Conservation and Management of Privately Owned Remnant Vegetation used for Commercial Flora Harvesting

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Remnant vegetation with verticordias on a farm near Lake King, Western Australia.

Financial assistance for this study was provided by the Australian Nature Conservation Agency under the 'Save the Bush' Program, Agriculture WA, the Water & Rivers Commission and CALM.

The recommendations in this report are based on available research and advice from producers currently in the industry. However no guarrantee is made to anyone following these recommendations. The unpredictabilities of weather and climate attach some risk to any management operation carried out in native remnant vegetation.

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Exports of Australian wildflowers have increased dramatically in the last decade in line with increasing consumption by the European Union, the US and Japan. This rapid increase in demand has stimulated widespread plantings of Australian natives and proteas, but a large proportion of the total production, particularly in W.A. comes from natural vegetation on Crown land and private property.

Increasing concerns about the spread of fungal diseases has led to a ban on the picking from Crown lands of three heavily harvested species. Continuing conservation issues and the vesting of Crown lands for conservation purposes has placed increasing reliance on privately owned bushland to supply the non-plantation part of the market. However, up till now there have been no guidelines about how the harvesting of cut-flowers can be carried out so as to protect the conservation values of farm bushland.

A study has been undertaken to come up with a set of guidelines for some representative cut-flower species from the south-west of Western Australia. Eight of the most heavily harvested species, or species of particular concern, were chosen for this purpose. Current producers of these species (*Agonis* sp., *A. parviceps, Banksia baxteri, B. coccinea, B. hookeriana, Dryandra formosa, Leptocarpus scariosus* and *Verticordia eriocephala*) were interviewed about their management methods. Surveys carried out in managed stands, monitoring and research results were used to arrive at a set of guidelines that would provide advice to current and intending producers. The guidelines will also help government authorities assess proposals to manage privately owned remnant vegetation for cut-flowers.

Over 60 specific recommendations for the sustainable management of farm bushland being harvested for cut-flowers are made in the report. The major management issues including fire, fertilizer, grazing, disease and horticultural operations such as pruning and slashing are covered. In addition, a summary is give of the biology, ecology and distribution of each of the eight species.

Summary of Recommendations

Section 2: *Agonis* sp.(Coarse Ti-tree) and *A. parviceps* (Fine Ti-tree)

1. Bushland being managed for the production of cut-flowers from ti-tree may be burned at no less than 10 year intervals to encourage the germination of nitrogen-fixing species and to "rejuvenate" the ti-tree.
2. The first harvest from ti-tree should be no less than 3 years after slashing or burning.
3. Slashing should be carried out in spring and should be done alternately with burning, i.e. slash after 6 years then burn after another 6 years.
4. Tractor -powered slashing should not be carried out more frequently than once in 10 years.
5. To reduce the risk of soil erosion tractor-powered slashing should not be carried out on steep (> 20%) slopes.
6. Bushland remnants being managed for ti-tree production should be fenced to exclude stock and that they not be grazed.
7. Fertilizer applied to remnant vegetation being managed for ti-tree should be at a rate of no more than 50 kg/ha N and contain less than 3% phosphate.
8. Fertilizer should not be applied more frequently than once each 10 years.
9. Fertilzer should not be applied closer than 50 metres from streams or waterways.
10. Management for the production of ti-tree from remnant vegetation should be carried out so as to minimize the potential for the introduction and spread of disease, e.g. machinery should be washed down before being taken into the remnant.

Section 3: *Banksia baxteri* (Baxteri) and *coccinea* (Coccinea)

1. The minimum interval between fires in remnant vegetation being managed for production of *Banksia baxteri* or *B. coccinea* should be 15 years.
2. The minimum interval between fires should be 20 years for heavily picked areas.
3. That chaining before burning may be used in remnant vegetation being managed for the production of cut-flowers from *B. baxteri* or *B. coccinea* but the interval between chaining and burning should not exceed a few weeks.
4. No fertilizer should be applied to remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* or *B. coccinea*.
5. Harvesting should not be carried out until *Banksia baxteri* plants are 10 years-old and *Banksia coccinea* plants are at least 12 years-old.
6. No more than 20% of blooms should be harvested if the cuts are to be made into old (> 2 y.o.) wood and the plants are less than 15 years old.
7. No more than 30% of blooms should be harvested if the cuts are in young (< 2 y.o.) wood and the plants are greater than 15 years old.
8. A stand should not be picked for a year prior to it being burnt.

9. Effective measures should be taken to protect remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* or *B. coccinea* from the introduction or spread of plant diseases
10. Pre-burn scrub rolling of remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* should take place in early autumn.
11. Remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* or *B. coccinea* should be fenced to exclude livestock and that it not be grazed.
12. Pruning carried out using hygienic methods can be used as a method of increasing production of *Banksia baxteri* blooms as an alternative to burning.
13. That areas of pasture included within fenced-off remnant vegetation containing *Banksia baxteri* or *B. coccinea* be planted with these species.

Section 4: *Banksia hookeriana* (Hookerana)

1 Remnant vegetation being managed for the production of cut-flowers from *Banksia hookeriana* should not be burnt at intervals of less than 15 years. Where picking has occurred this should be 20 years and longer for stressed stands.
2. No harvesting of blooms should occur before the plants are 6 years old.
3. No more than 20% of blooms should be harvested from plants between 6 and 8 years old and on these plants the cuts only be in 1 y.o. wood.
4. No more than 30% of blooms should be harvested from plants over 8 y.o. and that the cuts on these plants be in wood less than 3 years-old.
5. No harvesting should occur for a year prior to an area being burnt.
6. Adequate hygiene measures should be undertaken to protect remnant vegetation being managed for the production of cut-flowers from *B. hookeriana* from plant disease. Among these measures would be the washing down of machines and footwear before it is taken into the bushland.
7. Further research should be carried out into the plantation production of *B. hookeriana* and of methods of establishing it in degraded northern sandplains farmland.

Section 5: *Dryandra formosa* (Formosa)

1. The minimum time between burns in remnant vegetation that is being managed for the production of cut-flowers from *D. formosa* should be 12 years.
2. If the population has been harvested this interfire period should be no less than 15 years.
3. Remnant vegetation being managed for the production of cut-flowers from *D. formosa* should not be fertilized.
4. Plants should not be harvested until they are 6 years old, or have produced at least 5 main lateral flowering stems.
5. No more than 20% of flowering stems should be harvested from plants less than 8 years-old.

6. No more than 30% of flowering stems should be harvested from plants older than 8 years.
7. Harvesting should not occur in area in the flowering season immediately before a prescribed burn.
8. Remnant vegetation being managed for the production of cut-flowers from *D. formosa* should be protected from the introduction or spread of plant diseases by the application of appropriate hygiene measures such as the washing down of machinery, vehicles and footwear before it enters the area.
9. Remnant vegetation being managed for the production of cut-flowers from *D. formosa* should be fenced to exclude livestock and should not be grazed.
10. The many advantages of producing plantation-grown *D. formosa* should be promoted and further research should be carried out into improving strains and horticultural methods.

Section 6: *Leptocarpus scariosus* (Velvet Rush).

1. Remnant vegetation being managed for the production of cut-flowers from *L. scariosus* should have a minimum interval between burns of 15 years.
2. Burning should be done in late autumn after there has been sufficient rain to saturate the soil.
3. Ploughing is not a suitable method of management of remnant vegetation being managed for the production of cut-flowers from *L. scariosus.*
4. Slashing, which should be at least 30 cm above ground, should be carried out at no less than 10 year intervals.
5. No more than 25% of a remnant should be slashed in any one year.
6. No fertilizer should be applied to remnant vegetation being managed for the production of cut-flowers from *L. scariosus.*
7. *L. scariosus* should be cut no less than 30 cm above ground level.
8. There should be a minimum of 4 years between harvests of the same plant.
9. No more than 20% of female plants should be harvested in any one year.
10. Remnant vegetation being managed for the production of cut-flowers from *L. scariosus* should be fenced to exclude livestock and should not be grazed.
11. A knife should be used for harvesting to fascilitate an even cut.
12. Appropriate hygiene measures should be adopted to protect remnant vegetation being managed for the production of cut-flowers from *L. scariosus* from the introduction or spread of plant diseases.
13. Further research into methods of propagating and growing *L. scariosus* should be encouraged.

Section 7: *Verticordia eriocephala* (Cauliflower)

1. Remnant vegetation being managed for the production of cut-flowers from *V. eriocephala* should have an interval of at least 15 years between fires.
2. Chaining or ploughing should not be carried out in remnant vegetation being managed for the production of cut-flowers from *V. eriocephala.*
3. Fertilizers should not be applied to remnant vegetation being managed for the production of cut-flowers from *V. eriocephala.*

4. No more than 20% of plants in any one population of *V. eriocephala* should be harvested in any year.
5. No more than 50% of the stems suitable for picking should be taken from a plant in any year.
6. Harvesting cuts should not take place below the lowest live shoots.
7. Harvesting should not take place in the year before an area is to be burnt.
8. Appropriate protective measures should be undertaken in remnant vegetation being managed for the production of cut-flowers from *V. eriocephala* to prevent the introduction or spread of plant diseases.
9. Remnant vegetation being managed for the production of cut-flowers from *V. eriocephala* should be fenced to exclude livestock and should not be grazed.

Section 1

Introduction

1.1 Background to the project

The Department of Conservation and Land Management (CALM) regulates the flora industry in Western Australia under provisions of the *Wildlife Conservation Act 1950*. Under State policy and federal legislation (covering the export of native flora) the commercial harvesting of native flora must be sustainable both for the species itself and for the ecosystem in which it occurs. To ensure this, there is a requirement for mechanisms to be available for the management of this industry on both private and Crown land.

Controls relating to the conservation of remnant vegetation[1] on private property are exerted by Agriculture W.A., the Water Authority of Western Australia, and by CALM. Under the *Soil and Land Conservation Act 1945* Agriculture W.A. has responsibility for assessment of clearing applications for the effect of the proposed removal of native vegetation on soil conservation. The Water and Rivers Commission (WRC) is concerned with the protection of water quality within designated catchments and may regulate vegetation clearing under the *Country Areas Water Supply Act 1947*. Applications to clear vegetation, or other activities that may threaten vegetation may be referred to the Department of Environment for assessment under the *Environmental Protection Act 1986*. CALM is involved through the W.A. Flora Management Plan prepared for the Australian Nature Conservation Agency and CALM's policies relating to the protection and management of native vegetation.

Some of the techniques used to improve production of flowers, foliage or seeds from remnant vegetation have the potential to adversely affect the nature conservation values of that vegetation, and to contribute to soil and water degradation. So that the nature conservation values of remnant vegetation are not degraded by proposed commercial flora harvesting activities the three authorities (CALM, Agriculture WA, and WRC) propose to develop a joint approach to the issue through the preparation of management guidelines for these areas. The management guidelines would consider the main species and ecosystem types affected and the likely on-site and off-site effects from the proposed treatments. Final approval of the Management Plans would depend on the level of impact on nature, soil and water conservation.

The project reported here was initiated to assemble background information on the distribution, habitat and ecology of eight native species important to the commercial flora industry, and to prepare general management guidelines for these

[1]The phrase **remnant vegetation** as used in this report refers to <u>privately-owned</u> remnant vegetation, publically-owned remnant vegetation will be referred to as national park, conservation reserve etc.

species to assist private landowners in the development of sustainable management practices.

The species studied for this project (with the names used by producers in brackets) were;

Agonis sp., ("coarse ti-tree")
Agonis parviceps, ("fine ti-tree")
Banksia baxteri, ("baxteri")
B. coccinea, ("coccinea")
B. hookeriana, ("hookerana")
Dryandra formosa, ("formosa")
Leptocarpus scariosus ("velvet rush" for female plant, "seeded rush" for male)
Verticordia eriocephala ("cauliflower" or "brownii").

The two *Agonis* species, *D. formosa* and *V. eriocephala* are normally small to medium shrubs (< 2 m). The three *Banksia* species are large shrubs to small trees (2 - 5 m) *and L. scariosus* is a sedge to about 1 m. Their area of distribution covers a large part of the south-west of Western Australia although except for *B. hookeriana* and *V. eriocephala* they are confined to medium to high rainfall areas near the south west and south coasts. The quantities of these species harvested (established from pickers' or growers' returns) for Crown land, private remnant vegetation or plantations in 1994 are given in Table 1.1. The change between 1993 and 1994 in the amount of each species harvested is also shown.

Table 1.1. Approximate numbers of stems or bunches of the eight species considered in this study which were harvested in 1994/95 from three land categories. In brackets after each figure is the percentage change from the previous year.

Species	Crown Land	Private Remnant Vegetation	Plantations
Agonis parviceps (bunches)	194,015 (+19)	207,430 (+45)	12,607 (-17)
Agonis sp. (bunches)	80,072 (-11)	23,895 (-47)	900 (-62)
Banksia baxteri (stems)	0 [a]	812,936 (+0.2)	55,238 (-45)
Banksia coccinea (stems)	0	189,435 (-17)	85,788 (+97)
Banksia hookeriana (stems)	2,647,871 (+87)	294,017 (-1.5)	130,295 (+27)
Dryandra formosa (stems)	390,528 (-32)	81,738 (+241)	15,512 (-82)
Leptocarpus scariosus (bunches)	1477 (-63)	44,404 (+112)	68 [b]
Verticordia eriocephala (bunches)	296 (-99)	5,743 (-88)	1,002 (-84)

[a] Picking of *B. baxteri* from crown land banned in February 1993, 562,450 stems picked in 1992/93. [b] No *L. scariosus* produced in plantations in 1993. Conversion rates from stems to bunches: *Agonis*, 15, *Banksia*, 5, *Dryandra*, 12, *Leptocarpus*, 50, *Verticordia*, 5 stems/bunch

It can be seen from Table 1.1 that for some of the species, particularly *B. hookeriana, D. formosa* and *Agonis* sp., that most production comes from Crown Land. Only the three *Banksia* species and *V. eriocephala* have a large proportion of the total production coming from plantations. Concerns about the spread in native vegetation of 'dieback' disease caused by the root fungus *Phytophthora cinnamomi*, as well as the increasing area of Crown Land being vested for the conservation of wildlife (and therefore unavailable for picking), mean that a greater proportion of the production of all cut-flower species will need to come from private land in the future (Morgan and Fuss, 1994). In addition, because of rapid declines of the health of Crown Land populations, the picking of three species (*B. coccinea*, *B. baxteri*, and *V. eriocephala)* is now banned on Crown Land. Picking of *B. coccinea* was banned in 1991, followed by *B. baxteri* (1993) and *V. eriocephala* (1994). Since the beginning of the 1995 season restrictions have been placed on the picking of *D. formosa* from Crown land because of an apparent decline in the vigour of many stands.

Seasonal climatic conditions have a large effect on production levels, particularly from native vegetation. Market demand, government land managers' decisions, and the industry's perceptions of what these may be in the future and are other important factors. For instance, the large falls in the harvest of *V. eriocephala* across all categories of land (Fig. 1.1) are the result of different causes. For Crown land it was the banning of picking, whereas for remnant vegetation and plantations it was largely due to the very low rainfall in the south-west of the state in 1994.

It is evident from Table 1.1 that for all of these species Crown land or remnant vegetation is very important to the industry. They are likely to remain so for at least the next 8-10 years because this is the approximate lag-time between producers taking the decision to establish plantations and these plantations reaching full productive capacity.

1.2 Methods

Initial information on the distribution and ecology of the eight species in this study was obtained using literature searches, field trips and discussions with researchers. For those species that were not well represented in the W.A. Herbarium database the field trips allowed better mapping of their distribution. The vegetation and soils for some populations were well covered by previous surveys but others required additional information, which was obtained on the field surveys. In order to standardize descriptions of vegetation formations a modified version of the classification of Specht (1981) was adopted (see Appendix 1).

An important part of the project was the gathering of information on management strategies from producers who had been managing areas of remnant vegetation for cut-flowers. At least two producers for each of the eight species were interviewed about their management methods, and an attempt was made to cover the range of distribution of the species with these interviews. At each property information was gathered from the interview and from inspection of the remnant vegetation about the following;

- Vegetation type and soils
- Degree of disturbance
- Use of fire
- General health of population
- Years of production of cut-flowers
- Level of production
- Horticultural practises (pruning, slashing, fertilizers, etc.)

Additional information on the management of four species; *Agonis parviceps*, *Agonis sp.*, *Banksia baxteri* and *Leptocarpus scariosus* was also obtained from a related project "Management of bushstands for cut-flower and foliage production" being carried out by the Albany branch of Agriculture W.A. This project involved the application of various treatments to stands of four of these species located in managed bushland to determine the effects on bloom production of pruning, fertilizers and other treatments.

Detailed information on the effects of bushpicking on plant species richness and cover was obtained by locating a series of transects within areas of remnant vegetation. Three or four transects were located within each area and in adjacent populations of the particular cut-flower species within conservation reserves. A tape measure was stretched about 1.5 m above ground and the percentage of bare ground and number of species on the transect was also determined.

Data on plant health in various populations was obtained by assigning health scores to randomly selected plants and counting the number of dead plants. Several samples were taken from recently dead plants and sent to the CALM Vegetation Health Service for analysis to determine whether the cause was a species of *Phytophthora* root fungus.

1.3 Objectives of the project

The main objectives of this project were;

- to collate and summarize the available information on the distribution and habitat of the eight species,
- to assess the conservation status of the eight species in remnant vegetation being managed for cut-flower production taking into account the effect of management techniques,
- to determine the particular effects of various management techniques on the ecosystem it occurs in and other ecosystems linked to it, and,
- to make recommendations and prepare general management guidelines for the eight species which would will provide producers with guidance on production methods that are sustainable for the species and ecosystem where the species is growing in remnant natural bushland.

1.4 Acknowledgements

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Davy, Mr R., producer, Wellstead
Dick, Mr T, wholesaler, Perth
Gibson, Dr N., CALM, Perth
Lewis, Mr K. and Mrs J., producers, Eneabba
McDonald, Mrs J., producer, Northcliffe
McEvoy, Ms S., CALM, Perth
McMahon, Mr B., producer, Mt Barker
North, Mrs J., producer, Wellstead
Peironi, Mrs M., *Dryandra* Study Group, Perth
Pickles, Mr R., producer, Mt Barker
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Sieler, Ms I., Kings Park Gardens, Perth
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Tonkin, Mr C., producer, Coomberdale
Versluis, Mr R., producer, Walpole
Warne, Mr D. and Mrs S., wholesalers, Denmark
Webb, Mr M., Agriculture W.A., Albany
Wheeler, Dr J., CALM, Perth
Wills, Dr. R., CALM, Perth
Wilson, Mr P., ex producer, Mt Barker

Section 2

Agonis sp. ('coarse ti-tree') and *A. parviceps* Schau. ('fine ti-tree')

2.1 Distribution and climate

Flowering stems of the shrubs *Agonis* sp. (coarse ti-tree) and *A. parviceps* (fine ti-tree) are heavily picked from remnant bushland and State forest along the south-west coast of Western Australia for use as filler material for flower arrangements which include "focal" species such as *Banksia, Dryandra* and *Protea*. A small amount of the harvest is sold as fresh material, but most of it is dried before being packed and sent off to the wholesaler.

The taxonomy of the genus *Agonis* is currently being revised by Dr J. Wheeler of the Western Australian herbarium. In the past many pickers and public land managers assumed that the species being picked by the cut-flower industry along the south coast of Western Australia and the well-known Warren River Cedar (*Agonis juniperina*) were synonymous. It is now realized that not only are the two taxa different in form and response to fire but they are taxonomically sufficiently distinct to be separate species. The species of *Agonis* which is the second most heavily picked after *A. parviceps* is as yet unnamed but Dr Wheeler places it in the *A. juniperina* group. It will be referred to as *Agonis* sp. in this report.

As the name *Agonis juniperina* in the past has been applied to both the tree form (Warren River Cedar) and the *Agonis sp.* picked for commercial purposes herbarium records and botanical surveys up till now which identify a species as *Agonis juniperina* may refer to either of these taxa. However W.A. herbarium records up till 1995 are generally of *A. juniperina* proper judging from the descriptions which give the habit as being a tree from 3 to 10 m tall, and the associated plant species. In addition *Agonis sp.* has probably been mis-identified as *A. parviceps* in some surveys or has been thought to be a cross between *A. parviceps* and *A. juniperina*.

Agonis juniperina proper is not generally picked by the trade primarily because of the inaccessibility of its branches. It is a small to medium-sized tree which regenerates from seed and does not resprout after fire. It is found, generally as a low forest or thicket, along rivers and streams and adjacent to lakes and swamps from Augusta to Albany within about 25 km of the coast. In contrast, *Agonis sp.* is an erect shrub from 1 to 2.4 m tall which resprouts after fire. Its is found from the upper Carbanup River (SE of Busselton) to near Albany (Fig. 2.1) also generally within 25 km of the coast though there is one record from between Williams and Kojonup.

Agonis parviceps has a much wider distribution; it is found over much of the south-west from near Kirup to the Stirling Ranges and Wellstead (Figure 2.2). It has a similar habit to *Agonis sp.* being a resprouting, erect shrub from 1 to 2.4 m tall although it is occasionally found as a small tree to 3.5 m in areas protected from fire.

The climate in the zone where *A. parviceps* and *Agonis sp.* occur is classified by its hydroxeric index as humid to perhumid (Gentilli, 1972). Rainfall varies from about 700 mm in the north-east to 1400 mm in the far south near Walpole and Denmark. The annual rainfall within the main area of distribution of *Agonis sp.* is more than 1000 mm per annum. The agricultural growing season varies from 7 months in the northern part of the range of *A. parviceps* to 10 months in a near-coastal strip between Windy Harbour and Nornalup (Bureau of Meteorology, 1979).

2.2 Habitat and vegetation

2.2.1 *Geology and soils*

On the Blackwood Plateau and Darling Plateau south of a line from Kirup to Mount Barker *A. parviceps* is a widespread understorey species with an almost continuous distribution in jarrah-marri forests and woodlands growing on a range of soils from deep sands to loams (Smith, 1973; Beard, 1979a). It is a common understorey component of woodlands and forests of many of the soil units of the hills and plateau elements of Churchward *et al.*(1988) from the Donnelly River east to the Kalgan River. It is most prominent in the understorey where soils are sandy and seasonally wet (Strehlein, 1988). A podzol of the Keystone Soil Unit typical of the low open jarrah woodland with abundant *A. parviceps* in the understorey is given in Table 2.1.

Table 2.1. Description of a humus podzol of the Keystone unit typical of jarrah woodlands with *Agonis parviceps* prominent in the understorey (Churchward *et al.*, 1988).

0 - 15 cm	black peaty sand (pH 4.6)
15 - 40 cm	very light grey sand
40 - 68 cm	brown ferruginous and organic hardpan
68 - 90 cm	yellow sandy clay
90 -120 cm	mottled heavy clay (pH 5.0)

Agonis sp. is restricted to discrete patches of heathland on poorly drained deep sands formed from Pleistocene colluvium (Wilde and Walker, 1984). There are restricted occurrences of *Agonis sp.* on the Blackwood Plateau but the main range of this species is east of the Donnelly River. From Augusta as far as the Denmark River both *Agonis parviceps* and *Agonis sp.* are found in areas of heathland growing on the deep sandy flats of the Scott River Plain Land System of Tille and Lantzke (1990) and various soil-landscape units also formed from estuarine, lagoonal and lacustrine deposits (Wilde and Walker, 1984) described in detail by Churchward *et al.* (1988).

The soils are generally shallow, usually unconsolidated sandy alluvial sediments overlying granite in various stages of decomposition. Humus podzols are dominant with peaty podzols in less well drained sites. A representative soil description from the Pingerup unit of Churchward *et al.* (1988) is shown in Table 2.2.

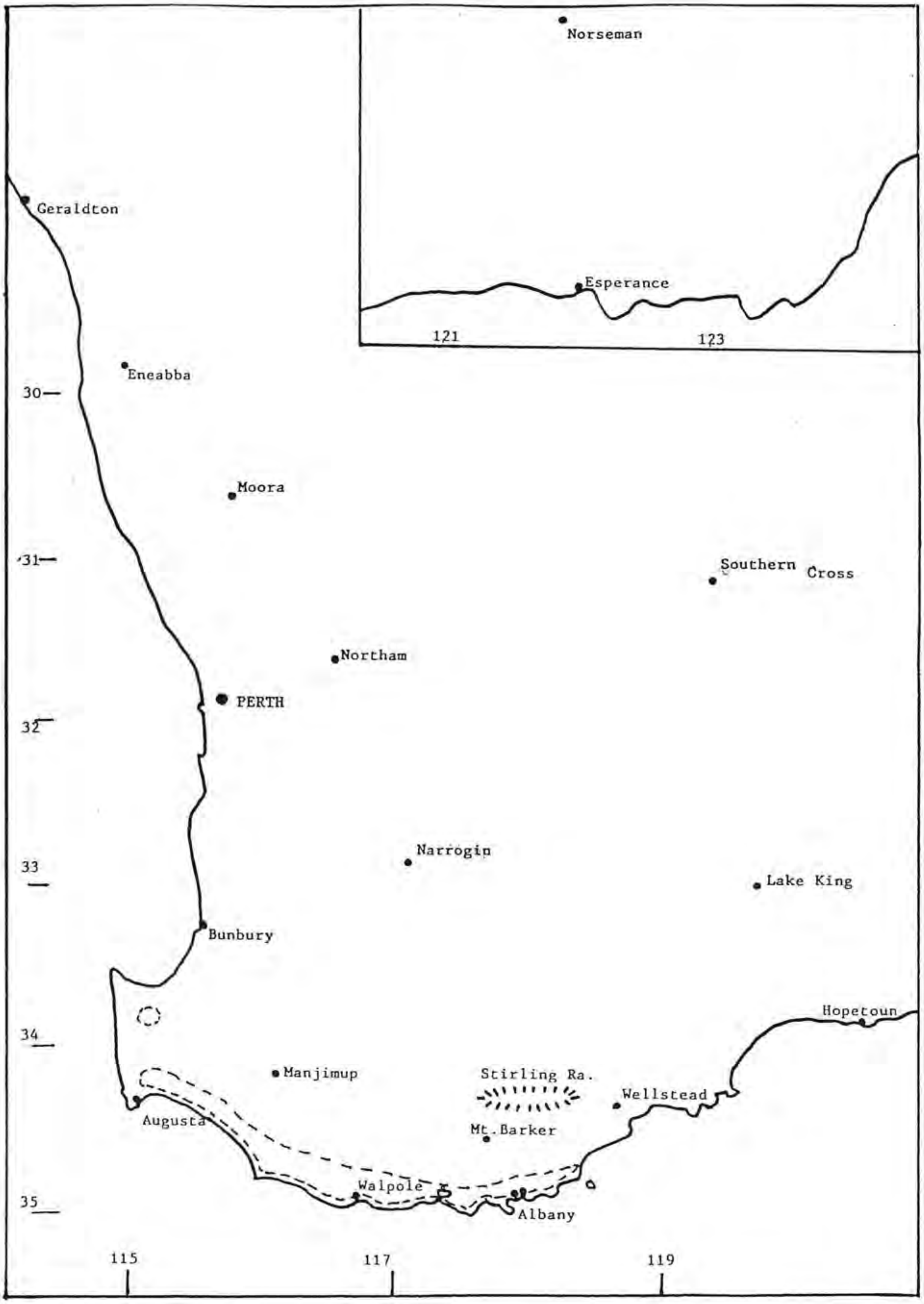

Figure 2.1. Distribution of *Agonis* sp.

