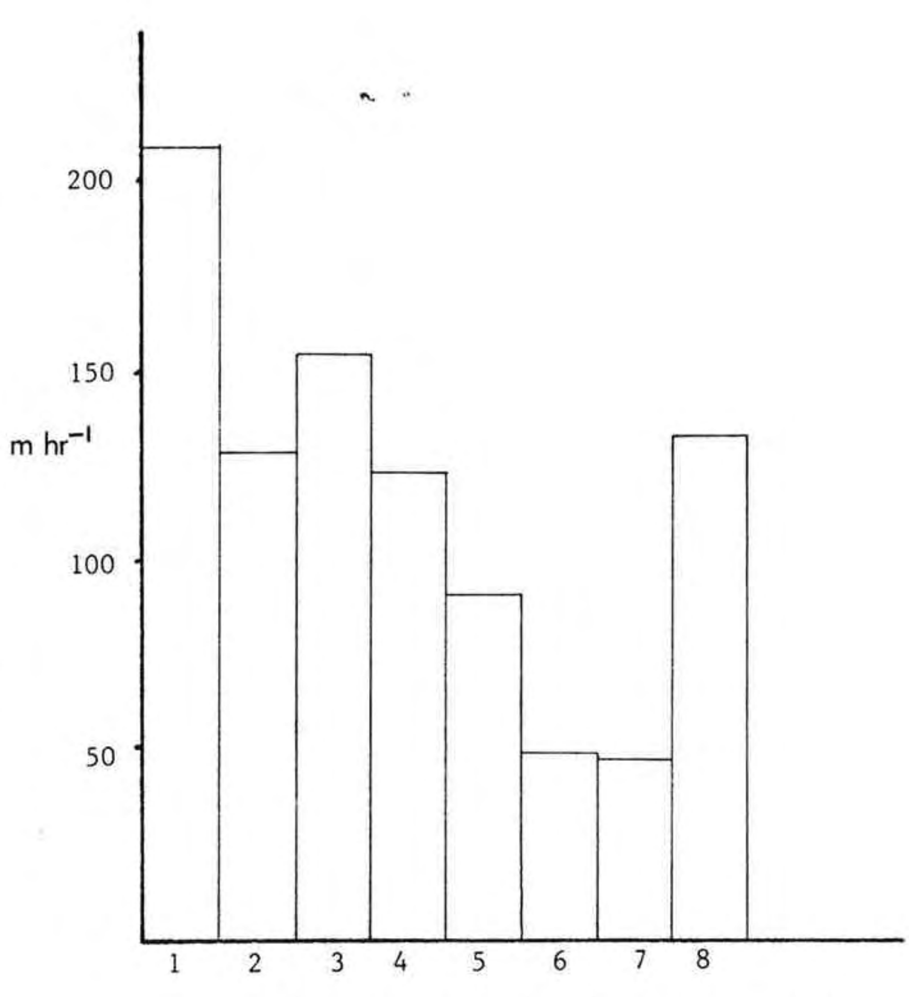


Figure 34. Mean rate of movement (mhr^{-1}) for each hour after the start of the active period for RTP8 (1984/85).

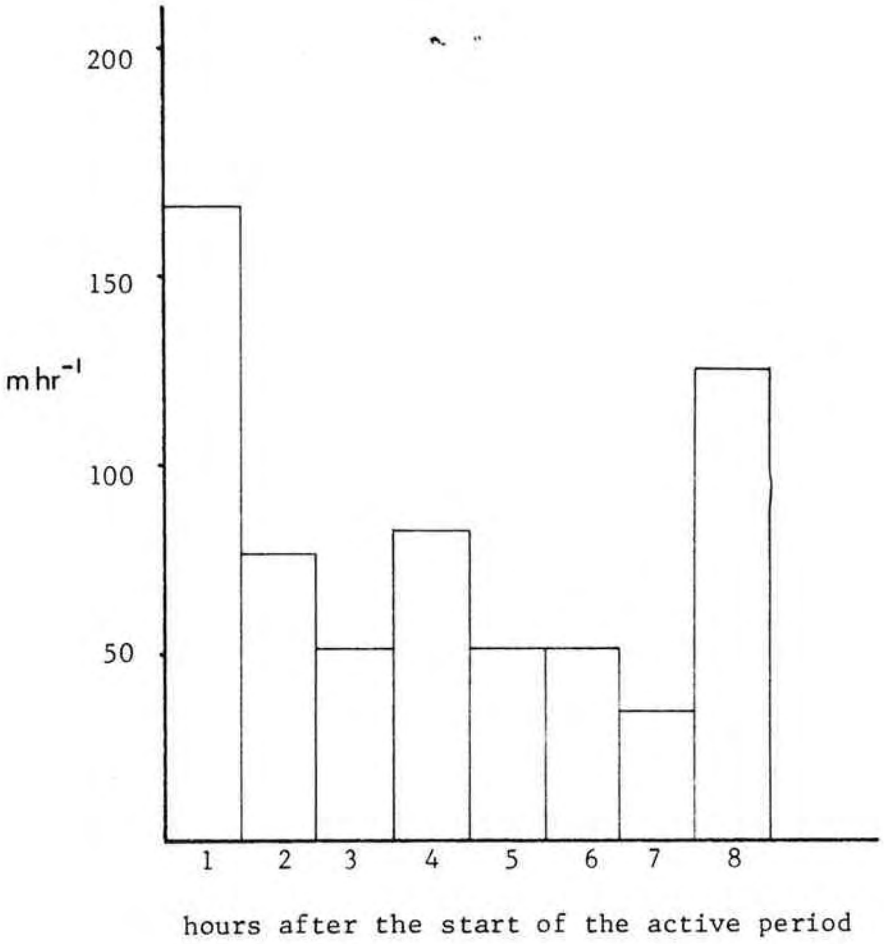
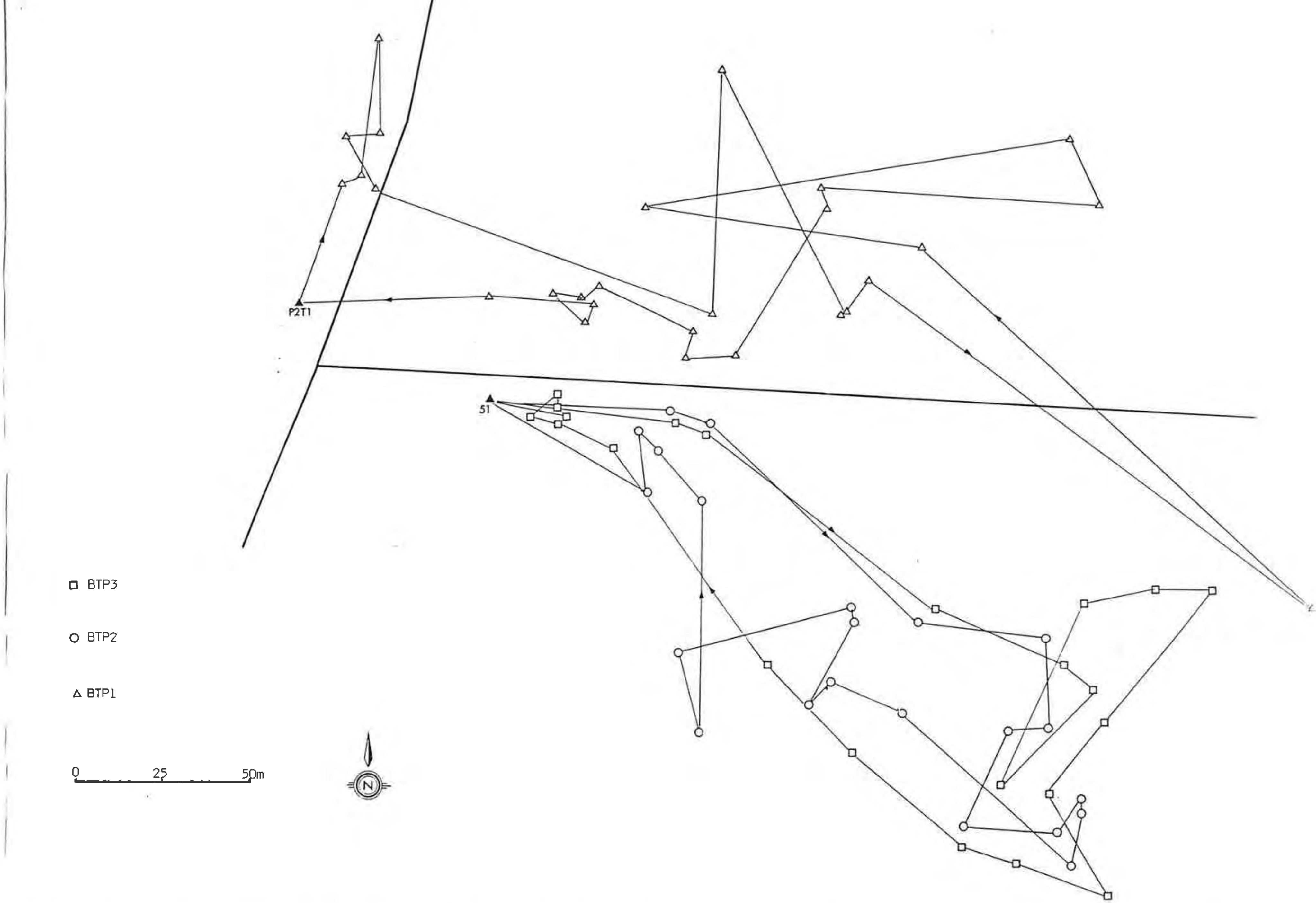


Figure 35. An example of one nights activity of three brushtail possums



A 1-way ANOVA, with the cluster groups as the co-variables and the total recorded time the animals spent in each grid square as the dependent variable, tested if any cluster group was preferred. Samples were assumed to be independent, however, whether or not an animal is in a particular grid square at a particular time is not independent but dependent on whether that animal is in a neighbouring grid square just before that square was sampled.

To reduce error source, data for several nights were pooled by superimposing all observations as a single master plan. Observations then recorded from any square were thus given some independence in terms of which adjacent square they were previously in.

A preference was shown by possums for habitat classified as cluster group C3, which overall had highest nutrient concentrations in the leaves. Areas of habitat classified as cluster group C3 had a significantly ($p < 0.025$) higher number of possum locations in them for both the 1983/1984 and 1984/1985 tracking periods.

The distribution of grid squares and cluster groups within component space showed which of the 10 habitat variables was important in delineating between cluster groups and was achieved using principle co-ordinate and canonical variate analysis (see Section 2.5.4). Good separation both of grid squares and cluster groups was achieved on components 1, 2 and 3 each of which is significant ($p < 0.005$) (Figs. 37, 38 and 39).

Cluster groups C2 and C3 were separated, in component space, from cluster groups C1 and C4 as they had a lower stand basal area of jarrah trees and a higher stand basal area of marri trees. Cluster group C3 was separated from the other cluster groups because of the significantly ($p <0.001$) higher concentrations of nitrogen, phosphorus and potassium in the foliage of marri trees and significantly ($p < 0.025$) higher concentrations of nitrogen in the foliage of jarrah trees in this cluster group. Cluster groups C2 and C3 were separated from cluster groups C1 and C4 becuase they had lower concentrations of calcium in the foliage of marri trees although the mean concentration of calcium does not differ significantly between any cluster groups ($p > 0.05$) (Table 27). Cluster groups C1 and C3 were separated from cluster groups C2 and C4 as the foliage of jarrah trees in these groups contained significantly ($p < 0.05$) higher concentrations of phosphorus. No separation results from the concentration of potassium in jarrah foliage even though the mean concentration of potassium in the foliage of jarrah trees in cluster group C3 was significantly ($p < 0.05$) higher than for those in cluster group C4. Cluster groups C1 and C3 were separated from cluster groups C2 and C4 as the concentration of calcium in jarrah trees in these groups was lower but not significantly ($p > 0.05$).

Interpretation of the ordination technique in relation to possum activity is summarised in Table 28.

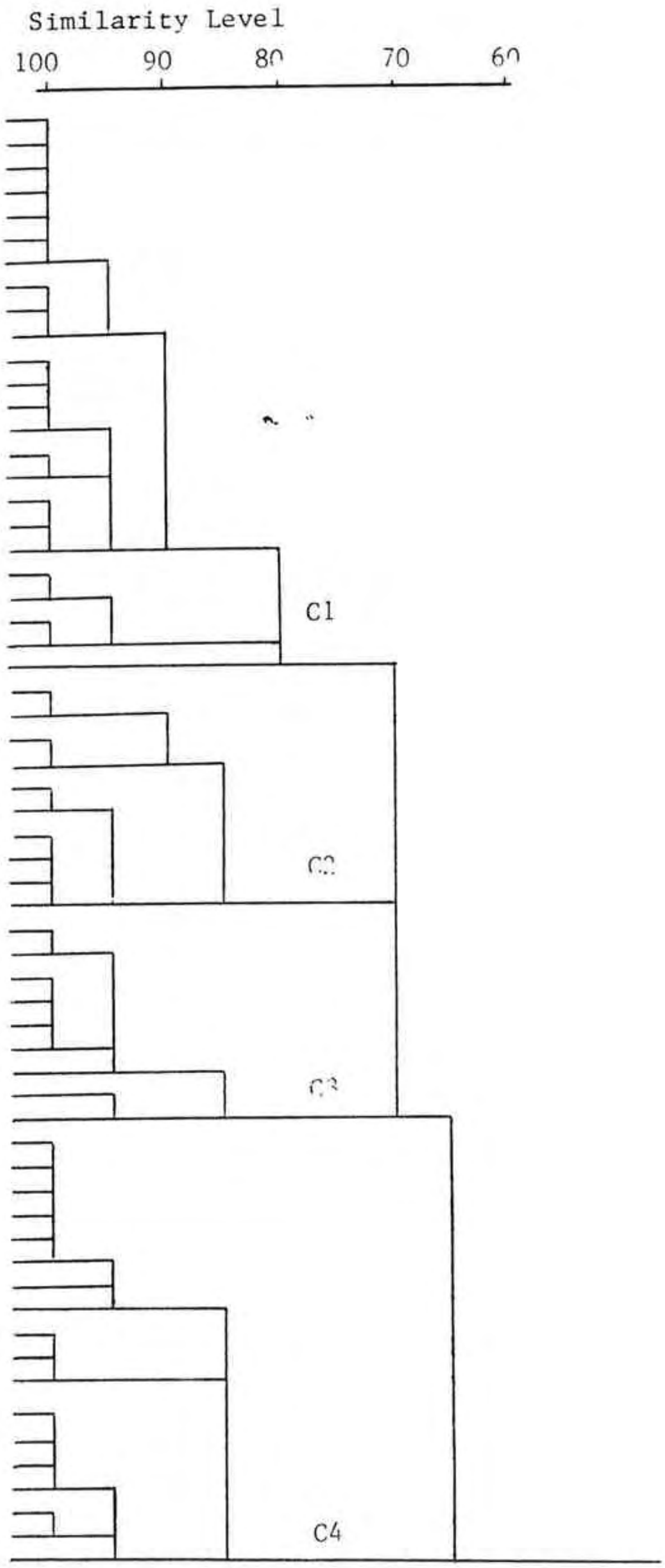
TABLE 27 : THE MEAN AND STANDARD DEVIATION OF EACH HABITAT VARIABLE FOR EACH CLUSTER GROUP

