Creation of conservation reserves and managing fire on granite outcrops – a case study of Chiddarcooping Nature Reserve in the Western Australian wheatbelt

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Abstract

This paper uses Chiddarcooping Nature Reserve, NE of Merredin in the eastern wheatbelt, as a case study to exemplify the history of reserve creation for the conservation of granite outcrop biodiversity, and the subsequent management of fire risks on the reserve. Conservation through reserves has been a pivotal management strategy in Western Australia during the period of agricultural expansion since World War 2. Perceptions of the significance of granite outcrops have varied, from vital importance to a threatening fire risk. After inclusion in pastoral leases from the 1870s, Chiddarcooping reserve was first created in 1926 to protect its locally important water supplies. A conservation purpose was added and the reserve doubled in area to 2610 ha in the 1960s in response to submissions from Forests Department Superintendant GE Brockway and Fisheries Department Fauna Protection Officer HB Shugg, who opposed an application for agricultural selection. The reserve was further enlarged to 5262 ha and made Class A in 1978 and 1983 respectively following additional biological research revealing important rare and relictual plant populations. Ongoing research to the present has reinforced the importance of the biodiversity values of the reserve.

The enlargement of Chiddarcooping Nature Reserve to its present size was opposed by local authority officials in the 1970s, who argued it was a fire risk. Recorded fires occurred on the reserve in 1975, 1978, 1987 and 2000. Bare granite rock provides a natural firebreak. Consequently, granite outcrops provide habitat likely to harbour plant and animal species seeking refuge from fire. A study of plant communities recovering from the 1987 wildfire on Chiddarcooping Nature Reserve confirms this view. Of 79 perennial plant species confined to granite there, 77% were obligate seeders, killed by fire and recovering only through seed germination. This is a high proportion of obligate seeder species, and suggests that caution should be used when contemplating use of fire on outcrops. Raking firebreaks and leaving the topsoil in place for vegetation recovery may be better for conservation than bulldozing permanent firebreaks, access considerations aside. Similarly, burning heaps pushed up following firebreak construction has long-term ecological consequences near granite outcrops, as it may sterilize soil seed banks and set back regeneration for many years. Fire should be avoided or used rarely on granite outcrops if nature conservation is a significant issue for land managers. At present we have little recorded history and much to learn about managing fire on granite outcrops.

Keywords: nature reserve, granite outcrops, fire, management

Introduction

The creation of public reserves with nature conservation values has a long history in Western Australia (Ride 1965, 1974, 1975; Hopper *et al.* 1979), arguably dating back to 1830 when Surveyor General JS Roe rejected applications for private ownership of land on the site of the future Kings Park (Burton Jackson 1982). As a management strategy, conservation through reserves has been pivotal, especially following World War 2 when bulldozing increased the rapidity with which extensive areas could be cleared for agriculture or other purposes. Reservation protected native biodiversity from such land uses.

Although the specific importance of Western Australian granite outcrops for biodiversity conservation has only been documented in recent decades (*e.g.* Main 1967; Withers & Hopper 1997 and papers therein), these landforms have been of significance to Aboriginal, colonial and contemporary people for many reasons. This significance is vital for successful conservation according to Holland and Rawles (cited in O'Neill & Holland 2000), who have recently proposed that 'conservation is ... about negotiating the transition from past to future in such a way as to secure the transfer of maximum significance'.

However, what is significant to some is inconsequential or even threatening to others. For example, native vegetation in summer-dry south-western Australia is susceptible to fire. Conservation reserves are a concern to land managers and others in terms of fire risk. Yet conservation reserves are highly valued for their natural attributes by a broad sector of the community, and destroying them because of fire risk would be unacceptable. Resolving such dilemmas in relation to the conservation of granite outcrops is a complex issue dependant on local circumstances, community decision-making and scientific input. At present we have little recorded history and much to learn about managing fire on granite outcrops.

This paper uses a single nature reserve in the eastern wheatbelt as a case study to exemplify the history of reserve creation for the conservation of granite outcrop biodiversity, and the subsequent investigation of plant responses to fire on the reserve. The study reveals issues that may be applicable and relevant to managing granite outcrop reserves elsewhere in south-western Australia and possibly beyond. Hopefully, the paper will stimulate others to question and investigate a subject deserving much more elaboration than is possible now.

Fire on granite outcrops

Granite outcrops provide natural firebreaks. Vegetation on outcrops is usually fragmented rather than continuous, and often low in stature and biomass. Moreover, pockets of vegetation may be bordered by areas of sheet rock or boulders containing no flammable material. Consequently, granite outcrops provide habitat likely to harbour plant and animal species seeking refuge from fire. Conversely, frequently burnt granite outcrops are likely to be invaded by fire-tolerant species, including weeds (*e.g.* Porembski 2000; Pigott 2000). If this is so, a precautionary management approach would be to minimise the use and impact of fire on granite outcrops, even in terrain and surrounding vegetation that is frequently burnt.

Fire is an environmental disturbance most commonly seen in vegetation that is seasonally dry, either tropical, subtropical or temperate. For example, the five regions of the world that have a mediterranean climate of cold wet winters and hot dry summers experience fire as a regular perturbation – California, Chile, South Africa, the Mediterranean and south-western and South Australia. Of these regions, south-western Australia and California's Sierra Nevada in particular have extensive granite outcrop systems, which are also to be found to a more limited extent in mediterranean South Australia and South Africa. It is appropriate, therefore, that a paper on managing fire is included in the present workshop proceedings.

Recent work by John Hunter and colleagues on the New England Tableland of northern New South Wales has shed considerable light on the fire ecology of granite outcrops in eucalypt forest and woodland (Hunter 1995, 1999; Hunter *et al.* 1998). For example, Hunter (1999) observed that a number of species dominated granite outcrop vegetation immediately after wildfires in north-eastern parts of his study area —, *Acacia adunca* (Mimosaceae), *A. latisepala*, *Actinotus gibbonsii* (Apiaceae), *Bulbostylis densa* (Cyperaceae), *Micrantheum hexandrum* (Euphorbiaceae), *Muehlenbeckia costata* (Polygonaceae), *M. rhyticarya*, *Monotaxis macrophylla* (Euphorbiaceae) and *Pelargonium australe* (Geraniaceae).

Immediately after fire, a number of factors favour fast-growing opportunistic herbaceous species and legumes. Such factors include a nutrient rich ashbed, soil enriched by smoke as a stimulant for germination (Roche *et al.* 1997a,b, 1998), full sunlight at ground level, and the removal or significant inhibition of long-lived woody dominants that normally sequester most light and nutrients in unburnt communities.

Hunter (1999) documented the seed germination characteristics of the herbaceous fast-growing short-lived *Muehlenbeckia costata* and *Monotaxis macrophylla* in the glasshouse, and conducted experimental burns in Bald Rock National Park to examine what stimulates the dramatic post-fire response observed after wildfire. He chose outcrops with no evidence of previous fire, outcrops that had been burnt by wildfire one year previously, and adjacent areas of eucalypt forest. Species present before the experiments were recorded. Then treatments such as clearing all vegetation from around the 2 m x 2 m plots prior to burning, or not so clearing, were undertaken to alter the intensity of the experimental summer fires. Species appearing monthly for a year after the experimental fires were recorded on the burnt plots and adjacent unburnt controls on the long unburnt granite outcrops, on the outcrops burnt by wildfire 12 months previously, and in adjacent forest. Within four months of an October wildfire, individuals of the prostrate herb *Muehlenbeckia costata* had spread 2 m and were flowering. They soon extended up to 5 m, and scrambled up adjacent plants to a height of 4 m. Within two years of germination, most plants had died, the few remaining only with 20 cm long shoots, heavily infested by a rust fungus. *Monotaxis macrophylla* was similarly short-lived and fast-growing. Both species had levels of seed viabilty exceeding 60%, but in the glasshouse germination was poor (6%) for *Muehlenbeckia costata*, and failed to occur for *Monotaxis macrophylla*. In the wild, Hunter (1999) found that granite outcrop vegetation had close to 50% of species killed outright by fire and having to recover solely through seed germination — a group called obligate seeders. The remaining half of species could resprout from underground organs or buds deep within protective bark — resprouters. In contrast, surrounding forest had only 12% of species being obligate seeder species killed by fire. The vast majority (88%) were resprouters.