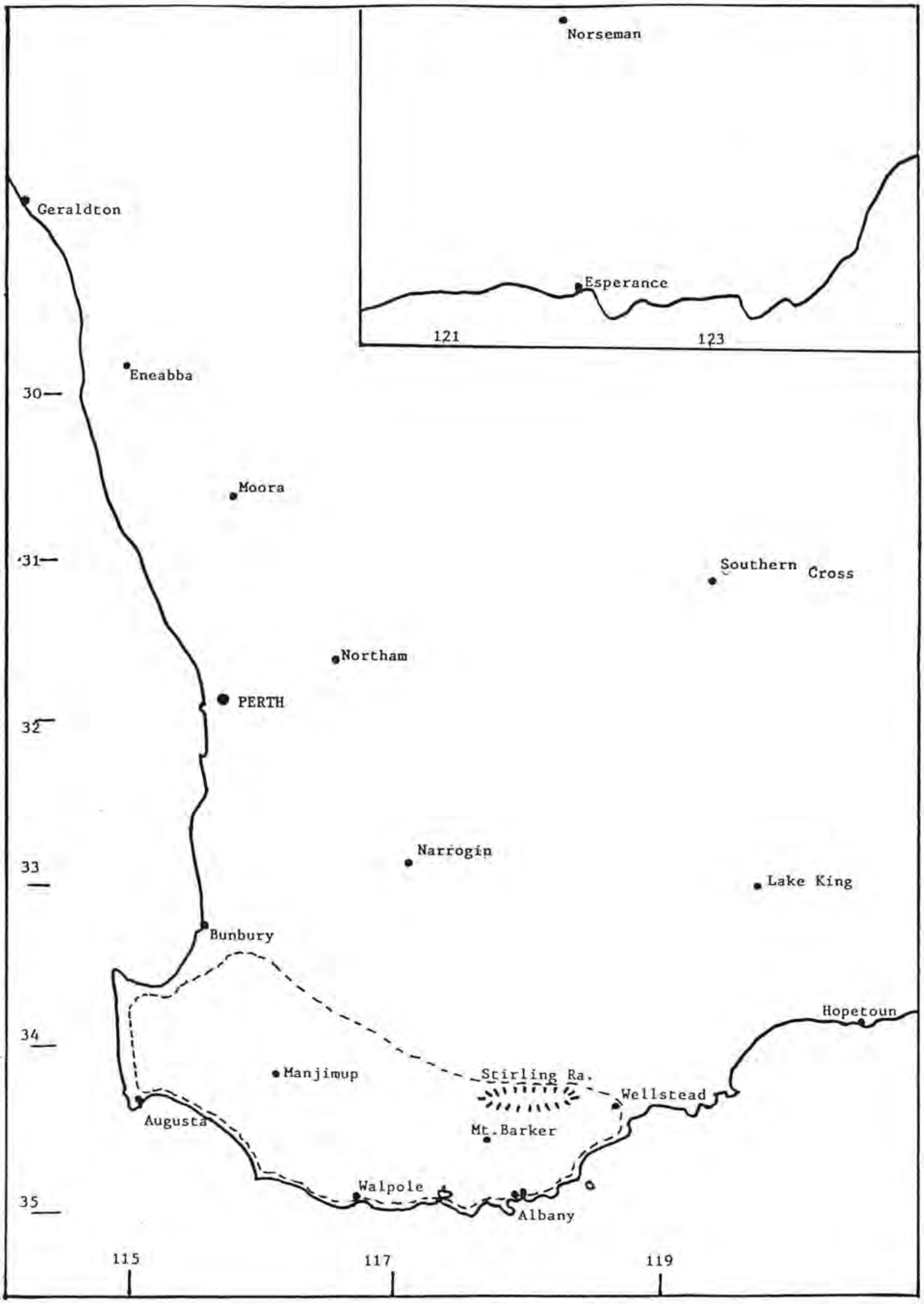

Figure 2.2. Distribution of *Agonis parviceps.*

Table 2.2. Description of humus podzol of the Pingerup Soil Unit (Churchward *et al.*, 1988) on which *Agonis sp.* and *A. parviceps* may be found.	
0 - 5 cm	grey sand
5 - 10 cm	grey sand - light grey mottles
10 - 20 cm	light grey-brown sand - lt grey mottles
20 - 40 cm	greyish-brown sand
40 - 70 cm	dark grey-brown gritty sand (pH 5.1)
70 - 90 cm	dark grey-brown gritty sand
90 -120 cm	grey loamy sand (pH 6.1)
120 cm	water table (hard pan at 150 cm)

Further inland *Agonis sp.* is found on poorly drained yellow solonetzic duplex soils and podzols formed predominately from Tertiary alluvial deposits, sometimes overlying Pallinup Siltstone (Wilde and Walker, 1984; Churchward *et al.* (1988). An example of a Caldyanup soil on Nornalup Road where *Agonis sp.* is a prominent component of heathland is given in Table 2.3.

East of the Denmark River the broad, inland swampy plains formed of Quaternary alluvium become much less extensive, and drainage lines are narrower (Muhling and Brackel, 1985) To the east of the Denmark River the Blackwater unit mostly comprises solonetzic soils with shallow sandy or silty A horizons over clay with very little, if any, *Agonis sp.* or *A. parviceps.* Between the Denmark River and just east of the Kalgan River it is found mainly in narrow bands along water-courses in association with *A. linearifolia*.

Table 2.3. Description of a yellow duplex soil of the Caldyanup unit on which *Agonis sp.* occurs (Churchward *et al.*, 1988).	
0 - 5 cm	dark grey sandy loam (pH 5.0)
5 - 10 cm	dark grey-brown loamy sand
10 - 25 cm	light grey-brown fine sand
25 - 60 cm	very light grey-brown fine sand (pH 5.4)
60 -100 cm	grey-brown fine sandy clay (pH 5.7)

2.2.2 *Vegetation formations and associated plant species*

On the Blackwood Plateau and along the south coast from Augusta to Walpole *Agonis sp.* is predominantly found within tall closed shrubland (2-3 m), closed heathland (1-2 m) and low heathland (0.5-1.0 m) formations. *Agonis parviceps* is also found within these vegetation formations, although it is more often found at the margins of heathland and in adjacent woodlands and low forest. The dominant species of these heathlands and shrublands are quite constant over this range and are listed in Table 2.4. for the Scott River plain and for a site near Walpole. From the evidence of this and the above mentioned studies, the plant community that *Agonis sp.* is most often found in could be called the *Beaufortia* *sparsa* (Swamp Bottlebrush)-*Homalospermum firmum* heathland association. Species richness may be quite high, the survey by N. Gibson and M. Lyons found 35 to 45 plant species per 100 m^2 plot in *Beaufortia sparsa -Homalospermum firmum* heathlands along the south coast.

The general structure of most of these heathlands is of shrubs 1-2 m tall over sedges 0.5-1 m tall, however areas of low heathland where the shrubs and sedges are below 1 m occur on flats where the water-table remains close to the surface (Plate 2.1). In areas adjacent to drainage lines a tall closed shrubland may occur where shrubs such as *A. linearifolia* (Rosa ti-tree), *Astartea fascicularis* and *Homalospermum firmum* and the sedge *Evandra aristata* exceed 2 m in height. Time since fire as well as edaphic conditions may have an effect on the structure of these formations.

As mentioned above *A. parviceps* is a common component of he understorey of jarrah-marri woodland and forest south-west of a line from Kirup to Albany. It appears to have a wide habitat tolerance but is most often found in situations where the soil is moist but well drained. Within the forest it generally grows up to 2 m in height and it appears that its stature is most dependant on time since fire (Plate 2.2). Plants typically co-occurring with *A. parviceps* in forests and woodlands are shown in Table 2.5 for a site on the Blackwood Plateau east of Margaret River (Smith, 1994) and near Walpole (Strehlein, 1988; Wardell-Johnson *et al.*, 1989).

Plate 2.1. Heathland near Walpole containing *Agonis* sp. (white flowers at right).

Plate 2.2. Jarrah forest north of Walpole with an understorey including *Agonis parviceps*.

Table 2.4. Typical species co-occurring with *Agonis sp.* or *A. parviceps* at heathland sites on the Scott River plain and near Walpole (N. Gibson, CALM Research, Woodvale, pers.comm.).

Scott River	Walpole
Acacia hastulata	*A. linearifolia* (Rosa Ti-tree)
Adenanthos obovatus (Basket Flower)	*Acacia myrtifolia*
Agonis parviceps	*Adenanthos obovatus*
Anarthria prolifera	*Anarthria prolifera*
Andersonia caerulea	*A. scabra*
Astartea fascicularis	*Astartea fascicularis*
Beaufortia sparsa (Swamp Bottlebrush)	*Beaufortia sparsa*
Dasypogon bromeliifolius	*Dasypogon bromeliifolius*
Evandra aristata	*Evandra aristata*
Homalospermum firmum	*Hakea varia*
Leptocarpus scariosus	*Homalospermum firmum*
Leucopogon parviflorus	*Leucopogon capitellatus*
Pericalymma ellipticum	*Psuedoloxocarya grossa*
Restio ustulatus	

Table 2.5. Plant species typically co-occurring with *Agonis parviceps* in woodlands and forests on the Blackwood Plateau and near Walpole (Wardell-Johnson *et al*., 1989).

Blackwood Plateau	Walpole area
Allocasuarina fraserana (Sheoak)	*Acacia browniana*
Andersonia caerulea	*Banksia grandis*
Eriostemon spicatus	*Boronia gracilipes*
Eucalyptus calophylla (Marri)	*Bossiaea webbii*
E. marginata (Jarrah)	*Burchardia umbellata*
Hibbertia hypericoides	*Eucalyptus marginata*
Hypocalymma angustatum (White Myrtle)	*Leucopogon australis*
	Kingia australis
Leucopogon capitellatus	*Macrozamis reidlii*
Melaleuca thymoides	*Pimelia longiflora*
Persoonia longifolia (Snottygobble)	*Persoonia longifolia*
Podocarpus drouynianus (Emu Plum)	*Xanthosia rotundiflora*
Pultanea reticulata	*Xanthorrhoea preissii*
Xylomelum occidentale (Woody Pear)	

2.3 Conservation status in remnant vegetation

2.3.1 *The effects of management on* Agonis sp. *and* A. parviceps

Because *Agonis* sp. and *A. parviceps* often occur together, have similar biology, and in fact hybridize, they will be treated together in this assessment of their conservation status in remnant vegetation. Both species are well represented in conservation reserves and their survival as a species is not threatened. *Agonis* sp. is the more restricted of the two and has a lot narrower ecological niche than *A. parviceps* so it is perhaps the most at risk in remnant vegetation. The flowering season for *Agonis sp.* is from March-June and for *A. parviceps* from September - December. Most private property production of cut-flowers from these two species comes from privately-owned land between Walpole and Albany on the south coast.

The management treatments used to increase the production of the two *Agonis* species include burning and slashing to rejuvenate mature plants, and fertilizing. The observed and possible effects of these treatments, and of harvesting itself, on *A. parviceps* and *Agonis* sp. and their susceptibility to disease (which may be introduced or spread by management techniques) are examined below.

Fire

Being lignotuberous and strong reprouters *A. parviceps* and *Agonis sp.* recover well after burning. The minimum inter-fire period in managed stands is about 5 years and the species appear to be able to withstand fires at this interval. Studies of the recovery after fire of resprouting shrubs have shown that pre-fire root starch levels (which was the major determinant of resprouting ability) are attained about 2 years after fire (Miyanishi and Kellman, 1986; Bowen and Pate, 1993).

However, burning is not a favoured treatment because it leads to the germination of a prickly *Acacia* (Wattle) species (*A. hastulata*), which interferes with picking, and of *Cassytha* (Dodder Laurel), a twining plant which wraps itself around the *Agonis* stems and renders them useless to the cut-flower industry. When burning is carried out it is generally done in early winter (sometimes late winter) to minimize possible damage to the plant rootstock. Lower fuel moisture levels in autumn produce higher fire intensities and drier soils allow heat to penetrate further into the soil increasing the risk of damage to lignotubers (Burrows, 1985). Research on the reprouting oak, *Quercus coccifera*, has shown that resprouting is more vigorous following spring burns, either because of the greater reserves following the spring growth flush, or because of the direct effect of warmer temperatures and increasing sunshine (Malanson and Trabaud, 1988).

There is some visual evidence to suggest that remnant vegetation which is burnt after being slashed has greater shoot growth than areas which are slashed only. This could be because of the more rapid release of nutrients caused by the fire and the stimulation of nitrogen fixation by legumes (Christensen and Abbot, 1989). A study of the dynamics of resprouting in the lignotuberous shrub *Banksia oblongifolia* (Zammit, 1988) found that although the speed of resprouting was similar after clipping and fire, the leading shoots grew significantly longer in burnt areas. Therefore not burning vegetation containing ti-tree to prevent the germination of prickly acacias deprives the ecosystem of much needed nitrogen. The application of fertilizers may be a method by which nutrient levels can be raised in areas that are slashed but not burnt but his has drawbacks in regard to the protection of conservation values (see below).

Recommendation: (1). Bushland being managed for the production of cut-flowers from ti-tree may be burned at no less than 10 year intervals to encourage the germination of nitrogen-fixing species and to "rejuvenate" the ti-tree.

Slashing

Slashing, chaining or rolling are used in preference to fire as a method of rejuvenating plants after periods of about 5 years. Slashing is the most commonly used method; the plants are cut, usually in autumn or winter, at 15 - 30 cm above the ground by tractor-mounted slashers (Plates 2.3 & 2.4). This is done to promote vigorous new growth with the long stems (40 - 50 cm) favoured by the wholesalers. However, root starch levels are highest in spring (e.g. Tomkins *et al.*, 1989) and this indicates that this would be the best time to slash considering the dependence of initial sprouting on stored reserves. After slashing the first heavy flowering of *Agonis sp.* is at 2 years and of *A. parviceps* at 3 years. One producer reported that he could get a 'light pick' (modest harvest) from *A. parviceps* 12 months after slashing if fertilizer was applied and if rains were favourable.

No observation of deteriorating plant health was made by farmers slashing on a five year rotation and regrowth was reported to be always vigorous. However, no research has been done into the biology of *Agonis* which would indicate whether cutting most of the above-ground material from plants at intervals of 5 or 6 years would lead to long term decline of those plants. There is a possibility that the vigour of resprouting will decline with plant age as has been reported for the northern hemisphere heathland species *Calluna vulgaris* (Berdowski and Siepel, 1988).

Seedling germination of *Agonis sp.* and *A. parviceps* does occur but is usually not much in evidence and most seedlings are probably 'shaded-out' by resprouting adult plants. It is probable that none of the stands now being managed by slashing has been slashed more than two or three times and it may take some time before any effects of increasing plant age on the level of shoot production, or mortality, will appear.

Fertilizers

Both *Agonis sp.* and *A. parviceps* appear to respond well to the addition of fertilizer; which is usually superphosphate or superphosphate and potash. One possible disadvantage of adding too much fertilizer, in regard to cut-flower production, is the production of vegetative shoots ('tips') above the flowering part of a stem. These shoots are not wanted by the trade and the shoots must be clipped off after harvesting, which increases labour costs. One producer has carried out a trial which looked at the advantage from adding single or combination fertilizers. He concluded from this trial that potassium enhanced flowering and that phosphorus and nitrogen caused too much 'tipping'. No formal research has been published on the effects of the addition of nutrients to *Agonis* species. However, current indications of an uncompleted trail by Agriculture W.A., Albany, is that addition of NPK (15:2.2:16.6) at 200 kg N/ha will significantly increase vegetative growth. There are, however, a number of risks in applying fertilizers to native vegetation and these will be discussed further in the next section.

Harvesting

Varying proportions of above-ground biomass are taken in the process of harvesting stems with the highest proportion being taken from young plants. However, plants are generally not harvested until 3 years after slashing, with the best 'pick' occurring at 4 years and a somewhat smaller one at 5 years after which the quantity of commercial quality stems on a plant is quite low. There were no reports of heavy picking of stems causing a decline in plant vigour so long as the first pick was at 3 years after slashing.

Recommendation: (2). The first harvest from ti-tree should be no less than 3 years after slashing or burning.

Disease

Agonis sp. and *A. parviceps* occur in areas which are favourable to the survival of and dispersal of the fungal pathogen *P. cinnamomi*, which causes "dieback" disease, i.e. on poorly drained, infertile sandy soils (Strelein, 1988). *Agonis* sp. appears not to be susceptible to the root-rot disease caused by the fungus, and *A. parviceps* has variable susceptibility. Some *A. parviceps* may be killed in badly affected sites, but it usually is one of the first species to re-invade affected sites (Dr R. Wills, pers.comm.).

Plate 2.3. Area of heathland near Denmark containing *Agonis* sp. photographed two years after being slashed as part of an Agriculture W.A. trial in April 1993.

Plate 2.4. Area of tall shrubland near Northcliffe containing *Beaufortia sparsa* (red flowers) and *Agonis parviceps* (at front near electric fence) slashed as part of an Agriculture W.A. trial in 1993. Photographed in 1995.

2.3.2 *The effects of management on the ecosystem*

In addition to affecting *Agonis sp.* and *A. parviceps* any management techniques employed by a producer will have some effect on other species within the ecosystem, either directly or indirectly, and possibly on other ecosystems. The various aspects of management for production of cut-flowers from the *Agonis* species will be examined below.

Fire

Within State forest and national parks the plant communities in which *Agonis sp.* and *A. parviceps* are found are burnt on a 6 to about 15 year rotation, with most burns occurring in spring. Under this fire regime the various forest and heathland communities appear to be quite resilient (see review by Christensen and Abbott, 1989). In remnant vegetation on farmland, apart from the fire periodicity, there are a number of external influences associated with the smaller bush areas and surrounding farmland, which may interact with fire to interfere with the normal regeneration process. These may include the effect of increased levels of wind, light, nutrients, water, grazing and the competition provided by weeds to the native species as they regenerate (Hobbs, 1993). The influence of these factors tend to increase as the size of the remnant decreases.

Most of the taxa listed in Tables 2.4 and 2.5 are resprouters and survive 100% scorch, the exceptions being the *Acacia* species, *Boronia gracilipes*, *Pultenaea reticulata, Pimelea longiflora, Leptocarpus scariosus* and *Andersonia caerulea*. The *Acacia* species and the other hard-seeded legumes, which are vital to the ecosystem (because they fix nitrogen), normally would germinate prolifically after a fire, but when fires are too cool or too infrequent they may become locally scarce (Shea *et al.*, 1979). On the other hand the nutrient rich ashbeds produced by fires, especially autumn fires which are soon followed by rain, provide an ideal matrix in which weed seeds may germinate (Bridgewater and Backshall, 1981). These weed species from nearby agricultural land, which are generally fast-growing may out-compete native seedlings leading to a decline in the diversity of remnant vegetation especially in regard to obligate seed regenerators.

The issue of fire in remnant vegetation is obviously a complex one. Because of the increased influence of external factors in remnant vegetation, especially small remnants, what may be an appropriate fire regime in 1000 ha of native vegetation may not be suitable in an area of 10 ha with the same vegetation type. In remnants below 5 ha there is a particular risk with burning because all of the remnant is within easy reach of weed propagules from the surrounding pasture. In addition all of the remnant could be regarded as "edge" habitat. Edge habitats experience environmental conditions quite different from those of the original vegetation (Ranney *et al.*, 1981).

Slashing

All other plants within an area managed for *Agonis* above 15 - 30 cm high would be directly affected by the slashing operation, and some non-resprouters (i.e. obligate reseeding legumes) would be killed. Smaller plants will get a chance to grow with reduced competition from the vigorous resprouters such as *Agonis sp.*, *A. parviceps*, *Homalospermum firmum, Evandra aristata* and *Astartea fascicularis* (Plate 2.5). Larger species, such as jarrah trees, Allocauarina fraserana (Sheoak) and *Xanthorrhoea preissii* (Blackboy or Balga) are avoided during the slashing.

Some cut-flower producers burn after slashing, but most do not because of the 'undesirable' species, mostly native obligate reseeders, which germinate after fire. In the absence of fire these species are likely to disappear from view in a particular piece of remnant vegetation, although the propagules of hard-seeded species may survive there for many years.

Without long-term research it is not possible to conclude whether slashing in the absence of fire, slashing plus fire, or fire alone would be the most disadvantageous for the long-term integrity of a stand of remnant vegetation. However, one slashing in 12 years, which is the recommendation here, is unlikely to have a long term effect on the composition of vegetation in a remnant, so long as it is alternated with burning. Therefore if a remnant was slashed in 1996, it could be burnt in 2002 before being slashed again in 2008.

The smaller the stand the more rapidly it will deteriorate all other factors being equal. A fenced 5 ha area of jarrah woodland in the Redmond area inspected as part of this study, which had been slashed twice and harvested for *A. parviceps* for about ten years had declined to the point where apart from jarrah there were only 4 or 5 other native species left in the entire remnant. By far the greatest proportion of ground cover was provided by *A. parviceps* and pasture species. An area of woodland this size in the natural state would have previously contained at least 25 native species (Wardell-Johnson *et al*, 1989). However, it is not known to what extent the ti-tree management practises contributed to the decline of this particular remnant.

The use of tractors to slash ti-tree stands probably causes some compaction of the soil and this together with the compaction that occurs during the harvesting process may lead to some environmental changes. Firstly there is the damage to other plant species and secondly there are changes in the soil density which may cause increased runoff, poorer aeration, and physically restrict root growth as has been documented for forest harvesting operations (e.g Incerti *et al.*, 1987 and references therein). Among the effects that can be envisaged are reduction in plant species diversity and an increase in the sedimentation of streams at least in the short term. The contribution of soil compaction to reduction in species diversity is perhaps the greatest risk because of the other disturbance factors impacting on remnant vegetation which have the same effect.

Recommendations: (3). Slashing should be carried out in spring and should be done alternately with burning, i.e. slash after 6 years then burn after another 6 years. (4) Tractor -powered slashing should not be carried out more frequently than once in 10 years. (5). Tractor-powered slashing should not be carried out on steep (> 20%) slopes.

Grazing

In general, areas of remnant vegetation being managed for 'ti-tree' production are fenced off from livestock, especially sheep, which are likely to graze *Agonis* and other species in autumn. However, some areas are deliberately lightly grazed by sheep in partly pastured paddocks to keep the area 'tidy'. Cattle do not eat *Agonis* but readily consume other species occurring with it. The detrimental effects to remnant vegetation caused by livestock are well established, access to remnant vegetation by domestic animals may lead to reduced litter, increased soil nutrients, soil compaction, and decreased plant and animal diversity (Scougal *et al.*, 1993; Abensperg-Traun *et al.*, 1995). Also weed seeds may be introduced *via* livestock and given a good start in life in the high nutrient local environment of their dung.

Recommendation:.(6) Bushland remnants being managed for ti-tree production should be fenced to exclude stock and they should not be grazed.

Fertilizer

In general phosphorus sensitive species (notably the Proteaceae) are low in abundance in the vegetation types in which *Agonis sp.* and *A. parviceps* occur. The main vegetation type that these two species are harvested from are dominated by Myrtaceous species which appear to respond well to additions of superphosphate or superphosphate and potash. However, there are some members of the Proteaceae, such as *Banksia grandis,* which are found in the jarrah woodlands managed for *A. parviceps* and *B. quercifolia* and *Adenanthos obovatus* in wet heathland which may be disadvantaged by additions of phosphorus.

The threat to a particular piece of remnant vegetation from long term applications of fertilizer is difficult to separate from the other extraneous factors which may lead to degradation of that ecosystem. The whole of small parcels of remnant vegetation (< 2 ha) surrounded by pasture are likely to receive influxes of fertilizer when it is applied to the surrounding pasture, especially when the remnant is long and narrow. Elevated levels of phosphorus have been observed up to 20 m into reserves from paddock edges (Smith, 1990; Scougall *et al.*, 1995) and increased importance values for alien plant species, which are favoured by higher nutrient levels, especially when combined with soil disturbance, typically extend over similar distances (Hobbs and Atkins, 1988).

Evidence for increased nutrient levels facilitating the invasion of native vegetation by weeds is provided by a study near Denmark carried out by Agriculture W.A., looking at the effect of added nutrients on the growth of ti-tree (*Agonis sp.*). The addition of N:P:K at 200 kg N/ha ("high fertilizer") after slashing of the ti-tree in autumn 1993 caused a significant decrease in the number of native species per metre of transect after 2 1/2 years (Figure 2.3). The site has been grazed in the past and is a small remnant (3 ha) surrounded by pasture on all sides. The proposed cause of the decline in native plant presence is the increased abundance of invasive species in the remnant. In the unfertilized plot the two non-native species were small and insignificant, whereas in the fertilized plots the invasive species were large and covered about 25% of the plot area (Plate 2.6). The important invasive species in the fertilized plots were the exotic *Hypochaeris glabra* (Flatweed) and *Holcus lanatus* (Yorkshire Fog) and the native rush *Juncus pallidus,* which thrives in improved pastures unlike most Australian plant species (see Lane, 1976).

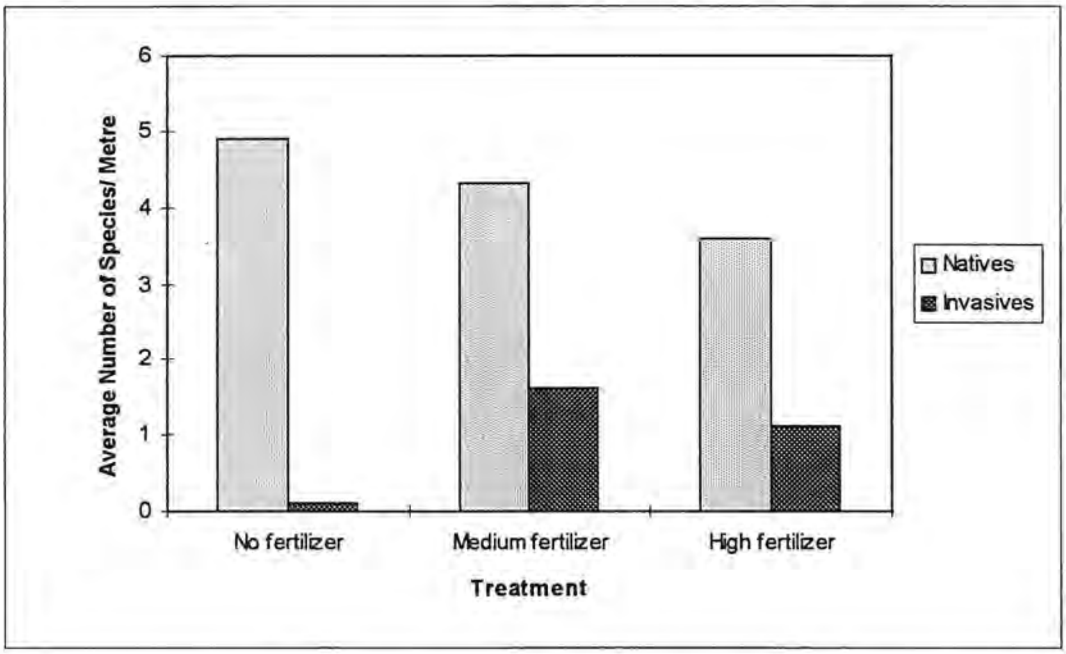

Figure 2.3. Number of native and invasive species per 1 metre of transect in a fertilizer trial being carried out in remnant vegetation near Denmark, Western Australia. The difference in numbers of native species between the "no fertilizer" and "high fertilizer" treatments is significant at $P < 0.05$.

The issue of excess fertilizer being washed into streams and finding its way into the various inlets along the south coast is an important one and will be addressed here. Several of these inlets, notably Princess Royal Harbour, Oyster Harbour and Beaufort, Wilson and Parry Inlets have indications of eutrophication, such as microalgal blooms and seagrass loss (Government of W.A., 1992). This eutrophication, or over-enrichment of the inlet ecosystems, is largely blamed on runoff of agricultural fertilizers, although the process of clearing and drainage of rural land itself has increased the nutrient load of south coast rivers.

The addition of fertilizers to remnant vegetation to encourage the growth of 'ti-tree' has the potential to increase the nutrient load of streams draining the area. The hazard is perhaps greater in the heathlands in which *Agonis sp.* occurs because they are generally found low in the landscape along streams and around swamps. The fact that both species are found mainly on sandy soils also increases the risk that fertilizer excess to that taken up by the plants, or nutrients released by decomposition of slashed vegetation, or fire, will find its way into waterways.

The addition of a low rate of low phosphorus fertilizer, similar to the "low fertilizer" treatment of the Denmark trial reported above may be advantageous in remnant vegetation that is slashed but not burnt. The fertilizer may have the effect of replacing the flush of nutrients that would occur after a fire. The debris after slashing would break down and release nutrients, but this would be at a much slower rate. It is unlikely that this low rate of added nutrients would increase weed invasion or leach into waterways if it applied no closer than 50 metres from streams.

Recommendations: (7) Fertilizer applied to remnant vegetation being managed for ti-tree should be at a rate of no more than 50 kg/ha N and should be no more than 3% phosphate. (8) Fertilizer should not be applied more frequently than once each 10 years. (9) Fertilizer should not be applied within 50 metres of a waterway.

Disease

There appears to be little evidence of *P. cinnamomi* ('dieback') in areas being managed for the production of cut-flowers from *Agonis sp.* and *A. parviceps*, although in some areas susceptible species such as *Banksia quercifolia* and various epacrids may have already been eliminated by the disease. However, because there are almost always some susceptible species in native vegetation of the south-west appropriate management must be undertaken to protect remnant vegetation from plant disease introduction or spread (see Appendix 2).

Recommendation: (10) Management for the production of ti-tree from remnant vegetation should be carried out so as to minimize the potential for the introduction and spread of disease, eg. machinery should be washed down before being taken into the remnant.

2.4 General discussion

Although the biology of *A. parviceps* and *Agonis sp.* is similar the situation in regard to their management and conservation is somewhat different. While *A. parviceps* is widespread and inhabits a number of vegetation types, *Agonis sp.* is much more restricted geographically and ecologically. The taxonomic confusion in regard to the genus *Agonis* is not helpful for management purposes. The fact that the two species are similar in appearance and that they hybridize with each other and with *A. linearifolia* means that reporting of harvest levels is probably not precise in regard to taxon. *Agonis* sp. has a number of sub-species or types which are very geographically restricted and for conservation purposes further clarification of the taxonomic status of *Agonis* would be welcome.

The general restriction of *Agonis sp.* to wetter areas, as well as its relatively small distribution, indicates that greater care is required for the sustainable management of this species and its ecosystem than with *A. parviceps.* For instance the risk of introducing or spreading "dieback" is greater in moist areas low in the landscape than it is in the drier areas typical of *A. parviceps.*

Another environmental concern which must be addressed in the sustainable management of these taxa for cut-flowers is that although they are quite resilient in regard to reprouting after harvesting or to slashing, the other species which occur in their habitat are often not so resilient.

Although some plantations of *Agonis sp.* and *A. parviceps* have been made between Albany and Walpole over the last several years it is likely that the proportion of total production originating from this source, which is currently about 3%, will remain relatively small for many years. This is because of the ready availability of ti-tree from remnant vegetation (*A. parviceps* in particular) and because the pressure to ban the picking of these species from crown land is not as great as it is for some other taxa.

Plate 2.5. Area of jarrah woodland near Walpole containing *Agonis parviceps* which was slashed in August 1994 and then accidentally burned in October 1994. Photographed in August 1995.

