

2001

Abundance, distribution and population characteristics of Western Grey Kangaroos (*Macropus fuliginosus*, Desmarest 1817) in Yellagonga Regional Park

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**Abundance, Distribution and Population
Characteristics of Western Grey Kangaroos
(*Macropus fuliginosus*, Desmarest 1817)
in Yellagonga Regional Park**



by Amy Chang

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of
Bachelor of Science (Biological Science) with Honours at the
Faculty of Communications, Health and Science,
School of Natural Sciences,
Edith Cowan University

Date submitted: 9 November 2001

USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

Abstract

Yellagonga Regional Park is located in the northwest corridor of Perth and constitutes 1400 hectares of wetlands, parkland, open forest and open woodland. Few studies have been conducted on the native fauna in the Park's upland habitats. For this reason, a study of the abundance and distribution of western grey kangaroos (*Macropus fuliginosus*) was conducted. A walked survey using direct counts and individual recognition of kangaroos during winter, recorded a total of 123 kangaroos, 51 pouch young and 23 unidentified individuals in Yellagonga Regional Park, and a further 24 kangaroos and 18 pouch young at Edith Cowan University's Joondalup campus. Two populations were identified, one alongside the north and northwest of Lake Joondalup and the other in the southern end of the Park between Woodvale Drive and Whitfords Avenue. Individuals in the northern population migrated freely between Yellagonga Regional Park and adjacent areas, while those in the southern population were mostly confined within the Park. Eight kangaroos sighted at Edith Cowan University's Joondalup Campus were also recorded in Yellagonga Regional Park and individuals sighted north of Lake Joondalup moved between Yellagonga Regional Park and Neerabup National Park. Both populations had highly biased female ratios that were attributed to higher mortality among the adult males, missed sightings and greater movement of males. *Macropus fuliginosus* did not show a preference for open woodland or open forest habitats. Distribution of the northern population was influenced by both understorey density and levels of human activity, while distribution of the southern population was mostly influenced by human disturbance. A low-level of management may be needed to ensure that future developments within and adjacent the Park do not limit the ranges of individuals or reduce the viability of populations.

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

- (i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;
- (ii) contain any material previously published or written by another person except where due reference is made in the text; or
- (iii) contain any defamatory material

Signature

Date 04/03/2002

Acknowledgements

Firstly I would like to thank my supervisor, Dr Alan Needham, for his guidance and support throughout the year and also with coming up with a project for my honours. I am grateful to Dr Needham for giving me the opportunity to work outdoors with one of Australia's most lovable icons and having confidence in me and the project I was working on. Without the help of Dr Needham, I would have still been trying to decide what to do for my honours.

I would especially like to thank Professor Harry Recher for sharing his thoughts, and Associate Professor Adrienne Kinnear and Bryan Duff for their assistance with the preparation of my thesis. Special mention goes to Kirsty Quinlan, Adam Davini and Jason Fraser for their invaluable assistance with laying out the quadrats. I am also grateful to all the other honours and postgraduate students and staff for their encouragement and support.

I would like to acknowledge Jayson Puls (Department of Conservation and Land Management), Peter Lambert (Department of Conservation and Land Management), Dr Peter Mawson (Department of Conservation and Land Management), Harry Gratte (Whiteman Park), the city of Joondalup and the city of Wanneroo for their time and assistance.

Finally, thank you to all my friends for keeping me smiling and to my loving parents who are always there for me.

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1 Introduction

Yellagonga Regional Park, established by the State Government in 1989, constitutes approximately 1,400 hectares and is located in the northwest corridor of Perth. The Park contains a variety of native flora and fauna, which contributes to the Park's attractions. The wetlands are the most significant feature of the Park as they constitute a large proportion of the Park (about 550 ha) and are a place of refuge for many native waterfowl species. With increasing urbanization around Yellagonga Regional Park and proposed developments within the Park, effective management of the Park is necessary to conserve the native fauna and their habitats. This has been illustrated by the decline in the abundance of native fauna in developed areas in the Perth Metropolitan Region (How & Dell, 1992; Kitchener *et al.*, 1987; Shortridge, 1909; Shortridge, 1936).

Few studies have been conducted on native fauna in upland habitats of Yellagonga Regional Park. A previous study has found that the Park's upland habitats house 6 native and 3 exotic mammal species (Bamford & Bamford, 1990). There have been many studies on the Park's wetlands and waterbirds (Bamford & Bamford, 1990; Bekle, 1992; Bekle, 1988; Kinnear & Garnett, 1997), which reflects the emphasis of a large proportion of conservation and management strategies towards the wetlands. To conserve the native terrestrial fauna in Yellagonga Regional Park more detailed studies are needed to ensure that they receive similar attention so that their protection and conservation in the Park can be achieved.

Western grey kangaroos (*Macropus fuliginosus*) are the largest mammals in the Park and contribute to the Park's attractions. There have not been any specific studies on *M. fuliginosus* in Yellagonga Regional Park or in any other parks and reserves in nearby urban areas, except Whiteman Park (Arnold *et al.*, 1991b; Wann & Bell, 1997; Bamford & Bamford, 2000). Therefore a study of the kangaroos in Yellagonga Regional Park was conducted as the first step towards what is hoped will be a series of studies on native fauna in the Park's upland habitats.

1.1 Objectives of the Study

There were two main aims of this study. The first aim was to accurately determine the abundance and location of *M. fuliginosus* within Yellagonga Regional Park. The second aim was to determine the number of *M. fuliginosus* populations, their distribution and factors that may influence their distribution in Yellagonga Regional Park. A minor objective was to gather as much data as possible, on the characteristics of population(s) to assist with the conservation of *M. fuliginosus* in Yellagonga Regional Park. This information will not only provide CALM with a guide to manage and conserve kangaroos, but will also be a reference for future studies of *M. fuliginosus* and a reference to assess if any developments in the Park will compromise the conservation of *M. fuliginosus*.

2 Literature Review

2.1 Western Grey Kangaroos (*Macropus fuliginosus*)

2.1.1 Status

Macropus fuliginosus was abundant and numbers in 1993 were estimated to be 433 800 ± 170 900 in Western Australia (Southwell, 1993). In the ICUN red list of threatened animals, *M. fuliginosus* has been placed in the category lower risk: near threatened and of least concern (ICUN, 2000). However, they are a protected species and state governments have three management strategies for their conservation. These are to maintain existing populations over their natural ranges, to contain their deleterious effects on other land management practices and manage the species as renewable natural resources providing that their conservation is not compromised (CALM, 1997; Macropod Management Advisory Committee, 2000; McNamara & Prince, 1986; N.P.W.S., 1997).

2.1.2 Distribution and Habitat

Macropus fuliginosus occurs in the southern and eastern regions of Australia (figure 2.1). The species is located along the southern coast of Australia, from the southwest of Western Australia to South Australia, to the northwest of Victoria, from central New South Wales to the southwest of the state and on Kangaroo Island (Kirsch & Poole, 1972; Anon., 1973). Present distributions also include Queensland and the Australian Capital Territory (Stanger *et al.*, 1998). Their distribution is limited to areas of uniform or winter rainfall (Pople, 1989; Short *et al.*, 1983) as they are not adapted to the arid regions of the interior, requiring more water to survive (Short *et al.*, 1983; Caughley, 1962; Caughley, 1964). Distribution of *M. fuliginosus* can also be influenced by the type of habitat, but to a lesser extent.

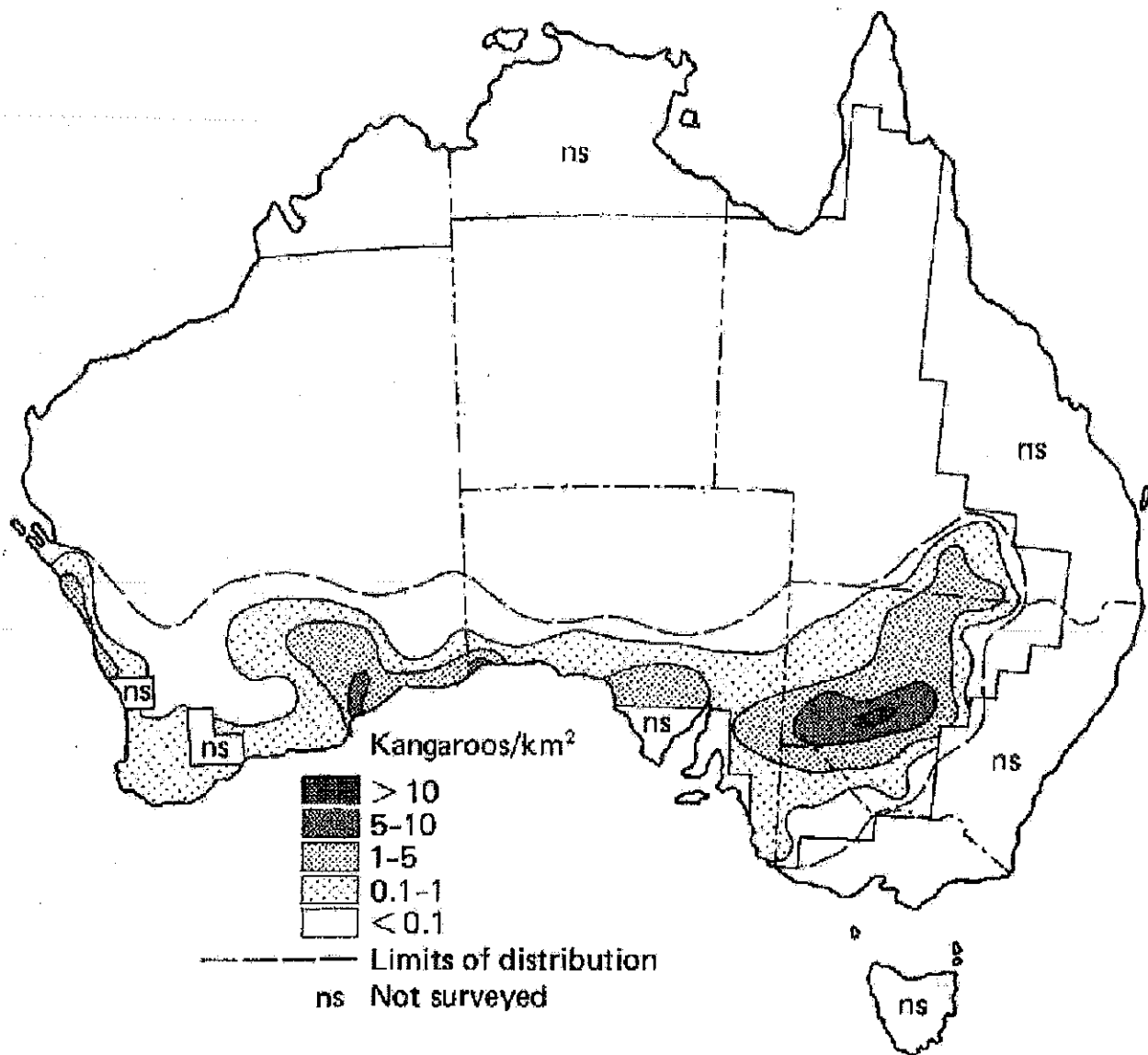


Figure 2.1 Distribution of *M. fuliginosus* in Australia (Caughley, 1987).

Western grey kangaroos are present in habitats offering an abundance of food and suitable protection from predators via vegetation cover (Coulson, 1990b; Priddel, 1988; McAlpine *et al.*, 1999). *Macropus fuliginosus* occurs in a variety of habitats including open forest, woodland, shrubland and heathland (Coulson, 1993b; Pople, 1989), however their presence in a habitat is dependent on the amount of vegetation cover (Arnold *et al.*, 1995; Coulson, 1990b). Grey kangaroos, *M. fuliginosus* and *M. giganteus*, are more dependent on cover than red kangaroos (*M. rufus*) and cover is sought as a behavioural response to reduce detection (Caughley, 1964). *Macropus fuliginosus* also utilise heterogeneous habitats and highest densities occur in areas of greater habitat heterogeneity (Coulson, 1993b; Short *et al.*, 1983).

2.1.3 Diet

Kangaroos are herbivores; these large macropods have similar diets and are classified as specialist grazers. Kangaroos are mainly grazers with grasses making up the majority of their diet (Halford *et al.*, 1984; Wann & Bell, 1997), but they are also browsers especially when food is scarce (Barker, 1987). Diet studies of *M. fuliginosus* in Western Australia indicate that native plant species as well as exotic species occur in their diet, with a preference for monocotyledons (Halford *et al.*, 1984; Wann & Bell, 1997). The presumption that native plants are favoured in the diet of *M. fuliginosus* due to their high nitrogen content, is suggested by their common occurrence in the diet and kangaroo movements over large distances to graze/browse on favoured species (Halford *et al.*, 1984; Barker, 1987; Dawson, 1989).

The availability of forage determines their composition in the diet of *M. fuliginosus*. The abundance of a plant species in the diet of *M. fuliginosus* depends on the type of habitat, abundance of the species within the habitat and seasonal availability of the plant (Dawson, 1989; Short, 1987; Barker, 1987). Seasonal changes to the composition of *M. fuliginosus* diet are evident with availability of forage (Coulson, 1990a; Barker, 1987; Dawson, 1989).

2.1.4 Habit

Kangaroos are partially diurnal, active throughout the day and night. Grazing activity is highest during the late evening for *M. fuliginosus* (Priddel, 1986; Caughley, 1964), but grazing also occurs early in the morning and throughout the night (Arnold *et al.*, 1988; Priddel, 1986). Seasonal changes in grazing time are associated with differences in day length (Priddel, 1986). *Macropus fuliginosus* grazes between 5.9 to 9.8 h day⁻¹, which decreases during summer but is similar in autumn, winter and spring (Priddel, 1986). Lower grazing activity during summer is due to longer exposure to higher temperatures in the daytime and increased resting periods required to reduce heat load (Arnold *et al.*, 1988). During the day, *M. fuliginosus* is located resting under vegetation cover and, if associated in a group, individuals will interact with other members of the group. All activities of individuals lie within their home range. Kangaroos have a strong fidelity to their home range and rarely leave their home range except in cases of drought and when resources are depleted (Priddel, 1987; Arnold *et al.*, 1992). The home range size of *M. fuliginosus* has been found to vary. In Baker's Hill (300 ha) the home range of *M. fuliginosus* was found to be between 39 – 70 ha (Arnold *et al.*, 1992). While in Hattah-Kulkine National Park (48 000 ha) the home range of *M. fuliginosus* was between 221 – 459 ha (Coulson, 1993a).

2.1.5 Social Organisation

Kangaroos form open membership groups (gregarious) and formation into groups is an anti-predator strategy used by macropods (Banks, 2001; Coulson, 1999; Jarman & Coulson, 1989). The random process of individuals joining and leaving a group affects group size and the composition of groups is continually changing (Caughley, 1962; Caughley, 1964). Group size is positively correlated with population density (Southwell, 1984a; Coulson, 1993a) and is also influenced by the type of habitat (Heathcote, 1987; Coulson, 1993a; Southwell, 1984a; Jarman & Coulson, 1989) and season (Johnson, 1983). Kangaroos commonly form groups of up to six individuals (Arnold *et al.*, 1990; Jarman & Coulson, 1989; Johnson, 1983), but form larger groups (mobs) when grazing (Coulson, 1999; Jarman & Coulson, 1989; Kaufmann, 1974) and when in open habitats (Heathcote, 1987).

2.1.6 Female Breeding

Breeding occurs all year round and the peak breeding season in the southwest is during summer (Burbridge, 1993). Western grey females become sexually mature at 14 to 18 months of age and each female produces about 1 offspring a year (Poole & Catling, 1974; Poole, 1973; Lee & Ward, 1989). The oestrus cycle is about 35 days, gestation is 30.5 days and young development in the pouch is about 42 weeks (Poole & Catling, 1974; Burbridge, 1993). Oestrus females usually have one young out of the pouch, one developing in the pouch and an embryo in embryonic diapause at the 8th cell stage in the womb (Dawson, 1995).

2.1.7 Census Methods

Various survey methods are available to estimate abundance and aerial surveys are commonly used for broad-scale surveys. Aerial surveys are non labour-intensive and are an inexpensive form of surveying over large areas, but are limited to open areas where the vegetation is not dense (Coulson & Raines, 1985; Southwell, 1989; Southwell *et al.*, 1990). Ground surveys have been utilised in regions that are unsuitable for aerial surveys but are infrequently used as they are expensive, time consuming and labour-intensive (Southwell, 1989; Coulson & Raines, 1985). Methods for surveying kangaroo density on the ground include pellet counts, drive counts and direct counts.

Pellet counts are an indirect form of surveying that rely on the observer's ability to count individual pellets or pellet groups assuming that pellets are not overlooked and no pellets are lost (degraded, trod on, etc.) during the survey (Johnson & Jarman, 1987). This technique is applicable in areas of varying topography and vegetation, and accuracy varies depending on its application (Southwell, 1989; Coulson & Raines, 1985).

Drive counts are used in large areas accessible by four-wheel drive (4WD). Personnel are equally spaced around the perimeter of the survey area and count kangaroos that are flushed out by the 4WD. This method requires many skilled personnel and relies on their surveying accuracy (Southwell, 1989; Coulson & Raines, 1985).

Direct counts involve an accurate census of every individual throughout the entire survey area. This method relies heavily on the observer's ability to accurately identify individuals and missed counts do occur (Johnson & Jarman, 1987; Southwell, 1989). However, the observer's ability to accurately identify individuals increases if sufficient time is spent observing individuals (Bateson, 1997).

2.2 Yellagonga Regional Park

2.2.1 Location and Topography

Yellagonga Regional Park, approximately 20 km northwest of Perth, constitutes approximately 1,400 hectares of parkland, wetlands, woodlands and open forests. The wetlands lie in the centre of the Park and consist of Lakes Joondalup and Goollelal, and Beenyup and Walluburnup Swamps (figure 2.2). Parks, open woodlands and open forests surround wetland vegetation which in turn enclose the wetlands. The Park's natural vegetation is conserved and protected by the Department of Conservation and Land Management (CALM).

