MANAGEMENT OF THE ECOLOGICAL VALUE OF ROADSIDE VEGETATION

by
Timothy John Wilson BA (Hons)

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DECLARATION

I hereby declare that none of the material contained in this thesis has been accepted for the award of any other degree or diploma in any institution and that, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference has been made in the text of the thesis. I consent to this thesis being made available for photocopying and loan, if applicable, and if it is accepted for the award of the degree.

Timothy John Wilson
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ABSTRACT

Seventy-one roadside corridors, four patch edges adjacent to roads and one patch core within the Coranda Environmental Association were sampled using line transects to examine changes in species composition and cover with distance from edge.

The sites were placed into one of 32 groups based on edge age; disturbance type; disturbance age; corridor width and transect location. Analysis was undertaken within groups to identify edge and core communities.

It was anticipated that there would be variation in the degree of edge effect commensurate with the age of the edge, time since disturbance and corridor width. Consequently intergroup analysis was undertaken to determine whether any of these variables individually affected species composition and cover.

Native species did not exhibit any response which could be interpreted as edge effect. Exotic species were regarded as an indicator of edge disturbance and were present in 28 of the 32 groups. The variation in location and extent of exotic invasion suggested that edge width could be as narrow as one metre or as wide as 500 m.

None of the variables accounted for all the variation in exotic or native species cover and it was concluded that this was probably due to variation in factors such as soil nutrient status, cover of native vegetation and litter. The overall trend suggested that senescent stands were most likely to become edge communities. Consequently it is suggested that the major threat to the long term conservation value of roadside vegetation is lack of a natural disturbance regime. Management methods should focus on maintenance of species richness and cover through the use of prescribed burning every 20-30 years. Other management issues to address are the use of roadsides as borrowpits and the invasion of bridal creeper.

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1. INTRODUCTION

A landscape corridor has been defined by Forman (1983, p. 376) as *"a strip of land which differs from the surroundings or matrix on each side. The corridor may be isolated or may be attached to a particular landscape element"*. Five different types of landscape corridors can be distinguished on the basis of their origin: environmental resource corridors (e.g. creeklines); spot disturbance corridors (e.g. firebreaks cleared in stands of native vegetation); planted corridors (e.g. windbreaks); regenerated corridors (e.g. fencerows); and remnant natural corridors (e.g. roadside vegetation left after clearing) (Forman, 1983). Bridgewater (1987) has used the term *ecolines* for these landscape corridors, which occur at a local landscape level, in order to distinguish them from *geolines* which are apparent at a continental level (eg. The Great Dividing Range).

A remnant natural corridor is an ecoline created by clearance of the surrounding natural land in such a way that only a strip of natural land remains in a matrix of human-dominated (i.e. urban/rural or cultural) land. This study is concerned with such remnant natural corridors of roadside vegetation and their long-term conservation value in human-dominated landscapes.

1.1 Conservation Value

Extensive clearance of natural land has occurred in many areas of Australia such as the Southern Agricultural Region of South Australia, the Western Australian Wheatbelt and the Wimmera of Victoria. The end result of clearance is a human-dominated landscape in which small patches and corridors of natural land occur as isolates or form networks in a matrix of urban/rural land. For example only four percent of the original natural land remains in the Peninsula Uplands Region of the

Mount Lofty Block Province, South Australia (Taylor, 1987). The majority of this four percent occurs as patches less than 20 hectares in size.

Because of its scarcity, all remnant natural land is of conservation value in human-dominated landscapes. Thus, in recent years, even the small strips of natural land occurring as corridors along roadsides in South Australia have assumed appreciable conservation value (Palmer and Lewis, 1987)

The conservation value of remnant natural corridors is determined by the benefits they may provide and costs they may incur. These can be placed into three categories. First, there are economic factors such as increased productivity from agricultural land and lower road maintenance costs. Second, there are social factors which include historical, cultural, recreational and educational benefits. Finally, there are ecological factors such as the value of remnant natural corridors as part of a nature reserve system for flora and fauna.

This study is primarily concerned with the ecological factors which determine the conservation value of remnant natural corridors along roadsides. It is, however, worth examining the social and economic factors before enlarging on the ecological factors in order to demonstrate how remnant natural corridors of roadside vegetation are of benefit to the whole community. For example, farmers may not see the necessity of retaining remnant natural corridors for flora and fauna, but they may appreciate the increased productivity provided by the shelter of remnant natural corridors, or the potential for preventing soil salinisation.

1.1.1 Economic Factors

The economic benefits of remnant natural corridors are of direct concern to individuals such as the rural landholder and the highway engineer. Soil stability, stock and crop shelter, firebreaks and weed and pest control may be directly related to the presence of remnant natural corridors.

A major value of remnant natural corridors is the stabilising effect they can have on both public and private land (Grieves and Lloyd, 1984). Water erosion causes siltation of drains and culverts in the road reserve, ultimately reducing their efficiency. The resulting overflow from blocked drains can subsequently cause damage to the other utilities present in the road reserve, such as underground cables and the road surface (Good and Nebauer, 1976). Erosion within the road reserve may extend to adjacent agricultural land, resulting in siltation of dams and creeks, gullying and removal of top soil and the consequent loss of production (Hedberg, 1977; Grieves and Lloyd, 1984).

Remnant natural corridors can provide a windbreak for crops (Breckwoldt, 1986). Protection by an efficient windbreak reduces evaporation, sand blasting and temperature stress by stabilising soil and air temperature, resulting in increased productivity. Lynch, Elwin and Mottershead (1980) found that significantly less evaporation of soil water occurred in sheltered paddocks resulting in higher herbage production.

The buffering effect of a remnant natural corridor may extend as much as 10 times its height. Bird, Lynch and Obst (1984) reported crop and pasture yields as much as 30 percent greater in the downwind zone of shelterbelts. According to Breckwoldt (1986) the benefits of a shelterbelt outweigh any loss of production due to root competition or rain interception; both reasons often cited for the removal of remnant natural corridors.

Livestock may also benefit from the shelter provided by a remnant natural corridor. Bird *et al.* (1984) reported a 31 percent increase in wool production in sheltered paddocks. The sheep in these paddocks were, on average, six kilograms heavier. Shelter is also important for reducing neo-natal lamb deaths. Egan, McLaughlin, Thompson and McIntyre (1972) found that only 8.5 percent of the lambs in sheltered paddocks died, compared with 22 percent in unsheltered paddocks.

The issue of remnant natural corridors as firebreaks or as agents in fire suppression, especially along roadsides, is a contentious one. The danger of remnant natural corridors acting as a wick was expressed by landholders following the 1983 Ash Wednesday bushfires in South Australia (*"The Advertiser"*, 1983). Contrary to this opinion, Stevens (1983a) concluded that remnant natural corridors along roadsides are less flammable than roadside strips of annual alien weeds and grasses and are therefore less likely to ignite. Once alight, however, a remnant natural corridor potentially provides a much larger fuel load.

Careful management of remnant natural corridors can ensure that they do not become a fire threat. Rather they may act as firebreaks. The danger created by a high fuel load can be ameliorated by prescribed burning (Breckwoldt, 1986). Prescribed burning has the added benefit of regenerating communities adapted to fire (Gill, 1977). Management of remnant natural corridors is less expensive than the management of grassed or weed-infested roadside strips which must be maintained at least on an annual basis (South Australian Roadside Vegetation Committee [SARVC], 1984).

There is an economic incentive for both landholders and government bodies to ensure that remnant natural corridors do not become weed infested. Once established, weeds are difficult and expensive to remove and can easily invade adjacent crop and pasture (SARVC, 1984). Weed infestation increases maintenance costs and the risk of fire and decreases the conservation value. Weed invasion from remnant natural corridors in pasture may reduce the amount of palatable fodder in pasture and the productivity of land under crop, as well as imposing the unnecessary cost of weed eradication.

Undisturbed remnant natural corridors can successfully resist weed invasion (Breckwoldt, 1986). Cooke (1983) noted that the presence of horehound (*Marrubium vulgare*) was rare in undisturbed remnant natural corridors along roadsides in the South Australian mallee, but was a common problem on cleared roadsides and disturbed remnant natural corridors along roadsides. Similarly, Lane (1976, 1979), working on the Mornington Peninsula in Victoria, found that relatively fewer noxious weeds occurred along roadsides where trees had been retained. This led Lane (1979) to conclude that the maintenance and establishment of trees should be part of the efficient control of noxious weeds on roadsides. This idea has been adopted on Southern Eyre Peninsula, South Australia as a long term means of weed control (S. Lewis pers. comm.). On private land, where stock can graze within remnant natural corridors, thus facilitating the spread and establishment of weeds, fencing is recommended to ensure minimal disturbance (Breckwoldt, 1986).

1.1.2. Social Factors

The social benefits of remnant natural corridors may be categorised as: aesthetics; recreation; education; and safety.

Although aesthetic quality is a subjective landscape attribute, Grieves and Lloyd (1984) suggest that many people travel to specific areas for the pleasure to be derived from the aesthetic beauty of the remnant natural corridors along roadsides. Similarly, pleasure can be derived from the patchwork effect that fencerows of remnant natural corridors lend to the agricultural landscape. In addition to the aesthetic quality of remnant natural corridors of roadside vegetation, they also provide shade and shelter at parking bays, and relief from the monotony of driving through an agricultural landscape (SARVC, 1984).

Remnant natural corridors may be of heritage or scientific significance and as such are of educational benefit to the community. Breckwoldt (1990) cites the Yarra gum (*Eucalyptus yarrensis*), the small-leaved gum (*E. parviflora*) and the purple diuris (*Diuris punctata*) as examples of endangered species which only occur on public land in remnant natural corridors along roadsides. Similarly, the *E. cneorifolia - Melaleuca uncinata* association on Kangaroo Island, South Australia is unreserved except for the remnants that occur on public land along roadsides (Mowling and Barritt, 1981).

The retention of remnant natural corridors along roadsides may contribute to road safety. Good and Nebauer (1974), National Association of Australian State Road Authorities [N.A.A.S.R.A.] (1982), and Grieves and Lloyd (1984) list the following safety benefits of remnant natural corridors along roadsides. Remnant natural roadside vegetation may:

a) reduce headlight glare and eyestrain;
b) cushion the impact of an uncontrolled vehicle:
c) reduce the velocity of crosswinds and minimise the amount of dust;
d) reduce the chance of a vehicle rolling;
e) reduce the monotony of driving;
f) be used to differentiate the functions of roads, ramps and pedestrian pathways;
g) delineate the road alignment, especially on curves and crests.

These benefits, however, are presumably limited to certain vegetation formations. For example, it is unlikely that saltbush-bluebush low-shrubland would significantly reduce road dust or cushion the impact of an uncontrolled vehicle. In addition, these benefits only pertain to well-managed remnant natural corridors of roadside vegetation. Overhanging limbs and otherwise encroaching vegetation are a potential hazard to traffic and should be removed in the interests of safety.

1.1.3 Ecological Factors

Forman and Godron (1981, p. 733) define a natural landscape as:

> *"... a kilometres wide area where a cluster of interacting stands of ecosystems is repeated in similar form ... The landscape is formed by two mechanisms operating together within its boundary - specific geomorphological processes and specific disturbances of the component stands."*

In contrast to a natural landscape, a human-dominated landscape (Taylor, 1987) is one in which the majority of interacting stands of native vegetation have been cleared and replaced by cultivated vegetation and human constructions. All that remains of the contiguous interacting stands of native vegetation, characteristic of a natural landscape, are remnant patches and corridors embedded in a cultural matrix. Therefore a human-dominated landscape is usually highly heterogeneous, composed of a number of different structural landscape elements, such as agricultural fields, urban areas, roads, and remnant natural land (Godron and Forman, 1983). In a human-dominated landscape much of the native vegetation is relict vegetation (Taylor, 1990). Such vegetation often has a canopy layer dominated by native plant species but an understorey dominated by adventive or cultivated plant species.

The component structural elements of a human-dominated landscape which are important for the conservation of flora and fauna are the remnant patches and corridors of natural vegetation. These structural elements potentially form a network of natural habitat for native flora and fauna.

Within this network, large patches provide areas of natural land in which the normal cycles of disturbances and regeneration/recolonisation may still occur. In small patches, however, disturbance may have disastrous effects on remnant biological communities and especially their faunal inhabitants. Small patches contain small populations which may become extinct due to fire, disease or other disturbance events (Simberloff and Cox, 1987). In order to prevent such extinction, dispersal between patches is essential. It has been suggested that corridors potentially allow dispersal to take place by providing a bridge for crossing the inhospitable environments of human dominated land (Merriam, 1984). For this reason, corridors may be important structural elements for the conservation of flora and fauna in human-dominated landscapes.

The initial impetus for the study of corridors in human-dominated landscapes came from the equilibrium theory of island biogeography (MacArthur and Wilson, 1967). Island biogeography theory states that the number of species on an island is a dynamic equilibrium between immigration and extinction. Thus, over time the species composition changes but the same equilibrium number of species is maintained. The rates of immigration and extinction are determined by an island's size and isolation. The larger the island the lower its extinction rate; the more isolated the island the lower its immigration rate.

According to this theory, corridors decrease the isolation of islands and increase their immigration rates. Therefore two islands of equal size and distance from a mainland would differ in their equilibrium number of species if one were connected to the mainland by a corridor.

Diamond (1975) applied the equilibrium theory to the design of nature reserves. He assumed that nature reserves were islands surrounded by a sea of altered habitat. On the basis of this assumption Diamond suggested that, wherever possible, corridors should be maintained between reserves in order to increase species richness. Corridors can increase species richness by providing habitat, increasing home range, allowing recolonisation after extinction, increasing population size and by allowing migration between patches.

In human-dominated landscapes remnant natural corridors can provide valuable additional habitat for flora and fauna. In Victoria, Loyn and Middleton (1981) found 85 species of bird in a remnant natural corridor of roadside vegetation 2.5 kilometres long and 70 metres wide. Arnold, Algar, Hobbs and Atkins (1987) surveyed 22 remnant natural corridors of roadside vegetation in the Kellerberrin District, Western Australia. The corridors varied in width from 3.0 metres to 46.2 metres. Nineteen species of terrestrial fauna and 41 species of avifauna were recorded at these sites. In Minnesota, U.S.A. planted shelterbelts provided alternative habitat for avifauna and small mammals that previously inhabited the now predominantly cleared natural land. Although the shelterbelts are human-manufactured, 11 species of mammals (Yahner, 1982) and 87 species of avifauna (Yahner, 1983a) were recorded as utilising the sites for foraging and predator avoidance.

Demographic stochasticity is a major problem for small populations at or below the minimum viable population size (Simberloff and Cox, 1987). In Ontario, Canada, movements along fencerow corridors between remnant patches, by white-footed mice (*Peromyscus leucopus*) and eastern chipmunks *(Tamias striatus)* suggest that fencerows provide corridors for recolonisation after extinction (Wegner and Merriam, 1979). *P. leucopus* was recorded five times to have moved between traplines in separate fencerows. A subsequent study by Middleton and Merriam (1981) demonstrated that *P. leucopus* recolonised "extinct" patches by utilising the fencerows as migration corridors for moving between patches. Eastern chipmunks (*T. striatus*) showed similar responses to that of white-footed mice. Individuals were caught three times moving between remnant natural patches and fencerows, but were never caught in fields (Wegner and Merriam, 1979). Henderson, Merriam and Wegner (1985) found that a local extinction in one remnant natural patch was readily recolonised by individuals from surrounding remnant natural patches. The connecting fencerows acted as both a migration corridor and a population source. The results for both *P. leucopus and T. striatus* concur with those of Merriam (1984) who concluded that the chance of population survival in remnant natural patches is increased by the presence of corridors.

In the Western Australian Wheatbelt, the value of remnant natural corridors is exemplified by the dependence of Carnaby's cockatoo (*Calyptorynchus funereus latirostris*) on such corridors for migration between nesting habitat and food habitat (Saunders and Ingram, 1987). Carnaby's cockatoo requires woodland vegetation for nesting and heath vegetation for feeding. Due to clearance these habitats are often separated by expanses of agricultural land. Therefore it is necessary for individuals to migrate some distance from nesting habitat to food habitat. Saunders and Ingram (1987) attribute the survival of populations of the species, in part, to the presence of remnant natural corridors along roadsides and railway lines which act as navigation aids directing the birds from habitat to habitat.

Remnant natural corridors do not only provide ecological benefits in human-dominated landscapes. Simberloff and Cox (1987) suggest six potential disadvantages of incorporating corridors into a conservation strategy.

First, corridors may allow wildfire, introduced predators or contagious diseases to migrate between reserves. Any of these catastrophes could result in population extinction.

Second, corridors, because they are narrow, increase the exposure of animals to predation. For example, in southern Wisconsin, U.S.A., Ambuel and Temple (1983) found that fencerow corridors had high densities of common grackles (*Tusicalus quiscula*) which prey on eggs and nestlings. Simberloff and Cox (1987) suggest that human predation by poachers could also be a possibility.

Third, corridors not only transport species which require conservation, but also those that do not. For example, Ambuel and Temple (1983) suggested that corridors act like a funnel, attracting opportunistic species such as predators, competitors and brood parasites, including common grackles, red-winged blackbirds (*Agelaius phoeniceus*), starlings *(Sturnus vulgaris)* and brown-headed cowbirds (*Molothrus ater)* into remnant natural patches. Similarly, in Ohio, U.S.A., Whitney and Somerlot (1985) noted that only opportunistic species of flora occupy narrow fencerows, thus allowing their migration between remnant natural patches.

Fourth, corridors along roadsides are exposed to increased levels of lead and other heavy metals. Fauna utilising such corridors may be prone to increased mortality due to lead poisoning. In addition, fauna inhabiting roadsides risk the possibility of death by vehicle collision (Oxley, Fenton and Carmody 1974).

Fifth, there are economic considerations which must be addressed. Harris (1985, *in* Simberloff and Cox, 1987) suggests that, in order to preserve corridors and their benefits, high bridges over rivers and highways should be considered. Simberloff and Cox (1987) argue that such constructions could cost US$6.86 million or more. Further, if one considers the continued maintenance costs, then the cost of preserving such a corridor is even more expensive. It may be easier and cheaper to physically translocate species in such cases.

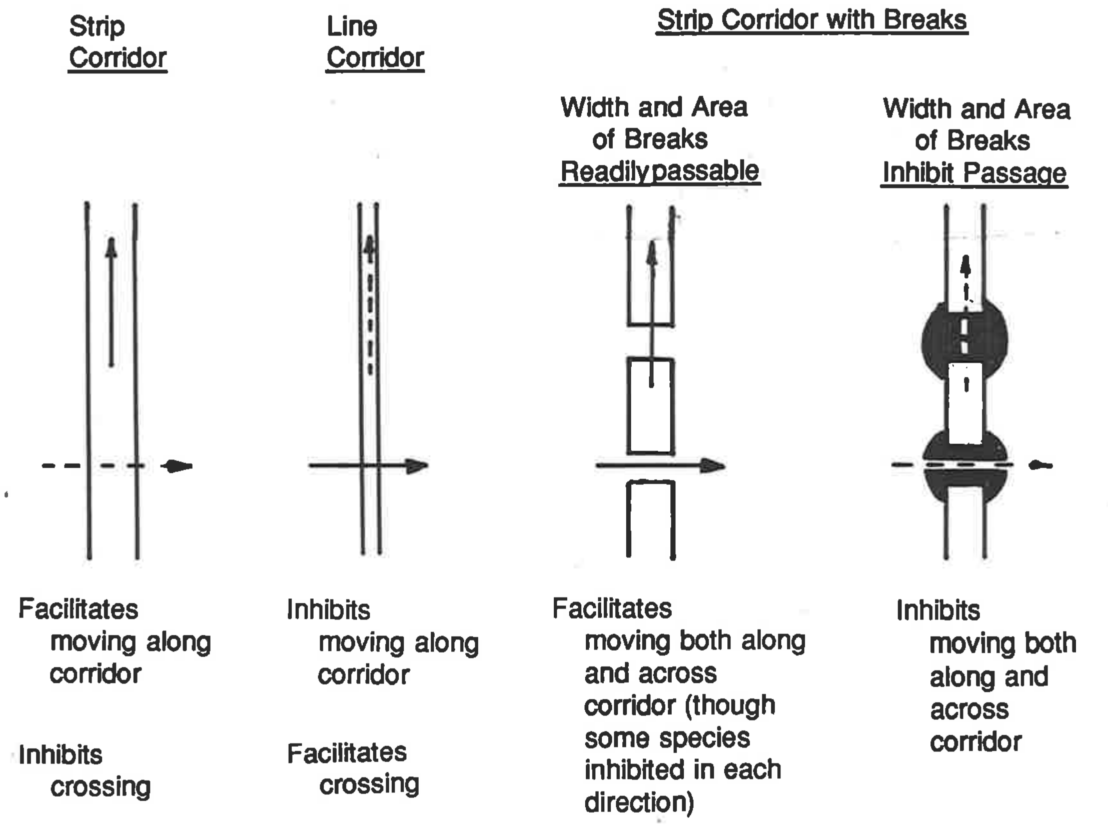
Finally, there are genetic considerations. Gene flow between separated populations is not necessarily desirable. There is the likelihood that local genetic variants of a species will be lost. This may affect the ability of a species to adapt to changing environmental conditions, and could ultimately result in the loss of two taxonomically different varieties of a species (Soule and Simberloff, 1986).

Several factors can limit the ecological benefits associated with remnant natural corridors. The occupation of remnant natural corridors by flora and fauna is determined by their internal and external structure (Forman, 1983) (Figure 1). The internal structure is defined in terms of vegetation structure and floristic composition. External structure is defined by factors such as the width and continuity of the corridor. Therefore the conservation value of all remnant natural corridors is not equal due to variations in their internal and external structural features.

Yahner (1982; 1983a,b) working in Minnesota, U.S.A., studied the utilisation of microhabitats in shelterbelts by terrestrial and avian fauna. The results show a close relationship between the internal factors of vegetation structure and floristic composition and the species present. For example, white-footed mice (*Peromyscus leucopus*) utilise habitat with dense woody understorey, low density of forbs and large overstorey trees, whereas the meadow vole (*Microtus pennsylvanicus*) utilise open areas of shelterbelts away from woody vegetation. Avifauna also were found to respond to vegetation structure and floristic composition. Spruce trees are favoured by mourning doves

Figure 1

Hypothesised effect of remnant natural
corridor types on species
movement (Forman, 1983)


Strip Corridor
Line Corridor
Strip Corridor with Breaks
Width and Area of Breaks Readilypassable
Width and Area of Breaks Inhibit Passage
Facilitates moving along corridor
Inhibits crossing
Inhibits moving along corridor
Facilitates crossing
Facilitates moving both along and across corridor (though some species inhibited in each direction)
Inhibits moving both along and across corridor

(*Zenaida macoura*), american robins (*Turdus migratorius*) and ring-necked pheasants (*Phasianus colchicus*). Pines attracted flycatchers (*Empidonax spp.*) and ruby-crowned kinglets (*Parus atricapillus*). Both spruce and pine provided suitable nesting sites for black-capped chickadees and dark-eyed juncos (*Junco hyemalis*).

In England, Arnold (1983) found that season as well as hedgerow structure influences the number and type of birds utilising a site. Hedgerow structure was defined as the length, height, width and cover of hedges; the length, depth, volume and cover of ditches; and the number of shrub and herb species in both. Short hedges had 12 species, tall hedges 17 species and narrow strips of woodland 19 species of avifauna. Specifically, tits favoured hedges with trees; wrens and robins favoured hedges with a diversity of shrub species, whilst song-thrushes favoured hedges with few shrub species. Therefore, as with shelterbelts, internal hedgerow structure is a major determinant of faunal species composition.

In the Western Australian Wheatbelt, Arnold *et al.* (1987) found that vegetation structure and floristic composition influence the types and numbers of avian species present in remnant natural corridors of roadside vegetation. In total, 41 species of birds were recorded, with mallee/heath and heath vegetation attracting more species than the structurally and compositionally less diverse woodland vegetation. However, woodland sites serve as habitat for galahs (*Cacatua roseicapilla*) which require tree hollows for nesting. The presence of a number of small insectivorous species was influenced by the presence of *Grevillea spp.*

Forman (1983) hypothesised that corridor continuity is a major factor influencing the ability of a corridor to function as a migration route (Figure 1) . This hypothesis is supported by Merriam (1984) who demonstrated statistically that greater levels of connectivity in a landscape increase the chances of population survival for *P. leucopus* in a human-dominated landscape.