VARIABLE	CLUSTER GROUP							
	C1		C2		C3		C4	
	X	SD	X	SD	X	SD	X	SD
% Concentration in Marri Foliage -								
Nitrogen	0.969±.024	0.116	1.131±0.038	0.122	1.297±0.063	0.188	1.173±0.028	0.119
Phosphorus	0.0458±0.002	0.007	0.0481±0.003	0.009	0.0671±0.003	0.009	0.0536±0.001	0.006
Potassium	1.222±0.005	0.261	0.978±0.009	0.294	1.439±0.105	0.315	1.116±0.057	0.241
Calcium	0.373±0.037	0.179	0.276±0.030	0.095	0.295±0.032	0.097	0.371±0.025	0.106
% Concentration in Jarrah Foliage								
Nitrogen	0.974±0.019	0.094	1.03±0.039	0.124	1.078±0.022	0.064	0.875±0.027	0.113
Phosphorus	0.056±0.001	0.006	0.048±0.002	0.006	0.055±0.002	0.006	0.045±0.002	0.008
Potassium	0.544±0.046	0.226	0.625±0.096	0.304	0.748±0.064	0.192	0.439±0.038	0.16
Calcium	0.344±0.025	0.123	0.397±0.041	0.131	0.281±0.018	0.054	0.385±0.031	0.131
Basal area m^2ha^{-1}								
Jarrah	16.91±0.87	4.08	3.64±1.29	4.27	7.56±1.44	4.33	18.00±2.17	8.42
Marri	10.00±0.81	3.80	14.09±1.70	5.66	11.11±1.67	5.01	12.13±1.23	4.75

TABLE 28 - INTERPRETATION OF THE ORDINATION OF HABITAT VARIABLES IN RELATION TO POSSUM ACTIVITY.

	CLUSTER GROUP			
Variable	C1	C2	C3	C4
% concentration in in Marri foliage				
Nitrogen	Low	Low	High	Intermediate
Phosphorus	Low	Low	High	Intermediate
Potassium	High	Low	High	Low
Calcium	Low	Low	High	High
% concentration in Jarri foliage				
Nitrogen	Intermediate	High	High	Low
Phosphorus	High	Low	High	Low
Potassium	Low	High	High	Low
Calcium	Low	High	Low	High
Basal area $m^2 ha^{-1}$				
Jarrah	High	Low	Low	High
Marri	Low	High	High	Low
Intensity of use by possums -				
1983/1984	3rd most intense	2nd most intense	most intense	4th most intense
1984/1985	4th most intense	3rd most intense	most intense	2nd most instense

Figure 36. A dendrogram of the grid cells.



C1 = Cluster Group 1
C2 = Cluster Group 2
C3 = Cluster Group 3
C4 = Cluster Group 4

Figure 37 . Position of grid cells in multivariate space; circled figures indicate members of cluster group C3.

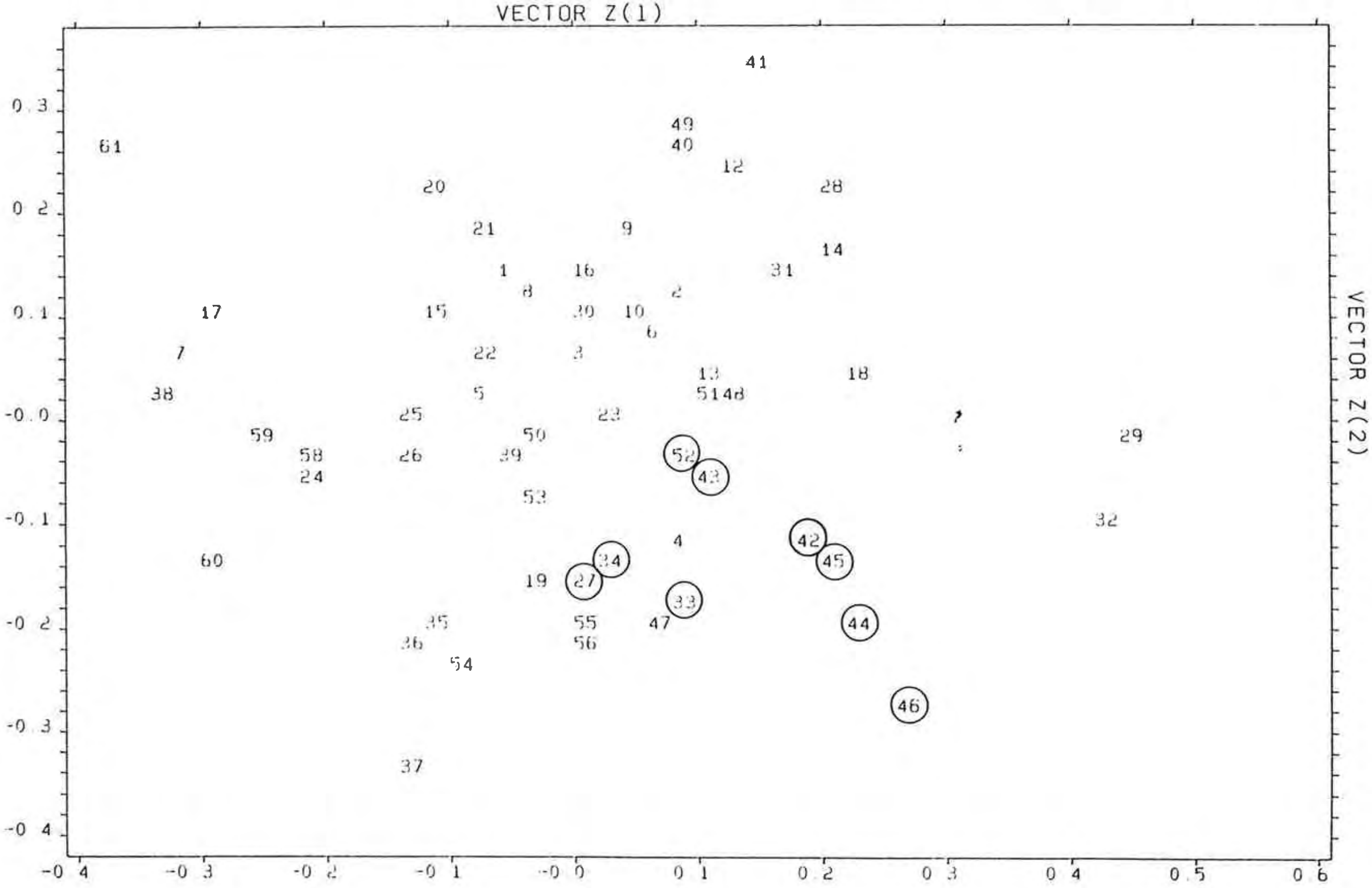


Figure 38 . Position of grid cells in multivariate space; circled figures indicate members of cluster group C3.

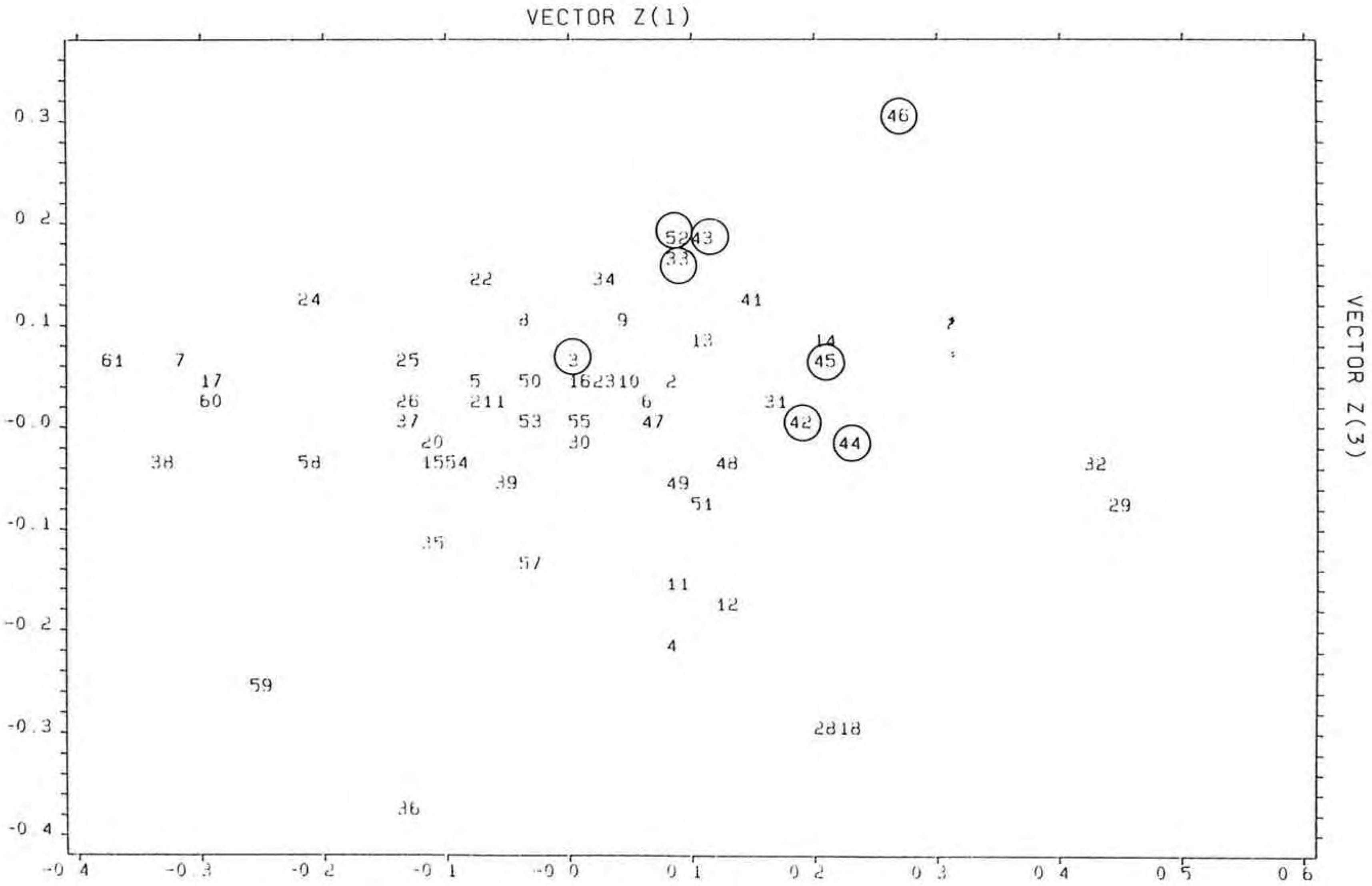
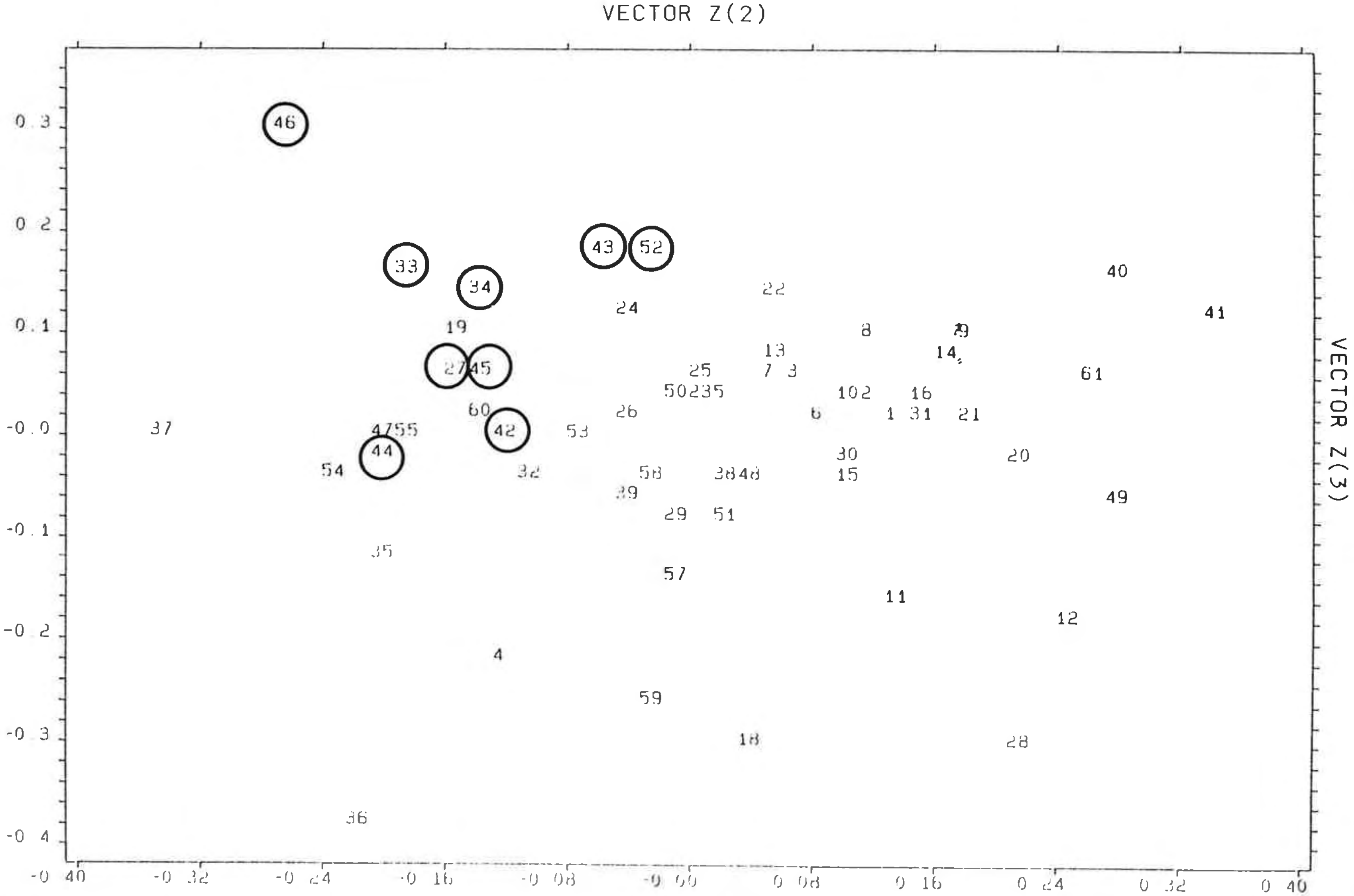


Figure 39. Position of grid cells in multivariate space; circled figures indicate members of cluster group C3.