2.2.2 History

In 1990 the Park was named Yellagonga Regional Park to honour Yellagonga, the leader of the Aboriginal tribe which inhabited the region north of the Swan River during the early period of European settlement. The Park contains some important historical remnants of early European settlement and has cultural significance to the Aboriginal community (DPUD, 1992). Yellagonga Regional Park was a significant camping ground due to its centrality within the Moro district. The Park was used as a east-west resting point between the foothills and the ocean, and a north-south resting point between Mt. Eliza and Moore River during the Aboriginal seasonal cycle of camp movements. The Park's other significance to the Aboriginal community includes its proximity to the ocean and other lakes and the abundance of food including wildfowl, kangaroos and other animals. The Park was widely used by the Aboriginal people for watering, hunting and gathering, tool making and other summer social activities (CALM, 2000). By the 1930's, a conflict on land rights between the early European

settlers and the Aboriginal community led to the breakdown of Aboriginal lifestyle and culture and their retreat from the Park (Brittain, 1990).

2.2.3 Vegetation

Areas within Yellagonga Regional Park have been altered since the arrival of the first European settlers. The Park was mainly modified for commercial operations such as market gardening, grazing, viticulture, orchards and timber cutting (DPUD, 1992). The Park has also been subjected to alteration for recreational pursuits (CALM, 2000). Although some areas of Yellagonga Regional Park have been transformed, much of the natural vegetation still remains.

Most of the undisturbed native vegetation is found in areas surrounding the lakes and swamps, along the northern and western parts of Lake Joondalup and some patches of vegetation occurring from the central to the southern areas of Yellagonga (figures 2.3 and 2.4). Upland vegetation comprises *Eucalyptus marginata* – *Corymbia calophylla* – *Banksia* spp. (jarrah-marri-banksia) open woodland, *E. gomphocephala* – *E. marginata* – *C. calophylla* (tuart-jarrah-marri) open forest and scattered tuarts (*E. gomphocephala*). Wetland vegetation comprises fringing vegetation, such as fringing *Melaleuca raphiophylla* (swamp paperbark) woodland and *E. rudis* (flooded gum) woodland, and emergent aquatic vegetation (*Baumea articulata*, *Typha orientalis*, mixed *B. articulata* *T. orientalis* and *T. orientalis/Schoenoplectus validus*) (DPUD, 1992; CALM, 2000).



Figure 2.2 Yellagonga Regional Park set in an urban environment (Kinnear & Garnet, 1997) and its location to Perth (CALM, 2000).

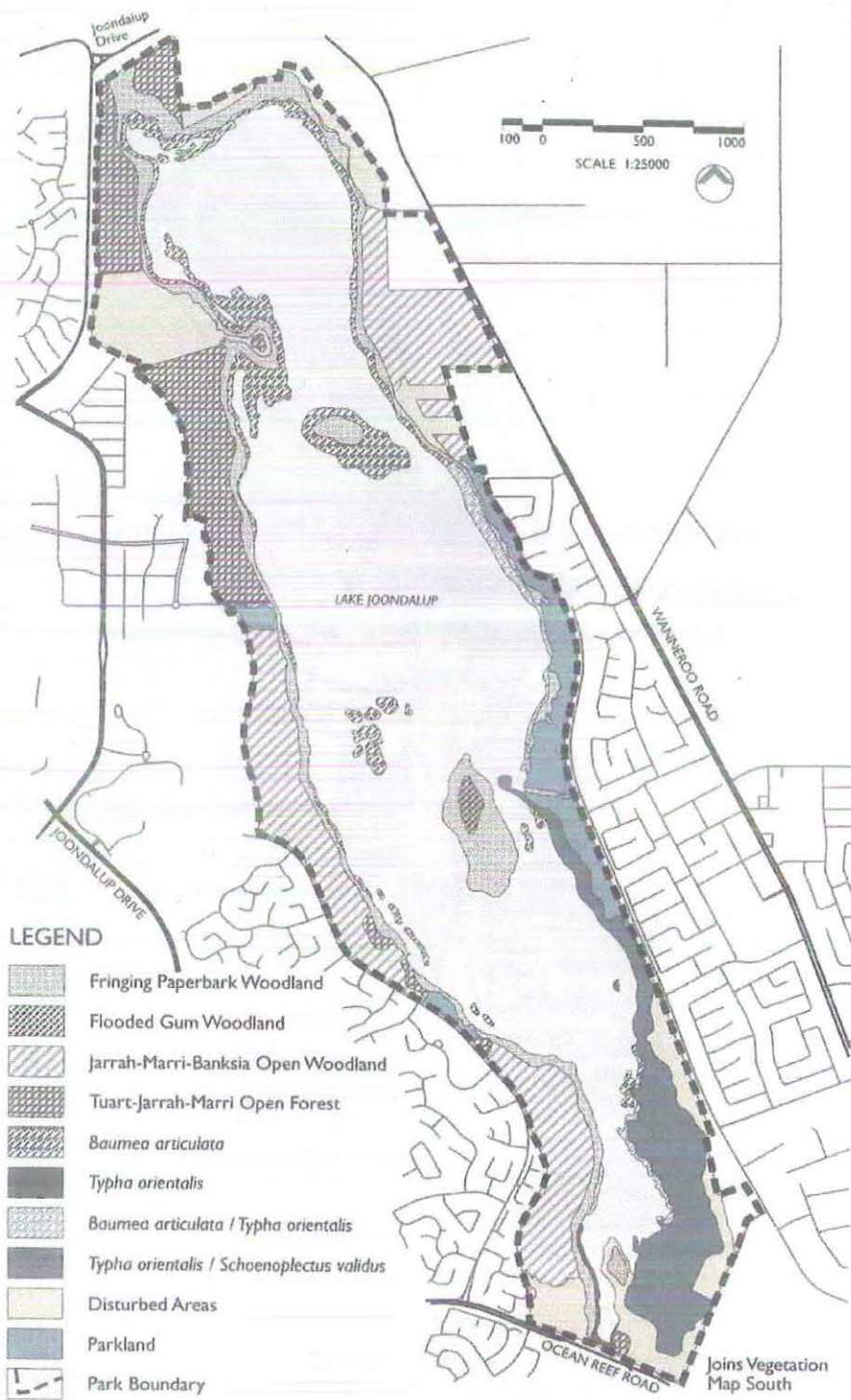


Figure 2.3 Vegetation map of Yellagonga Regional Park north of Ocean Reef Road (DPUD, 1992).

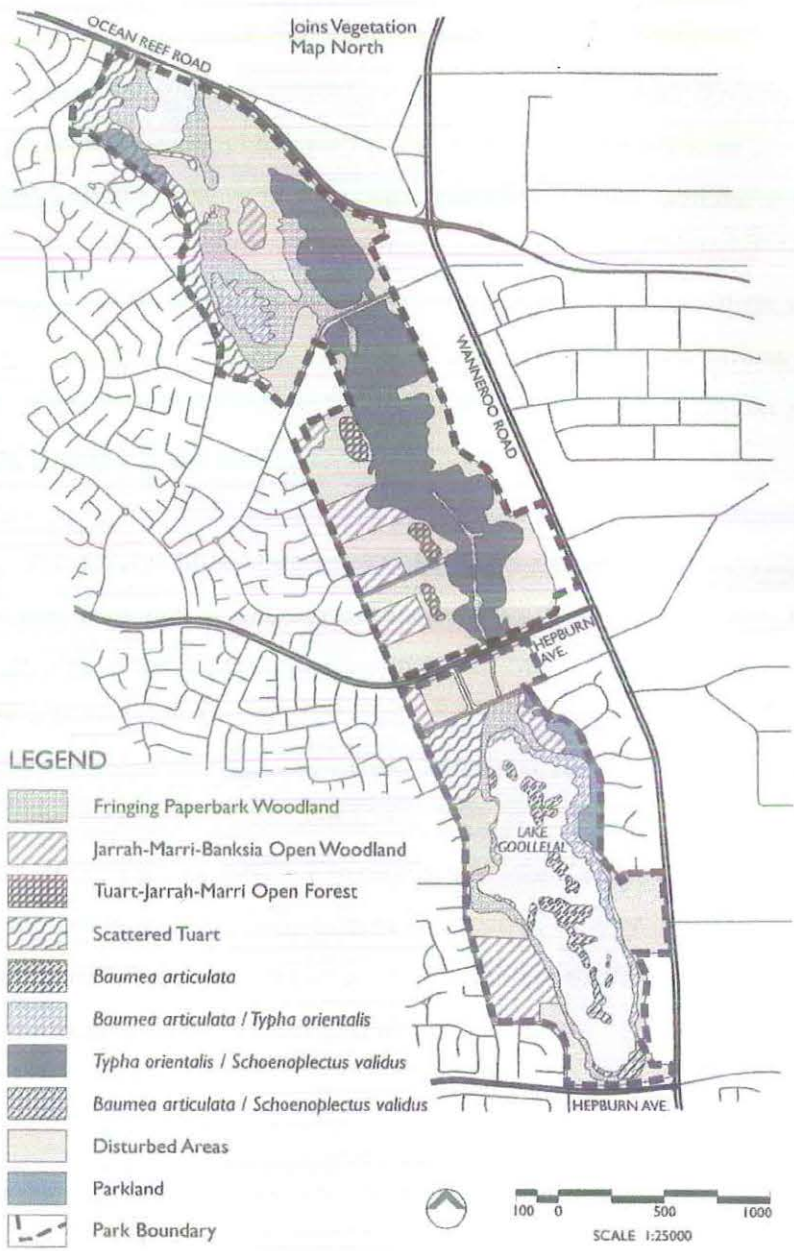


Figure 2.4 Vegetation map of Yellagonga Regional Park south of Ocean Reef Road (DPUD, 1992).

2.2.4 Conservation and Management

Many conservation issues have been raised by CALM, the City of Joondalup and the City of Wanneroo with regard to the protection, conservation and enhancement of the Park's biota. Issues include the protection of the wetland's flora and fauna, preservation of the health of the wetlands, conservation of natural upland vegetation, minimising conflicts caused by recreational usage and conservation values, control of weeds, rehabilitation of degraded areas and minimising the effects of fire (CALM, 2000). Areas of natural habitat have been placed under conservation and protection by CALM (figure 2.5 and table 2.1).

Previously, little attention has been placed on the conservation of the Park's native mammals, due to lack of information from appropriate studies. However, CALM has indicated in the Yellagonga Regional Park Draft management Plan (2000-2010) that efforts will be made to maintain viable populations and diversity of indigenous fauna. This may involve the removal of predators and reducing habitat degradation by the control or removal of exotic herbivores such as sheep and horses (Puls, pers. comm.; CALM, 2000; DPUD, 1992). Kangaroos have not been managed but presently CALM is attempting to increase their current distribution by slowly reclaiming private land in the Park, removing horses, removing fencing in the northern end of Lake Joondalup and placing kangaroo gates in fencing (Puls, pers. comm.).

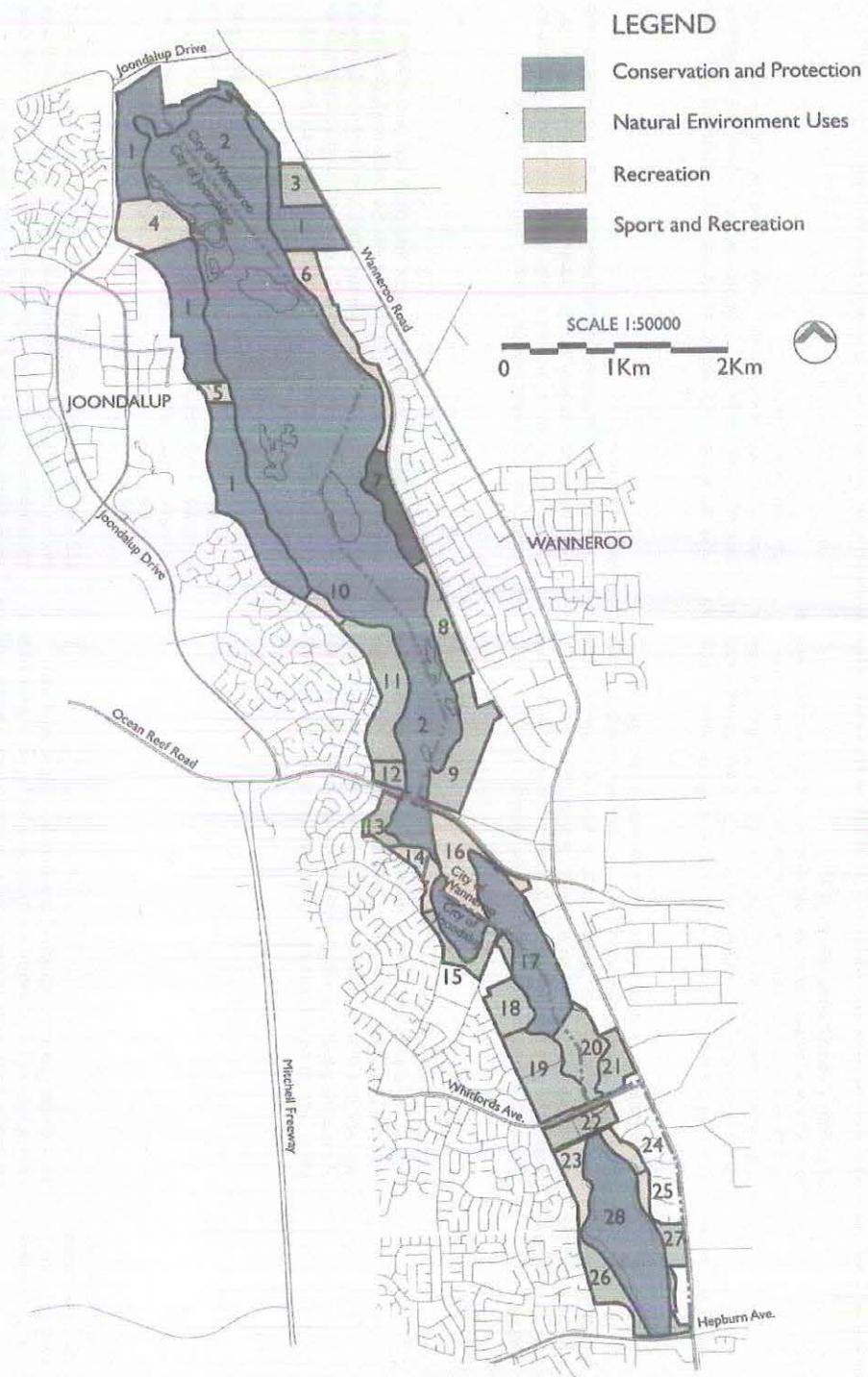


Figure 2.5 Management zones and areas of Yellagonga Regional Park (CALM, 2000).

Table 2.1 Management Zones in Yellagonga Regional Park.

Management Zone	Management Area	Management Agency	Management Emphasis	Acceptable Uses and Facilities
Conservation and Protection	1*	CALM	To protect and where possible enhance the conservation values and landscape qualities of the Park. Priority will be given to maintaining the natural state of conservation and protection areas with a minimum of impairment. Visible evidence of management will be minimal.	<p>*Upland Areas: Restricted public access. Unauthorised vehicles prohibited. Development of facilities such as nature trails, cycle tracks and through access are acceptable. Rehabilitation of vegetation. Habitat protection for bird species and other fauna. Education and research uses allowed.</p> <p>**Wetlands or Waterbodies: Restricted public access. Unauthorised watercraft and vehicles prohibited. Development of facilities, boardwalks and conservation platforms are acceptable in certain locations. Rehabilitation of fringing vegetation. Maintenance of water quality and other habitats to ensure survival of wetland ecosystems. Educational and research uses allowed.</p>
	2**	Jointly managed by CALM, the city of Joondalup and the city of Wanneroo		
	17** 28**	CALM CALM		
Natural Environment Uses	3, 8, 9, 11, 12, 13, 15, 18, 19, 20, 21, 22, 26 and 27	CALM	To provide for appropriate uses of the natural environment. Areas will be managed jointly for public use, conservation and enhancement of flora and fauna, and improvement of landscape qualities. Public use must be compatible with assigned purpose of the Park area. Visible evidence of management may be moderate to high. Management will encourage uses and develop facilities that promote conservation and education.	Public access primarily by walking trails and cycling paths. Some development of facilities necessary, these may include education nodes and facilities associated with visitor nodes. The provision of facilities will depend on the values of the area and the community demand for facilities. Rehabilitation and habitat protection may be necessary.
Recreation	4 5, 10, 14, 23 and 25 6 and 16 24	CALM City of Joondalup City of Wanneroo National Trust	To provide a variety of recreational opportunities. The type and intensity of facility provision will depend on the values of any given area, community demand for recreation and the appropriate management of the Park. Management involves minimising the impact of visitor activities through the sensitive placement and provision of access facilities. Visible evidence of management may be high.	Public use may be high in these areas. Predominantly passive recreation pursuits, allowing for park and picnic facility development. Commercial concessions may be considered appropriate within this management zone. Rehabilitation, landscaping and reticulation of areas may be necessary.
Sport and Recreation	7	City of Wanneroo	Sport and Recreation allows for areas to be used for indoor and outdoor sporting activities. Given these areas are of high use, management will endeavour to minimise incompatibilities with surrounding Park areas. Management involves minimising the impact of visitor activities through sensitive placement and provision of access facilities. Visible evidence of management may be high.	High use areas developed for active recreational pursuits. May include sporting ovals, car parking, buildings and reticulated and landscaped areas. Commercial concessions may be considered appropriate within this management zone.

(CALM, 2000)

2.3 Management of Kangaroos in Other Parks and Reserves

There are a limited number of relevant studies as most other surveys concentrate on kangaroo populations in rural areas (Taylor, 1980; Southwell, 1999; Southwell, 1993; Southwell et al., 1990; Southwell, 1987; Short et al., 1983; Fletcher & Southwell, 1987; Coulson & Norbury, 1988; Cairns *et al.*, 1991) and involve the use of culling in areas where high densities of *M. fuliginosus* occur (Pople & Grigg, 1999; Rawlinson, 1988; Johnson *et al.*, 1989; Bamford & Bamford, 2000). In urban areas, management of kangaroos has been limited and the use of culling has little application due to high public opposition towards culling. Whiteman Park and Hattah-Kulkine National Park were mentioned as Whiteman Park is located within the metropolitan area and other forms of managing kangaroos were raised in the study at Hattah-Kulkine National Park.