The nature and width of the break in corridor continuity is of major importance, with different species being unable or unwilling to cross gaps of certain types and widths. In Canada, Oxley *et al.* (1974) found that a number of small mammals (including *Tamias striatus, Sciurus carolinensis, and Peromyscus leucopus)* were reluctant to move between habitats separated by a road, where the width of the road was more than 20 metres. Wider roads were crossed almost exclusively by medium-sized mammals such as *Marmota monax.* In Germany, Mader (1984) found that, over a five-year period, carabid beetles (*Alax parallelus*) only crossed a six metre paved road twice. *Alax ater* only crossed once, and *Pterostichus niger* crossed a total of only seven times. In New South Wales, Barnett, How and Humphreys (1978) also found that road crossing by small mammals was inversely related to road width. Further, roads limited or stopped small-mammal movement even where the road was a long-unused and partly overgrown track.

Corridor width is assumed to determine which species can utilise a corridor. On the basis of their width, remnant natural corridors may be divided into two types: *line corridors* and *strip corridors* (Forman, 1983). Line corridors are so narrow that only edge species, generalists and opportunists will utilise them. Strip corridors, on the other hand, are wide enough to provide habitat for both edge species, generalists and opportunists as well as interior species. Edge species, opportunists and generalists are favoured by human-dominated landscapes and do not require special conservation measures (Kitchener, 1982; Whitney and Somerlot, 1986; Ambuel and Temple, 1983). Interior species conversely are sensitive to fragmentation and, in general, are the focus of conservation efforts. Terborgh (1974) terms these species *extinction prone species.*

Width is acknowledged as an important factor in determining species composition and corridor conservation value (Grieves and Lloyd, 1984). However there have been few studies of the effect of corridor width on species composition. Anderson, Mann and Shugart (1977), working in East Tennessee, U.S.A., found that narrow (12.0m) powerline corridors allowed few bird species to utilise the newly created habitat and those species that did utilise the corridor were edge species. The wider corridors (61.0m and 91.5m) on the other hand, were utilised by a number of open-country bird species such as the blue jay (*Cyanocitta cristata*), the red-tailed hawk (*Buteo jamaicensis*) and the white-eyed vireo (*Vireo griseus*). In the Western Australian Wheatbelt, Arnold *et al.* (1987) found that, in general, avian species numbers increased in wider remnant natural corridors along roadsides, however generalisations on the effect of width on species composition were not possible due to the influence of internal corridor structure in determining species composition.

Although there have been few studies of corridor width, the effect of remnant natural patch size on faunal species composition supports the assumption that width is an important factor for determining corridor conservation value. Galli, Leck and Forman, (1976) examined avian species distribution patterns in remnant patches of different sizes in Central New Jersey, U.S.A. Bird species composition in the smaller reserves (0.1, 0.2, 0.8 ha) was solely composed of edge species, such as american robins. This suggested that edge effects extended up to 20m into the patch. Therefore if interpreted in terms of corridor width, corridors would have to be greater than 40 m to provide habitat for interior species.

Kroodsma (1982a, b; 1984a, b) obtained similar results to those of Galli *et al.* (1976). Kroodsma examined the effect of induced edges on avian species composition in East Tennessee, U.S.A. He found that the bird communities adjacent to an induced edge could be separated into three categories: edge, interior and generalist. Edge species were most abundant in the first 60 metres and decreased thereafter, giving way to interior species. Generalist species occurred throughout the transect. This suggests that strip corridor widths would need to be over 120 metres to provide habitat for interior species, however, lesser widths may still act as migration routes.

Contrary to the results from North America, the clearance of rainforest in the Amazon Basin led to an impoverishment of bird species. It was anticipated that after clearance and creation of an induced edge there would be an influx of edge species, as occurred in North America (Wilcove, McLellan and Dobson, 1986); however, there were only 20 captures of two edge species. Overall 28 species were caught 10 metres from the edge, compared to 47 species 50 metres from the edge. These results concur with those of Terborgh (personal comment *in* Wilcove *et al.*, 1986). The suggested reason for the impoverishment is the high degree of habitat specificity in neotropical birds. In such a situation although there is not an influx of edge species, corridor widths would still need to exceed 100m in order to allow all interior species to utilise the corridor.

Evidence from the Amazon Basin shows that the creation of an induced edge also affects insect species. Wilcove *et al.* (1986) reported that, following clearance, there was an initial decrease in the species number of forest understorey butterflies. However, within one year species numbers had increased due to the invasion of light loving edge-species. These species were found 200-300 metres into the remnant patch. These results suggest corridor widths may need to be in the order of half a kilometre to conserve interior butterfly species.

Since Diamond (1975) suggested the principles for nature reserve design the equilibrium theory of island biogeography has been criticised by a number of authors

(Gilbert, 1980; Margules, Higgs and Rafe 1982; Simberloff, 1976). Simberloff suggests that the basic tenet of the theory, that of a dynamic equilibrium between immigration and extinction has not been proven and therefore the theory has prematurely been raised to the status of a paradigm. For this reason Gilbert (1980) suggests that its application to nature conservation and reserve design is premature.

Similarly, the incorporation of corridors into a nature conservation reserve network may be premature; for although corridors potentially provide benefits they also potentially have costs and limitations which could negate or at least minimise the benefits and therefore the conservation value of a corridor. The benefits, limitations and costs must be considered before a corridor is incorporated into a reserve design strategy. Simberloff and Cox (1987) term this type of decision making "risk analysis". They suggest that this type of analysis is required *before* corridors are incorporated into a conservation strategy.

1.2 Long-Term Conservation Value

The present conservation value of remnant natural corridors as habitats or migration routes for flora and fauna is largely dependent upon and evaluated on the basis their internal and external structure. However, in the long-term, changes in the natural disturbance regime which accompany the creation of a human-dominated landscape may change the internal and external structure of remnant natural corridors (Hobbs 1987), thereby potentially decreasing their initial conservation value for extinction-prone species.

Pickett and White (1985, p.7) define disturbance as "... *any relatively discrete event in time that disrupts ecosystems, community or population structure and changes resources, substrate availability or the physical environment*". Such an event *"directly,* *or indirectly, creates an opportunity for new individuals (or colonies) to become established"* (Sousa, 1984, p.336).

There are numerous kinds of natural disturbance, both physical and biological (Sousa, 1984). Physical disturbances include fire, flood, landslides, high winds, drought, tidal waves, hail, volcanic activity, earthquakes and climatic extremes. Biological disturbances, by animals, include activities such as predation, grazing, trampling, burrowing or digging. "*The sum of the disturbances operating in a given landscape is classed as its 'disturbance regime'.*" (Hobbs, 1987, p. 233). According to Sousa (1984) a particular disturbance regime is characterised by five attributes:

a) Areal extent;
b) Magnitude - consisting of both intensity and severity;
c) Frequency - measured at either a local scale (random point frequency) or a regional scale (regional frequency);
d) Predictability;
e) Turnover rate or rotation period.

In natural landscapes, types of disturbance and disturbance regimes vary widely and are a major reason for temporal and spatial variation in native vegetation (Sousa, 1984). Native species inhabiting a natural landscape are adapted to its disturbance regime. If that disturbance regime changes, naturally or due to human influence, then changes in floristic composition and vegetation structure may occur.

1.2.1. The Roadside Environment

Possibly the most important determinant of the conservation value of a remnant natural corridor of roadside vegetation is the roadside environment. At a general level the roadside environment is as diverse as the landscape it traverses, with variations in edaphic, geologic, climatic, social and agricultural factors determining the type of road and also the roadside vegetation (Way, 1977). More specifically, there is a range of physical factors which is peculiar to the roadside environment. These physical factors create similar environments and consequently may initiate similar biological responses. These factors, being peculiar to the roadside, are not found in the natural landscape and may be considered as disturbances. Such disturbances may cause changes to the structure and composition of remnant corridors of roadside vegetation consequently decreasing its value.

Thompson (1986) separates the common physical factors of the roadside into those which are traffic dependent, that is they are generated by traffic, and those which are traffic independent. Thompson's groups can be further subdivided into those that: a) are uniform in their impact and can be spatially restricted, such as many roadside management practices (these may be termed non-edge disturbances), and b) decrease in intensity with distance from their source and can not be spatially restricted (these may be termed edge disturbances) (Table 1). The different groups may vary in their long term impact on the roadside vegetation. The groupings are not independent but interact so that many different factors may affect roadside vegetation.

TABLE 1

ROADSIDE ENVIRONMENT DISTURBANCE TYPES

	EDGE EFFECTS	NON-EDGE EFFECTS
Traffic dependent factors	carbon monoxide carbon dioxide oxides of nitrogen and sulphur heavy metals oil dust temperature litter compaction	
Traffic independent factors	salt sand water run-off fertiliser pesticide herbicide insolation wind	grazing road constructions (drains, road fill, etc) fire roadside management techniques (borrow pits, mowing blading, pruning, herbicides etc) service easement management (electric cables, pipelines) fertiliser pesticide herbicide

Non-edge disturbances differ from edge disturbances in the following manner:

a) although their areal extent may vary, their intensity is uniform

b) they may cause a zonation of vegetation however this does not reflect a gradient.

Non-edge disturbances are related to traffic independent factors such as roadside vegetation management practices and road construction practices. The effect of the disturbance is dependent on the disturbance regime. The disturbance type may create a zonation of vegetation parallel to the road surface (Frenkel, 1970, Way, 1977, Wester and Juvik, 1983).

Variations in the frequency, intensity, and method of blading, mowing, ploughing or scraping results in different vegetation communities. A common goal in the United Kingdom is the management of "herblands" in roadside verges (Perring, 1969; Way, 1977; Thompson, 1986). Verges may be maintained so that they approximate old meadow grasslands (Way, 1977). This is achieved through cutting once or twice at the time of flowering. Zonation in the structure and composition are achieved through variations in the disturbance regime with distance from road. Ross (1986) reported that rotary mowing every three weeks favoured the establishment of prostrate species whilst flail cutting only once on spring produced a quite different composition.

Zonation or a complete change in the vegetation composition and structure is evident where road construction has altered the substrate changing the local edaphic conditions. Wester and Juvik (1983) reported a distinct zonation between introduced plant communities which occurred on imported road fill and the native plant communities which occurred on the indigenous soil. Stevens (1983b) concluded that the invasion of *Acacia longifolia var. sophorae* in the South-east of South Australia was due to the change of substrate and resultant decrease in soil moisture. Frenkel (1970) identified four management zones adjacent to Californian roadsides: Zones A, B, C and D. Zone A was the road shoulder which was heavily compacted road fill. Zone B was the road approach, this too was road fill substrate but less compacted than Zone A. Zone C was the ditch. Zone D was the least disturbed zone it was subject to occasional mowing or grading and was the zone most likely to contain regional flora.

The establishment of borrow pits for extracting road metal from within the road verge can cause a dramatic change to the roadside vegetation (Radford, 1987; Breckwoldt, 1990). However depending on the method of extraction the effect may differ markedly. If good rehabilitation practices such as those suggested by Walden (1982) are adopted, then the changes to vegetation may only be short term. However, if not rehabilitated or only poorly rehabilitated then the changes can be dramatic and long term (Radford, 1987).

The presence of other public and private utilities within the roadside verge, such as overhead or underground cables, firebreaks and water pipelines can necessitate the creation of vehicle service tracks, trenches or pruning of vegetation. This can result in changes to vegetation. Over-zealous pruning or clearance is unnecessary and there are now guidelines in most states of Australia for minimising disturbance caused by utility establishment and maintenance (Breckwoldt, 1990).

Fires may occur naturally, deliberately (vandalism) or deliberately (management). Whatever their origin they alter the composition and structure of the vegetation. In vegetation communities adapted to fires the use of fire as a tool for managing roadside vegetation may be appropriate if used correctly (Breckwoldt, 1990).

The result of non-edge disturbances is the creation of either permanent (through continuous management) or ephemeral changes in vegetation structure and composition. The disturbance may cause a zonation of different vegetation communities or completely alter the whole roadside community.

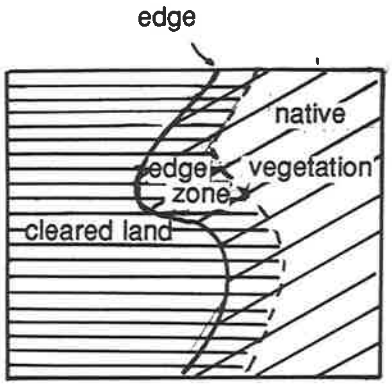
In human-dominated landscapes the most prevalent disturbance is that of clearance (Hobbs, 1987). Clearance of natural land is an intense disturbance event which permanently replaces the natural land with human-dominated land. Clearance not only has a direct effect on the natural land that has been cleared, but may also have an indirect effect on any adjacent remnant natural land. The effects on remnant natural land are termed *edge effects.*

Generally, an edge can be defined as *"a place where communities meet or where structural conditions within plant communities come together"* (Ward-Thomas, Maser and Rodiek, 1979, p.1). Edges may originate in three different ways and consequently three distinct edge types can be identified: inherent, induced, and maintained (Figure 2). Each of these edge types creates a different edge effect and edge zone.

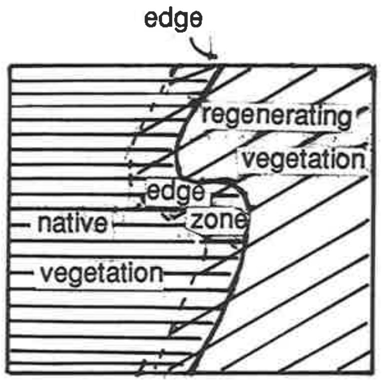
Inherent edges are relatively stable and permanent features of the landscape (Ward-Thomas *et al.*, 1979). They occur where there is a marked spatial change in the physical environment: for example, in soil type, topography or geomorphology. A change in the physical environment is reflected in a corresponding change in plant communities. The change in plant communities is normally a gradual transition as one community gives way to another, which results in an overlap of communities. The area of overlap is the edge zone. Inherent edge zones are usually richer in flora and fauna than the adjoining communities and, therefore, are important for wildlife management (Ward-Thomas *et al.*, 1979).

Figure 2

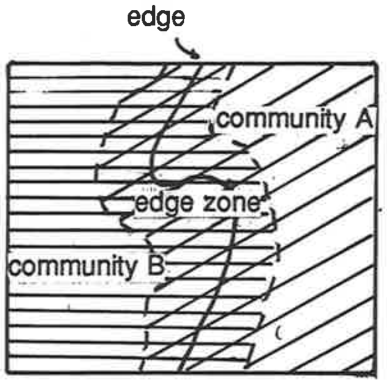
Edge types (Ward-Thomas *et al.*, 1979).



maintained edge



successional edge



inherent edge

In contrast to inherent edges, induced edges are relatively short-term feature of a landscape (Ward-Thomas *et al.*, 1979). Induced edges are a result of either natural or human disturbance, creating a short-term structural change within a plant community. The resulting edge zone is due to a temporal change in the physical environment of the undisturbed community in the vicinity of the edge. As the disturbed vegetation regenerates, physical conditions in the edge zone gradually return to original levels (i.e. levels occurring in undisturbed natural land and the edge zone community disappears).

Maintained edges are more or less permanent features of human-dominated landscapes. They represent a boundary between human-dominated land and remnant natural land. The edge effects associated with maintained edges may be important for the long-term conservation value of remnant natural corridors along roadsides.

The creation of a maintained edge induces changes in the physical environment of the adjacent remnant natural land. There may be major changes in microclimate, nutrients, toxins, dust or moisture. Solar radiation and wind exposure increase causing a decrease in soil moisture and generally, a more xeric environment (Ranney, Brunner and Levenson, 1981). Variation in the effect of solar radiation occurs with the aspect of an edge, the latitude and the vegetation formation. Wind similarly is variable in its effect, depending on edge aspect and predominant wind direction. Consequently, the width of the edge-zone varies. For example, in New Jersey, U.S.A. Wales (1972) found a 10 metre variation in edge zone width between north- and south-facing edges. North facing edge zones were only 10 metres wide while the southern, more exposed edge zones were 20 metres wide.

Changes in the physical environment of edge zones are reflected in the response of the flora. In deciduous forests of mid-western and eastern U.S.A. the creation of a maintained edge was found to initiate successional processes similar to those observed in forest gap succession (Whitney and Runkle, 1981). However, unlike forest gap succession where the community eventually returns to its original condition, a maintained edge zone begins at a climax condition and gradually retrogresses to reach a new equilibrium.

The general floristic changes that occur in maintained edge zones in the U.S.A. have been described by Wales (1972), Levenson (1976), Ranney *et al.* (1981), and Whitney and Runkle (1981). All studies reported an increase in second growth, early successional species. Such species were characteristically xerophytic, shade intolerant and possessed good vegetative reproduction (Wales, 1972). Such species were able to survive in a human-dominated landscape, exemplified by their presence in fencerows, and therefore do not require special conservation efforts (Whitney and Somerlot, 1981).

Similar, but less detailed, results have been reported in the Amazon Basin, where rapid clearance of natural land is taking place. Lovejoy, Bierregard, Rylands *et al.* (1986) reported that the creation of maintained edges led to immediate changes in the edge zone vegetation. Increased tree mortality and dense growth of vines and other second growth, early successional vegetation has occurred in the six years since clearance started.

Vehicle emissions produce a range of potentially harmful products such as carbon monoxide, carbon dioxide, hydrocarbons, nitrous oxides and heavy metals (Thompson, 1986). The most widely studied of these is lead. Ward, Reeves and Brooks (1975) estimated that 60% of lead emitted remains in the soil. The variation in lead concentrations with distance from road in soil and on plant surfaces is a function of time (Chow, 1970; Clift, Dickson and Roos, 1983), traffic volume (Wheeler and Rolfe, 1979), vegetation type (Clift *et al*, 1983; Whylie and Bell, 1973) and prevailing wind direction (Chow, 1970; Whylie and Bell, 1973). However in none of the studies was there any evidence to suggest that the vegetation on the verges was adversely affected by the lead levels. Studies on the uptake of lead by small mammals along highways in the USA (Getz, Verner and Prather, 1977; Mierau and Favara, 1975) both noted higher levels of lead in individuals closer to the road, however levels were five times lower than that required to produce a recognisable effect.

The effect of runoff from road surfaces can cause pronounced changes in the composition and structure of remnant natural roadside vegetation. Both Lathrop and Archbold (1980 a and b) and Johnson, Vasey and Yonkers (1975) noted differential effects of vegetation enhancement due to runoff from road surfaces in the Mojave Desert. The changes in vegetation were manifested as increases in species diversity and productivity near to the road surface.

On unsealed roads, deflation of road dust and its deposition on plant surfaces can occur during prolonged dry periods. Dust on leaf surfaces increases their absorptivity of radiation and may affect their plant productivity. Eller (1977) found that the absorbity of leaves along a motorway in West Germany was twice that of clean leaves and resulted in leaf temperatures two to four degrees celsius higher.

In agricultural areas introduction of soil nutrients into the road verge due to fertiliser spreading can create favourable environments for the establishment of weeds. Cale and Hobbs (1991) reported a significant correlation between the level of soil nutrients and the cover of exotic species. The level of soil nutrients was reported to be high close to the source (paddock) and low furthest from the source. Cale and Hobbs (1991) noted that in another study (Muir, 1979) the level of phosphorous had decreased to background levels after only seven metres, thus suggesting that corridors would need to be greater than seven metres wide in order to incorporate land without artificially high levels of soil nutrients. As many roadside corridors are only seven or so metres wide, their long term conservation value may not be high.

The creation of a maintained edge, therefore, segregates remnant natural land into two distinct communities: an edge zone community comprised of species which do not require special conservation efforts and an interior community potentially composed of extinction-prone species. In the long-term, only corridors wide enough to retain an interior community (i.e. strip corridors) will have conservation value for those species of flora and fauna in need of conservation.

The impact of a maintained edge may not be restricted to the initial edge zone. Ranney *et al.* (1981) suggested that, once established, maintained edge zones provide a source of early-successional species propagules which invade interior communities of remnant natural land. In addition the edge acts as a selective membrane filtering out interior species propagules. Therefore over time the ratio of early successional species to interior species will increase. Simulation studies (Ranney *et al.*, 1981) demonstrated that remnant natural patches in the size range 0-4 hectares eventually will be composed entirely of early successional species. If this is the case then even remnant natural corridors 200 metres wide will eventually only be of value to edge zone species.

The effect of non-edge disturbances on the long term conservation value of remnant natural corridors differs from that of edge disturbances. Whilst edge disturbances are largely uncontrollable, non-edge disturbances can be controlled; although we may be left with many legacies of previous non-edge disturbances. If detrimental non-edge disturbances can be controlled then remnant natural corridor composition and structure may be preserved or improved. Edge disturbances conversely are potentially a much greater threat to long term conservation value because they are not easily controlled and are an omnipresent environmental impact on remnant natural roadside vegetation.

1.3 Summary

In human-dominated landscapes remnant natural corridors may provide ecological, economic and social benefits for the community. However, remnant natural corridors may not only provide benefits but also costs. Consequently, in a particular location the ecological costs of remnant natural corridors may outweigh their benefits. Both the costs and benefits should be considered before incorporating corridors into a conservation strategy.

The ecological benefits may be limited by the internal and external structure of the remnant natural corridor. Internally, vegetation structure and floristic composition determine what fauna may utilise the corridor. Externally, the edge zone width and continuity of the corridor place constraints on both flora and fauna.

Edge zone width, particularly, is a most important structural feature. Narrow, line corridors are all edge zone and may provide habitat only for edge species. Wider, strip corridors have both an edge zone and an interior. Strip corridors may provide habitat for both edge species and extinction prone species and therefore may be of greater conservation value. Edge zone width may vary with change in aspect, latitude or vegetation type. In order to provide interior habitat, strip corridor width may need to be as little as 30 metres or as great as 600 metres depending on the width of the edge zone. Therefore it is not possible to extrapolate viable corridor widths from one area to another.

In the long term, edge effects may reduce the conservation value of remnant natural corridors which currently provide habitat or migration routes for extinction prone species. Even extremely wide corridors may become all edge zone due to the effect of the edge on the interior.

Simberloff and Cox (1987) note that too few studies have been undertaken to make definitive statements about the ecological value of remnant natural corridors. This is particularly the case in Australia where the few studies that have been done have concentrated on fauna so that little is known about the long term viability of the native vegetation in remnant natural corridors. Taylor (1987) has suggested that in the Southern Agricultural Region of South Australia, maintained edge zone vegetation may take the form of relict vegetation with a degraded native canopy layer and an adventive ('weedy' native/exotic) understorey. This suggestion is borne out by Cale and Hobbs (1991) who identified a positive correlation between the levels of exotics and the level of phosphorus, ammonia and nitrate introduced by fertiliser spreading. If this is the case then the remnant natural corridors along roadsides, watercourses and fencelines may have little long term conservation value for extinction-prone species, due to the annual influx of soil nutrients into the vegetation.

It is suggested that the development of edge zone communities does not happen immediately nor is their development consistent. The response of the existing community, the invasion of edge species and the increase in levels of nutrients or toxins is gradual and variable. Consequently one would expect to find roadside vegetation at various stages along a continuum of natural to relict vegetation. The condition of a community and its current conservation value may be dependent on the time since edge creation (clearance), the roadside/paddock environment, the internal disturbance history and the width of the corridor. These factors may be useful as a means of predicting the future conservation value of corridors in an area.

