

Chapter 1

Introduction

The popular perception of Australia's vast spinifex (*Triodia* spp.) deserts is that they are uniformly dry and hot, and that ecological processes within them are slow and primarily driven by intermittent rainfall events. In many respects, this view is a misconception, as past scientific research has found that fire too can play a major and dynamic role in the population processes that occur within these ecosystems (Burbidge 1943; Noble 1982; Suijddorp 1967). This thesis is concerned with better understanding how fire regimes affect vegetation processes in spinifex deserts, by examining the effects of fire season, interval and severity on plant recruitment and resprouting dynamics. In this first chapter I present the rationale for undertaking the thesis, along with a brief description of the ecology of the spinifex grasslands and a literature review of the effects of fire regimes on arid Australian vegetation. I conclude the chapter by outlining the structure of the thesis, together with an overview of the investigative approaches I used in each chapter.

Recent conflagrations in the spinifex grasslands

Between 2000 and 2002, central Australia experienced the largest fire season in three decades. Over 70% of the Northern Territory was burned, as well as large proportions of Western Australia and South Australia. The majority of these fires occurred in spinifex desert country in Aboriginal freehold lands, although a significant portion also occurred on pastoral lands (Allan, Phillips *et al.* 2003). Whilst the spatial extent of these fires has been coarsely mapped, there is still much uncertainty regarding the predominant season and interval in which they occurred, and there are questions regarding other fine-scale aspects such as proportions of fire sensitive vegetation types that were burned. There are also fears that these wildfires have had negative effects on the vegetation and fauna communities within the grasslands. However, as will become evident in the literature review later in this chapter, we know very little of the effects that fire regimes have on these systems.

The 2000-02 fire event offered a window of opportunity to observe, at first hand, the effects of large scale fires and to perhaps determine whether these fires had been as catastrophic as was believed. The central aim of this thesis is, therefore, to improve our

understanding of how fires in general affect the vegetation dynamics of the spinifex grasslands.

Spinifex and the spinifex grasslands

Spinifex grasslands are fire-prone ecosystems occupying approximately 22% of the Australian landmass (see Fig 1.1). They are distributed primarily across the country's arid

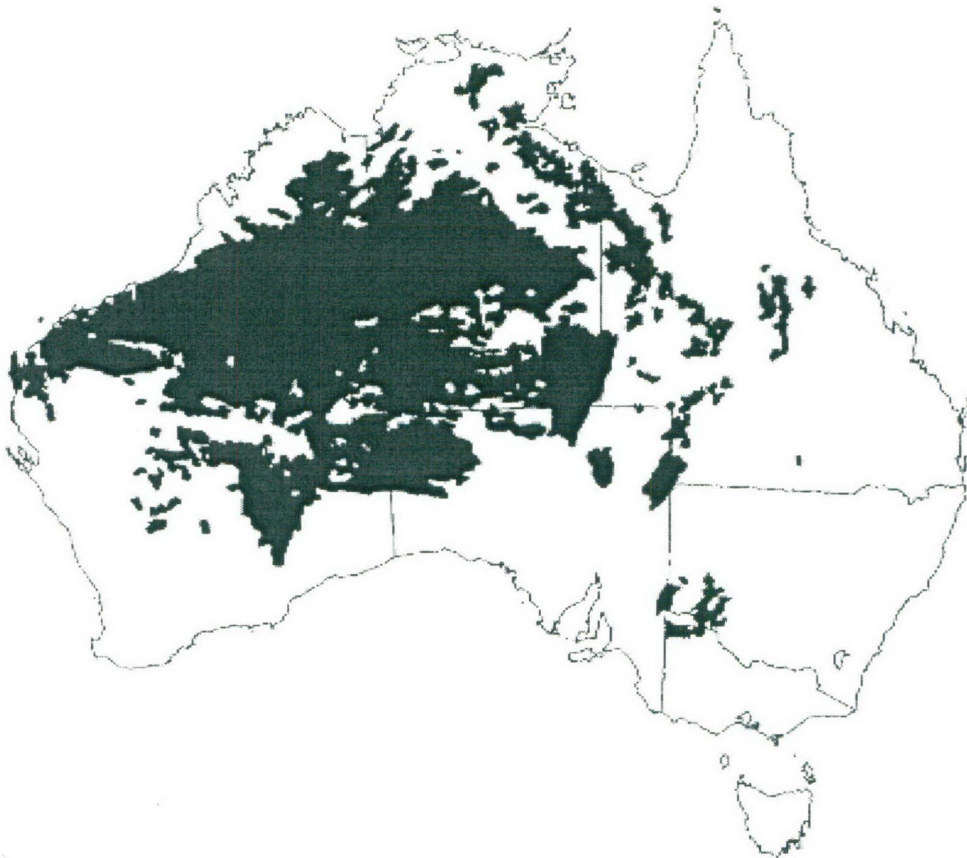


Fig. 1.1 The distribution of spinifex grasslands in Australia (adapted from Allan and Southgate, 2001).