These differences indicate the importance of granite outcrops as a refuge for fire-sensitive species, a recurrent feature of granite vegetation world-wide. The application of frequent fires to such vegetation may cause the local extinction of fire-sensitive obligate seeders because insufficient time elapses for growth to maturity and establishment of a seed bank. This has been observed on the New England Tableland, where heaths dominated by fire-sensitive outcrop shrubs were reduced by frequent fire to grasslands and sedges dominated by common resprouting species such as *Imperata cylindrica* and *Lomandra longifolia*. Similarly, the conversion of forests and shrublands to grasslands on the granitic islands of Bass Strait through frequent burning is well documented. For example, a tall forest of Tasmanian Blue Gum *Eucalyptus globulus* up to 90 m high once dominated the south-eastern corner of King Island. Soon after settlement in the 1830s, it was converted to open grassland through the use of fire (Chester 1997).

Hunter (1999) made an important observation comparing plant species present before and after three experimental fire treatments on granite outcrops in Bald Rock National Park. He found that responses to the treatments imposed were individualistic and based on the surrounding species pool available at each site (outcrop or forest area) and the initial composition of each plot. These results support the initial floristic composition model, where the initial species composition before a disturbance determines the subsequent composition. This is a surprising result as all sites were within relatively close proximity, being within only a few kilometres of each other and consequently within the same local vegetation community. Clearly, the notion of an orderly succession does not hold in these granite outcrop communities after fire. Life is a lottery, and getting to an outcrop first is as important as any advantage in competitive ability after a fire event.

In south-western Australia the importance of granite outcrops as fire refuges emerged from several studies in the 1980s. Perhaps the most famous case has been the Mount Gardner headland on the peninsula of Two Peoples Bay Nature Reserve, east of Albany, whose *Eucalyptus* and *Agonis* low forest with dense understoreys of shrubs and sedges adjacent to granite provided a last refuge for the critically-endangered Noisy Scrub-bird (*Atrichornis clamosus*; Smith 1985, 1987). A fire frequency of less than 10 years led to a reduction and near extinction of populations of these birds, whereas fire frequencies of the order of every 30 to 50 years were likely to lead to steady population growth. Subsequent fire exclusion has affirmed this hypothesis and led to a spectacular recovery of the species, enabling ongoing translocations to granitic terrain on Mt Manypeaks and elsewhere. The importance of Mt Gardner as a refuge from fire was evident from historical air photography, which showed that the extensive bare granite ridges provided a natural network of firebreaks, which prevented the whole area from being burnt at any one time. This is further borne out by the occurrence of rare plants such as *Banksia verticillata* and the relictual moss *Pleurophascum occidentale* on the granite outcrops of Mt Gardner (Hopper *et al.* 1990; Brown *et al.* 1998). The confinement of many rare plants to granite outcrops throughout the south-west was first documented by Rye & Hopper (1981), and emphasized subsequently by Muir (1985), Hopper *et al.* (1990; 1997) and Brown *et al.* (1998). This trend could be due to fire evasion, but rigorous experiments involving a range of rare species are needed to test such a hypothesis.

Building on an extensive series of studies, Hopkins (1985) argued that recovery of south-western vegetation from fire in the semi-arid wheatbelt and adjacent woodlands takes decades. Kitchener (1976) proposed that the average age of vegetation from some 400 wheatbelt locations was 21 years. Newbey (1985) suggested that no

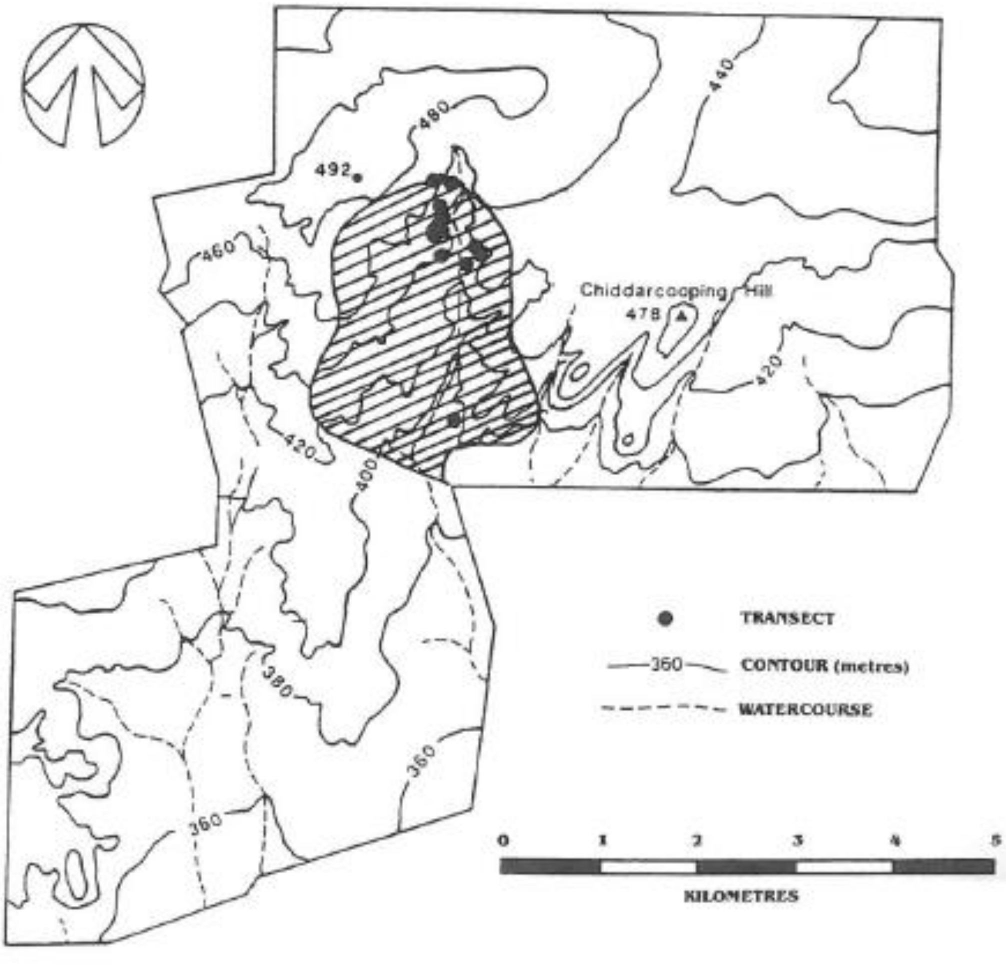

Figure 1. Plan of Chiddarcooping Nature Reserve showing contours, watercourses, transect locations and area consumed by the wildfire of November 1987 (modified from Weston 1985).

evidence of historical fire occurred in granite complex vegetation at the western end of Fitzgerald River National Park, whereas communities such as woodland, dwarf forest, shrub mallee and shrubland all were likely last burnt in the past 40 to 50 years. A wider survey of 300 sites in Fitzgerald River National Park estimated the age of granite outcrop communities including woodlands of *Allocasuarina huegeliana* (Plate 4) and *Acacia lasiocalyx*, as 80 to 100 or more years (Chapman & Newbey 1987).