The aims of this thesis are to:

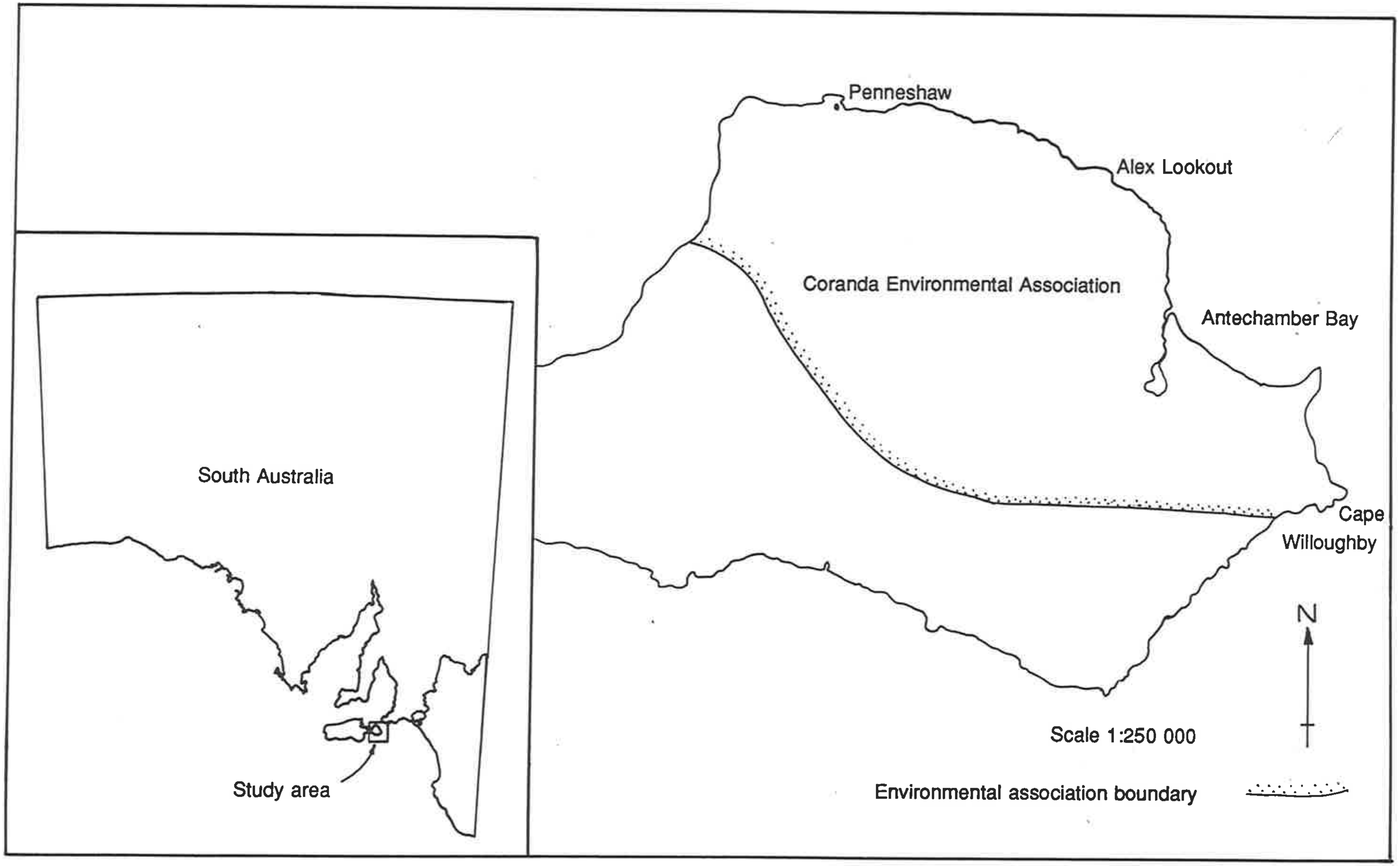
a) examine the effect of the above factors in a South Australian woodland environment on remnant natural corridors of roadside vegetation, and

b) to apply the results to the management of corridors in this and similar environments.

The environment selected for the study was the Coranda Environmental Association on Dudley Peninsula (Figure 3). This association is especially suitable for a study of the influence of edge and non-edge disturbances in roadside vegetation because topography, soils and climate are relatively uniform, and the physical environment (particularly edge age, disturbance age and disturbance type) of the roadside environment can be described with a reasonable degree of certainty for most areas.

Figure 3

Study area


Penneshaw
Alex Lookout
Coranda Environmental Association
Antechamber Bay
Cape
Willoughby
N
Scale 1:250 000
Environmental association boundary
South Australia
Study area

2. STUDY AREA

The Coranda Environmental Association occurs on Dudley Peninsula, Kangaroo Island, within the District Council of Dudley (Figure 3). Due to the amount of clearance, remnant natural corridors of roadside vegetation are an important landscape element in the Association. They contribute to the human-dominated landscape by forming part of the patchwork of paddocks and natural land characteristic of Dudley Peninsula (Figure 4, back pocket). They also represent a significant proportion of the remnant natural land, provide habitat for native animal species and potentially act as a corridor for their movement.

2.1 Physical Environment

According to Laut, Heyligers, Keig *et al.* (1977) the Coranda Environmental Association occurs within the Kangaroo Island Environmental Region of the Mount Lofty Block Province. The Coranda Environmental Association is an undulating upland plateau with lateritic remnants on the ridges. The plateau slopes gradually from north to south. The maximum elevation of 171 metres occurs near Alex Lookout on the north coast and gradually decreases to approximately 80 metres at various locations along the southern boundary of the study area. The plateau is dissected by numerous small seasonal watercourses which drain into the three main drainage systems: Willson River, Chapman River and Deep Creek.

The majority of the area is an elevated laterite plateau. The plateau is underlain by Precambrian and Early Palaeozoic folded metamorphics and igneous intrusions. Two small areas of Pleistocene calcareous dune sediments crop out in the north-west and the north-east of the study area (Daily, Milnes, Twidale and Bourne 1982).

On the laterite plateau the soils are Dy 5.43 imperfectly-drained, sandy, pedal mottled, yellow duplex soils of the Penneshaw Hills and Ridges Unit. The Pleistocene calcareous dune outcrops are characterised by Uc 6.13 weakly structured, well-drained reddish sands (Northcote, 1982).

The climate is cool temperate with a winter rainfall maximum. Only moderate seasonal and daily ranges of surface temperature occur due to the influence of the surrounding ocean and low elevation. The average annual rainfall is approximately 600 millimetres, with little variation occurring throughout the study area. The average maximum summer temperature is 21.2°C and the average minimum is 15.3°C. The corresponding winter averages are 14.2°C and 9.2°C. Winds are predominantly from the south and south-east in summer and the north and north-east in winter.

2.2 Vegetation

There have been few studies of the vegetation in the study area and consequently, as Lange (1982) notes, its current description serves only as a first approximation. Bauer (1959) provided a qualitative description of the vegetation associations and their distributions. The majority of the study area is dominated by the *Eucalyptus cneorifolia - Melaleuca uncinata* association. The steep coastal slopes on the northern side of the study area are dominated by the *Allocasuarina striata* association. Minor incursions of the *Eucalyptus diversifolia - E. rugosa* association occur along the southern boundary of the study area and at the mouth of the Chapman River.

Bauer's description of the vegetation is no longer wholly applicable due to the impact of European settlement. Extensive clearance of the vegetation over the last eighty years, especially since 1945, has fragmented the natural land into a network of corridors and patches surrounded by large tracts of cultural land (Figure 4, back pocket). Concurrently there have been changes to the physical environment of the remnant natural land which are likely to have had an influence on its structure and composition.

The areas of remnant natural land left after clearance have had different disturbance histories. There is a clear distinction between the disturbance history of remnant natural land on private land compared to that on public land. The majority of remnant natural land on private land is grazed or is periodically burnt to reduce the risk of wildfire. Grazing has resulted in relict vegetation (Figure 5), whilst too frequent use of fire has created communities dominated by species such as *Acacia paradoxa* and *A. pycnantha*.

On public land the vast majority of the remnant natural land occurs along the roadsides. Two types of remnant natural corridor may be identified on the basis of disturbance history. First there are those which are senescent and have not been directly disturbed for at least 80 years (Figure 6). These corridors have only been subject to the indirect disturbance of maintained edge effects, both traffic dependent and traffic independent. Second there are those corridors which have been directly disturbed by fire (Figure 7) and borrow pit excavation (Figure 8) in addition to being indirectly disturbed by maintained edge effects.

Direct disturbance of corridors is restricted to discrete areas. Conversely, indirect disturbance due to maintained edge effects is present in all corridors. Prior to 1945, clearance was restricted to the coastline and drainage lines. Between 1945 and 1983, the majority of the natural land was gradually cleared. The result is the creation of maintained edges of different ages (Figure 9, back pocket).

The roads in the study area are predominantly unsealed, only the main road from Penneshaw to Kingscote is sealed (Figure 10). Road surfaces are generally lower than

Figure 7

Roadside vegetation disturbed by fire

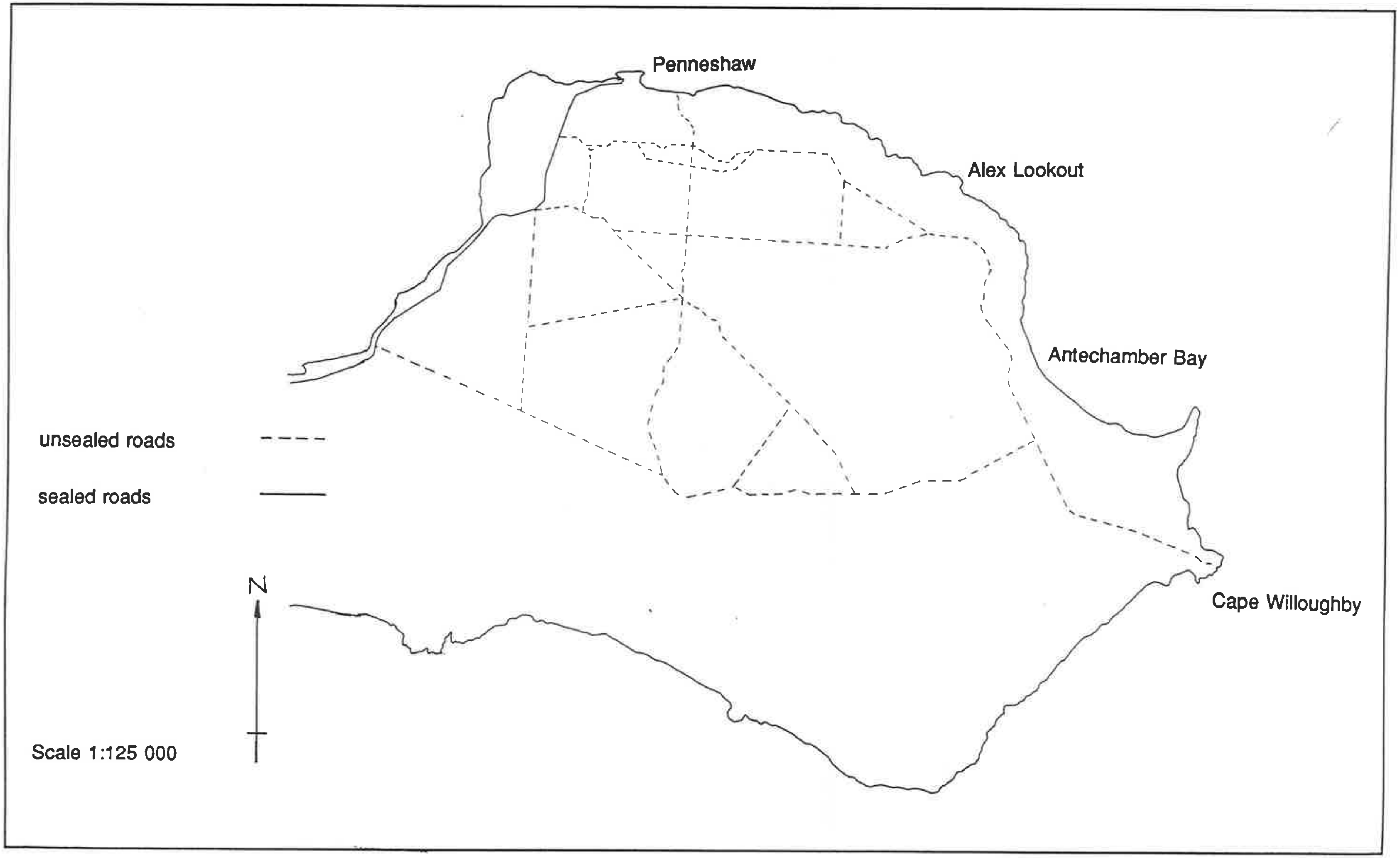
Figure 8

Roadside vegetation disturbed by
borrow-pit excavation

Trees at the back of the pit were
not disturbed by excavation

Figure 10

Road types


Penneshaw
Alex Lookout
Antechamber Bay
Cape Willoughby
unsealed roads
sealed roads
N
Scale 1:125 000

the adjacent verges and consequently runoff accumulates in the gutter at the side of the road rather than in the roadside vegetation, except where drains have been bulldozed into the vegetation. Traffic rates on the roads are low. The most heavily used road is the Penneshaw to Kingscote road which receives no more than 600 cars per day at peak times. Other roads carry between 50 to 100 cars per day in peak times (pers. comm. South Australian Department of Road Transport, 1987).

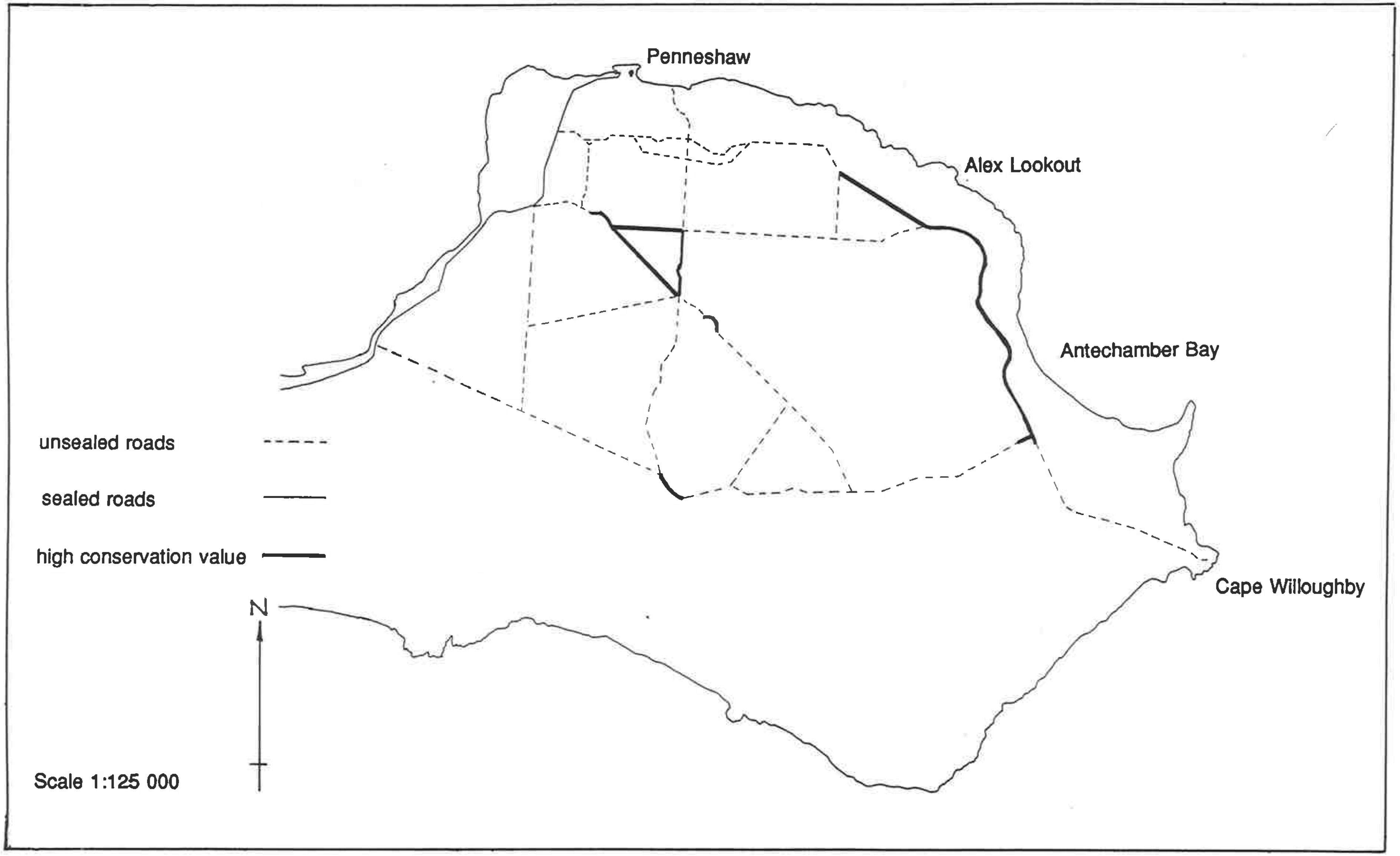
Corridor widths along roads vary according to the width of the road reserve and the location of the road within the road reserve. On one-chain roads (20.12 metres wide) corridors are between five and ten metres wide. On three chain roads (60.35 metres wide) corridor widths vary from 20 to 55 metres.

Management of the roads and roadsides is restricted due to the great length of the roadsides, the type of vegetation and the limited funds of the local government authority. The roads are graded on a biennial basis to level the road surface. Management of the vegetation is undertaken when it becomes a safety hazard or when fence maintenance is necessary, then selective pruning or bulldozing is employed to remove the offending vegetation. In addition eradication programmes to remove pest plants may be undertaken.

Bauer (1959) predicted that the roadside vegetation of Dudley Peninsula would one day be of conservation significance due to the rate at which land clearance was progressing at the time. This prediction was realised by the middle of the 1970's, at which time the majority of the natural land had been cleared. Palmer and Lewis (1987) assessed the conservation value of the roadside vegetation. Their study identified a number of strips of roadside vegetation which had high or very high conservation value (Figure 11). Numerous other strips of vegetation were of lower value due to the presence of weeds or the senescent state of the vegetation.

Figure 11

Remnant natural corridors of
high or very high conservation
value Palmer and Lewis (1990) not in refs


Penneshaw
Alex Lookout
Antechamber Bay
Cape Willoughby
unsealed roads
sealed roads
high conservation value
N
Scale 1:125 000

Bellchambers (1990) addressed the issue of managing the roadside vegetation. However, the proposed management solutions only addressed the issue in terms of maintaining the status quo and did not resolve the problem of the long term future of the vegetation. No studies of the dynamics of the roadside vegetation have been undertaken and consequently there is insufficient information on which to base management decisions.

3. METHODS

3.1 Site Selection

Initially, the date of vegetation clearance and the date and type of disturbance event were determined on the basis of air photo interpretation. South Australian Department of Lands aerial photography was available for the period 1945 - 1983. No aerial photography is available for the period prior to 1945. Post 1983 aerial photography, although available, was of no use as no clearance or disturbance had occurred within the study area during the period 1983 - 1988. Where possible the results of the photo interpretation were confirmed through discussions with landholders and local government officers.

Following air photo interpretation and interviews, sites were selected in the following way:

a) all potential sites were field checked to look for evidence of localised disturbance events such as woodcutting, grazing, fence realignment, trenching, bulldozing or tree pruning,

b) the site had to be within the *Eucalpyptus cneorifolia* - *Melaleuca uncinata* association (Bauer, 1959),

c) the approximate date of edge creation had to be known with reasonable certainty, and

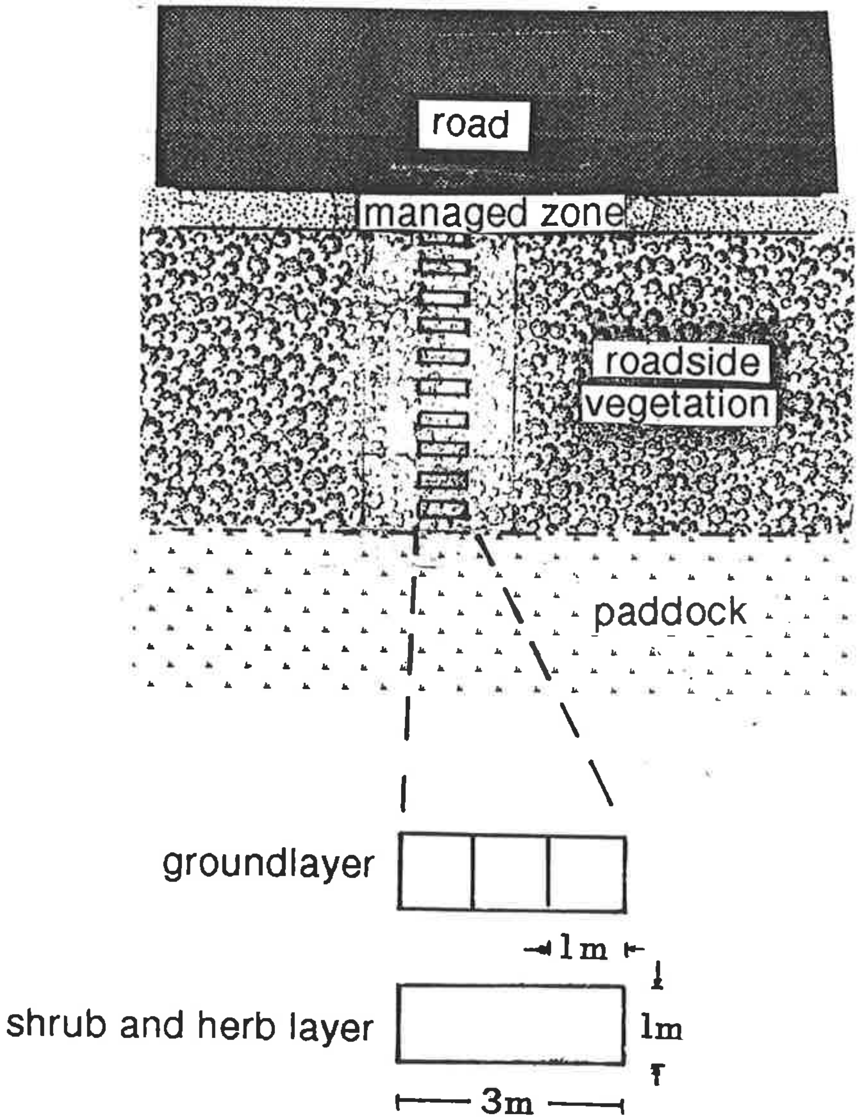
d) the approximate date and type of any non-edge disturbance events within the site had to be known with reasonable certainty.

3.2 Sampling Techniques

Sites were sampled using a random stratified line transect (Figure 12). Transects were oriented perpendicular to the orientation of the corridor, in order to sample across

Figure 12

Sample plot design


road
managed zone
roadside
vegetation
paddock
groundlayer
shrub and herb layer
1m
1m
3m

the edge-core-edge, or edge-core gradient. Transects were started at the boundary between the managed zone and the unmanaged zone of the roadside verge and finished at the corridor/paddock boundary. The sampling repetition varied according to the width of the corridor. Corridors between five and ten metres were sampled five times in order to provide sufficient data. Patch cores, patch edges and corridors greater than ten metres were sampled only three times. Transects were spaced 10 metres apart.

The same sampling design was used for both patch edge and patch core sample sites. As with corridor transects, patch edge transects were oriented perpendicular to the edge orientation. Patch core plots were not oriented in any particular direction but were located as close to the centre of the patch as possible. The length of both patch edge and patch core plots was fifty metres.

Visual estimates of the area of crown coverage were made for the tree (>5 metres) and tall shrub (>2m <5m) layers across the transect. The shrub and tall herb layer (>1m <2m) was sampled in three square metres plots (1m x 3m) which were located every other metre along the transect (Figure 12). The number of individuals of each species, where distinguishable, and the crown coverage and species of each individual were recorded.

The groundlayer (<1m) was sampled in paired one square metre plots also located every other metre (Figure 12). The number of individuals and the percentage of cover were recorded for each plant species. Coverage of bare ground, litter, plant bases and moss was also recorded. If the coverage of a plant species or any of the other categories was less than one percent it was recorded as one percent (for examples of data record sheets see Appendix 6.2).

Taxonomic nomenclature is according to Jessop and Toelken (1986).

3.3 Data Analysis Techniques

Sample sites were grouped into data sets according to:

- width
- non-edge disturbance age,
- non-edge disturbance type and
- edge age

Total cover of exotics and natives in the ground and shrub layers was combined for the purposes of analysis. In the few plots where total cover exceeded 100%, the species cover value which occurred in both layers, and hence was duplicated, was reduced to 100%. Coverage data was separated into native and exotic species groups.

Trends in cover across the data set transects were examined first in order to determine whether there was variation in cover with distance from edge for the two species groups. In order to do this average cover was plotted against distance from edge.

Cover values for plots within each data set were compared using the Kruskal-Wallis test; the non-parametric equivalent to analysis of variance. Comparisons were made in order to determine whether there was significant variation in cover across the corridor or patch - edge which could be attributed to distance from edge, and may indicate the presence of core and edge communities.

In order to examine the effect of edge age, non-edge disturbance age and disturbance type, cover data for all the plots in a site was combined and treated as site data representative of an homogeneous site rather than that of plots along a transect. For analyses of the effects of width, data sets were only compared for plots at the same distance from edge, so that some data sets from the central zone of wide sites were not used in this analysis. Comparisons between data sets were made using the Kruskal-Wallis test, or the Mann Whitney test where only two data sets were compared.