and semi-arid inland regions and are dominated by species of the genera *Triodia* (which now encompasses the genus *Plectrachne*), *Symplectrachne* and *Monodia* (Jacobs 1992). These grasslands occur in areas with mean annual rainfall of c. 200 to 300 mm per year (Beadle 1981), and are generally found on deep siliceous sands in sandplains and dunefields, or on skeletal soils in range and hill country (Allan and Southgate 2001;

Griffin 1990; Jacobs 1982). Spinifex grasses have a characteristic hemispherical growth form, known as a hummock, that in older plants may senesce in the centre, resulting in the formation of rings. Their leaves are highly sclerophyllous and in many species a highly flammable resin is produced on the leaves (Rice and Westoby 1999). The various species may be characterised as either 'hard' or 'soft', based on how rigid or pungent the leaves are, and on how much resin is produced by the leaves (Allan and Southgate 2001; Burbidge 1953).

The most extensive spinifex-dominated systems occur in Australia's arid sandplains and dunefields (see Fig. 1.2). These areas are generally dominated by a single



Fig. 1.2 Recently burned spinifex grassland – with *Triodia* seedlings and various ephemeral herb and grass species in the understorey, and resprouting Honey Grevillea (*Grevillea juncifolia*) and Desert Oak (*Allocasuarina decaisneana*) in the overstorey.

species of spinifex, although it is not uncommon for two or more species to grow in conjunction with each other (Griffin 1990; Winkworth 1967). Griffin (1990) described the three most extensive spinifex alliances in central Australia: the *Triodia pungens* alliance, the *Triodia basedowii* alliance and the *Triodia schinzii* alliance. He found that the distribution of these alliances was most strongly correlated with mean annual rainfall, but that the distributions could also be linked to the levels of certain nutrients, as well as topographic position and relative depth of the watertable.

The Haasts Bluff study area

History

The study area for this thesis was located primarily within the extensive stretches of spinifex desert in the Haasts Bluff Aboriginal Reserve, west of Alice Springs, Northern Territory (see Fig. 1.3). The Haasts Bluff Aboriginal Reserve was originally proclaimed as a reserve in 1920 as part of the Northern Territory's South West Reserve (Long 1989). This reserve was created to allow tribal Aboriginal peoples living in the area the opportunity to continue their nomadic way of life, with as little intrusion from European society as possible. The people who inhabited these lands at the time belonged to the Kukatja tribe, who inhabited the central ranges; the Pintupi, who occupied the sand hill country in the west; the Walpri, who lived in the sandplains in the north; and the Pitjantjatjarra, who lived in the sand hill and range country to the south and south-west (R. Larry 2004, pers. comm., 12 May). These tribes were among the last in Australia to have contact with European settlers, and nomadic families still lived in the area until 1984; when a final group walked in to Kiwirrkurra community from the Lake Mackay region of north-east Western Australia.