2.3.1 Whiteman Park

Whiteman Park (2600 ha) is located approximately 20 km northeast of Perth and management of fauna has been employed for over a decade. To conserve the few remaining Black-gloved Wallabies (*M. irma*) and other native fauna, a conservation area surrounded by a buffer zone was formed. The buffer zone assisted with minimising the effects of urbanisation on the conservation area (Arnold et al., 1991b).

High densities of *M. fuliginosus* (0.15 kangaroo/ha) occur in Whiteman Park (Bamford & Bamford, 2000). Large numbers of kangaroos have increased the grazing pressure on understorey vegetation and decreased the abundance of *M. irma* (Arnold et al., 1991b). Since 1991, kangaroos have been culled regularly under a Damage Control License to restrict the degradation of natural habitat that is essential for the recovery of *M. irma*. Annual culls are applied to the conservation area and the culled population is continually monitored to ensure populations have not been over-culled (Arnold et al., 1991b; Bamford & Bamford, 1990).

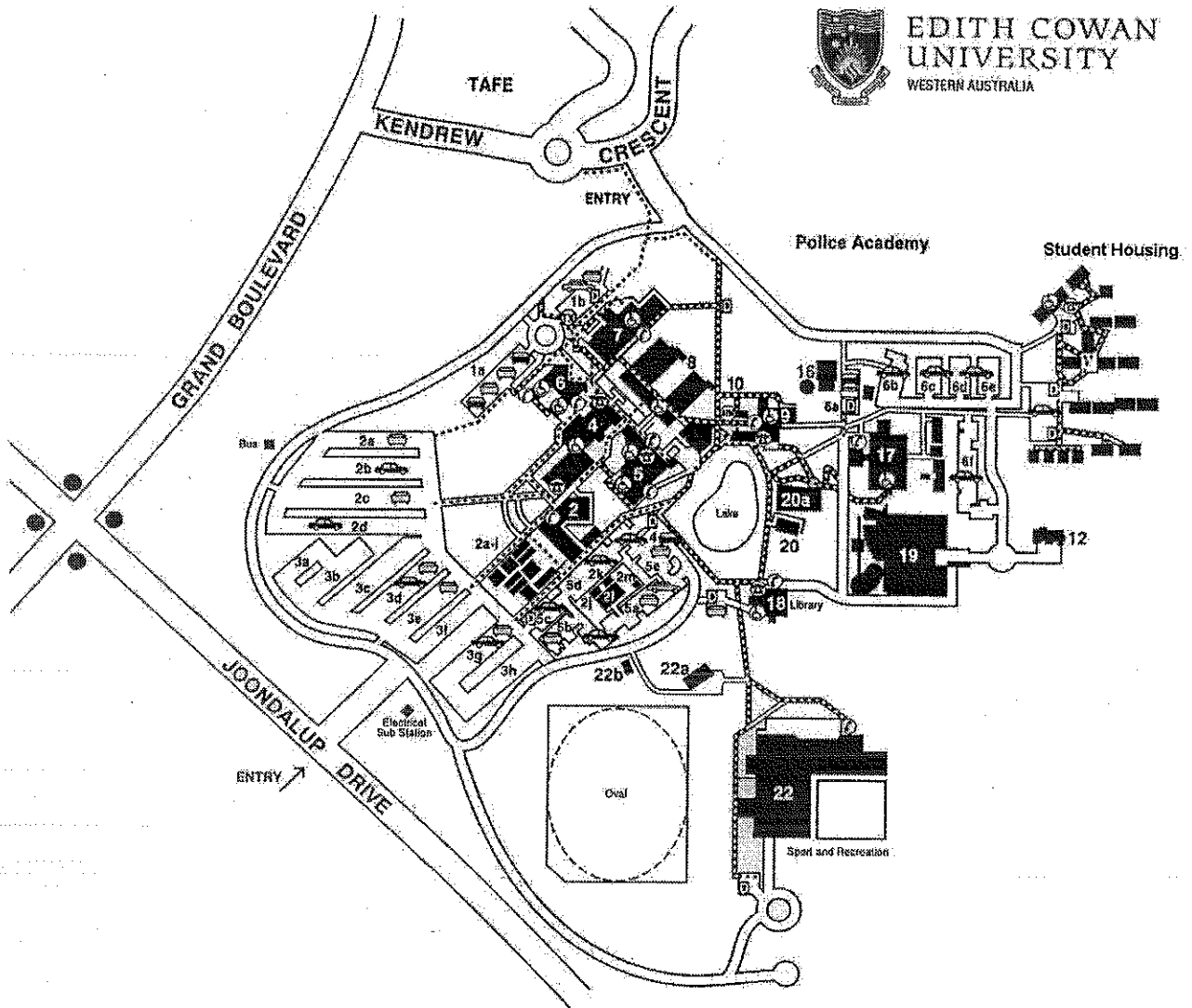
2.3.2 Hattah-Kulbine National Park

Two species of kangaroos, *M. rufus* and *M. fuliginosus*, occur in the 48,000 ha biosphere reserve in the semi-arid northwest region of Victoria. Vegetation communities were once extensive but have been reduced to remnants due to clearing for agriculture. Vegetation in the Park has also suffered from over-grazing from livestock and kangaroos, and in 1984 an attempt was made to reduce the population size of kangaroos by culling (Cheal, 1986). This was abandoned due to adverse public reaction and several studies have indicated that the density of kangaroos must be reduced to conserve vegetation remnants (Coulson & Norbury, 1988; Coulson, 1990a). No alternative management has been implemented since culling was ceased but several forms of management to reduce kangaroo abundance have been reviewed. These include shooting, poisoning, immunocontraception, reintroduction of predators, translocation, mustering kangaroos out of sensitive areas, one-way gate installation to reduce numbers in fenced areas and ecotone fencing (Coulson & Norbury, 1988).

3 Materials and Methods

3.1 Study Areas

An initial survey was conducted in late March and early April of 2001 to establish approximate locations of kangaroos in Yellagonga Regional Park. Sightings of kangaroos or their faecal pellets during walked surveys were noted on a map of Yellagonga Regional Park. Results from the initial survey and consultation with CALM indicated there were three concentrations of kangaroos in the Park and led to the establishment of three survey areas. Three sites in Yellagonga Regional Park were surveyed: the northern end of Lake Joondalup (site 1), the area surrounding Neil Hawkins Park (site 2) and the area adjacent to Duffy Terrace (site 4). Edith Cowan University's (ECU) Joondalup campus (site 3) (figure 3.1) was also included in the survey due its close proximity to Yellagonga Regional Park (figure 3.2) and due to the belief that some kangaroos were moving to the campus from the Park.



Legend

Bookshop, cafeteria, tavern, Wild Orchid Restaurant	9
Campus services, coffee shop	6
Centre for police research	8
Centre plant and plant room	16
Child care centre	12
Computer operations and computer engineering	5
Conference rooms	6, 8
Demountables	2a-g
ECU sports centre	22
Edith Cowan house	20
Faculty of Business & Public Management	8
- School of Justice & Business Law	8
- School of Marketing, Tourism & Leisure	8
Faculty of Communications, Health & Science	5, 17, 17a-f
- School of Biomedical & Sports Science	4, 8, 17a-f
- School of Communications & Multimedia	5
- School of Computer & Information Science	5
- School of Engineering & Mathematics	5
- School of Natural Sciences	17a-f, 19
- School of Nursing & Public Health	8
Faculty of Community Services, Education & Social Sciences	2, 4, 8
- School of International, Cultural & Community Studies	2, 4
- School of Psychology	2

Health & medical services	6
Lecture theatres	7
Leisure Science shed	22a
Library and media services	18
Pines Garden Cinema	20a
Reception, Student administration	6
Student Guild	10

- Visitor Carpark
- Staff Carpark (Zone A)
- Student Carpark (Zone B)
- Reserved Carpark
- Disabled Persons Parking
- Wheelchair Accessible Toilet
- Wheelchair Access Route
- Security Phone
- Public Phone
- ATM (Automatic Teller Machine)
- Taxi Station

Figure 3.1 Edith Cowan University's Joondalup campus site plan.

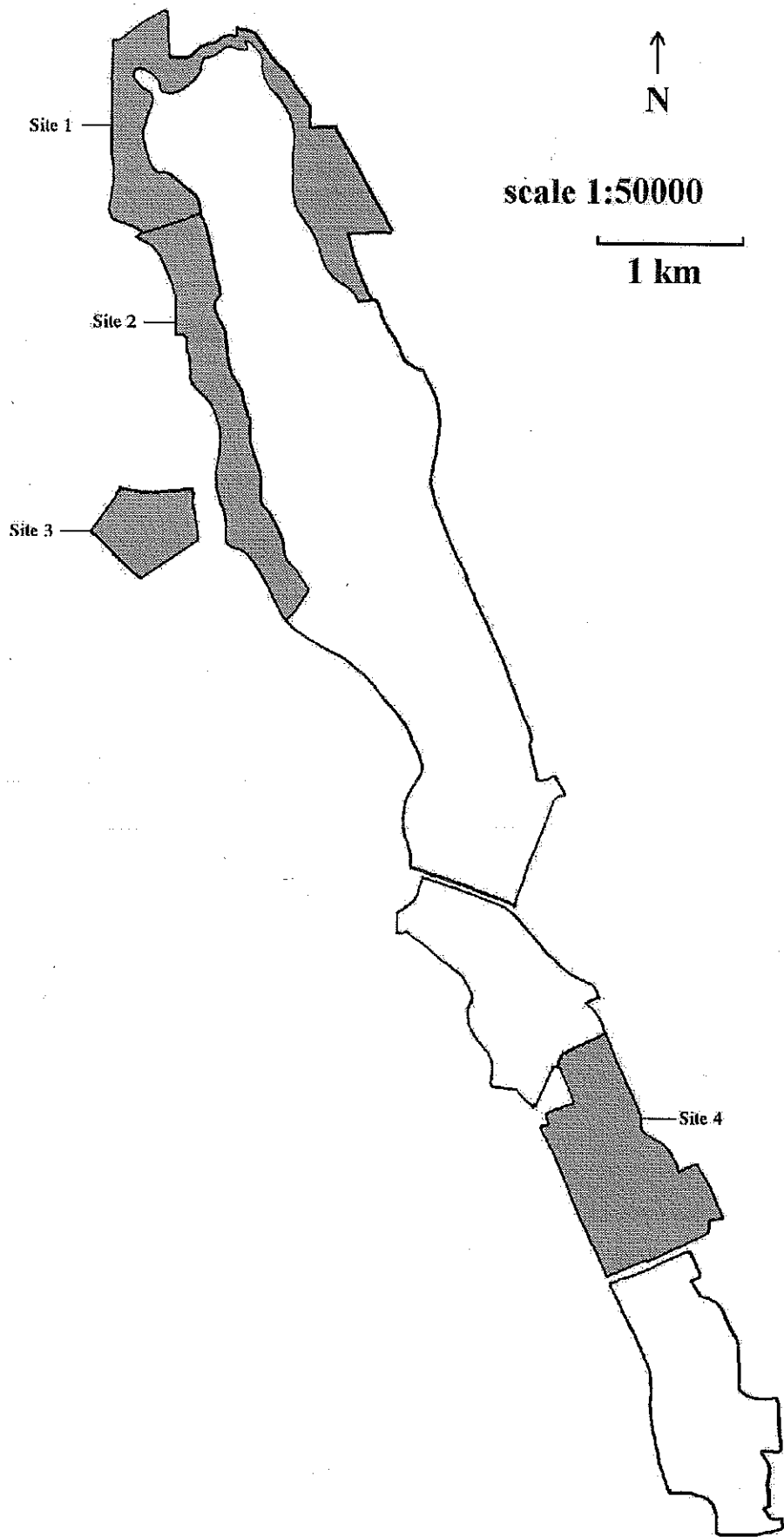


Figure 3.2 Study areas in Yellagonga Regional Park and their distance to Edith Cowan University's Joondalup campus.

3.1.1 Site 1

Site 1 is located in the northern end of Yellagonga Regional Park, surrounding the northern end of Lake Joondalup (approximately 1.1 km²). Native vegetation present in most areas have been relatively undisturbed by human activity. Upland habitats comprise tuart-jarrah-marri open forest (figure 3.3), jarrah-marri-banksia open woodland and a pine plantation. Wetland vegetation includes fringing swamp paperbark woodland and *Baumea articulata* (figure 3.4). Disturbed areas (cleared land) are present in the southern end of the site (figure 3.5) and fences run across the northern sections of the Park. The western side of Lake Joondalup has a more varied understorey density and topography, with a gentle slope down to the lake.

3.1.2 Site 2

Site 2 (approximately 0.66 km²) is situated in the middle of Yellagonga Regional Park, along the western side of Lake Joondalup. Neil Hawkins Park, frequented by many tourists and residents, is located in the centre of the site (figure 3.6). Vegetation comprises mainly tuart-jarrah-marri open forest and jarrah-marri-banksia open woodland (figure 3.7), fringing swamp paperbark woodland and *B. articulata*. Understorey composition is mainly constant and the height above sea level decreases moving towards the lake.

3.1.3 Site 3

Site 3 covers Edith Cowan University's Joondalup campus (approximately 0.40 km²) and is adjacent to site 2 and a state forest. Much of the area has been developed; a small artificial lake is found in the centre of the site and remaining vegetation has been subject to alteration. Jarrah-marri-banksia open woodland occurs along the fringes of the site, remnants of a pine plantation (figure 3.8) are located to the east of the campus and reticulated lawns are found throughout the site. Understorey vegetation is present only in the open woodland of a moderate density. The topography is mostly level, with a gentle slope down towards the centre of the campus.

3.1.4 Site 4

Site 4 (approximately 0.71 km²) is found in the southern part of Yellagonga Regional Park between Whitfords Avenue and Woodvale Drive. Much of the native vegetation has been altered since European settlement. Pockets of tuart-jarrah-marri open forest (figure 3.9) and jarrah-marri-banksia open woodland are found within disturbed areas (cleared land and market gardens). Fringing swamp paperbark woodland and part of Walluburnup Swamp are located in the upper central region of the site, while *Typha orientalis/Schoenoplectus validus* occurs throughout the middle area of the site (figure 3.10). Vegetation in the southwest parts of the site shows signs of recovery from a fire and has no understorey (figure 3.11). In the few remaining vegetated areas, the understorey is moderately dense and highly dense within the tuart-jarrah-marri open forest. The topography is relatively level, which has made the area suitable for horse agistment. Horses and stables are located in the central and northern areas of the site.



Figure 3.3 Tuart-jarra-marri (*Eucalyptus gomphocephala* – *E. marginata* – *Corymbia calophylla*) open forest.

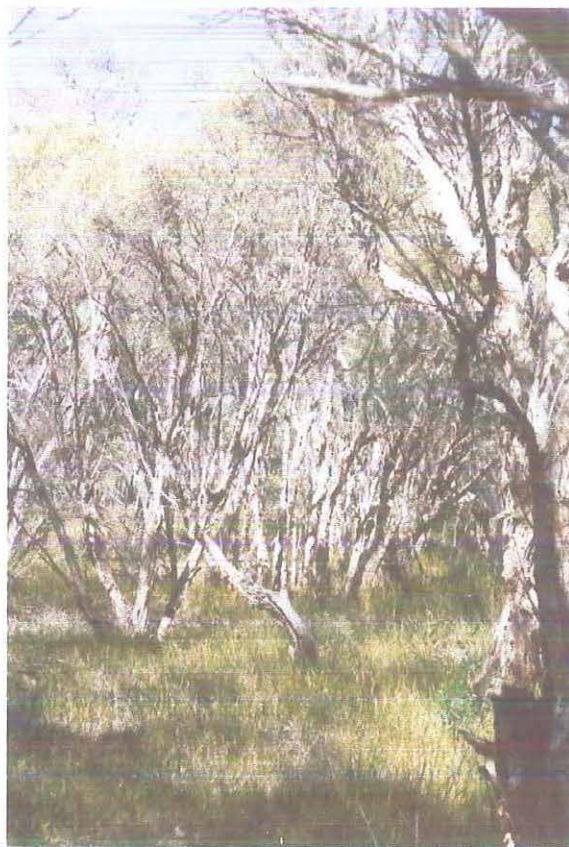


Figure 3.4 Fringing swamp paperbark (*Melaleuca raphiophylla*) woodland with *Baumea articulata* understorey.

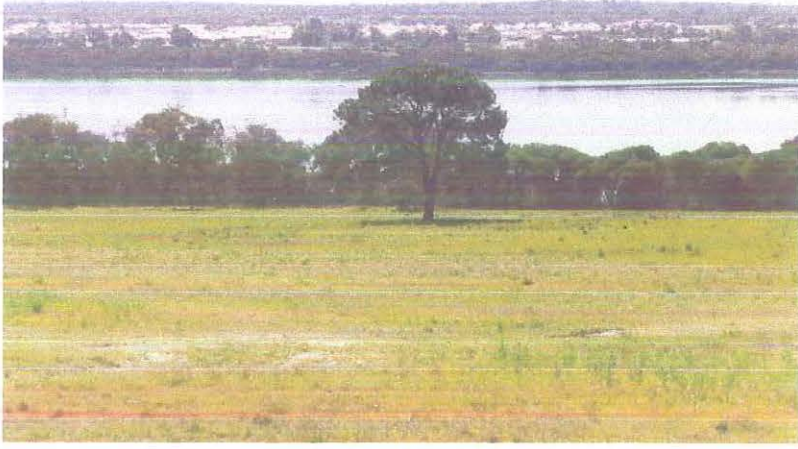


Figure 3.5 Disturbed area (Lot 1) west of Lake Joondalup in site 1.



Figure 3.6 Neil Hawkins Park located to the west of Lake Joondalup.



Figure 3.7 Jarrah-marri-banksia (*Eucalyptus marginata* – *Corymbia calophylla* – *Banksia* spp.) open woodland.



Figure 3.8 Remnant pine plantation in front of building 19.



Figure 3.9 Disturbed pocket of tuart-jarraah-marri (*Eucalyptus gomphocephala* – *E. marginata* – *Corymbia calophylla*) open forest in site 4.



Figure 3.10 *Typha orientalis/Schoenoplectus validus* stretching across the centre of site 4.

