Phytophthora cinnamomi Hazard System for the Northern Jarrah Forest

Field Book

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SUMMARY

Hazard is defined as the combination of site, climate and management factors that influence the potential damage caused by disease. Damage is the probability *P. cinnamomi* causing death of jarrah in the system described here. High mortality of jarrah on infected sites during 1982-84 gave the opportunity to develop a hazard system based on disease expression. Over 400 infected areas in the high and intermediate-low rainfall zones of the northern jarrah forest were surveyed since 1983 and analysed to identify the most effective hazard indicators. Vegetation was found to be a better predictor of hazard than were other site attributes measured. Plant species that changed monotonically between plots with low, intermediate and high impact were identified and used as "discriminating variables" in discriminant analysis. The analysis attempted to form discriminant functions by linearly combining the variables to maximize differences between the three hazard groups, low, intermediate and high. Weighting coefficients were assigned to each discriminating variable (plant species) and can be used to calculate function values. Depending on the presence of the indicator species, the species-weighting coefficients can be used to assign a hazard rating to uninfected sites. The present system can only be applied to healthy, undisturbed mid to ridge top sites in the high rainfall zone of the northern forest. Hazard is underestimated in areas with < 6 indicator species and

care needs to be taken in finding some of them. The 56 indicator species used in the system are described.

What is Hazard

Hazard has been used for many years by forest managers to describe sites according to fire danger. Hazard, however, has been little used to classify areas of the jarrah forest according to the consequences of *Phytophthora cinnamomi* infection. Hazard can be just as useful in assessing the consequence of disease as it has been in determining fire danger.

Hazard is defined in a disease context as the combination of site, climate and management factors that influence the potential damage caused by disease. Damage is the probability *P. cinnamomi* causing death of jarrah in the system described here.

Rating of disease hazard is an important part of the sound management of plant communities as it integrates disease matters with management concerns. It helps managers make ecologically informed decisions on scheduling and timing of operations and priorities between areas. Managers also become increasingly aware of the ecological implications of *P. cinnamomi* infection and the importance of integrated pest management.

Comparison of disease impact from site to site and prediction of long term effects of the fungus based only on current impact is difficult. The rate of disease development varies according to fluctuating environmental conditions due to the interactions between site, climate, pathogen, host and management (Shearer and Tippett 1989).

Thus one can never be quite sure from observations of current impact, how long sites have been infected and if the disease is fully expressed in terms of damage. For example a high hazard site may express intermediate or low impact for a long period, depending on the length of time conditions favour disease development. The true potential of disease can only be estimated by a hazard system that uses indicators that integrate the major environmental factors affecting disease development.

Development of the System

High mortality of jarrah on infected sites from 1982-84 gave the opportunity to develop a hazard system based on disease expression. At this time, an association between site factors, survival, sporulation and dispersal of *P. cinnamomi* deep within the soil profile and the infection of jarrah was recognised (Shea *et al.* 1983). There was also an appreciation that disease impact, like Havel site-vegetation types (Havel 1975a,b), occurred along a continuum within the forest according to site characteristics (Shearer and Tippett 1989).

From 1983-1985 sites infected with *P. cinnamomi* were described according to disease expression, landform, geology, soils, vegetation, site history and stand structure. Assessment occurred on the outer active edge of infected, in relatively undisturbed sites mainly in mid to ridge top positions with recent disease expression (leaves

still retained on dead jarrah). The disease expression was rated according to the following scale:

Low - Symptoms only evident in the shrub layer as a few scattered dead individuals. Understorey and overstorey healthy.

Intermediate - Most of the susceptible understorey species, but less than 10% of the overstorey dead. Dead overstorey trees scattered throughout the site and not clumped.

High - Most of the susceptible understorey and more than 10% of the overstorey dead.

It was assumed that disease was fully expressed in most of the sites and this was confirmed in subsequent analysis. Over 400 infected areas in the high and intermediate-low rainfall zones of the northern jarrah forest were surveyed since 1983 and analysed to identify the most effective hazard indicators.