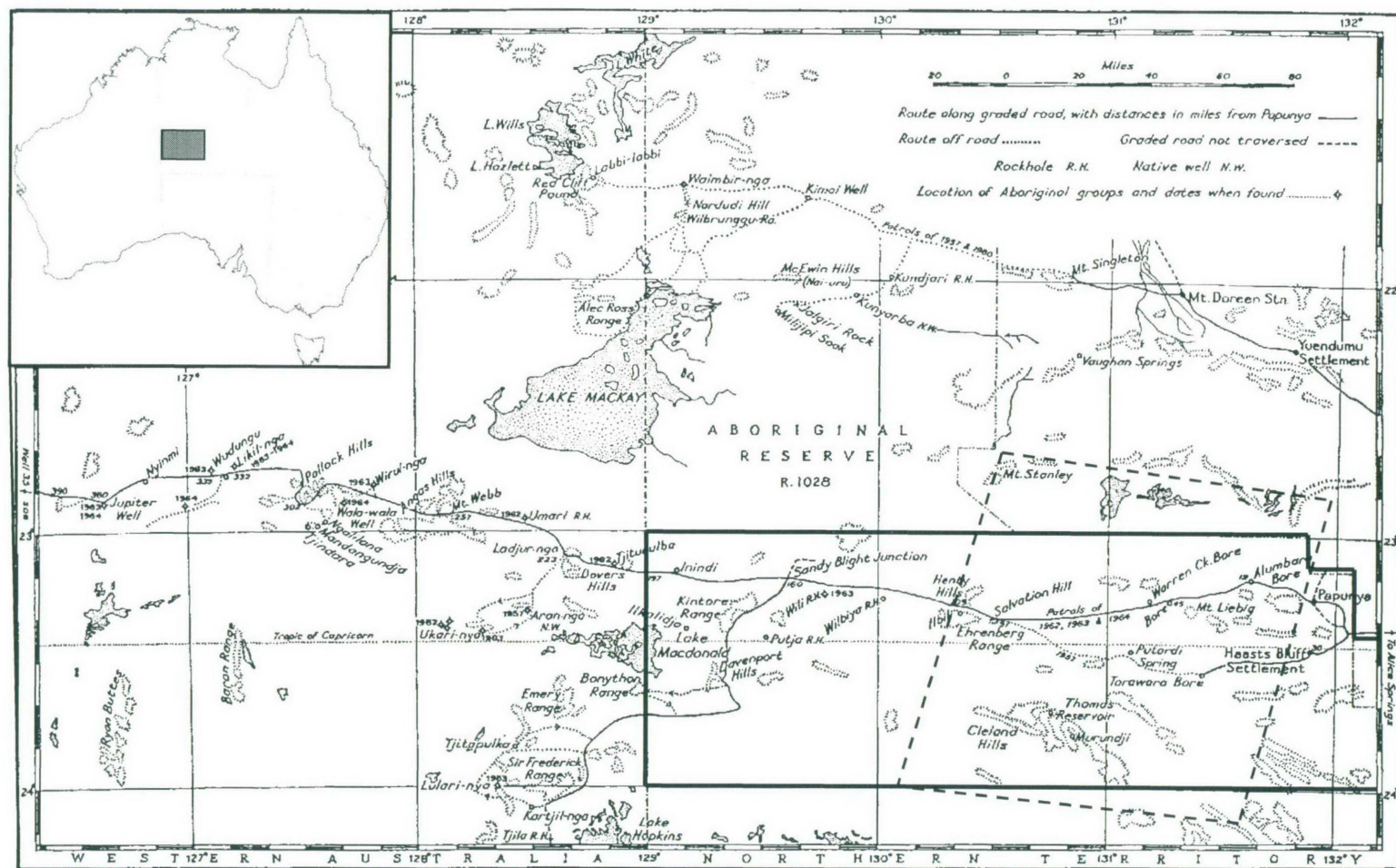


Fig. 1.3 Sketch map of study area in west central Australia (Adapted from Evans and Long (1965)). Bold line indicates border of Haasts Bluff Aboriginal Reserve, dashed line indicates boundary of study area.

In 1940, the northern part of the South West Reserve became classified as the Haasts Bluff Reserve. By this time, the policy of the government had shifted somewhat, and concerns had begun to emerge regarding the influx of 'western' Aboriginal tribes towards the township of Alice Springs (Long 1989). In response to this, and to reports of drought conditions in the west of the reserve, the Haasts Bluff ration depot was established in 1941 at Ngankerritja soak, south of the Haasts Bluff Range. Haasts Bluff was initially controlled by the Finke River mission but in later years came under the direct control of the Northern Territory administration. Throughout its early years, the settlement served primarily to distribute rations to 'settled' families of Aboriginal people and to arriving families still coming in from the bush. In 1976, through the gaining of legal status by the *Aboriginal Land Rights (Northern Territory) Act*, control of the reserve was transferred to Aboriginal peoples (Halcombe 2004). This transference of control led to the commencement of the outstation movement, which saw many of the Aboriginal people living at Haasts Bluff returning to live in their traditional lands in the west in small communities such as Browns Bore and Kintore. Today, the Aboriginal peoples of the Haasts Bluff reserve are dispersed across four settlements: Haasts Bluff (Ikuntji), Papunya (Warumpi), Mt Liebig (Arrmuntungu) and Kintore (Walungurru).