Weston (1985a) presented historical data suggesting that granite outcrop plant communities on Middle Island in the Recherche Archipelago that were unburnt for possibly 150 years do not lose species, even those opportunists seen only the first year or two after fire, as they are retained in soil seed banks. Storr (1965) found forests 12 to 15 m high of the normally small slow-growing obligate seeders *Callitris preissii* and *Eucalyptus conferruminata* on the granitic Bald Island near Albany, indicating that long periods between fires had preceded his visit. Muir (1985) suggested that the obligate seeder rock sheoak *Allocasuarina huegeliana* (Plate 4) near Quairading may regenerate well in the absence of fire for more than 60 years following the opening of the canopy as old trees die and collapse. Hence, a considerable body of data suggests that granite outcrops might be important refuges for fire-evading species in south-western Australia.

To test the hypothesis that granite outcrops provide refuge for fire-sensitive species, and to develop an understanding of postfire community dynamics in poorly documented mallee and lithic scrub vegetation, I commenced a study on Chiddarcooping Nature Reserve in the Western Australian wheatbelt in 1988. A lightning strike in November 1987 resulted in a significant wildfire that consumed vegetation on granite outcrops in the reserve, and was ultimately contained by a combination of large granite outcrops and a firebreak raked and bulldozed at the time (Fig 1). The bulldozed heaps were subsequently burnt in the spring of 1988 to remove concentrated piles of flammable dead wood and vegetation, as well as to enable future regeneration. This wildfire thus provided an opportunity to examine impacts on and responses of granite outcrop plant communities to fire, as well as regeneration on firebreaks and burnt spoil heaps.

In the present paper, after providing a historical account of the creation of Chiddarcooping Nature Reserve, I summarise early postfire regeneration data from the reserve, and briefly discuss implications for managing fire on granite outcrops. A larger and more detailed analysis of the ongoing post-fire monitoring project will be published elsewhere (C Yates, S Hopper, A Brown & S van Leeuwen, in preparation).

Chiddarcooping Nature Reserve

Chiddarcooping Nature Reserve is located approximately 100 km north-east of Merredin near the eastern margin of the Western Australian wheatbelt (Weston 1985b). It occupies an area of 5262 ha, straddling landforms on the upper slopes of a broad valley trending east-west (Fig 1). There are extensive granite ridges that feed south-flowing ephemeral creeklines within the reserve, as well as lateritic and yellow sandplain uplands overlying granite bedrock towards the northern end of the reserve. The highest point is 492 m, with most of the reserve lying between the 350-450 m contours. The granitoid rock is the most north-easterly occurrence of a medium to coarse-grained seriate granite and adamellite found throughout the south-west on the Yilgarn Block, a craton of ancient Precambrian granitoid rock that has been a continental nucleus for half the age of the earth itself (Chin & Smith 1981).

Annual rainfall is some 300 mm, received mainly in winter, although summer thunderstorms may also deliver significant precipitation. Winters are cool, with occasional frosts, while summer maximum temperatures average 33 °C, with records exceeding 46 °C.

The Kalamaia Aboriginal people

Chiddarcooping Nature Reserve lies within the area occupied by the Kalamaia Aboriginal people, just to the east of the line separating the uncircumcised Nyoongars of the south-west from dry country people who practised circumcision further inland (Maddock 1987). Evidence of Aboriginal occupation is in the reserve. Undoubtedly Chiddarcooping's sources of fresh water and topographic diversity were important, as well as components of its rich biodiversity not found in surrounding woodlands and mallee.

The meaning of Chiddarcooping is not recorded, although 'ing' is widely used in the wheatbelt as a geographical ending, presumably for 'place of' or 'home of', much the same as 'up' is used further south-west (Bindon & Chadwick 1992). The euphonic 'chiddarcoop' is reminiscent of the calls of common nectar-feeding birds such as honeyeaters, which abound at Chiddarcooping (Hopper 1981). The name is also reminiscent of 'chideok', used for 'honeysuckle' (nectar-rich banksias?) by southern wheatbelt Nyoongars, but banksias are not found at Chiddarcooping even though many nectar-rich plants are. The correct meaning of the place name remains a mystery.

European contact and pastoralism

Chiddarcooping Hill was missed by some 20 km by surveyors AC, FT and HC Gregory in August 1846, who traversed country they described as "barren waste" (Maddock 1987) to the north-west and north. Chiddarcooping Hill was included within a pastoral lease first taken up by BD Clarkson in 1874, who set up a hut and sheepyards at Ennuin some 40 km ENE of Chiddarcooping in 1875. A relative of Clarkson, George Lukin, in 1874 drove a mob of sheep from Toodyay to Ennuin in 15 days. In March 1878 Clarkson and Lukin applied to freehold 100 acres around their Ennuin homestead, but their partnership ended by 1880 and Lukin retained the lease, moving his base west from Ennuin to Wilgoyne 20 km NE of the future town of Mukinbudin.

In 1887 Surveyor-General J Forrest introduced new regulations for pastoral leases taken up after that time, applying a 1907 expiry date to ensure the opportunity for more intensive agricultural development. In the winter and spring of 1887, prospectors R Greaves, E Payne and H Anstey, together with an Aboriginal guide from Lukin's Wilgoyne homestead, traversed north-east and

Plate 1. Burnt stand of *Eucalyptus caesia* subsp *magna* resprouting from lignotubers one year after the 1987 wildfire. Other conspicuous resprouters are *Lepdiosperma viscida* and *Xanthorrhoea nana*. Seedlings of *Acacia lasiocalyx* are less than a metre tall. Stephen van Leeuwen and Professor Robert Wyatt in foreground. Chiddarcooping Nature Reserve, November 1988.

Plate 2. Same stand of *Eucalyptus caesia* subsp *magna* three years after the 1987 wildfire. *Acacia lasiocalyx* forms a dense understorey 2-3m tall beneath the resprouting mallees, which flowered within 18 months of the fire. November 1990.

Plate 3. Same stand of *Eucalyptus caesia* subsp. *magna* nine years after the 1987 wildfire. *Acacia lasiocalyx* still forms a dense understorey now 4-5m tall beneath the resprouting mallees. November 1996.

Plate 6. Another site of a bulldozed heap ten years after it was burnt. Note the flaking of surface rock that removed the dark cyanobacterial biofilm and *Grimmia laevigata* moss mats seen in the immediate foreground. Very little recovery of these cryptogams is evident on the spoil heap site. Similarly, the *Borya constricta* herbfield in shallow soil has been sterilized, and shows little sign of recovery. Chiddarcooping Nature Reserve, July 1998

Plate 4. (Left) Two year-old transect 10m x 1m through *Allocasuarina huegeliana* low forest burnt in the 1987 fire. Dr Mark Burgman left and Andrew Brown (obscured). Chiddarcooping Nature Reserve, November 1989.

Plate 5. (Right) Site of transect through bulldozed heap burnt in winter 1988, still with bare sterilized soil nine years after the 1987 wildfire. Normal recovery of the raked firebreak behind is evident. Chiddarcooping Nature Reserve, November 1996.

north from Muckinbudin to Elachbutting Hill and on south-east to Ennuin, where gold was discovered (Maddock 1987). This led to the proclamation of the Yilgarn goldfield in October 1888, with many prospectors passing through the future Mukinbudin area and eastwards to Ennuin thereafter. Because Chiddarcooping Hill lies along this line, it is probable that its plentiful water supplies in winter-spring soon became known and some parties availed themselves of it on the way to the Yilgarn fields.

There are two old stone-lined wells on the nature reserve, indicating water usage by prospectors, sandalwooders and pastoralists in the late 1800s and early 1900s. Moreover, a January 1888 map, prepared by HE Parry after a December 1887 survey, showed three routes to the Yilgarn Hills. One route, suggested by pastoralist Charles Adams of the Mukinbudin district, did indeed run directly east towards Ennuin through Geelakin, just 15 km south-west of and with a clear line of sight to Chiddarcooping Hill. Geelakin was by then leased by George Lukin. The 1888 map had annotated on this route 'This is a road suggested by one of the settlers Mr Adams but there is not any track at present'. Maddock (1987) noted that 'This route through 'Gilakin' later came to be well used enroute to the Golden Valley and Southern Cross'.