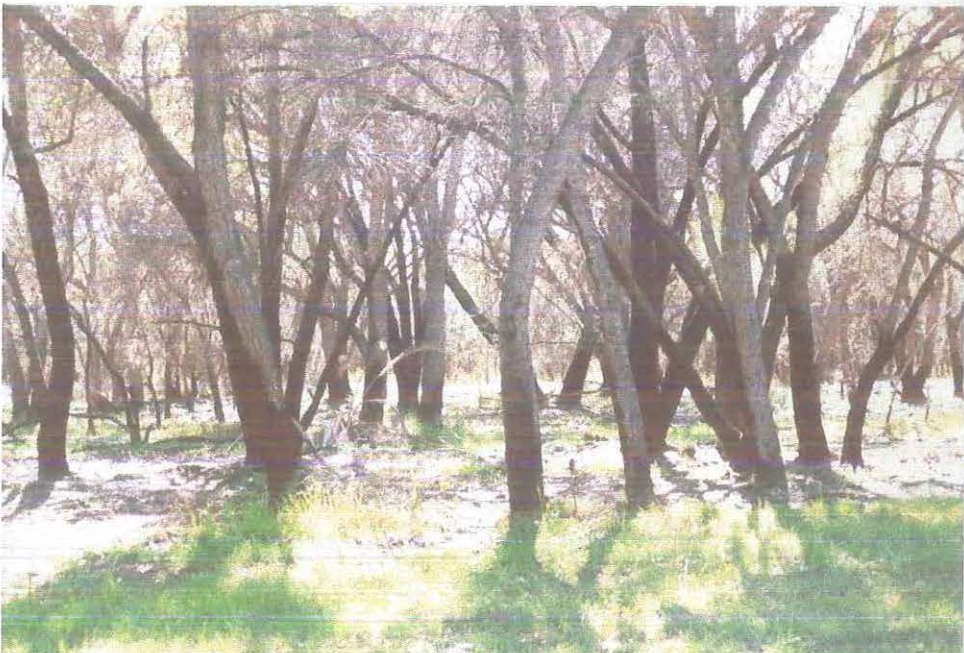


Figure 3.11 Burnt area of jarrah-marri-banksia (*Eucalyptus marginata* – *Corymbia calophylla* – *Banksia spp.*) open woodland.

3.2 Quadrating

To assist with the determination of distribution of kangaroos in Yellagonga Regional Park (sites 1, 2 and 4), 100 m x 100 m quadrats were laid out. Corners of quadrats were marked with flagging tape around trees in areas of dense vegetation and stakes with flagging tape in open areas. Quadrats were numbered on maps of the sites and were used as a quick reference when distribution was mapped.

3.3 Surveying

Walked surveys were conducted in mornings (0830 – 1100) and evenings (1500 – 1800) with the aid of field binoculars (12 x 50) to locate and identify kangaroos. In areas where the vegetation was dense, sighting of kangaroo(s) was also aided by audio detection. During every surveying occasion, following a similar route, the survey started at one end of survey area, moved through to the other end of the site and back to the starting point. This system of surveying minimised the chance that some kangaroos may have been overlooked during the survey. Types of human recreation, where the recreation occurred in the Park and frequency of human activity (number of people present on a daily basis) in areas of the Park were noted, along with relative understorey density during surveys.

3.3.1 Observation Periods

Observation times differed slightly in site 3 (ECU) compared with the other sites. The kangaroos surveyed in ECU were conducted as a pilot study but were included into the study when kangaroos were sighted moving to the campus from the Park. In ECU, observations started in late autumn, 5 days per week for two consecutive weeks. In Yellagonga Regional Park, observations took place during winter, 4 days per week for three consecutive weeks in one site before moving to the next site.

For every individual sighting the date, time, location, activity, vegetation cover and their associations with other kangaroos were recorded. Locations of kangaroos in Yellagonga were individually plotted on to maps based on their presence in a quadrat and any unidentified animals were separately mapped. If kangaroos were recorded

grazing, the plant grazed on was noted and identified using a dichotomous key by collection of plant parts (if possible, flowering parts).

3.3.2 Identification and Recognition of Kangaroos

Each animal was given a number, including the young at foot. Female kangaroos with pouch young were noted, but pouch young were not given a number as they were with their mother at all times. Characteristics of unidentified kangaroos (new sightings) that were recorded were sex, developmental class, breeding status (if female), build, body size, coat colour, facial markings, scars, torn ears and any other distinguishing features (Jarman *et al.*, 1989).

Kangaroos were classed into:

- Pouch young** – young that had not permanently vacated the pouch. Small pouch young were permanently within and caused a slight extension of the mother's pouch. Large pouch young caused a considerable extension of the mother's pouch, often the head protruding from the pouch opening and occasionally left the pouch for a short period of time (Southwell, 1984b)
- Young at foot** – young that had vacated the pouch but still followed the mother closely (Southwell, 1984b)
- Sub-adult** – individuals that were larger in size than the young at foot but smaller than adults and were occasionally seen with their mothers
- Adult** – mature male and female kangaroos; most were sexually active and usually larger than sub-adults

Records of individual characteristics were used to identify the animals and special associations between kangaroos also aided in identification. Attempts were also made to photograph kangaroos to assist with identification. A Cannon T70 SLR camera equipped with a 70-210 mm telephoto lens and a Sony digital still camera MVC-FD73 with 10x optical zoom were used.

3.4 Limitations of Survey Method

Walked surveys to determine the abundance and distribution of kangaroos were considered as the most appropriate method applied in urban study areas frequented by humans. Other forms of surveying kangaroos that involve capturing, containing or drugging the animals may have had negative reactions from the public. However, the use of individual recognition may have involved identification error in determining actual numbers as some animals may have been incorrectly identified, especially in areas of dense vegetation and when sightings of individuals were brief. Some kangaroos may also have been overlooked during the survey due to poor visibility, as they could have been undetected in habitats with vegetation cover and/or where the survey area was too large for one person to survey simultaneously moving from one end to the other, or due to the weather. Due to time limits and restrictions on the method applied; the distribution and movements of kangaroos outside of surveying occasions and Yellagonga Regional Park was not determined; the stability, growth rates, death rates and home ranges of populations could not be established; and detailed analyses of habitat preferences, diet, group formation, group activity ranges, individual distribution and sources of mortality were not conducted.

3.5 Analysis of Data

3.5.1 Distribution

Distribution of the kangaroos was analysed by their frequency of sighting and actual occurrence in 1 hectare quadrats. All sightings of each kangaroo, excluding pouch young, were combined and plotted on maps to illustrate the frequency of sightings. As individual kangaroos were recorded in more than one quadrat, their actual distribution was determined by the placement of a kangaroo to a quadrat where it was sighted the most and then combining individual locations of occurrence. The outlying locations where kangaroos were sighted determined the boundary of their distribution (Kaufmann, 1974) and information gathered from communication with a few residents about where kangaroos are located, how many there were and if they were seen outside of the Park's boundary also helped to determine distribution. Data of male distribution were insufficient to compare with female distribution, therefore male – female

distributions were not analysed. Distribution of *M. fuliginosus* was correlated with vegetation types and understorey structure, and related to feeding and resting areas.

3.5.2 Abundance

Density was determined by dividing the total number of kangaroos (excluding pouch young) sighted in Yellagonga Regional Park by their area of distribution. Male to female sex ratios, female to young at foot ratios and young at foot to sub-adult ratios were also determined for each population. Breeding status of females was categorised into breeding and non-breeding. Any females recorded with young at foot or pouch young were breeding, while females without young were considered to be non-breeding.

3.5.3 Human Disturbance

The levels of human disturbance in sections of the Park were determined by the frequency of Park use by humans. Low occurrences of human activity were areas where less than 3 people were seen during the 3 week survey. Moderate (medium) occurrences were areas where 3 - 5 people utilised the Park almost on a daily basis. Areas where human activity were present on a daily basis or were utilised by more than 5 people were classed as high levels of human disturbance.

4 Results

4.1 Abundance

A total of 124 kangaroos (not including pouch young but includes 8 also sighted at ECU) were positively identified in Yellagonga Regional Park. Efforts were made to determine the sexes of the young at foot and sub-adults, but the sex of most could not be positively determined. The 124 individuals comprise 7 adult males, 65 adult females, 17 sub-adults and 35 young at foot. Thirty females were carrying large pouch young and 22 females were carrying small pouch young. The density of kangaroos in Yellagonga Regional Park to the north of Ocean Reef Road was 1.4 kangaroos/ha and to the south of Ocean Reef Road was 0.70 kangaroos/ha.

At Edith Cowan University's Joondalup campus (site 3) there were 31 recorded kangaroos (not including pouch young). The 31 individuals comprised 19 adult females, 4 sub-adults and 8 young at foot. Seventeen females were carrying small pouch young and one female was carrying a large pouch young that had vacated the pouch a month later and was sighted both on campus (outside surveying periods) and in Yellagonga Regional Park. Seven of the 31 kangaroos were also sighted in Yellagonga Regional Park.

There were two adult kangaroos that were not identified (not recorded on survey sheets) in site 2 and most kangaroos could not be identified in site 1 due to the vegetation cover and their high level of wariness of humans. However, brief notes were made on unidentified kangaroos after each surveying occasion in site 1 and an estimated number of 21 unidentified kangaroos were sighted. Six of the individuals were young at foot, two were sub-adults and 11 were adults. The proportion of adult males to adult females could not be determined but there were at least 8 females and 2 males.

4.2 Population Characteristics

4.2.1 Demography

Two populations were identified, one in the north of Yellagonga Regional Park above Ocean Reef Road and the other below Ocean Reef Road. The northern population surveyed in sites 1 to 3 had 155 individuals (including pouch young); adult females constitute about a third of the population and the young (sub-adults, young at foot and pouch young) comprise almost two thirds of the population (figure 4.1). The southern population had 82 kangaroos (including pouch young). The majority were juveniles and pouch young, and adult females comprised over a third of the population.

Both populations had male to female ratios that were highly skewed towards females. The northern population had a ratio of 1:11.8 and the southern 1:7. The female to young at foot ratio and sub-adult to young at foot ratio for the northern population were 1.7:1 and 1:3.4, respectively. For the southern population, they were 2:1 and 1:1.1, respectively.

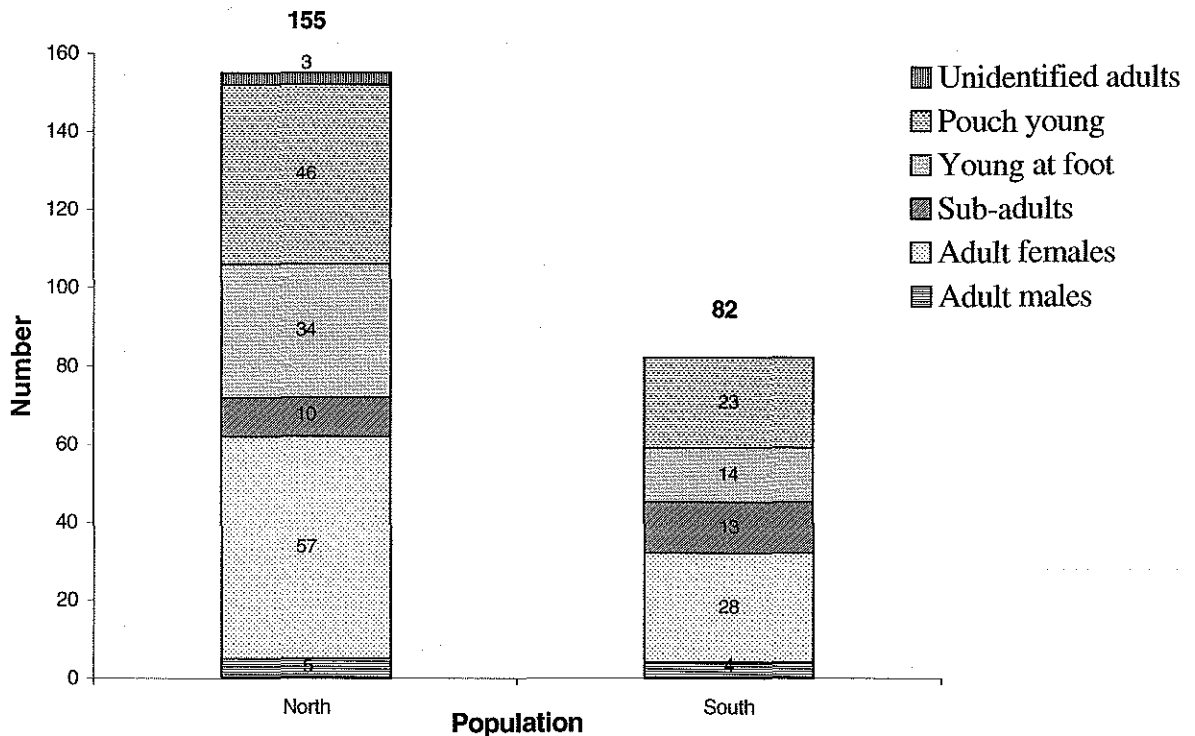


Figure 4.1 Demography of *M. fuliginosus* populations in Yellagonga Regional Park.

4.2.2 Daily Activity

Grazing and resting were the most frequently recorded activities. Grazing began during sunset, continued throughout the night and halted after sunrise. During the day grazing was minimal and resting was the primary activity offset by grooming and surveillance. On overcast days when temperatures were less than 20°C, the time an individual spent resting was observed to be lower, while grazing and movement were higher. The opposite occurred on sunny days where temperatures reached 22°C and above. Other activities observed in the late mornings were playful sparring among the sub-adults and young at foot, young at foot suckling and scratching.

4.2.3 Group Size and Formation

Most kangaroos were recorded in groups which ranged in size from 2 – 6 to 20 – 40 and some were solitary. The most common group size was between 2 and 6, and the formation of large mobs of twenty to forty individuals occurred when grazing. Kangaroos in the southern population were typically observed in groups of 10 to 30, few were solitary and groups of 2 and 3 were rare. Formation of groups was open and mixed, as many kangaroos often moved between groups. The two most common groups formed, in order of least occurrence, were mothers with sub-adults and young at foot, and mothers with their young at foot.

4.2.4 Reproductive Rates

Most adult females were recorded with pouch young and young at foot. During the survey, many females were observed carrying large pouch young and males were competing with each other for access to females. Mating attempts with females were also observed on two occasions. Only two females in the northern population and four females in the southern population appeared not to be breeding (table 1). Overall, 92% of the recorded females were producing offspring and 8% of censused females were non-breeding.

Table 4.1 Reproductive Status of Recorded Females in Yellagonga Regional Park during winter.

	Northern Population	Southern Population	Total
Breeding	35	24	59
Non-Breeding	2	4	6
Total	37	28	65

4.3 Predator Sightings

Acts of predation on *M. fuliginosus* were not observed during the survey, but they are vulnerable to predation. Foxes and wedge-tailed eagles were the only predators that were sighted in Yellagonga Regional Park. Foxes occurred only in the north of Yellagonga Regional Park where areas of natural habitat have been disturbed the least by human activity. Foxes were present in sites 1, 2 and 3, and were not observed in site 4. In sites where foxes were present, they were sighted only four times throughout the survey period. Wedge-tailed eagles were sighted twice, circling the southern parts of site 4, but were not observed in other areas of the Park. The eagles could have been present in northern areas of Yellagonga Regional Park as vegetation cover possibly obscured detection.

4.4 Distribution and Density

The northern population occurred only along the north and western side of Lake Joondalup (figure 4.2). Some areas of distribution to the north were estimated due to the large number of unrecorded kangaroos and insufficient data of identified individuals in site 1. None were spotted in the large section of cleared land north of Neil Hawkins Park (Lot 1) and east of Lake Joondalup. Kangaroos to the north of Lake Joondalup were observed in private property adjoining the Park and some kangaroos west of Lake Joondalup were also sighted at ECU's Joondalup Campus (figure 4.3). The areas of frequent use by *M. fuliginosus* in Yellagonga Regional Park were feeding and resting areas (figure 4.4). These were in Neil Hawkins Park and the areas surrounding Neil Hawkins Park. At ECU, areas of frequent use were the pine plantation in front of building 19 and ECU's soccer oval.

The southern population's distribution was generally confined to site 4, but they may have occurred in adjacent areas outside the observation periods (figure 4.5). Density was greatest in the northwest parts of site 4 that were the predominant feeding and resting areas (figure 4.6). None of the kangaroos were sighted along the eastern parts of site 4 during the survey period, but a kangaroo was sighted in the area when quadrats were being laid out.