Data from the high and intermediate-low rainfall zones were analysed separately because of differences in landform,

climate and disease expression between the two areas. Vegetation was found to be a better predictor of hazard than were other site attributes measured. Plant species that changed monotonically between plots with low, intermdiate and high impact were identified and used as "discriminating variables" in discriminant analysis. (Fisher 1936) The analysis attempted to form discriminant functions by linearly combining the variables to maximize differences between the three hazard groups, low, intermediate and high. Weighting coefficients were assigned to each discriminating variable (plant species) and can be used to calculate function values. The function values are coordinates positioning the plot or area in two dimensional "hazard space" (Fig. 1 and 3).

Depending on the presence or absence of the indicator species, the species-weighting coefficients can be used to assign a hazard rating to uninfected sites. The calculation of hazard ratings from plant species occurrence has been facilitated by the development of field sheets and a computer program. For the field sheets, the weighting coefficients have been converted into coordinates in two dimensional space; positive values being up or to the right, negative values down or to the left (Fig. 1). As the presence or absence of vegetation indicators in the site is determined, the weights representing distance in an up or down, left or right direction can be read off the checklist and used to update the position from the starting point in the two dimensional chart (Fig. 1). The weights are

accumulated by moving from the previous position determined from species occurrence. Once the necessary moves have been made for all indicator species occurring on the site, the hazard rating can be determined from the final position on the chart (Fig. 1). Alternatively, the indicator species present in a site can be marked on a sheet (Fig. 2) and the hazard rating obtained with the aid of a computer program. When sites not included in the initial analysis were used to validate the system, 88% of the high impact sites in the high rainfall zone were given a high hazard rating.

Important Boundary Conditions on the Application of the Hazard System

- The system is only for the high rainfall zone of the northern jarrah forest.

  The system for the intermediate-low rainfall zone is being tested.

- Assess healthy areas.

  Hazard is underestimated in infected areas due to loss of susceptible indicators.

- Assess undisturbed areas.

  Disturbance affects assessment of hazard by changing the environment and masks the occurrence of indicator species. The criteria used in the interpretation of aerial

photographs for *P. cinnamomi* infection, of at least 3 years after fire or logging, should also be used for mapping hazard. Research is continuing to determine the long term effects of disturbance on hazard.

- Assess mid to ridge top positions.

  The system has not been developed for the lower slopes of valleys and will underestimate hazard in these lowland areas.

- Hazard can be underestimated if less than 6 indicator species occur within an area.

  This is particually a problem in areas covered by thick water bush (*Bossiaea aquifolium*).

- Care needs to be taken in finding some of the indicator species. They are either difficult to detect when not flowering, they occur seasonaly or there may be problems in recognition.

  Difficult to detect. Extra care must be taken to search for the following in dense undergrowth in the non-flowering season: *Billardiera drummondianus, Comesperma virgatum, Patersonia pygmaea.*

Seasonal: *Drosera* spp., *Stylidium* spp., *Trichocline spathulata*. Best time is in spring.

Problems in Recognition: *Hibbertia perfoliata* - ensure that all leaves are perfoliate (see illustration later) and not confused with *H. amplexicaulis*.

The species have been included for evaluation.

- The hazard rating gives no indication of how quickly hazard will be expressed.

  This will depend on the interaction between site climatic and management factors (Shearer and Tippett 1989). Current research is investigating the processes that affect the rate of disease development to improve predictions of change in disease expression with time.

- Hazard rating predicts potential death of the jarrah overstorey.

  The system does not include the long term effects of infection on growth of jarrah on intermediate sites where jarrah can survive for long periods. Damage to the understorey, although important, is not included in the present system.

- The system cannot guarantee that *P. cinnamomi* infection will not cause death of jarrah in areas classified as low hazard.

- Hazard system development will be an ongoing process and improvements made once the system has been used in practice.

Mapping Hazard

It is unlikely that the field sheet illustrated in Fig. 1 will be used for the mapping of large areas. Assessment is much faster by recording the presence of the indicator species on a sheet similar to the example in Fig. 2. The hazard rating can then be determined and mapped later in the office. Direct entry into portable computers in the field may also be tried.