In 1888, perhaps after traversing this route, Government Geologist HP Woodward described the country between Mangowine (20 km SW of the future Mukinbudin) and the Yilgarn fields at Ennuin and Golden Valley as 'open', with large alluvial sandy plains in which 'huge masses of intrusive granite stand out in great bold hills' (Maddock 1987).

Official records of Chiddarcooping Hill commenced in a Lands Department lithograph showing areas leased for pastoral purposes at December 31st 1888 (Maddock 1987). The name 'Chiddarcooping' with a 'well' indicated just south-west of it was included on the western boundary of a rectangular lease held by George Lukin. This suggests that Lukin was probably responsible for the two stone-lined wells near Chiddarcooping Hill, and that the Aboriginal name had been adopted by pastoralists in advance of its recording by Government surveyors.

By 1888, Lukin's leases in the Eastern Division totalled 330 000 acres, and he employed a manager Brook Evans to run this vast enterprise. The Chiddarcooping area offered only light grazing around the well-watered granite outcrops, but must have been used often enough to justify construction of the two stone-lined wells. At this time, the Golden Valley mining town south of Ennuin had 314 residents (only 14 were female), two hotels and two stores, providing a significant local market for meat from Lukin's leases.

In 1889, given increasing demand for accurate survey information, 27 year-old mining surveyor HS King was employed on trigonometrical and mining surveys in the Yilgarn. King recorded the aboriginal names for features and localities, as well as details of soil types and vegetation. On March 2nd 1889 he was marking Chiddarcooping Hill as HK54. Geelakin Rock, 15 km to the south-west, was marked subsequently as HK55 (Maddock 1987), so King undoubtedly traversed parts of the present nature reserve. The well within the nature reserve a kilometre or so south-west of the summit of Chiddarcooping Hill was marked as HK64 on another traverse by King. Maddock (1987:12) noted that 'The presence of the high granite rocks must have been a boon to King, for they provided excellent sites from the top of which to take his readings to the next such rock or hill.'

By December 1889, in relation to the eastern wheatbelt, Commissioner for Crown Lands and Surveyor-General JF Forrest wrote that "The greater portion of this division is not likely to be utilised in the near future', due to the lack of rivers. However, Surveyors HS King and C Crossland wrote to Forrest in February 1891 noting that, subject to rainfall, there was a considerable extent of good forest country covered by giant mallee or salmon gum and low scrub, unexcelled in the colony for agriculture (Maddock 1987). Within 20 years Surveyor M Terry was classifying soil types prior to their survey for wheat farms.

By 1893 Lukin was in partnership with George Maddock, running a thriving butchery at Southern Cross. In 1896 Lukin moved to York and Maddock took over his extensive pastoral leases. Sandalwood became an increasingly important local product over the next few decades for Maddock, and the Chiddarcooping area did not escape from rapacious harvest of this aromatic small tree.

In 1901-2 Surveyor Alfred Canning mapped out the No 1 Rabbit Proof Fence in the district from Burracoppin due north (Broomhall 1991). Construction here was subsequently completed by 1904, with the fence passing midway across the 45 km line between Mukinbudin and Chiddarcooping to the east. This saved Chiddarcooping from early attention as a potential farming district. Land near Mukinbudin was made available for agricultural selection in 1910, but the number of settlers was a mere handful until the 1920s. In 1917 the WA Royal Commission on the Agricultural Industry had requested that the Surveyor General FS Brockman draw a line for the northern and eastern limits of wheat growing. His line ran from Burracoppin north-west close to the future townsite of Mukinbudin (Maddock 1987), leaving Chiddarcooping Hill well to the east beyond the intended limit of the wheatbelt.

Chiddarcooping Reserve created

Chiddarcooping reserve was first created in April 1926 for the purpose of "public utility", presumably to protect the wells and water supply for public purposes, but the reserve was not vested for management in any Government authority. At this time it was a quarter of its present size, and included only the south-eastern quadrant of the northern block centred on Chiddarcooping Hill itself (Fig 1). However, Chiddarcooping escaped development as a water catchment. Instead, low stone walls and a large tank for water supply were constructed on Geelakin Rock 15 km to the south-west, which was located closer to the broad valley floor supporting salmon gum and gimlet woodlands favoured by farmers in the district.

Agricultural development was slowed by the Depression and World War 2, but increasing post-war demand led to further land classification surveys, and farms trickled eastwards on suitable land surrounding Chiddarcooping. In 1959, an application from WC, DM and WA Carrod of Mukinbudin to have the reserve released for farming was received by the Under Secretary for Lands, who sought opinions from the Westonia Road Board, the Conservator of Forests and the Under Secretary for Mines in letters dated December 4th (*in litt*, archived files, Department of Land Administration and Department of Conservation and Land Management).

A reply dated December 16th 1959 from the Conservator of Forests, written by Superintendent GE Brockway, noted that Chiddarcooping reserve had negligible forestry value, with only odd patches of wandoo and a few salmon gums, but argued against release for agriculture and for expansion of the size of the reserve to include all the granite outcrop country to the west and north of Chiddarcooping Hill. Brockway put forward four reasons;

1. 'the area is rough and agriculturally unattractive, consisting of some very large massive granite outcrops, large areas of sand much of it with minor granite outcrops, some gravel areas and breakaways,
2. at the time of the (land) classification the rocky areas provided a habitat for some form of rock wallaby,
3. the dense wodgil thickets to the north of the granite rocks provided good protection for mallee fowl, and
4. there are considerable areas of unoccupied land in this locality which appear less unattractive as agricultural propositions but which have not the same suitability for fauna protection.'

Having also received advice from the Under Secretary for Mines who had no objection to Chiddarcooping reserve being made available for selection, on December 23rd the Under Secretary for Lands sought the additional opinion of the Chief Warden of Fauna in the Fisheries Department.

Arguments for a conservation reserve

Superintendent Brockway joined Fauna Protection Officer HB Shugg of the Fisheries Department on an inspection of Chiddarcooping reserve and adjacent land on August 17th 1960. They observed significant flora, with Harry Shugg noting:

'Around the bases of the rocks and in the eroded valleys between them, dense scrub containing acacia, casuarina, melaleuca and calothamnus occurred, while in the areas of deeper soil there were fine specimens of Southern Cross Mallee (*Eucalyptus crucis*) and Gungunnu (*E. caesia*)' (Plates 1, 2, 3). Fauna records included a flock of Major Mitchells, plentiful Singing Honeyeaters, a euro, scats of euro and rabbits, but 'no trace of rock wallabies could be found.'

Superintendent Brockway subsequently wrote to the Chief Warden of Fauna on August 26th advocating the creation of a larger reserve. He noted that

'The rugged inaccessible nature of much of this country, which ensures a large measure of protection to both flora and fauna, coupled with its generally low value for agricultural purposes, makes it well suited for reservation as a flora and fauna reserve… My own view, based on an intimate knowledge gained many years ago as a member of the party which carried out the land classification of this area, plus a recent short refresher examination of it with Mr Shugg, is that the whole area outlined in red should be reserved for the protection of flora and fauna… From the flora angle, I was particularly impressed by several groups of an outstanding strain of Gungunnu (*Eucalyptus caesia*). This is one of the most colourful and popular of our flowering Eucalypts and the colour and size of the blossoms of the Chiddarcooping trees surpass anything I have seen elsewhere – cultivated or otherwise.'

Shugg then penned a pivotal letter for the Chief Warden of Fauna to the Under Secretary for Lands dated September 7th 1960;

'Re Reserve 19210 and adjacent Crown land

Further to our previous correspondence, I am pleased to advise that an inspection of the above area has been made by an officer of this Department and the Superintendant, Forests Department.

I concur completely with the sentiments expressed by Mr Brockway, a copy of whose memo is attached and also of those expressed by the Conservator in his memo to you dated December 16.

I understand that the granite outcrops extend well into location 372 and it would seem most inadvisable to alienate it. Wherever the granite outcrop does occur land cannot be cultivated and is of very little use to agriculture.