4. RESULTS AND DISCUSSION

4.1 Site selection

A total of 76 sites were sampled (for coverage data see Appendix 6.2) . The location of each site is shown on Figure 13 (back pocket). There were 46 disturbed sites, of which 10 were local government borrowpits and 3 were patch edges, and 30 undisturbed sites of which one was a patch core and one a patch edge (for site descriptions see Appendix 6.4) .

The sites were initially separated into categories on the basis of disturbance type and width. This resulted in the following seven categories:

a) Category 1, patch core
b) Category 2, patch edge
c) Category 3, borrow pits
d) Category 4, undisturbed narrow corridors
e) Category 5, undisturbed wide corridors
f) Category 6, disturbed wide corridors
g) Category 7, disturbed narrow corridors

These categories were then further subdivided into smaller groups on the basis of the edge age and disturbance age. This resulted in a total of 32 groups each representing a single data set (Table 2). Not all groups had the same number of replicates due to the random distribution of edge ages, disturbance history, disturbance type and corridor widths within the study area.

The distinction between disturbed and undisturbed sites was based on the type of disturbance. Sites which had not been disturbed by non-edge disturbances such as

TABLE 2
ANALYSIS GROUPS

Group	Sites	Edge Age	Disturbance Type	Dist. Age	Category
1.1	082	-	undisturbed	-	patch core
2.1	001 003	1910	undisturbed	-	patch edge
2.2	028	1910	fire	1910	patch edge
2.3	051	1910	fire	1940	patch edge
2.4	070	1910	fire	45-54	patch edge
3.1	072 073 077 079	45 54	borrow pit	61-69	wide
3.2	074	45-54	borrow pit	69-78	wide
3.3	075	58-64	borrow pit	58-61	wide
3.4	076	58-64	borrow pit	55-58	wide
3.5	078	1940	borrow pit	58-61	wide
3.6	081	45-54	borrow pit	55-58	wide
3.7	080	45-54	borrow pit	55-58	wide
4.1	006 007 008 009 010 012 015 022	1910	undisturbed	-	narrow
4.2	014 026 029 030 036	1940	undisturbed	-	narrow
4.3	011 027 032 034 038	45-54	undisturbed	-	narrow
4.4	024 031	55-58	undisturbed	-	narrow
5.1	002 004	1910	undisturbed	-	wide
5.2	045 053 055 062	1940	undisturbed	-	wide
6.1	016 017 046 056	1940	fire	1940	wide
6.2	043 044 047 052 054 086	45-54	fire	1940	wide
6.3	064	58-64	fire	1940	wide
6.4	065 067	78-83	fire	1940	wide
6.5	018 066	45-54	fire	45-54	wide
6.6	063 071	1940	fire	55-58	wide
6.7	085	55-58	fire	1983	wide
7.1	037 039 040 057 058 059	45-54	fire	1940	narrow
7.2	042 068	55-58	fire	1940	narrow
7.3	050 069	58-64	fire	1940	narrow
7.4	048 049	64-69	fire	1940	narrow
7.5	023	55-58	fire	55-58	narrow
7.6	019	45-54	fire	45-54	narrow
7.7	035	1940	fire	64-69	narrow

fire or logging were defined as undisturbed. Such sites were presumably only disturbed by edge disturbances as a result of clearance. Conversely disturbed sites had been subject to non-edge effects as well as edge effects. Borrow pits were seen as an exceptional type of corridor and were analysed separately.

The definition between wide and narrow corridors was based on the number of potential sources of edge effects. Narrow corridors in the study area were defined as those less than 10 metres wide. These corridors were considered to be subject to edge disturbances from both sides. Consequently at any location within the corridor it was possible that the vegetation composition and structure was a result of the combination of both roadside and paddock edge disturbance. Wide corridors were between 20 and 56 metres. The vegetation at any location within the corridor was considered to be the result of disturbance from only one edge.

4.2 Edge analysis

The only exotic species present were small quaking grass *(Briza minor)*, hares tail grass *(Lagurus ovatus)*, bridle creeper *(Myrsiphyllum asparagoides)* and sour sob *(Oxalis pescaprae)*. Mistletoes, a native genera indicative of vegetation stress, are common along roadsides on mainland South Australia and in other states (M. Rast pers. comm.), but were not present in the study area. Other common weed species which have been reported in roadside vegetation (Hobbs and Atkins, 1988) such as *Avena fatua*, *Arctotheca calendula* and *Hypochaeris radicata* were noted in the study area on cleared roadside verges but were not encountered in any of the transects (for a list of all species see Appendix 6.5). No individual native species showed any particular pattern along the transect. Their occurrence was patchy and none reflected any trend.

The results of the transect studies revealed that the distribution and cover of natives and exotics was variable (Appendix 6.3). The patches disturbed by fire in 1910, 1940 and 1945-54 (Groups 2.2, 2.3 and 2.4 respectively) were not invaded by exotics nor was the borrow pit created in 1955-58 (Group 3.7). Conversely exotics occurred, although at low levels, up to 500 metres within an undisturbed patch core (Group 1) and up to 48 metres into a patch from the road edge (Group 2.1). Some groups were invaded throughout the transect (Groups 2.1, 4.2, 4.4 and 5.1) whereas in others exotics were only present at or near the edge. Exotic cover varied from 0% in many plots to a maximum of 70% (Group 3.6).

The variation in the distribution and cover of exotic species was not consistent; however in general exotic cover decreased with distance from the road-edge or paddock-edge. The exceptions were Groups 2.1 and 5.1 where similar levels of cover occurred throughout the transect and a number of other groups in which only occasional and low levels of exotics occurred with no apparent pattern. In most groups, however, there was no significant variation in exotic cover along the transect (Table 3). The lack of significant variation suggests that there was no difference between roadside edge and paddock edge nor any definition of edge and core.

Significant variation in exotic cover occurred in only Group 3.1 (1961-69 borrow pits with an edge age of 1945-54) and 6.1 (wide corridors disturbed by fire in 1940 with an edge age of 1940). The variation in both groups was between the cover values in several locations. However the variation in cover was not consistent and regardless of their location the majority of the plots were not significantly different. The distribution and cover of native species showed no statistically significant trend along the transect of any group.

TABLE 3

RESULT OF INTRA-GROUP ANALYSIS OF THE VARIATION IN CROWN COVER OF NATIVE AND EXOTIC SPECIES ACROSS A TRANSECT

GROUP	EXOTICS	NATIVES
GROUP 1	ONE SITE ONLY*	
GROUP 2.1	$H_c = 22.05$	$H_c = 19.48$
GROUP 2.2	ONE SITE ONLY*	
GROUP 2.3	ONE SITE ONLY*	
GROUP 2.4	ONE SITE ONLY*	
GROUP 3.1	$H_c = 45.96$**	$H_c = 4.6111$
GROUP 3.2	ONE SITE ONLY*	
GROUP 3.3	ONE SITE ONLY*	
GROUP 3.4	ONE SITE ONLY*	
GROUP 3.5	ONE SITE ONLY*	
GROUP 3.6	ONE SITE ONLY*	
GROUP 3.7	ONE SITE ONLY*	
GROUP 4.1	$H_c = 4.6192$	$H_c = 0.9841$
GROUP 4.2	$H_c = 0.6984$	$H_c = 1.7093$
GROUP 4.3	$H_c = 0.945$	$H_c = 2.2463$
GROUP 4.4	$H_c = 0.3214$	$H_c = 2.9544$
GROUP 5.1	$H_c = 11.4621$	$H_c = 8.5527$
GROUP 5.2	$H_c = 16.1249$	$H_c = 16.7925$
GROUP 6.1	$H_c = 25.8605$**	$H_c = 4.59$
GROUP 6.2	$H_c = 13.05$	$H_c = 21.91$
GROUP 6.3	ONE SITE ONLY*	
GROUP 6.4	$H_c = 23.5$	$H_c = 25.81$
GROUP 6.5	$H_c = 17.99$	$H_c = 10.71$
GROUP 6.6	$H_c = 11.57$	$H_c = 23.29$
GROUP 6.7	ONE SITE ONLY*	
GROUP 7.1	$H_c = 5.2513$	$H_c = 1.38$
GROUP 7.2	$H_c = 2.5$	$H_c = 2.25$
GROUP 7.3	$H_c = 1.3$	$H_c = 0.2857$
GROUP 7.4	$H_c = 3.2283$	$H_c = 5.037$
GROUP 7.5	ONE SITE ONLY*	
GROUP 7.6	ONE SITE ONLY*	
GROUP 7.7	ONE SITE ONLY*	

* not possible to test significance

** $0.05 < p<0.025$

H_c = Kruskal- Wallis non-parametric analysis of variance

The variation in the response of exotic and native cover response along corridor or patch edge transects suggests that:

a) the vegetation is not responding to the change of environment that develops due to the creation of an edge,
b) no such change of environment occurs,
c) the change of environment is complicated by other factors, or
d) the vegetation is responding but significant trends have not yet developed.

With respect to native species it may be that the creation of an edge has not substantially altered the existing environment. Whereas in North American deciduous forest light levels and edge aspect were important factors in determining the level and distance of the edge effect due to the closed nature of the canopy and the mesic environment (Ranney *et al.*, 1981), on Dudley Peninsula the vegetation is predominantly low open forest and the environment is xeric. Consequently, light levels may not play a significant role. Similarly, other factors which could cause a variation in the cover of native species such as the response time of the vegetation, soil nutrient levels or runoff may not be present in high enough concentrations or may be ubiquitous, and thus do not cause variation in native species cover.

The results for exotic cover are less clear. In those groups where exotics occur throughout the transect the result can be interpreted as suggesting that the communities have reached a point where they are all edge. In other groups with patchy distribution or where exotics occur only at or near the edge it appears that a change of environment does occur but that it is complicated by other factors which inhibit the invasion of exotics and thus prevent significant trends from developing in all sites. This variation in exotic cover may be due to factors such as edge age, disturbance age, disturbance type or width.

4.3 Within and between category comparisons

Comparisons were made to examine the effect of edge age, disturbance type, disturbance age and corridor width on the plant cover.

The transect data was combined and treated as site data in order to make comparisons both within and between the categories. Due to the vagaries of land use history it was not possible to obtain an equal number of replicates for each group. Nor was it possible to obtain complete temporal sequences in each category.

The average cover for native and exotic species is shown in Table 4. There was wide variation in the average cover of exotic and native plants. Exotics varied from 0% to 29% and natives from 0% to 60.86%.

4.3.1 Edge age

It was hypothesised that the age of the edge, that is the period of isolation, would affect the level of exotic and native cover in corridors. The effect of edge age was examined within Categories 4, 5, 6 and 7 (undisturbed narrow and wide and disturbed narrow and wide corridors respectively). Significant variations in level of plant cover did not occur in all categories and where significant differences did occur there was no consistent variation (Table 5).

There was a significant difference in the level of exotic cover in Category 4 (narrow undisturbed corridors) between Group 4.1 and Group 4.3, that is between 1910 and 1945-54 edges. However there was no corresponding difference between groups

TABLE 4
AVERAGE COVER (± 1 SE) OF EXOTIC AND NATIVE SPECIES IN EACH GROUP

GROUP	n	EXOTICS	NATIVES
1.1	25	0.64 ±0.77	8.08 ±3.42
2.1	50	2.74 ±1.03	7.16 ±1.98
2.2	25	0	12.68 ±5.27
2.3	25	0	10.2 ±4.94
2.4	25	0	31.8 ±6.1
3.1	54	0.7 ±0.86	32.5 ±7.8
3.2	14	0	43.8 ±16.36
3.3	24	0	23.5 ±7.31
3.4	25	0	19.38 ±13.04
3.5	18	1.6 ±3.27	41.7 ±12.82
3.6	13	5.0 ±11.19	38.09 ±17.83
3.7	13	1.7 ±3.55	23.46 ±17.14
4.1	31	15.84 ±6.01	12.7 ±4.4
4.2	20	14.05 ±9.14	4.15 ±5.14
4.3	18	5.11 ±4.49	7.72 ±5.96
4.4	6	29.0 ±41.23	10.5 ±9.19
5.1	24	8.38 ±4.59	9.8 ±6.65
5.2	62	4.29 ±2.19	9.99 ±3.43
6.1	52	6.17 ±3.64	3.67 ±2.22
6.2	72	0.28 ±0.28	19.72 ±4.79
6.3	24	0.04 ±0.07	5.36 ±1.51
6.4	48	0	37.58 ±6.29
6.5	37	0.03 ±0.05	33.0 ±7.29
6.6	35	7.09 ±6.47	7.54 ±2.38
6.7	13	0.69 ±0.5	30.76 ±8.64
7.1	20	5.85 ±9.75	27.25 ±13.41
7.2	7	0.14 ±0.35	30.42 ±22.93
7.3	6	0.83 ±1.68	45.83 ±34.98
7.4	7	2.42 ±4.78	60.86 ±18.11
7.5	5	6.6 ±6.78	6.6 ±5.19
7.6	4	0.5 ±1.59	0
7.7	4	0	12.75 ±19.92

TABLE 5

RESULTS OF INTER-GROUP COMPARISONS TO DETERMINE THE EFFECT OF WIDTH, DISTURBANCE DATE OR DISTURBANCE TYPE ON COVER OF NATIVE OR EXOTIC SPECIES

COMPARISON	GROUPS	EXOTIC	RESULT	NATIVE	RESULT
WIDTH narrow vs wide	4.2 & 5.2	U' = 204 U = 156	-	U' = 241* U = 119	5.2 > 4.2
	7.1 & 6.2	U' = 273 U = 207	-	U' = 271 U = 209	-
	4.1 & 5.1	U' = 391.5+ U = 166.5	4.1 > 5.1	U' = 331.5 U = 226.5	-
DISTURBANCE DATE older vs younger	7.1 & 7.6	U' = 40 U = 40	-	U' = 76 ** U = 4	7.1 > 7.6
	7.2 & 7.5	U' = 4 U = 31 **	7.5 > 7.2	U' = 28 U = 7	-
	6.2 & 6.5	U' = 1503 U = 1385	-	U' = 936.5 U = 1951.5*	6.2 > 6.5
	6.1 & 6.6	U' = 963 U = 909	-	U' = 548 U = 1324*	6.1 > 6.6
DISTURBANCE TYPE undisturbed vs disturbed	5.2 & 6.1	U' = 1251 U = 1174	-	U' = 1490.5++ U = 69.5	5.2 > 6.1
	5.2 & 6.6	U' = 1282 U = 888	-	U' = 1062.5 U = 1107.5	-
	4.4 & 7.2	U' = 18 U = 24	-	U' = 8 U = 34*	7.2 > 4.4
	4.3 & 7.1	U' = 231.5 U = 168.5	-	U' = 286.5* U = 113.5	7.1 > 4.3

*	0.05 < P < 0.025
**	0.025 < P < 0.01
+	0.01 < P < 0.005
++	0.001 < P < 0.0005

U and U'= Mann- Whitney non-parametric test of significance

4.1 and 4.4, that is between 1910 and 1955-58 edges. Therefore it is not possible to infer that exotic cover is varying with edge age in narrow undisturbed corridors.

Native species cover for Category 4 also varied significantly but not in the same manner as exotic cover. There was a significant difference in the cover of native plants between Group 4.1 and Group 4.2, but no difference between Groups 4.1, 4.3 and 4.4. Therefore as with exotics, the results suggest that edge age is not influencing the cover of native species in narrow undisturbed corridors.

Groups 7.1, 7.2, 7.3 and 7.4 represent narrow coridors all disturbed by fire in 1940 but with different edge ages (45-54, 55-58, 58-64 and 64-69 respectively). There was no significant difference in exotic cover between any of the groups. This result is surprising as there is approximately a twenty year difference in edge age. There was a significant variation in the level of native species cover between Groups 7.1 and 7.2 but not between any other group. Therefore in narrow non-edge disturbed corridors edge age does not account for the variation in plant cover or edge effect.

In narrow corridors (Categories 4 and 7) the variation in the level of native cover may be a function of the width of the site. Narrow sites only sample a very small proportion of a plant community and thus the chances of plants not being included in the corridor when the road and paddock are created must be higher. Consequently the variation in species cover, although significant, may not be due to any environmental factor, but rather the "inadequate sampling" of the community by clearance.

The exotic cover in undisturbed wide corridors (Category 5) was significantly greater in the 1910 edge age group (Group 5.1) than in the 1940 age group (Group 5.2). This is the characteristic response expected if edge age determines the level of exotic cover and suggests that in some instances the edge age may be a useful predictor of the quality of the corridor.

Native species cover in Group 5.1 and 5.2 did not vary significantly. The lack of variation in native species cover suggests that the community may not be responding to the effect of isolation, rather it continues to function and develop as it would normally in a large patch of natural land. This hypothesis is supported by the similar levels of native cover present in both Groups 5.1 and 5.2 and also in the patch core plot (Group 1.1).

Therefore in undisturbed communities which are very similar, edge age appears to be a useful factor for predicting the comparative levels of exotic cover. This implies that other factors which vary with edge age such as soil nutrient levels may also be varying accordingly.

In order to make a reliable conclusion about the effect of edge age on undisturbed wide sites it would be necessary to analyse a number of other edge age groups. With respect to exotic cover in Groups 5.1 and 5.2 it is noticeable that exotics occur throughout Group 5.1 and are restricted to edges in Group 5.2. The distribution in Group 5.2 although not significant may reflect a gradual encroachment of exotic species into the corridor over time ultimately resulting in invasion of the entire site after 50-80 years.

Groups 6.1, 6.2, 6.3 and 6.4 represent wide corridors disturbed by fire in 1940 but with different edge ages (1940, 45-54, 58-64 and 78-83 respectively). There was a significant difference in exotic cover between Group 6.1 and all other groups but no difference between Groups 6.2, 6.3 and 6.4. Therefore it was not possible to imply that variation in exotic cover occurred as a function of edge age. Similarly with native species there was significant variation between Group 6.4 and Groups 6.3 and 6.1. But there is no trend to suggest variation with edge age.

Edge age alone does not consistently account for the variation in either exotic or native cover. There are a number of possible reasons for this. First, with respect to native species, it is possible that fragmentation and the exposure of a corridor community has not caused any significant changes in the physical environment which would initiate a change in the cover of native species. Due to the lack of control plots it is not possible to test this hypothesis for all corridors. However the cover of native species in Groups 5.1 and 5.2 was very similar to that in Group 1 (patch core) and does suggest that on Dudley Peninsula corridor communities continue to develop in the same manner that they would in a large patch of natural land. Alternatively, it may be that the response time of the vegetation is very slow.

Second, with regard to exotic species, edge age did explain the variation in undisturbed wide corridors, with the oldest edge age having higher levels than the younger edge age group. However, there were not enough data set groups in Category 5 to draw a reliable conclusion. No significant variation which could be attributed to edge age occurred in any of the other categories and consequently it is not possible to conclude that edge age causes significant variation in exotic cover in all situations.

Therefore, on Dudley Peninsula edge age alone does not appear to be useful as a predictor of the extent of exotic nor native plant cover and thus long term conservation value of corridors. This suggests that the variation in physical factors that may occur as a result of edge creation may be modified by other overriding factors.

4.3.2 Disturbance history

For wide corridors, comparisons were made between undisturbed corridors with an edge age of 1940 (Group 5.2) and corridors disturbed in 1940 and 55-58 with an edge age of 1940 (Groups 6.1 and 6.6 respectively). There was no significant difference in exotic cover between Group 5.2 and Group 6.1 or between Group 5.2 and Group 6.6. This result suggests that where edges have been present for approximately 45 years and the non-edge disturbance occurred more than 30 years ago that the internal conditions which favour exotic plant establishment are similar in both disturbed and undisturbed groups.

There was no significant difference in native cover between Group 5.2 and 6.6. However, there was a significant difference between Group 5.2 and 6.1. This result is converse to expectation. Group 6.1 and 6.6 were disturbed in the last forty years and it was anticipated that they would both have higher native cover than the undisturbed site (Group 5.2). It is possible that variations in the non-edge disturbance regime have caused the variation in native species cover. However, the lack of consistent variation suggests that the age of the non-edge disturbance is not a useful determinant of native species cover in wide corridors.

For narrow corridors two comparisons were made. First, between undisturbed corridors with an edge age of 45-54 (Group 4.3) and corridors disturbed in 1940 with an edge age of 45-54 (Group 7.1). Second undisturbed and disturbed corridors with an edge age of 55-58 (Group 4.4 and 7.2 respectively).

In neither comparison was there a significant difference in exotic cover. Therefore where edges have been present for 30 years or more and the vegetation has not been disturbed for more than 40 years non-edge disturbance does not appear to influence exotic cover in narrow corridors. In both comparisons native cover was significantly greater in the disturbed sites, suggesting that in these cases non-edge disturbance may have influenced native species cover.

The comparisons for both wide and narrow corridors only examine edge ages of approximately 1940, 1945-54 and 55-58. Consequently it is only possible to conclude that for corridors where the edge age is greater than 30 years that non-edge disturbance as not the only factor determining exotic and native cover. In order to make reliable predictions it would be necessary to examine a more complete temporal sequence.

4.3.3 Disturbance time

The time at which a corridor is disturbed by non-edge disturbance event may influence the cover of native or exotic species. Older disturbed corridors may have higher exotic cover and lower native cover. For both wide and narrow corridors comparisons were made between corridors with the same edge age but different disturbance ages.

For wide corridors two comparisons were made. First, between sites disturbed by fire in 1940 and 55-58 (Groups 6.1 and 6.6 respectively) and second between sites disturbed by fire in 1940 and 45-54 (Groups 6.2 and 6.5). Exotic cover did not vary significantly in either comparison suggesting that it is not influenced by the age of disturbance. Native cover was greater in Groups 6.6 and 6.5 than Groups 6.1 and 6.2. suggesting that the time of disturbance may influence native cover.

In narrow corridors comparisons were made between sites with a disturbance time of 1940 and 45-54 (Groups 7.1 and 7.6 respectively) and sites with a disturbance time of 1940 and 55-58 (Groups 7.2 and 7.5 respectively).

There was no consistent variation in exotic cover. Exotic cover was significantly greater in Group 7.5 when compared with Group 7.2 however there was no difference between Groups 7.1 and 7.6. Thus disturbance time did not consistently influence exotic cover.

Similarly native cover did not vary consistently. Cover in Group 7.1 was significantly greater than exotic cover in Group 7.6. However native cover in Groups 7.2 and 7.5 was not significantly different. Thus, as with exotic cover, disturbance time alone did not adequately explain the variation in native cover.

4.3.4 Width

In order to examine the effect of corridor width on exotic and native cover, comparisons were made between groups with identical edge and non-edge disturbance histories but differing corridor widths. Three sets of comparisons were made. First, between narrow and wide undisturbed corridors with an edge age of 1910 (Groups 4.1 and 5.1). Second, narrow and wide undisturbed corridors with an edge age of 1940 (Groups 4.2 and 5.2). Third narrow and wide corridors disturbed by fire in 1940 with an edge age of 45-54 (Groups 7.1 and 6.2).

There was no consistent variation in exotic cover. Exotic cover did not vary significantly between Groups 4.2 and 5.2 or between Groups 7.1 and 6.2. However, exotic cover in Group 4.1 was significantly greater than exotic cover in Group 5.1.

Native cover responded in similar fashion to exotic cover with only one out of the three comparison being significantly different (native cover in Group 5.2 was greater than native cover in Group 4.2).

Therefore, as with the other variables examined corridor width does not account for all the variation in exotic or native cover. Consequently it can not be used as a predictor of corridor condition or conservation value.

4.3.5 Borrow pits

There was significant variation in exotic cover across Group 3.1; however it was not possible to interpret this in terms of edge development as the variation was not consistent, with a significant difference occurring between only two plots.

It was not possible to test for variation in exotic cover in any other borrow pit group due to the lack of replicates. However in Groups 2, 3 and 4 there were no exotics and in Groups 5, 6 and 7 exotics did occur but only right at the edge. Native species cover showed no significant variation across any transect.The possible reasons for this are either insufficient time has elapsed for an edge to develop, or unsuitable substrate. As corridors (with similar edge ages) in other areas have been invaded it is unlikely to be edge age. Consequently the most probable is the lack of a suitable substrate. None of the borrow pits sampled had been rehabilitated after the borrow material (laterite rubble) had been removed, consequently the narrow pits were generally a hard pan of B horizon with only occasional patches of A horizon. Such an environment may not be conducive to the establishment of exotic species. Exotic species cover did occur right at the edge of some of the sites (Groups 5, 6 and 7) where the laterite rubble had not been extracted.