Spacing of transects will need to be assessed as the system is put into practice. Spacings greater that 100m have not been tested.

Fig. 3 shows individual hazard ratings plotted in two dimensional hazard space for an uninfected area of Myara block and Jones catchment assessed on a 50 m grid. The figure emphasizes that hazard is a continuum with ratings being biased towards the high or low end depending on the site characteristics of an area.

Fig. 4 illustrates differences between areas in partitioning uninfected areas into hazard ratings. The Myara area has a much greater proportion of the landscape as high hazard than Jones catchment. Considerably more mapping needs to be done to estimate accurately the proportion of the uninfected landscape occupied by low, intermediate or high hazard sites. Mapping will also assist in the recognition of bounderies between areas of equal hazard rating in the field.

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INDICATOR SPECIES	WEIGHT F_1	WEIGHT F_2
Acacia alata	R2	-
Acacia drummondii	R3	U1
Acacia nervosa	L1	U1
Adenanthos barbigerus	R3	D4
Adenanthos obovatus	R4	U2
Allocasuarina fraseriana	R1	U2
Baeckea camphorosmae	R3	-
Billardiera drummondiana	L4	U5
Clematis pubescens	L1	U2
Comesperma virgatum	L3	-
Conostylis pusilla	R5	U2
Conostylis serrulata	R1	D2
Conostylis setosa	L1	-
Dampiera linearis	R1	D2
Daviesia decurrens	R3	D4
Dianella revoluta	R1	U2
Drosera species	R1	U2
Dryandra nivea	R2	D1
Dryandra sessilis	R1	-
Eriostemon spicatus	R2	U4
Eucalyptus calophylla		
Eucalyptus patens	L5	U10
Gompholobium capitatum	L2	D5
Grevillea wilsonii	R1	U2
Hakea amplexicaulis	L1	U1
Hakea lissocarpha	R1	U1
Hemigenia curvifolia	L2	U1
Hibbertia hypericoides	L3	-

INDICATOR SPECIES	WEIGHT F_1	WEIGHT F_2
Hibbertia perfoliata	L2	U3
Hibbertia pilosa	L3	U7
Hibbertia quadricolor	R3	D1
Hibbertia silvestris	L1	D2
Hovea chorizemifolia	-	D2
Hypocalymma angustifolium	R3	U1
Hypocalymma robustum	R2	-
Isopogon sphaerocephalus	R5	U3
Lasiopetalum floribundum	R2	D3
Lechenaultia biloba		D3
Lepidosperma angustatum	R2	U4
Leucopogon nutans	L5	D1
Loxocarya fasciculata	L1	U2
Melaleuca preissiana	L9	U1
Opercularia echinocephala	R1	D1
Patersonia pygmaea		U1
Pentapeltis silvatica	R4	D6
Phyllanthus calycinus	L2	U1
Pimelea ciliata	R2	U1
Platysace tenuissima	L1	U3
Pteridium esculentum	L1	D5
Sollya heterophylla	L1	-
Sphaerolobium medium	L11	U15
Stylidium sp.	R3	U2
Styphelia tenuiflora		U2
Thysanotus dichotomus	R1	U1
Trichocline spathulata	R1	U1
Trymalium floribundum		D2