Geography and climate

The geography of the Haasts Bluff reserve is diverse (Perry, Litchfield *et al.* 1962). In the south the reserve is dominated by a complex system of erratically oriented sand dunes, while in the north it is characterised by more regular parallel dunes, which grade into a large flat sandplain in the north east. The soils of both the northern and southern sand dune/plain systems are similar, being composed primarily of deep, red siliceous sands. These soils are nutrient poor, have little horization or development of organic layers, and are relatively free draining (Prescott 1952). Through the centre of the study area, running in an east-west direction, lays the western most extension of the Macdonnell Ranges (see Fig. 1.4). This section of the ranges is comprised of a number of smaller ranges and hills, including, from east to west, the Haasts Bluff Range (Anyarli), the Belt Range (Kunapuli), Mt Crawford (Mungeraka), Mt Liebig (Arrmuntungu), Mt Udor and Mt Liesler (Walungurru).



Fig. 1.4 Mt Crawford (Mungeraka) with mulga (*A. aneura*) shrubland-spinifex grassland mosaics in the foreground.

These ranges and mountains are composed primarily of quartzite and are of Palaeozoic and upper Proterozoic origin. Clay pans, salt lakes and smaller outcrops of sandstone, soft limestone and dolomite also occur sporadically throughout the study area (Perry, Mabbutt *et al.* 1962).

The climate of the region is characterised by high seasonal and diurnal fluctuations in temperature and solar radiation (Gibbs 1969). Temperatures in summer can reach 50⁰ C, while in winter, night-time temperatures regularly reach below freezing point. Rainfall in the region is always unpredictable and droughts are common. Summer thunderstorms contribute up to 70% of annual rainfall, and in Alice Springs, the 100-year mean annual rainfall is 271 mm (Griffin, Price *et al.* 1983). For this PhD project, there were no reliable long-term rainfall stations in the Haasts Bluff study area. Consequently, a broad regional estimate of the rainfall of previous years was arrived at by averaging rainfall data from the neighbouring Derwent, Newhaven and Glen Helen pastoral stations and from the Mereenie gas fields. These locations are situated adjacent to the study area's northern, eastern and south eastern boundaries, and the average of their annual rainfalls

was considered a reliable indicator for general rain that had occurred within the study area.

Fire regimes in the spinifex grasslands

Spinifex grasslands are believed to have experienced two known shifts in fire regime in the past. The first came with the occupation of inland Australia by Aboriginal people, which would have occurred gradually during the Pleistocene (Bowman 1998; Kershaw, Clark *et al.* 2002; O'Connell and Allen 1998; Smith 1989). The second came as the result of European colonisation of inland Australia, which occurred much more rapidly during the past 150 years (Griffin and Friedel 1985; Griffin, Morton *et al.* 1990). Prior to European arrival, Aboriginal peoples living in the spinifex grasslands were perpetually lighting small-scale fires. They did this for numerous reasons, including as a means of promoting the growth of feed for animals such as kangaroos and emus, to promote the growth of food plants, as a means of improving the ease of travel through otherwise overgrown terrain and as a hunting aid (Gould 1971; Kimber 1983). The accounts of early settlers and explorers attest to the Aborigines prodigious use of fire throughout the spinifex lands (Giles 1979; Stuart 1975; Warburton 1875). Giles (1979) commented on the use of fire by Aboriginal tribesman living in the spinifex sand hill country west of Haasts Bluff in the Northern Territory:

...the natives were about, burning, burning, ever burning; one would think they were of the fabled salamander race, and lived on fire instead of water.

This burning regime of the Aboriginal peoples maintained spinifex vegetation in a fine-grained mosaic of different stages of post-fire maturity. It is widely held that this mosaic burning system was crucial for the existence of native mammal fauna, as it provided a broad array of food sources and provided zones of protection against predators (James, Landsberg *et al.* 1995; Morton 1990; Morton, Stafford-Smith *et al.* 1995).

As European settlers encroached on inland regions, a rapid dispersal of Aboriginal people away from tribal lands occurred. These peoples, who formerly occupied vast areas of spinifex desert, were drawn into Christian missions and station homesteads. In some cases they were attracted by the lure of food supplies and permanent water, in others they were forcefully removed from their territories (Bird, Bird *et al.* 2005; Long 1989). One of

the outcomes of this ‘depopulating’ of the spinifex areas was that the grasslands were no longer subject to regular burning. The absence of Aboriginal firing in spinifex grasslands is presumed to have shifted the fire regime toward one that is characterised by infrequent but intense and widespread wildfires. The main documented periods of occurrence of these contemporary wildfires have been during the early 1920s, the mid-1970s, and recently during the early period of the current millennium (Griffin and Friedel 1985). Each of these fire events was preceded by periods of widespread rainfall and it is hypothesised that antecedent rain drives such fire ‘events’ by producing contiguity of fuels which enable flames to spread (Griffin, Price *et al.* 1983).