I am informed that this must be one of the outstanding areas of its kind and that it might well become an important national park. I strongly recommend therefore that the whole of the area bordered red on the accompanying sketch, including the existing reserve on location 373 be set aside as a reserve for "water and conservation of flora and fauna" and vested in the Fauna Protection Advisory Committee.'

This submission was ultimately successful, with some inbuilt delay because Yilgarn Location 372 to the west of Chiddarcooping reserve was held as a special lease by WC and DM Carrod until December 31st 1969, after which consideration for its addition to the reserve was proposed by the Under Secretary for Lands. In the meantime, on December 7th 1960, Governor Charles Gairdner assented to a doubling of the size of Chiddarcooping reserve to *ca* 2610 ha, adding substantial areas of granite outcrops to the west of Chiddarcooping Hill as far as the east flank of the major north-south creekline (Fig 1), as well as extensive yellow sandplain and lateritic uplands to the north.

This did not stop applications for agricultural use, however. The Under Secretary for Lands wrote to the Chief Warden of Fauna on November 19th 1964 indicating that an application had been received for the portion of Flora and Fauna Reserve 19210 north of the future Morrison Road (location 1428), and asking if there were any objections. A terse reply, penned on November 27th by Shugg on behalf of the Chairman of the Fauna Protection Advisory Committee stated: 'This is an outstanding area not duplicated elsewhere in any other reserve of its type, and I am quite opposed to any part of it being removed from the control of my committee.'

Surrounded by new farms

Incremental land clearance essentially isolated Chiddarcooping Nature Reserve from other areas of native vegetation. By 1968, all of the reserve's eastern boundary and most of the southern block abutted cleared farmland, with similar agricultural landuse rapidly approaching other boundaries. As the number of surrounding farms increased, the issue of access to neighbours and roads through the reserve became important to the local community.

A significant proposal influencing the northern part of the reserve emerged in a letter of April 28th 1972 from the Under Secretary for Lands to the Director of Fisheries and Fauna, requesting views on a proposal from the Shire of Westonia seeking protection of a reserve to extend Morrison Road east-west through the Chiddarcooping Flora and Fauna Reserve. For reasons unclear in archival material, a reply dated July 25th 1972 raised 'no objection ... provided the protected road runs along the southern boundary of location 1428.' Agreement to this roadworks proposal is puzzling given the strength of earlier correspondence protecting the reserve's boundaries and biodiversity values. Perhaps a narrow road reservation was regarded as a relatively small but important concession to local community needs compared with agreeing to applications to alienate larger sectors of the reserve for agriculture.

In any event, some local attitudes to Chiddarcooping became apparent two years later, after the Under Secretary for Lands wrote on December 11th 1973 to the Director of Fisheries and Fauna, requesting consideration for a proposal to reserve for the purpose of the conservation of flora and fauna Yilgarn Location 374 immediately south-west of the then existing Chiddarcooping reserve. Fauna Warden JE Neal from Wongan Hills conducted a field inspection and interviews on the matter late in January 1972. In his report, he noted:

'... interviewed Westonia Shire Clerk Mr D Marsh. ... he seemed perturbed that it was not going to be thrown open for selection. He said that a number of farmers in the area had not been able to expand further and he thought that this would give them the opportunity. He said he thought that there were quite enough reserves in the Shire and considered that block 374 as a Fauna Reserve would constitute a dangerous fire and vermin hazard particularly as it adjoined Chiddarcooping Hill Reserve.'

After reviewing his observations on flora and fauna, and in view of the discussion with the Westonia Shire Clerk, Fauna Warden Neal consequently recommended that

'... 374 would be an invaluable acquisition as a Fauna Reserve. However, its close proximity to the identical Chiddarcooping Hill Reserve, and the fire hazard involved should, I feel, be professionally considered in this instance.'

Chief Research Officer AA Burbidge was subsequently consulted, and supported the recommendation to accept the Under Secretary for Lands' offer of Location 374 as a nature reserve, adding the suggestion that it should be added on to Chiddarcooping Reserve rather than created as a new reserve on its own. This advice was conveyed in a letter to the Under Secretary for Lands dated March 15th 1974, who subsequently decided to enlarge Chiddarcooping accordingly, and also add the substantial granite outcrops west of Chiddarcooping Hill on location 372 now that the special lease held by W C and D M Carrod had expired. However, location 372 was split in two so that only its eastern rocky half (now location 1486) was added to the reserve, while the western half was made available for agricultural selection. Thus, by June 1974, the intention to enlarge Chiddarcooping Nature Reserve to its present size of 5262 ha (Fig. 1) was established, and relevant paperwork prepared. However, formal gazettal did not occur until four years later, on June 16th 1978.

The creation of the reserve occurred in a local context of agricultural expansion into marginal farming country. It was driven by State Government officials with an interest in nature conservation against the wishes of some local community interests. Such a controversial origin is a familiar story associated with the creation of other, but not all, conservation reserves at this time.

Fires and firebreaks

Fires undoubtedly had occurred at Chiddarcooping from the mid-late Tertiary onwards as Australia drifted north from Antarctica and rainforest was replaced by contemporary vegetation (Hopper *et al.* 1996). However, details of past fire regimes have yet to be investigated on the reserve, and recorded fire information is very recent. Government records of fire I have traced became a reality for the newly enlarged Chiddarcooping Nature Reserve on the 11th and 12th of February 1975. A large fire front from farmland to the west approached the northern sector of the west boundary of Chiddarcooping Nature Reserve either side of Morrison Road. Two new firebreaks each about a kilometre long were bulldozed through the reserve ahead of the fire on a north-south alignment off Morrison Road, but the fire stopped short of these as it ran into granite outcrop country and ran out of combustible fuel. On this occasion the fire ignition risk was clearly located on land alienated for agriculture, and the Nature Reserve served to protect other farmland through the extinguishment of the blaze.

In the mid 1970s, the Department of Fisheries and Wildlife successfully applied to Government for an increased allocation to construct new firebreaks on nature reserves in the wheatbelt. Some 1221 km of firebreaks had been constructed or planned up to June 1976 (Burbidge & Evans 1976), including nature reserves containing major granite outcrops such as Boyagin (144 km), Chiddarcooping (60 km), Mt Caroline (6 km), Tutanning (13 km), and Two Peoples Bay (35 km). Chiddarcooping's 60 km were put in place by November 1975, and included coverage of all external boundaries, both sides of Morrison Road, and north-south internal firebreaks bisecting the northern and southern blocks.

The mid 1970s was also the last period when attempts to sequester parts of the nature reserve for agricultural development occurred. On September 27th 1976, the local member of parliament wrote to the Director of Fisheries and Wildlife conveying a request from an adjacent landowner who desired to swap some rocky uncleared land on his property for part of the southern block of Chiddarcooping Nature Reserve. The Director subsequently refused this application in a reply dated January 25th 1977.

Class A status achieved

Detailed biological research on Chiddarcooping Nature Reserve commenced in June 1978, the same month when the present-day boundaries were formally gazetted. Together with Flora Wildlife Officer B Haberley, I, as a recently appointed Flora Conservation Research Officer with the Department of Fisheries and Wildlife, embarked upon a survey of known populations of *Eucalyptus caesia* (Plates 1, 2, 3) in the wheatbelt, visiting and mapping the species on Chiddarcooping during June 8th and 9th. A series of investigations on the conservation biology of this attractive pink-flowered rare mallee ensued, and is still ongoing (Hopper 1981; Hopper *et al.* 1982, 1985; Hopper & Burgman 1983; Moran & Hopper 1983; Rye & Hopper 1982). In 1978 the species was considered both rare and possibly endangered by commercial seed collection, so it was included under the first schedule of flora declared in 1980 as Rare under the Wildlife Conservation Act (Rye & Hopper 1981).