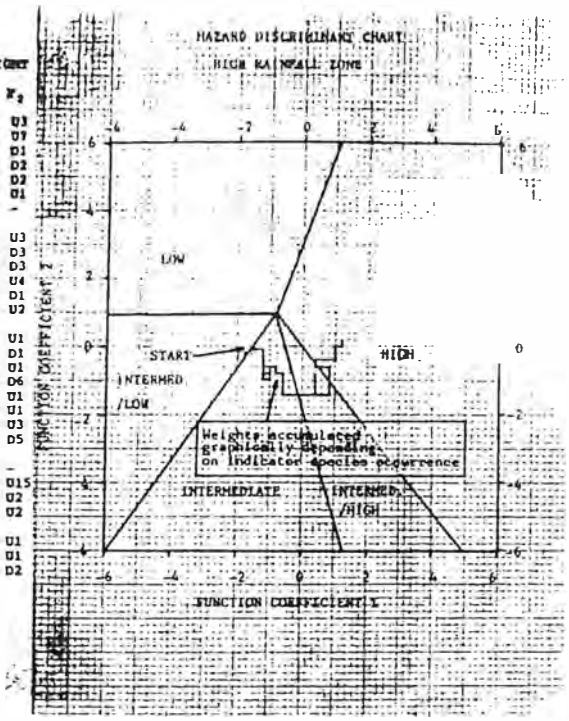

Figure 1 Field sheet for immediate determination of *Phytophthora cinnamomi* hazard. The weights for the plant indicator species were scaled to correspond to the squares on a two dimensional grid. The path indicates the summing of weights, depending on indicator species presence, to determine *P. cinnamomi* hazard.

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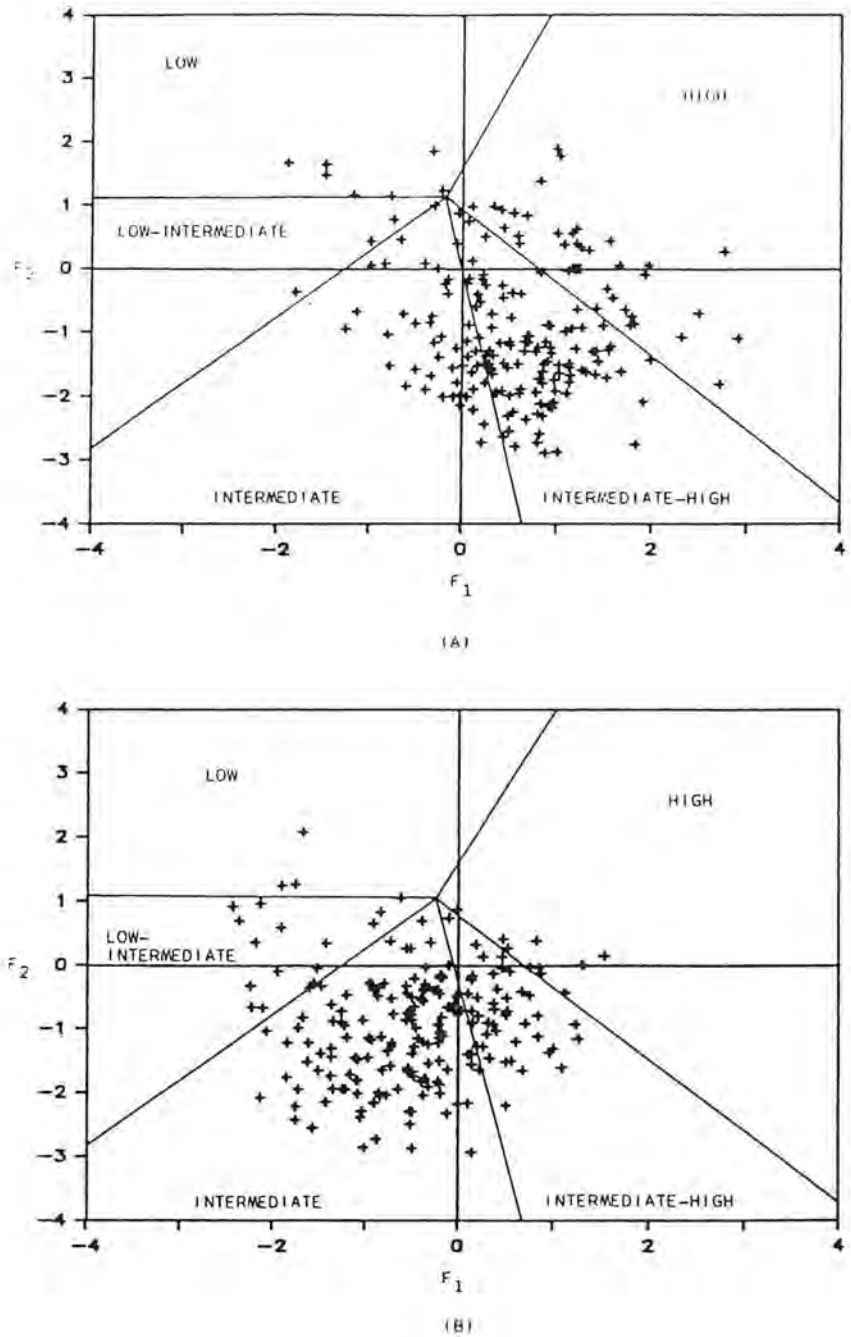