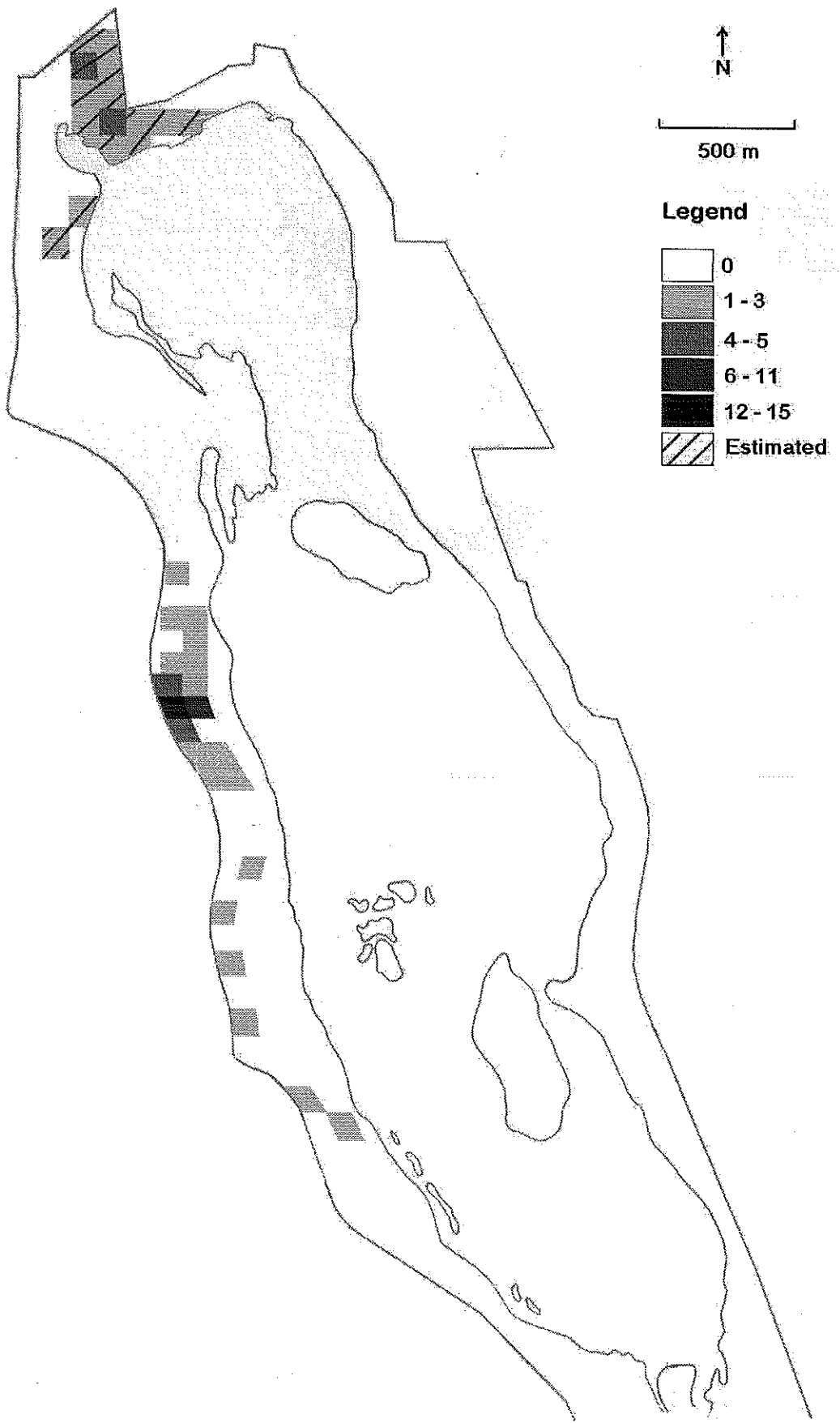


Figure 4.2 Observed distribution and density (kangaroos/ha) of *M. fuliginosus* in northern areas of Yellagonga Regional Park during winter.

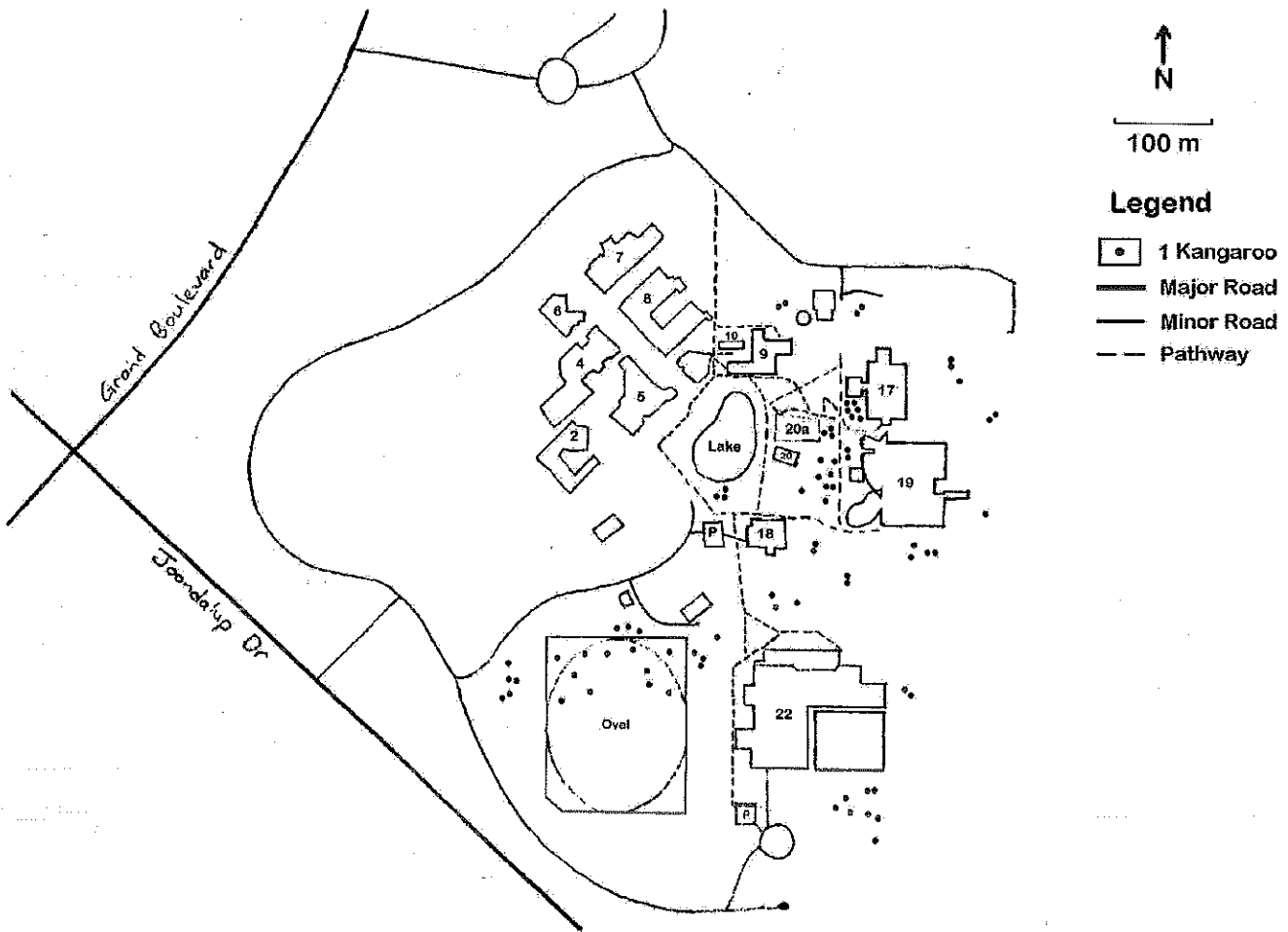


Figure 4.3 Sightings of *M. fuliginosus* in Edith Cowan University's Joondalup campus over 2 weeks in late autumn.

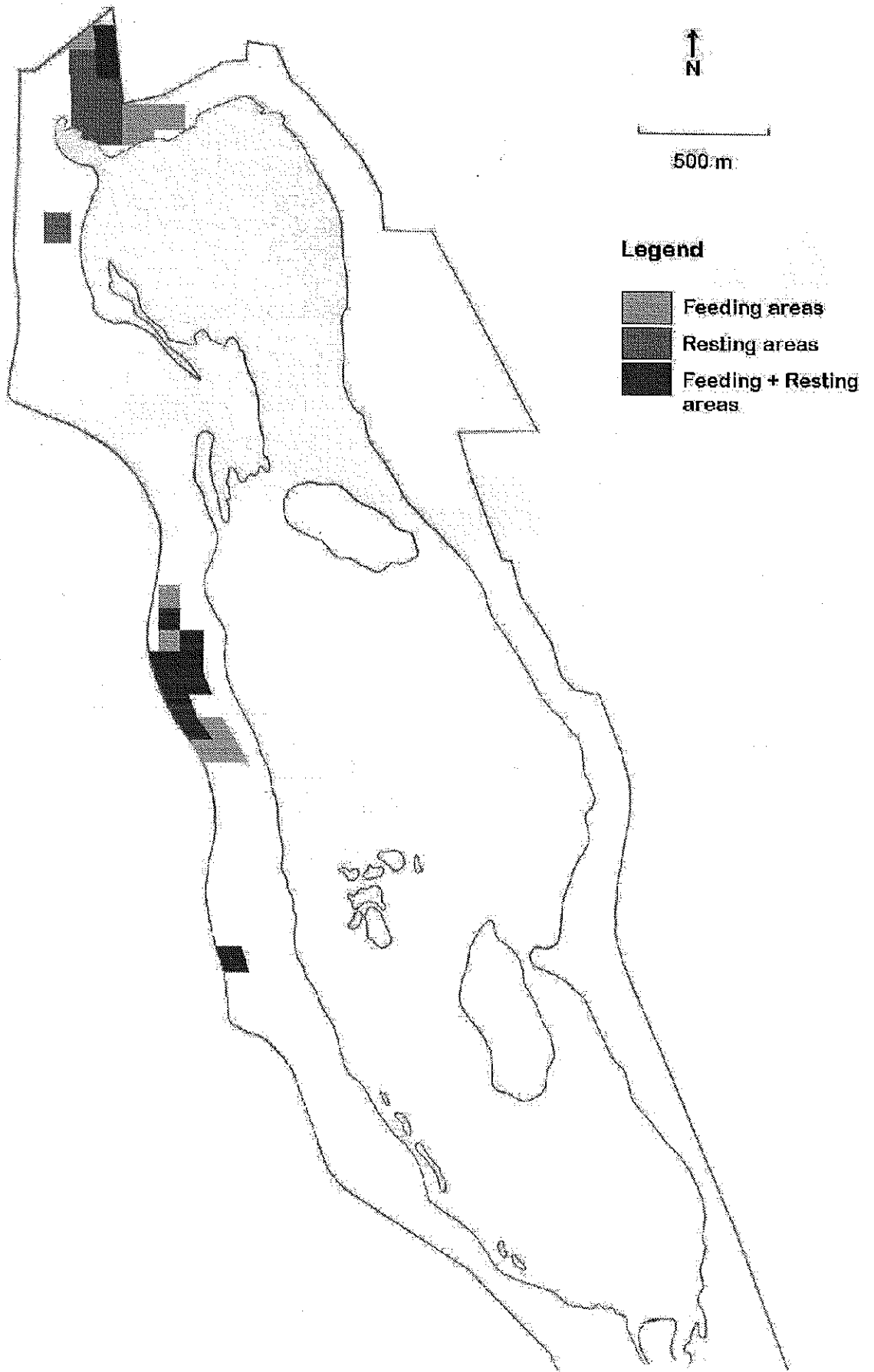


Figure 4.4 Grazing and resting areas of the northern *M. fuliginosus* population in the mornings and evenings during winter.

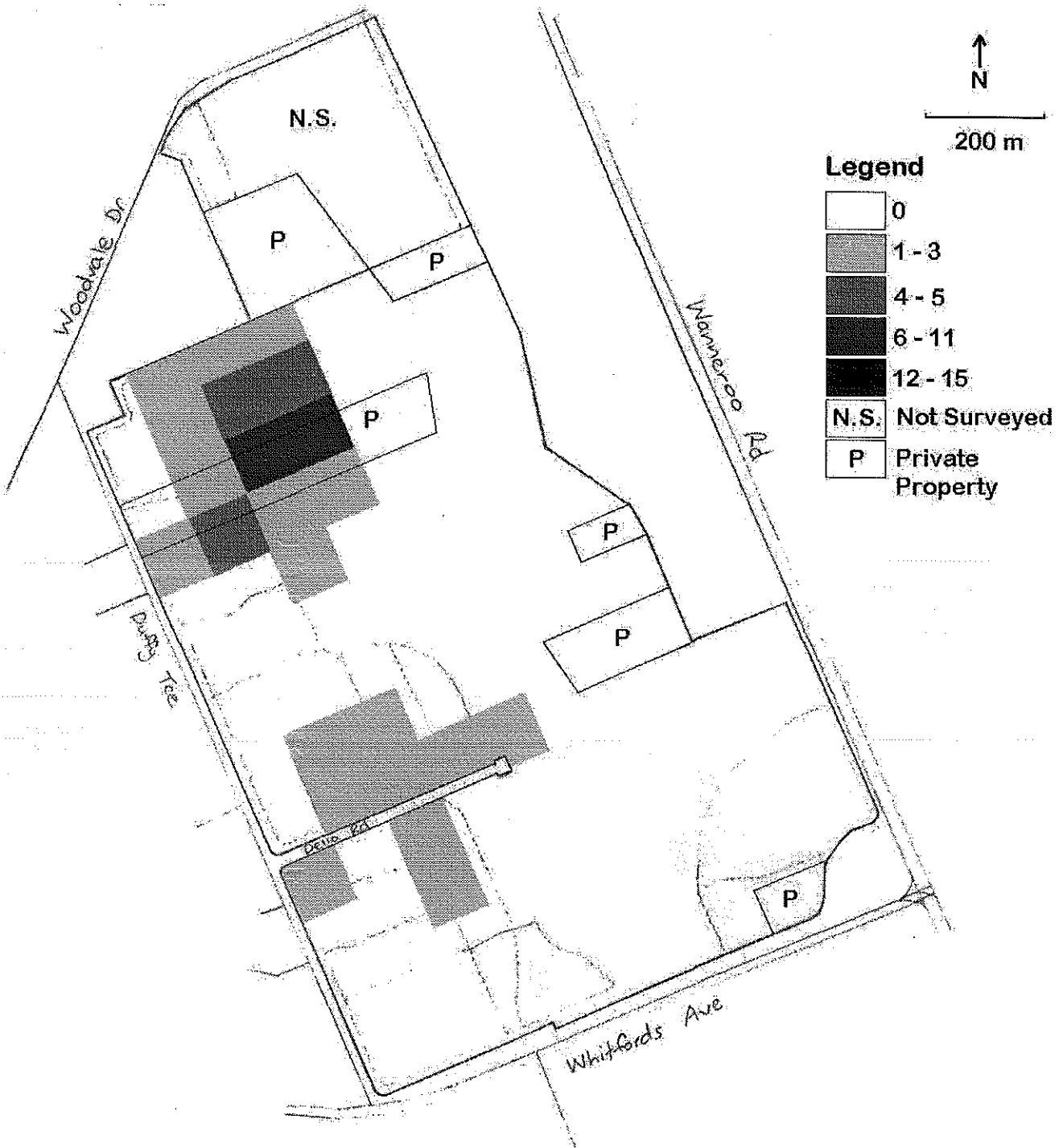


Figure 4.5 Observed distribution and density (kangaroos/ha) of *M. fuliginosus* in site 4 during winter.

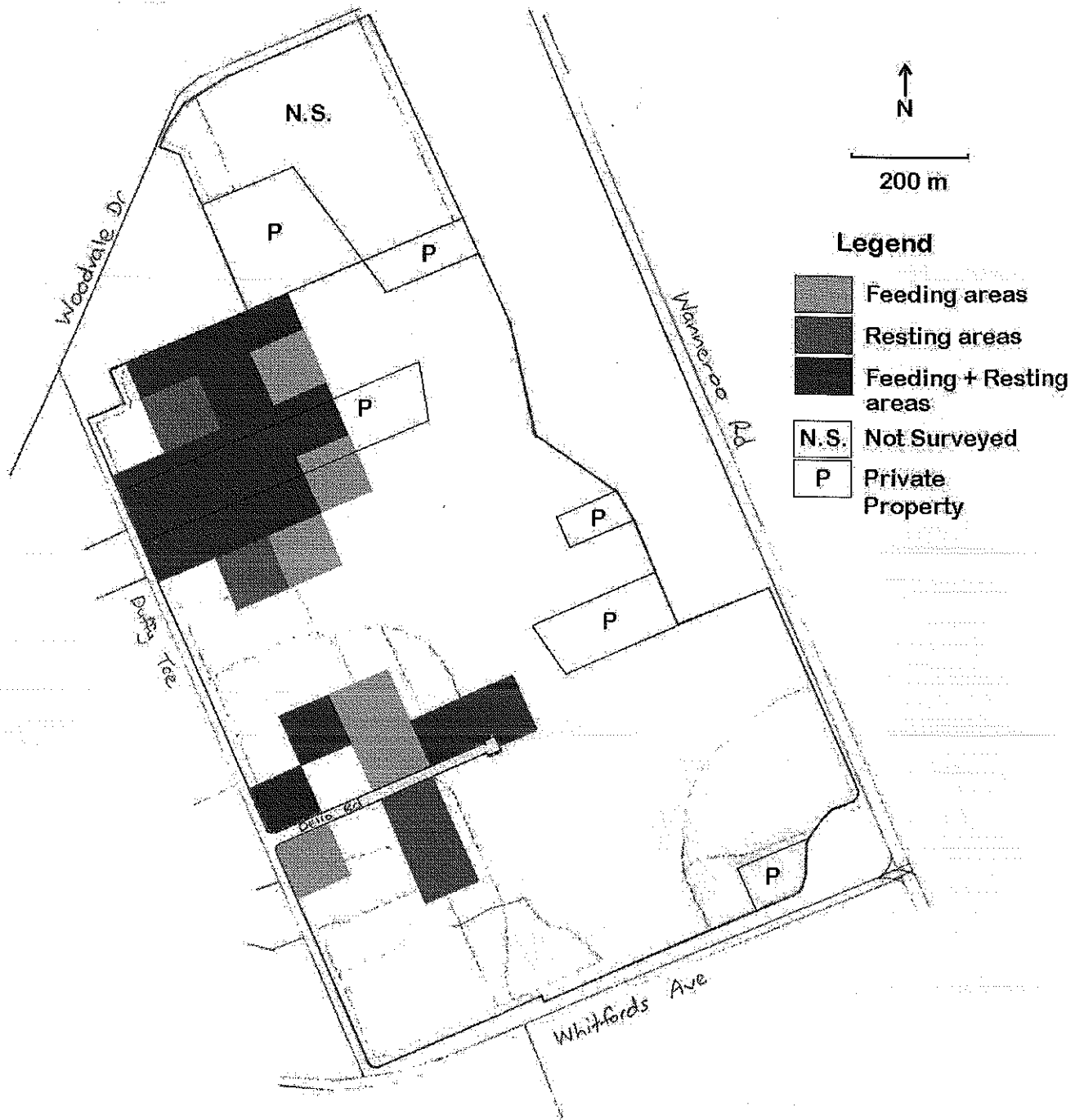


Figure 4.6 Grazing and resting areas of *M. fuliginosus* in site 4 in the mornings and evenings during winter.

4.4.1 Movement

Movements between Yellagonga Regional Park and adjacent areas were observed. Some kangaroos in the northern population were sighted moving to and from the Park's boundary to ECU's Joondalup campus, and those in the northern end of Lake Joondalup were seen moving to the Park from areas north of Yellagonga Regional Park. Kangaroos were also observed moving into Joondalup campus through residential areas and the police academy construction sites to the northwest of Joondalup campus. A few were also sighted in remnant bushland around the West Coast College of TAFE Joondalup campus outside surveying times. Kangaroos in the southern population were not observed outside Yellagonga Regional Park. However comments by a resident and council employee indicated that very few were seen in areas north and south of site 4 and some movements occur to residential property in the northeast of site 4 to graze.