There was no significant difference in native species cover and no discernible trend occurred. For native species it is doubtful that unsuitable substrate is the reason as the cover of species ranged between 19.1% and 43.8%.

4.4 Summary

The result of the transect study suggests that edge effects may be manifested by the presence of exotic cover. However the presence of exotics and their cover is not wholly explained by edge disturbance. Other non-edge disturbance factors such as disturbance age appear to be influencing exotic invasion and thus modifying the effect of edge creation. A number of sites were totally or almost totally invaded by exotics. In these cases the influence of the non-edge disturbance has presumably been negligible or at least the same in all cases and consequently it has been possible for exotics to establish throughout the corridor.

In general the sites which were invaded throughout were undisturbed sites, although some disturbed narrow sites were also totally invaded. The complete or almost complete invasion of undisturbed sites compared to the generally uninvaded state of disturbed sites suggests that the longer a site remains undisturbed by natural non-edge disturbance mechanisms the more likely it is to be invaded by exotics. This conclusion concurs with Rejmanek (1989) who noted that, if for stochastic reasons only, senescent sites are more likely to become invaded.

Hobbs (1989) and Bridgewater and Blackshall (1981) both observed that the more open communities such as woodlands with an open shrub layer were more susceptible to invasion than those with more dense shrub layers. This explains some of the variation on Dudley Peninsula, but there did not appear to be a consistent relationship, with exotic cover varying independently of the native cover in some cases, perhaps due to the low nutrient status of the soil.

The lack of consistent variation in the cover of native and exotic species with regard to disturbance age, disturbance type, edge age and corridor width may be due to inadequate sequences of data, but overall it appears to reflect the complexity of environmental variables which influence exotic and native cover making simple single factor, temporal correlations inadequate. For example, the variation in native species composition and cover in sites disturbed by fire is possibly due to the variation in aspects of the disturbance regime, such as frequency, intensity and season. These factors have been noted elsewhere to have a major impact on the post fire community (Noble, 1989).

If exotics are used as the indicator of edge effect, then on Dudley Peninsula edge width varied from 0 to 500 m. In relation to Forman's (1983) concept of strip and line corridors the variation in the extent of exotic cover on Dudley Peninsula suggests that strip corridors may need to be as wide as one kilometre or only as narrow as six metres, depending on the site factors. This represents the worst and best scenarios, but serves to highlight that many corridors have the potential to provide habitat for native plants, regardless of their width. However, narrow corridors are probably of lesser value to native fauna than wide corridors because of the limited amount of habitat and protection they provide.

Forman (1983) suggested that corridors could be divided into two basic types : line corridors and strip corridors on the basis of whether they were all edge (line corridors) or had both an edge and a core (strip corridors). No edge and core communities were statistically defined in any of the corridors samples. However using the presence of exotic species as an indicator of edge effect many of the corridors were edge to some extent. This segregation into edge and non-edge corridors was not solely on the basis of width. Thus whilst the concept of line and strip corridors appears useful as a definition of corridor types, even within vegetation association it is not possible to define corridors as line or strip solely on the basis of width, due to the effect of other factors. Thus from the point of view of landscape planning it may not be possible to deduce which corridors are line and which are strip.

Forman (1983) defined five different corridor types. These are ideals, in reality a corridor connecting two patches may represent a combination of corridor types. For example on Dudley Peninsula a number of the corridors represented a combination of spot disturbance, regenerating and remnant natural corridors. It is suggested that an additional corridor type, the complex corridor, is included in Forman's list.

4.5 Management

Corridors which are similar in structure and composition to to the plant communities of large areas of natural land are the most valuable. Consequently the aim of management should be to minimise those factors which promote exotic establishment and maximise those factors which promote native establishment.

On Dudley Peninsula, those sites which were consistently invaded by exotics were predominantly undisturbed sites and those that had not been disturbed for a long time. These sites were open woodlands or low open forest with an open understorey. The corridor sites that were all core represented sites which were disturbed more recently and/or had a closed shrub layer.

It is suggested that corridors should be managed to maintain a high species cover and species richness. This may be achieved through occasional pyric disturbance. The periodicity of the disturbance may only need to be every 20-30 years or so based on the current coverage and species richness of sites on Dudley Peninsula which have been disturbed by fire. However, additional study would need to be done on the vital attributes of individual species to determine what is the best burning frequency (Noble and Slatyer, 1980); or indeed whether burning can be used as a management tool at all. In addition to frequency, pyric management would need to consider:

- the season for burning because of the importance of ambient air and soil temperatures and soil moisture (Bradstock, 1989; Noble, 1989; Wellington, 1989).
- the surrounding land uses and the disturbance history of the vegetation.

Pyric disturbance may not work in the senescent old undisturbed sites due to the lack of viable seed in the seed bank. Such sites may require enhancement of species richness through the use of direct seeding and supplementary hand planting of indigenous species.

There is the possibility that pyric disturbance may encourage the establishment of exotics (Cale and Hobbs, 1989) because of the amount of phosphorus freed by burning. In the study area those sites which had been most recently disturbed by fire had negligible levels of exotic invasion. Consequently burning does not appear to encourage exotic invasion on Dudley Peninsula.

Borrow pits were not invaded by exotics to any great degree, however native regeneration was also poor. Better rehabilitation practices such as ripping the pit floor, returning the topsoil and direct seeding would encourage better regeneration. Alternatively laterite rubble may be obtained from within farm paddocks where there is no vegetation. The latter would be a much better and simpler alternative, as no native vegetation would need to be cleared and the continuity of corridors would be preserved.

Bellchambers (1989) suggested a number of management techniques for roadside vegetation on Dudley Peninsula. These mainly related to issues of safety and aesthetics and did not consider the maintenance or enhancement of the ecological value, except where vegetation destruction could be minimised through better pruning techniques. Employing only these techniques will lead to the inevitable degradation of corridors through senescence and invasion.

Pyric disturbance of the vegetation may be a suitable management strategy for the plant communities, but it may be counterproductive in terms of fauna conservation. Burnt patches may represent impassable barriers and consequently breaks in continuity of the corridor. This may be of particular importance to the movement of terrestrial fauna.

Thus there is a management quandary. Pyric disturbance is necessary in order to retain or enhance the conservation value of corridors. However the breaks in corridor continuity created by the disturbance may have deleterious effects on fauna. This is a worst case scenario, but it does highlight the need to consider the requirements of fauna in a corridor management plan. Possible options could include burning only small sections at a time. The length of such sections would be dependent on the species that inhabit the corridor.

The proposed management strategy has only considered the ecological value of roadside vegetation. It is recognised that in cultural landscapes roadside vegetation has other values such as aesthetic, historical, emotional, economic and educational, and that roads must be safe.

On Dudley Peninsula two issues which are particularly sensitive are, first, the stand of senescent *Eucalyptus cneorifolia* on the main road outside Penneshaw which has aesthetic and emotional values for locals and visitors (Figure 14), and second the safety of the roads, which is decreased by overhanging branches (Figure 15).

The senescent stand of *E. cneorifolia* is represented by the data in Groups 1, 2.1, 5.1 and 5.2. These sites are all invaded by exotics to some degree. There is no

Figure 14

Senescent roadside vegetation on the main road outside Peneshaw

Figure 15
Overhanging branches

Although the cantilivered effect has aesthetic appeal
it has reduced the road to a single track
with no room for overtaking or avoiding other cars.

Figure 16

Bridle creeper

The understorey at this location has been completeldy overgrown by bridle creeper

become more susceptible to exotic invasion. Thus, regardless of when the surrounding land was cleared, it appears that the communities continue to function as normal until they reach a certain stage of structural and compositional development after which they are more likely to be invaded. These results concur with those of Bridgewater and Blackshall (1990) and Hobbs (1989) that certain communities are more invasible regardless of whether they are receiving increased levels of disseminules and nutrients. In such cases it may be only a matter of time before they are invaded (Rejmanek, 1989).

The development of relict vegetation may not be the inevitable consequence of fragmentation . In a number of corridors disturbed by fire the level of exotic invasion was negligible or non-existent. Fire could successfully be used as a management tool to ensure the long term conservation value of the corridors.

In order to devise a management plan for the corridors more research needs to be undertaken to determine:

a) which physical factors, if any, are varying with distance from the edge
b) the significance of non-edge disturbances in determining corridor composition and structure
c) which species of flora and fauna inhabit the corridors and what management strategies will be necessary to ensure that the corridors continue to provide a habitat or movement corridor.

The results of such studies should be examined within the framework of the risk-analysis (Section 1.1, p25) suggested by Simberloff and Cox (1987) in order that a realistic management plan can be formulated for the corridors.

Finally, the results of this study imply that the response of remnant natural corridors of sclerophyllous open woodland and low open forest to the creation of maintained edges are not only quite different to that of patches of deciduous closed forest communities in high rainfall environments in North America or rainforest of South America but also will vary between vegetation communities in Australia depending on biological, physical and cultural factors. Consequently, management recommendations can only be site specific, and should only be made following an assessment of the edge and non-edge disturbance types of the roadside vegetation communities in question. This does not mean that corridors should not be protected, rather that once protected research to better understand the dynamics of roadside communities should be undertaken to ensure their wise management.

Appendix 6.1

Data record sheets

Shrub and Herb Layer

Site #

Subsite #

subplot	species	height class		coverage dm²	liana	non thalloid epiphyte

subplot	species	height class		coverage dm	liana	non thalloid epiphyte

Groundlayer

Site #

Subsite #

subplot	species	coverage %	liana

subplot	species	coverage %	liana

Appendix 6.2

Cover data for sites

PERCENTAGE COVER OF NATIVE SPECIES

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
001	50	patch edge*	4	3	0	14	0	0	3	1	13	4	11	2	1	1	3	2	8	19	6	15	7	21	8	15	2			
002	25	corridor	1	20	23	3	8	14	9																3	2	77	12	9	0
003	50	patch edge*	6	22	16	0	5	13	5	4	8	4	8	26	2	6	1	15	9	0	1	0	0	22	6	15	1			
004	22	corridor	9	10	4	1	6	0																		2	18	2	3	0
006	6	corridor	15	38																										25
007	7	corridor	0	30																									6	0
008	7	corridor	4	23																									10	22
009	7	corridor	8	32																									35	10
010	7	corridor	0	10																									11	38
011	7	corridor	1	0																									5	4
012	5	corridor	6	0																										9
014	9	corridor	0	0	0																								0	4
015	7	corridor	0	10																									0	0
016	32	corridor	0	0	0	1	0	0	0	0													0	0	0	0	0	0	0	17
017	23	corridor	0	8	0	0	0	0																	8	0	0	2	0	0
018	26	corridor	3	29	4	1	3	13	6																4	15	0	11	3	12
019	8	corridor	0	0																									0	0
022	9	corridor	9	2	10																								13	19
023	9	corridor	12	9	5																								6	1
024	6	corridor	14	13																										14
026	8	corridor	0	12																									21	45

			PERCENTAGE COVER OF NATIVE SPECIES																											
SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
027	6	corridor	22	25																										40
028	50	patch edge*	38	19	20	31	3	19	19	33	13	25	2	8	1	1	20	3	1	6	15	1	17	22	0	0	0			
029	7	corridor	0	0																									0	0
030	7	corridor	0	0																									0	0
031	6	corridor	0	0																										22
032	6	corridor	0	0																										0
033	6	corridor	54	14																										13
034	5	corridor	25	9																										7
035	7	corridor	18	2																									3	28
036	6	corridor	0	1																										0
037	6	corridor	7	0																										1
038	9	corridor	0	0	0																								0	1
039	5	corridor	92	86																										40
040	6	corridor	21	11																										8
042	7	corridor	17	21																									40	3
043	23	corridor	25	23	25	52	23	8	11																28	17	36	32	33	67
044	21	corridor	42	62	61	58	54	73																		80	63	40	18	27
045	25	corridor	0	0	0	3	5	0	0																0	0	7	0	0	0
046	23	corridor	0	0	0	0	0	0																	0	0	0	0	6	0
047	25	corridor	0	0	1	1	3	4	0																0	0	11	4	7	16
048	7	corridor	51	89																									58	47

PERCENTAGE COVER OF NATIVE SPECIES

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
049	6	corridor	39	87																										55
050	6	corridor	51	100																										64
051	50	patch edge*	0	0	0	0	0	0	0	0	0	0	12	12	2	11	13	16	28	17	8	7	27	13	12	42	35			
052	27	corridor	2	1	3	0	0	0	0															14	4	7	17	12	12	75
053	23	corridor	5	0	4	5	21	20																	10	3	14	4	19	0
054	23	corridor	0	17	18	18	20	14																	9	7	13	15	0	0
055	25	corridor	24	0	6	17	2	2	13																28	6	6	3	6	16
056	23	corridor	16	25	6	24	2	2																	9	0	2	6	18	39
057	7	corridor	85	44																									10	20
058	7	corridor	20	31																									14	27
059	5	corridor	14	0																										14
062	47	corridor	31	64	54	44	34	4	9	21	6	9	5	4					0	0	0	0	0	0	2	6	23	20	22	11
063	47	corridor	0	8	0	22	9	2	11	0	7	11	6	8					14	19	23	11	15	0	1	4	10	19	0	11
064	56	corridor	0	0	2	0	7	1	7	13	11	8	0	4	3	10	9	15	8	6	10	4	7	2	3	9	2	6	2	1
065	47	corridor	56	34	66	61	38	53	72	74	40	46	44	66					72	54	83	32	44	70	37	40	67	52	39	22
066	50	corridor	35	63	54	55	51	55	60	32	67	74	42	27	48				26	15	37	32	49	68	41	48	46	48	43	34
067	47	corridor	2	31	18	9	14	29	27	32	13	29	33	14					39	55	54	17	44	22	25	10	6	3	11	5
068	5	corridor	11	74																										47
069	5	corridor	9	19																										32
070	50	patch edge*	37	25	4	12	11	23	34	15	34	29	43	28	17	47	46	55	21	28	42	44	33	61	55	22	29			
071	21	corridor	3	8	6	12	1	17																		0	6	0	0	0

PERCENTAGE COVER OF NATIVE SPECIES

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27*	27	25	23	21	19	17	15	13	11	9	7	5	3	1
072	27	corridor	19	40	100	100	65	56	52															62	38	73	24	75	53	50
073	27	corridor	40	30	7	1	33	0	0															0	8	71	75	51	40	75
074	27	corridor	60	42	65	1	60	80	36															14	5	22	55	16	85	72
075	47	corridor	1	1	44	14	7	37	45	30	0	33	19	55					29	27	1	18	26	27	0	0	0	0	20	31
076	50	corridor	1	2	3	5	15	0	0	8	12	0	0	6	0				0	0	38	51	16	53	14	17	69	67	100	100
077	21	corridor	10	23	47	0	40	54																		4	1	0	39	67
078	35	corridor	4	15	17	12	59	16	74	27	36											34	54	75	45	54	68	97	28	35
079	29	corridor	46	0	0	8	0	3	19	25														62	23	4	0	23	0	20
080	26	corridor	82	13	17	13	0	1	38																8	0	10	14	31	78
081	27	corridor	5	20	31	43	50	38	67																100	73	28	7	23	10
082	n.a	patch core**	1	11	2	5	5	3	9	1	6	3	30	6	13	4	2	13	6	0	1	0	13	23	5	12	28			
085	25	corridor	36	52	19	59	24	34	14																28	20	44	36	17	17
086	25	corridor	46	22	12	4	8	3	22																28	21	31	20	7	6

* plot location increases in distance from patch edge up to 50 metres

** plots do not represent cover with distance from edge

PERCENTAGE COVER OF EXOTIC SPECIES

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
001	50	patch edge*	2	0	0	18	10	8	1	7	4	10	8	3	2	6	5	1	1	3	0	3	3	7	7	3	0			
002	25	corridor	24	1	1	2	2	2	4																8	8	17	22	38	33
003	50	patch edge*	7	1	0	2	1	0	3	2	1	2	2	0	1	0	0	0	0	0	0	0	0	2	1	0	0			
004	22	corridor	0	0	0	4	9	7																		3	2	0	0	14
006	6	corridor	10	30																										25
007	7	corridor	22	53																									35	69
008	7	corridor	2	0																									1	14
009	7	corridor	14	5																									5	0
010	7	corridor	4	17																									20	19
011	7	corridor	0	0																									1	3
012	5	corridor	10	20																										11
014	9	corridor	40	7	4																								28	44
015	7	corridor	12	9																									34	10
016	32	corridor	5	0	0	0	0	0	0	0													0	0	0	0	0	0	0	5
017	23	corridor	35	23	5	0	0	0	0															0	0	0	10	18	33	0
018	26	corridor	0	0	1	0	0	0	0																0	0	0	0	0	0
019	8	corridor	2	0																									0	0
022	9	corridor	1	3	0																								0	36
023	9	corridor	0	14	4																								5	10
024	6	corridor	55	23																										96
026	8	corridor	43	19																									46	50

PERCENTAGE COVER OF EXOTIC SPECIES

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
027	6	corridor	0	9																								10
028	50	patch edge*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
029	7	corridor	0	0																							0	0
030	7	corridor	0	0																							0	0
031	6	corridor	0	0																								0
032	6	corridor	25	16																								28
033	6	corridor	22	5																								0
034	5	corridor	0	0																								0
035	7	corridor	0	0																							0	0
036	6	corridor	0	0																								0
037	6	corridor	0	0																								0
038	9	corridor	0	0	0																						0	0
039	5	corridor	0	0																								0
040	6	corridor	0	0																								2
042	7	corridor	0	0																							0	0
043	23	corridor	0	0	0	0	0	0	0															0	0	0	0	0	0
044	21	corridor	0	0	0	0	0	0																	0	3	2	5	0
045	25	corridor	20	0	17	0	0	0	0															0	0	0	0	0	0
046	23	corridor	0	0	0	0	0	0																0	0	20	14	10	60
047	25	corridor	0	0	0	0	0	0	0															0	0	0	0	0	2
048	7	corridor	1	0																							0	0

			PERCENTAGE COVER OF EXOTIC SPECIES																											
SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
049	6	corridor	2	0																										14
050	6	corridor	1	0																										4
051	50	patch edge*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
052	27	corridor	9	0	0	0	0	0	0															0	0	0	0	0	0	0
053	23	corridor	0	0	1	0	0	17																	0	0	0	0	2	12
054	23	corridor	0	0	0	0	0	0																	0	0	0	0	0	0
055	25	corridor	1	3	0	0	3	18	22																7	12	41	2	1	0
056	23	corridor	0	0	0	0	0	0																	0	0	0	47	9	27
057	7	corridor	0	0																									22	92
058	7	corridor	0	0																									0	0
059	5	corridor	0	0																										1
062	47	corridor	0	0	0	0	0	0	1	0	3	0	0	0					0	0	0	1	1	1	5	7	12	16	3	37
063	47	corridor	67	8	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0	0	0	3	18	18	67	67
064	56	corridor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
065	47	corridor	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0	0	0	0	0	0	0	0
066	50	corridor	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0
067	47	corridor	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0	0	0	0	0	0	0	0
068	5	corridor	1	0																										0
069	5	corridor	0	0																										0
070	50	patch edge*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
071	21	corridor	0	0	0	0	0	0																		0	0	0	0	0

			PERCENTAGE COVER OF EXOTIC SPECIES																											
SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
072	27	corridor	0	0	0	0	0	0	0															0	0	0	0	0	0	5
073	27	corridor	0	0	0	0	0	0	0															0	0	0	0	0	0	20
074	27	corridor	0	0	0	0	0	0	0															0	0	0	0	0	0	0
075	47	corridor	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0	0	0	0	0	0	0	0
076	50	corridor	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0
077	21	corridor	0	0	0	0	0	0																		0	0	0	0	0
078	35	corridor	1	0	0	0	0	0	0	0	0											0	0	0	0	0	0	0	0	28
079	29	corridor	10	1	0	0	2	0	0	0														0	0	0	0	0	0	0
080	26	corridor	0	0	0	0	0	1	0															0	0	0	0	0	1	22
081	27	corridor	0	0	0	0	0	0	0															0	0	0	0	0	0	70
082	n.a	patch core**	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	3	2	0	0	0	0	9	0			
085	25	corridor	0	0	0	0	0	0	0																0	0	0	0	3	0
086	25	corridor	0	0	0	0	0	0	0																0	0	0	0	0	0

* plot location increases in distance from patch edge up to 50 metres

** plots do not represent cover with distance from an edge

PERCENTAGE COVER OF BAREGROUND

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
001	50	patch edge*	1	5	0	3	0	8	2	0	0	0	33	0	0	0	0	0	0	0	0	0	0	0	1	0	0			
002	25	corridor	0	0	0	0	0	0	0																0	0	0	0	0	0
003	50	patch edge*	2	5	12	17	17	14	38	16	19	11	13	1	0	9	9	0	9	7	9	30	67	12	18	9	0			
004	22	corridor	0	20	11	6	6	2																		6	0	17	17	10
006	6	corridor	0	4																										0
007	7	corridor	22	53																									35	69
008	7	corridor	2	0																									1	14
009	7	corridor	14	5																									5	0
010	7	corridor	4	17																									20	19
011	7	corridor	0	0																									1	3
012	5	corridor	10	20																										17
014	9	corridor	0	0	0																								0	0
015	7	corridor	0	0																									0	12
016	32	corridor	5	0	0	0	0	0	0	0													0	0	0	0	0	0	0	0
017	23	corridor	0	0	0	0	0	0																	0	0	0	0	0	53
018	26	corridor	0	0	7	23	17	3	8																0	0	33	5	11	8
019	8	corridor	0	0																									0	0
022	9	corridor	0	0	0																								0	0
023	9	corridor	0	0	0																								0	0
024	6	corridor	10	4																										0
026	8	corridor	56	24																									0	0

PERCENTAGE COVER OF BAREGROUND

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
027	6	corridor	39	0																										0
028	50	patch edge*	6	25	8	3	0	1	5	0	0	0	33	28	14	0	0	0	4	12	1	0	3	0	0	0	0			
029	7	corridor	10	0																									0	0
030	7	corridor	0	0																									0	0
031	6	corridor	60	9																										1
032	6	corridor	0	0																										0
033	6	corridor	0	0																										0
034	5	corridor	0	0																										0
035	7	corridor	0	0																									0	0
036	6	corridor	0	0																										0
037	6	corridor	0	0																										0
038	9	corridor	0	0	0																								0	0
039	5	corridor	0	0																										0
040	6	corridor	0	0																										0
042	7	corridor	45	0																									0	0
043	23	corridor	0	0	0	3	12	0	0																0	0	0	0	0	12
044	21	corridor	83	24	0	0	0	0																		0	0	0	2	33
045	25	corridor	33	0	0	0	0	0	0																0	0	0	0	0	0
046	23	corridor	17	17	17	17	17	17																	17	17	17	17	17	17
047	25	corridor	0	0	0	0	8	0	0																0	0	0	0	0	0
048	7	corridor	30	2																									0	0

PERCENTAGE COVER OF BAREGROUND

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
049	6	corridor	0	0																										0
050	6	corridor	4	0																										0
051	50	patch edge*	33	33	0	33	47	45	13	8	18	12	17	33	60	43	45	62	7	33	40	22	37	30	20	25	40			
052	27	corridor	38	25	30	0	0	0	0															0	0	0	0	33	47	17
053	23	corridor	0	17	0	0	17	0																	0	0	0	0	0	0
054	23	corridor	33	28	25	10	1	2																	1	0	0	1	0	0
055	25	corridor	27	48	0	0	0	0	0																0	7	0	3	0	0
056	23	corridor	7	8	0	7	0	0																	0	0	0	47	9	27
057	0	corridor	9	19																									9	8
058	7	corridor	0	0																									0	0
059	5	corridor	78	20																										20
062	47	corridor	0	0	0	0	0	0	0	0	0	0	0	0					0	0	0	0	0	0	0	0	0	0	0	0
063	47	corridor	0	32	15	48	0	8	0	0	0	0	1	16					30	22	8	8	0	0	0	0	0	0	25	33
064	56	corridor	0	0	0	0	0	2	40	17	0	0	0	1	33	7	5	9	15	0	0	0	0	0	17	0	0	0	0	0
065	47	corridor	17	0	23	0	33	7	0	3	37	62	40	37					8	12	13	34	26	13	20	23	2	6	0	12
066	50	corridor	23	0	0	0	0	0	0	47	0	0	0	0	0				0	0	0	12	0	0	6	1	25	12	0	0
067	47	corridor	65	56	7	2	2	13	15	19	9	33	71	73					60	24	16	32	0	0	0	0	0	0	3	23
068	5	corridor	11	0																										0
069	5	corridor	10	0																										0
070	50	patch edge*	30	0	0	0	0	3	0	4	0	0	3	15	33	0	0	0	0	17	0	0	0	0	0	0	0			
071	21	corridor	20	0	0	6	10	0																		0	0	0	0	0