Plate 2.6. Area of heathland containing *Agonis* sp.which was slashed in 1993 and fertilized with NPK at 200 kg N per hectare which has since been invaded by the exotic grass *Holcus lanatus* and several other weeds.

Section 3

***Banksia baxteri* R.Br. and *B. coccinea* R.Br.**

3.1 Distribution and climate

Banksia baxteri and *B. coccinea*, in their natural habitat, are confined to the south coast of Western Australia between about 117^{o} and 121^{o} east longitude (Fig 3.1 and 3.2). The western-most occurrence of *Banksia coccinea* is near Youngs Siding 35 km west of Albany and it is found as far east as Stokes Inlet (Taylor and Hopper, 1988).

The western-most recorded occurrence of *B. baxteri* is in the vicinity of Ross Peak in the Stirling Ranges. Another, disjunct, western population is in the Millbrook Nature Reserve 20 km north west of Albany. The most eastern recorded sighting of *B. baxteri* is near Fanny Cove in the Stokes National Park 60 km west of Esperance.

Over much of their distribution the two species co-occur, being adapted to similar soil and climatic conditions. In general they are restricted to within 40 km of the coast, except in the Stirling Ranges where topography modifies the climate. The mean annual rainfall over their range is greater than 400 mm and rises to between 500 and 700 mm in their most extensive area of occurrence south east of the Stirling Ranges. The number of months per year when average rainfall exceeds effective rainfall (i.e. the agricultural "growing season") ranges from 7 in the east of the species' range to 8.5 north of Albany (Bureau of Meteorology) and is classified as a subhumid to humid Mediterranean type climate (Gentilli, 1972).

3.2 Habitat and vegetation

3.2.1 *Geology and soils*

About 90% of the populations of *Banksia baxteri* surveyed for the *Banksia* Atlas (Taylor and Hopper, 1988) were found on sand or sand over laterite. It is seldom found on clayey or loamy soils. Likewise most surveyed stands of *B. coccinea* were on sandy soils (80%), but about 10% occurred on loamy soils (Taylor and Hopper, 1988).

The most extensive populations of *B. baxteri* and *B. coccinea*, south of the Stirling Range between the Kalgan and Pallinup Rivers, occur on colluvial sands associated with stabilized dunes and hummocks within the Chillinup Soil Unit (Churchward *et al.*, 1988). The Chillinup unit is a broadly undulating plain which slopes gently to the south east from 180 m to 100 m elevation. Local relief is less than 10 m and there are many swamps and lakes, some with lunettes, which act as local sumps. Linear dunes are aligned ESE and there are sandy hummocks near salt lakes (Churchward *et al.*, 1988). Between the deep sands of the ancient dunes are yellow duplex soils which are typically moderately acid grey-brown sands with bleached A_2 horizons and mottled yellow sandy-clay subsoils at 30-40 cm (Northcote *et al*, 1967, Churchward *et al.*, 1988).

The *Banksia* woodlands and shrublands which include *B. baxteri* and *B. coccinea* mainly occur on the deeper sands of the dunes and hummocks (Newbey, 1995) whereas mallee-heathland is found on the intervening shallower soils. In the area between Manypeaks and Wellstead the deep, undifferentiated sands of the dunes and hummocks were named Corimup Sand by Bettenay and Poutsma (1962) and in the Fitzgerald River area they have been called Qualinup Sand by Newbey (Moir and Newbey, 1995). The survey by Bettenay and Poutsma (1962) of 35,000 ha between the Manypeaks townsite and South Stirlings indicated that the Corimup Sands comprised about 15% of this area. A typical profile of Corimup Sand is given in Table 3.1.

Table 3.1. A profile of Corimup Sand from the Manypeaks area typical of the soils on which *Banksia baxteri* and *B. coccinea* are found.

0-7 cm	brownish-grey fine sand (pH 5.6, 20% gravel)
7-40 cm	light grey fine sand (pH 4.7, 8% gravel)
40-275 cm	very light grey fine sand (pH 4.8, 0% gravel)

The Chillinup soils are pre-quaternary deposits of quartzite sand formed predominantly from Pallinup Siltstone. The siltstone had its origins in the deposits within a shallow transgressive sea which had its coast along the southern slopes of the Stirling Range (Muhling and Brakel, 1985). Further east between the Pallinup and Phillip Rivers both species occur on deep sands similar to those of the Chillinup formation which are also derived from Pallinup Siltstone (Thom and Chin, 1984; Newbey, 1995). *Banksia baxteri* and *B. coccinea* are also found on quartzite sands eroded from the pre-Cambrian bedrock of coastal hills and ranges from near Albany to Hopetoun (Newbey, 1995).

Outliers of *B. baxteri* and *B. coccinea* occur in the Stirling Ranges on alluvial sands of uniform texture derived from erosion of the quartzite sandstone of the ranges. Another disjunct occurrence of the two species is on deep colluvial sands in the vicinity of the Susetta River in the north of the Fitzgerald River National Park. The soils here have an A horizon consisting principally of grey siliceous sand of the Jacup Sand Series which is derived from granitoid rock of the Yilgarn Block (Newbey, 1995).

To the north and west of Albany *B. coccinea* occurs, mainly without the presence of *B. baxteri*, on deep sands of the Dempster Soil Unit (Churchward *et al.*, 1988). Like the soils of the Chillinup Unit these are derived from Pallinup Siltstone, though under a wetter climate. *Banksia* and *Eucalyptus staeri* woodland containing *B. coccinea* occurs on the sandy gentle slopes adjacent to the laterized spurs and ridges of this soil unit.

3.2.2 *Vegetation structure and associated plant species*

In the Fitzgerald River area, 150 km NE of Albany, Newbey (1995) recognizes a *Banksia baxteri* tall open shrubland association as a component of the widespread *Eucalyptus tetragona-E. bupestrium-Banksia baxteri-B. attenuata* plant community (Aplin and Newbey, 1990). The association is restricted to deep grey sands of the Qualinup soil type which has developed from spongilite on the Marine Plain land surface. The upper stratum of the shrubland (with a canopy cover of about 20%) is typically formed from *B. baxteri* and several other tall shrubs 2 to 3 m high (including *B. coccinea*) with a low, species rich lower stratum of shrubs up to 1 m high with a canopy cover of about 50%.

Similar shrublands dominated by *B. baxteri* are found on linear dunes formed of yellow-grey siliceous sands of the Chillinup Soil Unit (Churchward *et al.* 1988) near Wellstead (Plate 3.1) and near Cheynes Beach (Plate 3.2). Lists of the most common species occurring with *B. baxteri* in the Fitzgerald River area and near South Stirlings (50 km NNE of Albany) are given in Table 3.2. Except for the presence of the (scattered) eucalypts the Wellstead vegetation is very similar to Newbey's *Banksia baxteri* tall open shrubland association. Most of the commercially picked stands of these two species occur in this type of shrubland dominated by *B. baxteri*. The South Stirlings site has a relatively low proportion of the two *Banksia* species and is dominated by *Lambertia inermis,* however there are areas at South Stirlings which are dominated by *Banksia baxteri* and *B. coccinea*.

Banksia baxteri and *B. coccinea* also occur as a minor component in association with *B. attenuata* in tall shrublands growing on the siliceous sands derived from the quartzite of the coastal hills between Albany and Bremer Bay (Newbey, 1995). The three *Banksia* species form the upper stratum at 2.1-3.0 m with occasional mallee eucalypts. A second stratum may consist of *Banksia oreophila* and *Hakea victoria* and a third stratum of shrubs of *Melaleuca, Agonis, Adenanthos* and *Acacia* shrubs to 1.5 m. A species rich assemblage of low shrubs and sedges occurs below this (Newbey, 1995, Chapman and Newbey, 1995).

In Millbrook Nature Reserve north of Albany *B. coccinea* occurs in a low woodland dominated by *B. attenuata* or *Alllocasuarina fraseriana* and *Eucalyptus staeri*. *Banksia coccinea* 1.5-2.0 m tall form an understorey to the low trees along with *Agonis* and *Melaleuca* species. Beneath this are low shrubs and sedges (Griffin, 1985).

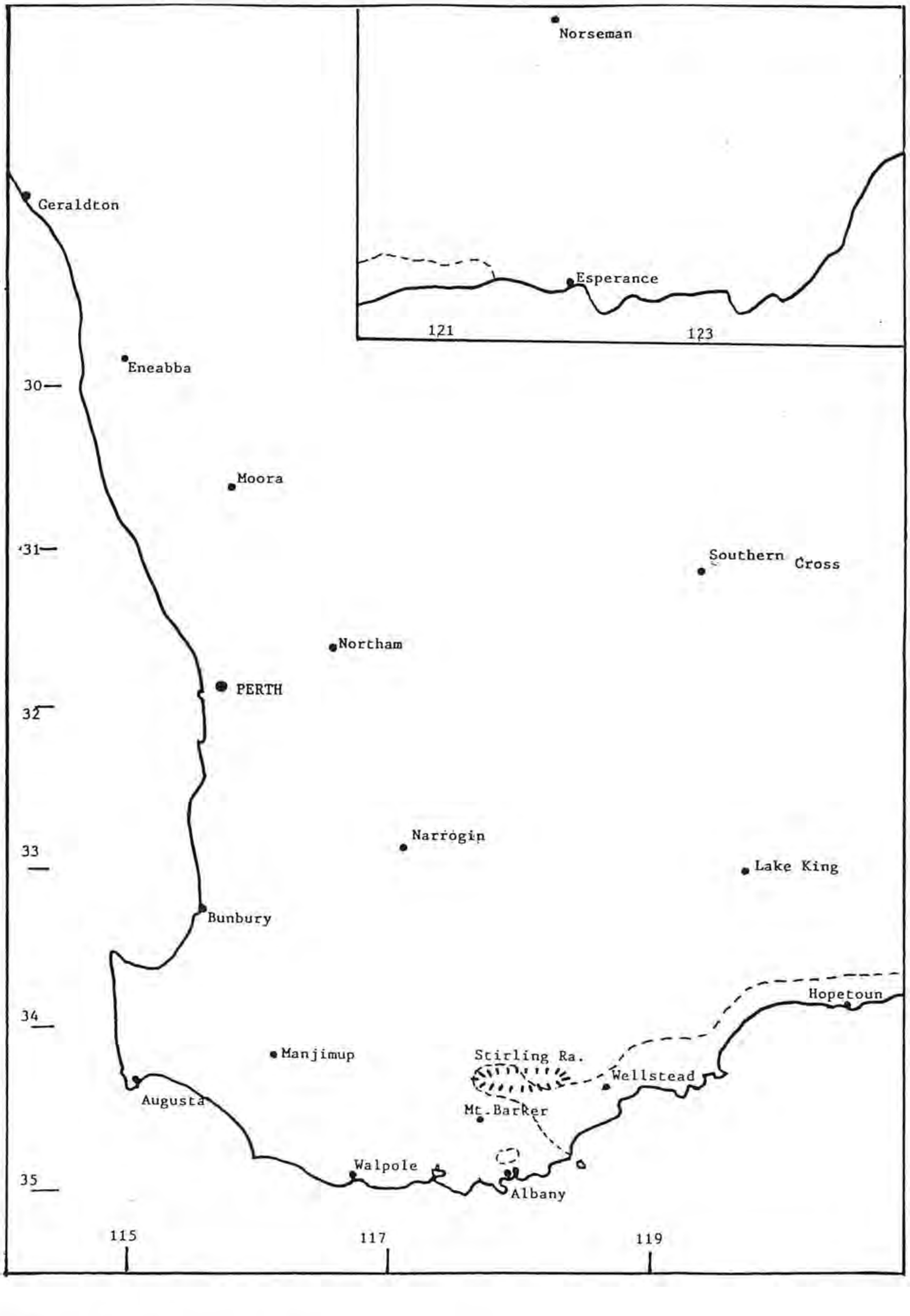

Figure 3.1. Distribution of *Banksia baxteri.*

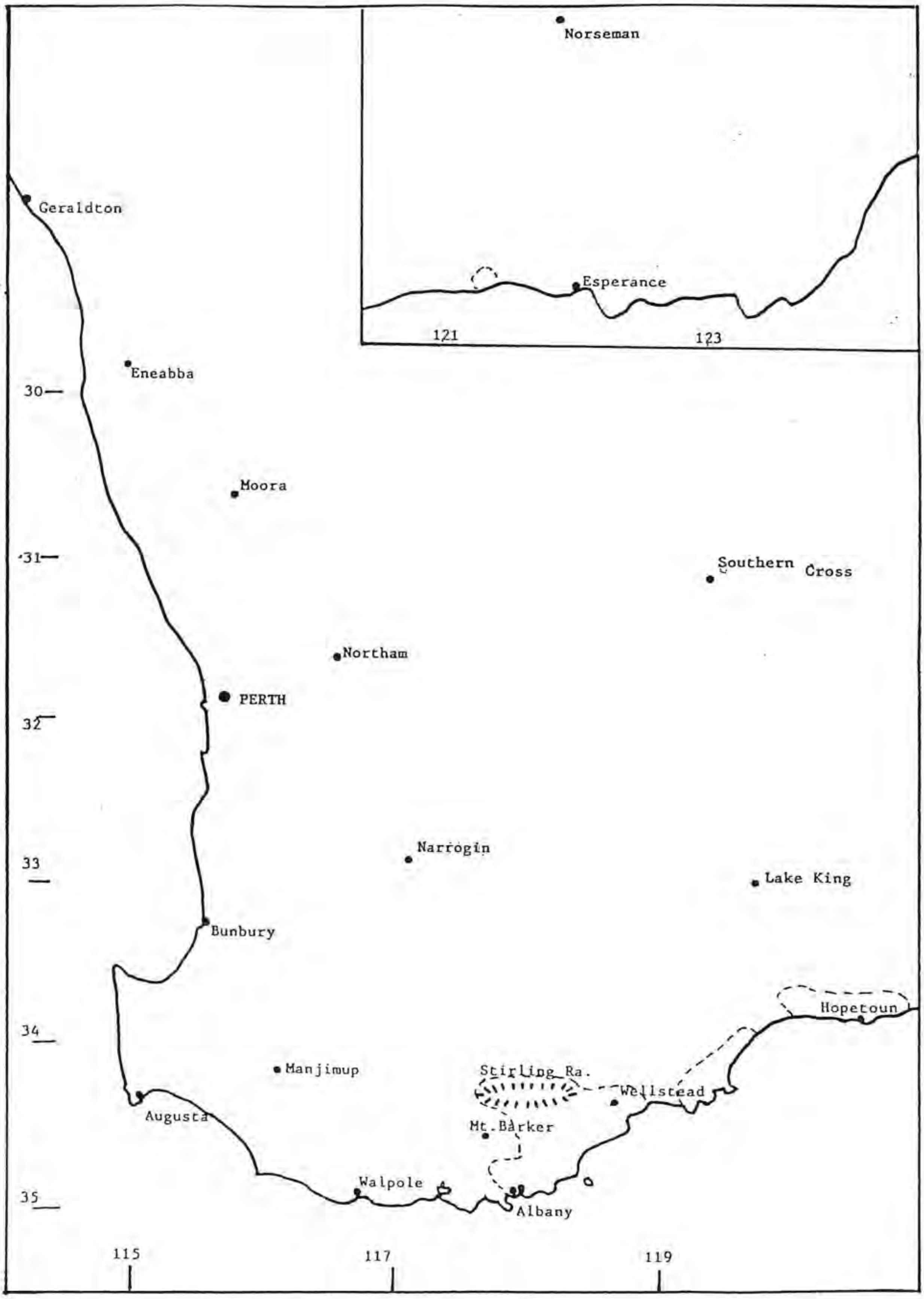

Figure 3.2. Distribution of *Banksia coccinea*.

□

Table 3.2. Plant species commonly occurring in association with *Banksia baxteri* and *B. coccinea* at two sites NE of Albany.

Wellstead	South Stirlings
Adenanthos cuneatus	*Adenanthos cuneatus*
Banksia attenuata (Slender Banksia)	*Anarthria prolifera*
Caustis dioica	*Beaufortia empetrifolia*
Cyathchaete clandestina	*Caustis dioica*
Eucalyptus decurva (Slender Mallee)	*Dryandra mucronulata*
E. staeri (Albany Blackbutt)	*Eucalyptus decipiens* (Redheart)
Lambertia inermis (Chittick)	*E. pachyloma* (Kalgan Plains Mallee)
Lepidosperma angustatum	*E. tetragona* (Tallerack)
Leucopogon tamaricinis	*Hakea marginata*
Melaleuca thymoides	*Isopogon trilobus*
M. striata	*Lambertia inermis*
Verticordia harveyi	*Melalauca striata*
	M. thymoides

Plate 3.1. Tall open shrubland near Wellstead containing *Banksia baxteri* and *Banksia coccinea* (minor component).

Plate 3.2. Tall open shrubland near Cheynes Beach containing *Banksia baxteri* (large shrubs) and *Banksia coccinea* (small slender plants at front). This stand is affected by *Phytophthora cinnamomi* dieback and stem canker.

3.3 Conservation status in remnant vegetation

3.3.1 *Management effects on* Banksia baxteri *and* B. coccinea

Fire

Adult plants of both *Banksia baxteri* and *B. coccinea* are killed by fire and regenerate only from seed (Plate 3.3). However *B. coccinea* is less serotinous than *B. baxteri* and establishes seedlings between fires in favourable seasons. Witkowski *et al.*, (1991) found for the eastern population they studied that seed storage of *B. coccinea* rose rapidly to peak at 16 years post fire after which it declined as the plants senesced and died. However Bathgate and Shearer (n.d.) in a survey of 50 stands across the western part of the range of *B. coccinea* found that the rate of seedbank accumulation varied greatly between populations. A western population of *B. coccinea* , at Gull Rock near Albany had continued to accumulate seed up to 36 years of age. Bathgate and Shearer (n.d.) attributed the declining rate of accumulation of seed in the eastern population studied by Witkowski *et al.*, (1991) to the fact that it was extensively diseased.

Witkowski *et al.*, (1991) concluded that *B. coccinea* is both adapted to more frequent fires than *B. baxteri* in terms of early seed production but in the continued absence of fires is able to replace a significant proportion of parent plants with interfire recruits. In contrast *B. baxteri* releases few seeds interfire and there is little recruitment by this means (McCaw and Smith, 1992). This species keeps on accumulating a aerial seed bank well past 20 years, indeed healthy 40 year-old stands of this species have been noted (Witkowski *et al.*, 1991). As noted above, some healthy populations of *B. coccinea* can may also accumulate seeds well past 20 years.

Preliminary modelling of the population dynamics of *B. baxteri* and *B. coccinea* indicates that with fire intervals of < 13 years *B. coccinea* would become dominant whereas at > 20 years between fires *B. coccinea* may disappear from a local population and longer lived species such as *B. baxteri* and *B. speciosa* will dominate (Witkowski *et al.*, 1991). However, given the ability of *B. coccinea* to germinate and establish between fires (although perhaps only in favourable seasons) it is unlikely to disappear. Although the fire dynamics of south coast banksias has not been studied *per se* Witkowski *et al.* (1991) speculate that assuming the ability to resprout increases fitness to frequent fire (Keeley and Zedler, 1978) the low proportion of resprouting species on the southern sandplains (when compared to the northern sandplains) indicates that fires have been less frequent there over evolutionary time. Southern banksias also accumulate seed banks at a slower rate than those on the northern sandplains which is a factor which must be borne in mind when devising fire management policy. In terms of the balance between *B. baxteri* and *B. coccinea* Witkowski *et al.* (1991) recommend that to preserve *B. coccinea* within a stand, an interfire interval of 16 years or less is required but this recommendation is made on limited evidence.

Fire intervals within remnant vegetation on farms within the natural range of *B. baxteri* and *B. coccinea* are most commonly between 8 years and about 20 years, with the age of most areas perhaps being in the upper end of this range. Although under extreme conditions areas may reburn after only five years (McCaw *et al.*, 1992) it is probable that 6 to 8 years is required before the tall open shrubland in which *B. baxteri* and *B. coccinea* are found will carry fire under typical fuel reduction burning conditions. It is likely that burning of remnant vegetation has become less frequent over the last 10 - 15 years as the need for clearing burns has declined. Most areas of remnant vegetation were burnt a number of times from the mid 1960's to the mid 1980's during the peak decades of development of farms on the southern sandplains. There are few farmers who have adopted a particular burning regime as such for their remnant vegetation and most burning is either *ad hoc* or accidental (C. Robinson, pers. comm.). Those who burn their remnant vegetation with the object of promoting the productivity of their cut-flower species tend to burn in late autumn or winter.

When extensive picking of *B. baxteri* and *B. coccinea* blooms began on the south coast about 15 years ago most stands of remnant vegetation were quite young because of escapes from clearing burns and production per hectare was high. Productivity has fallen considerably in much remnant vegetation as the stands have aged and also as the incidence of plant disease has increased (C. Robinson, pers. comm.). Pressure to increase productivity from remnant vegetation has also come about through the ban on Crown land picking of these two species since 1991. In addition, falling sheep prices have made the picking of bushstands more attractive to farmers. Consequently some farmers who in the past have harvested *B. baxteri* and *B. coccinea* from their remnant vegetation have burnt their remnant vegetation to rejuvenate the banksias. Robinson (1991) reported that an inappropriate combination of ploughing and burning on private property near Manypeaks had caused remnant vegetation which had been a prolific producer of commercial blooms of *B. coccinea* to be now dominated by *B. attenuata* (which is a resprouter).

Interfire interval for this southern sandplains vegetation should be at least 15 years, even without allowing for the effects of picking or disease. Considering the relatively slow build up of seed stores on southern banksias (Witkowski *et al.*, 1991; Shearer and Bathgate, n.d.) and the prevalence of plant diseases, the effects of picking on potential reproductive ability may even be more deleterious to these species than has been shown to be the case with *B. hookeriana* where heavy picking reduced the number of viable seeds stored per plant by 57% (Obbens et al., 1991). At 10 years of age in the area studied by Witkowski *et al.* (1991) unpicked *B. baxteri* held only 12 viable seeds/plant on average while *B. coccinea* carried 51 viable seeds/plant. Harvesting of blooms from wild populations of both species may start when the plants are 5 or 6 years old. The effects of disease, however, may mask in many cases the results of a decline in seed storage caused by heavy picking.

Recommendations: (1) That the minimum interval between fires in remnant vegetation being managed for production of *Banksia baxteri* or *B. coccinea* should be 15 years. (2) That the minimum interval be 20 years for heavily picked areas.

Chaining

Scrub rolling or chaining is sometimes used in the southern shrublands as a method of facilitating prescribed burning by increasing both the continuity of the fuel bed and the proportion of dead fuel (McCaw and Smith, 1992). This allows the shrublands to burn under milder weather conditions and produces more controllable fires. Chaining before burning also causes more of the adult plants to be consumed by the fire. When chaining is not carried out, the dead adult plants which may remain standing for many years, make it difficult to gain access to the regenerated population of banksias for harvesting (Plate 3.4).

It is difficult to draw any firm conclusion about the effect of chaining on the conservation status of *B. baxteri* and *B. coccinea*. The practice is apparently not widespread and where it is used before prescribed burning it appears to increase the density of seedlings (pers. observ.). However McCaw and Smith (1992) warn that the time lag between knocking down of the vegetation and burning should not be more than 'a few weeks' to minimize potential seed losses. The major potential disadvantage of chaining or rolling is the risk of introducing plant disease to the remnant vegetation. However, provided that sufficient precautions are taken, chaining before a burn should not lead to long-term changes in the structure or composition of the vegetation. The fire will kill all above-ground plant parts in any case.

Recommendation: That chaining before burning may be used in remnant vegetation being managed for the production of cut-flowers from *B. baxteri* or *B. coccinea* but the interval between chaining and burning should not exceed a few weeks.

Fertilizers

Fertilizers are not applied to *B. baxteri* or *B. coccinea* growing in remnant vegetation to increase the production of blooms. As with most Proteaceae high phosphorus levels in particular may increase mortality in these two banksias. The benefits of applying fertilizer to native vegetation to enhance the flower production of a particular species is problematical. While the growth of certain desirable species, in terms of dry matter production, may be increased (eg. Grove, 1988) the effect on flowering, particularly in the long term is uncertain. For instance Lamb and Klausner (1988) found that the addition of phosphorus and phosphorus plus nitroegn to *Protea repens* increased flowering in the year after application but decreased vegetative growth. Therefore while more flowers may be produced but stem length, which is often very important in the cut-flower trade, may be reduced.

Because of the known detrimental effects of adding nutrients to native vegetation (eg. Specht, 1963; Specht *et al.*, 1977) and because no research has been carried out into the effects of fertilizers on banksia species growing in native vegetation their use can not be recommended.

Recommendation: (4) No fertilizer should be applied to remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* or *B. coccinea*.

Harvesting

Although no studies into the effects of picking *per se* of *B. baxteri* and *B. coccinea* have been carried out (as they have for *B. hookeriana*) a study into the conservation status of both species (Robinson, 1991) found that it contributed to the spread of *Phytophthora* root disease. It is reasonable to assume that the effects of heavy picking on *B. baxteri* and *B. coccinea* will be similar to that established for *B. hookeriana* by Obbens *et al.* (1991) and for *Brunia albiflora* a South African serotinous species (Rebelo, 1988) in that the removal of a substantial proportion of stems, especially in old wood will cause a disproportionate decrease in the number of viable seeds stored per plant. Indeed it is likely that the effect will be even more severe in regard to *B. coccinea* because of its lower rate of branching and much lower number of flower heads (and fertile cones) per plant in older cohorts (Witkowski *et al.*, 1991).

If the recommendations for *B. hookeriana* are used as a guide no more than 20% of blooms should be taken in any one season. However, a larger proportion (up to about 30%) may be taken if the cut is not made into old (> 2 y.o.) wood. The slower rate of seed accumulation on the two southern banksias indicates that harvesting should not start till about 15 years. The 10 year-old plants of *B. baxteri* and *B. coccinea* studied by Witkowski et al. (1991) had less than 5 flower heads per plant, and although the number increased rapidly for *B. baxteri*, at 21 years the average number on *B. coccinea* was only 10 flower heads/plant. The populations studied by Witkowski *et al.* (1991) are towards the eastern extremity of the range for both plants and it appears that growth rates and the allocation to reproduction are higher in more western populations (Bathgate and Shearer, n.d.).

Recommendations: (5) No more than 20% of blooms should be harvested if the cuts are to be made into old (> 2 y.o.) wood. (6) No more than 30% of blooms should be harvested if the cuts are in young (< 2 y.o.) wood and the plants are greater than 15 years old. (7) That harvesting not be carried out until *Banksia baxteri* plants are 8 years-old and *Banksia coccinea* plants are at least 10 years-old. (8) A stand should not be picked for a year prior to burning.

Disease

Both *B. baxteri* and *B. coccinea* are highly susceptible to the dieback fungus *Phytophthora cinnamomi* (McCredie, 1985) and other species of *Phytophthora*. Robinson (1991) has documented the devastating impact of various plant diseases, especially *P. cinnamomi*, on the southern sandplains. Observations and analyses carried out by C.A.L.M. staff prior to 1991 determined that no significant population of *B. coccinea* from Redmond to Cape Riche (covering the major part of its range) was free from the *Phytophthora* pathogen. Because of its larger range and more extensive populations *B. baxteri* was not so badly affected, but *P. cinnamomi* has been isolated from populations across its range (Robinson, 1991). Many stands of both species in remnant vegetation have also been severely affected (Plate 3.5) and some farmers have ceased to harvest blooms from their remnant vegetation because of this.

Aerial canker disease (caused by species of *Cryptodiaporthe, Botryosphaeria, Cytospora,* and other air-borne fungi) , is also widespread on the southern sandplains (Shearer, 1994) and most Proteaceae there are seriously affected by these pathogens (Wills and Keighery, 1994). A survey reported by Bathgate and Shearer (n.d.) found aerial canker present in over 70% of the 50 stands visited. The most severe infections of canker occurred in stands greater than 14 years old. There has been concern that the use of secateurs by wildflower pickers hasten the spread of these diseases (by cross infection), however Shearer and Bathgate (n.d.) found that although a stem wound increased the rate of infection, the most destructive stem canker, *Cryptodiaporthe*, could infect through unwounded tissue. Stress, such as that caused by abnormal temperatures, may aid in the establishment and spread of aerial canker disease (Shearer, 1994; Bathgate and Shearer, n.d.).

Good hygiene measures are obviously vital in the sustainable management of remnant vegetation for *B. baxteri* and *B. coccinea* cut-flower production (see Appendix 2). The risk of spreading *Phytophthora* is probably higher with harvesting of *B. coccinea*, because peak flowering is in late winter and spring, than it is for *B. baxteri* which flowers in summer. However on the southern sandplain summer rain often occurs creating the conditions for rapid sporulation of the fungus and the conditions for its spread in soil attached to vehicles and feet. Although wildflower pickers have not been the only mechanism whereby soil-borne plant pathogens have spread on the southern sandplains, the movement of pickers from stand to stand and from crown land to private land is strongly suspected of playing a large role in the ramification of infections in the past.

With air-borne fungi the situation is more complex. One air-borne canker (*Cryptodiaporthe*) which has devastated several populations of *B. coccinea* on the southern sandplains is probably a native species. Another, *Botryosphaeria*, is thought to be introduced. These pathogens appear to establish more easily in older populations of banksias which are under some stress (eg. heavy picking, drought) already, and find more ready access through wounds in the stem. The long-term prognosis for areas affected by aerial canker is not clear, there is perhaps a better chance than with soil-borne pathogens that the vegetation will recover, especially when droughts do not recur too frequently. However death rates of 98% have been observed in some stands of *B. coccinea* will undoubtedly lead to long term effects. Management of banksias to prevent infection with aerial stem cankers would concentrate on reducing the chance of cross-infection by disinfecting secateurs between plants and on preventing stress to the extent that this is possible. Manageable stresses include level of harvest, grazing by livestock.