The biological effects of fire regime on arid Australian vegetation

In this review I will examine literature concerning the effects of the three main elements of fire regime (intensity, season and interval) on the dynamics of the standing vegetation and seed banks in arid Australia. Where literature concerning aspects of fire regime effects in arid Australia is lacking, I refer to literature from more mesic regions of Australia and from arid and semi-arid ecosystems overseas.

Fire intensity and severity

Standing vegetation

Above-ground fire intensity is a direct determinant of mortality among weakly sprouting arid Australian species such as *Acacia aneura* (mulga) and *Aluta maisonneuvei*, with high intensity crown fires routinely consuming most if not all standing fire-killed vegetation (Hodgkinson 1982; van Leeuwen, Start *et al.* 1995). Above-ground intensity also influences the survival of arid plants that resprout from aerial regenerative structures (epicormic resprouters), such as those that occur in species belonging to genera such as *Allocasuarina*, *Brachychiton* and *Hakea*. Levels of aerial intensity during fire are governed by factors such as the topography of the landscape, wind, fuel load and fuel structure (Bond and Van Wilgen 1996; Cheney 1981; Schimmel and Granstrom 1996). The survival of above-ground vegetation is therefore determined by the interaction between these factors and physiological traits such as bark thickness, water status, and the intrinsic resilience of meristematic tissue to heating. Hence the age and size of

individual plants are also strong determinants of recovery under different fire intensities (Hodgkinson 1998; Moreno and Oechel 1991; Wright, Bunting *et al.* 1976).

Fire severity, which refers to the magnitude of soil heating during fire, is an especially important component of fire regime in arid Australian ecosystems, owing to the large proportion of species in these systems that regenerate from underground organs after being burned (Hodgkinson 1982; Maconochie 1982). The post-fire survival of these species is largely determined by the positioning of underground organs in relation to temperature gradients that exist during fire between soil surfaces and lower, more insulated layers. The slopes of these gradients are driven by factors that control the magnitude of the heat pulse entering the soil, such as fuel load, fuel density and the structure of the extant vegetation (Alexander 1982; Bradstock, Auld *et al.* 1992; Preisler, Haase *et al.* 2000). Other important factors include those that relate to the insulating properties of the soil, such as physical structure, mineral composition and percentage soil moisture (Aston and Gill 1976; Valette, Gomendy *et al.* 1994). Other determinants of survival for resprouting species include bud number, lignotuber size and the intrinsic resilience of meristematic tissue to heating (Auld 1990; Bradstock and Myerscough 1988; Canadell, Lloret *et al.* 1991; Cary and Morrison 1995; Flinn and Wein 1977; Morrison 2002; Odion and Davis 2000).

As far as I am aware, studies on the effects of fire intensity on standing vegetation in the Australian arid zone are limited to two: one carried out by CSIRO in the woodlands and mulga-dominated shrub lands of central Australia (Griffin and Friedel 1984), and another carried out by Vesk *et al.* (2004) in the semi-arid shrub lands of western NSW. The CSIRO trials showed that the post-fire mortality of both resprouting and non-resprouting shrubs was significantly higher under higher fire-line intensities (above-ground temperatures). Conversely, the western NSW study found that fire intensity had little effect on species that were classed as either strong or weak resprouters. However, for those species that displayed a variable response, likelihood of survival after high-intensity fire was linked to the depth of resprouting tissue, as well as to morphological characteristics such as stem number, the size of the lignotuber, stem diameter and plant height.

Seed banks

Fire intensity and severity can also influence arid plant population dynamics by interacting with seed dispersal and germination processes (Hodgkinson 1991; Hodgkinson and Oxley 1990; Morrison 2002). For plants that possess canopy-held seed banks, exposure to high levels of fire intensity can be important by helping to trigger the release of seeds from fruits. This sudden release of seed is believed to facilitate the establishment of seedlings by 'satiating' seed predators and allowing a store of seed to accumulate in the soil after fire (Janzen 1971; Wellington 1989). Lower-intensity fires may reduce the recruitment potentialities of such species by reducing the quantity of seed that is released after fire. The characteristic of having canopy-stored seed is known as serotiny, and it is a common trait among genera in the Australian arid zone such as *Eucalyptus*, *Hakea* and *Allocasuarina* (Keith 1996).