PERCENTAGE COVER OF BAREGROUND

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
072	27	corridor	93	0	0	0	35	60	0															0	95	100	0	0	0	0
073	27	corridor	0	75	100	99	98	100	94															100	92	0	65	85	72	50
074	27	corridor	30	82	70	100	60	30	73															100	95	85	82	10	0	0
075	47	corridor	69	0	30	15	100	90	0	53	55	65	48	49					75	87	49	23	0	50	50	80	100	90	0	0
076	50	corridor	99	98	98	95	98	100	100	92	95	100	100	100	100				100	100	100	50	35	0	0	0	0	25	0	0
077	21	corridor	45	71	50	100	60	89																		99	99	100	84	10
078	35	corridor	0	48	0	91	38	75	24	69	94											83	6	40	47	55	0	0	0	0
079	29	corridor	60	99	100	92	98	50	20	69														0	100	100	75	50	50	50
080	26	corridor	85	95	49	70	100	98	28																89	100	0	90	98	25
081	27	corridor	0	0	0	0	0	0	0																0	0	0	0	0	0
082	n.a	patch core**	8	5	3	3	3	10	2	2	17	7	2	10	4	1	0	2	3	7	24	23	21	16	14	33	16			
085	25	corridor	30	65	0	6	13	22	44																13	4	0	0	28	0
086	25	corridor	5	2	0	0	0	0	0																0	0	0	0	3	10

* plot location increases in distance from patch edges up to 50 metres

** plots do not represent cover with distance from an edge

PERCENTAGE COVER OF LITTER																														
SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
001	50	patch edge*	75	75	100	72	68	75	76	78	87	77	53	93	83	83	83	94	90	81	82	82	80	78	81	83	82			
002	25	corridor	92	79	75	95	91	86	87																88	90	20	66	79	67
003	50	patch edge*	89	91	82	72	80	78	69	77	73	85	79	86	96	89	91	93	89	93	91	70	33	85	77	86	66			
004	22	corridor	58	70	85	90	80	92																		89	80	81	80	43
006	6	corridor	90	51																										72
007	7	corridor	78	40																									60	31
008	7	corridor	97	93																									96	77
009	7	corridor	87	95																									95	80
010	7	corridor	96	82																									78	77
011	7	corridor	79	100																									99	94
012	5	corridor	100	95																										88
014	9	corridor	60	93	95																								72	53
015	7	corridor	88	73																									57	78
016	32	corridor	90	100	100	99	100	100	100	100													100	100	100	100	100	100	100	95
017	23	corridor	65	77	95	100	100	100																	92	100	100	88	82	13
018	26	corridor	97	83	80	75	83	97	92																97	100	100	87	73	89
019	8	corridor	97	100																									100	100
022	9	corridor	99	95	95																								92	64
023	9	corridor	97	86	92																								89	74
024	6	corridor	35	72																										12
026	8	corridor	1	57																									54	47

PERCENTAGE COVER OF LITTER

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
027	6	corridor	61	86																										90
028	50	patch edge*	91	68	71	88	92	74	71	96	83	82	65	72	85	100	78	94	94	88	95	98	93	100	99	99	100			
029	7	corridor	90	100																									100	100
030	7	corridor	100	100																									100	100
031	6	corridor	40	90																										98
032	6	corridor	75	84																										73
033	6	corridor	43	94																										69
034	5	corridor	86	100																										96
035	7	corridor	100	100																									100	100
036	6	corridor	100	100																										99
037	6	corridor	99	100																										99
038	9	corridor	100	100	100																								100	99
039	5	corridor	60	90																										100
040	6	corridor	100	98																										96
042	7	corridor	44	94																									94	87
043	23	corridor	98	97	100	95	86	98	91																97	100	95	98	99	88
044	21	corridor	15	63	100	96	81	97																		98	95	88	87	63
045	25	corridor	30	99	83	99	100	67	100																100	100	97	100	100	100
046	23	corridor	83	83	83	83	83	83																	83	83	55	54	72	23
047	25	corridor	100	100	100	100	92	100	100																100	100	100	100	92	93
048	7	corridor	49	70																									97	100

PERCENTAGE COVER OF LITTER

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
049	6	corridor	84	98																										80
050	6	corridor	83	100																										86
051	50	patch edge*	67	67	100	67	50	55	87	92	82	88	83	62	36	57	43	36	92	67	60	70	63	70	77	72	60			
052	27	corridor	52	75	70	100	100	100	100															100	100	100	100	65	42	83
053	23	corridor	95	83	95	95	83	74																	90	97	96	96	88	86
054	23	corridor	67	70	64	66	50	88																	93	95	100	96	95	100
055	25	corridor	62	49	96	76	97	80	77																93	78	59	92	95	100
056	23	corridor	88	92	100	93	100	100																	100	100	99	53	81	57
057	7	corridor	97	80																									69	0
058	7	corridor	96	94																									95	98
059	5	corridor	20	80																										59
062	47	corridor	45	63	65	76	80	93	80	99	99	99	95	100					100	80	72	93	78	78	83	79	76	83	100	100
063	47	corridor	33	52	85	43	98	91	100	100	98	97	98	75					70	78	91	91	98	100	100	93	82	82	0	0
064	56	corridor	100	100	98	100	100	98	60	83	100	97	100	95	67	91	93	90	85	83	94	99	98	99	83	100	100	83	98	98
065	47	corridor	50	79	60	83	66	91	92	47	59	36	56	61					85	83	82	63	71	65	73	60	65	91	74	81
066	50	corridor	76	100	100	99	79	83	66	19	66	66	67	66	100				99	99	67	50	65	65	61	75	74	64	67	96
067	47	corridor	33	27	91	94	98	86	85	81	91	67	24	20					4	60	83	65	97	98	97	99	98	93	76	70
068	5	corridor	89	100																										99
069	5	corridor	90	100																										100
070	50	patch edge*	68	100	100	98	100	93	100	94	96	91	93	85	65	92	92	92	95	77	95	96	97	99	97	98	88			
071	21	corridor	80	100	99	87	73	97																		83	100	100	100	100

PERCENTAGE COVER OF LITTER

SITE	WIDTH (m)	TYPE	DISTANCE FROM EDGE (m)																											
			1	3	5	7	9	11	13	15	17	19	21	23	25	27	27	25	23	21	19	17	15	13	11	9	7	5	3	1
072	27	corridor	0	100	0	0	0	0	55															65	0	0	100	70	70	50
073	27	corridor	80	25	0	0	0	0	0															0	0	0	0	100	20	0
074	27	corridor	10	13	10	0	15	40	0															0	0	0	0	75	65	82
075	47	corridor	30	99	65	83	0	5	94	45	45	35	50	40					20	0	50	63	100	50	50	20	0	10	99	97
076	50	corridor	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	50	65	97	92	98	86	50	100	100
077	21	corridor	55	25	50	0	40	0																		0	0	0	5	89
078	35	corridor	95	50	0	5	52	0	48	25	0											14	85	49	50	45	85	88	95	37
079	29	corridor	30	0	0	0	0	47	74	20														98	0	0	25	50	50	47
080	26	corridor	0	0	50	17	0	0	70																10	0	100	9	0	53
081	27	corridor	98	100	99	100	100	95	100																99	100	100	100	98	25
082	n.a	patch core**	90	95	95	97	97	89	98	97	74	91	95	88	93	98	100	93	91	90	74	74	76	77	84	57	84			
085	25	corridor	34	31	90	79	86	76	51																85	89	100	98	55	96
086	25	corridor	79	53	96	99	65	100	98																84	71	81	74	92	88

* plot location increases in distance from patch edge up to 50 metres

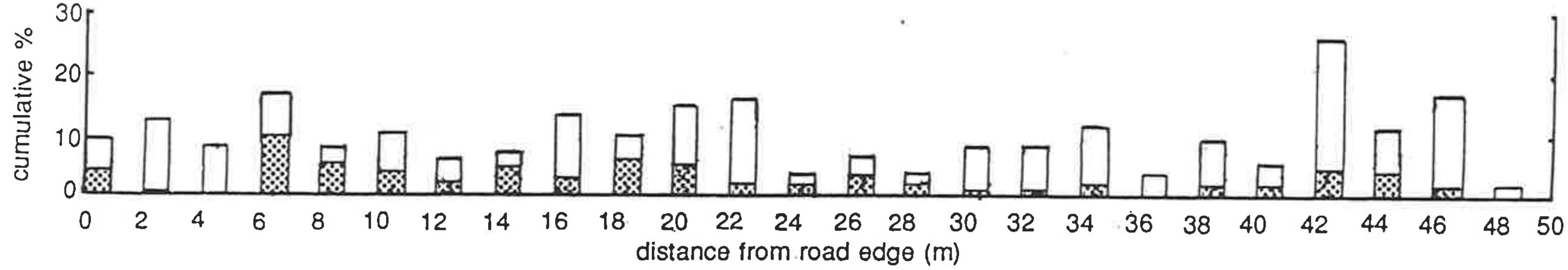
** plots do not represent cover with distance from edge