Figure 3 Hazard ratings determined on a 50 m grid for
(A) and area of Myara block and
(B) Jones catchment.

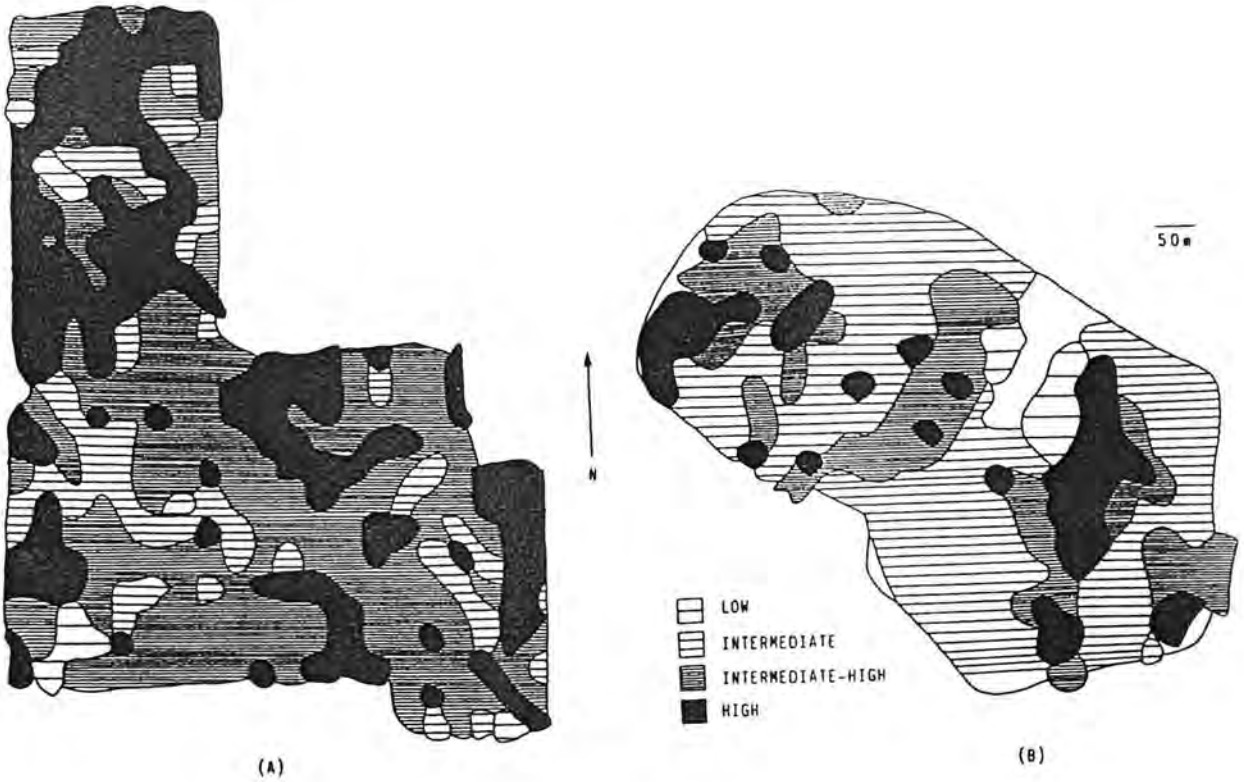


Figure 4 Distribution of *Phytophthora cinnamomi* hazard in uninfected areas of (A) Myara block and (B) Jones catchment.

DESCRIPTION OF PLANT INDICATOR SPECIES

Acacia alata **Winged Wattle**

Height: Shrub to a height of 1-3 metre.