3.2.6.2 - Habitat variables influencing the pattern of movement of the ringtail possum (RTP8)

Cluster analysis on data for foliar nutrient content of jarrah and marri trees and forest stand structure, obtained from 36 grid squares, in and around RTP8's utilized area (See Section 2.4.7.2), grouped the squares into 5 distinct cluster groups at the 80% similarity level. No significant ($p > 0.05$) preference was shown by RTP8 for any cluster group.

Cluster analysis on the data for foliar nutrient values grouped the grid squares into 3 distinct cluster groups at the 75% similarity level while cluster analysis on the data for forest stand structure grouped the grid squares into 4 distinct cluster groups at the 75% similarity level. No significant ($p > 0.05$) preference was shown for any cluster group regardless of the data source.

The inability of this technique to explain the movements of RTP8 is probably attributable to an inadequate data set as only one possum was tracked intensively for only 4 nights. Personal observation, and data collected by the staff of the Manjimup Forests' Department by spotlight around the study areas intermittently since 1971, suggests that ringtail possums prefer trees of sapling size (Jacobs 1955) as a food source (Table 29). Tyndale-Biscoe and Calaby (1975) agree, suggesting that the ringtail possum confines itself to the lower strata while Davey (1984) found that ringtail possums occupied habitats characterized by a dense myrtaceous understory in the Kioloa State Forest in N.S.W.

Data presented in Table 30 suggests that brushtail possums prefer larger marri trees. This is further substantiated by the evidence presented in Section 3.2.4.1. and that Ringtail possums prefer smaller trees, particularly jarrah.

TABLE 29 - SIZE AND SPECIES OF TREE IN WHICH POSSUMS WERE SIGHTED DURING SPOTLIGHT RUNS

BRUSHTAIL POSSUMS					RINGTAIL POSSUMS				
Size of tree	Marri		Jarrah		Size of tree	Marri		Jarrah	
	No. of sightings	(%)	No. of sightings	(%)		No. of sightings	(%)	No. of sightings	(%)
Large	28	(22.8)	11	(15.1)	Large	18	(25)	16	(12.0)
Medium	36	(29.3)	35	(47.9)	Medium	23	(31.9)	48	(36.1)
Small	28	(22.8)	23	(31.5)	Small	27	(37.5)	66	(49.6)
Dead	5	(4.0)	4	(5.5)	Dead	2	(2.8)	3	(2.3)
Ground	26	(21.1)	0	(0)	Ground	2	(2.8)	0	(0)
TOTAL	123	(100)	73	(100)	TOTAL	72	(100)	133	(100)

CHAPTER FOUR - DISCUSSION AND CONCLUSIONS

4.1 PRECISON, ACCURACY, BIAS AND EXPERIMENTAL DESIGN

4.1.1 Location of trees suitable for occupation by possums

A "habitat tree" is easily defined but indentification of such trees in the field is subjective and thus prone to imprecision and/or bias if adequate care is not taken. Because a hollow is visible it does not necessarily mean that it is used by possums; likewise, because a tree has a scratchtrack it does not mean possums are climbing the bole to reach a hollow. Many trees without hollows have "good" scratchtracks (pers.obs.) and presumably such trees are being climbed for feeding purposes.

To keep imprecision, inaccuracy and bias to a minimum during location of trees, I gained experience in identification of trees occupied by possums while working on two studies which used radiotelemetry of common brushtail possums during 1981 (Inions 1981C, Vellios 1981). During the course of these studies, 7 possums were followed to 28 "habitat trees".

As a further check of the authenticity of the trees located, 22 "habitat trees" in the Boyicup plot were climbed and evidence of use by possums was recorded (see Section 2.2.7). Fifteen were assessed correctly, 3 were labelled "habitat trees" incorrectly while 4 "habitat trees" were located which were missed during the 1983/84 assessment.

4.1.2 Measurements of physical parameters of the hollows

Climbing methods imposed limitations on the height in trees to which hollows could be assessed, thus creating a bias towards trees with hollows below 11 m above the ground. As the height of hollows above the ground was very variable in this study (Section 3.1.4.3), those reached gave a reasonable sample although whether or not the pattern of use of higher hollows was the same as the lower ones is not known.Serventy and Whittell (1976) and Saunders (1979), studying birds nesting in hollows considered the height of hollows was unimportant in giving bias to results, as did Raphael and White (1984).

I used the intensity of the scratchtrack as an index of usage of trees. To avoid over-rating the scratchtrack as a result of possums climbing the tree to reach foliage, dead trees, or trees with thin crowns were selected. Scratchtracks may also be over-rated if more than one possum occupies the hollow. This is generally the case for mothers with young (see Section 3.2.4). This problem was resolved partly by surveying in May when the young had become independent and had dispersed (pers.obs.)(Inions 1981c).

4.1.3 Estimating the age of "habitat trees"

The diameter growth curves used for predicting the age of "habitat trees" should be treated with caution. The method used selected representive plots throughout the forest and measured,(underbark) at regular intervals (~ 10 years), the diameter of all trees of d.b.h.u.b. > 10 cm. The data do not include any measure of crown position or health of each tree, so the results are an average value of increment over a range of diameter classes. Therefore, diameter increment data of suppressed trees will underestimate age and vice versa.

A second problem arises from the representativeness of the growth period over which the increments occurred (~ 10 years). No indication can be gained as to how representive it was. There is evidence which suggest that the growth rate of jarrah is accelerated after fires of high intensity (Kimber 1978, Abbott and Loneragan 1983a) therefore the period lapsed since the last major fire event, at each increment plot, will affect its representativeness. This source of inaccuracy is alleviated partly by the scattered nature of the increment plots, each having experienced a major fire event at different times in their history and, as such, the result is an average.

4.1.4 Fluctuations in the population of possums

Both species of possum are considered r-selection (opportunist) strategists by Tyndale-Biscoe (1979) and thus display variable population densities with time (Southwood 1977). Varying population densities may influence the number of trees in use in an area, so any variation in tree usage detected in the Boyicup plot by the 1983/84 survey may not have resulted from fire-caused factors.

To detect any variation in tree usage due to population fluctuations,the unburnt Yerdicup plot was used as a control with the assumption that any fluctuation in density of possum populations will be reflected equally in both sites.

4.1.5 Equipment

The accuracy of directivity of the portable receiver and the yagi antenna was not calculated. Accuracy was good when locating possums during the day, or retrieving transmitters which had been dislodged form the possum's neck.

The accuracy of the estimates of the ratio of the time spent on the ground to the time spent up a tree, obtained from the Y.E.W. recorder tracings, was not calculated. However, in a test in which a transmitter, attached to an 8 m. high pole was raised and lowered at different positions on the grid, the ratio of the time spent on the ground to the time spent up a tree was calculated. When this ratio was compared to that obtained from the Y.E.W. recorder trace, the results were similar.

4.1.6 Tracking routine

Inaccuracy and/or imprecision may have resulted from the tracing routine used. Two compass bearings were needed to determine an animal's position. As the time taken to reach a recording station and take a bearing was sometimes in the order of 10 minutes, the animal may have moved or was in the process of moving to a new locality and thus gave inaccurate bearings when plotted on a map. As no field assistance was available, this problem was unavoidable. The time span between consecutive bearings decreased as the efficiency of data-collecting increased with practise.

4.2 USAGE OF SHELTER SITES

The type of hollow used by brushtail possums varies geographically. In forested areas of Australia, hollows in "habitat trees" are most commonly utilised (Winter 1976, Mackowski 1984) but in New Zealand a wide range of shelter sites are used with one study showing that the majority of den sites were at or below ground level, in tree root systems, hollow logs and stumps (FRI 1980). In central Australia; river courses lined with E. camaldulensis Dehnh are preferred but possums have been found away from these areas utilizing termite mounds and rock holes as den sites (Finlayson 1961, Parker 1973), while on the treeless Barrow Island, possums occupied limestone ridges (Allen and Bradshaw 1978).

Ringtail possums are not as variable in their choice of shelter site. They use mainly dreys or hollows in "habitat trees" (How 1978) but a community of ringtail possums in a sub-climax Leptospermum laevigatum thicket at Sandy Point on Western Port Bay, lived exclusively in nests (How et al. 1984) and Thomson and Owen (1964) recorded similar results. In my study the use of dreys was rare.

The number of shelter sites used by a possum is as variable as the type of shelter itself. Variability is evident between individuals, species and geographic position (Vellios 1981, F.R.I. 1980).

The selection of arboreal shelter sites has advantages over those on the ground for avoidance of predators particularly terrestial predators such as the fox (Vulpes vulpes), feral cat (Felis catus) and dingo (Canis familiaris dingo) all of which prey on possums (Newsome et al. 1983, Christensen 1978 and Inions 1981c). MacLennan (1984) suggests that brushtail possums spend no more time on the ground than is necessary to obtain their food requirements and move from one tree to another as a means of avoidance of predators.

Alternative forms of refuge used by radiotracked possums during this study are presented in Table 23. The most common and intensively used form of refuge for both species was the "habitat tree". The degree to which other forms of refuges were used varied with the individual, a point also noticed by Menkhorst (1984b). No evidence was gathered to relate the availability of arboreal shelter sites to those on the ground.

In contrast to work in other areas, on my plots the ringtail possum preferred "habitat trees" rather than dreys and it does not, to any great extent, line its hollow with shredded bark, which was a significantly preferred feature of nest boxes used by ringtail possums (Ambrose 1982). The shift in shelter site preference, shown by this subspecies, from the nominate race, may be due to the long association of its habitat and fire. Fire is, and has been, a frequent event in my study area and behavioural adaptations such as building dreys or lining a hollow with flammable material would be detrimental to the survival of the individual in a fire.

The physical act of building a drey requires an effort, particularly if it is destroyed by fire, and consumes energy. This affects what may be a very delicate energy budget, particularly in such a nutrient-poor environment (see MacLennan 1984 and Section 4.7). As a result of a fire-prone environment and a delicate energy budget, the ringtail possum may have evolved the behavioural adaptation of selecting hollows in "habitat trees" as its main form of shelter site.

4.3 CHARACTERISTICS OF THE "HABITAT TREES"

4.3.1 Spatial distribution and species of "habitat tree"

Although the negative exponential relationship is common in jarrah forest, it is not universal. All tree species in the jarrah forest exhibit a wide range of diameter and age classes, but in different stands, species often show an inconsistency in the frequenty of occurrence in diameter-classes (Abbott 1984b). The method of regeneration may be a possible reason for this phenomenon as it largely determines the structure of a forest (Jones 1945). The lack of uniformity for diameter-class structure for some stands in jarrah forest creates groups of even-aged plants, with any stand consisting of a collection of such groups recruited at different times (Stoate 1923, Abbott 1984b). Similar demography was described by Mackowski (1984) for unlogged blackbutt forests which consisted of evenaged cohorts of trees which gave an irregular uneveraged structure (Jacobs 1955).

Given the variable structure of jarrah forest, it may not be assumed that "habitat trees" occupy a particular percentage of the stand structure. However, a greater percentage of the "habitat trees" are found in the mature, overmature and dead components of the stand (Mackowski 1984, Ambrose 1982). These "habitat trees" comprise a very small component of the forest (~ 0.005%).

This is not surprising given the long periods of time required for the agents which cause the formation of hollows to act, and the negative exponential relationship shown at both study sites between the frequency of trees in the different diameter classes.

Although a random distribution best describes the spatial pattern of "habitat trees" in both my study areas (Section 3.1.3) a different description may apply in forests consisting of groups of evenaged plants or cohorts. Such was the case reported by Ambrose (1982).

The spatial pattern of distribution of "habitat trees" is an important concept to be considered when delineating areas for retention strips, corridors of original vegetation or other areas of wildlife refuge in intensively managed forest. If the distribution of "habitat trees" is contagious each cohort containing the "habitat trees" could be viewed as an island, thus the biogeographic island theory (Diamond 1975) may be applied when retaining habitat (Gilpin and Diamond 1980).

The species of tree did not influence the selection of "habitat trees" by possums; the characteristics of individual hollows seemed more important for selection. However, Serventy and Whittell (1976) state that salmon gum (E.salmonophloia F.Muell) is the preferred nesting tree chosen by cavity-nesting birds, with wandoo (E. wandoo Blakely) the second preference. Their information came from egg collectors and naturalists who were active in areas forested mainly by salmon gum where wandoo occurs only in small pockets. No information is available in Australia which proves that the species of "habitat tree" directly affects its selection by users of cavities. This is not the case overseas. The species of snag (white fir) preferred by birds for nesting in the forests of the Sierra Nevada mountains was measured both in the highest proportional use and greatest deviation from availability by Raphael and White (1984). Preference for tree species was shown to vary geographically.

In contrast to overseas, Australia does not have primary excavators such as woodpeckers (Picidae). There is a relationship between the site selected for excavation by primary excavators and the presence of softened heartwood caused by fungal heart rots (Thomas et al. 1979). Primary excavators select these sites as less energy is required to excavate in rotten wood (Conner et al. 1975). The preference for snags of particular species by the secondary users of cavities is probably a function of their dependence on primary excavators for the provision of hollows (Dennis 1971). It therefore takes a long time to develop a resource of hollows in Australian forests.

Although the species of tree does not have a direct effect on selection of a "habitat tree", it will influence the choice indirectly in that the number of suitably sized hollows available varies with forest type and the tree species (Ambrose 1982).