Ongoing work on *Eucalyptus caesia* brought me back to Chiddarcooping in successive years, and I began collecting other plants of interest. For example, the common inland wandoo trees on the reserve and elsewhere were researched in collaboration with CSIRO botanist Ian Brooker, and subsequently named as the new species *Eucalyptus capillosa* subsp *capillosa* (Brooker & Hopper 1991). The first collection of a large white-flowered scale-leaved triggerplant was also made. This was subsequently passed to geneticist Dave Coates for investigation, found to be a new species (Coates & James 1996; Coates 2000), and formally named as *Stylidium chiddarcoopingense* (Lowrie *et al.* 1999).

As part of a general review of the classification of nature reserves, the Senior Clerk Reserves Robert Powell wrote to me on June 9th 1982 seeking advice as to whether a request should be made for Chiddarcooping Nature Reserve to become Class A, which would mean that its purpose or boundaries could only be changed through agreement of both houses of parliament. I prepared an affirmative report based on my field notes and research data. The Department's submission of 22 June 1982 argued "Chiddarcooping Nature Reserve contains 54% (550) of the total number of known wild *Eucalyptus caesia* subspecies *magna* (or "silver princess"), and 26% of the total known wild plants of the species as a whole. It is the only reserve with subspecies *magna* on it other than Billyacatting Hill Nature Reserve, which has only 9 plants. Chiddarcooping Nature Reserve therefore is essential for the conservation of this valuable ornamental eucalypt, gazetted as rare flora." Other values of the reserve were highlighted, including the spectacular granite landscapes, the presence of many granite rock endemic plants and species at the margins of their geographical distribution, an outstanding honeyeater avifauna (Hopper 1981), and the likely presence of other rare plants.

After the Under Secretary for Lands determined that the Under Secretary for Works had no objections, the reserve was reclassified to Class A, its purposes reordered to "conservation of flora and fauna, and water", and vesting assigned to the Western Australian Wildlife Authority on October 11th 1983. It has remained with this classification subsequently, other than vesting presently being with the National Parks and Nature Conservation Authority, and day to day management is now the responsibility of the Department of Conservation and Land Management.

Preliminary biological surveys by Department of Fisheries and Wildlife staff for a proposed management plan were undertaken in 1982. Judith Brown and Andrew Williams collected plants, including the first record of an unusual relictual *Acacia* with terete net-veined phyllodes that was subsequently named as *A. lobulata* (Cowan & Maslin 1990).

Further significant advances in knowledge of Chiddarcooping's flora and vegetation arose when consultant botanist Arthur Weston was contracted by CALM's newly formed Planning Branch to undertake a detailed botanical survey as a baseline document for the proposed management plan. Weston (1985b) made collections and observations on five field trips between September 1984 and February 1985. He presented data in the form of vegetation maps, a species list, and paid special attention to identifying rare, restricted and otherwise significant species and communities. Weston identified 21 rare and geographically restricted plant species on the reserve.

In relation to fire, Weston recommended that 'best short-term fire management policy is to exclude fire until a detailed, well-researched, long-term management plan to preserve habitat, flora and fauna complexity is developed. Development of such a plan requires the accumulation and integration of more information about the reserve than is currently available.' Weston's survey occurred at a time when it had been many decades since fire had swept most of Chiddarcooping Nature Reserve. Within two years this would change for the central valley, and within 15 for the entire northern half of the reserve.

1978, 1987 and 2000 wildfires

Late in 1978 areas on the north-western boundary north and south of Morrison Road, and on the western side of the southern block were burnt by wildfire (Weston 1985b). The lack of fuel on granite outcrops stopped some of this fire front, but a new firebreak trending south-west was cut for the specific purpose of stopping the fire in the north-west sector of the reserve. This was the same area burnt in February 1975. The consequences for biodiversity of such a short interval between fires were unknown.

The November 1987 lightning strike led to much of the main central valley outcrops west of Chiddarcooping Hill being burnt (Fig 1). The ignition point was south-west of Chiddarcooping Hill, and the fire spread west and north-westwards up the main valley before being headed off by a combination of bare rock and a raked and bulldozed firebreak cut specifically across the main creekline and down its east flank to stop the fire (K Wallace, CALM, personal communication).

Most recently, Chiddarcooping Nature Reserve experienced another lightning strike near the southern boundary of the north block on January 7th 2000. An extensive fire then consumed the northern half of the reserve, including all the central granite valley area burnt in 1987. Once out of the granite outcrop country, the fire rapidly continued north into the uncleared private property encompassing Coorancooping Hill (P Roberts, CALM, pers comm). It was stopped by cleared farmland on the boundaries of the nature reserve and adjacent private property to the north, except for the area west of Chiddarcooping Hill where a firebreak was constructed through large granite outcrops and the blaze eventually extinguished. Other new firebreaks were cut into the reserve in the vicinity of Chiddarcooping Hill in attempts (some successful, some not) to head off the blaze.

This wildfire was the first in 25 years to realize farmer's concerns about the Nature Reserve being a source of ignition and risk to their land. However, the fire did not encroach beyond the boundaries of the nature reserve onto farmland, except to the north where uncleared remnant vegetation extended into private property. As with any fire, a range of opinions was considered in trying to secure control. Some suggested running grids of firebreaks through the reserve, but this was resisted by CALM staff concerned for biodiversity as well as for the effectiveness of such an intrusive measure. Some firebreak construction ensued, but the idea of an extensive grid was not adopted.

It is clear that data on the effect of fire regimes on biodiversity would materially assist management decisions relating to wildfire control. Biodiversity is the full range of living organisms and the processes that sustain them. So what is known of Chiddarcooping's biodiversity?

Biodiversity values

Chiddarcooping Nature Reserve has important biodiversity values, containing an unusually diverse array of possibly 600 species of vascular plants (Weston 1985b). As indicated above, a number of these were unnamed until recently, including common dominants such as inland wandoo (*Eucalyptus capillosa* subsp *capillosa* Brooker & Hopper 1991). Chiddarcooping Nature Reserve is the type locality for *Eucalyptus crucis* subsp *lanceolata* (Brooker & Hopper 1982), the relictual and critically endangered Chiddarcooping wattle *Acacia lobulata* (Cowan & Maslin 1990; Brown *et al.* 1998) and the Chiddarcooping endemic *Stylidium chiddarcoopingense* (Lowrie *et al.* 1999). There are several other rare, relictual or biologically interesting plants on the reserve (Weston 1985b).

The main plant communities in the reserve identified by Weston (1985b) are low forests, woodlands, mallee, kwongan shrublands and resurrection and herbaceous communities on granite. Resurrection communities include ferns, mosses, herbs and woody herbs or subshrubs that appear dead when dry but become green after rainfall. Rare communities include mallee stands dominated by *Eucalyptus caesia*, *E. petraea*, *E. stowardii* and *E. erythronema*. Inland wandoo *E. capillosa* subsp *capillosa* woodlands were also uncommon, and one with *Acacia lobulata* as understorey is unique.

Of the 530 plant taxa recorded by Weston (1985b), the largest genera were *Acacia*, with 35 species, *Eucalyptus*, with 19 species, and *Melaleuca*, with about 20 species. Chiddarcooping Nature Reserve is especially rich in plants, exceeded in the wheatbelt only by larger national parks such as Lesueur, Stirling Range, Fitzgerald River and Kalbarri, and by nature reserves at Tutanning, and the Wongan Hills.

Only 19 of the 530 plant taxa recorded by Weston (1985b) are weeds, a remarkably low number for a wheatbelt reserve. All 19 are annuals, and none occupied significant areas. This reflects the large size and relatively low level of disturbance experienced by Chiddarcooping Nature Reserve since the 1870s. Bulldozing an extensive grid of permanent firebreaks, removing the topsoil in the process, may significantly change this situation, opening the way for a much more substantial presence of weeds in the reserve. This has been the case for Kings Park, where excessive unplanned track and firebreak construction has exacerbated the weed problem (Anon 1995).