Appendix 6.3

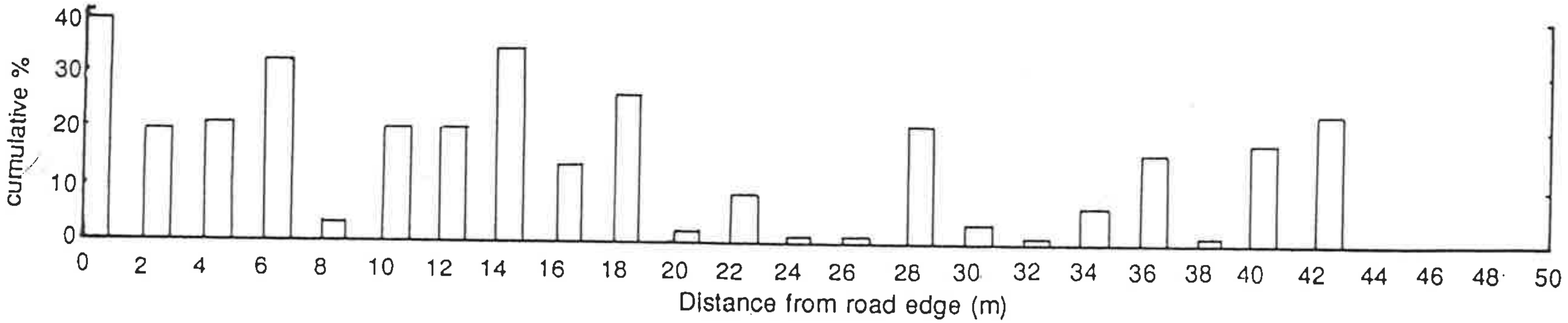
Histograms of exotic and native cover

▒ exotics

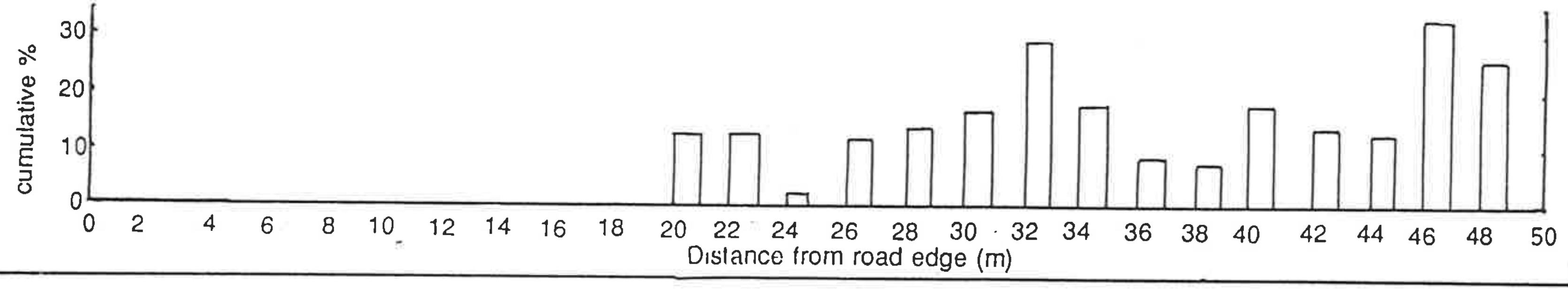
□ natives



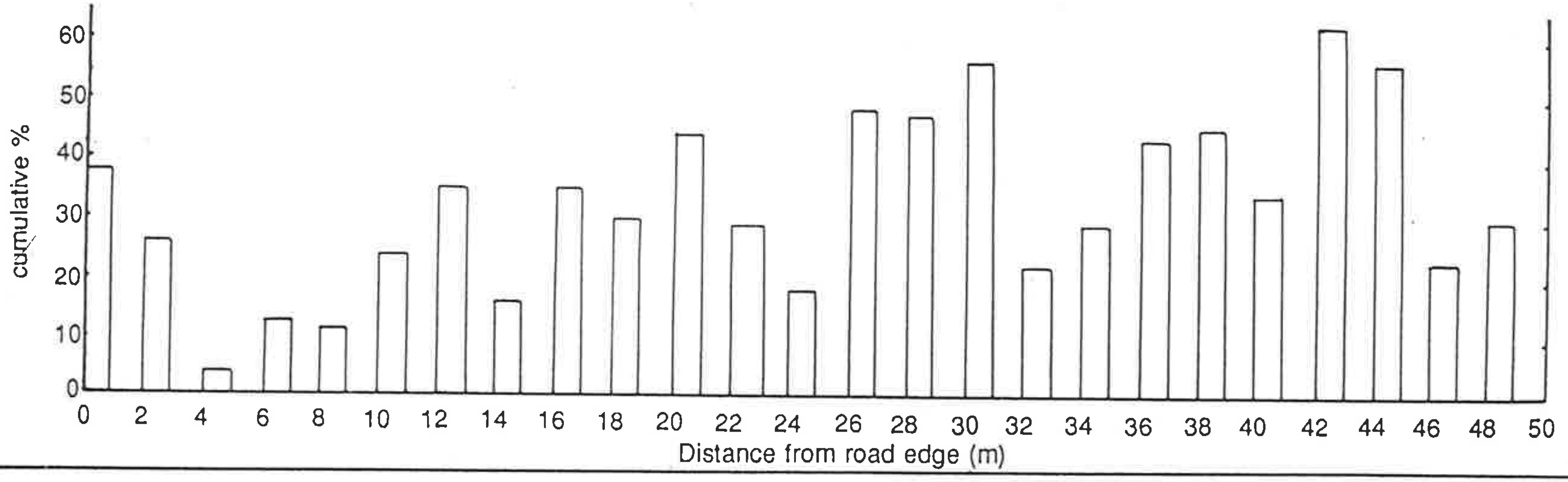
Group 2.1



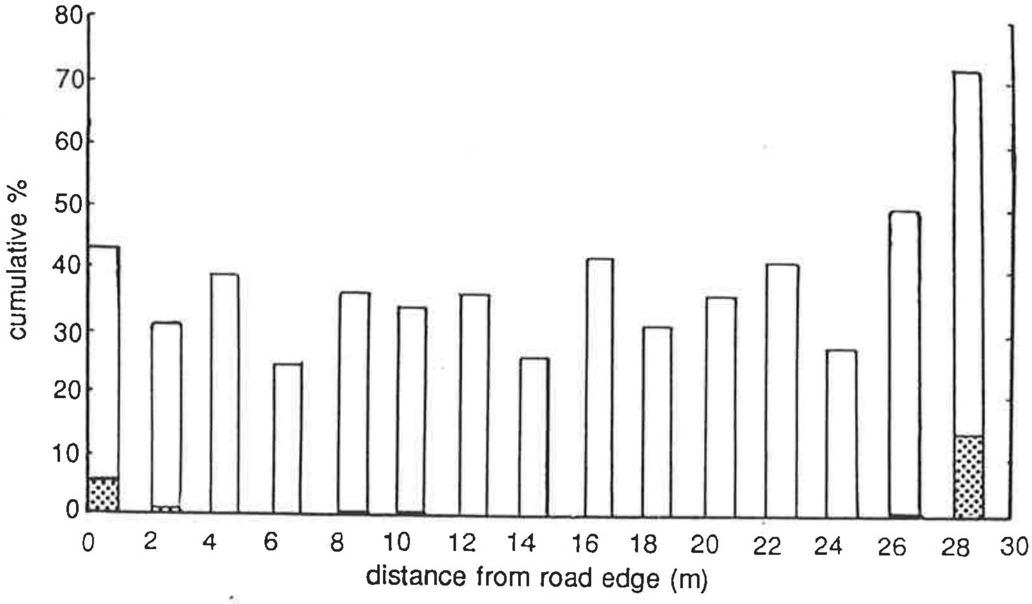
Group 2.2



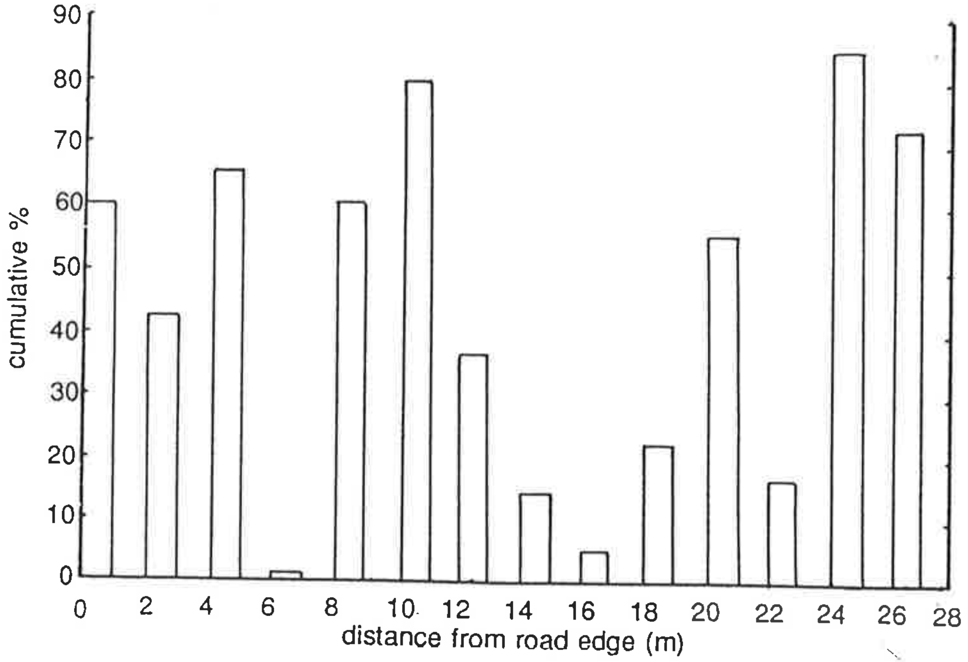
Group 2.3



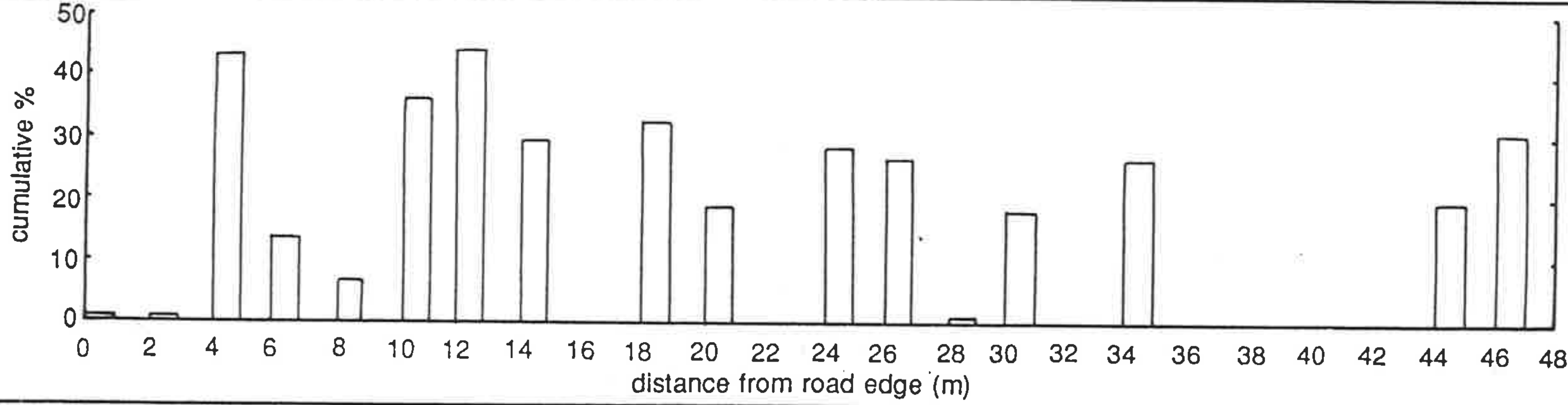
Group 2.4



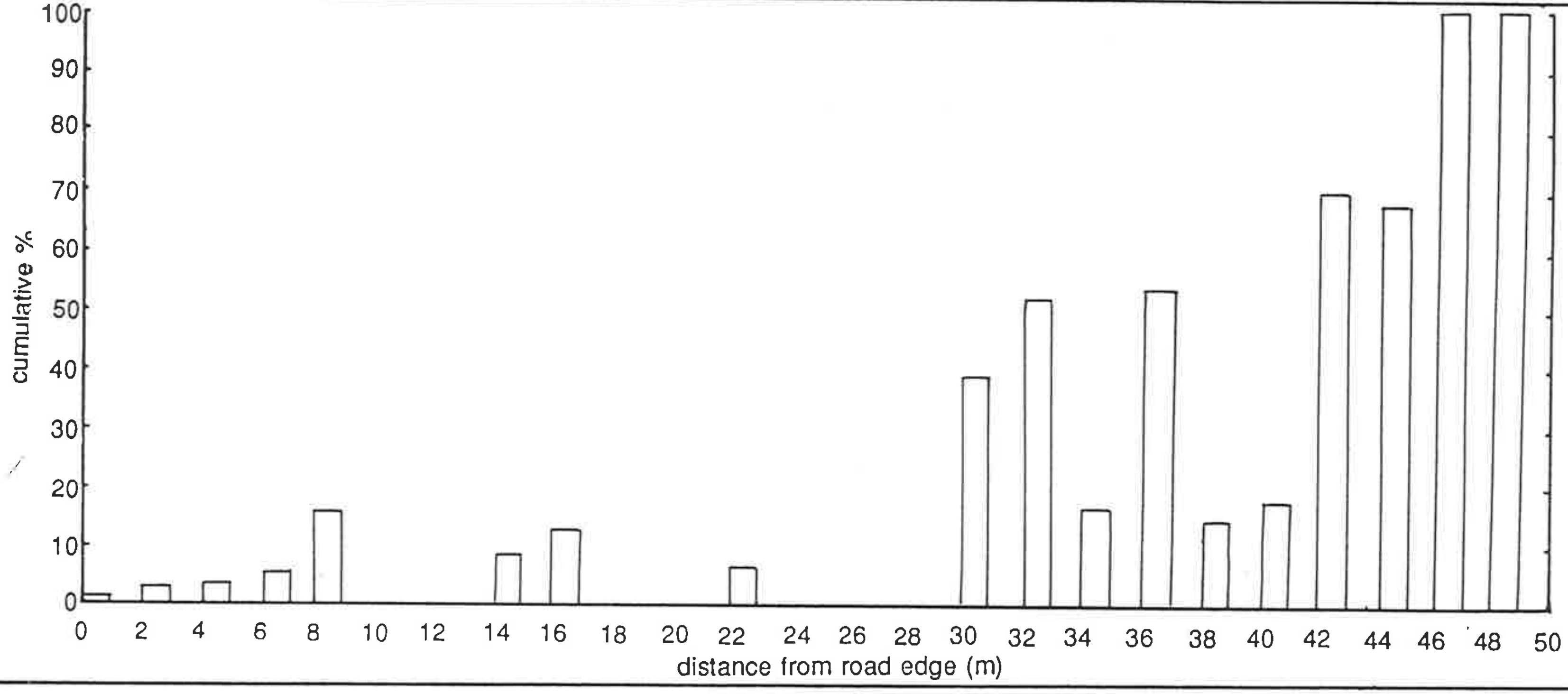
Group 3.1



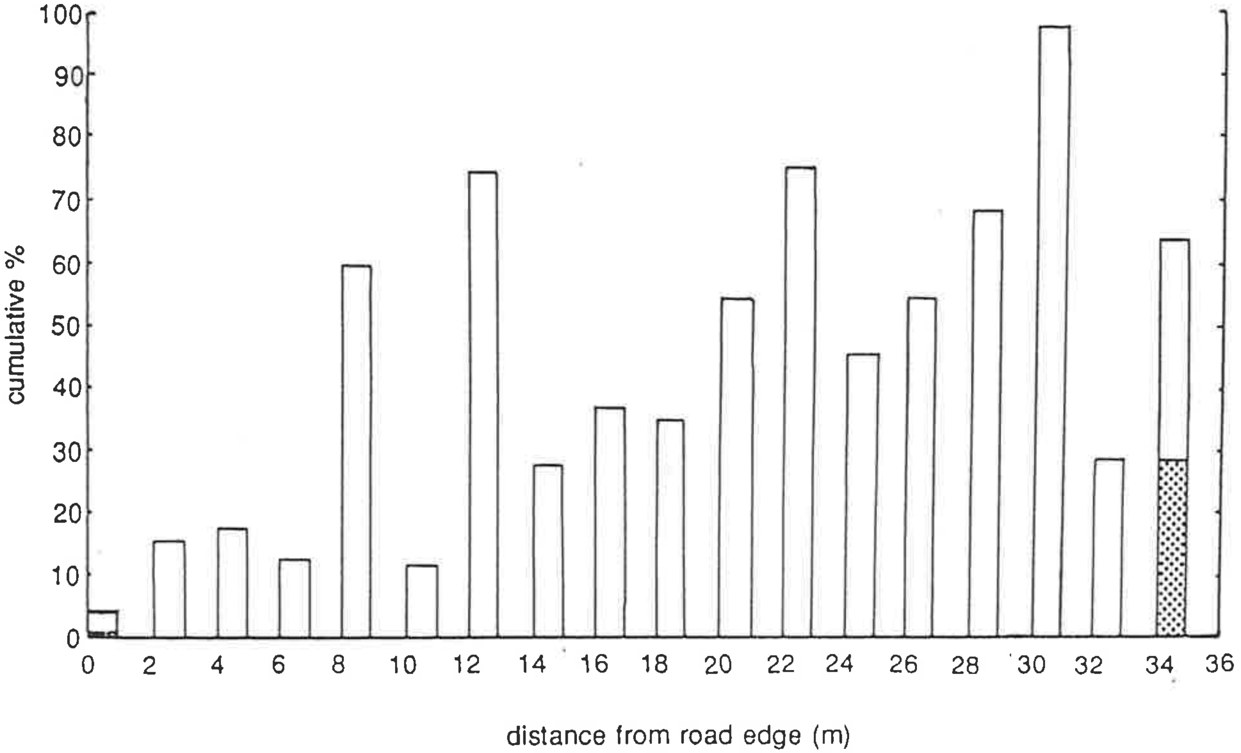
Group 3.2



Group 3.3

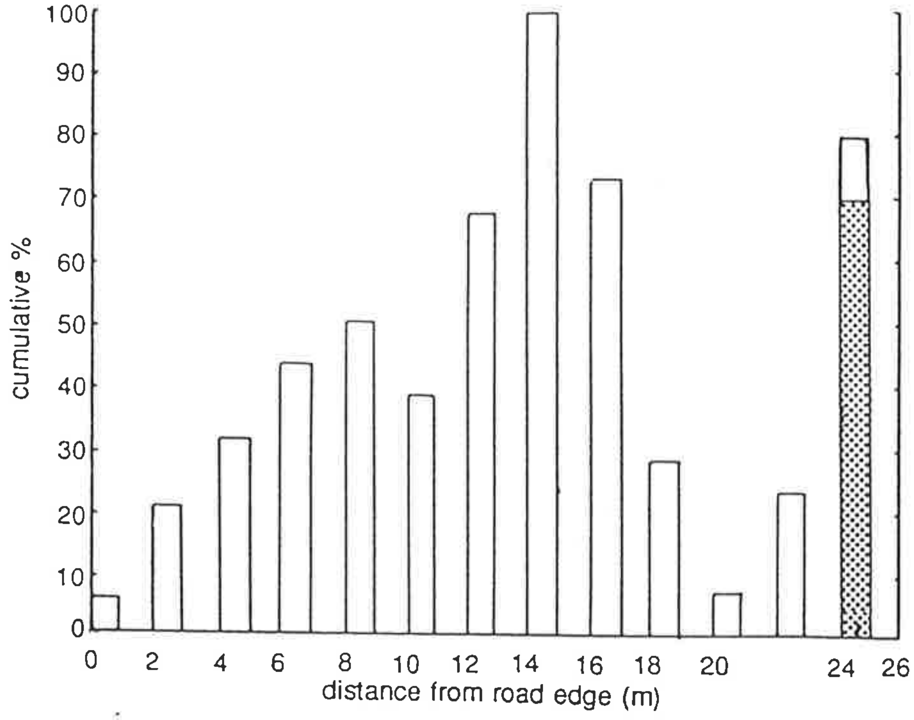


Group 3.4

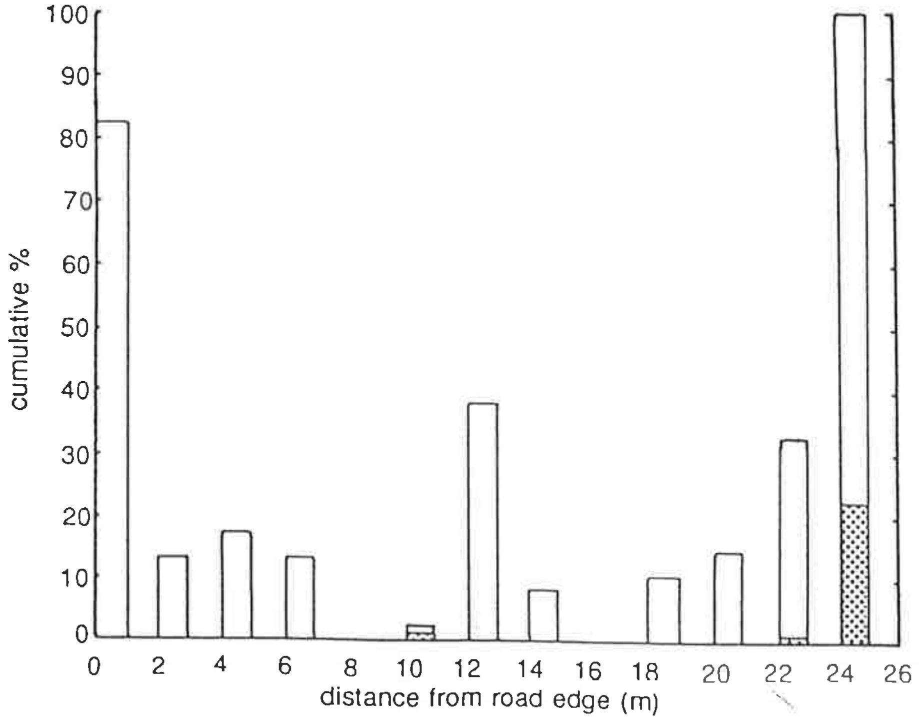


100
90
80
70
60
50
40
30
20
10
0
cumulative %
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
distance from road edge (m)