Few Australian studies have documented the number of hollows used in any forest area (Menkhorst 1984b). Between 2.3 and 7.0 "habitat trees" per hectare were used by possums in my study (Section 3.1.2). This is markedly less than the 82 hollows per hectare found by Ambrose (1982). Ambrose assessed all hollows whereas in my study only those used by possums were recorded. Such hollows in my study were larger and thus less common. In 2 study areas on the north coast of N.S.W., 6.7 and 13.7 hollow-bearing trees per hectare were available. These trees were under-utilised by the possum and glider population of the area (Mackowski 1984). Ten species of non-passerine birds also used 7.5 hollows per hectare in a 15 ha woodlot in the south-west of W.A. (Saunders et. al. 1982).

4.3.2 Physical parameters affecting the selection of a "habitat tree"

The height of the "habitat tree" and of the entrance hollow above the ground was variable and of little importance. These results agree with those of Saunders (1979) for position of holes selected by black cockatoos. In contrast to the random use of natural hollows, brushtail possums preferred nestboxes placed 4 m to 5 m above the ground while ringtail possums preferred boxes placed 4 m above the ground (Ambrose 1982, Golding 1979, Calder 1979 and Menkhorst 1984b). Winter (1976) noted that brushtail possums select "habitat trees" with hollows more than 6 m above the ground for regular use. In North America, the height of a snag is of particular importance and each cavity-using speices has distinct requirements for the minimum diameter and height of snags used for nesting and shelter (Thomas et al. 1979). Selection of hollows within a particular height range partitions the resource and reduces interspecific competition for similar cavities. The importance of the height of the "habitat tree" and of the entrance hole in influencing its selection by fauna varies geographically and between communities.

The diameter of "habitat trees" is an important influence in its selection for two reasons. Firstly, a plant must be large enough to support branches or a bole sufficiently large to house a cavity. Secondly, diameter is related to age (Abbott 1984b): before a tree develops hollows a sufficient period of time must have elapsed to allow the agents which produce the hollows to act.

In both study areas before the fire, no tree with a d.b.h.o.b. below 45 cm contained a hollow of adequate dimensions for use by possums. Although many trees with a d.b.h.o.b. < 45 cm were of sufficient size to house a cavity,they were too young. Therefore the time required for the formation of a holow is the limiting factor not the size of the tree.

Hollows of sufficient size for possums and gliders do not develop in blackbutt with a d.b.h.o.b. below 100 to 125 cm (Mackowski 1984). These hollows form in trees 200 years old and longevity is 300 years. Eucalypts in Victoria developed their first hollows at over 100 years of age and reached their maximum number of hollows per tree at about 400 to 700 years (Ambrose 1982). In my study the youngest "habitat trees" used by possums, before the fire, were about 200 years old for marri and 300 years for jarrah and the average age of "habitat trees" was 350 years and 500 years for marri and jarrah respectively. Thus the agents causing formation of hollows are more effective in marri.

As such long periods of time are required for hollows to form, "habitat trees" are generally in the mature, overmature, or dead categories posed by Jacobs (1955) (Ambrose 1982, Mackowski 1984). The condition of living "habitat trees" is variable within these categories and between sites.

Unlike the situation in North America, no parameter of a "habitat tree" was detected which directly affected its selection by cavity-users. Providing an adequate hollow exists, no distinction is made between trees. The question now arises what constitutes an adequate hollow? The dimensions which make a hollow attractive will vary with species and many studies, particularly on birds, have demonstrated that the size of a hollow will be the separating factor partitioning the resource of cavities (e.g. Saunders 1979, Saunders et al. 1982, Raphael and White 1984, Ambrose 1982 and Golding 1979).

There is no evidence that any species of cavity-user prefers nest boxes constructed from sawn timber to those constructed from hollow logs (Menkhorst 1984b). Consequently, nest boxes have been used to estimate the optimum dimensions of a hollow for use by possums and gliders. Estimates for optimum cavity dimensions for the brushtail possum include an entrance diameter of 12 to 15 cm, a depth below the entrance of 16.5 to 74 cm, a cross sectional area of 42 to 682 cm^2 with no preference for the aspect of the entrance (Ambrose 1982, Menkhorst 1984b). The ringtail possum prefers an entrance diameter of 6.5 to 8 cm, a depth below the entrance of 25 to 40 cm, a cross-sectional area of 200 to 800 cm^2 and a preference for northerly aspects (Ambrose 1982, Golding 1979 and Calder 1979).

Possums do not use deep hollows exclusively. Ambrose (1982) reports the use, by a brushtail possum of a box 16.5 cm deep and Menkhorst (1984b) states that brushtail possums have been observed using natural hollows which have the entrance level with the floor. This situation was observed for both ringtail and brushtail possums during my study.

The only parameter that I found to significantly affect the use of hollows by possums, was the depth of the cavity floor below the entrance hole. Deeper hollows were preferred. Although only one parameter was significant, other parameters may exert influence. Obviously there is a lower limit to the size of the entrance hole and a minimum diameter of the cavity, below which it is physically impossible for the possum to occupy a cavity. Brushtail possums in Queensland select hollows with an entrance diameter greater than 10 cm for regular use (Winter 1976). An insufficient sample size may be one reason that I found only one parameter to be significant. It is also possible that in reality possums are only selecting deep hollows.

The benefits of using deep hollows include reduced temperature fluctuations (Calder 1979) and better insulation properties. Schmidt (1979) detected a negative correlation between temperature fluctuations and the depth of the hollows. The better insulation properties of deeper hollows will affect breeding success in birds and possibly possums: the mean date of egg laying of female great tits (<u>Parus major</u>) roosting in well insulated, warmer nest boxes was earlier than for females roosting in less insulated, cooler boxes (O'Connor 1978). Earlier laying can be advantageous; more time to feed the young may increase the success of fledglings (Cody 1966). A further advantage of deep hollows is evasion of predators. On one occasion I saw a wedgetailed eagle (Aquila audax) land in a "habitat tree" and examine a hollow. Deep hollows not only pose a physical difficulty to the predator in that the prey is difficult to reach but the prey is more difficult to detect as deep hollows are darker.

The use of next boxes at any one site is often highly seasonal (Ambrose 1982, Golding 1979 and Menkhorst 1984b). Menkhorst (1984) suggests this is due to the insulating properties of a box compared to natural hollows nearby (Calder 1979), the availability of natural hollows, seasonal variations in food supply, competition for hollows and predation. Therefore, parameters which may be significant during a particular season may be irrelevant during another. This study was undertaken during the summer months, so any parameter which is significant during winter remained undetected.

4.4 THE EFFECT OF FIRE ON "HABITAT TREES"

4.4.1 The short term effects.

The short term effect of fire on "habitat trees" was catastrophic, with 37.8% of these trees destroyed (i.e., burnt to the ground or hollows burnt out) and 6.1% suffered heavy damage, though their hollows remained intact. The damage to "habitat trees" was proportionally greater than that suffered by other trees with a d.b.h.o.b. > 40 cm. Abbott and Loneragan (1983a) noted that frequent low-intensity fires had little effect on the growth rate or survival of jarrah and did not appreciably affect the incidence of fire scars. High intensity fires did increase tree mortality and the incidence of fire scars, but only slightly, as high temperatures around the base of a tree did not occur for long enough to kill cambium.

The conflicting reports of damage between data of Abbott and Loneragan (1983a) and my own data may be explained by the type of tree selected for measurement. Trees selected by Abbott and Loneragan were chosen if they were living and undamaged by fire at the point of measurement (breast height) and therefore were of better condition than "habitat trees"in the Boyicup area before the fire. Consequently, they had a higher probability of survival in fire. "Habitat trees" in Boyicup before the fire were generally unhealthy, with 72% of the trees dead or in poor condition, while at Yendicup only 52% were in this condition. Had a fire, with similar characteristics to that experienced at Boyicup been lit at Yendicup, the percentage of trees destroyed would probably have been less.

Of the healthy "habitat trees" at Boyicup, 13% were destroyed. This mortality rate is higher than that quoted by Abbott and Loneragan (1983a) for jarrah forest after intense fire. "Habitat trees" seem to suffer higher degrees of fire damage than other similarly sized trees. This is probably due to the age of the "habitat tree" and thus the fungal and termite infections usually found in trees containing hollows (Perry et al. 1985), which increased the flammability of the individual.

The intensity of a fire will affect the degree of damage inflicted on a forest stand (Abbott and Loneragan 1983a) and the "habitat tree" component. Burrows (1985) has shown that the number and size of stems of Banksia grandis killed in jarrah forest after fire is directly related to fire intensity. Most "habitat trees" destroyed experienced moderate (1000 - 1500 kW m^{-1}) fire intensities. Fire of low intensity (<350kW m^{-1}) is used on a large scale, by the Department of Conservation and Land Management, to reduce the buildup of fuels in jarrah forests, however, it appears "habitat trees" are only marginally affected by such fires.

The equation relating the intensity of a fire and the condition of the "habitat tree" to the expected damage it will sustain in a fire (Section 3.1.5.4) was kept as simple as possible. The value representing the condition of the "habitat tree" may be assigned subjectively in the field (see Appendix 3) while the value representing the intensity class may be calculated using the fire behaviour tables developed by

Sneeuwjagt and Peet (1976), a common practice among foresters in Western Australia. Given the 2 variables, expected damage to the "habitat tree" may be predicted. This may be of some value to management if "habitat trees" are to be retained after logging operations, particularly if regeneration burns are involved.

Although species of eucalypts display different susceptibilities to fire damage (Jacobs 1955, McArthur 1968) the destruction of "habitat trees" was not species-specific. The single most important feature of a tree species which influences its susceptibility to fire damage is the thickness and character of the bark (McArthur 1968). The bark of marri is rough, persistent and flaky while the bark of jarrah is stringy and fibrous, which makes it distinct from all south-west trees except red tingle (*E.jacksoni* Maiden) and Albany blackbutt (*E.stoeri* Maiden) (Kessell and Gardener 1924). Bark thickness is easily determined and is the single most important factor affecting susceptibility to damage by fire (McArthur 1968). A random sample of 80 trees (40 jarrah, 40 marri), all from within the 40 to 60 cm d.b.h.o.b. class, selected from the inventory plates used to obtain increment data, showed that the mean bark thickness of marri (2·9 ± 0.1 cm) was significantly ($p < 0.001$) greater than that for jarrah (2.3 ± 0.1 cm). One might have expected a larger increase in destruction of jarrah from the 77% of "habitat trees" that were dead or in poor condition before the fire than in marri, in which 68% of "habitat trees" were dead or in poor condition before the fire. However, this was not the case, so jarrah "habitat trees" appear less susceptible to fire damage than marri "habitat trees".

Bark thickness varies with the diameter and age of a tree (Jacobs 1955, McArthur 1968) with older, larger, trees less susceptible to fire damage. However, "habitat trees" are prone to greater degrees of fire damage than other components of the forest with equivalent size. This may be explained by their higher incidence of fungal and termite infection and the generally poor or decadent condition of such trees which increases their flammability.

The fire at Boyicup was lit during autumn. A fire lit under the same environmental conditions during spring would have been less intense and resulted in less damage (Nicholls 1974). During spring the moisture contents of the fire fuels, soil profiles and the "habitat trees" themselves, would have been greater thus reducing their flammability. McArthur (1968) lists the moisture content of the bark as one of the factors affecting susceptibility to fire damage. The moisture content of both phloem and the fibrous dead bark is greater in spring than for autumn. The moisture content of the fibrous dead bark is important as it will determine the combustion rate and the distance the fire will travel up the bole into the crowns. Frequently, the dry outer bark ignites from the effects of radiant heat without actual flame contact and crown fire formation readily occurs under these conditions (McArthur 1968). During spring, when moisture contents are higher, these circumstances occur less frequently. This decreases not only the amount of fire damage but also the number of hollows directly excavated by the fire.

4.4.2 The long term effect of fire on "habitat trees".

Of the remaining 51 "habitat trees" at Boyicup after the fire, only 33 (64.1%) were used regularly 32 months later; however, 221 new "habitat trees" were used at this time. This represents a 433% increase in the number of "habitat trees" used regularly, on the number available immediately after the fire. This increase in numbers did not occur at Yendicup where the number of "habitat trees" used regularly decreased by about 7%. New "habitat trees" seem to be the direct result of the fire and were excavated by burning rather than fungi or termites, which are the usual agents credited with the formation of hollows (Mackowski 1984, Ambrose 1982, Perry _et al._ 1985). This is evident by the charcoal in many of the hollows examined in the burnt area and the significant reduction of the mean height of the entrance to the hollow for "habitat trees" in use at Boyicup 32 months after the fire. This result is not surprising given the amount of dead branches retained in the crowns of eucalypts (Jacobs 1955), particularly in the jarrah in the study area (pers. obs.), and the flame heights during intense fire. Smith (1981) estimated the heights of flames around the edge of the fire at Boyicup as 6 m but stated that estimates of flame height in the centre of the area were impossible because of poor visibility. Nicholls (1974) reports flame heights of 8.7 m and 10.9 m in jarrah forest during intense spring and autumn burns respectively and that two thirds of the trees were fully scorched and defoliated. There is no reason to believe, judging by the amount of crown scorch in Boyicup, that the flame heights in the centre of the study area were not equivalent to, or greater than those reported by Nicholls.

High-intensity fires are known to cause significant defects and mortality in eucalypts (McArthur 1967, Peet and Williamson 1968, Peet and McCormick 1971, Nicholls 1974 and Nicholls and Cheney 1974), however, many of the defects in this case are beneficial to cavity-using fauna for sites of refuge. During low-intensity fires, such as those used by the Department of Conservation and Land Management for fuel reduction, flame and scorch heights are lower (Nicholls 1974), thus the effect of fire on the formation of hollows will become mainly indirect by affecting the activities of fungi and termites.

Initially, termite and fungal damage were considered independent (Greaves et al. 1965, 1967). However, Perry et al. (1985) have shown that termite attack on the heartwood of jarrah is confined to regions that have been visibly affected by fungus, i.e., termite attack is secondary to fungal attack. Perry et al. also suggests that the same applies to other trees of the south-west of Western Australia. Lesions caused by fire or mechanical damage are important routes through which decay fungi enter a tree (McCaw 1983, Wilkes 1982 a, b). Gum veins and shakes are the result of fire damage not severe enough to kill the cambium (Nicholls 1974); they remain enclosed and inaccessible to fungal spores. Jarrah boles thus affected remain free of termite attack and consequently hollows. Fire damage which results in the death of the cambium produces a scar which is liable to fungal infection while being occluded. Such patches of included sapwood are the routes through which termites penetrate adjacent fungus-affected heartwood (Perry et al. 1985, McCaw 1983).