4.5 Vegetation Associations

Kangaroos were found in all types of upland habitats and there was no apparent preference for the tuart-jarraah-marri open forest or the jarraah-marri-banksia open woodland (figure 4.7). However, there was a preference for reticulated lawns and disturbed areas when feeding occurred in the early mornings and evenings. During the day, kangaroos returned to shelter in the open forest or woodland. Kangaroos in the southern population were an exception as they remained in cleared areas to rest after feeding (figure 4.8).

The relative density of understorey plants appeared to influence distribution of *M. fuliginosus* as the highest kangaroo densities were found in moderate vegetation cover and few were observed in dense or sparse understorey (figure 4.9). Most areas in site 4 were cleared and remaining vegetation either provided little cover from predators and human activity or was too dense for kangaroos to move through (figure 4.10).

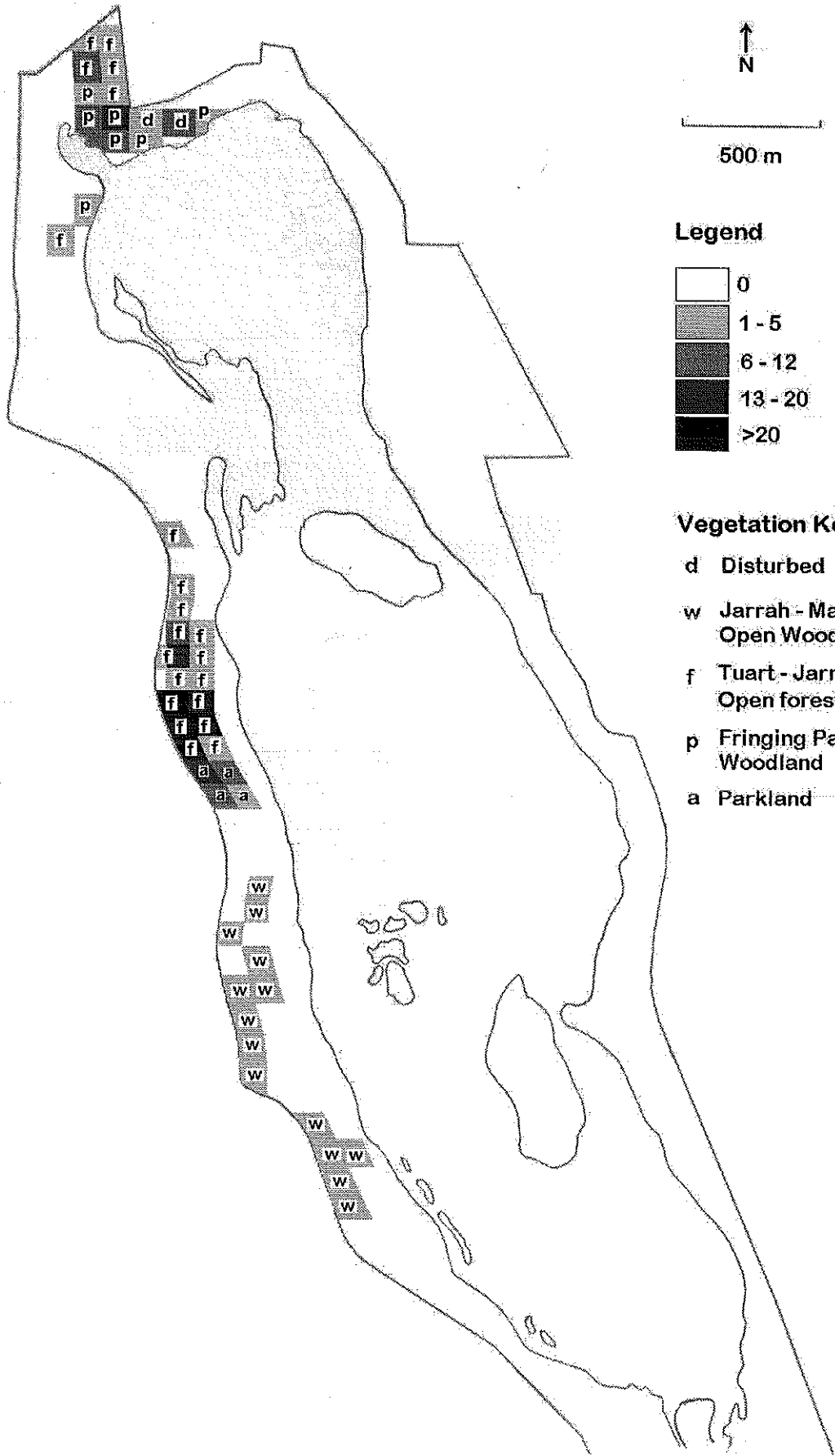


Figure 4.7 Sighting frequencies (kangaroos/ha) of *M. fuliginosus* in relation to habitat types around Lake Joondalup.

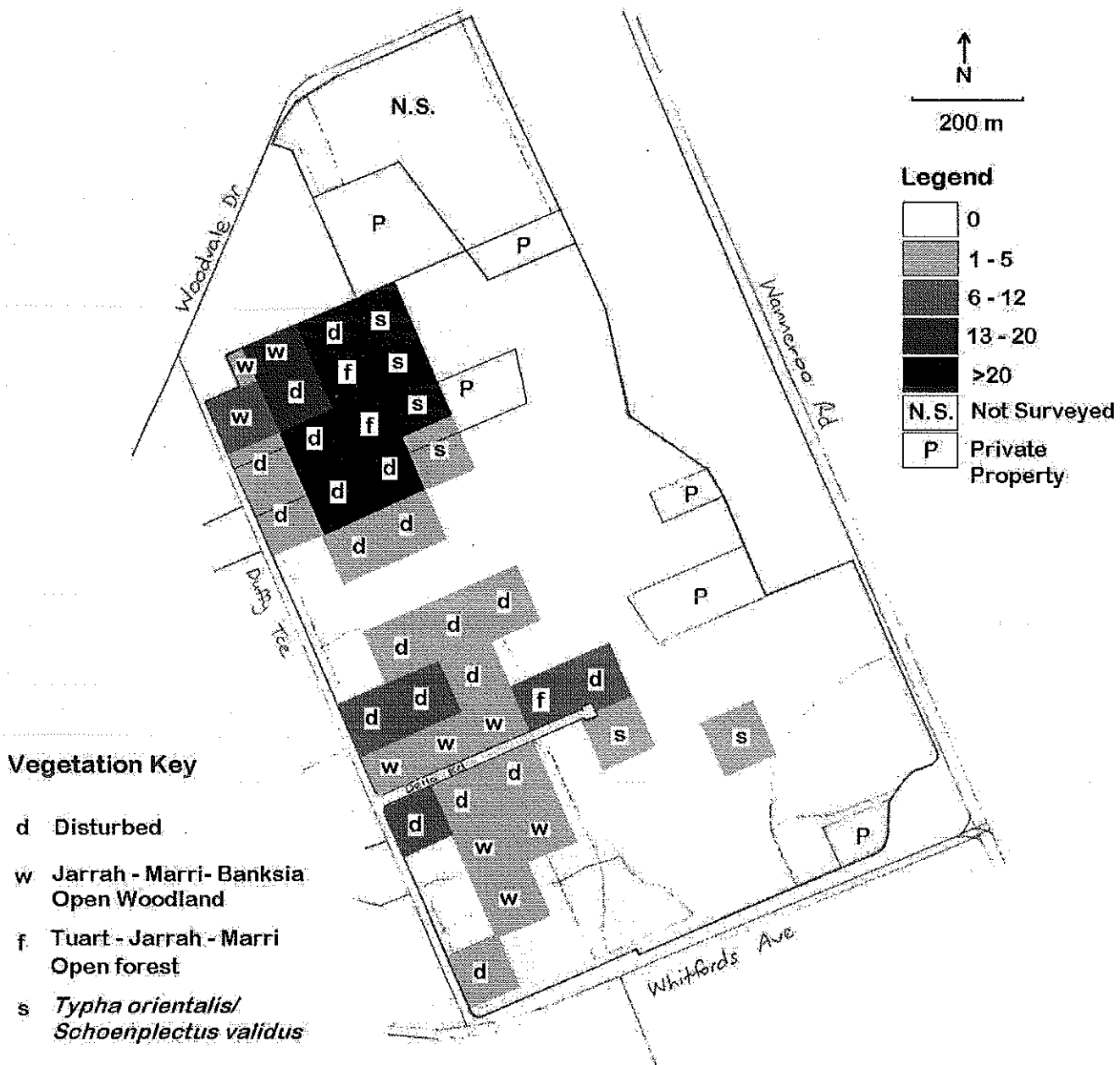


Figure 4.8 Sighting frequencies (kangaroos/ha) of *M. fuliginosus* in relation to habitat types in site 4.

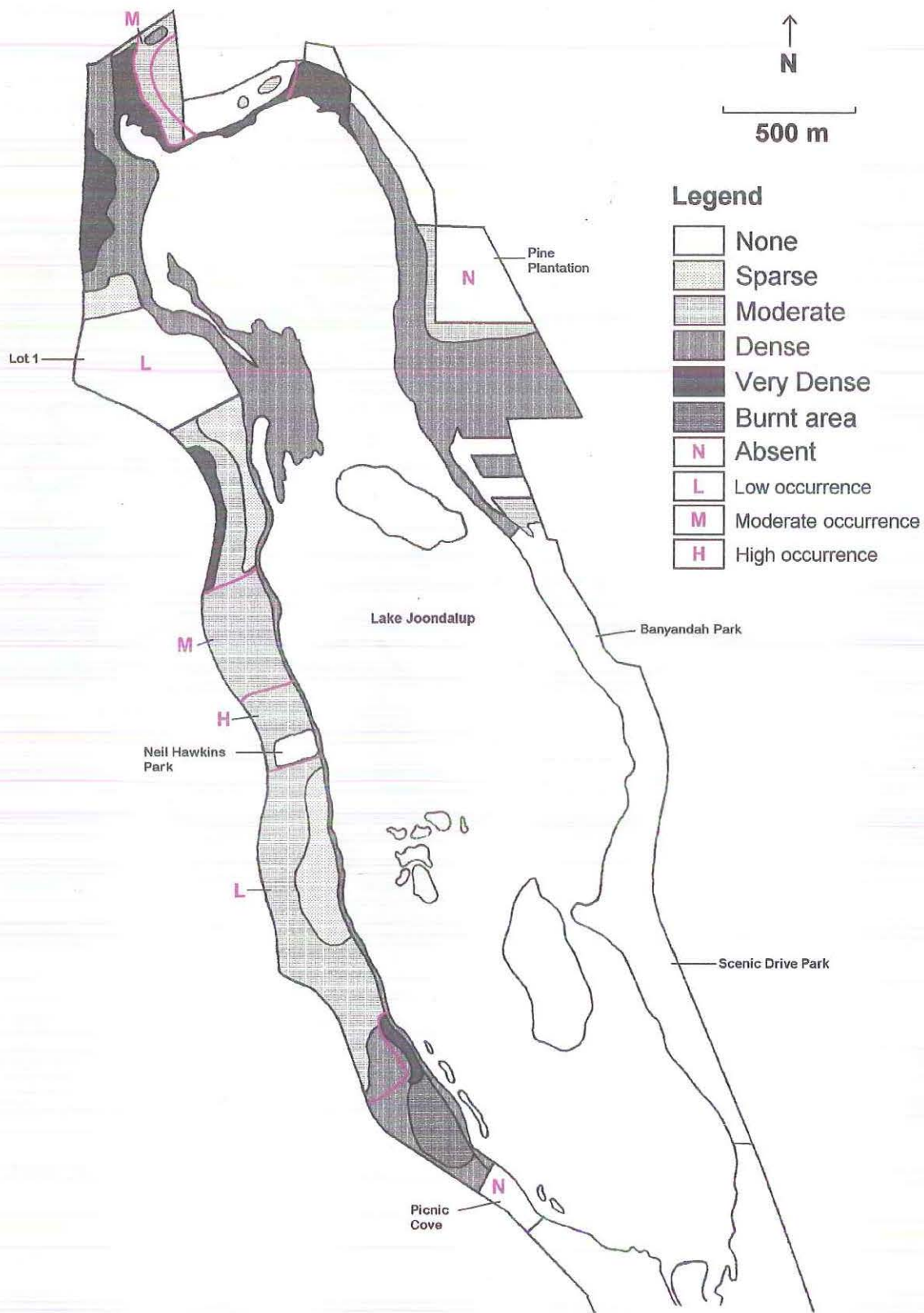


Figure 4.9 Occurrence of *M. fuliginosus* in relation to relative understorey density around Lake Joondalup. Low being that the frequency of sightings were less than 6 kangaroos in a quadrat, moderate is where frequency of sightings were between 6 – 15 kangaroos in a quadrat and high is where frequency of sightings were greater than 15 in a quadrat.

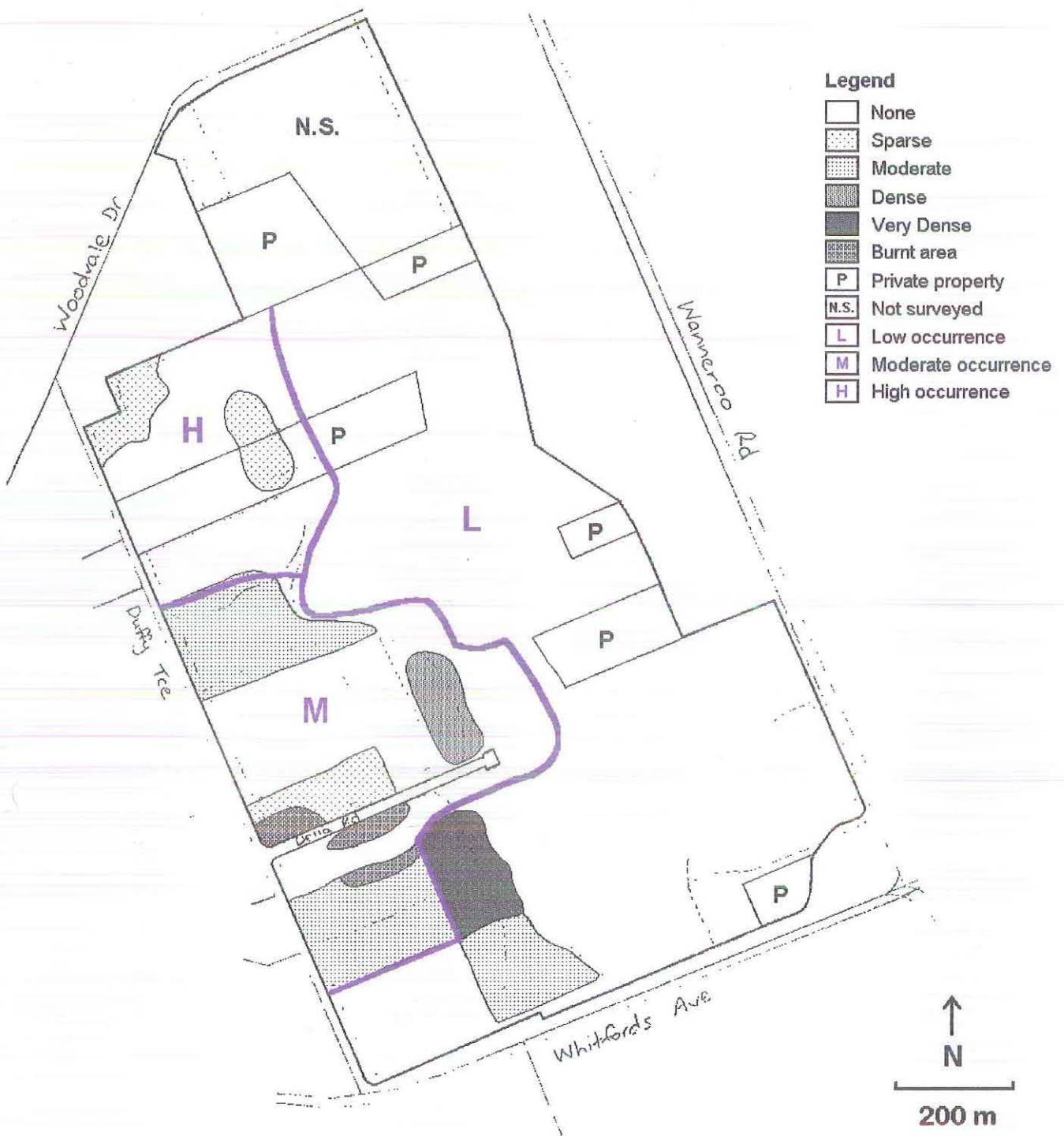


Figure 4.10 Occurrence of *M. fuliginosus* in relation to relative understorey density in site 4. Low being that the frequency of sightings were less than 6 kangaroos in a quadrat, moderate is where frequency of sightings were between 6 – 15 kangaroos in a quadrat and high is where frequency of sightings were greater than 15 in a quadrat.

4.5.1 Diet

Kangaroos were observed feeding mostly on grasses and other monocots. Some fed on leaves of *Macrozamia reidleyi*, *Eucalyptus spp.*, *Dryandra hewardiana* and *Hibbertia cuneiformis*. The northern population had access to artificial food sources as they were fed parrot mix and bread by visitors to Neil Hawkins Park.

4.6 Extent of Human Activity/Interaction

Human activity was observed in all areas of Yellagonga Regional Park (figures 4.11 and 4.12) and higher levels of human activity occurred around Lake Joondalup. The most frequent activities were dog walking, recreational walks, riding bicycles, feeding birds and kangaroos in Neil Hawkins Park and picnicking in parklands around Lake Joondalup. In site 4 the most frequent human disturbances observed were horse agistment and dog walking. Horse agistment was mostly confined to the south of site 4, while people walking their dogs occurred throughout the west of site 4. In other sections of Yellagonga Regional Park, areas of greatest human activity occurred in Neil Hawkins Park, the stretch of open forest and woodland above and below Neil Hawkins Park and the parklands to the east of Lake Joondalup. The most prominent activity in Neil Hawkins Park was bird feeding during the day and observing and feeding kangaroos in the evenings. Recreational walks were the primary activity in areas of natural habitat to the west of Lake Joondalup, and dogs accompanied most walkers. Dog walking also occurred in Lot 1. Most dogs in site 4 and west of Lake Joondalup were not walked on leashes.