Fire severity is an important driver of population dynamics for arid species with soil-stored seed banks, through its interaction with seed germination and mortality processes (Griffin and Friedel 1984; Harrington, Wilson *et al.* 1984; Hodgkinson 1991; Hodgkinson and Oxley 1990). The precise response of soil-borne seed banks to fire is determined by the positioning of seeds along the previously described soil temperature gradient. This spatial relationship between seeds and heat is controlled by factors pertaining to the penetration of heat in soils, such as the spatial arrangement and density of the fuel array, and also by factors that influence the vertical and horizontal distribution of seed, such as overland flow of water, location of seed sources, dispersal syndromes and harvesting by ants (Hodgkinson, Harrington *et al.* 1980; Kemp 1989).

No studies have directly investigated the effects of fire intensity on seed bank dynamics in spinifex communities, although a number of studies relating to other aspects of seed bank dynamics have taken place. Bradstock *et al.* (1992) looked at fuel arrays and their effects on soil heating in mallee shrub lands of western NSW, and Simpson (1999) investigated the spatial distribution of seed banks in relation to fuel in the Tanami Desert. Various studies have also examined the levels of heating required to break dormancies of seeds of spinifex species (Bradstock 1989; Hodgkinson and Oxley 1990; Nano 2005). These studies on seed treatments found that a large proportion of spinifex species require either heat or smoke from fire to induce germination.

Fire season

Standing vegetation

Studies on the effects of fire season on plant survival are limited in the Australian arid zone (Griffin and Friedel 1984; Noble 1989b), however its effects are well recognised in more mesic Australian regions and in semi-arid systems internationally (Bowen and Pate 2004; de Groot and Wein 2004; Lamont, Swanborough *et al.* 2000; Malanson and Trabaud 1988). There are two main hypotheses that explain the variable resprouting responses of plant species subject to fire under different seasons. The first is the ‘ambient temperature’ hypothesis, which predicts that seasonal variation in fuel characteristics and climatic conditions produce higher levels of intensity during summer seasons. This in turn is believed to cause increased levels of plant attrition (Johnson 1992; van Wagner 1973). Overseas studies from savannah ecosystems have generally failed to bear out this hypothesis (Drewa, Platt *et al.* 2002; Olson and Platt 1995), although two studies from mesic Western Australia have demonstrated that increased fire intensity in summer can promote greater initiation of inflorescences in *Stirlingia* and *Xanthorrhoea* species (Bowen and Pate 2004; Lamont, Swanborough *et al.* 2000). These flowering responses are hypothesised to occur because intense summer fires cause deeper damage to the root crown, which in turn elicit greater stimulation of bud foci.

The second hypothesis concerning seasonal fire effects on resprouting is the ‘plant physiology’ hypothesis. Under this hypothesis, growing-season fires elicit higher levels of damage because carbohydrate reserves are largely mobilized into the expansion of above ground stems during these seasons (Matlack, Gibson *et al.* 1993; Wade and Johansen 1986). This hypothesis predicts that repeated growing-season fires deplete stored reserves, eventually resulting in genet death. There is widespread international support for this hypothesis, both from mesic (de Groot and Wein 1999; de Groot and Wein 2004; Malanson and Trabaud 1988) and Mediterranean systems (Drewa, Platt *et al.* 2002; Olson and Platt 1995). There is also support for this hypothesis from studies in mesic Australia (Bowen and Pate 1993; Lamont, Swanborough *et al.* 2000). In semi-arid Australia, researchers have found that the resprouting dynamics of various mallee *Eucalyptus* spp. and *Eremophila* spp. are strongly affected by season (Hodgkinson 1986; Noble 1982). These studies found that mortality rates were significantly higher after fires

that occurred at the end of the growing season, when carbohydrate reserves had largely been depleted.

Post-fire resprouting can also be influenced by interactions with environmental conditions. For example, in French studies of the Mediterranean shrub *Quercus coccifera*, increasing post-fire vigour following spring burns was attributed to plants growing better under conditions of higher ambient air temperatures, longer day lengths and the reduced likelihood of frosts (Malanson and Trabaud 1988). Support for the interactive effects of fire season and growing conditions have also been offered by studies of the resprouting Canadian shrub *Betula glandulosa*. This study found that higher ambient air temperatures during summer promoted increased fire-stimulated growth in *B. glandulosa* (de Groot and Wein 1999; de Groot and Wein 2004). Some studies have also suggested that higher soil temperatures following summer compared to winter burns can promote more rapid and vigorous recovery of burned plant communities (Malanson and Trabaud 1988).