Recommendations: (9) Effective measures be taken to protect remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* or *B. coccinea* from the introduction or spread of plant diseases

Plate 3.3. Area of tall shrubland recovering after fire. Large dead shrubs are mainly *Banksia baxteri, seedlings of B. baxteri* are visible at lower right

Plate 3.4. Area of *Banksia baxteri* shrubland chained and burnt in 1990. In the background is an area that was burnt but not chained.

3.3.2 *The effects of management on the ecosystem*

Fire

It is generally held that fire is characteristic of the southern sandplains because of the long summer drought and the frequency of summer lightning strikes (McCaw and Smith, 1992). There is also abundant documentary evidence that the aborigines of the south coast practiced deliberate regulated burning and that the vegetation was a relatively small-scale mosaic of different age classes (Hallam, 1975). There has been much less research into the fire ecology of the southern sandplains than those north of Perth but limited evidence (Witkowski, 1991) indicates that at least some serotinous southern banksias are adapted to longer intervals between fires than those of the north. However, as mentioned previously, based on the available evidence interfire intervals in the banksia shrublands of the south coast should be at least 15 years.

At present however plant diseases are a much bigger threat to remnant vegetation and its fauna than is too frequent burning on the south coast. This is partly because access of livestock to many of these areas has produced low or intermittent fuels which often do not carry fire.

Chaining

A study done in mallee shrubland near the Stirling Range (McCaw and Smith, 1992) concluded that much of the seed released from some species through desiccation of the follicles (in this case *Hakea crassifolia*) in the time between felling and burning will be consumed by the fire. This would probably result in a reduced germination of those species. McCaw and Smith (1992) recommended that scrub rolling operations be carried out in early autumn so that seed capsules on felled stems are not exposed to prolonged drying (which stimulates seed release) during summer.

Recommendation: (10) Pre-burn scrub rolling of remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* should take place in early autumn.

Grazing

Many of the areas of remnant vegetation from which *B. baxteri* and *B. coccinea* are or have been harvested are grazed or used by stock for shelter for at least part of the year (Plate 3.6). This typically causes a reduction in plant and animal diversity (Scougal *et al.*, 1993; Abensperg-Traun *et al.*, 1995) and an increase in the proportion of bare ground. Data on percentage of bare ground and number of species intersected by a transect for two shrubland sites dominated by *B. baxteri* near South Stirlings is presented in Figure 3.3. Whereas there is little difference in the number of species the remnant vegetation site has twice as much bare ground as the nature reserve site.

The importance of fencing off remnant vegetation both to protect the banksias and to prevent general deterioration of the vegetation in generally accepted by farmers on the southern sandplains. The cost of doing this however is often an impediment. It was recommended by one farmer from Wellstead that remnant vegetation should not be burned if it is not fenced because of the damage that sheep do to the vegetation as it recovers from fire.

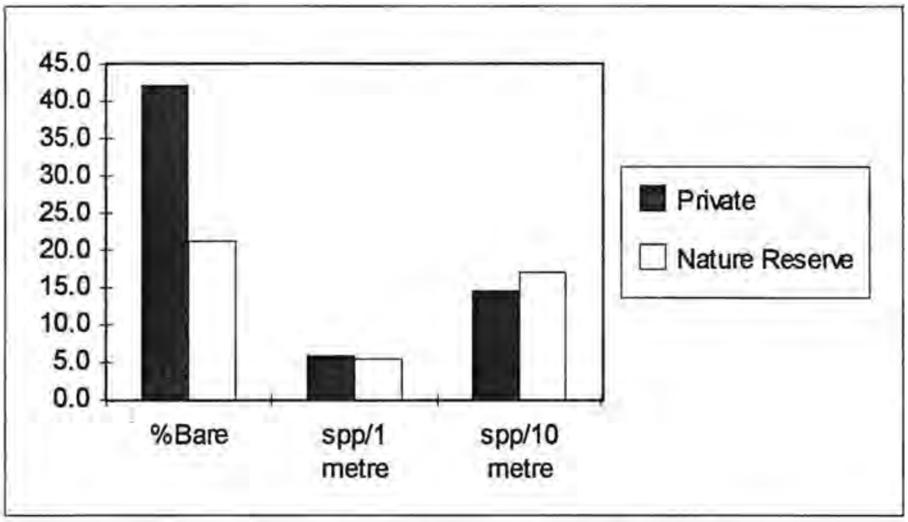

Figure 3.3 Percentage of bare ground and number of native species along transects through tall open shrublands dominated by *Banksia baxteri* in privately owned remnant vegetation and in a nature reserve near South Stirlings. The *B. baxteri* had been heavily picked in the privately owned vegetation and lightly picked in the nature reserve.

Not only does grazing lead to a reduction in the conservation values of remnant vegetation the movement of livestock through these areas is probably important in the spread of soil-borne plant pathogens both within and between patches. The extra stress put on remnant vegetation by livestock, as well as the increased environmental stress associated with small patches of vegetation (Hobbs, 1993), would increase the potential for infection by aerial canker diseases.

Recommendations: (11) Remnant vegetation being managed for the production of cut-flowers from *Banksia baxteri* or *B. coccinea* be fenced to exclude livestock and should not be grazed.

Fertilizer

Fertilizers are not applied to stands of *B. baxteri* and *B. coccinea* to increase production although as with all vegetation surrounded by farmland the influx of superphosphate in particular from neighbouring pasture may have some detrimental effects on the native flora. The application of high levels of superphosphate (> 90 kg Ha P) to shrubland ecosystems on infertile soils has been shown to result in a decrease in the proportion of banksia and other Proteaceae, an increase in some other native species and an increase in the invasion of weeds (Specht, 1963; Specht *et al.*, 1977). In general the application of phosphorus to native vegetation will increase the dominance of legumes while the addition of nitrogen will decrease their dominance and favour non-legumes.

Disease

There is no doubt that many crown land and privately owned populations of *B. coccinea* and to a slightly lesser extent *B. baxteri* have been severely affected by various plant diseases. A study of a range of southern plant communities found that 38% of the 460 taxa assessed were susceptible to *P. cinnamomi* and 59% of 436 taxa examined showed symptoms of aerial canker activity (Wills and Keighery, 1994). Vegetation with a high representation of the Proteaceae (e.g. the *Banksia baxteri* shrublands; Newbey, 1995) may be particularly altered by the effects of the root pathogen *Phytophthora cinnamomi* (Wills, 1993). Wills and Robinson (1994) have examined the threats to flora-based industries, which apart from cut-flowers includes honey production and tourism as well as the potential in medical uses of native flora.

3.4 General discussion

A number of farmers who have been active in the harvesting of *B. baxteri* and *B. coccinea* cut-flowers for many years see the industry moving out of bush picking of these species and into plantation production. Their reasons for this mainly involve the problems caused by disease, the series of recent droughts which have caused a major decline in flower production. As discussed above, the widespread practice of allowing livestock to graze in remnant vegetation has also contributed greatly to the decline in the vigour of south coast banksia shrubland. Apart from these factors, the patently superior productivity of cultivated *Banksia baxteri* and *B. coccinea* has been brought to light by a few farmers who have planted small plots and the focus by Agriculture W.A. on floriculture in recent years.

Nevertheless, productivity of bush stands can be increased, and there now appears to be an alternative to burning as a way of "rejuvenating" stands, at least in regard to *B. baxteri*. Research recently conducted by Agriculture W.A. at Wellstead has shown that light pruning can substantially increase the number of commercial blooms produced on 11 year-old plants (Robinson *et al.*, 1996). Light pruning of eleven year-old plants, cut back from the stem tip down to a stem diameter of 7 - 10 mm produced an increase in total bloom production and in the percentage of commercial quality blooms.

One farmer from near Wellstead has combined the job of fencing off his remnant vegetation, from which he no longer picks *B. baxteri*, with establishing plantations of this species. He has fenced both the remnant vegetation and the cleared deep sands adjoining it which now carry poor pasture but once carried banksia shrubland (Plate 3.7). The fenced pasture areas have been planted with *B. baxteri* seedlings taken from adjacent burnt areas of remnant vegetation and these have shown far superior growth to nearby wild seedlings of a similar age (Robinson *et al.*, 1996). The transplanted seedlings produced an average of 34 times more leaves than the wild seedlings in adjacent bush.

While it is possible to sustainably manage remnant vegetation for the production of *B. baxteri* and *B. coccinea* cut-flowers in the short-term, providing care is taken, there is little doubt that the proportion of blooms from these species originating from plantations (in 1994 this was 7% for *B. baxteri* and 45% for *B. coccinea*) will grow rapidly over the next ten years. Agriculture W.A. is devoting a considerable amount of research to improving the productivity of cultivated *B. baxteri* and *B. coccinea* and several other banksias (e.g. Fuss and Sedgley, 1991; Rohl *et al.*, 1994) and the economic benefits of planting these species for cut-flowers are made more obvious by the widespread influence of plant disease and drought on remnant vegetation populations (Plate 3.8).

Recommendations: (12) Pruning carried out using hygienic methods can be used as a method of increasing production of *Banksia baxteri* blooms as an alternative to burning. (13) That areas of pasture included within fenced-off remnant vegetation containing *Banksia baxteri* or *B. coccinea* be planted with these species.

Plate 3.7. Area of sandy soil adjacent to remnant vegetation near Wellstead that has been fenced off and planted with *Banksia baxteri* seedlings.

Plate 3.8. *Banksia coccinea* in jarrah woodland in the Mount Martin reserve near Albany with signs of aerial canker appearing on some of the foliage (front left). Much of the population of the species in this reserve are badly affected by *Cryptodiaporthe*.

Section 4

***Banksia hookeriana* Meiss.**

4.1. Distribution and climate

The natural distribution of *Banksia hookeriana* Meiss. is contained within a 75 km x 35 km square on the Northern Sandplains 250 km north of Perth (Taylor and Hopper, 1988; Witkowski and Lamont, 1994) although the area actually inhabited by the species is much less than this. A map of *B. hookeriana* sightings is given in Taylor and Hopper (1988) but most of these locations are biased to roads and tracks along which observations are made. A more precise indication of the actual distribution, based on Taylor and Hopper (1988), on sightings made during this study and on soil and geomorphological grounds is given in Fig. 4.1. Rather than the 2600 km^2 distribution implied by the range given by Witkowski and Lamont (1994), *B. hookeriana* is actually confined to about 400 km^2.

The most northerly population of *B. hookeriana* occurs at Mt Adams (Cowling *et al.*, 1987). The most southerly extensive occurrence is about 15 km south of Eneabba on the northern slopes of the Lesueur Uplands. There has been an isolated roadside sighting further south about 5 km north of Warradarge. There are two records of *B. hookeriana* being found near Irwin 15 km east of Dongara and 15 km further north than Mt Adams but this population was not recorded during the *Banksia* Atlas surveys (Taylor and Hopper, 1988).

The east-west extent of *B. hookeriana* is about 15 km in the southern part of its range. Further north, near the Arrowsmith River it is found between Arrowsmith Lake and Yandanooka Hill 25 km east of there. Its distribution narrows to about 8 - 10 km on the eastern side of the Eneabba Plain north of Eneabba.

Climate in the area is Mediterranean and is classified by the hydroxeric index as semi-arid (Gentilli, 1972) and there are about 4.5 months per year when average rainfall exceeds effective rainfall (Bureau of Meteorology, 1979). Eneabba receives an annual rainfall of about 550 mm, mean temperatures are about 21^{o}C in summer and 13.5^{o}C in winter.

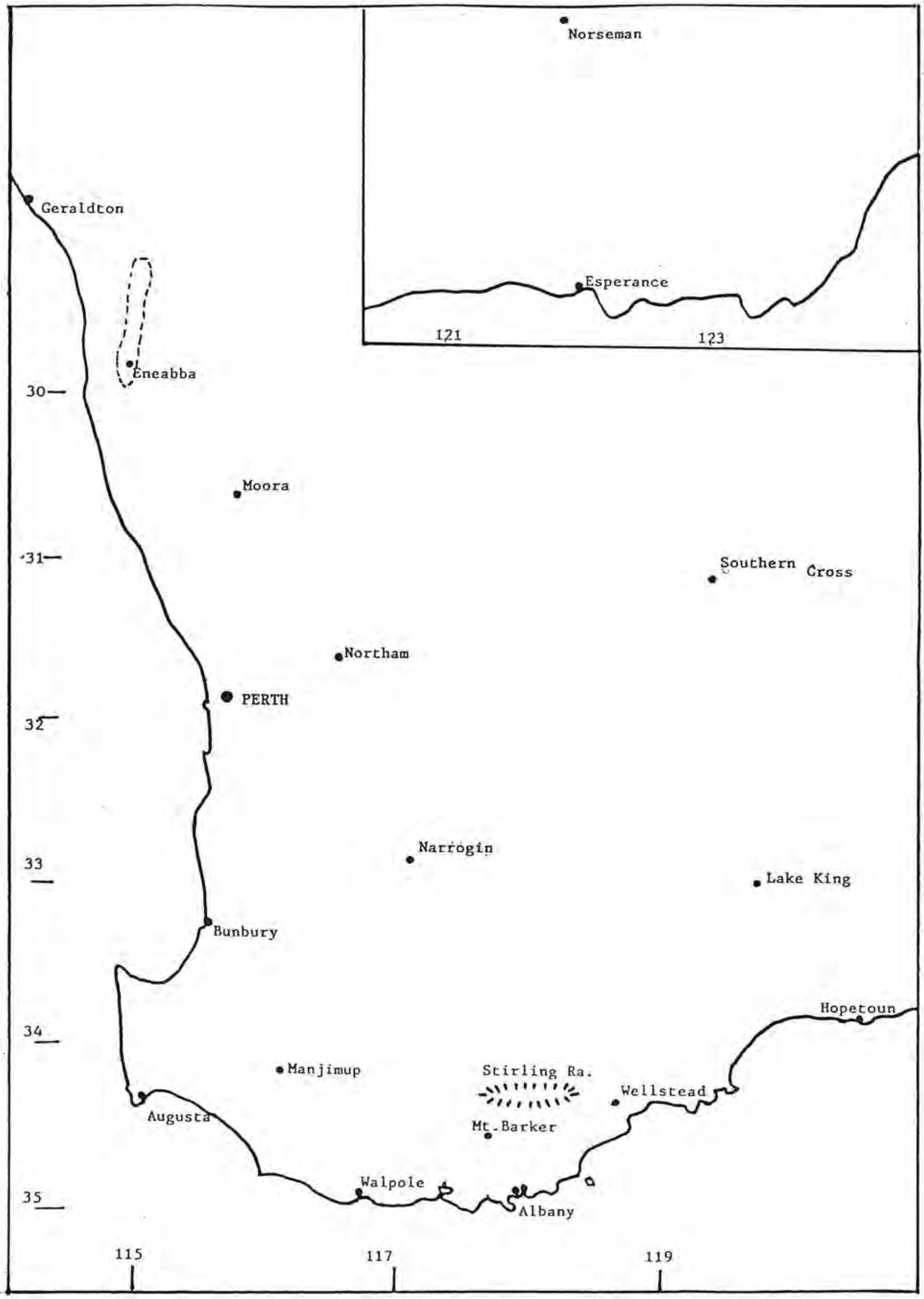

Figure 4.1. Distribution of *Banksia hookeriana*.

4.2. Habitat and vegetation

4.2.1 *Geology and soils*

Banksia hookeriana is predominantly restricted to an area of alluvial fans bounded on the south and east by highlands of laterized Mesozoic strata (the Dissected Region) and to the north and west by the coastal belt of Pleistocene and Holocene limestone dune systems. The alluvial fans formed where the westward-flowing rivers decreased in gradient as they approached the coastal belt. These alluvial quartz sands are of early Pleistocene to Recent age and have since been overlain in places by younger alluvium, colluvium and aeolian sand (Lowry, 1974). An ancient coastline is marked by the boundary of the Alluvial Fans Region with the Dissected Region. Sand rich in rutile, ilmenite and other heavy minerals that was probably deposited in an embayment of this ancient shoreline, occurs near Eneabba at the base of the scarp (Lowry, 1974).

The Alluvial Fans Region (otherwise called the Eneabba Plain) is a plain between 20 and 80 m above sea level covered with deep, leached sands, with a coloured, but not compacted layer below the bleached zone, which have in places been blown into low dunes by the predominant westerly wind (Lowry, 1974). These low dunes generally stand 5 to 10 m above the plain. The dune sands may be pale grey, pale yellow or yellow, and there may be clay lenses imbedded at various depths (Hnatiuk and Hopkins, 1981a). In between the dunes are gently undulating plains dissected by small ephemeral steams and at the western margin of the region is a chain of small seasonal wetlands and lakes. In these broad interdunal areas the sand is shallower and there may be a sandy clay substrate at 1 to 2 m in depth (Northcote *et al.*, 1967).

B. hookeriana is restricted to the upper slopes of dunes and on low dune plateaux. Lamont *et al.* (1989) have demonstrated that *B. hookeriana* is probably excluded in its seedling stage from lower, moister sites and higher, drier sites by competition with other species. A soil description at a *B. hookeriana* site is given in Table 4.1 (Hnatiuk and Hopkins, 1981b).

Table 4.1. Description of a soil on a broad low dune near Eneabba carrying *Banksia hookeriana*.

0-6 cm	Light brownish grey sand, organic staining
6-30 cm	Yellowish brown sand
30-100 cm	Brownish yellow sand

4.2.2 *Vegetation types and associated plant species*

Banksia hookeriana is found within a vegetation type which has been variously called "scrub-heath" (Low and Lamont, 1990), *Banksia* heath (Elkington, 1988) and tall closed-heathland (George *et al.*, 1979) but would be called tall shrubland, or perhaps tall open shrubland, using the system of structural classification outlined in Appendix 1 (see Plate 4.1). Heathland proper occurs in the swales between the dunes, where the vegetation is, at maturity, mostly 1 to 1.5 m tall and the species composition is generally quite different (Hnatiuk and Hopkins, 1981). Obviously the height of plants in all structural formations depends on time since fire, but it is the height at maturity (8-10 years post fire) which is used for classification of northern sandplains vegetation. Beard (1976b; 1979b) gave the name Erindoon System to the vegetation complex associated with the Eneabba plain.

An intensive study by Low and Lamont (1990) at a site near Eneabba 12 years after fire found that *B. hookeriana* and two other *Banksia* species; *B. attenuata* and *B. menziesii* (all 1 to 2.5 m high) comprise 80% of the aerial biomass. Shrubs in the lower stratum, 0.25-1 metre high, contributed 18.5% of the aerial biomass, these were mainly *Beaufortia elegans, Eremaea beaufortioides* (Myrtaceae), *Conospermum tripilinervum* and *Petrophile* spp. (Proteaceae). Members of the Proteaceae contributed 84.3% of the total aerial biomass.

Small trees of *Eucalyptus todtiana* (Coastal Blackbutt or Prickly Bark) occasionally emerge from the tall shrubland but in general the vegetation formation which contains *B. hookeriana* throughout its range is similar in structure to that described by Low and Lamont (1990). There is a generally poor correlation between vegetation classifications based on physiognomy and those based on floristics in the northern sandplains (Hnatiuk and Hopkins, 1981; Griffin, 1992), however the vegetation associated with *B. hookeriana* could be placed within a *Banksia attenuata-B. menziesii-E. todtiana* alliance which is widespread on sandy soils in the southern part of the Irwin Botanical District (Griffin, 1992; 1993). Common species occurring with *B. hookeriana* east of Eneabba (Hnatiuk and Hopkins, 1981a; 1981b) and west of Eneabba (Elkington, 1988) are given in Table 4.2.

Plate 4.1. Tall open shrubland dominated by *Banksia hookeriana* and *Xylomelum angustifolium* in Lake Erindoon Reserve near Eneabba.

Plate 4.2. Young *Banksia hookeriana* (3 - 4 years-old) in remnant vegetation near Eneabba.

Table 4.2. Plant species commonly occurring with *Banksia hookeriana* on the northern sandplains.

East Eneabba	West Eneabba
Adenanthos cygnorum	*Andersonia heterophylla*
Banksia menziesii (Menzies Banksia)	*Banksia attenuata*
B. sphaerocarpa	*B. sphaerocarpa*
Conspermum triplinervum	*Beaufortia elegans*
Dryandra tortifolia	*Conospermum triplinervum*
Eremaea beaufortoides	*Eremaea beaufortoides*
E. violacea	*E. violacea*
Eucalyptus todtiana (Coastal Blackbutt)	*Eucalyptus todtiana*
Melaleuca acerosa	*Hibbertia crassifolia*
Pityrodia bartlingii	*Hibbertia* aff. *hypericoides*
P. hemigenioides	*H. furfurcacea*
Stirlingia latifolia	*Jacksonia floribunda*
Synaphea polymorpha	*Loxocarya fasciculata*
Thysanotus rectantherus	*Meleleuca acerosa*
Xylomelum angustifolium (Sandplain Woody Pear)	*Mesomelaena stygia*
	Xylomelum angustifolium

4.3 Conservation status in remnant vegetation

4.3.1 *Management effects on* B. hookeriana

As was explained in the section on distribution of this species it has a small natural range of about 400 km^2 and within this range *B. hookeriana* is restricted to the crests and slopes of sand dunes which make up a small proportion (probably less than 20%) of the land area. Much of the land within the home range of *B. hookeriana* has been cleared for agriculture or mining. Surveys done for the *Banksia* Atlas (Taylor and Hopper, 1988) found only 11% of *B. hookeriana* populations to be located within conservation reserves, a figure which is confirmed by this study. A breakdown of the vesting of the main range of *B. hookeriana* is given in Table 4.3.

Vesting	**Area (km^2)**
Private Property	220
Conservation Reserve	40
other Crown land	160
Total	**420**

Table 4.3. Distribution of potential *B. hookeriana* habitat by vesting.

From the data shown in Table 4.3 it can be seen that not only are the populations of *B. hookeriana* in remnant bushland potentially valuable as a source of cut-flowers but they comprise a significant proportion of the total area of this species existing in a more or less natural state. The various aspects of management of remnant vegetation as they impact on *B. hookeriana* both in regard to cut-flower production and its existence in these remnants, will be examined below.

<u>Fire</u>

Banksia hookeriana, a highly serotinous obligate seed regenerator, that is it only regenerates from seeds which are stored on the plant in woody cones until the plant is killed by fire. The optimum fire regime for *B. hookeriana* has been calculated to be 15 - 17 years (Enright *et al.*, 1995) to provide the maximum likelihood of successful recruitment of the next generation and to minimize resource wastage in a low-nutrient environment. However the recent interfire interval for areas of Northern Sandplains heathland ranges from 7-10 years (Enright *et al.*, 1995) to about 40 years in very limited areas (Lamont and Whitten, 1993).

One current producer recommended a fire rotation period of 10 years for rejuvenating stands so that plants produce the long, straight-stemmed blooms required by the market. The first flowers are produced at an age of 3 or 4 years and the highest production of marketable blooms occurs on 6 - 8 year old plants (Plate 4.2). After 9 or 10 years, stems are mostly short and crooked and few marketable blooms are able to be picked off most plants. At a plant age of 10 years Enright *et* *al.* (1995) found 200 - 250 viable seeds stored per *B. hookeriana* plant whereas at 15 years there are 750 - 850 viable seeds per plant. These figures are for unpicked plants, heavy picking has been shown to decrease viable seeds number per plant by 57%, both because of the removal of blooms and through a reduction in plant health (Witkowski *et al.*, 1994). Because viable seeds are only set after the age of 5 years, a fire at this time may lead to a rapid reduction in local population numbers as has been noted in several instances (Enright *et al.*, 1995; R. Smith, pers.observ.).

Although there may be around 100 viable seeds stored on *B. hookeriana* in a picked population burnt at 10 years of age, seedling mortality over the first summer was found to vary between 35% (spring burn) and 68% (autumn burn) (Enright and Lamont, 1989). The evidence suggests that 15 years between fires is sufficient for parent replacement by seedlings to occur in healthy populations but if the stand is affected by drought, disease or years of heavy picking there may be a decline in the population unless the interval is substantially longer. Plants that are dead before the fire are usually incinerated along with the seeds stored in their cones. If there are unusually dry conditions in the first year post-fire there may be a higher rate of seedling death. The value of the population as regards its current cut-flower potential must thus be balanced against the risk of a reduction in numbers of *B. hookeriana* in a stand.

Burning of *B. hookeriana* in remnant vegetation mostly takes place in late autumn after there has been some rain. Research has indicated that whereas autumn burning may cause more seedlings to be alive at the end of the first winter, later density-dependant thinning reduced the difference so that the number of seedlings per parent plant was identical at the end of the first summer (Enright and Lamont, 1989). Therefore, there appears to be little difference between spring and winter burning in regard to *B. hookeriana* recruitment, but burning in more open stands may be more easily achieved in autumn.

Recommendations: (1) Remnant vegetation being managed for the production of cut-flowers from *Banksia hookeriana* should not be burnt at intervals of less than 15 years. The interval should be 20 years or more for previously harvested stands.

Fertilizers

Fertilizer is generally not applied to stands of *B. hookeriana* to enhance production although there may be some accidental drift of fertilizer from paddocks. The species has been found to respond to increased levels of N, K and Ca (in conjunction with increased water) by producing significantly greater canopy size, cone mass and cone, follicle and seed numbers (Lamont *et al.*, 1994). However, all Australian Proteaceae are sensitive to high levels of phosphorus.

Harvesting

The effects of harvesting on the reproductive success and shoot growth of *B.*

hookeriana, have been the subject of a substantial amount of research by scientists from Curtin University (Obbens *et al.*, 1991; Witkowski and Lamont, 1994; Witkowski *et al.*, 1994). This research showed that the harvesting of 30% of the blooms from several heavily-picked Crown land populations of *B. hookeriana* near Eneabba (over an eight year period) led to a further 35% reduction in flower head production compared to unpicked populations. There were also marked (~50%) reductions in canopy size, number of fertile cones and viable seeds stored per plant in the picked populations. Although the effect of this sharp reduction in seed availability in the heavily picked areas on recruitment after fire has not been studied, it is expected that because there are less *B. hookeriana* seeds compared to those of other species there may be a decline in the population of this species (Lamont and Whitten, 1993).

The disproportionate reduction in the number of flowering heads produced on picked plants was attributed to a 56% reduction in the number of upper axillary growing points by the process of bloom removal. In order to obtain the required length of stem (~300 mm) on the bloom from wild plants pickers often cut within the zone of dead or senescent leaves (usually in 3 y.o. wood), where there are apparently few axillary buds (Obbens *et al.*, 1991). Consequently only 24% of cut stems resprouted and there was no compensatory growth in response to picking, bloom production per plant fell after picking because of the low level of resprouting after cutting and the low reproductive potential of the resprouts (Witkowski *et al.*, 1994). A much higher proportion of stems that had the flower head removed by cockatoos resprouted compared to picked stems (63% vs. 24%). It was proposed that this was due to the fact that cockatoos removed only the flower head and did not affect the axillary buds on the upper stem from where the next season's branches arise, whereas these were removed by pickers with the 300 mm of stem attached to the bloom (Witkowski *et al.*, 1994).

In addition to reducing the number of blooms produced per plant, heavy picking was also shown to coincide with an increase in the proportion of seeds released spontaneously because of the increased exposure to light and consequently higher temperatures within the more open canopy of the harvested plants. The number of seeds that were eaten by insect larvae in heavily picked plants was also greater compared to unpicked plants (16.6% vs. 12.8%) possibly because of greater exposure of follicles within the more open canopies to flying insects, or to a reduction of predator defences as a consequence of the stresses brought about by bloom picking (Witkowski *et al.*, 1994). Heavy picking over a long period was also found to remove a substantial proportion of nitrogen, phosphorus and other major nutrients from the above-ground pools of this nutrient-poor ecosystem (Obbens *et al.*, 1991).

Picking from the Crown land populations studied by the Curtin University researchers started when the plants were 5 years old, whereas picking from private property populations may start as early as 3 or 4 years. This difference may be because the private property plants where most picking is done (around the edge of the remnant) grow faster than those in large reserves. The "edge effect" of much larger and more productive *B. hookeriana* plants may be quite pronounced, and is presumably due to the greater access to water these plants have because they only have shallow-rooted pasture plants to compete with on one side of their canopy

(Plate 4.3). A small area (~1200 m^2) of 8 - 10 year-old plants near the edge of a remnant on farmland at Eneabba has been claimed to have produced the equivalent of 17,000 stems/ha per week which is substantially above the levels per hectare over eight years recorded by Witkowski *et al.* (1994) for Crown land populations.

While it appears likely that parts of some populations of *B. hookeriana* in remnant bushland produce more commercial blooms/plant than Crown land populations in the same area because of the "edge effect", this advantage (in terms of the reproductive potential of the plant) may be nullified by the proportionately greater harvest from these plants. There are instances where recruitment of *B. hookeriana* after fire in heavily picked remnants near Eneabba has been very successful but there are others where it has been poor. Whereas the farmer concerned blamed this poor recruitment of seedlings on the weather or grazing by sheep, it may have also been partly due to insufficient seed being stored in the canopy of the adult plants.