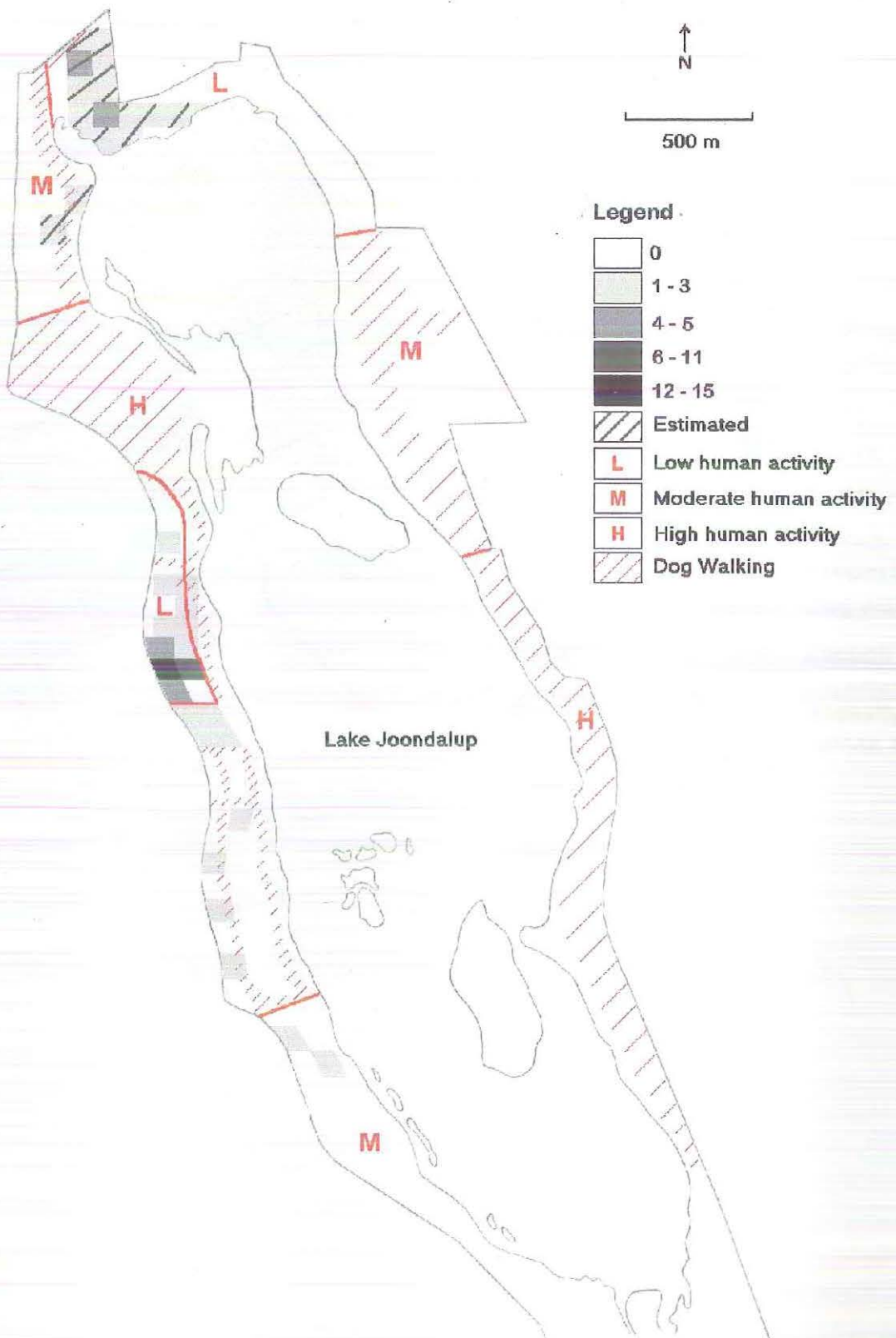


Figure 4.11 Association between the densities (kangaroos/ha) of *M. fuliginosus* in northern sites of Yellagonga Regional Park and levels of human disturbance. Areas of low human activity were defined as less than 3 people seen during the 3 week survey, moderate areas were where 3 – 5 people were seen almost on a daily basis and high were areas where more than 5 people were present or people were present on a daily basis.

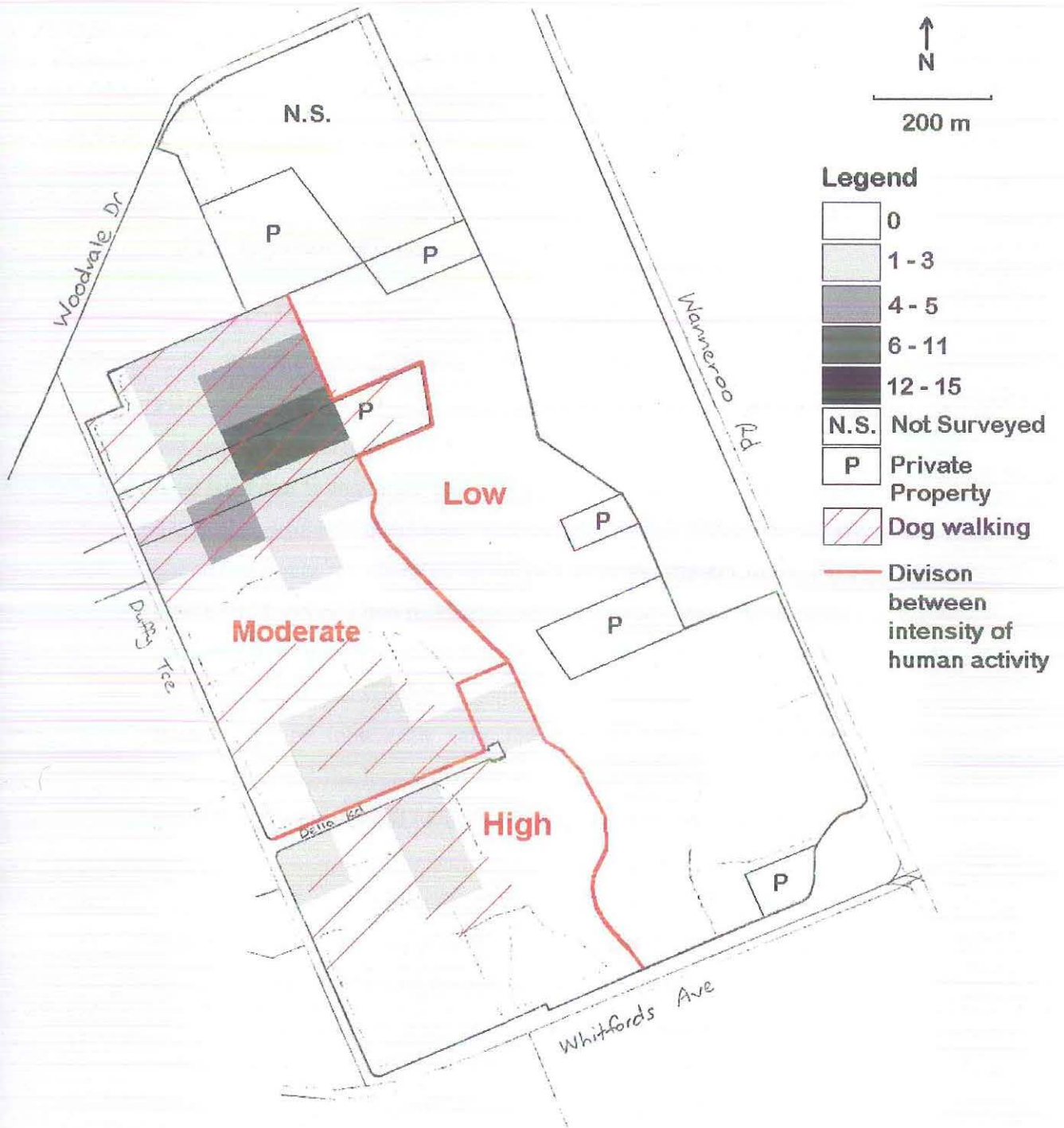


Figure 4.12 Association between the densities (kangaroos/ha) of *M. fuliginosus* in site 4 and levels of human disturbance. Areas of low human activity were defined as less than 3 people seen during the 3 week survey, moderate areas were where 3 – 5 people were seen almost on a daily basis and high were areas where more than 5 people were present or people were present on a daily basis.

5 Discussion

5.1 Population Ecology

5.1.1 Density

The densities of the two populations of *M. fuliginosus* in Yellagonga Regional Park were slightly different (1.4 kangaroos/ha and 0.70 kangaroos/ha for the northern and southern populations, respectively). The difference in abundance was most likely to have been due to the larger numbers of mobile individuals in the northern population, while the southern population was mainly static. Kangaroos in site 4 (southern population) were not observed to migrate to areas adjacent to the Park as these areas have been developed into residential and commercial areas. Areas to the north and west of Lake Joondalup were not as heavily developed as areas surrounding site 4, allowing some migration between Yellagonga Regional Park and adjacent areas to occur. Recruitment of individuals into the northern population, assisted by increased urbanisation and the loss of habitat in areas surrounding the northern end of the Park may have also contributed to the higher density of the northern population.

Other factors which may account for the larger abundance of the northern population include habitat, availability of forage, predation and proportion of females in the population. Habitats of the two populations differed slightly but should not have affected densities as both populations had access to abundant food sources and water all year round. Differences in densities may not have been a result of predation as it was observed to be low in the park. If more time had been available, a survey to estimate the density of predators in the Park would have been conducted to determine if predation is a significant factor which limits population size. The greater proportion of females in the northern population and the northern population's access to artificial food sources may have contributed to the population's higher growth rate and observed density. Artificial feeding results in an increase in population size as kangaroos are given the perception that food is abundant and breeding increases (Lambert, pers. comm.). In the northern population, greater numbers of young are produced each year due to the larger proportion of females and the long-term result of the higher recruitment of young is a greater population size.

Some studies on the density of *M. fuliginosus* populations are remotely comparable to this study (table 5.1). This is due to the differences in the techniques used to estimate abundance, habitats present in survey areas, location of survey areas and the management of populations in other surveys. However, the density of kangaroos in Yellagonga Regional Park is compared to other areas to illustrate the differences between density estimates using different survey methods and to compare some differences between populations in natural and disturbed environments.

There are always some errors involved with independent survey methods and density estimates. This has been illustrated in the study at Whiteman Park where slight differences in density were obtained from different methods of surveying. In addition, densities in other studies were estimated in the entire survey area, not by their area of distribution as calculated in this study. If density had been determined for the total area of the Park (231.8 ha, excluding lakes and swamps) then the density of kangaroos would have been 0.96/ha. However, this estimate is still 0.44 – 0.85 kangaroos/ha higher than the densities recorded in other surveys (Arnold *et al.*, 1991a; Arnold *et al.*, 1994; Bamford & Bamford, 2000).

Densities of kangaroos in Baker's Hill, Durokoppin Nature Reserve and Whiteman Park were lower than densities recorded in Yellagonga Regional Park. Populations in Whiteman Park and Baker's Hill are annually culled to limit population size. Other factors that regulate population size include the predation of young by foxes at Baker's Hill and rainfall that governs the availability of forage in Durokoppin Nature Reserve. In contrast to populations in these locations, populations in Yellagonga Regional Park are not culled and forage is abundant throughout the year.

Hattah-Kulkyne National Park was the only study where extremely high densities of kangaroos occurred. The high abundance of kangaroos in the Park was due to the provision of water and improved pasture conditions from agricultural development and the decline of dingo predation (Cheal, 1986). The season when the survey was conducted also influences the estimate of density as population densities are highest during summer after young animals vacate the mother's pouch (Coulson & Norbury, 1988).

Table 5.1 Densities of Wild Kangaroo Populations in Western Australia and Victoria.

Area	Location	Species Present	Habitat(s)	Survey Method	Season Surveyed	Density (kangaroos/ha)	Source
Baker's Hill	Semi-arid region of southern Western Australia, 90 km NE of Perth	<i>M. fuliginosus</i>	Wandoo woodland	Lincon Index capture-recapture method	Late autumn	0.52	(Arnold <i>et al.</i> , 1991a)
Durokoppin Nature Reserve	Western Australia's central wheatbelt	<i>M. fuliginosus</i> <i>M. robustus erubescens</i>	Woodlands Shrublands Heaths	Aerial survey	Late summer	0.16 ± 0.024 (total ± s.e.)	(Arnold <i>et al.</i> , 1994)
Whiteman Park	20 km NE of Perth	<i>M. fuliginosus</i>	Parkland Woodlands Thickets	Pellet counts Direct counts	Early spring Late winter and early spring	0.15 0.11	(Bamford & Bamford, 2000)
Hattah-Kulkyne National Park	NW of Victoria	<i>M. fuliginosus</i> <i>M. rufus</i>	Mallee scrub Riverine woodland Open sandhills Saline flats	Hayne's line transect model using walked transects	Summer to mid-autumn	460	(Coulson, 1990a)

The high densities estimated in Yellagonga Regional Park compared to other reports do not appear to be a result of survey error or difference in surveying season, but due to the abundance of forage and predation pressure which appeared to be low. The other surveys were conducted in a season where the estimated number of kangaroos reflected the size of the population for the year and not during a season where numbers peaked as pouch young vacates the pouch. In Yellagonga Regional Park the survey was conducted before numbers peaked as the numbers of kangaroos would be highest during summer, then slightly decline and remain constant until the next breeding season. Kangaroos in Baker's Hill and Durokoppin Nature Reserve occur in environments where populations are regulated by the availability of forage and predation, while populations in Hattah-Kulkyne National Park are regulated by the availability of forage. Whereas populations in Yellagonga Regional Park and Whiteman Park occur within environments where kangaroos have access to food and water throughout the year and predation on populations are negligible or absent. In Whiteman Park, kangaroo populations are culled because they occur in a disturbed environment and factors which regulate population size are absent. Therefore lower densities were reported in Whiteman Park compared to Yellagonga Regional Park.

5.1.2 Age structure

Abundances of young (sub-adults, young at foot and pouch young) in both populations were slightly greater than adults. This reflects the high fertility of females in both populations and low predation of young by foxes and Wedge-tailed Eagles. The health of the animal influences their reproductive capacity. In drought conditions or when food and water becomes scarce, females enter anoestrus to reduce energy expenditure involved with reproduction to increase their chances of survival (Short, 1987; Barker, 1987). The high fertility of females indicates that resources for population growth were abundant. Alternatively, the lower numbers of adults may have been due to the higher mobility of adults, especially males, higher mortality among the adults or a population with a high growth rate.

The proportion of adults in the southern population was slightly lower (by 4%) than adults in the northern population. Although individuals in the southern population were not sighted outside the Park, migration into and out of the Park may have

occurred. Adults (especially males) in the southern population may have higher mobility than adult males in the northern population, therefore, fewer adults were recorded in site 4. Another factor for the lower abundance of adults may have been due to the greater mortality among adults in the southern population.

A general trend exhibited by the young in both populations, was a decrease in the number of individuals in an age class with the more mature age class. The loss of pouch young after emergence from the pouch has been associated with predation of young (Banks *et al.*, 2000; Arnold *et al.*, 1991a). Banks, *et al.*, (2000) conducted a replicated predator removal experiment to determine whether predation by foxes (*Vulpes vulpes*) limited the recruitment of young in wild populations of eastern grey kangaroos (*M. giganteus*). Foxes were baited with 1080 poison in removal sites and fox densities were less than 0.5/km in removal sites and 0.8-2.0/km in nonremoval sites. In sites where fox densities were high, the predation of young by foxes was significant. Kangaroo populations in Yellagonga Regional Park were similar to populations in the removal sites as Banks *et al.*, (2000) reported that 50% of young were lost after emergence from the pouch in nonremoval sites. While in Yellagonga Regional Park a 30% difference was recorded between the abundance of pouch young to young at foot. This indicates that the current levels of fox predation have low impact on the mortality of juveniles in Yellagonga Regional Park.

Arnold *et al.*, (1991) has suggested that high mortality of the young at foot is a normal feature among the large macropods and other reasons that contribute to the loss of juveniles, such as nutritional stress from change in diet as young are weaned, are only conjecture. The loss of juveniles in Yellagonga Regional Park may have occurred during development in the pouch, resulted from injuries or stress from domestic dog attacks, injuries obtained from sparring, motor vehicle encounters or from diseases.

The ratios of young at foot to sub-adults in the southern population were almost at a 1:1 ratio, while the young at foot outnumbered the sub-adults by 3:1 in the northern population. This indicates that mortality of sub-adults in the southern population was lower or their movements were mostly confined within the Park. The lower occurrence of sub-adults in the northern population was likely due to their greater mobility to areas outside the Park. The higher mobility of sub-adults exposes them to greater incidences

of attacks by dogs or encounters with motor vehicles, which may result in higher deaths of juveniles in the northern population.

5.1.3 Female Breeding

The high breeding success of most *M. fuliginosus* females were related to the adequate provision of food, water and shelter in the Park and also to the good state of health of the individuals. As food and water were abundant all year round, other reasons may account for the few females that were not observed to be breeding. These females may have been carrying very small pouch young or may have just reached sexual maturation. Initial mating does not occur in *M. fuliginosus* until 1 to 2 months after onset of sexual maturity with births not less than a month after mating (Poole & Catling, 1974). Also observed in females was that some enter anoestrus during winter (Poole & Catling, 1974; Poole, 1973).

Breeding in both populations at Yellagonga Regional Park occurs throughout the year. During late autumn and early winter most females were recorded with small pouch young and few with large pouch young. During surveys in late winter most females were recorded with large pouch young. Most pouch young would be expected to vacate the pouch in spring as seasons of female breeding in Yellagonga were similar to those recorded in other surveys. The peak breeding season has been found to occur during spring in *M. fuliginosus* and births are concentrated in summer (Norbury *et al.*, 1988; Banks *et al.*, 2000).