Fire in the jarrah forest creates hollows directly, by burning holes in trees; or indirectly, by providing a site of infection for fungi and thus termites. The increase in the number of "habitat trees" at the Boyiucp site is a direct effect of the fire, as the time period involved with the formation of hollows by fungi and termites is far in excess of 32 months (Wilkes pers. comm. 1985).

The increase in the number of "habitat trees" used may partly be the result of increased competition for hollows due to an influx to the burnt area of animals attracted by more favourable environmental conditions. This would force possums to use lower-quality hollows otherwise left unoccupied at the time of the initial survey of "habitat trees". Most of the "habitat trees" located were created directly by the fire and were not merely the result of increased inter- and intra-specific competition.

Despite the increase in the number of "habitat trees" in use at Boyicup after the fire, no significant difference exists between the distributions of proportions for pre and post-burn data for tree species, condition of the "habitat trees" and the position of the hollow. The pattern of distribution of the "habitat trees" also remained unaltered. It therefore appears that many of the hollows in use before the fire had been formed directly by past intensive fires. Historically, the area has been subject to fire at frequent intervals with the most severe recorded fire occurring in 1949-50 when the area was burnt by a wildfire. Although no information is available about the intensity of the wildfire, it is assumed to be at least equal to that experienced at Boyicup. Before 1955 the Forest Department of Western Australia was maintaining a strategy of excluding fire from state forests (Peet 1967), therefore the period of litter accumulation would have been greater in 1949-50 than that before the fire in 1981 at Boyicup. Consequently, given the period of litter accumulation and that the wildfire was in summer, its intensity could be assumed to be high.

Although the evidence is not conclusive, my data suggest that fire plays a significant role in decreasing the mean diameter, thus mean age of "habitat trees" that are available. As natural hollows take so long to develop, holes in these younger trees were probaly formed by fire. The mean ages of jarrah and marri "habitat trees" in use 32 months after the fire were reduced by about 100 years and 57 years respectively. The youngest "habitat tree" in use at Boyicup before the fire was 280 years for jarrah and 160 years for marri. These ages were reduced to 85 and 100 years respectively 32 months after the fire. The oldest "habitat tree" in use at Boyicup was 730 years for jarrah and 550 years for marri. Thirty two months after the fire, the oldest jarrah "habitat tree" was 680 years while marri remained unaltered. The age range (Table 14) can be used to estimate longevity of "habitat trees" by subtracting the lower age limited from the upper. Longevity is estimated at about 500 years for jarrah and 400 years for marri. Because the two extremes of the age range have been used in the calculations and given the likely effects of fire on "habitat trees" the estimate must be considered the upper limit, and, because of the method used to age the trees, viewed with caution.

The effect of fire on "habitat trees" may be viewed on a short- and long-term basis. In the short-term, intense fire destroys a high proportion of the "habitat trees" with susceptibility to fire damage related to the condition of the tree and the fire intensity experienced. In the longer term, fire creates "habitat trees" indirectly by providing sites for fungal infection and subsequent termite attack and reduces the mean age of "habitat trees" and the age at which they produce hollows.

The importance of fire to the creation of hollows for use by fauna has been previously overlooked in the literature. Whether similar results to mine would be yielded in other forest types is an area requiring further research.

The selection of arboreal shelter sites has advantages over those on the ground for avoidance of predators, particularly terrestrial predators such as the fox (Vulpes vulpes), feral cat (Felis catus) and dingo (Canis familiaris dingo), all of which prey on possums (Newsome et al. 1983, Inions 1981c and Christensen 1978). MacLennan (1984) suggests that brushtail possums spend no more time on the ground than is necessary to obtain their food requirements and move from one tree to another as a means of avoidance of predators.

Alternative forms of refuge used by radio-tracked possums during this study are presented in Table 23. The most common and intensively used form of refuge for both species was the "habitat tree".

The degree to which other form of refuge were used varied with the individual, a point also noted by F.R.I.(1980) and Menkhurst (1984b).

Unlike other areas, the ringtail possum preferred "habitat trees" rather than dreys and it does not, to any great extent, line its hollow with shredded bark, which was a significantly preferred feature of nest boxes used by ringtail possums (Ambrose 1982). The shift in shelter site preference, shown by this sub-species, from the nominate race may be due to the long association of its habitat and fire. Fire is, and has been, a frequent event in my study area and behavioural adaptations such as building dreys or lining a hollow with flammable material would be detrimental to the survival of the individual in a fire.

The physical act of building a drey requires an effort, particularly if it is destroyed regularly by fire, and consumes energy. This affects what may be a very delicate energy budget, particularly in such a nutrient-poor environment (see MacLennan 1984 and Section 4.7). Therefore, as a result of a fire prone environment and delicate energy budget, the ringtail may have evolved the behavioural adaptation of selecting hollows in "habitat trees" as its main form of shelter site.

4.5 THE SELECTION AND USE OF THE UTILISED AREA

An appreciation of an animal's relationship with its habitat involves knowledge of how it uses its environment - spatially and temporally. This is determined from study of the home-range: the methods and problems involved in evaluating this are reviewed by Sanderson (1966).

The size of the area utilized by brushtail possums varies between sexes (Dunnet 1964), individuals (Green 1984), habitat (How 1978) and temporally (Ward 1978). For example, How (1972) working in N.S.W., Dunnet (1964), working in the A.C.T., and Crawley (1973) working in New Zealand, found the range areas of male brushtail possums were 7.41 ha., 3.01 ha. and 0.81 ha. respectively while those of females were 5.67 ha., 1.08ha. and 0.4 ha. respectively. In my study, the mean size of the utilized areas was larger than most published accounts.

Methodology may be one explanation of the differences as home-ranges determined by live trapping and radiotracking give significantly different results (Green 1984). Ward (1978) found that home-ranges determined by radiotelemetry were twice as large as those determined by Crawley (1973) who used live trapping in the same area. The size of the home range increases as a function of body weight (Harestad and Bunnell 1979), however, as possums used in my study are at the lower end of the range published for weights (Table 21) for female brushtail possums (Straham 1983), body size is not a plausible explanation for the larger home-range that I recorded. Size of home range is also influenced by food availability and food habits (McNab 1983). The smaller home-ranges found in New Zealand may well reflect a more edible biomass ha^{-1} than equivalent habitats in the eastern states of Australia (Green 1984). Likewise, habitats in the eastern states may be of higher quality than those used in this study. The density of the population has been suggested as the most likely reason for the variation between home-range size (Kean 1967, Crawley 1973).

Little is known about the variation in size of home-range between populations of ringtail possums, however, Tyndale-Biscoe (1973) gave the average home-range of ringtail possums as 0.37 ha. This figure is markedly less than the 2.6 ha I recorded for RTP8. The Western Australian sub-species of the ringtail possum is larger than its eastern states counterparts, therefore the larger area recorded as utilised in this study may be attributed to the larger body size (Harestad and Bunnell 1979), the fact that the animal was male, the method used and/or the inferior quality of the habitat.

Because of the variability between individual possums, it is not possible to relate the mean size of the utilised area for each year to the time lapsed after the fire. Although no significant difference was detected between the 2 means, it is possible that this result was due to individual variability. BTP3 increased her utilised area by 23.1% in the second year of the radiotelemetry study. However, similar results were found by Ward (1978) in the absence of fire, but he also recorded a decrese in the abundance of preferred food during the second year of his study. When most of the requirements of a species are provided in a small area, its home-range may be smaller than the average for that species (Jewell 1966). On the other hand, if resources are spread over a larger area, large ranges may be expected.

The usual presentation of home-range, the boundary line method, implies that the habitat is used homogeneously. This is rarely the case; individuals use various core areas differentially. This has been demonstrated for primates (Kaufman and Rosemblum 1966), Kaibab squirrels (Hall 1981), Numbats (Christensen et al. 1984), brushtail possums in New Zealand (Ward 1978) and in my work in Western Australia (Section 3.2.3).

An animal may have a number of core areas, the prominence of which may vary with time. Why is one area used more frequently than another? Ward (1978) found that the excursions and shifts in the home-range of 4 brushtail possums radiotracked in New Zealand indicated that although the animals were generally sedentary, they were not confined to one area but responded positively to various opportunities as they occurred. They moved over a surprisingly small area each night ($\sim < 1000$ m^2), yet their movements, particularly the excursions, were closely related to food supply and distribution. That they moved so little is indicative of how concentrated their resources were.

Habitat selection by arboreal folivores involves a complex interaction among many factors, such as the physiological state of the animal and of the plants used as food; the recent past-history of movement and feeding by the folivore; the more remote social history of the individual and perhaps its ancestors; plant species-diversity and composition in the portion of the forest where the animal is found; and seasonal changes in the composition and availability of the various plants which the animal uses (Montgomery and Sunquist 1978). Information in such detail is expensive and difficult to collect. Information for use by the forest manager needs to be quick to obtain and usually quantitative. Habitat variables, few in number, need to be identified which, in isolation, explain significantly large amounts of the variance associated with habitat selection.

On a macroscale the nutrient concentration of the eucalypt communities appears to be the major determinant of density and species richness of arboreal folivores in south-eastern N.S.W. (Braithwaite 1984). Other variables influencing the macrodistribution of arboreal folivores in south-eastern N.S.W. are listed by Kavanagh (1984) as flat to undulating landform profile, a long period of time since severe fire, and a high degree of forest maturity. Some of these variables listed by Kavanagh may not be relevant to other forest types: for example, time since severe fire would be less important in jarrah forest because of the difference in fire tolerances of the trees in the two ecosystems.

On a microscale the selection of core areas within a home-range or utilised area is similar to the selection of a home-range within a habitat type. The availability and quality of the food supply appears to exert the most influence on selection of core areas by brushtail possums (Ward 1978). In the jarrah forest where the overstorey consists of only 2 tree species the diversity of the food source is limited; quality becomes the deciding factor. The quality of the food source may be measured by the nutrient values of the foliage, as was the case for macrodistribution. Whether the nutrient content of the foliage of jarrah and marri trees explains a significant amount of the variance involved with selection of core areas in other seasons was not determined in this study.

4.6 TERRITORIALITY

4.6.1. Intra-specific territoriality

Areas utilised by brushtail possums in my study were not exclusive in space or time. Although Dunnet (1964) found that male brushtail possums maintained almost exclusive "territories" and Winter (1976) observed that high ranking males and females occupied exclusive ranges, it was not the case in denser populations in New Zealand (Crawley 1973, Ward 1978). Green (1984), on re-assessing Dunnet's data, found it did not support the concept of territorial males and non-territorial females.

Core areas were shared extensively, particularly by parent-offspring pairs. The favoured area of the forest represented by cluster-group 3, was shared by BTP3 and BTP2 in 1983/84 and by BTP9 and BTP4, and BTP3 and her offspring during 1984/85. BTP1's core areas were exclusive and separate from the favoured cluster-group. Why BTP1's core area did not coincide with the other possums, despite her regular short sorties into the area, was not determined. However, enough information was gathered to put forward the hypothesis that she was excluded as a result of hierarchy. Ward (1978) also noticed that some animals were dominant over others when several were feeding together. Triggs (1982 quoted in Green 1984) defines "dominants" as those adults over 100 g heavier than their calculated standard weight for length. She found allow level of overlap of home ranges between the dominants of the same sex. In any areas, BTP3 was larger than BTP1 (Table 21) and was probably the dominant, but both animals were older than other animals used in the study. Why then was BTP1 excluded from cluster-group 3 while other animals were tolerated?. One possible explanation is that local settlement by females may promote a matrilineal social organisation through the establishment of local groups of closely related females (Clout and Edwards 1984). BTP3 and BTP1 may have belonged to different social groups. Core areas may be exclusive as a group basis rather than individually and a re-assessment of the function of female spacing behaviour and further research involving polymorphic genetic markers is required. The idea of closely related groups of females occupying particular localities may help explain why dispersal of the young, regulated by antagonistic encounters (Winter 1976), is male-biased (How 1972). The migration of young males to new matrilinear social groups not only would increase the genetic diversity of the grups but may also have some selective advantage to males in between male competition for females. Further research into this topic is needed.

The concept of territoriality is not applicable to the entire utilised area in this case but this is not to suggest it does not occur for strategic areas. Winter (1976) suggests that a system of mutual avoidance exists between co-dominants of each sex and only the area around a "habitat tree" was defended. The lack of evidence to support any suggestion that possums, other than parent and current-year offspring, share "habitat trees" suggests that Winter's observation also applies to my study.

A number of "habitat trees" are controlled by one possum at any one time although these trees may be recycled if they are relinquished by the current owner. "Habitat trees" are clearly labelled as occupied, by "totem poles", a series of gouges in the cambium of saplings surrounding the base of the "habitat tree" and made by the incisor teeth. Such gouges are also found on branches surroudning the entrance hollow. Many totem poles also carry polished sections of bark which may be the result of continued rubbing by the animal, possibly depositing a secretion as an olfactory marker (Allen 1982). Areas around "habitat trees" are physically defended. During the 1984/85 tracking programme BTP3 and her offspring remained around "habitat tree" T51, after descent, for much longer than normally expected; after some time the presence of an untagged brushtail possum was noticed. With much vocal commotion the intruder was driven off and BTP3 and offspring proceeded to cluster-group 3 in the usual manner.

Den sites are defended by both sexes of possums (Jolly 1981) and similar results have been found for bird species nesting in cavities in trees (Saunders 1979).

Despite the scanty evidence, I believe that matrilineal social groups of female brushtail possums are exclusive, but the degree of this is not known. Within such social groups, a hierarchy exists and "habitat trees" are defended regardless of social group.