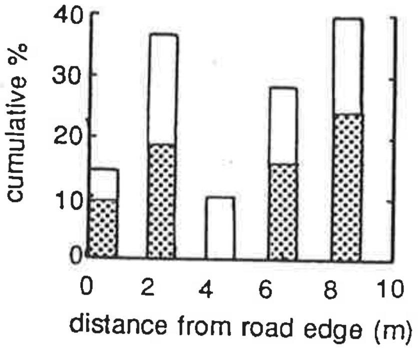
Group 3.5



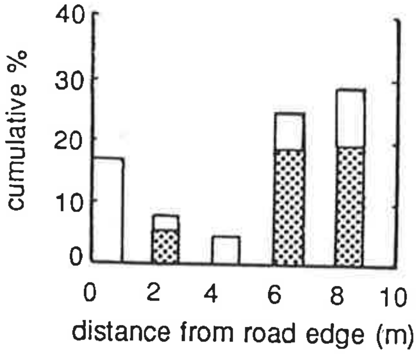
Group 3.6



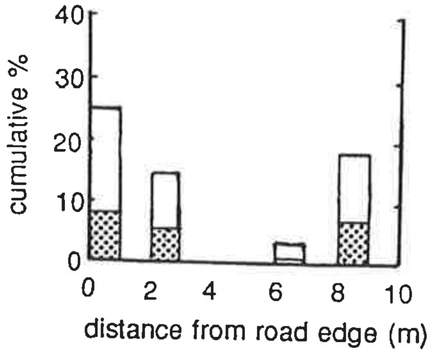
Group 3.7



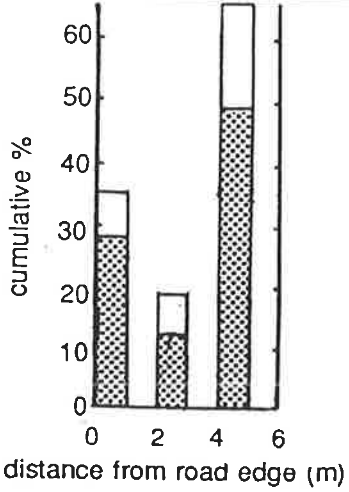
Group 4.1



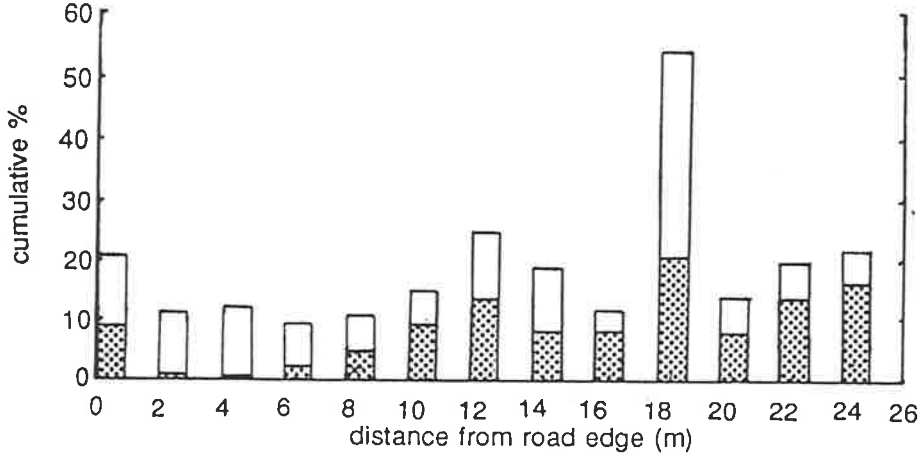
Group 4.2



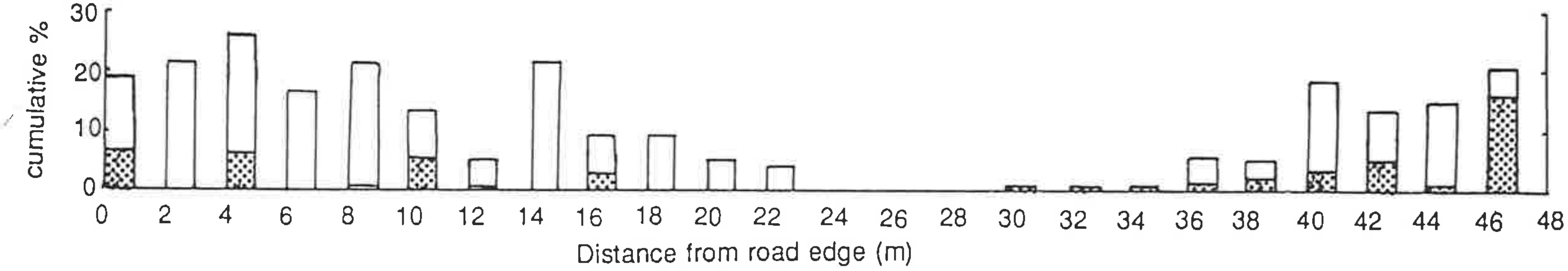
Group 4.3



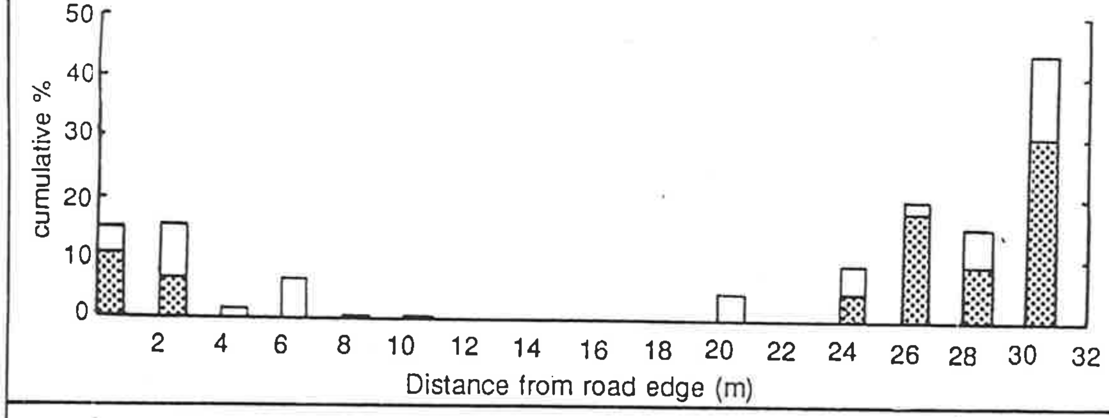
Group 4.4



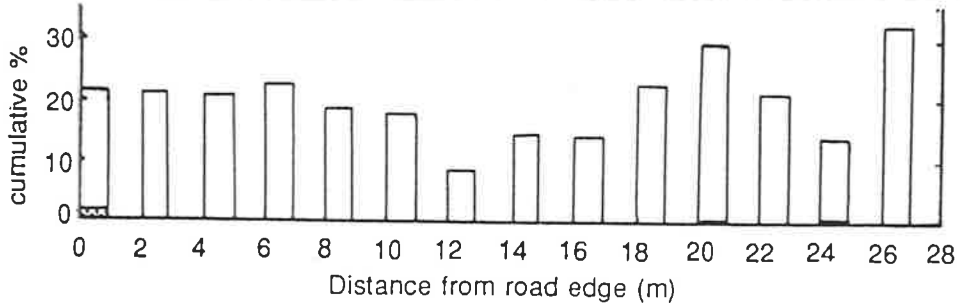
Group 5.1



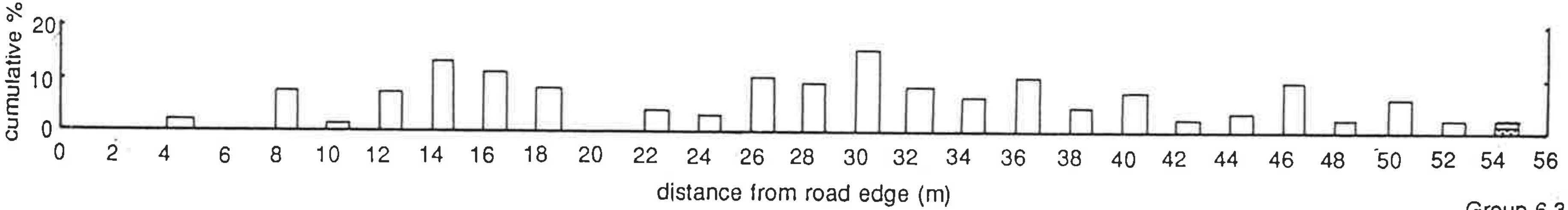
Group 5.2



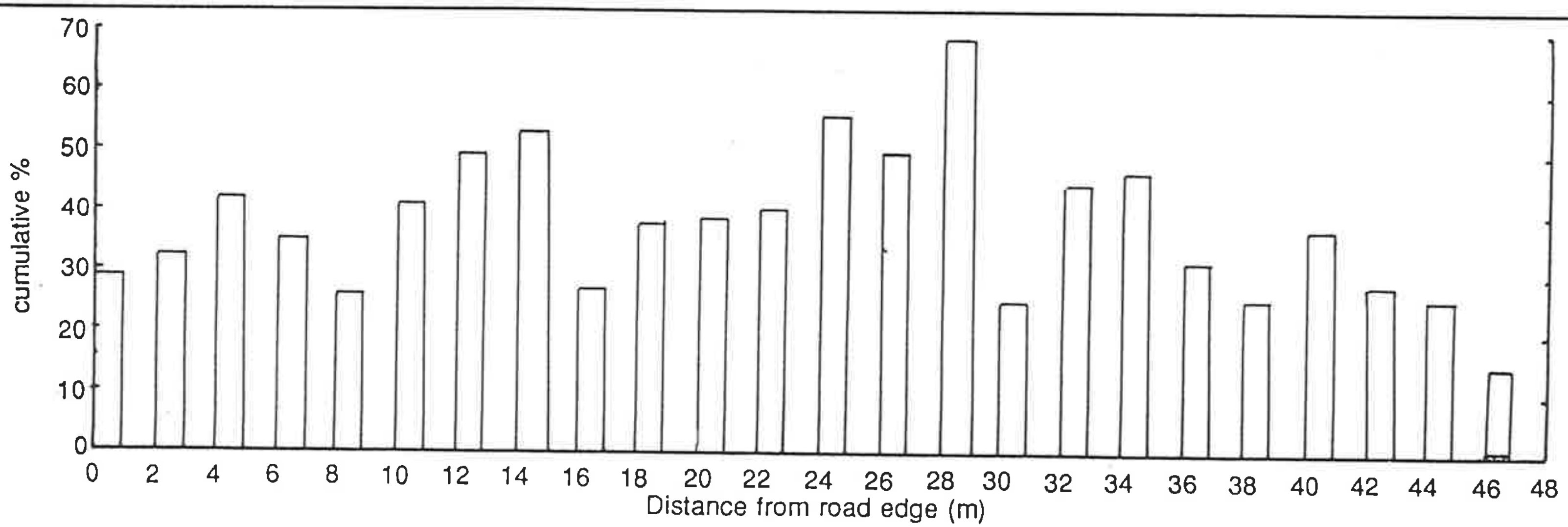
Group 6.1



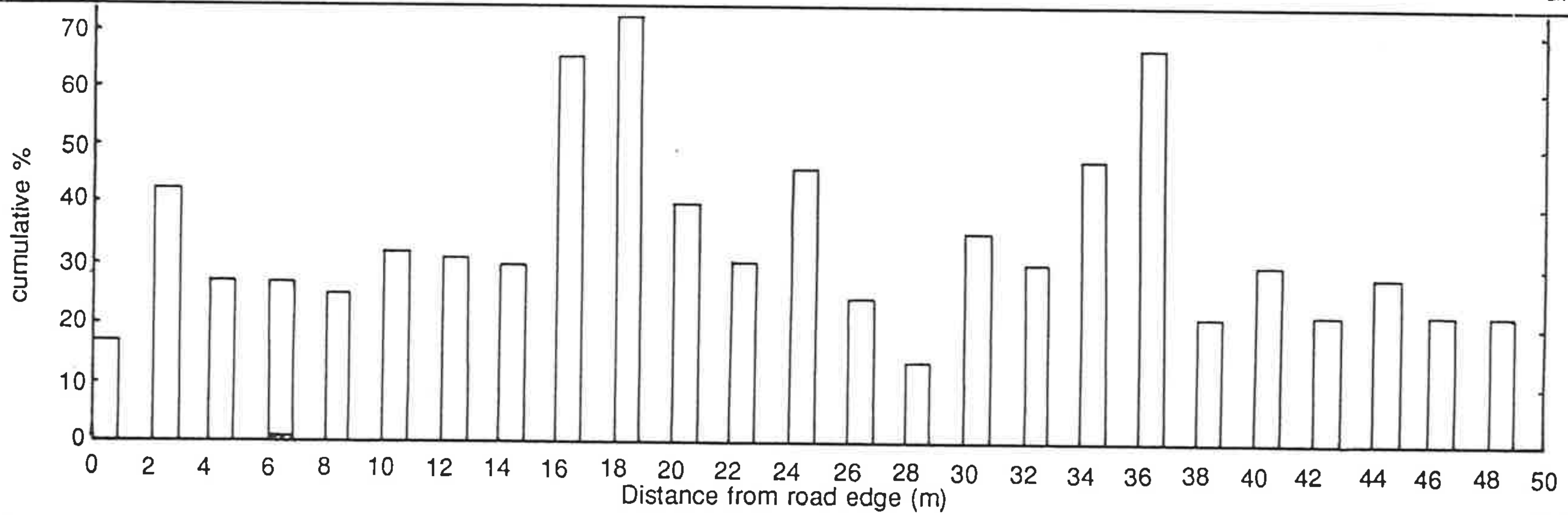
Group 6.2



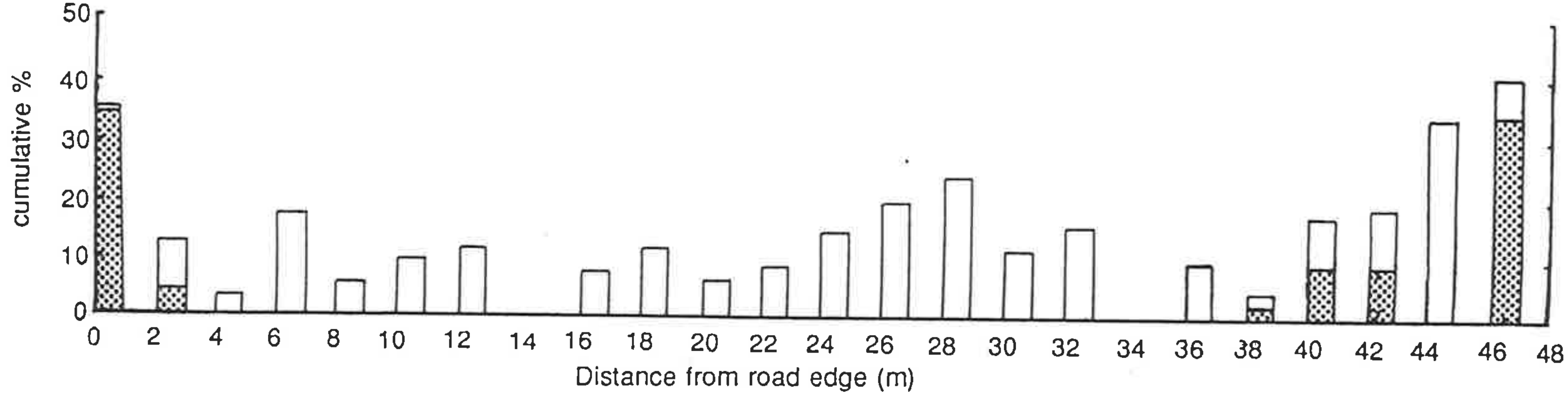
Group 6.3



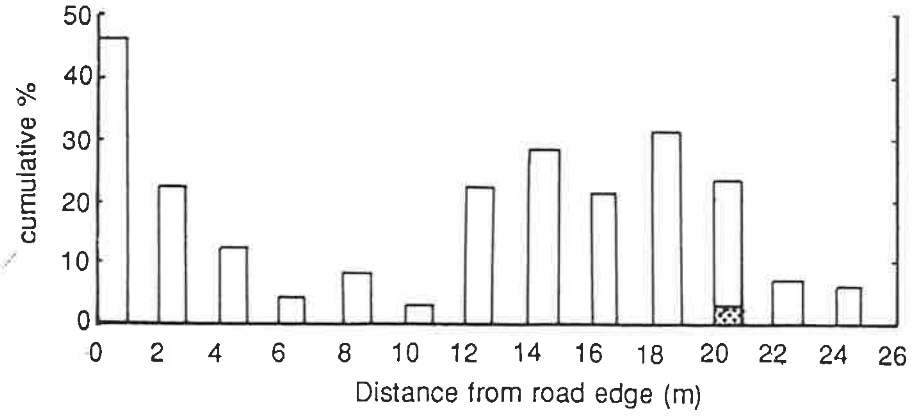
Group 6.4



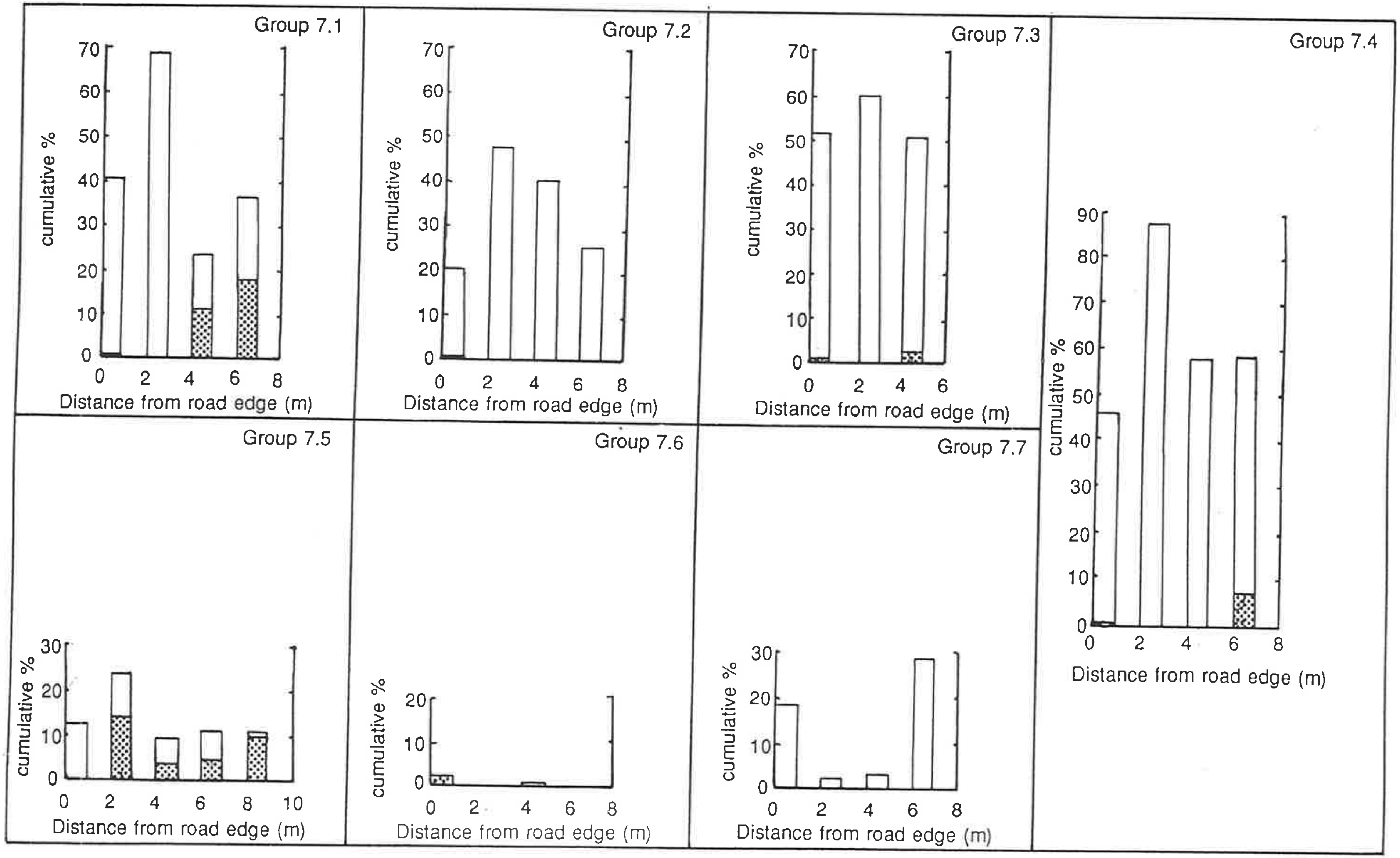
Group 6.5



Group 6.6



Group 6.7


Group 7.1
cumulative %
0
10
20
30
40
50
60
70
0
2
4
6
8
Distance from road edge (m)
Group 7.2
cumulative %
0
10
20
30
40
50
60
70
0
2
4
6
8
Distance from road edge (m)
Group 7.3
cumulative %
0
10
20
30
40
50
60
70
0
2
4
6
Distance from road edge (m)
Group 7.4
cumulative %
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
Distance from road edge (m)
Group 7.5
cumulative %
0
10
20
30
0
2
4
6
8
10
Distance from road edge (m)
Group 7.6
cumulative %
0
10
20
0
2
4
6
8
Distance from road edge (m)
Group 7.7
cumulative %
0
10
20
30
0
2
4
6
8
Distance from road edge (m)

Appendix 6.4

Group Descriptions

GROUP 1.0

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia

E. rugosa

Understorey

Natives

Brachyloma ericoides

Choretrum glomeratum

Clematis microphylla

Correa reflexa v. nummularifolia

Daucus glochidiatus

Eucalyptus cneorifolia

Myoporum insulare

Orthosanthus multiflorus

Pimelea stricta

Rhagodia crassifolia

Senecio odoratus

Exotics

Exotic grass

Oxalis pescaprae

GROUP 2.1

Structure

Low open forest

Species List

Overstorey

Acacia pycnantha
Correa reflexa var. nummularifolia
Calytrix sp.A
Eucalyptus cneorifolia
E. rugosa
Olearia axillaris

Understorey

Natives

- Acacia paradoxa
- A. pycnantha
- Acianthus caudatus
- Acrotriche cordata
- A. depressa
- Astroloma humifusum
- Clematis microphylla
- C. reflexa v. nummularifolia
- C. reflexa v. reflexa
- Daucus glochidiatus
- Dianella revoluta
- Eucalyptus cneorifolia
- Moss
- Myoporum insulare
- Olearia axillaris
- Orthosanthus multiflorus
- Pimelea serpifolia
- P. stricta
- Rhagodia crassifolia
- Senecio odoratus

Exotics

Exotic grass
Myrsiphyllum asparagoides
Oxalis pescaprae

GROUP 2.2

Structure

Low open forest

Species List

Overstorey

Correa reflexa v. nummularifolia
Eucalyptus cneorifolia

Understorey

Natives

Acacia myrtifolia
Acrotriche depressa
Astroloma conostephoides
A. humifusum
Choretrum glomeratum
Clematis microphylla
Correa reflexa v. nummularifolia
Dianella revoluta
Drosera macrantha ssp. planchonii
Eucalyptus cneorifolia
Goodenia ovata
Hibbertia riparia
Lasiopetalum behrii
Moss
Olearia teretifolia
Orthosanthus multiflorus
Rhagodia crassifolia
Stipa sp.

Exotics

-

GROUP 2.3

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia
E. diversifolia

Understorey

Natives

Acacia myrtifolia
Acrotriche patula
Astroloma conostephoides
Calytrix sp. A
Correa reflexa var. nummularifolia
Eucalyptus cneorifolia
Moss
Thryptomene ericaea

Exotics

-

GROUP 2.4

Structure

Low open forest

Species List

Overstorey

Allocasuarina striata
Correa aemula
Eucalyptus cneorifolia
Melaleuca gibbosa
M. uncinata
Xanthorrhoea tateana

Understorey

Natives

Acrotriche depressa
Allocasuarina muelleriana
Astroloma conostephoides
Correa reflexa v. reflexa
Drosera auriculata
D. whittakeri
Eucalyptus cneorifolia
Hibbertia riparia
Lepidosperma carphoides
L. congestum
Melaleuca gibbosa
M. uncinata
Moss
Thryptomene ericaea
Xanthorrhoea tateana

Exotics

-

GROUP 3.1

Structure

Tall sparse shrubland

Species List

Overstorey

Allocasuarina striata
Eucalyptus cneorifolia

Understorey

Natives

Allocasuarina striata
Astroloma conostephoides
A. humifusum
Beyeria lechenaultii
Daviesia genistifolia
Hibbertia riparia
Lepidosperma carphoides
L. congestum
Leptomeria aphylla
Melaleuca gibbosa
Xanthorrhoea tateana

Exotics

Exotic grass

GROUP 3.2

Structure

Tall sparse shrubland

Species List

Overstorey

Allocasuarina striata

Eucalyptus cneorifolia

Understorey

Natives

Allocasuarina striata

Lepidosperma carphoides

Melaleuca gibbosa

Xanthorrhoea tateana

Exotics

-

GROUP 3.3

Structure

Medium open shrubland

Species List

Overstorey

Eucalyptus cneorifolia

Understorey

Natives

Acacia paradoxa
Acrotriche depressa
Astroloma conostephoides
A. humifusum
Choretrum glomeratum
Daviesia genistifolia
Dianella revoluta
Grevillea illicifolia
Hibbertia riparia
Lasiopetalum behrii
Lepidospermum carphoides
Leptomeria aphylla
Melaleuca gibbosa
Micrantheum demissum
Pultenaea rigida
Thryptomene ericaea

Exotics

-

GROUP 3.4

Structure

Medium open shrubland

Species List

Overstorey

Eucalyptus cneorifolia

Understorey

Natives

Astroloma conostephoides
A. humifusum
Calytrix tetragona
Calytrix sp. A
Daviesia genistifolia
Grevillea illicifolia
Hibbertia riparia
Isopogon ceratophyllus
Lepidosperma carphoides
L. congestum
Leptomeria aphylla
Melaleuca gibbosa
Micrantheum demissum
Pultenaea rigida
Xanthorrhoea tateana

Exotics

-

GROUP 3.5

Structure

Medium very open shrubland

Species List

Overstorey

Acacia pycnantha

Understorey

Natives

Acacia paradoxa
Astroloma conostephoides
A. humifusum
Correa reflexa v. reflexa
Daviesia genistifolia
Eutaxia microphyalla
Haloragis eichlerii
Hibbertia riparia
Lepidosperma congestum
Melaleuca gibbosa
Micrantheum demissum
Styphelia exharrena
Xanthorrhoea tateana

Exotics

-

GROUP 3.6

Structure

Low very open woodland

Species List

Overstorey

Allocasuarina striata
Beyeria lechenaultii
Callistemon rugulosus v. rugulosus
Eucalyptus cneorifolia

Understorey

Natives

Acacia paradoxa
Acrotriche depressa
Astroloma conostephoides
A. humifusum
Choretrum glomeratum
Correa reflexa v. reflexa
Callistemon rugulosus v. rugulosus
Dianella revoluta
Haloragis eichlerii
Hibbertia riparia
Lasiopetalum behrii
Phyllanthos australis
Styphelia exharrena

Exotics

-

GROUP 3.7

Structure

Low very open shrubland

Species List

Overstorey

Callistemon rugulosus v. rugulosus
Eucalyptus cneorifolia

Understorey

Natives

Acacia paradoxa
Allocasuarina striata
Astroloma humifusum
Callistemon rugulosus v. rugulosus
Choretrum glomeratum
Dianella revoluta
Goodenia ovata
Haloragis eichlerii
Hibbertia riparia
Lasiopetalum behrii
Melaleuca gibbosa
Pimelea stricta
Styphelia exharrena

Exotics

-

GROUP 4.1

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia
E. rugosa
Melaleuca gibbosa
Myoporum insulare

Understorey

Natives

Clematis microphylla
Correa reflexa v. nummularifolia
C. reflexa v. reflexa
Dianella revoluta
Eucalyptus cneorifolia
Goodenia ovata
Hibbertia riparia
Lepidosperma carphoides
Melaleuca gibbosa
Myoporum insulare
Olearia axillaris
Orthosanthus multiflorus
Rhagodia crassifolia

Exotics

Exotic grass

GROUP 4.2

Structure

Low open forest

Species List

Overstorey

Correa reflexa v. reflexa
Eucayptus cneorifolia
Melaleuca lanceolata

Understorey

Natives

Acacia myrtifolia
Callistemon rugulosus v. rugulosus
Correa reflexa v. reflexa
Dianella revoluta
Eucalyptus cneorifolia
Hibbertia riparia
Lepidosperma carphoides
Olearia teretifolia
Rhagodia crassifolia

Exotics

Exotic grass

GROUP 4.3

Structure

Low open forest

Species List

Overstorey

Allocasuarina striata
Callistemon rugulosus v. rugulosus
Callitris rhomboidea
Calytrix tetragona
Correa reflexa v. reflexa
Eucalyptus cneorifolia
Melaleuca gibbosa
Rhagodia crassifolia

Understorey

Native

Acacia myrtifolia
Billardieria cymosa
Callistemon rugulosus v. rugulosus
Correa reflexa v. reflexa
Dianella revoluta
Eucalyptus cneorifolia
Haloragis eichlerii
Hibbertia riparia
Lasiopetalum behrii
Lepidosperma carphoides
Melaleuca gibbosa
Pimelea stricta
Rhagodia crassifolia
Senecio odoratus

Exotics

Exotic grass

GROUP 4.4

Structure

Low open forest

Species List

Overstorey

Allocasuarina striata
Eucalyptus cneorifolia
Melaleuca gibbosa

Understorey

Natives

Astroloma humifusum
Correa reflexa v. nummularifolia
C. reflexa v. reflexa
Dianella revoluta
Eucalyptus cneorifolia
Hakea rostrata
Lasiopetalum behrii
Melaleuca gibbosa

Exotics

Exotic grass

GROUP 5.1

Structure

Medium open forest

Species List

Overstorey

Eucalyptus cneorifolia
E. rugosa

Understorey

Natives

Acacia paradoxa
Acianthus caudatus
Clematis microphylla
Dianella revoluta
Moss
Myoporum insulare
Olearia axillaris
Rhagodia crassifolia
Senecio odoratus
Stipa sp.

Exotics

Exotic grass
Myrsiphyllum asparagoides
Oxalis pescaprae

GROUP 5.2

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia

Understorey

Natives

Acacia paradoxa
Beyeria lechenaultii
Billardiera cymosa
Calytrix sp A
Clematis microphylla
Correa reflexa v. nummulariifolia
Correa reflexa v. reflexa
Dianella revoluta
Eucalyptus cneorifolia
Lasiopetralum schulzenii
Lepidosperma congestum
Moss
Orthosanthus multiflorus
Pimelea stricta
Pultenaea daphnoides
Rhagodia crassifolia
Stipa sp.

Exotics

Exotic grass
Myrsiphyllum asparagoides
Oxalis pescaprae

GROUP 6.1

Structure

Low open forest

Species List

Overstorey

Acacia paradoxa
Eucalyptus cneorifolia
Melaleuca gibbossa
M. uncinata

Understorey

Natives

Choretrum glomeratum
Clematis microphylla
Correa reflexa v. reflexa
Dianella revoluta
Eucalyptus cneorifolia
Lasiopetalum behrii
Lepidosperma carphoides
Melaleuca gibbosa
M. uncinata
Moss
Thryptomene ericaea

Exotics

Exotic grass
Myrsiphyllum asparagoides

GROUP 6.2

Structure

Low open forest

Species List

Overstorey

- Allocasuarina striata
- Callistemon rugulosus v. rugulosus
- Eucalyptus cneorifolia
- E. diversifolia
- Melaleuca gibbosa
- M. uncinata
- Pultenaea daphnoides
- Xanthorrhoea tateana

Understorey

Natives

- Acacia myrtifolia
- A. paradoxa
- Acrotriche depressa
- A. patula
- Allocasuarina striata
- Astroloma conosephoides
- A. humifusum
- Brachyloma ericoides ssp. bicolor
- Callistemon rugulosus v. rugulosus
- Callitris rhomboidea
- Calytrix sp. A
- Choretrum glomeratum
- Correa reflexa v. nummularifolia
- Correa reflexa v. reflexa
- Daviesia genistifolia
- Dianella revoluta
- Drosera whittakeri
- Eucalyptus cneorifolia
- Haloragis eichlerii
- Hibbertia riparia
- Lasiopetalum behrii
- Lepidosperma carphoides
- L. congestum
- Melaleuca gibbosa
- M. lanceolata
- Moss
- Orthosanthus multiflorus
- Phyllanthos australis
- Pultenaea daphnoides
- Thryptomene ericaea
- Xanthorrhoea tateana

Exotics

- Exotic grass

GROUP 6.3

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia
E. diversifolia

Understorey

Natives

Acacia paradoxa
A. pycnantha
Correa reflexa v. nummularifolia
C. reflexa v. reflexa
Eucalyptus cneorifolia
E. diversifolia
Lasiopetalum behrii
Lepidosperma carphoides
Melaleuca gibbosa
Pomaderris oraria
Rhagodia crassifolia
Thryptomene ericaea

Exotics

Exotic grass

GROUP 6.4

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia
E. diversifolia

Understorey

Natives

Acacia myrtifolia
A. paradoxa
Acrotriche cordata
A. depressa
Astroloma conostephoides
A. humifusum
Beyeria lechenaultii
Callistemon rugulosus v. rugulosus
Calytrix tetragona
Choretrum glomeratum
Correa reflexa v. nummularifolia
C. reflexa v. reflexa
Daviesia genistifolia
Dianella revoluta
Drosera macrantha ssp. planchonii
D. whittakeri
Eucalyptus diversifolia
Eutaxia microphylla v. microphylla
Goodenia ovata
Grevillea illicifolia
Hakea rostrata
Hibbertia aspera
H. riparia
Isopogon ceratophyllus
Lasiopetalum behrii
Lepidosperma carphoides
L. congestum
Leptomeria aphylla
Leucopogon parviflora
Logania ovata
Melaleuca uncinata
Micrantheum demissium
Moss
Olearia teretifolia
Pimelea stricta
Pomaderris oraria
Pultenaea rigida v. rigida
P. viscidula
Thryptomene ericaea
Trymalium wayi
Xanthorrhoea tateana

Exotics

Exotic grass

GROUP 6.5

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia
E. conglobata
E. diversifolia
Olearia axillaris

Understorey

Natives

Acrotriche patula
Allocasuarina striata
Astroloma conostephoides
A. humifusum
Callistemon rugulosus v. rugulosus
Calytrix tetragona
C. sp. A
Cheilanthes austrotenuifolia
Choretrum glomeratum
Correa reflexa v. nummularifolia
Daviesia genistifolia
Dianella revoluta
Dichondra repens
Drosera macrantha ssp. planchonii
D. whittakeri
Eucalyptus cneorifolia
Grevillea illicifolia
Hibbertia aspera
H. riparia
Lasiopetalum behrii
Lepidosperma carphoides
Leptomeria aphylla
Micrantheum demissum
Moss
Pultenaea daphnoides
P. rigida v. rigida
Styphelia exharrena
Thryptomene ericaea

Exotics

Exotic grass

GROUP 6.6

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia
E. diversifolia
Melaleuca uncinata

Understorey

Natives

Acacia myrtifolia
A. paradoxa
A. pycnantha
Correa reflexa v. reflexa
Eucalyptus cneorifolia
E. diversifolia
Lasiopetalum behrii
Lepidosperma carphoides
Melaleuca gibbosa
Moss
Orthosanthus mulitflorus
Pomaderris oraria
Rhagodia crassiflora
Thryptomene ericaea

Exotics

Exotic grass

GROUP 6.7

Structure

Low open forest

Species List

Overstorey

-

Undestorey

Natives

Acacia myrtifolia
Acrotriche depressa
A. patula
Astroloma conostephoides
A. humifusum
Beyeria lechenaultii
Choretrum glomeratum
Correa reflexa v. nummularifolia
Eucalyptus cneorifolia
Goodenia ovata
Haloragis eichlerii
Hibbertia riparia
Lasiopetalum behrii
Micrantheum demissum
Moss
Orthosanthus multiflorus
Scaevola aemula
Spyridium spathulatum
Stipa sp.

Exotics

Exotic grass

GROUP 7.1

Structure

Low open forest

Species List

Overstorey

Acacia paradoxa
Allocasuarina striata
Callistemon rugulosus v. rugulosus
Eucalyptus cneorifolia
Haloragis eichlerii
Hibbertia riparia
Lepidosperma carphoides
L. congestum
Melaleuca gibbosa
M. uncinata
Micrantheum demissum
Phyllanthos australis
Styphelia exharrena
Thryptomene ericaea
Xanthorrhoea tateana

Exotics

Exotic grass

GROUP 7.2

Structure

Low open forest

Species List

Overstorey

Allocasuarina striata
Eucalyptus cneorifolia
E. diversifolia
Melaleuca gibbosa
M. uncinata

Understorey

Natives

Allocasuarina striata
Astroloma conostephoides
Correa reflexa v. reflexa
Daviesia genistifolia
Dianella revoluta
Eucalyptus cneorifolia
Hibbertia riparia
Lasiopetalum behrii
Lepidosperma carphoides
L. congestum
Melaleuca gibbosa
Phyllanthos australis
Styphelia exharrena
Xanthorrhoea tateana

Exotics

Exotic grass

GROUP 7.3

Structure

Low open woodland

Species List

Overstorey

Allocasuarina striata
Eucalyptus cneorifolia
E. diversifolia
Hakea rostrata
Melaleuca uncinata

Understorey

Natives

Acrotriche depressa
Allocasuarina striata
Hibbertia riparia
Lepidosperma carphoides
L. congestum
Melaleuca uncinata
Micrantheum demissum
Xaxthorrhoea tateana

Exotics

Exotic grass

GROUP 7.4

Structure

Tall moderately open shrubland

Species List

Overstorey

Acacia paradoxa
Allocasuarina striata
Eucalyptus cneorifolia
Melaleuca gibbosa

Understorey

Natives

Acacia myrtifolia
Callistemon rugulosus v. rugulosus
Dianella revoluta
Goodenia ovata
Haloragis eichleri
Hibbertia riparia
Lepidosperma carphoides
L. congestum
Melaleuca gibbosa

Exotics

Exotic grass

GROUP 7.5

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia

Understorey

Natives

Acacia paradoxa
Acrotriche depressa
Correa reflexa v. reflexa
Eucalyptus cneorifolia
Hibbertia riparia
Lasiopetalum behrii
Melaleuca gibbosa

Exotic

Exotic grass

GROUP 7.6

Structure

Low open forest

Species List

Overstorey

Eucalyptus cneorifolia

Melaleuca uncinata

Understorey

Natives

-

Exotics

Exotic grass

GROUP 7.7

Structure List

Low open forest

Species List

Overstorey

Callistemon rugulosus v. rugulosus
Eucalyptus cneorifolia

Understorey

Natives

Acacia myrtifolia
Beyeria lechenaultii
Callistemon rugulosus v. rugulosus
Correa reflexa v. nummularifolia
Eucalyptus cneorifolia
Goodenia ovata
Hibbertia riparia

Exotic

-

Appendix 6.5

Species List

Species List

Acianthus caudatus

Acacia myrtifolia

Acacia paradoxa

Acacia pycnantha

Acrotriche cordata

Acrotriche depressaas

Acrotriche patula

Allocasuarina muelleriana

Allocasuarina striata

Astroloma conostephoides

Astroloma humifusum

Beyeria lechenaultii

Billardiera cymosa

Billardiera versicolor

Brachyloma ericoides ssp. bicolor

Callistemon rugulosus var. rugulosus

Callitris rhomboidea

Calytrix sp. A (syn Lhotzkya glaberrima)

Calytrix tetragona

Cassytha glabella

Cheilanthes austrotenuifolia

Choretrum glomeratum

Clematis microphylla

Correa reflexa var. nummularifolia

Correa reflexa var. reflexa

Daucus glochidiatus

Daviesia genistifolia

Dianella revoluta

Dichondra repens

Drosera auriculata

Drosera macrantha ssp. planchonii

Drosera whittakeri

Eucalyptus cneorifolia

Eucalyptus conglobata

Eucalyptus diversifolia

Eucalyptus rugosa

Eutaxia microphylla v. microphylla

Goodenia ovata

Grevillea illicifolia

Hakea rostrata

Haloragis eichlerii

Hibbertia aspera

Hibbertia riparia

Isopogon ceratophyllus

Lagurus ovata

Lasiopetalum behrii

Lasiopetalum schulzenii

Lepidosperma carphoides

Lepidosperma congestum

Leptomeria aphylla

Leucopogon parviflora

Logania ovata

Melaleuca gibbosa

Melaleuca lanceolata

Melaleuca uncinata

Micrantheum demissum

Myoporum insulare

Myrsiphyllum asparagoides

Olearia axillaris

Olearia teretifolia

Orthosanthus multiflorus

Oxalis pescaprae

Phyllanthos australis

Pimelea serpifolia

Pimelea stricta

Pomaderris oraria

Pultenaea daphnoides

Pultenaea rigida var. rigida

Pultenaea viscidula

Rhagodia crassifolia

Scaevola aemula

Senecio odoratus

Spyridium spathulatum

Thryptomene ericaea

Xanthorrhoea tateana

Unidentified

Exotic grass

Moss

Native grass

Stipa sp.

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