The effect of reduced *B. hookeriana* seed storage in the edge zone of remnant vegetation near Eneabba was evident for one stand near Eneabba which was accidentally burned only 5 years after the previous burn. Whereas seedling recruitment was poor around the edge (and there were many weeds), further into the stand recruitment was much better. It may be envisaged that the practice of picking mostly from the edges of stands, and subsequent poor germination or survival there may lead to contraction of the *B. hookeriana* populations towards the centre of the remnants.

Recommendations: (2) No harvesting of blooms should occur before the plants are 6 years old. (3) No more than 20% of blooms be harvested from plants between 5 and 8 years old and on these plants the cuts only be in 1 y.o. wood. (4) No more than 30% of blooms should be harvested from plants over 8 y.o. and the cuts on these plants be in wood less than 3 years-old. (5) No harvesting should occur for the year prior to an area being burnt.

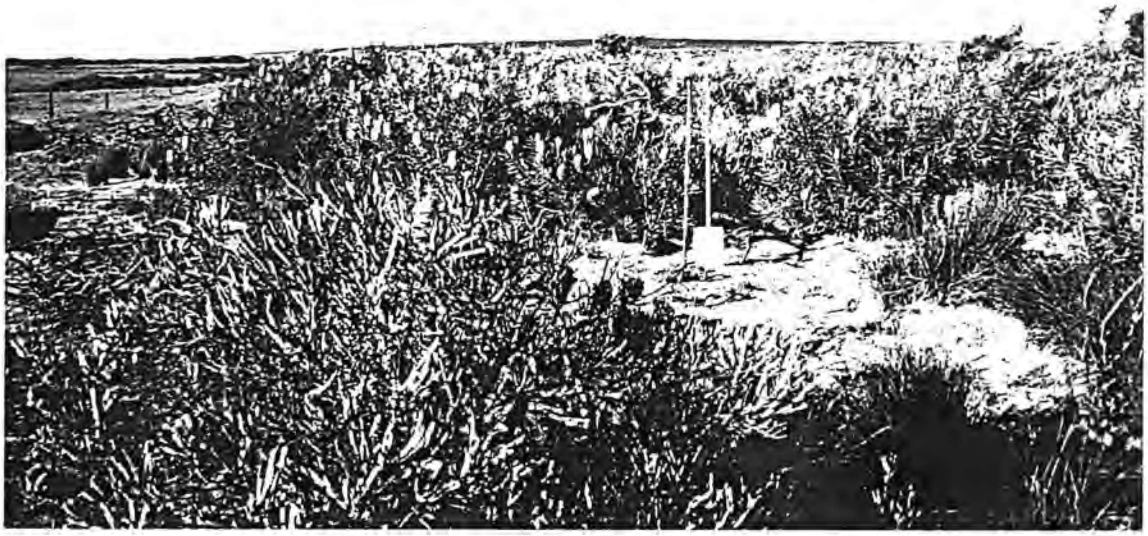

Plate 4.3. Four year-old stand of *Banksia hookeriana* near Eneabba showing larger plants associated with the 'edge effect'.

Plate 4.4. An area of heathland dominated by *Banksia hookeriana* that was burnt in 1988 and in 1994.

Disease

Banksia hookeriana had the fourth highest level of susceptibility to the dieback fungus *Phytophthora cinnamomi* of the 49 *Banksia* species tested by McCredie *et al.* (1985). Of 144 *B. hookeriana* plants inoculated with the fungus about 97% were dead after 396 days. Fortunately, however, root disease caused by the various species of *Phytophthora* does not appear to be very extensive on the northern sandplains yet. Small infections of various species of *Phytophthora* have been found around the sand mining operations and along roadsides near Eneabba which are probably due to the transporting in of mining machinery and roadbuilding activities (Hart, Simpson and Assoc., 1991). To date, these infections near Eneabba do not appear to have spread away from artificially created wet areas or natural drainage lines and so have not affected the typical *B. hookeriana* habitat which is quite dry. There is one record of a *B. hookeriana* death caused by *Phytophthora megasperma*. However, *P. citricola* has shown the ability to survive and kill plants on dry upland sites (Hart, Simpson and Assoc., 1991).

Some of the more mature stands of *B. hookeriana* in remnant vegetation in the Eneabba area exhibit high numbers of deaths of this species some of which may turn out to be as the result of pathogens. Harvesting of *B. hookeriana* takes place during the time of year when the pathogens are most active (Shearer and Tippett, 1989; Shearer, 1994). Thus there is considerable risk of spread of these diseases on the vehicles and footwear of wildflower pickers and hygiene measures should be implemented to protect vegetation being accessed for picking (see Appendix 2).

Recommendations: (6) Adequate hygiene measures should be undertaken to protect remnant vegetation being managed for the production of cut-flowers from *B. hookeriana* from plant disease. Among these measures would be the washing down of machines and footwear before it is taken into the bushland.

4.3.2 The effects of management on the ecosystem

Fire

More than 60% of the plant species occurring on the northern sandplains are capable of resprouting after fire (Bell *et al.*, 1984; Wills, 1989). Most obligate reseeders belong to the families Asteraceae (which are predominantly annuals), Mimosaceae and Epacridaceae. Of the plant species shown in Table 4.2 which commonly occur with *B. hookeriana* (which is itself a reseeder) only two, *Adenanthos cygnorum* and *Beaufortia elegans,* are known to be obligate reseeders. It is hypothesized by Bell *et al.* (1984) that the high proportion of reprouters to seeders in the Northern Sandplains vegetation compared to the chaparral shrublands of California (where it is *c.*44%) is a response to the greater environmental stress (including more frequent fires) acting on the Western Australian shrublands.

Because of the dominance of resprouters, canopy cover and above-ground biomass recover rapidly after fire in the Northern Sandplains to attain pre-fire levels at around 7 years (Bell *et al*, 1984; Delfs *et al*., 1987). This rapid re-attainment of pre-fire fuel levels means that the vegetation can sustain a fire as little as three years after the previous fire, although only under severe weather conditions (Delfs *et al*., 1987). The time from fire to peak flowering of the bulk of Northern Sandplains (non-annual) seeders varies from 3 to 7 years, with most species taking 5 years (Wills, 1989). Given that it will take several years after peak flowering is reached before sufficient seed is produced to replace the parents, it follows that if fires re-occur at intervals of less than 7-9 years some species will decline in numbers locally, or disappear.

The typical interfire interval of about 10 years for remnant vegetation on the Northern Sandplains would appear to be sufficient for most obligate reseeders to have set sufficient seed to successfully re-establish after fire. However, the proviso must be that other stresses (i.e. disease, drought) have not reduced the ability of species to produce the necessary propagules. The effects of drought appear to be more widespread in remnant bushland on the Eneabba Plain than in the nearby nature reserves which may be due to the build up of plant stress from a number of causes. Other stresses that act on remnants surrounded by farmland (i.e. grazing, fertilizer drift, wind erosion) may reduce the reproductive potential of the plant species, particularly the obligate reseeders, within them. If this is the case then 10 year fire intervals may not be sufficient to preserve all taxa. An area of remnant bushland burnt twice in the last eight years is shown in Plate 4.4, there was a high incidence of weeds and much bare ground here.

As noted above, it is recommended that remnant vegetation being managed for the production of cut-flowers from *B. hookeriana* be burnt at intervals of not less than 15 years because of the extra stresses placed on the vegetation by picking.

Plate 4.5. Soil erosion caused by cattle in an area of tall shrubland north of Eneabba dominated by *Banksia hookeriana*.

Plate 4.6. *Banksia hookeriana* planted in an area of degraded heathland near Coomberdale.

Grazing

Many privately-owned stands of remnant vegetation on the Northern Sandplains are not fenced off from livestock. The effect of grazing in removing native species is quite evident in the smallest remnants where it has often proceeded to the extent that only mallee eucalypts and a few large banksias are left and the understorey is composed of introduced pasture species. Areas where stock 'camp' may become denuded and prone to wind erosion (Plate 4.5). In fenced remnants where grazing may only be sporadic, or seasonal, the damage to the vegetation may be less noticeable. The results of transects done in remnant vegetation to assess the affect of grazing on canopy cover and species richness in remnants on the Eneabba Plain are shown in Figures 4.2 and 4.3.

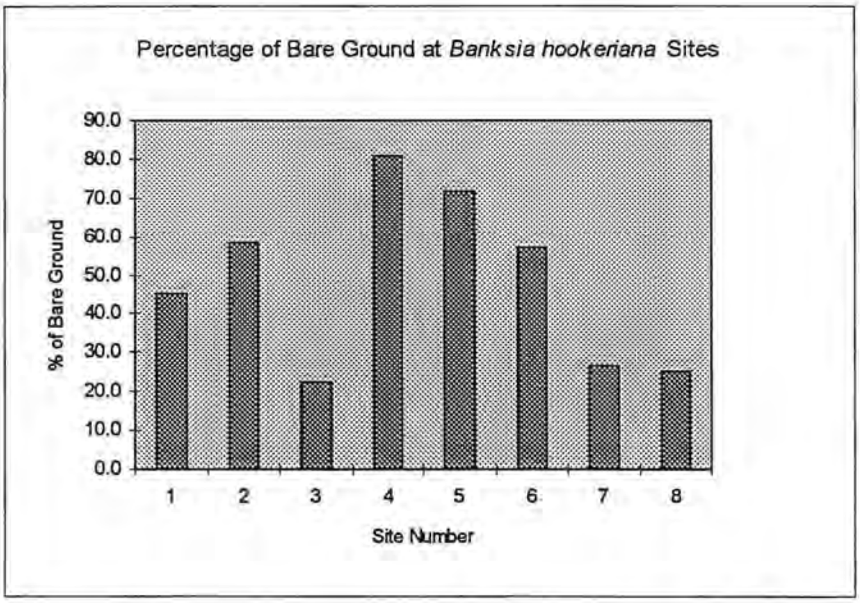

Figure 4.2. Percentage of bare ground measured along transects through vegetation containing *Banksia hookeriana* in remnant vegetation and conservation reserves. Site 1: Fenced remnant, long unburnt, has been grazed, Site 2: Unfenced, grazed remnant, burnt *c.* 1990, Site 3: Lake Logue Nature Reserve, burnt *c.* 1988, Site 4: Unfenced, grazed remnant, burnt *c.* 1990, Site 5: Unfenced, grazed remnant, burnt 1989, 1994, Site 6: Fenced, ungrazed remnant, burnt 1991, Site 7: Fenced, lightly grazed remnant, burnt *c.* 1985, Site 8: Northern Beekeepers Reserve, burnt *c.* 1985.

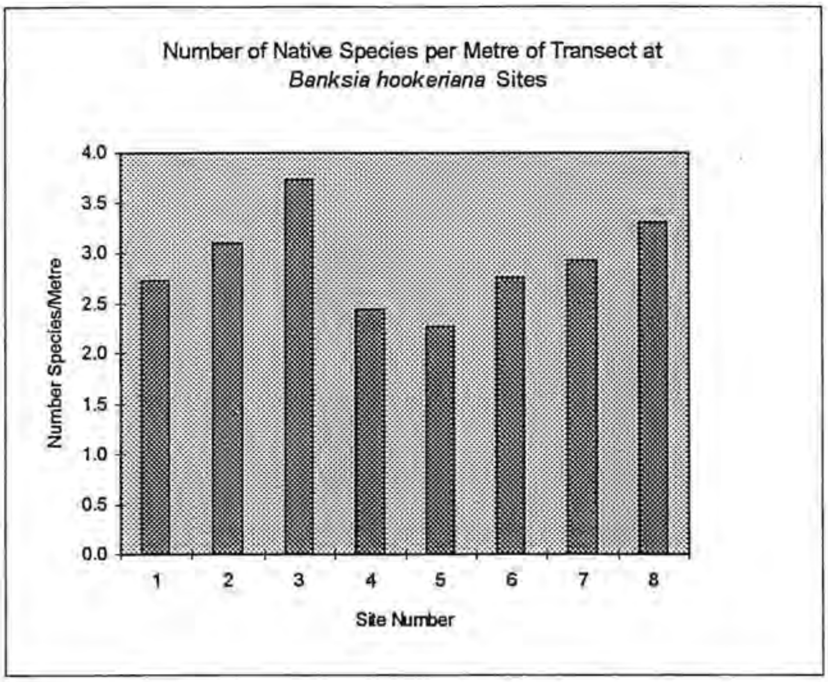

Figure 4.3. Species richness measured along transects through vegetation containing *Banksia hookeriana* in remnant vegetation and conservation reserves. Site numbers are as in Figure 4.2.

Recommendations: (7) Areas of remnant vegetation being managed for the production of cut-flowers from *B. hookeriana* should be fenced to exclude stock and should not be grazed.

Mining

Mining for mineral sands for ilmenite, rutile and zircon has taken place near Eneabba since 1974 (Baxter, 1979). Much of the recent mining has taken place on farmland in the Eneabba West area which includes remnant vegetation containing *B. hookeriana* (Elkington, 1988). Mining of the A.M.C. leases in this area is projected to remove the remnant vegetation which produced 25% of the total *B. hookeriana* stems picked from private property in 1994 (J. Lewis pers. comm.). Considering the large proportion of the total wild population of *B. hookeriana* which occurs in remnant vegetation the loss of any of these areas is of some concern.

Disease

Many of the species commonly found with *B. hookeriana* are also susceptible to disease caused by various species of the root fungus *Phytophthora* (Hart, Simpson and Associates, 1991). Species commonly found with *B. hookeriana* such as *B. menziesii, B attenuata, B. prionotes, Leucopogon striatus, Stirlingia latifolia, Adenanthos cynorum* and *Conospermum triplinervum* are all known to be killed by one of the *Phytophthora* pathogens in the Eneabba area.

While *P. cinnamomi* is the most common species and perhaps has caused the greatest impact in the area, it is generally limited to wet sites or to plants growing near drains (Hart, Simpson and Associates, 1991). The one species commonly found in dry sites and which perhaps presents the greatest danger to the species of *B. hookeriana* habitats is *P. citricola*.

4.4 General discussion

From the data presented above it is apparent that the 200 km^2 or so of potential *B. hookeriana* habitat (of which perhaps only 50% actually contains *B. hookeriana*) in private hands that is not yet cleared is a major part of the total in existence. Only a small portion of this is currently being managed for the production of *B. hookeriana* for cut-flowers however (accounting for *c.* 8% of total production), and most of the harvest comes from the crown land populations and from plantations. About 65% of the private property harvest of *B. hookeriana* stems comes from two farms near Eneabba. Therefore, potentially a much greater proportion of the harvest of *B. hookeriana* could come from remnant vegetation but there appears to be a number of factors working against this;

1. *Banksia hookeriana* is readily available from unvested Crown land, although many populations are old and have been heavily picked in the past,
2. Many of the remnant vegetation stands have been degraded by grazing and other factors, are old and do not appear to be an attractive proposition for harvesting,
3. Many farmers are reluctant to become cut-flower producers because the job cannot be mechanized,
4. The costs of managing for cut-flower production are perceived to outweigh the benefits.

Banksia hookeriana can be easily propagated and grows well without the need for irrigation, on northern sandplain soils outside its normal range (Mrs R. Tonkin, pers. comm.). Three or four year-old plants (planted in rows 2m x 3m) observed growing in an area of slightly degraded heathland near Watheroo had stem production exceeding that to be expected from naturally occurring plants of the same age in remnant vegetation (Plate 4.6).

Although there remain opportunities to increase the production of *B. hookeriana* for cut-flowers from remnant vegetation at least in the short-term, it is desirable that further effort is put into developing the silviculture of this geographically restricted species. The wild populations of *B. hookeriana* have almost all been harvested over the last ten years and although those on crown land are in a reasonably healthy condition compared to many banksia stands on the south coast it is perhaps only a matter of time before the stresses caused by harvesting combined with others brought by a succession of drought years for instance cause mass deaths or poor seedling recruitment after fire. In the longer term the major economic value of *B. hookeriana* in remnant vegetation could well be as a source of genetic material for improving the cultivated lines of this very popular cut-flower.

Recommendations: (7) That further research should be carried out into the plantation production of *B. hookeriana* and of methods of establishing it in degraded northern sandplains farmland.

Section 5

Dryandra formosa R.Br.

5.1 Distribution and climate

Dryandra formosa has a scattered distribution from near Stewart Road in Black Point Forest Block 25 km south-west of Nannup to Two Peoples Bay 25 km east of Albany and inland to the peaks of the Stirling Ranges and Table Hill (Fig. 5.1). The greatest concentration of populations is within the area bounded by Chitelup Hill, Mt Mitchell, Mt Lindesay and Table Hill. However, even within this area the distribution of *D. formosa* is discontinuous, being confined to pockets of suitable soils. Most populations would cover no more than 50 - 100 ha.

Annual rainfall within the area of occurrence of *D. formosa* varies from 700 mm in the Stirling Range to about 1200 mm in the Mt Lindesay-Granite Peak area with most populations receiving more than 1000 mm. The number of months when average rainfall exceeds effective rainfall ranges from 7.5 for the Stirling Range populations to 9 for the most southern populations (Bureau of Meteorology, 1979). It is likely, however, that the populations on the peaks of the Stirling Range actually have a more mesic climate than the figure given above indicates because the peaks are shrouded in mist or cloud for many days of the year (Courtney, 1993).

5.2 Habitat and vegetation

5.2.1 *Geology and soils*

Dryandra formosa predominately occurs on soils derived from crystalline metamorphic and igneous rocks, predominantly granites and gneisses, of the Precambrian Yilgarn Block. Exceptions to this are in the Stirling Range where the parent rock is sandstone of the middle Proterozoic Stirling Range formation and at Stewart Road where the parent material is Mesozoic sedimentary rock of the Perth Basin (Wilde and Walker, 1984; Muhling and Brakel, 1985).

Cainozoic deposits of laterite, produced by *in situ* weathering of the underlying rocks, mantle much of the Yilgarn Block and although *D. formosa* sometimes occurs on soils directly overlying granite or gneiss (as at Mt Clarence in Albany) it is predominantly found in soils with a high content of pisolithic gravel and there is often massive laterite at the surface. However, these lateritic soils are often thin, without a well developed pallid zone (Wilde and Walker, 1984) and the Precambrian basement rocks are close to the surface.

As mentioned above, *D. formosa* predominantly occurs in soils with a high lateritic content, on the Porongurup Range, Wilyung Hill and Pwakkenbak Hill (Mt

Barker) these are of the Barrow soil unit (Churchward *et al.*, 1988). Within the Barrow unit *D. formosa* occurs in the shallow gritty loams around the exposed granite and gneiss and downslope in gravelly yellow duplex soils. At Mt Clarence and Mt Martin near Albany the soils belong to the Gardner soil unit.. A podzol from near Mt Clarence in Albany which carries *D. formosa* is shown in Table 5.1 (Churchward *et al.*, 1988). Within the Gardner unit soils range from shallow, gritty loamy soils around the exposed granite and gneiss to iron podzols downslope. On the Torndirrup Peninsula *D. formosa* is found both on soils derived from granite (Gardner unit) and from limestone (Meerup unit). The calcareous soils of the Meerup unit are undergoing podzolization (Enright, 1978) but *D. formosa* appears to grow in both acidic podzols and alkaline soils.

Table 5.1. A podzol carrying *D. formosa* near Mt Clarence, Albany.

0-5 cm	dark brownish grey loamy fine sand
5-20 cm	grey fine sand
20-30 cm	light grey fine sand
30-100	very light grey fine sand

In the Table Hill, Mt Roe and Mt Lindesay areas *D. formosa* occurs on soils of the *Ly* division within the Lindesay unit and *Mty* division within the Mattaband unit (Churchward *et al.*, 1988). Within these units *D. formosa* is restricted to the summit areas of ridges and hills and the adjacent upper slopes where the soil is generally shallow gravelly sand, often with massive laterite near or at the surface. These soils would fit the description of Shallow Sandy Gravels (Worsley Series) or Yellow Brown Gravelly Sand (Lennard Series) of Tille (1993). *Dryandra formosa* tends not to be found on soils within these units that have low lateritic gravel contents; it is generally not found on the grey-brown gritty duplex soils of the Lindesay unit or the yellow gritty duplex soils of the Mattaband unit. A typical soil profile in the area of a *D. formosa* population at Table Hill Block is shown in Table 5.2.

Table 5.2. A sandy gravel carrying *Dryandra formosa* in Table Hill Block north-east of Walpole.

0-5 cm	dark grey gravelly sand
5-30 cm	yellow brown gravelly sand
30 cm +	yellow brown gravelly sand, lateritic boulders

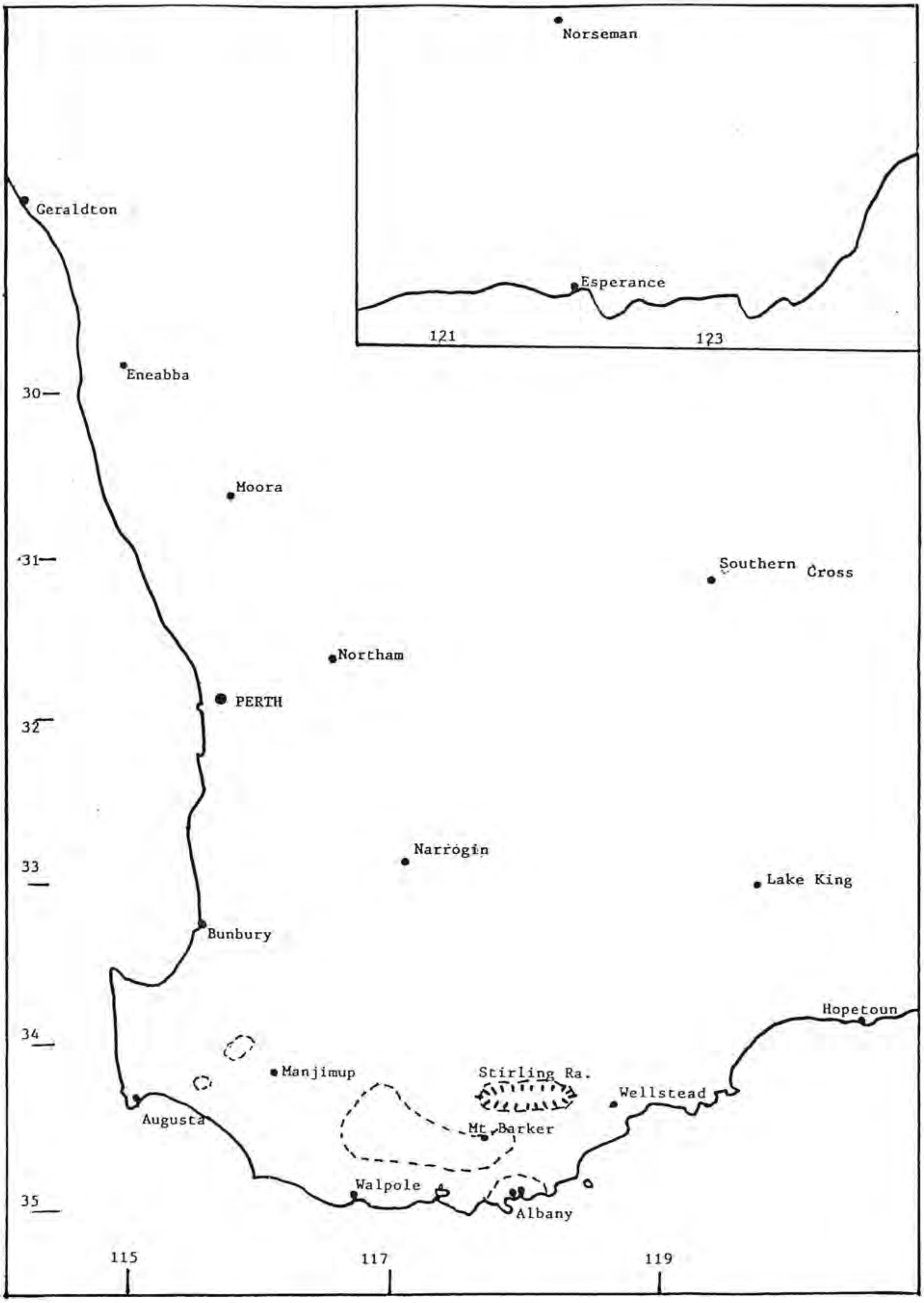

Figure 5.1. Distribution of *Dryandra formosa*.

The small populations of *D. formosa* west of Manjimup in the Mt Lewin and Yanmah areas are unusual in that they occur on alluvial red loams along valley bottoms and on lower slopes. In the Stirling Range *D. formosa* is found on skeletal soils derived from the underlying sandstone. These soils are a colluvium of fragments of sandstone, quartzite and ferruginous sandstone and superficial deposits of sand and muddy sand (Semeniuk, 1993). The Stewart Road population is growing on a soil similar to the boulder phase (lateritic boulders at the surface) of the Forest Grove Gravelly Sand of Smith (1951) or the Shallow Sandy Gravel of Tille (1993).

5.2.2 *Vegetation structure and associated plant species*

Most populations of *D. formosa* occur in jarrah-marri (*Eucalyptus marginata-E. calophylla*) forest or jarrah low forest, with the exceptions being the populations in the Stirling Range and on the Torndirrup Peninsula south of Albany which occur in closed heathlands or shrublands. However most of the non-forest populations occur in conservation reserves and are not harvested for cut-flowers or seed. In the Table Hill and Sharpe Block areas (Plate 5.1) the vegetation composition corresponds most closely to the Type S vegetation of Strelein (1988) which is classified as good to medium quality predominantly jarrah forest on lower fertility gravelly podzols. A list of some of the species that occur in areas carrying *D. formosa* at Table Hill is given in Table 5.3. The vegetation is similar in composition at Stewart Road and in the Mt Barker area. In the Yanmah and Mt Lewin areas west of Manjimup on nutrient-rich alluvial loams the forest resembles Strehlein type Q and U. At the Mt Martin Reserve NE of Albany where the densest populations of *D. formosa* are found (Plate 5.2), the vegetation is a low jarrah or *E. staeri* forest. Common species at Mt Martin are listed in Table 5.3.

Plate 5.1. Unpicked *Dryandra formosa* in jarrah-marri forest in Sharpe Block north of Walpole.

Plate 5.2. *Dryandra formosa* (1.5 - 2 m high) in the Mt Martin Reserve near Albany.

Table 5.3. Plant species commonly co-occurring with *Dryandra formosa* in low forest on gravelly soils at Table Hill Forest Block NE of Walpole and at Mt Martin Reserve near Albany.

Table Hill	Mt Martin Reserve
Acacia extensa	*Acacia drummondii*
Agonis hypericifolia	*Agonis hypericfolia*
Bossiaea ornata	*Banksia grandis* (Bull Banksia)
Daviesia preissii	*Bossiea linophylla*
Eucalyptus calophylla (Marri)	*Crowea angustifolia*
E. marginata (Jarrah)	*Eucalyptus calophylla*
Hakea amplexicaulis	*Eucalyptus marginata*
H. lissocarpha (Honey Bush)	*Grevillea pulchella*
H. ruscifolia	*Hakea varia*
Hovea elliptica (Oval-leafed Hovea)	*Leucopogon verticillatus*
Leucopogon australis	*Loxocarya fasciculata*
L. propinquus	*Petrophile diversifolia*
Loxocarya fasciculata	*Xanthosia rotundifolium*
Macrozamia reidlii (Zamia Palm)	
Petrophile diversifolia	
Xanthorrhoaea preissii (Blackboy)	

On the Torndirrup Peninsula *D. formosa* occurs in a a wind-pruned heathland on podzolic and calcareous soils over granite, and around granite outcrops. Enright (1978) has shown that the podzols and non-podzols carry a somewhat different suite of plant species but *D. formosa* appears to be one of the species which occur on both soil types. A list of some of the species co-occurring with *D. formosa* in heathland on calcareous soils near Cable Beach on the Torndirrup Peninsula is given in Table 5.4. On the peaks of the Stirling Range *D. formosa* occurs in tall closed shrubland (called a thicket by Beard) with a relatively consistent floristic composition between peaks. A few of the peaks carry stunted jarrah and marri but otherwise there are almost no species in common with the vegetation at other *D. formosa* populations. A list of the characteristic species of the tall closed shrubland of the Stirling Range peaks (Beard, 1979a) is given in Table 5.4.

Table 5.3. Plant species commonly co-occurring with *Dryandra formosa* in wind-pruned heathland on the Torndirrup Peninsula and in tall closed shrubland on the peaks of the Stirling Range.

Torndirrup Peninsula	Stirling Range
Adenanthos sericeus (Wooly Bush)	*Acacia drummondii*
Andersonia simplex	*Andersonia echinocephala*
Hakea trifurcata	*Banksia solandri*
Mesomelaena tetragona (Semaphore Sedge)	*Beaufortia decussata*
Olearia axillaris (Coast Daisy Bush)	*Isopogon latifolius*
Pimelea ferruginea	*Kunzea recurva* var *montana*
Scaevola nitida (Shining Fan-flower)	*Oxolobium atropurpureum*
Spyridium globulosum	*Sphenotoma* aff. *dracophylloides*

5.3 Conservation status in remnant vegetation

5.3.1 *Management effects on* Dryandra formosa

Fire

Little is known about the ecology of *D. formosa* in the wild and data gathered during this study and an associated monitoring project of the species at several Crown land populations has provided much of the ecological information reported here. Information on the seed biology and germination of *Dryandra* species in general is given by Alcock (1991, 1992). *Dryandra formosa* is an obligate seed regenerating species and is killed by fire. However fire is not necessary for germination and seedlings may appear in any season once mature plants are present (Mr R. Pickles, pers. comm.). The seeds (there are one or two) are contained within a woody follicle, there may be 4 to 7 follicles per seed head. Seed maturation takes several months after which the follicles open and the seed is dispersed onto the ground, the seeds are winged so to some extent they are wind dispersed.