How then is this organisation maintained and why? There is strong evidence that the density of animal populations is regulated by social interaction (Tamarin 1983). Green (1984) suggests that social organisation is a density regulator which is orientated towards establishing and defending individual space and so long as residents can effectively defend their core resources, the success of others attempting to establish will be density dependent. Thus residents may regulate density by controlling key resources such as "habitat trees" (How 1972, Hocking 1981). Green (1984) goes on to suggest that this regulating mechanism has evolved primarily in 2-dimensional, rather than a 3-dimensional, space as the defence of key resources is at ground level. This is achieved by scent-marking and encounters when using common trails. Certainly 2 dimensional control over key resources is the most evident (e.g. totem poles), however, possums are well-endowed with other attributes both vocal, chemical and behavioural for disputes over key resources or status which may directly or indirectly affect individual control of a resource. A conclusion of Gates and Aitken (1984) was that Trichosurus has a well developed auditory system capable of meeting the requirements of the demanding acoustic environment in which it lives, with specially well developed mechanisms for processing the localisation of sound in space. This must be an adaptation to live in 3-dimensions.

Unlike the brushtail possum which previously has been considered to have a social structure based on the individual, the ringtail possum has a social structure based on pairs or groups (How 1978). It is well-known as a gregarious species, with adults, usually a female and male pair, sharing nests. Groups of individuals also share clusters of nests (Thomson and Owen 1964). High densities of ringtail possums have been recorded by Pahl (1984) (23.5 ringtail possums ha^{-1}) and How et al. (1984) (12-14 ringtail possum ha^{-1}). The degree to which the species is gregarious varies geographically (Winter and Atherton 1984) and, as the species is morphologically variable there may be parallel variation in social organisation.

Very little can be concluded from this study about the social structure and territoriality of the ringtail. Two distinct groups of several individuals were known and located by listening to their twittering calls on nights when radiotelemetry was not undertaken. The degree of interaction between these groups was undetermined. During searches by spotlight of the two areas containing the groups, pairs of individuals were often found. Four ringtail possums were seen in the utilised area of RTP8, which suggested overlap of utilised areas.

On a number of occasions, adult pairs of ringtail possum were found cohabitating the hollow, an occurrence rare among the brushtail possum population.

It seems that the ringtail possum is more social than the brushtail possum, but more research is required into the social organisations of both species.

4.6.2. Interspecific territorialty

The availability of nest sites is listed by Strahan (1983) as probably a major factor which limits distribution and abundance of the ringtail possum. Excepting that resident brushtail possums defend core resources,such as "habitat trees", as a means of density regulation (Green 1984), one would expect a high degree of interspecific competition between the two species for similar sites. The brushtail possum is the larger and more aggressive of the two species and would probably be at a competitive advantage in such situations.

At least for the limited number of observations during inspections of hollows, ringtail possums and young brushtail possums occupied lower quality hollows than did established brushtail possums. During one inspection, a pair of adult ringtail possums was located sheltering in a hollow which was shallow and provided very little protection from the elements. The prominence of the scratchtrack suggested that the site was used regularly, perhaps as a result of the shortage of available hollows.

The shortage of hollows available to the ringtail possum, coupled with its smaller size and slower movement on the ground than the brushtail possum, made it easier prey. This may have contributed to the decrease in abundance of the species in recent years. Ringtail possums are less abundant than brushtail possums in the study area (pers. obs.).

4.7 DIET

For the brushtail possum, the proportion of the diet made up by eucalypt leaves, varies widely with geographic locality (Kerle 1984). Even within one geographic region such as the south-west of Western Australia, the proportion varies from 66% in an area with a variety of shrub species to 95% where the habitat contains only eucalypts and pasture (Sampson 1971, Christensen 1980b). As for many herbivores, plant availability is not the predominant factor controlling food selection and possums do not always utilise the most abundant plant species (Freeland and Winter 1975, Fitzgerald 1978, Cork and Pahl 1984, Fitzgerald 1984, Kerle 1984). There is consistency between the works of Kirk (1920), Zotov (1949), Kean and Pracy (1953), Manson (1958), Gilmore (1965) and Harvie (1973), all working in New Zealand and Freeland and Winter (1975) in Australia who reported that the average number of leaf species eaten per night was 3 and there was a strong selection for leaves of a few of the many species present.

The reasons for an animal's selection of food is complex and, although many hypotheses have been formed, no consensus has yet been reached (Arnold 1964, Moss and Parkinson 1972, Janzen 1978, Freeland and Winter 1975, Onuf 1978). Factors possibly causing diet-selection are listed by Kerle (1984) as; the presence in plants of deleterious toxins; nutritive value in terms of protein, carbohydrates, minerals or vitamins; and the digestibility of the food in relation to fibre levels.

Many authors tend to favour one explanation only. Fraenkel (1959) argued that all green plants fulfil nutritional requirements and that responses to secondary plant substances were entirely responsible for specificity. Janzen (1978) described the world, as detected by the eyes or olfactory system of a folivore, not so much coloured green as smelling of morphine, caffeine, tannin, phenol, terpene, canavanine, latex, phyto-haemagglutinin, oxalic acid etc. Janzen goes on to suggest that toxicity be measured by the difference between the energy gain by ingesting a toxic food and the energy expended in countering its toxins. Because of toxicity and the problems of detoxification, Fitzgerald (1978) suggests that mammalian folivores consume a variety of plant food at any one time, although she also attributes this to the sheer bulk of leaves required to provide adequate nutrition or inadequate nutritional constituents of leaves.

The large concentrations of toxic secondary compounds in eucalypt leaves is assumed to limit consumption by brushtail possums (Freeland and Winter 1975) and the nutritional shortfall is overcome by eating a variety of other plants, notably grasses. Freeland and Winter (1975) also hypothesised that toxins in the eucalypt leaves indirectly regulate possum populations at levels that afford the eucalypt tree some degree of protection from predation. MacLennan (1984) agrees with Freeland and Winter and suggests that brushtail possums in open woodland are barely able to maintain themselves at a positive energy balance as a result of high toxin levels in the eucalypt leaf and the shortage of readily obtainable supplementary foods. He argued that the high proportion of time brushtail possums spend immobile is an adaptation to conserve energy, and has evolved in response to energy balance problems caused by the high toxin levels in their eucalypt diet and that long periods of immobility displayed by the Koala (Phascolarctos cinereus Goldfuss) (Smith 1979) and Greater Glider (Petauroides volans Kerr) (Kehl and Borsboom 1984) serve the same function.

The factors governing whether a given secondary compound can be ingested without an overall negative effect are listed by Janzen (1978) as; the condition of the animal, the dosage, the past experience of its inducible enzyme system with the compound or related compounds, the past experience of its gut micro-flora with that compound, the simultaneous ingestion of nutrients, the simultaneous ingestion of synergists or antagonists of the secondary compound, the use of the secondary compound as a medicine, and the use of the secondary compound as a scent mark or pheromone. Clearly, the role of secondary substances is complex.

Other evidence suggests that the influence of toxins on selection of diet is secondary. Reports of brushtail possums feeding exclusively on a single food in a night, many of which are highly toxic (Kerle 1984) suggests that while toxins may have some influence on food selection, they are not the most important factor. Brushtail possums are known to browse Gastrolobium spp. which contain monofluoracetic acid (1080) (King et al. 1978). The LD_{50} of brushtail possums in New South Wales ranges from 0.34 to 1.03 mg kg $^{-1}$ (McIlroy 1982) while King et al. (1978) found it to be greater than 125 mg. kg $^{-1}$ in Western Australia.

The concentration of nutrients in the foliage seems related to the densities of populations and diversity of arboreal marsupials (Braithwaite 1984) as species might be expected to occur at higher densities in richer, more productive habitats (Belovsky 1981, Klein 1970). Onuf (1978) pointed out the importance of nutrient selectivity in insects: and nutrient concentration was shown to be an important factor determining damage by grazing insects to Eucalypt forests and woodlands (Fox and Macauley 1977). Such damage was irrespective of quantities of toxic compounds in the foliage. Ullrey *et al.*(1981) noted that the koala prefers to browse eucalypt leaves high in a number of elements including potassium, while Cork and Pahl (1984) showed that ringtail possums maximised their intake of nitrogen while minimising their cell wall intake for a given species of food as a consequence of selection of young foliage.

Kavanagh (1984) found that, although the presence of high levels of nitrogen in the mature foliage of some eucalypt species characterises forests important for arboreal marsupials (Braithwaite *et al.* 1983), it did not explain the preference of greater gliders for the different tree species in the study area. However, Cork and Pahl (1984) point out that total nitrogen cannot be considered to estimate protein-nitrogen in forages of eucalypts.

The absolute role of nutrient content of forages in diet-selection of possums is, like the role of secondary compounds, unknown. Both secondary compounds and nutrient values of foliage, if taken in isolation can be shown to significantly influence diet-selection in the majority of cases. No study has fully explored the interactions between toxins, nutritive values and the fibre levels in the forage.

Brushtail possums, when moving from tree to tree frequently pass one or more trees of the same species. They also commonly return to the same tree of the same species night after night (MacLennan 1984). The koala (Robins and Russell 1978) and the greater glider (Kehl and Borsboom 1984) exhibit similar behaviour. This habit caused particular difficulty in locating "habitat trees" during my study as "feed trees" often possessed scratchtracks classed as very good and if adequate care was not taken were easily mistaken as "habitat trees". These behaviour patterns imply selection of particular trees of greater suitability and that selection may be related to differences in the chemical composition of co-specific trees (Southwell 1973). Cluster-group 3 was high in nutrient values and was the area most sought after by possums, but whether the animals chose the area for its nutritional value, because it was more productive or if in fact nutrient values were a surrogate variable and perhaps correlated with toxin levels, was not determined. Whatever the reason for selection of "feed trees" they could be categorised by high values for foliar nutrients.

Browsing was not random once an animal selected a suitable tree. On a number of occasions I observed that brushtail possums, while sometimes standing on their haunches, pulled clumps of leaves towards themselves only to release the clump without browsing it. A new clump then was examined. Even within selected clumps only particular leaves were selected, usually the leaves from the current year and usually the second and third whorls of leaves (Plates 20 and 21). Epicormic growth was particuarly popular (Plate 222. Similar preference for young leaves was found for the greater glider (Kavanagh 1984) and the ringtail possum (Cork and Pahl 1984). Young foliage has higher nitrogen and lower cell-wall concentrations than mature foliage of the same species (Cork and Pahl 1984). The selection of young as opposed to mature foliage agrees with results of studies by Arnold and Dudzinski (1978) and Arnold (1981).

The foraging strategy adopted, i.e., selected area, selected trees or groups of trees, selected clumps of leaves and selected leaves within a clump, may be an attempt to maximise nutritional quality of toxic substances within the food source. Selectivity should be a major factor in a feeding strategy of possums given the low nutritional quality of the eucalypt leaves and the problems involved with their digestion (Freeland and Winter 1975), the sheer bulk of leaves required (Fitzgerald 1978), the finite volume of the stomach and caecum and the rate of passage of the food through the gut (Wellard and Hume 1981, Herd 1978). Even though the standard metabolic rate of marsupials is approximately two-thirds that of eutherians (Dawson and Hulbert 1970), maximisation of energy is probbably a major objective of a feeding strategy.

The ringtail possums are also selective, not only preferring young foliage but also the foliage of sapling-sized trees, particuarly jarrah (Table 29). Ringtail possums, although occurring throughout most of the forested areas of Australia, are most abundant in sub-climax communities (How 1978). Cates and Orians (1975) found that earlier sucessional plant species were significantly more palatable to the generalist herbivore than later successional and climax plants, probably due to the smaller investment in defensive substances of the earlier species. If saplings are considered subclimax to the mature forest, my results are consistent with How's observation. Young and mature leaves differ in chemical composition but there is insignificant interaction between tree age and leaf age (Cork and Pahl 1984).

There is a high degree of overlap of the distributions of brushtail and ringtail possums throughout the study area. The two species, while existing sympatrically and adopting similar selective criteria of forage (i.e., young foliage of particular trees) utilise different components of the forest. The food resource is partitioned and, as no antagonistic interactions were observed between the two species, partitioning has probably evolved from consumptive competition (Schoener 1983). It would seem unlikely that foliage need be partitioned in a forest especially when only two species of possum are involved. However, if we accept the propositions of Freeland and Winter (1975) and MacLennan (1984), that because of secondary toxins and the low quality of eucalypt foliage as a food source, the eucalypt leaves indirectly limit possum populations, partitioning may be explained. Interspecific competition from insects, which also prefer young foliage high in nutrient content (Fox and McCauley 1977), may aggravate the situation. Although the most-utilised food source for each species is separate, there is considerable dietary overlap and the partitioning of the resource should not be considered inflexible (Table 29). Further research is required into resource-partitioning by the two possum species to determine if leaf material is limiting and the cause of the partitioning. If it is, limiting it may well be a reason for the absence of the more k-selection strategistsamongst arboreal mammals from the forests of south-west Western Australia.

How selection of food is achieved is not understood; it is unlikely that the animals directly recognise factors such as nitrogen or fibre content. The selection criteria appear to be complex and often dependent on the interaction of several components (Janzen 1978), not just the nutrient content of the foliage.

Plate 20. Young foliage with some evidence of browsing.

Plate 21. Foliage which has been browsed by possums.

Plate 22. Epicormic growth which has been browsed by possums. The serrated edge of the leaves along the mid rib is characteristic of possum browse.

4.8 PATTERNS OF ACTIVITY

Two broad patterns of activity were noted. The first involved movement along the ground from a preferred "habitat tree" to the preferred area for feeding. The distance involved was about 200-300 m. This is much shorter than that reported by Green and Coleman (1981) for a similar activity pattern employed by brushtail possums in New Zealand, which travelled up to 1.5 km to reach pasture. BTP3 and RTP8 travelled on the ground exclusively, which involved additional energy expenditure because of the distances travelled and the greater risk of confrontations with predators. These disadvantages may have been countered by the quality of the "habitat tree" selected by providing greater protection from predators and temperature fluctuations thus providing energy savings.

Other possums used "habitat trees" on the periphery or in their most intensively-used areas, thus minimising the distances needed to travel to desired areas. If the "habitat trees" were of good quality this strategy would be most economical in terms of energy expenditure, however, lower quality "habitat trees" would inflict energy costs in terms of temperature fluctuations and predator avoidance. BTP1 used this strategy exclusively while BTP4 and BTP9 and occasionally BTP2 used a combination of the 2 patterns of activity, neither of which seemed related to the weather.

Possums in my study spent more time involved in terrestrial activity than brushtail possums studied in the eastern states of Australia (MacLennan 1984) or New Zealand (Ward 1978). Ward (1978) stated that: "The sheer bulk of leaves required to provide adequate nutrition, or the inadequate nutritional constituents in leaves, may necessitate the ingestion of some supplementary foods". The foliage of jarrah and marri leaves is notoriously low in nutrients and within the utilised area of the possums in this study only two tree species are found. To obtain a supplementary food source, possums must resort to the understorey.