Another important factor for resprouting plants will be the interaction between season of fire and prevailing rainfall patterns. This should be especially so in arid environments where rainfall is inherently unpredictable and patchy. Unfortunately the effect of plant water status on resprouting ability is poorly understood, and I am aware of only two studies that have investigated the matter (Hodgkinson 1992; Riba 1997). In Riba's study, it was found that resprouting of the Mediterranean shrub *Erica arborea* was strongly enhanced by increased water availability. Likewise, in Hodgkinson's study it was concluded that rates of shrub resprouting in a burned poplar box (*Eucalyptus populnea*) woodland were largely determined by the availability of water during the post-fire period. From these two sources, it appears that post-fire rain is an important driver of resprouting dynamics in semi-arid systems, and it seems likely that drought after fire could seriously reduce the ability of woody species to regenerate by vegetative means.

Seed banks

Season of burn is also likely to have an effect on seed bank dynamics in arid ecosystems, as the more intense below-ground heating of summer fires may facilitate greater dormancy release of hard-seeded species that require heat stimulus to induce germination (Auld and Bradstock 1996; Snyman 2005; Tang, Boulter *et al.* 2003; Wills and Read 2002). Trade-offs exist in such situations, however, as higher summer fire intensities may

also elicit increased levels of seed death for shallowly buried seeds (Smith, Loneragan *et al.* 2000).

Seed bank dynamics of arid plants are also likely to be affected by season of fire through interactions with the reproductive phenology of plants. If fires occur whilst a population is in flower or while seeds are immature, seed dispersal into the seed bank may become reduced drastically (Whelan 1995). Season of fire may also influence seed bank dynamics through its interaction with seasonal and annual fluctuations in seed production and seed bank populations (Keeley 1977; Kinloch and Freidel 2005; Williams, Congdon *et al.* 2005). If seasonal peaks in seed abundance are synchronised with the timing of fire, there can be much greater potential for the germination and establishment of increased numbers of seeds. This may be especially so for the many spring-fruited arid *Acacia* species, whose seeds require the heat from fire for dormancy release and normally only establish under post-fire conditions (Letnic, Dickman *et al.* 2000; Nano 2005).

Fire interval

Standing vegetation

Short fire intervals are relatively uncommon in spinifex grasslands owing to the scarcity of rainfall in these regions. In the mallee spinifex communities of western NSW, fire return intervals are estimated to be approximately 19 years (Noble 1993). In central Australia, spinifex communities are predicted to burn after 6300 mm of cumulative rainfall and at intervals ranging from 17-28 years (Allan and Griffin 1986; Gill 2000). In the Tanami Desert and the Pilbara region, which are higher rainfall zones, minimum fire return times range from 8-13 years (Allan and Southgate 2001; Gill 2000).

Despite the generally low frequency of fires in spinifex communities, fire intervals can occasionally be as short as 2–3 years. However, this only happens in the irregular event of high rainfall occurring soon after an initial fire. Such events permit the growth of ephemeral grass species such as *Aristida holathera* and *A. inaequiglumis* and it is these short-lived grasses that are the primary fuel sources in short interval spinifex fires (Latz, 2005, pers.comm. 27 June). *Triodia* spp. are generally only a very minor component of fuels of these short-interval fires, due to their slow growth rates. Also,

because *Aristida* fuels are light and of low density, the temperature intensities of fires fuelled by *Aristida* species are also much lower than fires fuelled by *Triodia* species.

Studies on the effects of fire interval on arid Australian vegetation include Noble's (1989a; 1989b) study at "Birdswood" station in western NSW, and Hodgkinson's (1986) studies from "Coolabah" station, also in western NSW. These studies demonstrated that a wide degree of sensitivity to short fire intervals exists among arid Australian plants. For species such as *mitchelli* and mallee *Eucalyptus* spp., that were regarded as strong resprouters, four annual burns produced low mortality rates of around 20–40%. For species with weak resprouting capacities, such as *Acacia aneura* and *Cassia*, two successive annual burns produced close to 99% mortality.