After emergence growth may be slow. Most seedlings in jarrah forest near Stewart Road 45 km east of Augusta were less than 15 cm high 2 years after germination following fire. Growth rates may be higher in shrublands or where canopy cover is less. The first flower heads on most plants at Table Hill north of Walpole appeared in the fourth year after an autumn fire. However at this age there were less than 3 flower heads per plant.

Pollination rates may vary substantially, 4 year-old unpicked plants at Table Hill monitored during 1995 had a 63% rate of fruit set (i.e. proportion of flowers that developed into fruit) whereas the 7 year-old population at Mt Martin had a 47% fruit set. The level of seed predation may be high on older plants. All of the mature seed heads from a sample of the 1994 flowering of 12 year-old plants at Table Hill were predated. The seed viability of *D. formosa* (as tested by tetrazolium chloride) was much lower (10%) than the three other obligatory reseeder species of *Dryandra* tested by Bell *et al.* (1987) which all had 50% viability or more. However like the other reseeder *Dryandra* species it had a high germination rate.

From the preliminary data available it appears unlikely that *D. formosa* growing in jarrah forest (from which most commercial stems are picked) has produced enough viable seed for parent replacement till about 8 years after fire. The 4 year-old plants at Table Hill averaged only 1 fruit per plant. *Dryandra formosa* is only slightly serotinous and probably most seed is shed from the hard follicles within the first 18 months after maturing. After 2 years fruit that has not opened and dispersed its seed is very likely to have been predated. It is not known how long dispersed seed of *D. formosa* remains viable. However, it does not have a hard coat and is likely to be the last flowering before fire that is most important in determining the seedbank available for regeneration.

Because of its lack of serotiny and dependence on seed regeneration *D.*

formosa is vulnerable to too frequent fire. If fire recurs within 3 or 4 years regeneration may be very poor because of an insufficient aerial seed store or seedbank. No enough research has been carried out to date to be able to recommend an ideal interfire period for *D. formosa* but it is unlikely to be less than ten years and probably more than this in harvested populations.

Dryandra formosa has disappeared from much of the area it once inhabited around Mt Barker. Partly this has been because of complete clearing of the native vegetation, but it is also no longer present in much of the remnant vegetation. To a large extent this is because of grazing pressure (see below) but too frequent fire must also have played a part. Although the burning of remnant vegetation was quite frequent in the past, primarily because of escapes from clearing burns (e.g. Rodger, 1961), it is now rare except for on roadsides and shire reserves. The two largest *D. formosa* populations on private property in the Mt Barker area, covering 30 ha and 100 ha, have not been burnt for 12 and 22 years respectively. Both of these populations occur on steep hillsides and because fuel levels are high prescribed burning would be difficult to control. The understorey of other, heavily grazed, remnants is either sparse or composed of annual grasses.

Recommendations: (1) The minimum time between burns in remnant vegetation that is being managed for the production of cut-flowers from *D. formosa* should be 12 years. (2) If the population has been harvested this interfire period should be no less than 15 years.

Fertilizers

Fertilizer is not applied to *D. formosa* growing in remnant vegetation, however there is probably some influx of fertilizers applied to pasture. Like all other Proteaceae *D. formosa* would be sensitive to relatively high phosphorus levels and drift of superphosphate into remnant vegetation should be prevented

Recommendation: (3) Remnant vegetation being managed for the production of cut-flowers from *D. formosa* should not be fertilized.

Harvesting

Harvesting of *D. formosa* generally requires that about 30 - 40 cm of the stem is taken with the bloom, however there has lately been some demand for shorter stems for placement into woven baskets. On wild plants of up to 7 - 8 years old most of the main stems are of commercial length but on older plants many of the stems are shorter and often too thick. Over-harvesting when the plants are young, which is much in evidence in crown land populations around Mt Barker and Table Hill (Plate 5.3) may kill the plants or leave them misshapen. The general consensus amongst producers spoken to during this survey is that the plants not be harvested till they are 4 years old. However the monitoring of wild populations to date indicates that most plants have set only one fruit at 4 years.

The level of harvesting of individual plants varies but is generally higher on younger plants (30 - 50% of blooms) than on older plants on which the proportion of commercial stems is lower. Considering the dependence of the species on reproduction by seed the level of harvesting should be no more than about 20%, especially on younger plants and harvesting of wild populations should not start till the fifth or sixth year. Of 80 four year-old plants being monitored in State forest north-east of Walpole not one had more than 3 commercial length (30 cm) stems. Harvesting for seed collection, which only requires that the flower-head be taken, is potentially less damaging to younger plants. It has a greater potential to reduce the availability of seed in a given area because only pollinated flowers are taken. The small amount of *D. formosa* seed collected from the wild means that this deleterious effect would only be localized.

Recommendations: (4) Plants should not be harvested until they are 6 years old, or have produced at least 5 main lateral flowering stems. (5) No more than 20% of flowering stems be harvested from plants less than 8 years-old. (6) No more than 30% of flowering stems be harvested from plants older than 8 years. (7) Harvesting should not occur in area in the flowering season immediately before a prescribed burn.

Disease

Dryandra formosa is susceptible to the pathogenic root fungus *Phytophthora cinnamomi* however the disease is not widespread in most populations. There appears to be small *P. cinnamomi* infections in the Mt Martin population (which is a flora reserve) and at Table Hill Block - which is the most heavily picked crown land area. Dieback caused by *P. cinnamomi* has also severely affected shrublands in the Stirling Range National Park (Wills, 1993) in which *D. formosa* is an important component (Beard, 1979a). A weak fungal pathogen, *Pestalopsis* sp., has been recovered from leaf lesions in a number of proteaceous species occurring with *D. formosa* west of Mt Barker which, together with drought stress, may be contributing to the decline of the vegetation in the area (C. Robinson, pers.comm.)

The harvesting period for *D. formosa* blooms (mid August - late September) unfortunately occurs at the time of year when the potential for spread of soil-borne fungi like *P. cinnamomi* is at a maximum (Shearer, 1994). Therefore great care should be exercised during the harvesting process to avoid introducing the pathogen or spreading it within a population by the movement of soil (see Appendix 2).

There are also signs of aerial canker fungus affecting some of the coastal populations of *D. formosa* and new licence conditions brought in for the harvesting of this species from crown land specify that secateurs be disinfected between plants to help prevent spread of the fungi.

Recommendations: (8) Remnant vegetation being managed for the production of cut-flowers from *D. formosa* should be protected from the introduction or spread of plant diseases by the application of appropriate hygiene measures such as the washing down of machinery, vehicles and footwear before it enters the area.

Pruning

Pruning is a commonly used method to improve the production of commercial blooms in plantations and there is some evidence that it also works well for *D. polycephala* growing in remnant vegetation (Hussey and Wallace, 1993; pp. 189-190). More research into appropriate pruning methods for wild *D. formosa* needs to be carried out before precise recommendadtions can be made. Tip-pruning of 12-18 month-old seedlings to increase the number of lateral branches has been reported to be successful in remnant vegetation *D. formosa* near Mt Barker.

5.3.2 The effects of management on the ecosystem

Fire

Prescribed fire is not used frequently in the management of *D. formosa* in remnant vegetation although most crown land populations undergo regular fuel reduction burns. As discussed above *D. formosa* is vulnerable if fire recurs before it has produced enough viable seeds to replace the parent plants and the same is true of all other obligate seed regenerators that occur with it. Obligate seed regenerators comprise about 30% of the jarrah forest species (Bell and Koch, 1986) but comprise almost all of the soil-stored seedbank (Vlahos and Bell, 1986). Prescribed burns are carried out in the State forests and reserves managed by CALM at intervals of 6 - 10 years. Studies have shown that recurrent fires at intervals as short as 6 years in jarrah forest cause no long-term change in species composition (Christensen and Abbott, 1989), however the situation in bushland remnants surrounded by pasture may be quite different. A combination of frequent fire with influxes of weed propagules and fertilizer together with the changed environment of remnant edges and grazing pressure may cause irreversible changes in the species composition of the remnant. The recommendation made in the previous section is that the minimum interfire period in remnant vegetation being manged for the production of cut-flowers from *D. formosa* be 10 years.

However, while in the past too frequent fire may have caused deterioration in bushland remnants containing *D. formosa* this appears to be no longer the case. The remnants visited during this survey were either long-unburnt or had been severely damaged by livestock grazing.

Grazing

Livestock grazing has probably caused most damage to remnant vegetation containing *D. formosa* since the widespread burning associated with land clearing ceased over thirty years ago. Several remnant vegetation patches visited in the Mt Barker area had been so severely affected by grazing that there were only 7 - 10 native species per 100 m^2 compared to the usual 30 - 50/ 100 m^2 for jarrah forest (Worsley Alumina Pty Ltd, 1985). Surprisingly there were few weed species in these remnants, perhaps because of shading by the canopy of jarrah and marri, and the ground was covered by a thick canopy of leaves (Plate 5.4). The *D. formosa* in these grazed remnants were tall and misshapen from past harvesting. In contrast to long unburnt populations in reserves there was no sign of interfire establishment of seedlings and it is probable that these are killed by sheep soon after emerging.

An assessment of the health of the *D. formosa* in these remnants compared to those in a nearby reserve which has been illegally picked in the past is shown in Fig. 5.1. It can be seen that the private property population is more unhealthy and that twice as many of the plants are dead in comparison to the reserve population. It should be noted that the reserve (managed by the local authority) has been heavily picked, illegally, for many years and this population is in a poor state of health compared to more protected populations such as those at Mt Martin.

The amount of damage caused by grazing and livestock use of remnants in general is dependant on the size of the remnant. That is, smaller remnants with a greater edge to area ratio are more seriously affected by grazing, and disturbance generally, than larger remnants (Laurance, 1991). One large producer lets his sheep graze through 500 ha of bushland from which he has been picking *D. formosa* for 8 years with no concern that damage would be done to the plants. Interfire establishment of *D. formosa* takes place within this remnant so grazing pressure is probably quite low. However he also reported unexplained deaths of *D. formosa* and the bush is more open than it would otherwise be.

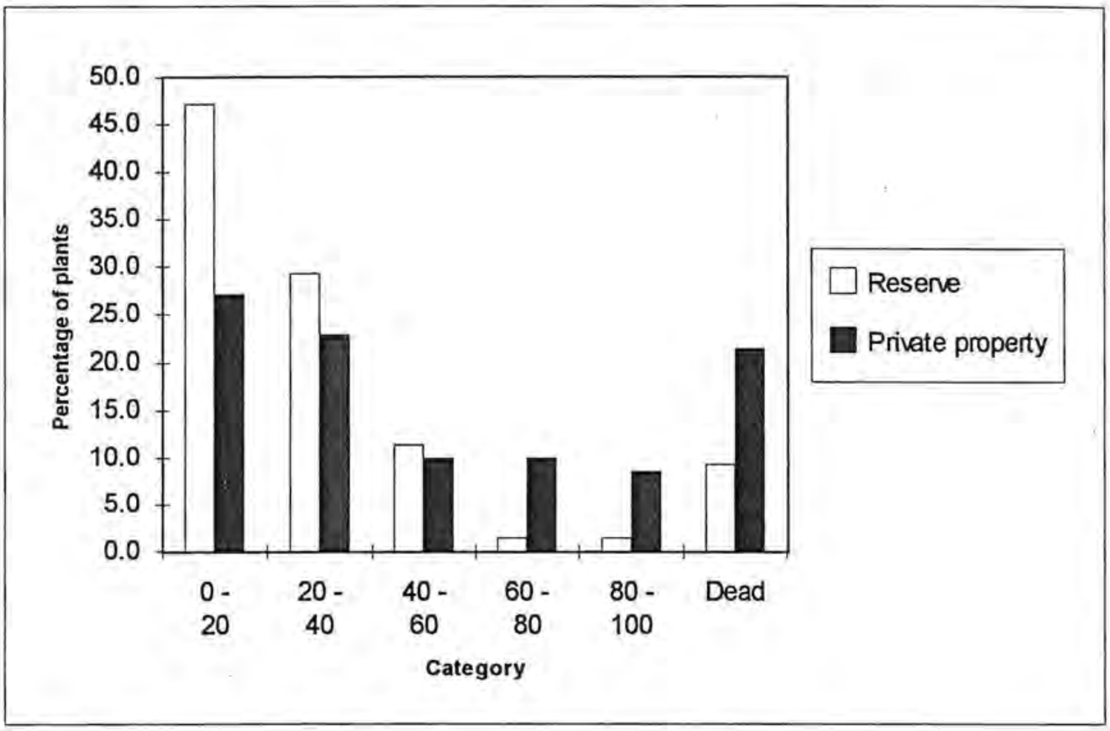

Figure 5.2. Percentage of *Dryandra formosa* in various health categories at two sites near Mt Barker. The reserve had been heavily picked (illegally) for cut-flowers and the private property remnant had been picked and is currently open to grazing by sheep. The health category indicates the approximate percentage of dead leaves on individual plants.

Recommendations: (9) Remnant vegetation being managed for the production of cut-flowers from *D. formosa* be fenced to exclude livestock and not be grazed.

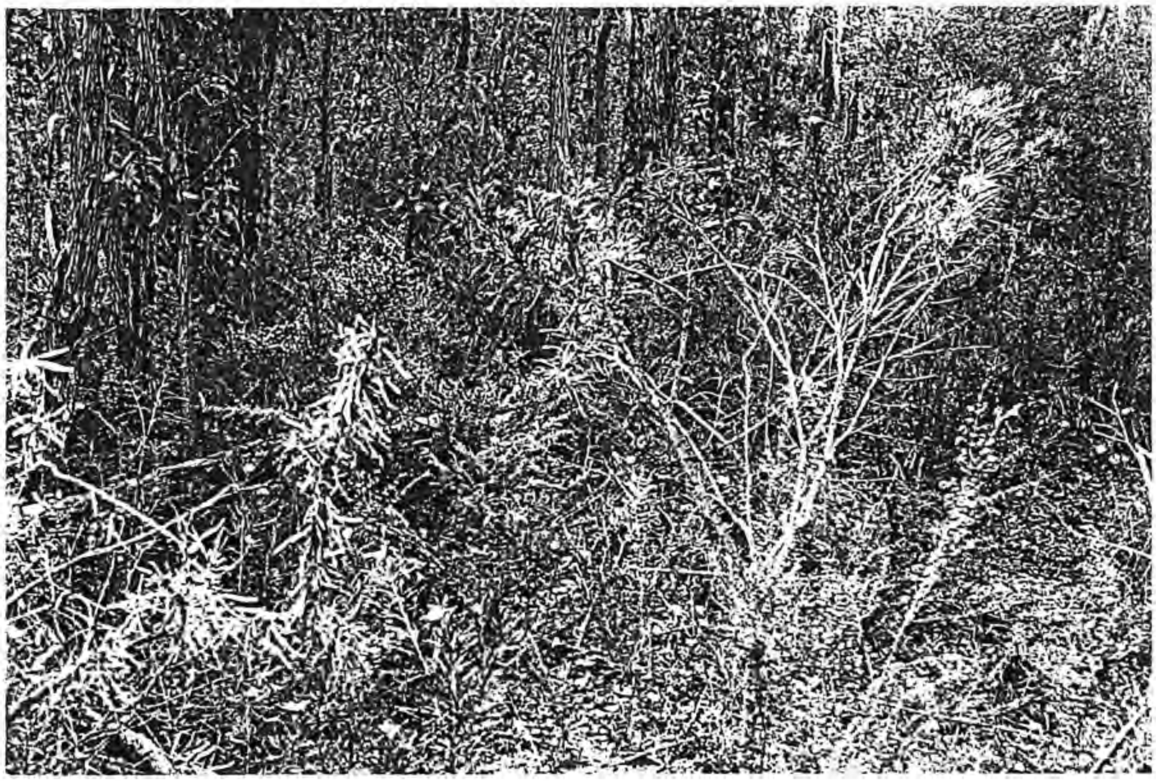

Plate 5.3. *Dryandra formosa* plants at Yanmah west of Manjimup that have been heavily harvested over many years.

Plate 5.4. Previously harvested *Dryandra formosa* in grazed remnant vegetation near Mt Barker.

5.4 General discussion

In 1980/81 438,000 stems of *D. formosa* were harvested (Burgman and Hopper, 1982); the total harvest had fallen seven-fold to 57,000 by 1993. This huge fall in the total production of *D. formosa* may be ascribed to two main causes. Firstly, many private property populations have disappeared or have been severely degraded due to clearing and grazing. Secondly most of the populations on reserves and in State forest are now "old" and have been heavily picked over many years and so have few commercial quality stems.

Although the most extensive populations of *D. formosa* occur in State forest, flora reserves and national park the species is under threat in all of these areas. Fungal disease is present in most populations, although in State forest the infections are minor. Illegal harvesting in conservation reserves is an ongoing problem. Recent changes to wildflower picker licence conditions have attempted to address the problems of harvesting from plants that are too young, overharvesting of plants and spread of disease. The extent to which these conditions are being observed will be determined by monitoring. While limitations on access for wildflower pickers and others may help control the spread of soil-borne pathogens controlling the spread of air-borne fungi is a more intractable problem.

Non-plantation private property populations of *D. formosa* represent only a small proportion of the total, perhaps as little as 10 percent. In 1993 remnant vegetation was the source of only 4% of private property production of *D. formosa* compared to about 15% from plantations. Although a greater proportion of the harvest of *D. formosa* could be sourced from remnant vegetation (and has been in some years) it is probable that plantations will provide the bulk of production within five years. There are a number of reasons for this. Firstly picking in State forest, especially in the Table Hill - Mt Roe area which has the most extensive populations, is being phased out over the next four years. Remnant vegetation has the potential to make up some of this future shortfall, but it will be most easily covered by production from plantations.

Dryandra formosa is easy to cultivate and will grow well in south coastal areas without the need for irrigation (Plate 5.5). Following initial pruning of the single shoot 6 months after planting specimens in the Mt Barker and Walpole area have borne 30 to 40 commercial stems four years after planting out as seedlings. At this age in the jarrah forest plants are usually still single-stemmed and only just producing their first flowers. However a lot more *D. formosa* needs to be planted to make up the projected shortfall.

It is possible to produce *D. formosa* from remnant vegetation in a sustainable way and improved management practices may increase the level of production from currently harvested areas. However the potential to increase the area of privately-owned remnant vegetation harvested for *D. formosa* is very limited. A number of areas open to continuous grazing are probably too degraded to support natural regeneration and the economic benefits of regenerating them to produce *D. formosa* cut-flowers is dubious, which is not to say that they should not be fenced off from stock. Much of the other naturally occurring *D. formosa* is old or senescent and occurs in steep forested country with heavy fuels. The economics of producing *D. formosa* cut-flowers from these areas must be quite marginal. One farmer, who has probably the largest privately-owned population of *D. formosa,* has picked it in the past when time has allowed but did not do so this year because he was too busy on the farm.

Another farmer near Mt Barker does not pick his naturally occurring stands of *D. formosa* for cut-flowers any more but uses them as a source of seed for sale and for raising seedlings which he then plants in small areas of recently burnt bushland on his farm. The seedlings are planted into lightly cultivated soil and pruned 6 months later. Their rate of growth has been almost as good as those in pasture-based plantations because they have little competition for the first few years until the understorey shrubs regenerate.

In the long-term private property populations of *D. formosa* in remnant vegetation are probably more valuable as sources of seed for plantations. Certain precautions would need to be taken to ensure the sustainability of this harvesting. As with reseeder banksias no more than 20% of seed-heads should be taken from individual plants, especially those younger than 8 years. A years "rest" from harvesting should occur before prescribed burning and burning should not be carried out less than 10 years after the previous fire. Hygiene measures to prevent the introduction or spread of fungal pathogens should be rigorous.

Recommendations: (10) The many advantages of producing plantation-grown *D. formosa* be promoted and further research be carried out into improving strains and horticultural methods.

Plate 5.5. *Dryandra formosa* (3 year-old) in cultivation near Walpole.

Section 6

Leptocarpus scariosus R.Br.

6.1 Distribution and climate

Leptocarpus scariosus is found from near Gingin in the north to Two Peoples Bay in the south and inland as far as Northam and Lake Muir (Fig. 6.1). It occurs in swampy areas on the Swan Coastal Plain and in the jarrah forest on the Darling Plateau but is most common along the south coast from Augusta to Albany.

The climate over its range is mediterranean with a winter rainfall maximum which is less pronounced in the south. *Leptocarpus scariosus* is found mainly within the humid and perhumid rainfall regions (Gentilli, 1972). Rainfall totals vary from 700 mm for its northern and inland range limits to 1400 mm in the far south between Windy Harbour and Denmark and the number of months when average rainfall exceeds effective rainfall ranges from 6 in the north near Perth to 10 on the south coast (Bureau of Meteorology, 1979).

6.2 Habitat and vegetation

6.2.1 *Geology and soils*

Leptocarpus scariosus is predominantly found in swampy areas among podzolized Pleistocene sand dunes with subdued relief. On the Swan Coastal Plain and on the Scott Plain this soil association is referred to as Bassendean Sand (Geological Survey of Western Australia, 1975). Along the south coast *L. scariosus* is mainly found on humus or peaty podzols (Table 6.1) of the Blackwater, Owingup and Kordabup land units (Churchward *et al.*, 1988). Inland on the southern edge of the Darling Plateau *L. scariosus* is found on humus or peaty podzols within the Caldyanup and Pingerup land units which form broad, poorly-drained plains between ridges (Churchward *et al.*, 1988). Within these land units *L. scariosus* is particularly associated with ephemeral or permanent swamps and the margins of lakes and streams.

On the Blackwood Plateau and northern Darling Plateau there are scattered occurrences of *L. scariosus* in wet, acid, leached peaty podzols in broad valleys and depressions (McCutcheon, 1980; Havel, 1975).

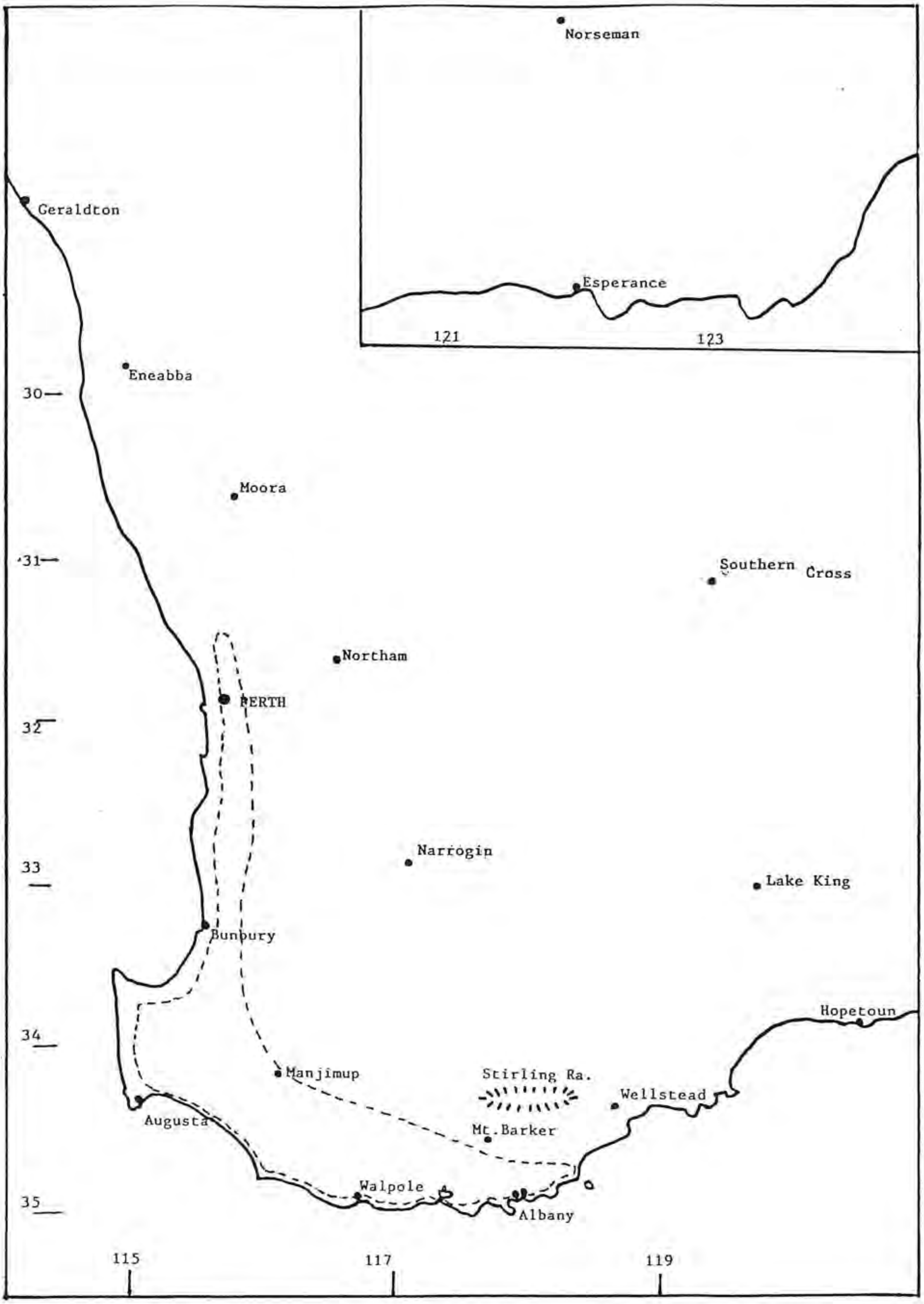

Figure 6.1. Distribution of *Leptocarpus scariosus.*

Table 6.1. A humus podzol typical of those on which *Leptocarpus scariosus* occurs within the Pingerup soil unit south of Northcliffe.

0-15 cm	black peaty sand, much root material (pH 5.4)
15-30 cm	very dark grey sand (pH 5.3)
30-60 cm	light grey moist sand (pH 5.0)
60-95 cm	dark brown indurated sand (pH 4.7)

6.2.2 *Vegetation structure and associated plant species*

Leptocarpus scariosus can be found in a range of vegetation structural types from woodland to sedgeland. In the northern jarrah forest it is found in *Melaleuca preissiana-Banksia littoralis* woodland, *Eucalyptus marginata-E. calophylla* woodland and on the margins of creeks and swamps within *E. patens-E. megacarpa* forest (Havel, 1975). On the Swan Coastal Plain *L. scariosus* is found in sedgelands in association with *Lepidosperma* spp. or in open shrublands in association with *Melaleuca* spp. and *Astartea fascicularis* around and in freshwater swamps (Halse *et al.*, 1993).

On the Scott Plain and eastwards to Two Peoples Bay *L. scariosus* is found in open shrublands, heathlands, closed heathlands, tall closed shrublands, low open woodlands, and in sedgelands around the margins of lakes and swamps (McArthur and Clifton, 1975; Halse *et al.*, 1993; pers.observ.). Within the shrublands, heathlands and woodlands *L. scariosus* is mostly found along the edges of small watercourses or at the edges of swamps. *Leptocarpus scariosus* commonly occurs within the *Beaufortia sparsa-Homalospermum firmum* closed heathland association (see Section 2) which is found from the Scott Plains to Two Peoples Bay east of Albany (Plate 6.1). The sedgeland formation on the Scott Plain occurs in circular sandy depressions which are seasonally inundated, *L. scariosus* and several other Restionaceous rushes and Cyperaceous sedges form a dense sward typically 0.8-1.2 metres high with scattered shrubs to 1.5 metres (Robinson, n.d). Around the edge of the depression taller shrubs and some low trees are often found (Plate 6.2).

At Lake Powell near Albany *L. scariosus* occurs with several other rushes below a low forest of *Agonis juniperina* and *Melaleuca* sp. just below or at the water mark. Field observations indicate that *L. scariosus* can withstand some inundation but it appears not to be found in areas that are flooded for more than a few months. However little is known about the effect of duration of inundation on the distribution of wetland plant species in Western Australia. Plant species found with *L. scariosus* in a sedgeland at Lake Moates near Albany (Halse *et al.*, 1993) and a closed heathland on the Scott River plain (N. Gibson, pers.comm.), are given in Table 6.2.

Plate 6.1. *Leptocarpus scariosus* in remnant vegetation near Northcliffe. This area has been harvested for 8 years, most plants in the foreground are male.

Plate 6.2. *Leptocarpus scariosus* in depression within remnant vegetation on the Scott River plains.

Table 6.2. Plant species occurring with *Leptocarpus scariosus* in a sedgeland (Lake Moates near Albany) and a heathland (Scott River) on the south coast of Western Australia.

Lake Moates	Scott River
Anarthria scabra	*Amperea volubilus*
Dampiera sp.	*Baumea articulata*
Evandra aristata	*B. vaginalis*
Leptocarpus coangustatus	*Boronia juncea*
Leptocarpus scariosus	*Cyathochaete clandestina*
Stylidium scandens	*Hakea ceratophylla*
Xanthosia rotundifolia	*H. linearis*
	Lepidosperma logitudinale
	Leptocarpus diffusis ms
	L. scariosus
	L. tephrinus
	Melaleuca lateritia
	M. polygaloides
	Restio applanatus

6.3 Conservation status in remnant vegetation

6.3.1 *Management effects on* Leptocarpus scariosus

There has been little research into the ecology of rushes (members of the Restionaceae) until recent years even though they are important members of most south-west Australian vegetation communities. However some pioneering work into their basic biology has recently been carried out by scientists at the University of W.A. and Kings Park and Botanic Gardens. Information on the ecology of *L. scariosus* reported here is based partly on that research and partly on field observations by myself, Mr C. Robinson (Agriculture W.A., Albany) and several producers.