During spotlighting sessions brushtail possums have been seen on the inflorescence of Xanthorrhoea spp. and a group of 5 brushtail possums was seen in a flowering bull banksia. Possums are also known to browse Bossiaea orinata (Inions 1981b).

4.9 FLUCTUATIONS IN THE POPULATION OF POSSUMS IN RELATION TO FIRE

4.9.1. Introduction

Fauna of the jarrah forest respond to the residence of fire per se and to a fire regime, although the reasons for the response are complex (Newsome and Catling 1983). The flora of the jarrah forest is adapted to fire. The northward drift of the Australian continent carried it into dry latitudes some 45 million years ago, consequently, it has features indicative of a long association with poor soils,drought and fire. Mount (1969) considers eucalypt forest to be fire dependent and suggests that they are successful competitors against alternative vegetations because they have evolved adaptations which enable them to flourish after fire and survive for long periods between fires. It has also been suggested that eucalypt forests are not only a fire climax but that they produce volatile oils to ensure that it remains so (Mutch 1970). Consequently, the classic Clementsian view of succession has limited application to communities subject to the truncating effects of recurrent fires (Noble and Slatyer 1981).

Adaptation of a floral community is not just to fire per se, but to a particular fire regime, where survival is influenced by the frequency of the fire, its intensity and seasonal occurrence (Gill 1975; 1977).

There is much less information concerning the responses of the Australian fauna to fire. What studies there are have concentrated on defining the responses of species and communities to fire and examining the evolutionary effects of what has probably been a long association with wildfire (Singh _et al._ 1981). Whether or not Australian fauna is adapted to fire is a matter for conjecture.

Catling and Newsome (1981) put forward an _a priori_ set of propositions that the Australian vertebrate fauna is fire-adapted. Each proposition was tested with examples and rejected where appropriate. They concluded that further understanding will support the hypothesis of fire-adaptiveness for the majority of the Australian vertebrate fauna.

Merrilees (1968) calculated that 33 per cent of the fauna of large marsupials of Western Australia has disappeared in the last 30 000 years because of changes in the vegetation brought about by the increased use of fire by Aborigines (Singh <u>et al.</u> 1981. Thiry thousand years may be insufficient time for an evolutionary response on the part of the animals to the new conditions (Catling and Newsome 1981). Survivors may have no particular adaptation to fire but are general enough in their habits to cope with the change in habitat brought about by fire. After a detailed study of the woylie and the tammar wallaby, living in a flammable dry sclerophyll habitat, Christensen (1980b) considered that neither species had any specific adaptation to surviving fire. They survived by reason of their mobility and the general characteristics which enable mammals to cope with the problems of living. A proposition put forward by Catling and Newsome (1981), to argue for fire-adaptiveness of fauna, was that the difference in fecundity between the ringtail possum, brushtail possum and the greater glider is the reverse of the fire-prominence of their habitats. However, this may be equally explained by the quality, in terms of nutrient values, of their habitats. In the more fire-prone environments, the r-selection strategists are found because of the unpredictability of the environment.

The range of responses of fauna to fire is complex. There is no one response or sequence of them and the literature displays many inconsistencies in life histories, body size, longevities, diets, sites of shelter and predation of the species concerned (Newsome and Catling 1983), and the nature of the fire itself. In an attempt to predict some changes in faunal populations after fire, 6 demographic models, based on the change in the abundance of food, shelter and predators, were proposed by Newsome and Catling (1983).

In my study too few data were collected to enable the formulation of demographic models, however, the absolute population changes with time may be predicted using the number of "habitat trees" ha^{-1} as a surrogate variable for population size. No significant difference exists between proportions for each class of scratch-track intensity before and after the fire at Boyicup. Consequently, it is unlikely that the situation was one of fewer possums using more trees less often.

Population fluctuations will be examined in the short and long term and will be related to the affects of fire on shelter, food and predation.

4.9.2 The immediate effects of fire.

Studies of both wildfire and prescribed burns have shown that populations of most species survive fires and return to the regenerated forest as soon as it reaches a stage of growth suitable to the species (Recher and Christensen 1980) and the proportion of the population which will survive the fire is a function of the species concerned and the nature of the fire.

It has been estimated that 80% to 90% of the invertebrate litter fauna is destroyed by fires of low to moderate intensity (Leonard 1972, Abbott 1984a). Vertebrate fauna suffer less dramatic effects. Heptofauna generally survive in large numbers because of their habit of taking refuge under stones etc., thus avoiding radiant heat (Recher and Christensen 1980, Christensen *et al.* 1981). Avifauna easily avoid fires of moderate to low intensity and generally move to unburnt areas until the fire passes, then return to areas they occupied before the fire (Disney 1968, Christensen and Kimber 1975, Cowley 1978).

Mammals exhibit similar survival patterns during fires of low to moderate intensity (Christensen and Kimber 1975). Of the 26 woylies and 4 tammar walabies radiotracked before, during and after 2 experimental burns, only one woylie was killed by the fire (Christensen 1980b).

The impact of extensive high intensity wildfires is more severe. Hemsley (1967) found large numbers of dead birds washed up on Tasmanian beaches after wildfire in the area. Similarly, during a severe wildfire in the Nadgee Nature

Reserve in south-east N.S.W., swarms of birds were seen, when caught up in the smoke column, to suffocate and fall into the sea. Counts along beaches afterwards revealed 550 dead birds of 38 species (Newsome 1985). During wildfire, mammals are also overtaken and killed (Heislers 1974, Recher et al. 1975). During the fire at Nadgee, observers out to sea saw wallabies and kangaroos leap off cliffs into the sea to escape the fire; only to drown in the attempt (Newsome et al. 1975). Forty-one carcasses of wallabies and kangaroos were found immediately after the fire (Fox 1978).

During the fire at Boyicup, possums remained in their "habitat trees" in the majority of cases. Of the 4 brushtail possums radiotracked by Vellios (1981) during the fire at Boyicup, all remained in their "habitat trees". Two perished when their "habitat trees" ignited, presumably from asphyxiation, while the surviving two possums remained in their "habitat trees" until after midnight before they descended.

Some brushtail possums took refuge on the branches of "safe" trees immediately after the flame front had passed. This behaviour was, presumably, the result of the animal being forced from its hollow by ignition of the "habitat tree" (Plate 23). The probability of a possum surviving the immediate effects of fire seems to depend on the probability of its "habitat tree" surviving. This in turn depends on its condition and the intensity of the fire which it experiences (Section 3.1.5).

In a search of the area after the fire, 7 brushtail and 4 ringtail carcasses were found. A further 3 brushtail possums were found alive but severely burnt. The pads of their feet were swollen and their claws damaged to such an extent that climbing was prevented. These animals took refuge in holes in the ground created by the excavation of tree roots by the fire. Although mortality was high, some possums did survive (Plates 24).

On the night of the fire, both surviving possums in Vellios' (1981) study, moved out of the burnt area only to return to their original utilised areas the following night. One

Plate 23. A brushtail possum takes refuge on a safe branch as a "habitat tree", containing a radiotagged possum, burns in the background.

Plate 24. A severely burnt ringtail possum found after the fire. Note the swollen pads.

animal's utilised area straddled the boundary of the fire and it continued to use its utilised area as it had before the fire. The other, on returning to within the confines of the burnt area, remained there for the following 5 months. It did move its utilized area to a region where some trees had escaped defoliation and increased the size of its range from 3.22 ha to 7.77 ha, presumably due to the scarcity of food resources.

Although initial fire-induced mortality of animal populations may be high, some survive. However, the surviving population often experiences a rapid decline in numbers. This is particularly evident for small mammals (Cowley et al. 1969, Leonard 1972, Christensen and Kimber 1975, Recher et al. 1975, Newsome et al. 1975). Christensen (1980b) observed a similar decline in numbers of woylies and tammar wallabies following fire and Newsome et al. (1975) noted a decline in the numbers of wallabies and kangaroos in the year following the Nadgee fire.

Although I have no direct evidence to support the assumption that the surviving possum population suffered a post-fire population decline, for the following reasons I believe it was the case;

(i) the scarcity of the food resource - most trees were completely defoliated and the shrub layer destroyed - only in small isolated areas was browse found, and

(ii) increased rates of predation.

Because of the increased distances between feed trees and the reduction in the amount of crown through which possums could move, animals would be forced to spend greater portions of their time involved in terrestrial activities, particularly travelling. This, coupled with the reduction of ground cover, would lend itself to higher rates of predation.

A shortage of food and increased predation, caused by the reduction in the available cover, is attributed by Heislers (1974), Christensen (1980b) and Christensen and Kimber (1975) as responsible for the decline in mammal numbers following fire. Certainly a food shortage was evident as most trees in the burnt area were defoliated and the plentiful fox prints in the ash beds suggested that predation was common. Twenty-one fox scats were collected from the area and hair analysis revealed that 7 contained possum fur (Inions 1981c).

A shortage of shelter sites is not considered to influence post-fire population decline in this case. The decline is best described by the combination of the demographic models I and V of Newsome and Catling (1983), i.e.; acute shortage of food and increase in predators.

4.9.3. The long term effects of fire

Using the number of "habitat trees" in use per hectare as an index for population size, the possum population at Boyicup 32 months after the fire increased by about 300% on the population size before the fire and about 490% on the population size existing 3 weeks after the burn. At Yendicup the population decreased in size by about 6% (Fig. 40). This may be due to a population of possums becoming more active after a fire and using more "habitat trees", thus giving the impression that the population has increased. However, a past study indicates that this is unlikely (Inions 1981c) .An initial decrease in the size of a faunal population followed by rapid increase is a characteristic response to the fire-induced changes in habitat and food supply (Recher and Christensen 1981). All groups of mammals studied by Newsome et al. (1975), before, during and after the fire at Nadgee, became much more abundant 2 to 6 years after the fire, than before. The size and rate of regeneration of populations was related to body size; small, medium and large sized mammals reaching peaks of population in that order. The same has been reported for avifauna (Kimber 1974, Christensen and Kimber 1975) and heptofauna (Cogger 1972).

Seral responses, of faunal communities, to fire are absent in many cases (Catling and Newsome 1981) and Roberts (1970) found a sharp and persistent decline in the numbers of species in the understorey after a fire in a heathland in Eastern Australia. A seral response was absent or severely truncated for recolonising fauna at the Nadgee Nature Reserve after fire despite the peaks in abundance for different species (Newsome et al. 1975). Conversely, Fox and Mckay (1981) found a clear seral response by small mammals on their heathland site. Why some responses are seral and not others, why some species should change greatly in numbers but not others and why species diversity should change only sometimes is not understood.

Changes in the composition of communities with developing succession are seen more clearly in North America, with its richer fauna and clear seral response of regenerating vegetation (Cook 1959). In Australia, responses are often masked, perhaps due to equilibria between competing species, or suites of species, being interrupted too frequently by fire for clear succession to emerge (Huston 1979). Too few data exist to determine if the responses of the brushtail and ringtail possums are seral.

4.9.4 Temporal difference in the relative abundance of possum populations

Shelter sites, possibly limiting before the fire, were not limiting immediately after. Many hollows were created directly by the fire (Section 4.4) and less fauna was available to occupy them. If availability of "habitat trees" is limiting, the possum population would be expected to increase in direct proportion to the increased availability of the "habitat trees" until some other factor or combination becomes limiting. Consequently, a graph of population size against time lapsed since the fire would be expected to plateau at the point of limitation (Fig. 40).

A decrease in predation may have caused the increse although this does not seem likely. The main predators of possums in the study area are the fox and the dingo, both of which have large range areas (Strahan 1983). As the fire covered a small area, it probably had no effect on the abundance of these predators. Consequently, any change in predation due to fluctuations in the fox and dingo populations would occur equally at the Yendicup site.

The third explanation involves a change in the qualty and/or quantity of the food source resulting from the effects of fire.

The quality of habitat for arboreal folivores, as defined by nutrient content of the foliage, is notoriously poor in south-west Western Australia. The distribution of mediterranean climatic zones correlates with soils exceptionally poor in nutrients (Kruger et al. 1983) and the mediterranean region of Western Australia is recognised as one of the two most nutrient-impoverished of the six mediterranean ecosystems (Lamont 1983). However, the biomass of the jarrah forest is equal to or greater than other forests with ecosystems which have higher nutrient levels (Hingston et al. 1980/81).

Not only is the jarrah tree proficient at obtaining and utilising nutrients: it has the ability to alter its surrounds in a manner which gives itself a competitive advantage over its floral competitors. Such a situation is considered consistant with the "inhibition" model proposed by Connell and Slatyer (1977).