Mortality of resprouting plants after short fire intervals is commonly attributed to the exhaustion of reserves of non-structural carbohydrates (NSC) (Noble 1982; Vlok and Yeaton 2000). A number of studies have demonstrated this effect experimentally, although these studies imposed extremely high perturbation rates that would not normally occur under natural situations (Cruz, Beatriz *et al.* 2003; Olano, Menges *et al.* 2006). Under natural conditions, the concentration of NSC in plants necessary to recover after fire need only be sufficient to support regrowth until a positive carbon balance is restored. It has been found that these concentrations of NSC are recovered extremely quickly in mesic plant species, with studies from south-western Australia demonstrating that the resprouting shrub *Stirlingia latifolia* can recover pre-fire levels of NSC in as short as 1.5 – 2 years (Bowen and Pate 1993). Exceedingly short fire intervals can also have impacts on the age structure of resprouter populations since resprouting ability is often age- or size-dependent (Hodgkinson 1998).

Seed banks

No studies have directly assessed the impacts of short fire interval on seed banks in the Australian arid zone. In mesic Australia, however, short fire intervals are widely held to have detrimental effects on obligate seeding vegetation (Ashton 1976; Cary and Morrison 1995; Keith 1996; Morrison, Cary *et al.* 1995; Nieuwenhuis 1987). The highest danger for these species is when follow-up fires occur before seedling cohorts have reached reproductive maturity (Bradstock and Myerscough 1988). Such events may cause the death of all standing vegetation as well as the depletion of seed bank reserves. This can

result in localised extinctions, depending on how exhausted soil seed banks have become (Ashton 1976; Bradstock and Myerscough 1988; Keith 1996; Pannel and Myerscough 1993).

Populations of short-lived and ephemeral species are generally resilient to short fire intervals since such plants have usually reached reproductive maturity by the time follow-up fires occur. For these species, shorter fire intervals may actually be preferred. This is because longer fire intervals can enable larger resprouting perennials to appropriate the majority of resources, thereby preventing smaller statured ephemeral species from establishing (Hodgkinson 1998; Lunt and Morgan 1999; Morgan 1998; Morgan 1999).

Fire interval can also interact with seed bank dynamics through its influence on fire intensity. Shorter fire intervals produce less intense fires owing to the lesser time available for fuel to accumulate (Morgan 1998; Smith, Loneragan *et al.* 2000). This may mean that seeds that require heat to break dormancy germinate poorly under short fire intervals due to decreased heat penetration in soils. No studies have investigated the effects of fire interval on seed bank dynamics in spinifex vegetation.

Thesis outline

This thesis examines the effects of the various components of fire regime on the vegetation dynamics of the spinifex flora of the Western Desert of Australia. The paucity of research on fire in this system means that hypotheses regarding the effects of fires on this vegetation type will be largely generated from the knowledge base that this literature review identified from other systems. A brief outline of the structure of the thesis is given below, while specific aims and hypotheses are presented in the introductory sections of each chapter.

In Chapter 2 I take the opportunity that has arisen from the recent central Australian fire event and test the hypothesis that contemporary fire regimes are characterised by large scale wildfires. To do this I construct a fire history map that draws on satellite imagery from 1979–2002. Chapter 3 concerns the physical aspects of fire's impacts on soil temperature regimes, and outlines the results of soil temperature experiments that were carried out using thermocouple temperature sensors. Chapter 4 reports the results of a large-scale field experiment in which the effects of fire interval,

season and time-since-fire on vegetation are investigated. This chapter has been accepted for publication in 'The Australian Journal of Botany'; hence the format for this chapter deviates slightly from that of the remaining thesis. Chapter 5 presents the results of a glasshouse experiment and a seed flotation experiment in which the effects of time-since-fire and fire interval on seed bank dynamics were investigated. The glasshouse experiment also tested the effects of heat and smoke treatments on seed germination processes. Chapter 6 examines mechanisms behind the seasonal effects of fire on seedling recruitment that were observed in Chapter 4. Chapter 6 presents the results of a manipulative field experiment in which the interactive effects of seed predation, germination and deterioration on *Acacia* seed bank populations were investigated. Chapter 7 builds on the soil temperature information of Chapter 3, and tests the effect of fire severity, fire season and fire interval on the resprouting dynamics of four *Acacia* species common in the spinifex grasslands. This chapter has been accepted for publication in 'The International Journal of Wildland Fire'; hence the format for this chapter deviates slightly from that of the remaining thesis. In Chapter 8 I put forward the main conclusions of the thesis and outline how I believe they may be applied in a management context. In this chapter I also offer recommendations for further areas of research.