In some situations *L. scariosus* sedgelands appear to be a successional stage in a transition from open water to shrublands, woodlands and even forests. As lakes dry out, or are made shallower by influxes of sediment, the bare ground may be colonized by *L. scariosus* and sometimes other rushes and sedges, which can persist if flooding is only seasonal and of several months duration. In time the wetland may further dry out, partly because of the presence of *Leptocarpus*, so that shrubs such as *A. parviceps* and *Beaufortia sparsa* can establish. The presence of shrubs probably reduces the growth of *L. scariosus* and certainly makes harvesting it more difficult. It is at this stage that producers look at rejuvenating the stand. As well as allowing seedling *L. scariosus* to establish in the absence of competition, the removal of competing vegetation by ploughing or burning probably causes the water table to rise somewhat which is also more favourable to the rush. The ramifications of such management practices and their effect on the vegetation are discussed below.

Fire

Leptocarpus scariosus is a seed regenerator with a relatively small rhizome in comparison to its above-ground parts. The perrenating buds in the rhizomes of *L. scariosus* are shallow and the plant is usually killed by fire (Pate *et al.*, 1991) (Plate 6.3). If the fire occurs when the soil is saturated or inundated the plant may survive if the rhizome is sufficiently insulated from heat. For this reason if burning is used as a method of rejuvenating stands of *L. scariosus* it should be done early in spring or in autumn after there has been enough rain to saturate the ground. Provided that the rhizomes are sufficiently protected burning will remove old dead culms on mature plants and stimulate the germination of seedlings, provided that there is a seedbank. However, burning *L. scariosus* is a risky business

Female plants become reproductively mature in the sixth or seventh year after germination and when flowering commences it is only in a few culms Seeds take 12 months to mature and then are released onto the ground over summer (I. Sieler[2], unpublished data). The seeds are probably not long-lived and germination after a fire is therefore based on the previous season's seed-set. Based on this data stands

[2] I. Sieler, Kings Park and Botanic Gardens, Perth.

of *L. scariosus* should not be burned at less than 10 year intervals if there is a risk that the plants will be killed, and that the harvest should be light in the season prior to the burn.

Recommendations: (1) Remnant vegetation being managed for the production of cut-flowers from *L. scariosus* should have a minimum intervall between burns of 15 years. (2) Burning should be done in late autumn after there has been enough rain to saturate the soil.

Ploughing and slashing

Ploughing or disking is sometimes used as a method of rejuvenating stands of *L. scariosus*. The stands may have become less productive because the plants are old, or other species (native or exotic) may have invaded the sedgeland and are shading or otherwise competing with *L. scariosus* . Ploughing will kill most adult plants, especially if it is done under dry conditions. A poor germination, because of a lack of seeds, may occur if the stand has been heavily harvested in the season prior to the cultivation. *Leptocarpus scariosus* may also propagate vegetatively from pieces of rhizome (R. Clarke, pers.comm.) and this may be a reason why ploughing could me more successful in rejuvenating a stand than burning it. As with burning it will be up to seven years before a harvest can be expected from the ploughed area if seedling regeneration is the primary method of re-establishment. However, ploughing involves a major disturbance of the remnant vegetation and may lead to substantial vegetation modification as well as increasing the risk of soil erosion.

Slashing, in contrast to ploughing, need not result in the death of the adult plants if it is done above about 30 cm from the ground. It will have the effect of temporarily lessening the competition from shrubs, and of removing dead culms from the *L. scariosus* plants. However, slashing.may kill non-resprouting plants (including *L. scariosus*) and there may be a major change in species composition if seedling germination or survival is poor. To allow for this no more than 25% of a remnant should be slashed in any one year.

Recommendations: (3) Ploughing is not a suitable method of management of remnant vegetation being managed for the production of cut-flowers from *L. scariosus*. (4) Slashing, which should be at least 30 cm above ground, should be carried out at no less than 10 year intervals. (5) No more than 25% of a remnant should be slashed in any one year.

Fertilizers

Most stands of *L. scariosus* in remnant vegetation are subject to substantial inputs of phosphorus and other nutrients, either through direct application or through influxes of nutrients in water washing from adjacent paddocks. The natural habitat of *L. scariosus* is quite infertile but limited evidence suggests that it responds positively to additions of superphosphate. Research carried out into the ecology of fens in Britain (which are analogous to the sedgelands of SW. Australia) suggests that influxes of nutrients into these wetlands contributes to the dominance of a few species and a loss in species richness (Wheeler, 1983). However sedge and rush dominated wetlands play a valuable role in nutrient adsorption from sediments in many areas because of their capacity for 'luxury consumption' and association with rhizobial fauna (Chambers *et al.*, 1995).

Both *A. parviceps* and *B. sparsa*, which are shrubs that commonly occur in association with *L. scariosus,* have increased vegetative growth in response to applications of fertilizer (C.J. Robinson, pers.comm.) and therefore applying nutrients to stands of *L. scariosus* may encourage these species. Other species which are favoured by eutrophication (nutrient enrichment) of the wetlands containing *L. scariosus* are agricultural weeds such as native and introduced species of *Juncus*. It is possible that *L. scariosus* is competitively displaced as the nutrient level of its habitat increases but it would be difficult to separate this effect from those due to the various other disturbances.

Recommendations: (6) No fertilizer should be applied to remnant vegetation being managed for the production of cut-flowers from *L. scariosus.*

Harvesting

Leptocarpus scariosus is harvested by cutting the culms high enough above the ground to give a commercial stem length (50 - 70 cm). The cut is made with various implements such as knives, 'whippersnippers', hedgecutters and even chainsaws. Research carried out by Sieler (unpublished) and Robinson and Smith (1995) has shown that the height of cutting is crucial to the survival or future growth of individual *L. scariosus* plants (Plate 6.4).

In a trial examining different cutting heights it was found that of 50% of plants died when 100% of the plant was harvested at ground level. The plants that survived this treatment produced an average of only six new culms the following season compared to 59 new culms when the entire plant was harvested at 30 cm above ground level (Sieler, unpublished). The study by Robinson and Smith (1995) also found a relationship between cutting height and degree of regrowth of the culms. Regrowth was found to be poor on plants cut below 30 cm. If plants were cut low on one side and high on the other (as often happens when hedge-cutters are used) regrowth was absent or poor on the low cut side and good on the side where the cut was above 20 cm. When cutting was much below 30 cm the regrowth was usually only peripheral or occurred next to any culms that were not harvested, an effect also noted by Sieler (Plate 6.5).

Although most *L. scariosus* pickers harvest with hedge-cutters or 'whipper snippers' because of the time savings it is difficult to get an even cut with these tools and so regrowth is deleteriously affected. One long time producer interviewed always cut her *L. scariosus* clumps with a knife because this produced an even length of product and made it easier to leave some culms on the plant, which she felt facilitated regrowth.

Leptocarpus scariosus culms regrow very slowly. Sieler (unpublished) found that only 55% of the original weight of culms regrew in the year after 100% of a clump was harvested 30 cm above the ground. Producers indicate that it requires at least 3 or 4 years before culms regrow to commercial length (50-70 cm).

Female plants of *L. scariosus* ('velvet rush') are more commercially valuable than the male plants ('seeded rush') and so are preferentially picked. This may have the effect over a number of years of producing a stand of predominantly male plants, which has obvious ecological as well as economic ramifications. The effect is magnified by the fact that in general female plants are outnumbered by male plants in natural populations.

Recommendations: (7) *L. scariosus* be cut no less than 30 cm above ground level. (8) There should be a minimum of 4 years between harvests of the same plant. (9) No more than 20% of female plants be harvested in any one year.

Disease

See following section.

Plate 6.3. Area of *Leptocarpus scariosus* that was burnt when the soil was too dry - all the adults were killed and there has been no seedling establishment.

Plate 6.4. Area of *Leptocarpus scariosus* in remnant vegetation near Northcliffe that was harvested in 1994.

6.3.2 *The effects of management on the ecosystem*

Fire

These days fire appears to be a rare event in remnant vegetation (surrounded by farmland) containing *L. scariosus*. The habitat-type being naturally wet will often not burn when fire travels through neighbouring vegetation on drier soils. In its natural state vegetation containing *L. scariosus* is probably more likely to burn in autumn than at other times of year, when soils are at their driest. The sedgelands and shrublands which contain *L. scariosus* are composed of a mix of seeders and resprouters as are most other Western Australian vegetation types and thus are adapted to a variety of fire frequencies. However no studies have been done into the fire ecology of these vegetation types.

As mentioned above, remnant vegetation being managed for the production of cut-flowers from *L. scariosus* should not be burnt any more frequently than every 10 years, and very small areas (< 2 ha) perhaps should not be burnt at all.

Grazing

Much of the remnant vegetation containing or (potentially containing) *L. scariosus* is currently grazed by livestock. Farmers appear to be reluctant to fence these areas because, being wet, they have green pasture well into the summer. At times cattle graze on *L. scariosus* and in some years this is reported to cause a large decline in the harvest. This is probably most likely to occur in drier years, when there is less pasture available and when the *L. scariosus* areas are more easily accessed by livestock.

The negative impact of livestock access to remnant vegetation is well documented - among the effects are soil compaction, disease spread, nutrient enrichment, trampling, weed introduction and a general decline in native species richness. The failure to fence remnant vegetation containing valuable cut-flower species such as *L. scariosus* is a little puzzling, particularly when it has been lucratively harvested for ten years or so. It is probably often due to the economics of the situation not being properly considered. Unfortunately remnant vegetation that is to be harvested for cut-flowers or seeds does not meet the requirements for assistance under the Remnant Vegetation Protection Scheme.

Recommendations: (10) Remnant vegetation being managed for the production of cut-flowers from *L. scariosus* should be fenced to exclude livestock and should not be grazed.

Disease

In general members of the Restionaceae (such as *L. scariosus)* are not prone to pythiacious root diseases such as that caused by *P. cinnamomi* but there have been instances of infection by *Armillaria* root rot (Shearer, 1994). The other dominant family of the southern sedgelands, the Cyperaceae, is also not susceptible to plant diseases. Nevetheless there are some species often found scattered through this vegetation type, or on the periphery that are highly susceptible, notably members of the Proteaceae (*Hakea, Adenanthos, Banksia*) and Epacridaceae (*Leucopogon, Astroloma* etc.).

The fact that *L. scariosus* habitats are often grazed makes it highly likely that 'dieback' would be spread into them if it already existed on a farm, as the moist conditions would ensure that the disease would persist if there were host plants present. For the sustainable management of remnant vegetation, adequate protection measures must be undertaken to prevent the introduction or spread of plant disease (see Appendix 2).

Recommendations: (11) Appropriate hygeine measures should be adopted to protect remnant vegetation being managed for the production of cut-flowers from *L. scariosus* from the introduction or spread of plant diseases.

6.4 General discussion

Although it has a quite wide geographic range because of its particular habitat requirements, *L. scariosus* is quite limited in local extent. Natural populations usually cover no more than two or three hectares in a narrow band around the edge of a lake or along a stream. Because of the various threats to wetlands (such as increases in salinity and water table changes) in the south-west of Western Australia even some populations of this species in conservation reserves are at some risk (Halse *et al.*, 1993). *Leptocarpus scariosus* was one of only seven species found growing only in fresh water amongst the 150 species found in the 106 wetlands surveyed by Halse *et al.* (1993). It also appears to be quite sensitive to water-level, at permanent lakes *L. scariosus* was only found growing around high watermark, whereas in seasonal wetlands the rush grew a wider littoral zone between low and high watermark.

Because of its ability to colonize bare or disturbed ground and persist there if the seasonal water-table range is suitable *L. scariosus* has the potential to expand its distribution on individual farms. This appears to have occurred with several presently harvested private property populations of *L. scariosus*. After swamps have been cleared or drained, for instance, *L. scariosus* has established in areas where previously the the competition from shrubs was too great or the water was too deep. In other cases where the water-table has come closer to the surface because of clearing and land becomes too wet for pasture *L. scariosus* may again increase its distribution. However this expansion of its range by *L. scariosus* probably does not occur if disturbance levels, especially by grazing, are too high.

At present very little *L. scariosus* is harvested from plantations (Plate 6.6). It is likely that harvesting of *L. scariosus* from Crown land and State forest will eventually be banned because of the fragility of wetland habitats. A declining harvest from Crown land over recent years has coincided with a large increase in private property production (up 138% between 1993 and 1995). There has apparently been sufficient previously unexploited private property populations to more than make up for the shortfall from Crown land but it is doubtful whether this level of production can last without careful management.

Because of the undesirability of intentionally modifying remnant wetland vegetation so that *L. scariosus* can increase in area the preferable alternative is to establish the species in suitable areas as a method of rehabilitation. With appropriate weed control wet areas that now produce sub-standard pasture could be planted to this species to produce a monetary income as well as providing ecological benefits (Chambers *et al.*, 1995). *Leptocarpus scariosus* may be established from transplantation of rhizomes or from seed and can be harvested two years after planting out as seedlings (R. Clarke, pers.comm.). However, further work on practical methods of propagation of this species is required. A pilot project established by a local landcare district, for instance, which would prove the practicability of this and publicize it would be of great benefit to the wetlands of the south coast.

Recommendation: (12) Further research into methods of propagating and growing *L. scariosus* be encouraged.

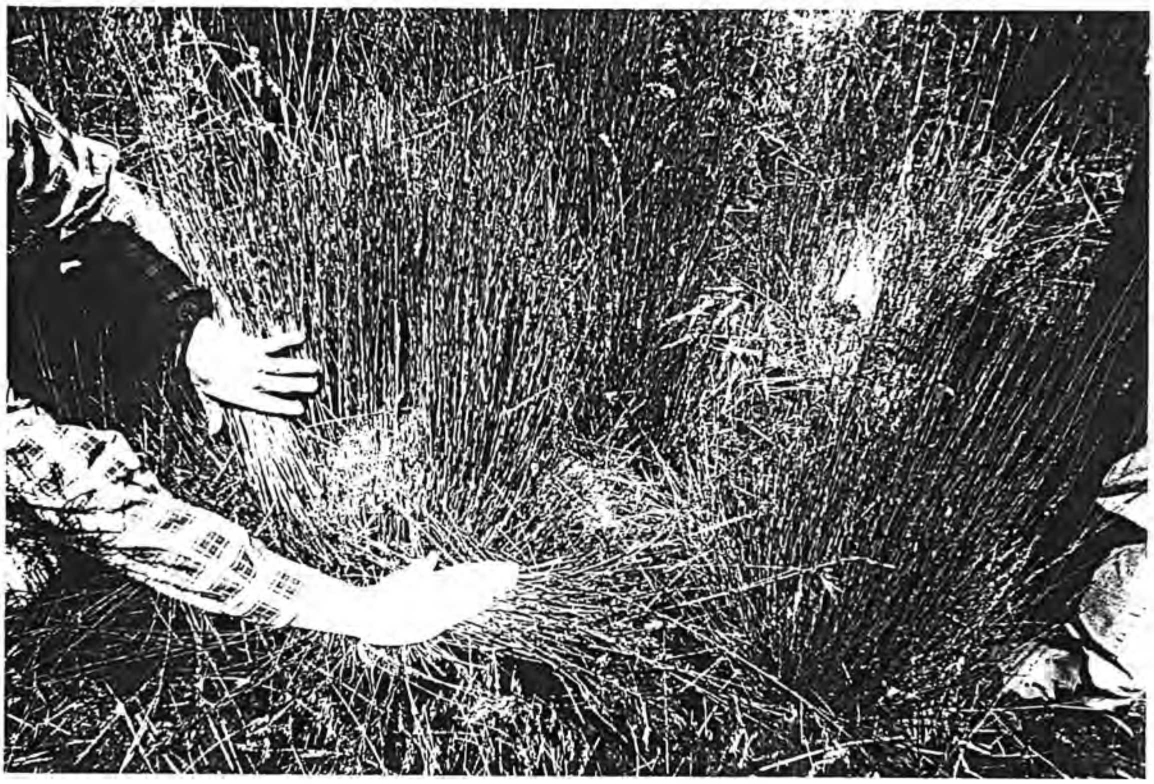

Plate 6.5. Peripheral growth of culms on *Leptocarpus scariosus* that was harvested in 1994.

Plate 6.6. *Leptocarpus scariosus* under cultivation near Walpole.

Section 7

Verticordia eriocephala A.S.George

7.1 Distribution and climate

Verticordia eriocephala has a wide distribution in the south-west of Western Australia from the Mt Adams area near Mingenew in the north inland to Boorabin 80 km east of Southern Cross and south to Mt Ragged 140 km NE of Esperance (McEvoy and True, 1995). There is an outlying population near Point Culver on the Nullarbor Plain 260 km NE of Esperance (Fig. 7.1). Within this area its populations are not particularly extensive, being confined to pockets of suitable soil and islands of remnant bush amongst farmland. *Verticordia eriocephala* has recently been taxonomically separated from the closely related *V. brownii* R.Br. (George, 1991), the latter species is found along the south coast from Hopetoun to Mt Ragged.

The climate within the range of *V. eriocephala* is Mediterranean in type and using the hydoxeric index is subhumid or semi-arid in the main, although the population at Boorabin is in the arid region (Gentilli, 1972). The number of months in which average rainfall exceeds effective rainfall varies from about 2.5 for the most north-eastern and eastern populations to about 6 for the *V. eriocephala* occurrences near Ravensthorpe and Lake Grace. Total annual rainfall within the range of *V. eriocephala* increases from 250 mm for the populations at Boorabin and Point Culver to about 550 mm near Eneabba and Beverley (Bureau of Meteorology, 1979).

7.2 Habitat and vegetation

7.2.1 *Geology and soils*

Verticordia eriocephala is found on a wide variety of soil types derived from a various rock-types, but the species is mostly found on yellow and yellow-brown sands and sandy loams (McEvoy and True, 1995). There is sometimes a substantial gravel content. Soil drainage is usually good to very good and soil reaction varies from nuetral to moderately acid East of Moora these sands and gravelly sands are colluvial deposits of local origin largely derived from the ferruginous duricrusts which mantle much of the Great Plateau and which are thought to represent, together with the underlying pallid zone, fossil soils which formed under wetter conditions during the early Tertiary Epoch (Mulcahy, 1960; 1973).

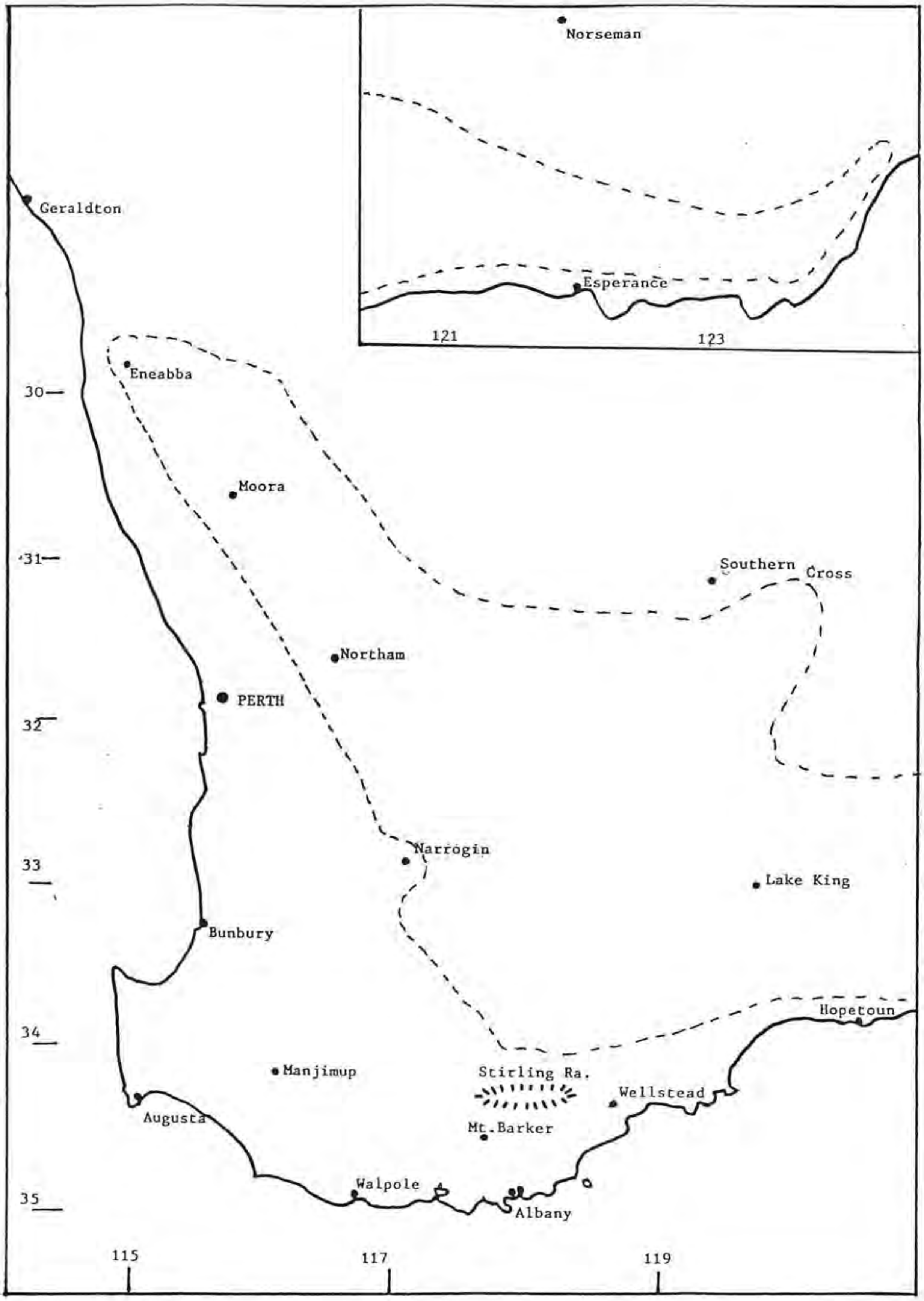

Figure 7.1 Distribution of *Verticordia eriocephala*.

A subset of populations will be examined to illustrate the range of edaphic conditions. Coomberdale west and Wongan Hills are in the northern wheatbelt and Bendering, Dragon Rocks and Lake Magenta are in the south-eastern wheatbelt. As previously mentioned *V. eriocephala* is often restricted to remnants of the original vegetation amongst cleared farmland and it is possible that the current distribution, especially in the wheatbelt, does not fully reflect the original range of habitats in regard to soils and associated vegetation.

Coomberdale west: In this area *V. eriocephala* is found on light grey sands over yellow sands over sandy clays at 1.2 to 1.8 m (Reeves, 1992). There is some evidence that the presence or absence of *V. eriocephala* in this area is related to the depth of the sandy clay, where it comes closer to the surface *V. eriocephala* is replaced by other species of *Verticordia* (Mr Clive Tonkin, farmer of Coomberdale, pers.comm.) These soils were derived from the Mesozoic sediments of the Dandaragan Plateau as colluvium weathered from ferruginous sandstone (McArthur, 1991). A soil description is given in Table 7.1.

Wongan Hills reserves: At Wongan Hills Reserve A25808 *V. eriocephala* is found on light yellow sandy loam over yellow gravelly sand, and on light brown sandy loam with a bleached horizon (Coates, 1988; this study). On other reserves in the area *V. eriocephala* also prefers yellow sandy gravels over gravel or ironstone on residual sandplains (Coates, 1992a). This soil is similar to the Wongan Sand (McArthur, 1991, p.120) and was probably formed in a similar way to the yellow sandy earths of the Quailing depositional surface described by Mulcahy (1960) for the central wheatbelt, that is that they are derived from the ferruginous zone upslope by weathering and subsequent colluvial transport.

Bendering Reserve: Within this reserve *V. eriocephala* occurs on light yellowish to pale brown sandy loams and sandy clay loams over dense gravel and massive laterite at depths of 15 to 25 cm. (Muir, 1977). A description of a soil on which *V. eriocephala* occurs in Bendering Reserve is given in Table 7.1. This soil also appears to have developed in a landscape position analogous to the Quailing erosional surface of Mulcahy (1960).

Dragon Rocks Nature Reserve: *Verticordia eriocephala* is predominantly found on sands to sandy-loams sometimes with an admixture of gravel, over clay at 50 to 70 cm in low-lying areas and gravelly sands over ironstone or gravel on the lateritic plateau (Coates, 1992b).

Lake Magenta Reserve: *Verticordia eriocephala* is found growing on orange-brown gravelly sands (Coates, 1986). The gravelly soils in this area tend to be underlain by massive laterite.

Table 7.1. Description of a soil carrying *V. eriocephala* on the northern sandplains (Coomberdale west).	
0-10 cm	light grey sand (pH 6.3)
10-70 cm	yellow sand (pH 6.6)
70 cm +	yellow gravelly sand

Table 7.2. Description of two soils carrying *V. eriocephala* in the south-eastern wheatbelt (Bendering Reserve).	
Soil 1	
0-1 cm	dark brown sandy clay loam, organic matter
1-15 cm	light yellowish brown sandy clay loam
17 cm +	hard compact laterite
Soil 2	
0-1 cm	dark brown sandy loam, organic matter
1-15 cm	pale brown sandy loam
15-25 cm	pale brown gravelly sandy loam (90% gravel)
25 cm +	hard compact laterite

7.2.2 *Vegetation structure and associated plant species*

Verticordia eriocephala is found in a range of vegetation types; open shrubland, through heathland and tall shrubland to low open woodland. However it appears to be predominantly found in heathlands and tall shrublands. Time since fire is obviously important in determining the height and openness of these structural formations and in the early post-fire years they may have the appearance of low open shrublands.

As would be expected *V. eriocephala* occurs with a very wide range of species, and except locally it could not be said to be associated with a particular alliance or community-type. There is a high level of species richness and a low level of floristic uniformity between stands (= high *beta* diversity) on sandplains throughout the drier parts of the south-west of Western Australia (George *et al.*, 1979; Brown, 1989; Griffin, 1992) and the number of different species which occur in association with *V. eriocephala* at its various populations is ample evidence of this. Nevertheless, there are a few species which are found in association with *V. eriocephala* both on the northern sandplains and south-eastern wheatbelt e.g. *Allocasuarina acutivalis, A. campestris, Astroloma serratifolium, Hakea lissocarpha, Lysinema ciliatum, V. chrysantha* and *V. picta.* Of the 54 populations surveyed by McEvoy and True (1995), *V. eriocephala* most often occurred with *Allocasuarina campestris, Ecdeioclea monostachya* and species of the sedge *Mesomelaena.*

On the northern sandplains from Watheroo to Moora *V. eriocephala* is often found in heathlands and tall shrublands with occasional small trees such as *Actinostrobus arenarius* (Sandplains Cypress), *Banksia attenuata* (Slender Banksia), *Eucalyptus pyriformis* (Pear-fruited Mallee) and *Xylomelum occidentale* (Sandplains Woody Pear) (Plate 7.1). Plant species lists for two representative sites on the northern sandplains, near Wongan Hills (Coates, 1992a) and at Coomberdale west (Reeves, 1991) are given in Table 7.3. In the eastern and south eastern wheatbelt *V. eriocephala* is generally found in tall shrublands and in heathlands, often with a scattered mallee eucalypt component (Plate 7.2). Muir (1977) gives the following description for a tall shrubland in Bendering Reserve containing *V. eriocephala.* The upper stratum consists of *Allocasuarina acutivalis* and occasional *Eucalyptus foecunda* shrub mallee 2-4 m tall, 10-30% canopy cover over a second stratum 1-2 m tall of *Hakea falcata, Petrophile ericifolia, Persoonia striata* and *Grevillea hookerana* and other shrubs with a canopy cover of 10-30%. A third stratum is formed of low shrubs, 0.3-0.5 m tall, of *Melaleuca, Daviesia, Dryandra* and *Micromyrtus* species with 30-70% cover and there was a sparse fourth stratum of sedges up to 0.1 m. Some of the plant species found in association with *V. eriocephala* at two sites in the south-eastern wheatbelt, at Dragon Rocks Nature Reserve (Coates, 1992b) and Lake Magenta Nature Reserve (Coates, 1986) are listed in Table 7.4.

Table 7.3. Plant species co-occurring with *Verticordia eriocephala* at two sites on the northern sandplains.

Wongan Hills	Coomberdale west
Actinostrobus arenarius (Sandplains Cypress)	*Actinostrobus arenarius*
Adenanthos drummondii	*Allocasuarina humilis*
Allocasuarina humilis	*Banksia attenuata* (Slender Banksia)
Calothamnus quadrifidis	*B. menziesii* (Menzies Banksia)
Conospermum stochaedis	*Cryptandra pungens*
Eremaea pauciflora	*Hibbertia pungens*
Grevillea eriostachya	*Jacksonia furcellata*
G. armigera	*Macrozamia reidlii* (Zamia Palm)
Hakea incrassata	*Petrophile linearis*
H. trifurcata	*P. media*
Jacksonia fasciculata	*Stirlingia latifolia* (Blueboy)
Leptospermum erubescens	*Verticordia densiflora*
Melaleuca aff. *cordata*	*V. grandis*
Petrophile ericifolia	*Xanthorrhoea preissii* (Blackboy)
P. media	*Xylomelum angustifolium* (Sandplains Woody Pear)

Table 7.4. Plant species co-occurring with *Verticordia eriocephala* at two sites in the south-eastern wheatbelt.