There have been a few intensive biological studies of plants at Chiddarcooping. Published work on *Eucalyptus caesia* subsp *magna* has already been mentioned (Hopper 1981; Hopper *et al.* 1982, 1985; Hopper & Burgman 1983; Moran & Hopper 1983; Rye & Hopper 1982). Ongoing studies of pollination ecology (Hopper & Wyatt, unpublished) have revealed fresh insights. For example, in the wild at Chiddarcooping, as well as in cultivation, *E. caesia* subsp *magna* has a range of nectar accessability features that are associated with more reliable honeyeater visitation and potentially greater movement among trees by honeyeaters than is seen in subspecies *caesia* at Boyagin Rock. *Magna* has fewer, larger, more widely dispersed flowers on any given day, treble the nectar available per flower per day, with continuous daily production, and daily sugar concentrations that remain low at levels preferred by honeyeaters.

Recent DNA studies of *E. caesia* by Margaret Byrne and Siegy Krauss are helping to resolve the evolutionary sequence of populations. Chiddarcooping's stands of subspecies *magna* may be derived from the nearby Yanneymooning Hill population of subspecies *caesia*, but have a large number of genetic differences in chloroplast DNA, signalling either a long period of independent evolution or very rapid evolutionary divergence.

Coates (2000) and Coates & James (1996) established similar significant genetic divergence of *Stylidium chiddarcoopingense* from its nearest relative *S. nungarinense*. Moreover, the relictual status of *Acacia lobulata* has recently been confirmed using DNA markers by Margaret Byrne and colleagues (CALM, personal communication).

Chiddarcooping's well-watered south-facing slopes flanked by large granite outcrops appear to have been important habitat enabling the persistence of species for very long periods of time during the climatically turbulent late Tertiary and the Pleistocene ice ages (Hopper 1979, 2000; Hopper *et al.* 1996). Harry Shugg's prediction that Chiddarcooping would become an important National Park has been borne out as research on its biodiversity continues.

A comprehensive survey of the fauna, fungi, cryptogams and other biodiversity of Chiddarcooping Nature Reserve has yet to be undertaken. A start was made in the mid 1980s in anticipation of a proposed management plan (S Moore, CALM, personal communication), but this project was deferred in the face of other priorities. Based on discoveries already made on the flowering plants, it is highly probable that the reserve will yield rare, relictual and otherwise significant invertebrates and other organisms when adequately surveyed.

Plant responses to the 1987 fire

The 1987 wildfire consumed a stand of *E. caesia* and presented an opportunity to examine recruitment after fire of this and associated species of granite outcrops. Weston's (1985b) recent survey of the flora and vegetation of Chiddarcooping Nature Reserve provided a useful and thorough benchmark for the prefire plant communities.

A total of eighteen 10 m x 1 m permanently marked transects were established to monitor postfire regeneration (Fig 1). The transects were placed on areas with the densest seedlings of *E. caesia* subsp *magna*, *E. crucis* subsp *lanceolata*, and *E. petraea*, to maximise information on mallee eucalypt recruitment and seedling survivorship, as well as in representative areas of other common granite outcrop species such as *Allocasuarina huegeliana* (Plate 4), *Hakea petiolaris*, *Thryptomene australis* and *Borya constricta*. In addition, some transects were established across the bulldozed and raked northern firebreak and adjacent spring-burnt bulldozed spoil heaps (Plate 5) to track regeneration of plants and compare this with adjacent undisturbed plant communities burnt by the wildfire.

A total of 129 species were recorded in the 18 transects, 28 of which were not listed among the 530 taxa for Chiddarcooping Nature Reserve by Weston (1985b). This represents a 22% increase in taxa recorded for the granite outcrop communities on the reserve. Of the 28 new records, 15 were annuals, 10 were perennial shrubs (including 5 legumes), and three were short-lived postfire opportunists such as *Gyrostemon subnudus*. One legume, *Gompholobium marginatum*, was found to represent a significant inland range extension based on herbarium records. The blue china orchid *Cyanicula ashbyae*, described recently (Hopper & Brown 2000), was recognised as new to science for the first time in 1978 when found at Chiddarcooping. Clearly, fire on wheatbelt granite outcrops reveals hidden and sometimes unexpected biodiversity.

The transect study established the presence of high floristic complexity over short distances, a well known feature of granite outcrop vegetation (Hopper *et al.* 1997). Species richness was highest in the *Borya-Thryptomene* transect (54 taxa, mainly annuals), and lowest in the spring-burnt spoil heap (10 taxa). The most common species found in the 18 transects after wildfire included;

Allocasuarina campestris (16 of the 18 transects)
Acacia lasiocalyx (15)
Gyrostemon subnudus (15)
Calothamnus quadrifidus (14)
Dampiera haemotricha subsp *dura* (14)
Glischrocaryon aureum (14)
Acacia restiacea (13)
Grevillea paniculata (13)
Spartochloa scirpoidea (13)
Billardiera erubescens (12)
Lepidosperma viscida (12)
Thysanotus dichotomus (11)
Vulpia myuros (11)
Melaleuca macronychia (11)
Pentaschistis airoides (11)
Eucalyptus crucis subsp *lanceolata* (10)
Dodonaea viscosa subsp *spathulata* (10).

There are several interesting aspects to this list of common species. Firstly, as documented by Weston (1985b) for the whole reserve, weeds are few (only the two annual grasses *Vulpia myuros* and *Pentaschistis airoides*). Normally, wheatbelt granite outcrop herbfields are replete with weed species, constituting up to 20%+ of all taxa (Ornduff 1987; Ohlemueller 1997). The large size of Chiddarcooping Nature Reserve and the central location of the transects on the reserve may explain its remarkably low weed numbers.

Secondly, only 5 of the 15 most common native species are resprouters capable of regenerating from underground buds off lignotubers or rhizomes (*i.e. Glischrocaryon aureum, Spartochloa scirpoidea, Lepidosperma viscida, Melaleuca macronychia* and *Eucalyptus crucis* subsp *lanceolata*). The majority of species are woody seeders, killed by wildfire and regenerating only from seed stored in the soil or in their canopies.

Indeed, looking at all 129 species found in the transects, 86% are seeders and only 14% are resprouters at Chiddarcooping. Even deleting the 50 annual species and focussing only on the 79 perennials, 77% are still seeders compared with 23% resprouters. This is in marked contrast to many other plant communities in south-western Australia, where the proportions are reversed with around one third of the species are seeders and two thirds resprouters. Some frequently burnt south coastal communities such as at Two Peoples Bay Nature Reserve east of Albany have only 8% seeders and 92% resprouters (AJM Hopkins, CALM, personal communication), while Bell (1985) found 34% seeders and 66% resprouters among 152 species from the Badgingarra-Jurien kwongan. Bennett (1987) found in mallee communities of the Ravensthorpe Range that 42% of species were seeders and 58% resprouters. Hassell (2000) recorded 51% seeders and 49% resprouters among 277 species of mallee and banksia shrublands in the Fitzgerald River National Park. Van der Moezel & Bell (1984) came closer to or exceeded the Chiddarcooping situation in a study of communities north of Esperance, recording between 61-100% seeders and 29-0% resprouters at seven different sites.

The dynamics of Chiddarcooping granite outcrop communities following wildfire show predictable patterns. Greatest species richness is seen in the first year following fire, and declines steadily thereafter (Plates 1, 2, 3). For example, many of the 50 species of annuals in the transects were only seen in the 1988 winter-spring (except for the open *Borya-Thryptomene* community, where annuals persisted over several years). The orchid *Cyanicula ashbyae* (Hopper & Brown 2000) flowered only in that same spring and was not seen in subsequent years, although undoubtedly it was present as underground tubers. *Gyrostemon subnudus* declined from one of the most common species in the first year after fire to a few straggly survivors by the third year.