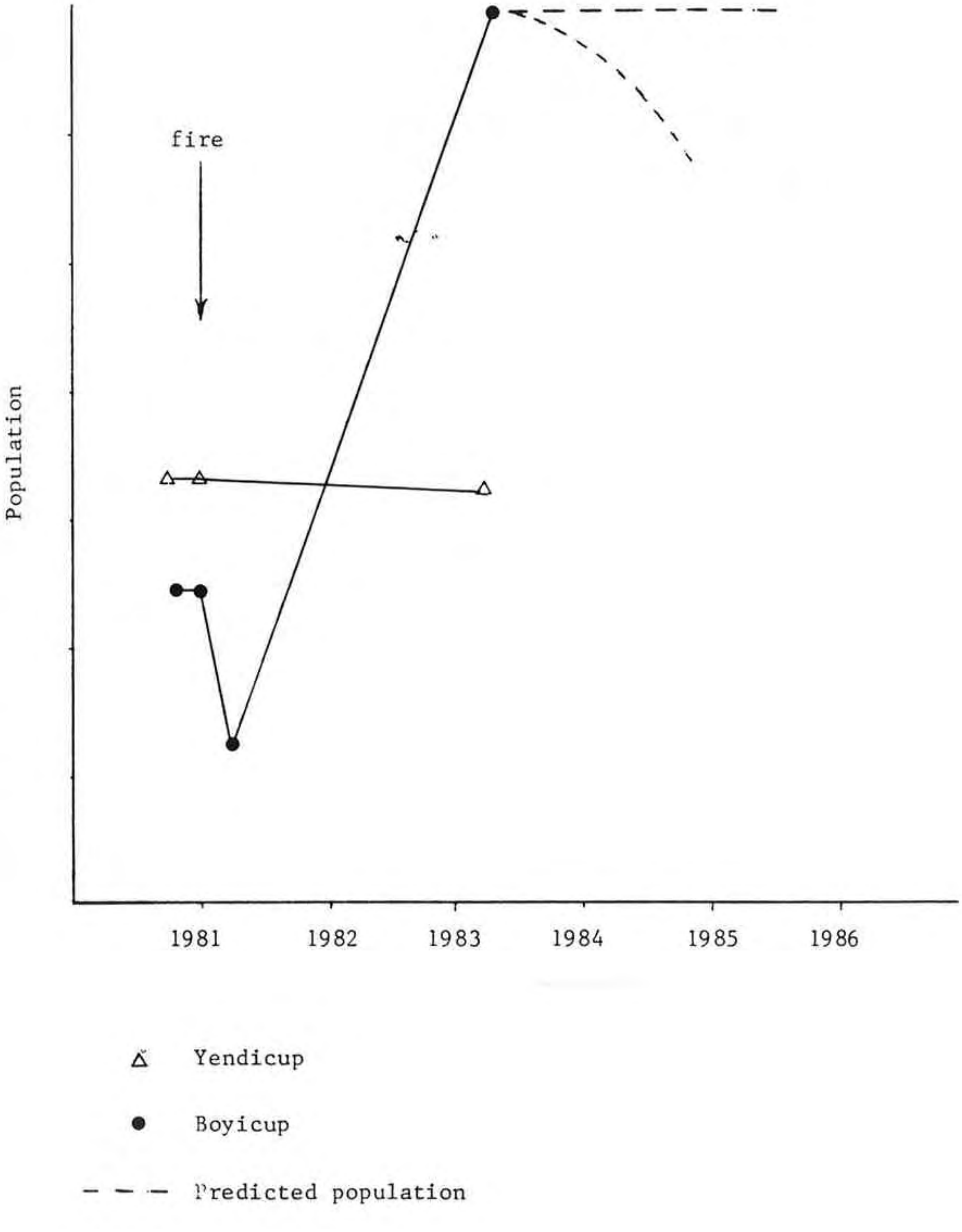
The environment, low in available nutrients, induced by the nature of the eucalypt, may be altered by fire. This is due to a combinaton of factors including the removal of competition, an increase in soil pH, the availability of ash nutrients, breakdown of inhibitory compounds, stimulated mineralisation of nitrogen and phosphorous in soil and the effect of partial soil sterilisation on the soil microflora (Humphreys and Craig 1981). Not only do more nutrients become available after a fire but they are recycled more rapidly (Groves 1983, Rundel 1983). Understorey species, which develop prolifically after a fire, may act to delay the re-introduction of the inhibition model by contributing nitrogen to the ecosystem, acting as a nutrient soak which conserves nutrients mobilised within the soil, and by depositing a more nutrient-rich litter which dilutes the effect of eucalypt litter.

Whether the inhibition model is in place or not will affect the quantity of available nutrients in the jarrah forest. The amount of nutrients available in the system in situ would be expected to be reflected by the foliar nutrient levels (Braithwaite 1984, Van Loon and Love 1973) and thus reflect the quality of the habitat for possums.

The increase in the possum population may be a direct result of the increased quality of the habitat due to the removal or modification of the inhibition model and the subsequent release of nutrients. If this is the case, a graph of population size against time lapsed since the fire might show a slow decline after an early peak as more and more nutrients become unavailable, as the influence of the inhibition model is restored (Fig. 40). If this is the case, then the activation of the inhibition model not only enables the eucalypt to compete successfully but also affords the forest some protection by lowering the carrying capacity for folivores.

To determine whether the availability of "habitat trees" or the quality of the habitat is limiting to populations of possums, further assessment of the number of "habitat trees" ha^{-1} and the foliar nutrient values of the two study areas is required.

Figure 40. Fluctuations in the populations of possums with time.



CHAPTER FIVE - IMPLICATIONS OF THE RESULTS TO MANAGEMENT

5.1 INTRODUCITON

Two points need to be stressed. The first is that the recommendations made are based on the limited knowledge gained in an exercise which examined only one portion of the very interactive and complex community of fauna which uses hollows in trees. The second is that all studies presented in this thesis were undertaken within the Perup Fauna Management Priority Area, therefore, the results may only apply to that area. Their relevance to other ares of the jarrah forest remains speculative.

5.2 RETENTION OF "HABITAT TREES"

A "habitat tree" is any tree, regardless of size, age, species or condition, which supports a hollow of adequate dimensions to enable its use by possums. Only the depth of the hollow significantly affects the frequency of use of the tree and trees used frequently may be identified in the field by the prominence of the scratchtrack on the bole (Plate 1). The prominence of the scratchtrack can be related to the depth of the hollow and trees with prominent scratchtracks support hollows with superior dimensions.

The distribution of "habitat trees" is random and this pattern should be maintained.

The condition of the "habitat tree" should be considered as it affects the degree of damage it will sustain in a fire. The condition class may be subjectively determined in the field (see Appendix 3). The expected damage a "habitat tree" will sustain during a fire may be predicted using the condition class, fire intensity and the equation presented in Section 3.1.5.

Which habitat variable, or combination, limits possum populations was not determined during this study. If "habitat trees" are limiting, the more retained per hectare the greater will be the possum population, until some other factor becomes limiting. If the quality of the habitat is limiting, the base level for the number of "habitat trees" retained per hectare will vary with nutritional quality of the habitat and will, therefore, be related to the time since the last major fire.

5.3 THE IDENTIFICATION OF THE QUALITY OF THE HABITAT

Possum diversity and abundance are greatest in habitats characterised by high foliar nutrient values (Braithwaite 1984, Section 3.2.6). If the quality of the habitat is limiting it will reflect the abundance of the possums in the area and thus, providing there is no shortage of "habitat trees", the number of "habitat tres" in use ha^{-1}. High quality habitat will show larger numbers of "habitat trees" ha^{-1} than poor, which may be used as a simple field guide to habitat quality. Further work is required to develop correlations.

5.4 LOGGING OPERATIONS

Both study areas have been subjected to group-selection type logging and both areas support viable populations of possums.

The group-selection logging operations in jarrah forest generally only removed sound jarrah trees with a d.b.h.o.b. >40 cm although this diameter limit has varied with time (Abbott and Loneragan in press). This leaves marri and unsuitable jarrah to develop into or remain as "habitat trees" in the absence of intensive silvicultural operations.

In the absence of stand improvement operations, retained marri and jarrah trees provide enough hollows to support viable populations of possums. In the 1920's and 1930's, most of the high quality jarrah forest was given a 'regeneration cleaning' in which worthless jarrah and marri were removed (Lane-Poole, n.d. in Abbott and Loneragan in press). However, regeneration cleaning and stand improvement ceased due to shortages of labour during World War II and were not resumed. During the

1970's all trees of d.b.h.o.b. > 60 cm were removed in stands of mean mature co-dominant height > 20 m during logging operations, unless regeneration was inadequate for restocking. The thinning of stands of immature jarrah trees resulting from the silvicultural treatment of the 1930's, removed or killed useless or cull trees and was practised in intensive management units since 1967 (Abbott and Loneragan in press) but ceased in the mid 1970's. The current prescription for silvicultural treatment of jarrah forest is designed to maintain the most rapid diameter increment consistent with maximum wood production (Bradshaw 1983). In those areas where silvicultural treatment required the removal of large useless trees, "habitat trees" may be absent or in short supply.

After logging, regeneration of jarrah forest comes from the release of ground coppice. Halving the basal area of an area of jarrah forest will result in about one third of the ground coppice developing into sapplings (Abbott and Loneragan 1984b). In areas where an adequate ground coppice is available, logging which removes sufficient basal area will promote the development of saplings, thus diversifying the vertical structure of the forest stand. Jarrah saplings are the favoured stand component of the western ringtail possum.

5.5 FIRE

Although fire of high intensity is initially detrimental to both the possum population and the existing resource of "habitat trees", it is beneficial in the longer term as it increases the availability of hollows by direct excavation of branches.

Fires of low intensity (< 350 kW m^{-1}) do not seem to have a marked effect on the availability of "habitat trees".

Fires of high intensity destroy the inhibition model and increase the quality of the habitat suitable for possums, for a number of years after the fire.

5.6 MISCELLANEOUS

The western ringtail possum is a sub-species with morphological and behavioural differences from the nominate race, and may warrant specific status (Winter 1978, McKay 1984). The lack of information about this unique and rare possum (Government Gazette 1983) warrants further investigation into the effects of some forest management practices on its biology.

Any further study which requires data about the position of an animal in space and time and used to identify its preferred habitat would benefit from using a radiotelemetry procedure as described by F.R.l. (1980).

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APPENDIX I - GLOSSARY *

age class distribution, normal. A complex series of age classes in such proportions as will permit equal volumes from annual or periodic fellings under the given rotation and silvicultural system.

available fuels. The part of a fuel mass sufficiently low in moisture content for ignition and burning to take place.

basal area. The area of the cross seciton of a stem, usually of a tree at breast height (1.3 m above ground on the high side of the tree). When applied to a crop, the sum of the basal areas of all stems on the total basal area per unit of area.

basal area prism. An optical wedge used to estimate the basal area of a forest stand.

basal area sweep. The process of measuring stand basal area with an optical prism or relescope from a plot having no fixed area, only a central point.

block. A main territorial division of a forest, generally bounded by natural features and bearing a local proper name.

buffer. An area of land managed in such a way as to protect another area from outside influences.

diameter, breast height. The diameter of a tree measured at the standard reference point, nominally 1.3 m above ground on the uphill side of the tree, or at the nearest representative point.

epicormic shoot. A shoot originally from a dormant bud, and arising on the tree trunk or an older branch.

fire regime. The history of fire in a particular stand including the frequency, intensity and season of burning.

flame height. The vertical distance between the tip of the flame and the ground or fuel bed.

over mature. A tree or stand in which, as the result of age, growth has almost entirely ceased and is now balanced by decay and deterioration.

sapling. A young tree from the time it reaches 1 metre in height until the trunk reaches 15 cm in D.B.H.

scorch. Injury to bark, flowers, foliage or fruit by fire, excessive sun, dry, cold, salt-laden, fume-laden, or unduly strong winds, or unbalanced nutrition.

stag. A standing dead tree.

stand. An aggregation of trees or other growth sufficiently uniform in composition, age, arrangement and condition as to be distinguished from adjacent forest or growth.

* after McKinnell (1982).

APPENDIX II

LIST OF FAUNA SPECIES RECORDED IN THE STUDY AREA **

LIST OF VERTEBRATE SPECIES

MAMMALS

Grey Kangaroo (*Macropus fuliginosus*)
Brush Wallaby (*Macropus irma*)
* Tammar (*Macropus eugenii*)
* Woylie (*Bettongia penicillata*)
Brush Possum (*Trichosurus vulpecula*)
* Common Ringtail (*Pseudocheirus peregrinus*)
Pygmy Possum (*Cercartetus concinnus*)
Bandicoot (*Isoodon obesulus*)
* Native Cat (*Dasyurus geoffroii*)
Brush-tail Phascogale (*Phascogale tapoatafa*)
Mardo (*Antechinus flavipes*)
Common Dunnart (*Sminthopsis murina*)
* Numbat (*Myrmecobius fasciatus*)
Southern Bush Rat (*Rattus fuscipes*)
Water Rate (*Hydromys chrysogaster*)
Lesser Long-eared Bat (*Nyctophilus geoffroyi*)
Nyctophilus major
Gould's Long-eared Bat (*Nyctophilus gouldii*)
Gould's Wattled Bat (*Chalinolubus gouldii*)
Chocolate Bat (*Chalinolubus morio*)
Little Bat (*Eptesicus pumulis*)
Tasmanian Pipistrelle (*Pipistrellus tasmaniensis*)
White-striped Bat (*Tadarida australia*)
Little Flat Bat (*Tadarida planiceps*)
Echidna (*Tachyglossus aculeatus*)
Cat (*Felus catus*)
Dingo (*Canis familiaris*)
Mouse (*Mus musculus*)
Rabbit (*Oryctolagus cuniculus*)
Fox (*Vulpes vulpes*)

* Species which are rare, or otherwise in need of special protection.

** After Christensen et al. (in press).

APPENDIX III. DESCRIPTION OF SUBJECTIVE GROUPINGS OF "HABITAT TREES" CHARACTERISTICS.

HABITAT TREE CONDITION:

STATE	CLASS	DESCRIPTION
DEAD	OLD	Less than 1/3rd of the bole covered with bark.
	RECENT	Greater than 1/3rd of the bole covered with bark.
ALIVE	POOR	Decadent or diseased crown, usually receding. Low leaf area index
	FAIR	Crowns less than vigorous, some in recession while other remain stagnant
	GOOD	Healthy vigorous crowns with a high leaf area index.

SCRATCHTRACK INTENSITY

CLASS	DESCRIPTION OF SCRATCHTRACK
POOR	Visible though discontinuous for the length of the bole. Shallow path worn into bark.
FAIR	Visible and continuous for the length of the bole. Shallow path worn into bark.
GOOD	Readily visible, continuous the length of the bole. Deep path worn into the bark but not exposing inner cambrium
VERY GOOD	Readily visible even at a distance, continuous the length of the bole. Deep path worn down to inner cambrium

APPENDIX III Contd..

DAMAGE CLASSES

STATE	CLASS	DESCRIPTION
INHABITABLE	UNBURNT	Blackening of the bole, some scorch of lower branches.
	HEAVY	Complete crown scorch and/or defoliation may create hollow butt
UNINHABITABLE	SEVERE	Possum hollow destroyed, tree still standing.
	DESTROYED	Tree burnt to ground level.

APPENDIX IV: BURNING CONDITIONS

DATE: 24/1/81

Wind speed at 1.5 m above ground level : 1130 h to 1245 h - N.E. @ 3.3 km h^{-1}

: 1245 h to 1530 h - S.E. @ 3.8 km h^{-1}

Max. temperature : 26.5^{o}c at 1400 h

Min. R.H. % : 35% at 1400 h

Fine fuel moisture content % : 5.6%

Soil profile moisture content %
@ 2 cm depth : 3.6%
@ 10 cm depth : 12.5%

Atmospheric conditions : Unstable below the inversion layer, which was between 600 m and 1000 m above sea level, and stable above.