Dragon Rocks Nature Reserve	Lake Magenta Nature Reserve
Allocasuarina acutivalis	*Allocasarina microstachya*
A. campestris	*Baeckea preissiana*
Astroloma serratifolium	*Coleanthera myrtoides*
Callitris preissii (Cypress Pine)	*Dodonea caespitosa*
Eucalyptus albida (White-leaved Mallee)	*Eucalyptus tetragona* (Tallerack)
E. loxophleba (York Gum)	*Gastrolobium crassifolium*
Grevillea integrifolia	*Hakea varia*
Hakea cygna	*Leptospermum* aff. *roei*
H. multilineata	*Melaleuca holosericea*
Leptospermum incanum	*M. subtrigona*
Melaleuca platycalyx	*Petrophile divaricata*
Verticordia chrysantha	*Synaphea petiolaris*
V. picta (Painted Featherflower)	*Verticordia acerosa*

Plate 7.1. *Verticordia eriocephala* in northern sandplains heathland, Watheroo National Park.

Plate 7.2. *Verticordia eriocephala* in tall shrubland east of Lake King which has not been burnt for 30 years.

7.3 Conservation status in remnant vegetation

7.3.1 *Management effects on* Verticordia eriocephala.

Fire

Verticordia eriocephala is killed by fire and is an obligate reseeder as defined by Bell *et al.* (1984). The germination requirements of *V. eriocephala* are not known although it is assumed that most germination takes place after fire although seedlings are not always present around dead adults post-fire (Reeves, 1992). *Verticordia eriocephala* can also establish in the absence of fire in disturbed soil. The densest population of *V. eriocephala* seen in remnant vegetation during the present study was in an area that had been ploughed, but not burnt, 20 years ago. Flowering occurs mainly in November and December and the abundant flowers abscise and fall to the ground in late January.

Pollination rates are low and only about 3% of abscised fruit contained seeds which had a germination rate of 18% by staining test (Reeves, 1992). Studies reported by McEvoy and True (1995) found that self pollinated flowers (35%) had a higher germination rate than outcrossed flowers (20%) and that the application of smoke significantly increased seed germination. Reeves (1992) found that there were about 55 viable seeds per square metre in the soil below the adult plants immediately following flower abscission. Seed longevity in the soil may be short, after a year in storage resmoked *V. eriocephala* seeds did not produce any germinants (McEvoy and True, 1995)

The uncertainty of *V. eriocephala* germination after any one fire indicates that the species may undergo local extinctions from time to time. However the large populations of *V. eriocephala* inspected during this study had established following initial clearing for agriculture which included chaining and burning or ploughing between 10 and 25 years ago. Intentional burning is now generally not carried out in remnant vegetation harvested for *V. eriocephala* cut-flowers and instead chaining is sometimes used as a method of rejuvenating the stands. However, given the proven deleterious effect of harvesting on mortality and seed production in *V. eriocephala* (see below) there is a risk that a wildfire may result in very poor regeneration in heavily harvested stands.

Recommendation: Remnant vegetation being managed for the production of cut-flowers from *V. eriocephala* should have an interval of at least 15 years between fires.

Chaining/ploughing

The large private property populations of *V. eriocephala* inspected during this have established after the land was initially chained, burnt and ploughed in preparation for sowing to pasture or crop. However within a year or two of the original clearing these areas had been allowed to revert to natural vegetation. In one case (an area of 80 ha) the vegetation has been chained, but not burned, twice since the original clearing in 1967. The 'light' chaining was carried out, in autumn, to rid the area of 'undesirable' species such as *Jacksonia furcellata* and *Adenanthos sericeus*. Reportedly the chaining did not harm the *V. eriocephala* because it bent and did not snap off, and picking was possible later in the year. It was also claimed that the chaining improved the *V. eriocephala*, though it is not clear whether this was because of a temporary lessening of competition or some other mechanism such as stimulation of seed germination.

Chaining of *V. eriocephala* does not appear to be necessary to obtain good 'crops' of *V. eriocephala*, as several other sites visited had been producing at good levels over many years without this operation being carried out (Plates 7.3 & 7.4). The removal of 'undesirable' species may make harvesting easier, but the malformation of *V. eriocephala* stems evident at this site may be at some cost in production terms. Ploughing or heavy chaining may be a way of encouraging mass germination of *V. eriocephala* as a way of rejuvenating stands but not enough is known about its requirements to be able to prescribe when and under what conditions this should be carried out for best effect. With most remnant vegetation being of relatively small area and surrounded by pasture it is likely that agricultural weeds will establish in a heavily disturbed are to the detriment of *V. eriocephala* and the other native species that occur with it.

Recommendation: (2) Chaining or ploughing should not be carried out in remnant vegetation being managed for the production of cut-flowers from *V. eriocephala*.

Fertilizers

Fertilizers are generally not applied to wild stands of *V. eriocephala*. Raised nutrient levels in native vegetation as a result of fertilizer drift or deliberate application increase the risk of weed invasion.

Recommendation: (3) Fertilizers should not be applied to remnant vegetation being managed for the production of cut-flowers from *V. eriocephala*.

Harvesting

Two studies have looked at the effects of harvesting on *V. eriocephala*. Reeves (1992) applied six treatments to plants growing on private property near Moora. Groups of plants were light picked (20% of flowering stems removed), medium picked (50% ditto) and heavy picked (100% ditto). For each of the picking intensities half of the plants had no shoots remaining below the cut and on the other half had some shoots left on the cut stem. Survival (after 1-2 years) was 100% for light and medium picked plants, regardless of whether shoots were left below the cut, 97.5% for heavy picked plants with shoots below the cut but only 5% for those plants where 100% of stems were taken and no shoots were left. McEvoy and True (1995) after a study comparing picked with non-picked populations of *V. eriocephala* that the mortality rate increases with the degree of harvesting. For heavily harvested plants (>80% of the corymb removed) mortality was 96%.

Reeves (1992) also found that heavily harvested plants with shoots left below the cut regrew at a substantially faster rate than did the other treatments which all had similar rates of regrowth. It was surmized that this was because the plant, lacking reproductive ability, employed all available resources in the redevelopment of a flowering corymb as quickly as possible.

It was found by Reeves (1992) that plants that had been heavily picked had a significantly lower number of seeds per 1000 fruits than control or light- and medium picked plants. These results have been supported by further research by Ph.D. student Shauna Roche detailed in McEvoy and True (1995). Roche has also found that the soil seedbank was up to 7 times less at a harvested site than an unharvested site.

In order to ensure that enough seed reserves are available at any time Reeves (1992) recommended that, no more than 20% of plants in any population be harvested in any one year and that no more than 50% of the stems suitable for picking be taken from any one plant. Evidence gathered by McEvoy and True (1995) and by the present study supports these recommendations.

Recommendations: (4) No more than 20% of plants in any one population of *V. eriocephala* be harvested in any year. (5) No more than 50% of the stems suitable for picking be taken from a plant in any year. (6) Harvesting cuts should not take place below the lowest live shoots. (7) Harvesting should not take place in the year before an area is to be burnt.

Plate 7.3. *Verticordia eriocephala* (reddish leaves) in an area of remnant vegetation near Lake King which was chained and burnt 20 years ago.

Plate 7.4. Area of remnant vegetation near Lake King with abundant *Verticordia eriocephala* and other verticordias that was chained and burnt 20 years ago and has been harvested for 8 years.

Disease

At present disease does not appear to be present in wild populations of *V. eriocephala*. This is probably mainly because the species predominantly occurs outside the range of the major diseases of native plants (Shearer, 1994). It is likely that the climate is too dry for the persistence of fungal diseases over most of the range of *V. eriocephala* but it may be at risk in near coastal areas in the south east of its range. However some pathogens show evidence of being adapted to drier areas (Shearer, 1994) and further adaptations or new diseases may occur and adequate hygiene measures need to undertaken to protect all remnant vegetation from the introduction and spread of plant disease (see Appendix 2).

Recommendations: (8) Appropriate protective measures should be undertaken in remnant vegetation being managed for the production of cut-flowers from *V. eriocephala* to prevent the introduction or spread of plant diseases.

7.3.2 The effects of management on the ecosystem

Fire

The vegetation types that *V. eriocephala* is found in, which range from low heathlands to tall shrublands (i.e. 'kwongan', Pate and Beard, 1984) are adapted to fire and drought. The high proportion of sprouters in the current flora is probably an indication that fire has become more frequent as a mediterranean climate has become fully developed over the last 5000 years or so (Bell *et al.*, 1984). The optimum interfire interval for kwongan vegetation is impossible to specify, but the 'natural' regime (i.e. what occurred in the absence of human intervention) is thought to have been at frequencies of 25 - 50 years (Bell *et al.*, 1984), although van der Moezel *et al.*(1987) suggest that it may be as low as 8 - 15 years for northern kwongan near Badgingarra. However severe fire weather, characterized by high temperatures, low humidity and strong winds occurs regularly each summer with the formation of pre-frontal low pressure troughs (McCaw, 1995). Given this annual predisposition to fire and the fact that aborigines used fire as a land management tool it is thought that over the several thousand years prior to the arrival of Europeans a complex mosaic of patches of different fire age was built up in the dry sclerophyll vegetation of south-western Australia. A recreation of this pattern of different fire ages and of fires in different seasons is thought to be the best way to manage the flora and fauna in conservation reserves (Bell *et al.*, 1984; Atkins and Hobbs, 1995).

Being an obligate reseeder *V. eriocephala* is sensitive to recurrent fire. However, except on some road verges where burning may be biennial or triennial and in reserves adjacent to townsites, fire is now a rare occurrence in most reserves and patches of remnant vegetation throughout the wheatbelt (McEvoy and True, 1995). A decrease in fire frequency is fragmented natural vegetation is a common outcome of agricultural development (Gibson *et al.*, 1988; Simberloff, 1993). The frequency in many of the smaller areas of remnant wheatbelt vegetation surrounded by farmland is probably in the range of 20 - 30 years, many of them have not been burnt since clearing burns ceased in the 1950's or 1960's.. The four areas of remnant vegetation containing *V. eriocephala* inspected during this study had not been burnt for 10, 20, 28 and 30 years respectively, over 60% of the populations surveyed by McEvoy and True (1995) had not been burnt for between 20 and 50 years.

Too great an interval between fires, however, may be a problem for some reseeder species which do not recruit in the absence of fire. Although several studies in Western Australian kwongan (cited in Bell *et al.*, 1984) have shown that there is minimal drop in species richness with time since fire it would be interesting to know if this is true for smaller patches of remnant vegetation surrounded by farmland. As stated above the recommended minimum interval between fires in remnant vegetation being managed for *V. eriocephala* is 15 years.

Chaining/ploughing

The light chaining of kwongan to remove 'undesirable' species obviously has an effect on the conservation values of remnant vegetation because it removes (or diminishes) some taxa, at least in the short - term. The effect of two light chainings in twenty years in remnant vegetation near Moora was to remove larger species or keep them in a juvenile condition (Reeves, 1992). Although this technique was recommended by this producer for increasing production of *V. eriocephala* its use is probably not widespread. All of the large areas of remnant vegetation containing *V. eriocephala* inspected as part of the present study had been ploughed 10 to 20 years ago as part of a clearing operation. It is claimed that the ploughing resulted in an increase in the proportion of *V. eriocephala* in these areas - which indicates that some other species had decreased.

While ploughing or heavy chaining remnant vegetation containing *V. eriocephala* probably results in an increase in the density of this species (and other *Verticordia* spp.) it is difficult to recommend this as a technique for improving the value of a stand, for a number of reasons. Firstly there would be a loss of all production in the treated area for three or four years. Secondly there is an unknown but perhaps substantial negative effect on other species. Thirdly disturbance of the soil by ploughing and the temporary removal of competition by native species may favour the invasion of agricultural weeds. This may especially be a problem around the edges of remnants which have received influxes of nutrients from adjacent paddocks (Hobbs and Atkins, 1988). Once exotic annual species have established around the edges of remnants following major disturbance to the kwongan vegetation re-establishment of the native species may be extremely slow (see Plate 7.5).

Reeves (1992) suggested that one effect of chaining remnant vegetation to promote *V. eriocephala* may have been to reduce the number of potential pollinators of this and other species through changes in the habitat. Several species of Hymenoptera, Diptera and Coleoptera that were observed in areas of undisturbed vegetation nearby were not present in the managed bushland.

As stated in the previous section chaining or ploughing to rejuvenate stands of *V. eriocephala* is not recommended as a management technique.

Grazing

As has been stressed previously grazing by domestic animals may cause severe degradation of remnant vegetation (Plate 7.6). Although sheep generally do not graze *Verticordia* they do graze other species such as kangaroo paw (*Anigozanthus* spp.) (C. Tonkin, pers.comm.) Although kwongan vegetation is less attractive to livestock than some other vegetation types stock will access it if allowed to and cause damage if it is not fenced (N. Silver, pers.comm.).

Recommendations: (9) Remnant vegetation being managed for the production of cut-flowers from *V. eriocephala* should be fenced to exclude livestock and should not be grazed.

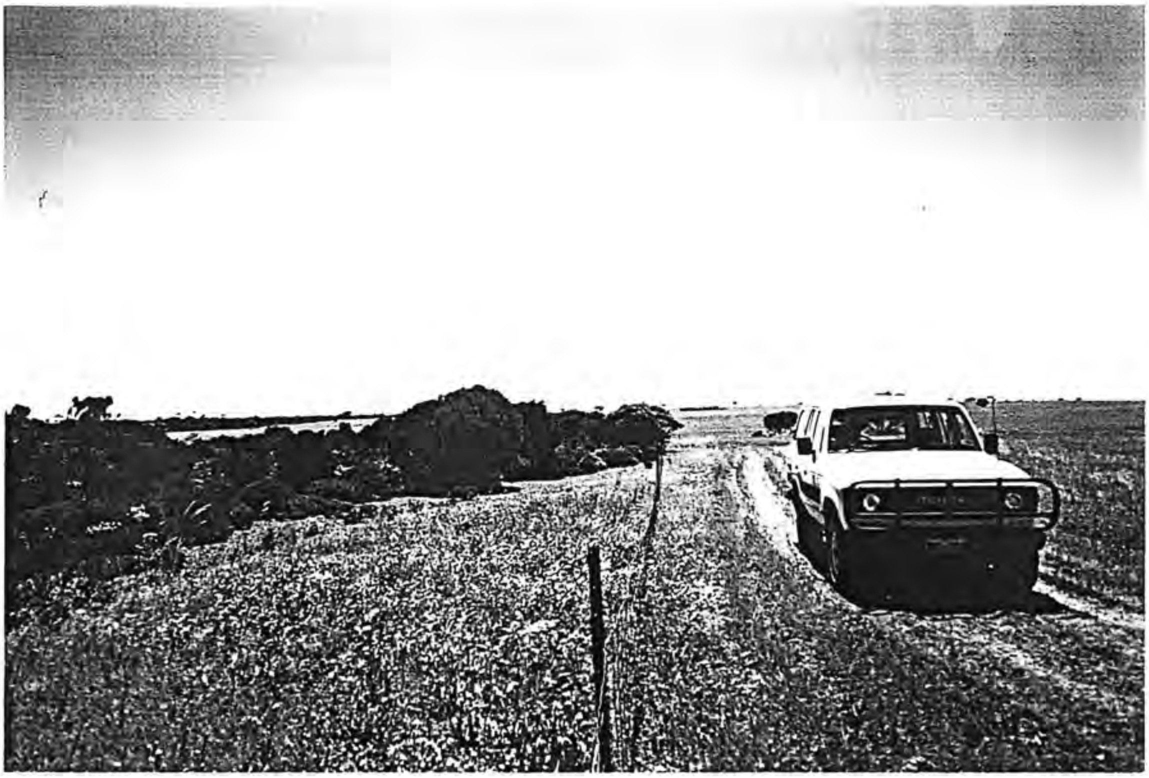

Plate 7.5. Area of remnant vegetation near Lake King fenced for 15 years showing lack of regeneration of native species in previously cropped and pastured area.

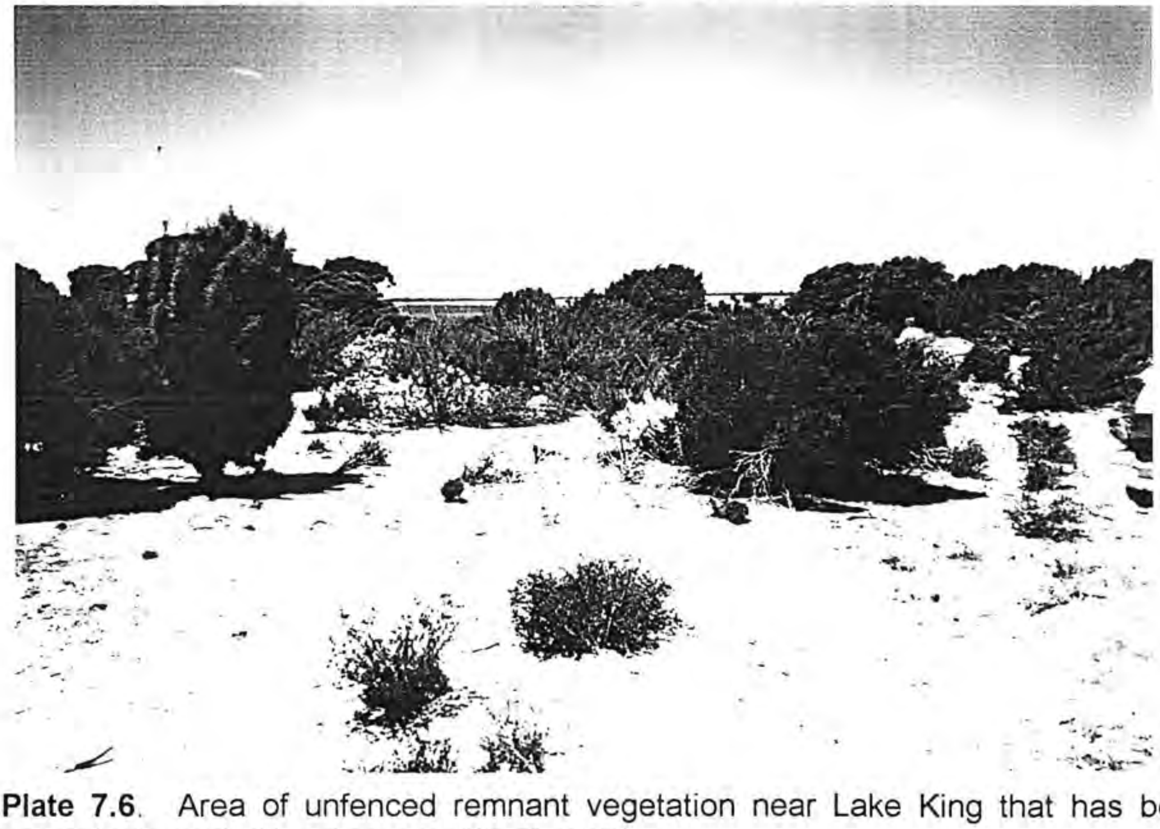

Plate 7.6. Area of unfenced remnant vegetation near Lake King that has been severely degraded by sheep and feral rabbits.

7.4 General discussion

The survey of *V. eriocephala* populations by McEvoy and True (1995) found that most occurred on small reserves (many of which did not have conservation as a purpose) and on road verges. This was particularly the case in the western wheatbelt where agricultural clearing has been the most extensive. A large proportion of the sites recorded on the W.A. herbarium database from the early years of this century no longer exist because of clearing of the vegetation. McEvoy and True (1995) reported that of the 7 populations of *V. eriocephala* found on non-roadside reserves within CALM's Moora District all had been harvested in the past although only one of these could have been legally harvested before 1994 because it was vacant Crown land.

At one of the harvested remnant vegetation sites visited during the present study (in the northern wheatbelt) picking has caused a higher rate of mortality than has occurred in unpicked populations (McEvoy and True, 1995) even though the farmer concerned has been very careful over the last 10 years to limit his pick and not to cut too close to the ground. It is possible that the effect of soil compaction has contributed to this increase in mortality. At another large area of harvested *V. eriocephala* in the eastern wheatbelt, an inspection, backed up by the producer's assurances, found no apparent increase in mortality. These two sites are several hundred kilometres apart and have different histories of disturbance and picking which may explain this difference in mortality. There is no doubt that the wide geographic spread of *V. eriocephala* populations would cause variations in the way different populations respond to harvesting and climatic conditions.

Picking of *V. eriocephala* at a low level from suitably protected remnant vegetation may prove to be viable and cause no great harm to the conservation values of remnant vegetation for a number of years but there are several good reasons why plantation cultivation should be encouraged.

1. The major private property natural populations currently being harvested are at least 200 km from Perth and the markets which involves a significant transport cost.

2. The number of remnant vegetation populations of *V. eriocephala* of sufficient density to be commercially viable is very limited.

3. The peak flowering season for *V. eriocephala* occurs at grain harvest time and thus many farmers find it difficult to find the time to pick.

Work done by Agriculture WA has shown that although propagation of *V. eriocephala* is difficult from bush collected materia, there can be an acceptable strike rate from healthy stock plants (McEvoy and True, 1995). However, high transplanting losses may occur and research is progressing on methods of establishing and cultivating the species including investigations into nutritional and mycorrhizal factors.

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APPENDIX 1

Vegetation Formations of South-western Australia (modified from Specht, 1981)

	Foliage Projective Cover of Tallest Stratum				
Life form of tallest stratum	100-70%	70-50%	50-30%	30-10%	<10%
Trees >30 m Trees 10-30 m Trees 5-10 m	Tall closed forest Closed forest Low closed forest	Tall forest Forest Low forest	Tall open forest Open forest Low open forest	Tall woodland Woodland Low woodland	Tall open woodland Open woodland Low open woodland
Shrubs 2-5 m Shrubs 1-2 m Shrubs <1 m	Tall closed shrubland Closed heathland [1] Low closed heathland	Tall shrubland Heathland Low heathland	Tall open shrubland [2] Open shrubland [2] Low open shrubland [2]	Tall open shrubland Open shrubland Low open shrubland	
Sedges > 2 m Sedges 1-2 m Sedges < 1 m	Tall closed sedgeland Closed sedgeland Low closed sedgeland	Tall sedgeland Sedgeland Low sedgeland	Tall open sedgeland Open sedgeland Low open sedgeland		

1. If the shrubs are non-sclerophyllous or halophytic, closed shrubland (100-70% PFC) or shrubland (70-50% PFC) may be substituted.
2. A heathland or shrubland with more than 60% sedges is called a sedgeland

Appendix II.

Hygiene measures which should be undertaken to protect remnant vegetation from the introduction or spread of plant diseases.

- Ensure that all machinery or footwear entering the remnant is free of soil and mud (pay particular attention to contractors). Wash off any soil in a "safe" area with compressed air or high pressure hose.
- Minimise the movement of vehicles and stock across the boundary between known (or suspected) infected areas and uninfected areas.
- Do not use road-making material from infected sites, many shire gravel pits are infected with "dieback" fungi.
- Minimize the movement of machinery or vehicles through remnant vegetation (i.e. a track or road through a remnant is not a good idea).
- Prevent livestock from entering the remnant.
- Soil-bourne fungi tend to move downhill with water flow, divert roadside drains and drains from yards and other heavily used areas, away from remnant vegetation.
- Methylated spirits is a fast-acting way of disinfecting footwear, tools and implements. Wiping secateurs with methylated spirits between plants when harvesting helps to prevent cross-infection.

(modified from Hussey and Wallace, 1993).

Appendix III

Guidance table for applications to manage native vegetation for cut-flower and seed harvesting

TABLE A3

Species	Vegetation Type	Regeneration Mode	Minimum Fire Interval (yrs)	Slashing	Chaining or ploughing	Fertilizer	Pruning	Age at First Harvest (yrs)[1]
	Treatments/Operations							
Agonis sp.	south coast heathland	resprouter shrub	10	yes[2]	no	yes[3]	-	3
Agonis parviceps	jarrah woodland	resprouter shrub	10	yes[2]	no	yes[3]	-	3
Banksia baxteri	south coast shrubland	seeder shrub	15 (20)[4]	no	no[5]	no	yes[6]	8
Banksia coccinea	south coast shrubland	seeder shrub	15 (20	no	no[5]	no	yes[6]	10
Banksia hookeriana	north coast shrubland	seeder shrub	15 (20)	no	no	no	yes[6]	6
Dryandra formosa	south coast jarrah forest	seeder shrub	12 (15)	no	no	no	yes[6]	6
Leptocarpus scariosus	south coast wetland	seeder rush	15	no	no	no	-	8
Verticordia eriocephala	wheatbelt heathland	seeder shrub	15	no	no	no	-	6

Note: Adherence to the recommendations should protect the conservation values of remnant vegetation being harvested for cut-flowers in the short to medium term (10-25 years) providing adequate hygeine measures are taken to prevent the introduction or spread of plant disease and the remnant is fenced and not grazed. However, the unpredictability of weather conditions attaches some risk to any management operation in remnant native vegetation.

[1] That is time after resprouting for ti-tree (*Agonis* species) or germination for seeders.
[2] It is recommended that for *Agonis parviceps* and *Agonis* sp. that slashing be alternated with burning, ie. burn after 6 years then slash after another 6 or vice versa.
[3] It is recommended that if slashing is carried out instead of burning that fertilizer may be added once after slashing at the rate of no more than 50 kg/ha of nitrogen and with no more than 3% phosphate. Fertilizer should not be applied within 50 metres of a waterway or stream.
[4] The figure in brackets indicates minimum fire interval in previously picked stands.
[5] Except for just before prescribed burning
[6] If pruning is carried out it should be into new (1-2 year-old) wood.

The likely effects of treatments or operations which are not in accordance with the guidelines presented in Table A3.

In this section an attempt is made to describe the likely outcomes in regard to the conservation status of remnant vegetation if the guidelines in table A3 are not followed. The outcome in any one area of remnant vegetation is difficult to predict, and depends on many factors, but some general indication can be obtained from the many studies carried out into the ecology of remnants over the last 10 years. These are summarized in Hobbs (1993).

<u>*Agonis parviceps* (fine ti-tree) and *Agonis* sp. (coarse ti-tree)</u>

Fire: Intervals less than 10 years

- Loss of seeders (ie. *Acacia hastulata, A. myrtifolia, Pultanea reticulata*)
  particularly if the interval is less than 5-6 years
- Invasion of agricultural weeds
  initially around the edges of larger remnants
  rapidly over the whole of small (< 5 ha) remnants
- Long-term loss of nitrogen accumulation in soil

Slashing: Not alternated with burning (ie. carried out every 5-6 years)

- Loss of seeders (ie. *Acacia hastulata, A. myrtifolia, Pultanea reticulata*)
- Long-term reduction of nitrogen accumulation in soil
- Soil compaction

Chaining or ploughing

- Loss of seeders
- Increased erosion risk with ploughing

Fertilizer: Greater than recommended levels or frequency

- High nitrogen - reduction in native legume component
- High phosphorus - increase in native legume component
- Increase in agricultural weeds

Age at First Harvest: Less than 3 years

- Loss of vigour and decline of reprouting ability is possible if first harvest occurs too soon after slashing or fire

***Banksia baxteri* (baxteri), *B. coccinea* (coccinea) and *B. hookeriana* (hookerana)**

Fire: Intervals less than 15 years

- Loss of seeders (ie. *Banksia baxteri*, *B. coccinea*, *B. hookeriana, Lysinema ciliatum*)
  through lack of seed storage, exhaustion of reserves
  particularly if the interval is less than 10 years

- More rapid invasion of agricultural weeds

Fertilizer: Application or drift of,

- Banksias sensitive to high phosphorus levels

- More rapid invasion of agricultural weeds

Pruning: Into older (> 2 year old) wood

- Reduction in re-shooting ability, reduction in flowering

- Increase in plant mortality if in 4-6 year-old wood

Age at First Harvest: Less than 10 years for *B. coccinea*, 8 years for *B. baxteri* and 6 years for *B. hookeriana*

- Decrease in flower production capacity and seed storage - more likely to be insufficient seed for regeneration

Dryandra formosa

Fire: Intervals less than 12 years

- Loss of seeders (ie. *Acacia extensa, A. drummondii, Bossiaea linophylla*)
  particularly if interval is less than 6 years because of insufficient seed production

- More rapid invasion of agricultural weeds

Fertilizer: Application of or drift of,

- *Dryandra formosa* sensitive to high phosphorus levels
- Legumes disadvantaged by increased nitrogen levels
- More rapid invasion of agricultural weeds

Pruning: Into wood older than 2 years

- Possible reduction in flower production and seed storage capacity

Age at First Harvest: Less than 6 years

- Reduction in flower production and seed storage capacity

Leptocarpus scariosus

Fire: Interval less than 15 years

- Loss of seeders (including *Leptocarpus scariosus*) through reduction in seedbank
- Increased weed invasion

Slashing/chaining/ploughing

- Loss of seeders
- Increased erosion risk
- Soil compaction
- Changed vegetation structure

Fertililzer: Application or drift,

- Leaching of nutrients into waterways
- Invasion by agricultural weeds

Age at First Harvest: Less than 8 years

- Female *Leptocarpus scariosus* plants not reproductively mature till 6 - 7 years of age

Verticordia eriocephala

Fire: Interval less than 15 years

- Loss of seeders (ie. verticordias, *Callitris preissii*, *Banksia violacea*) because of insufficient time to build up seedbank
- More rapid invasion of agricultural weeds

Chaining/ploughing:

- Loss of non-resprouting species
- Change in vegetation structure
- Soil erosion risk

Fertilizer; Application or drift of,

- Native legumes disadvantaged by increased nitrogen levels
- More rapid invasion of agricultural weeds

Age at First Harvest: Less than 6 years

- Plant too small