Resprouters and seeders displayed different seedling recruitment patterns, exemplified by *Eucalyptus crucis* and *Allocasuarina huegeliana* respectively (Fig 2, Plate 4). Even though an average of 10 seedlings per square metre was recorded for the mallee *E. crucis* in 1988, this declined to just one by the next year, and all had died by three years after the 1987 wildfire. Canopy cover for this species' transect developed rapidly from annuals and lignotuberous resprouts over the first two years, then thinned and gradually increased again as leader shoots of *E. crucis* started to dominate. Flowering off resprouting shoots occurred within 18 months for *E. caesia*, and within three years for *E. crucis*.

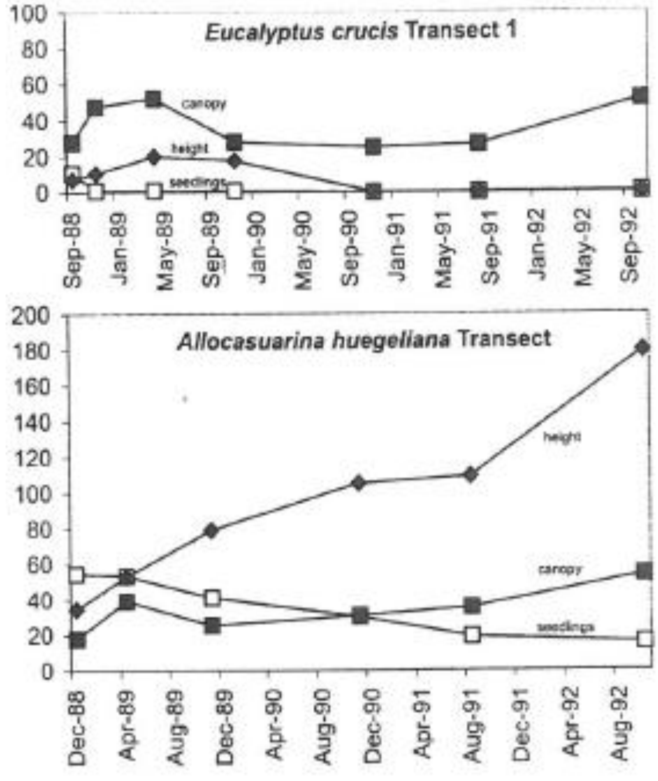

Figure 2. Projected canopy cover, number of seedlings per square metre and mean seedling height in 10m x 1m transects for *Eucalyptus crucis* subsp *lanceolata* and *Allocasuarina huegeliana* in granite outcrop vegetation at Chiddarcooping Nature Reserve following a wildfire in November 1987.

Rock sheoak or Kwowl (*Allocasuarina huegeliana* – Plate 4), in contrast, produced seedling densities approaching a mean of 60 per square metre in the first postfire year, and declined gradually to 20 some four years later. Seedlings had grown to a mean height of 1.8 m by this time, but fruiting had not occurred to any significant extent until 9 years after the fire, and even then, seedlings were averaging only about 3-4 m in height. The need for a considerably longer period of time to elapse before a reasonably sized seed bank develops is evident at Chiddarcooping. Moreover, Muir (1985) showed that *Allocasuarina huegeliana* may successfully regenerate in the absence of fire. It is not essential to burn vegetation for recruitment of this obligate seeder.

In relation to regeneration on the bulldozed spoil heaps and raked firebreak, a striking difference was evident within three years of the 1987 wildfire (Fig 3). The plant community on the firebreak, which had only been raked by a bulldozer as a deliberate policy to leave the soil intact and minimise soil in push heaps (K Wallace, CALM, personal communication), recovered in a comparable if not more vigorous fashion to adjacent undisturbed communities. In contrast, most of the spring-burnt spoil heap showed little or no regeneration. It had been effectively sterilized. This situation prevailed for the next two years (Fig. 2), and, indeed, for at least 9 years after the fire (Plates 5, 6). Similarly, firebreaks bulldozed in 1975 with their topsoil removed show extremely slow rates of recovery when left abandoned. Raking and leaving the topsoil intact on temporary firebreaks is very much a preferred option in terms of achieving rapid recovery of native biodiversity.

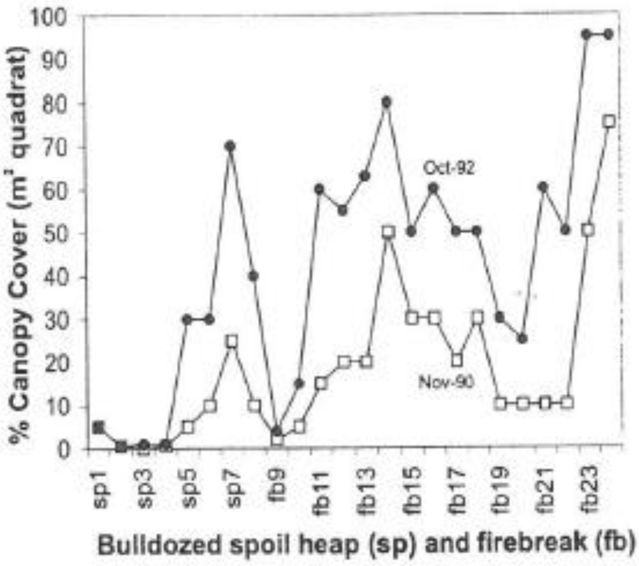

Figure 3. Projected canopy cover in 1m x 1m quadrats in a line transect from a bulldozed spoil heap burnt in spring 1988 across a raked firebreak through granite outcrop vegetation at Chiddarcooping Nature Reserve following a wildfire in November 1987. The prefire vegetation was a dense tamma (*Allocasuarina campestris*) and *Melaleuca uncinata* thicket.

Conclusions

It is important to emphasize that the detailed Chiddarcooping study relates to only one fire event at one location. Generalizing from such a low sample size needs to be treated with caution. What can be said, however, is that the hypothesis that granite outcrops provide refuge for fire-sensitive species is supported – Chiddarcooping granite outcrop communities have a remarkably high proportion of obligate seeder species that are fire-sensitive. Perhaps the refugial opportunities provided by the granite landscapes of Chiddarcooping account for the unusually high number of rare species documented for the reserve. Investigations of the life histories of these species would shed some light on this hypothesis.

Although the study tracking post-fire regeneration has covered barely a decade, it is clear that for some species of obligate seeders, intervals between fires measured in decades are likely to be required to ensure an adequate seed bank is available and local extinction is averted. The more recent wildfire in January 2000, which burnt over communities consumed in the November 1987 fire, provides a good opportunity to test this hypothesis.

For managers, this small study suggests that fire should be used with considerable caution on wheatbelt granite outcrops. Imposing a regime of regular prescribed burning without knowing recovery times for fire sensitive species could pose considerable risk to biodiversity on granite rocks.

Protection from fire seems the best strategy on present information where native vegetation persists on granite. Where firebreaks are intended to be temporary, they should be raked with the topsoil left intact because of the rapid recovery of native vegetation with reduced erosion that follows. Permanent firebreaks, with topsoil removed by bulldozing or grading with a blade are extremely slow to regenerate when no longer required in many communities. Hence their extent and location should be carefully considered.

Burning bulldozed spoil heaps may sterilize soil seed supplies. It would be preferable to spread such heaps over greater areas, and leave them unburnt if this is a practical option, as they provide habitat for fauna and decomposers such as fungi.

On granite outcrops completely denuded of native vegetation, and where the soil remains intact, a fire might stimulate some regeneration of soil-stored native plant seed. However, adequate weed control measures would need to be in place, and fire should not be used on a recurrent basis following the initial attempt at a regeneration burn. Alternatively, smoke dissolved in water could be applied, obviating the need to burn to stimulate germination (Roche *et al.* 1997a, 1997b, 1998). Working cautiously, on small areas, with an experimental approach, is advocated because we have so much to learn about fire and its impact on biodiversity. A wider examination of fire and its management on granite outcrops is needed to rigorously test some of the ideas presented above.

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