5.1.4 Sex ratios

Sex ratios of adults in both populations were highly female biased. A female biased sex ratio (1:3 male:female ratio) was recorded in Hattah-Kulkyne National Park (Norbury *et al.*, 1988). Sex ratios of *M. fuliginosus* in Durokoppin Nature Reserve (1:1.39) (Arnold *et al.*, 1994) and Baker's Hill (1:2.1) (Arnold *et al.*, 1991a) were also slightly female biased. The female bias in those populations were a result of male biased mortality during drought (Norbury *et al.*, 1988), surveying biases and difference in migration rates of males (Arnold *et al.*, 1994). In other studies highly biased sex ratios were due to the dynamics of predation (Duffy, 1994; Pentland, 1999; Berger &

Gompper, 1999). Foxes are considered a significant predator of large macropods when high densities of foxes are present (Banks et al., 2000). However, smaller macropods are more vulnerable to predation by foxes (Robertshaw & Harden, 1989; Kinnear *et al.*, 1988).

The high adult female bias in populations at Yellagonga Regional Park may have resulted from a number of reasons. Predation was not considered to have skewed sex ratios as levels of predation appeared to be low. Robertshaw and Harden, (1989) consider the dynamics of fox predation on large macropods to be negligible. However, fox predation of juveniles or other sources of mortality among juveniles may have contributed to the female biased sex ratio in adults, as most macropods were found to have a slight male bias or parity between sexes at birth (Johnson, 1989). Although, female biased sex ratios of pouch young have been recorded for *M. fuliginosus* and *M. robustus erubescens* (0.5:1 and 0.57:1 male:female ratios, respectively) (Arnold et al., 1994).

The greater proportion of mobile individuals in the northern population may have underestimated the number of adult males. A sample of the population could have been surveyed as the northern population may have been part of a larger population with a distribution that encompassed a large area outside of and including Yellagonga Regional Park. In addition, some males may have been missed when they were not present in the Park during the survey period, due to the higher mobility of males. Males have larger ranges than females as *M. fuliginosus* adult males move over large distances to check the status of oestrus females and to reach feeding and resting areas (Priddel, 1987).

The low abundance of males may have been due to high mortality among the adults. During breeding, males will compete with each other for access to the females and often males obtain injuries from the encounter and death may result. Higher mobility of males indicates that males have higher risk of being killed by motor vehicles on the roads, which may have also contributed to higher mortality among adult males.

5.1.5 Male and Female Activity Ranges

Male and female activity ranges were not established in Yellagonga Regional Park and their estimation was not appropriate or viable in this study. However, it is believed that male activity ranges were larger than female activity ranges as individual male sightings were less frequent than individual female sightings. Sightings for individual males were generally less than twice a week, while for individual females sightings generally occurred more than three times a week. *Macropus fuliginosus* home ranges vary from 39 ha to 70 ha (Arnold et al., 1992) and males generally have larger ranges than females (Arnold et al., 1992; Priddel, 1987; Priddel, 1988). Most individuals of both sexes never move more than 6 km, but the highest recorded movement of western grey females was 10 to 19 km and 85 km by a western grey male (Priddel, 1987). The higher mobility of adult males was probably the reason why males were sighted less frequently than females.

5.1.6 Daily Activity

Macropus fuliginosus was most active during the mornings and evenings. Periods of grazing and resting were similar to other studies. In this study, grazing was dominant in the early mornings and during the evenings, beginning during sunset and ending after sunrise. In other studies, grazing has been found to be prominent early in the morning, during the evening and throughout the night (Priddel, 1986; Caughley, 1964; Arnold et al., 1988). Daytime temperatures have been found to affect times spent resting and grazing during the day and periods of resting were higher when maximum daily temperatures reached 22°C and above (Priddel, 1986). In this study, resting was dominant during the day and the duration of resting was influenced by temperature.

5.1.7 Group Size and Formation

The formation of groups and group sizes of populations in Yellagonga Regional Park were typical of kangaroos and other macropods (Johnson, 1983; Southwell, 1984a; Southwell, 1984b; Jarman & Coulson, 1989; Coulson, 1999). During feeding, kangaroos formed large mobs for shared surveillance to increase individual feeding time and reduce time spent surveying (Jarman & Coulson, 1989; Coulson, 1999) and reduce the risk of predation (Jarman & Coulson, 1989; Banks, 2001). After feeding, mobs

dispersed and formed smaller groups in the northern population. The southern population was different as they remained in large groups (over 20 individuals) after feeding. The increased exposure of individuals in the southern population due to limited vegetation cover resulted in the formation of large groups as observed in several other populations (Coulson, 1990b; Heathcote, 1987; Southwell, 1984a).

Females with young at foot were recorded alone more often than other individuals. Females tend to isolate themselves from other members of the group when the young is at a permanent stage of leaving the pouch or is a small young at foot (Jarman & Coulson, 1989). Several hypotheses have been used to account for the solitariness of females with young at foot. Stuart-Dick (1987) suggested the solitariness of females as an adaptive response associated with complexities involved with expelling the young from the pouch. Another suggestion was that the mother could be isolating her young away from the group as they are more vulnerable targets to predators (Jarman & Coulson, 1989). Croft (1981) suggested that the poor locomotor ability of the young restricts movements of the pair to remain in close proximity to the group, or that isolation is to avoid separation during the group's alarm and flight.

5.1.8 Habitat Utilisation

Differences in habitat utilisation were observed in the two populations at Yellagonga Regional Park. The southern population was observed to utilise cleared areas more than areas of natural habitat. The use of cleared areas to feed and rest during the day and night appeared to be due to high levels of human disturbance and lower occurrence of natural habitat. About 70% of site 4 did not have any canopy cover as most parts were cleared and wetland vegetation provided little shelter. The remaining open forest and open woodland habitats may have insufficient space to shelter most individuals and suitable forage in these habitats was probably low. However, when temperatures are greater in summer individuals may move into forest and woodland habitats after grazing to shelter from the sun.

The northern population was observed to utilise areas of natural habitat more than cleared areas. During the day *M. fuliginosus* fed and rested in the open forest and open woodland, and rested only in fringing swamp paperbark woodland. In the

evenings, kangaroos moved out of the forest and woodland into more open areas (Neil Hawkins Park) to graze. Kangaroos were not sighted in Lot 1, as dog walking was the primary disturbance during the day. However, kangaroos may move to Lot 1 to feed during the night. *Macropus fuliginosus* fecal pellets were present in low amounts in Lot 1 and during some morning surveys, individuals were observed moving through vegetation below Lot 1 towards the section of open forest above Neil Hawkins Park. This does indicate some use of the cleared area for grazing but night surveys need to be conducted to confirm their presence in Lot 1.

5.2 Distribution

5.2.1 Movement

The northern population appeared to have a greater distribution than the southern population due to the larger numbers of mobile kangaroos in the northern population. Some individuals in the northern population were observed to move to areas adjacent the Park and Neerabup National Park (located about 1 km northwest of the Park). Individuals may have moved further south along the west of Lake Joondalup than the observed southern limits of distribution. A recent fire could have affected movements into the burnt area even though the initial survey did not find any evidence of their presence in the Park south of site 2 after the fire, as kangaroos may have previously occurred in the area before it was burnt. Individuals could be moving to the burnt area at night to graze on regenerating vegetation as it has been found that firebreaks attract kangaroos by opening up dense undergrowth and encouraging the growth of grass (Taylor, 1980). The erection of a fence along the northern boundary of the Park during the study could have impeded movements of kangaroos between Yellagonga Regional Park and Neerabup National Park. This may have affected the level of sightings during the survey in site 1. However, kangaroos were observed to move into the Park through private property.

In the southern population, movement was generally confined to site 4 as most of the Park's boundary had been fenced and the surrounding area is a heavily developed urban environment. Although emigration from the Park was not observed, some individuals (possibly males) in the southern population may be moving into and out of

the Park. Few individuals were sighted in the eastern parts of site 4 which was probably due to fences and wetland vegetation across the centre of the site that restricted movements to the area. The absence of suitable vegetation cover may have also been another factor limiting movements to the eastern parts of site 4.

The distribution of populations in the Park may have been underestimated as differences in distribution occur seasonally and during the time of day. Kangaroos have been shown to have slight differences in daytime and nighttime ranges that mostly overlapped (Coulson & Norbury, 1988; Arnold et al., 1992; Arnold & Steven, 1988). Differences in seasonal distribution occur mainly due to pasture conditions and availability of forage (Arnold & Steven, 1988; Priddel, 1988; Coulson, 1990b). Individuals probably had night ranges that partially overlapped their daytime ranges and seasonal differences in distribution would be negligible as forage is abundant throughout the year in Yellagonga Regional Park. Had underestimation of distribution occurred, it would have most likely been due to the exclusion of their nighttime distribution.

5.2.2 Factors Limiting Distribution

The levels of human disturbance and understorey density were the most significant influences of distribution in Yellagonga Regional Park. Disturbance was the primary factor that governed the distribution of the southern population. During the day individuals were observed to graze and rest in areas of minimal human activity in the northwest of site 4 where the highest densities of kangaroos occurred. It was unusual that the southern population preferred the cleared areas instead of the open woodland as *M. fuliginosus* exhibits a preference for habitats offering shelter (Caughley, 1964; Cairns et al., 1991). The species also exhibited high levels of wariness of humans as they were either absent or present in low densities where human activity occurred. This behaviour was also observed in another study (Arnold et al., 1995). Although the level of human activity was lower in site 4 than northern areas of the Park, human disturbance was inferred as the primary influence on distribution.

The type of upland habitat did not affect distribution of the northern population, as kangaroos were present in tuart-jarrah-marri open forest, jarrah-marri-banksia open

woodland and fringing swamp paperbark woodland. Understorey vegetation and human activity were most likely to influence distribution of individuals in the northern population. High level of sightings occurred in moderate understorey density where understorey vegetation provided sufficient cover from observation. Few were sighted in sparse vegetation or dense vegetation. Although the level of sightings was lower in dense vegetation, missed counts may have occurred and numbers could have been slightly higher. However, dense vegetation restricts movements of individuals (Arnold & Steven, 1988; Caughley, 1964; Southwell, 1987; Taylor, 1980) and it would have been highly unlikely that high densities occurred in areas of dense vegetation. Some variations in density were observed in areas of moderate vegetation density that was attributed to levels of human activity. High kangaroo densities and greater level of sightings occurred in areas where low levels of human activity were present. These factors may have been the reason why no kangaroos were sighted in Lot 1 and east of Lake Joondalup. In Lot 1, high levels of Park use and the presence of dogs may have discouraged movements into the area during the day, but kangaroos may be moving into the area to graze at night when levels of human activity are lower. Kangaroos were not sighted east of Lake Joondalup probably due to dense vegetation to the northeast of the Lake restricting movements of the animals and high levels of human activity. However, kangaroos could move through residential areas adjacent the Park to reach areas east of Lake Joondalup.

5.3 Feasibility of Direct Counts

The approach taken to survey the abundance and distribution of kangaroos was considered the most appropriate due to the nature of the study area. Yellagonga Regional Park is set in an urban environment and is visited regularly by people. In areas of high human activity the application of other methods to determine the abundance and distribution of populations that involve capturing and releasing kangaroos are unsuitable. Pellet counts were another method that could have been applied but the method only estimates densities and does not give an indication of the sex ratios and age structure of populations nor accurately determine the distribution of kangaroos. Estimates of abundance by pellet counts have been found to be no more accurate than total counts (Bamford & Bamford, 2000).

The abundance determined by total counts may have contained some degree of error as surveyed numbers may not reflect actual numbers in Yellagonga Regional Park. Individuals may have been incorrectly identified or missed during surveys, resulting in minor errors in the estimation of abundance. One reason for this was poor visibility during some surveying occasions when kangaroos were partially concealed behind vegetation, were sighted briefly before hopping off or were too far away to be accurately identified. The weather also affected the level of sightings as visibility was lower during rain and in fog in the mornings. Kangaroos may have also been mistakenly identified when similar individuals, probably siblings, could not be distinguished. Another reason for mistaken identity that may have resulted could be due to fresh scarring or change in physique over time that led to the recording of the same kangaroo twice.

Some errors that occurred during the survey could have been avoided if the method of surveying kangaroos was slightly modified. Instead of an intense, repetitive survey during a short time frame in sections of the Park, surveys could be conducted once a fortnight during winter (and in summer if more time was available), simultaneously throughout the entire area of the Park (in regions where kangaroos are found) with 2 or 3 surveyors on the ground. The area of the Park is too large to be covered in a day, so surveyors could each have their own section(s) of the Park to survey. These modifications would reduce the possibility of missed counts occurring during these surveys and results obtained between the northern and southern populations would not have seasonal variations as surveys for both populations are conducted at the same time. Another alteration to the method would be omitting photographs of kangaroos for identification as photographs of kangaroos often did not contribute to identifying individuals and most kangaroos were too far away to be photographed.

6 Conclusion and Recommendations

6.1 Status of *Macropus fuliginosus* in Yellagonga Regional Park

There are two large populations of *M. fuliginosus* in Yellagonga Regional Park. Populations are expected to gradually increase due to low rates of mortality, if levels of disturbance to populations remain low. However, increasing developments around Yellagonga Regional Park and proposed development within the Park will increase disturbance to populations and numbers may decline as a result. To monitor population trends and to determine whether increased urbanisation and disturbance will negatively affect *M. fuliginosus*, further surveys need to be conducted at least every 5 years to ensure that populations are stable.

6.2 Management

A low-level of management may be required for *M. fuliginosus* to maintain viable populations in Yellagonga Regional Park. To conserve the species in the Park, CALM may wish to consider the recommendations to decrease kangaroo density, reduce some forms of human recreation in certain areas of the Park and limit the number of developments in the Park.

Current densities of *M. fuliginosus* in the Park are higher than those reported in other locations. In the southwest forests of WA, densities of *M. fuliginosus* have been estimated at 0.0086/ha (Short et al., 1983). It is difficult to suggest a suitable density for *M. fuliginosus* in the Park as many of the animals move in and out of Yellagonga Regional Park to surrounding areas. However, it is this author's belief that kangaroos should be maintained at a lower density in the Park, as high densities of *M. fuliginosus* will eventually create a problem. Increased grazing pressure and a reduction in the regeneration of native plants may result and the decrease in understorey cover will expose smaller native mammals to increased levels of predation. Kangaroos may also move into residential areas to graze and higher mortality on roads adjacent the Park may occur.

To prevent populations from increasing to higher densities, CALM should consider taking the following actions. Artificial feeding of kangaroos by visitors to Neil Hawkins Park may need to be stopped as artificial feeding gives kangaroos a perception of higher availability of food that will result in increased breeding (Lambert, pers. comm.). Revegetation of sections of site 4 may need to be considered as kangaroo densities are found to be higher in cleared areas with abundant pasture (Short & Bayliss, 1982; Coulson, 1990b; Pople & Grigg, 1999; Calaby & Grigg, 1989). CALM should also consider not limiting the movement of kangaroos within the Park and migration into and out of the Park by the erection of fencing or other barriers. This suggestion is more difficult to control due to increased development of areas surrounding Yellagonga Regional Park. However, installation of kangaroo gates in fencing and creating wildlife crossings may facilitate kangaroo movements in and out of the Park.

Consideration should be given to reducing levels of human activity, especially dog walking, along the northwest of Lake Joondalup where high densities of *M. fuliginosus* occur. CALM could encourage people bringing their dogs to the Park to walk their dogs on leashes or adopt the suggestion by Bamford & Bamford, (1990) to exclude dogs from certain areas. The exclusion of dogs may be applied in conservation areas and areas where high densities of kangaroos occur.

The urban growth around Yellagonga Regional Park will place greater pressures on Park use. A number of developments have been proposed in the Yellagonga Regional Park Draft Management Plan 2000-10 in preparation for the increased demand to Park use. Most of the proposed developments in the report may not have implications for the conservation of *M. fuliginosus*, if developments are restricted in conservation and protection areas and in areas where kangaroos occur. However, three proposed developments may disrupt *M. fuliginosus* movements within the Park, their movement to adjacent areas of the Park and create a greater disturbance to populations. The proposed developments are the dual access pathway, a botanic garden incorporated with a tourist centre at Duffy Terrace and commercial visitor service building(s) in Lot 1.

CALM may wish to consider modifying the placement of the dual access pathway. Some sections of the proposed pathway along the west of Lake Joondalup may disrupt movements of kangaroos to areas adjacent the Park and narrow the corridor for

movement, exposing kangaroos to higher levels of human disturbance. A section of the pathway adjacent to Duffy Terrace may also need to be modified as it leads people into an area where kangaroo activities are high during the day.

Careful consideration may need to be given to the proposed developments at Duffy Terrace and in Lot 1. These developments may create disruptions to movements and increase disturbance in areas where *M. fuliginosus* occur, especially during construction of the buildings. Planning of the building's exterior landscape may also need to be considered as lawns and other vegetation may attract kangaroos to graze on the plants on display and provide an alternative food source that could result in increased population growth.

Other recommendations that may assist the conservation of *M. fuliginosus* in the Park could also be considered by CALM. Disturbance to *M. fuliginosus* habitats may need to be kept at a minimum level. Predation of kangaroos by foxes was not considered a significant factor limiting population growth. However, foxes are considered to limit the population size of smaller animals and high fox densities have been shown to be a significant predator of juveniles of the large macropods. Foxes may need to be controlled in future to conserve kangaroos and other small native animals in the Park. *Macropus fuliginosus* population trends should be monitored closely if fox control is implemented as foxes may have a minor involvement in regulating population size. Finally, there is a need for further studies on *M. fuliginosus* in the Park. These may involve determining the night ranges of the species; assessing how developments within and around the Park will impact on the Park's populations; conducting a diet study of *M. fuliginosus* in the Park and a detailed floristic study of understorey vegetation; and studying the movements of mobile individuals to the Park and determining their locations outside the Park.

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Appendix 1

Samples of Survey Sheets

Animal Information Sheet

Number 73

Sex ♀ If ♀, Breeding status Py

Developmental class Adult

Build/Size Slim build / med. size

Facial markings/features white mark on forehead

Coat colour light brown - brown, hint of red

Other distinguishing features fine black hairs on snout, large Py
black spot on right cheek under eye, fine grey hairs on
ears