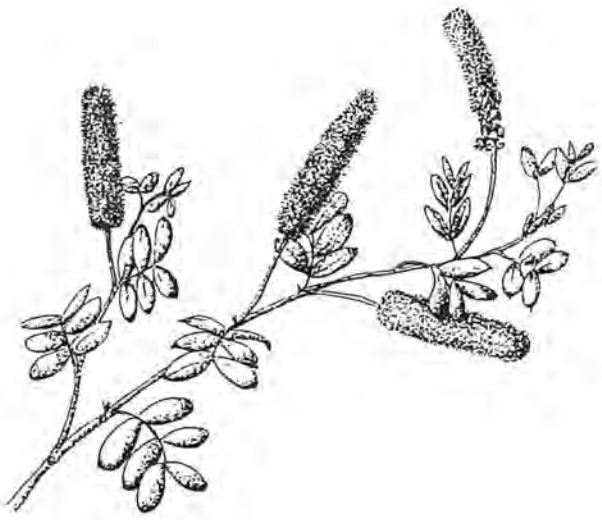
Leaves: Does not have leaves.

Bark: The stem substitutes for the absence of leaves. It has a thin flat stem which is green in colour, 1cm across. It also has very sharp spikes on the stem.

Flower: Bright yellow in colour. Round shaped flowers 1cm in diameter. Flowers from April to October.

REF: Marchant *et al.* (1987) Part 1: 215-216.

Acacia drummondii **Drummonds Wattle**



Height: Spreading shrub, 2 metre high.

Leaves: Feather shaped leaves, 1 cm long. Dark green colour with a bluish tinge.

Bark: Smooth dark green in colour.

Flower: Bright yellow in colour, 1-4 cm long. The most distinguishing feature of this acacia are the long cylindrical shaped flowers. Flowers from July to November.

REF: Marchant *et al.* (1987) Part 1: 220.

Acacia nervosa **Rib Wattle**

Height: Small spiky shrub, 30 cm high.

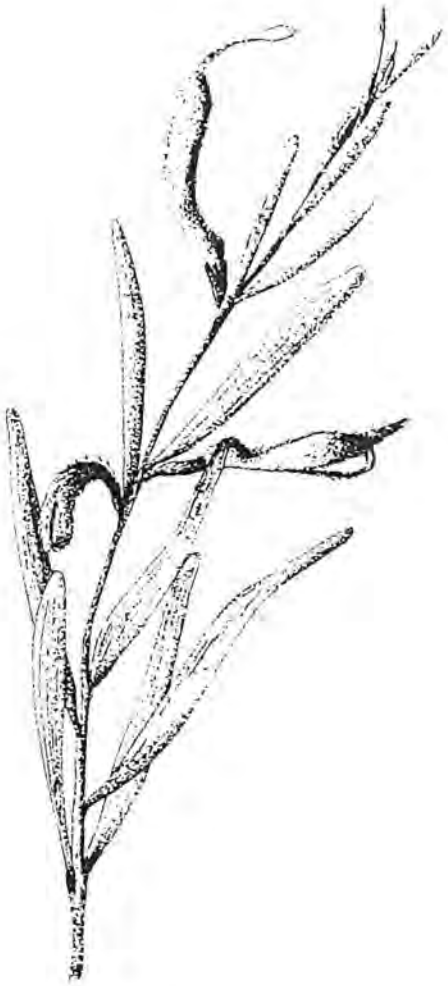
Leaves: Dark green leaves with a shiny surface. Lanceolate shaped leaf, 4 cm long which tapers to a sharp point. The leaf has a prominent mid rib and leaf margin which are a cream colour.

Bark: Light brown to grey in colour. Small spikes growing at the leaf stem junction.

Flower: Bright yellow in colour. Round shaped flowers, 1cm in diameter. Flowers from June to October.

REF: Marchant *et al.* (1987) Part 1: 226.

Adenanthos barbigerus **Hairy jugflower**



Height: Many stemmed shrub in a cluster up to 70 cm high.

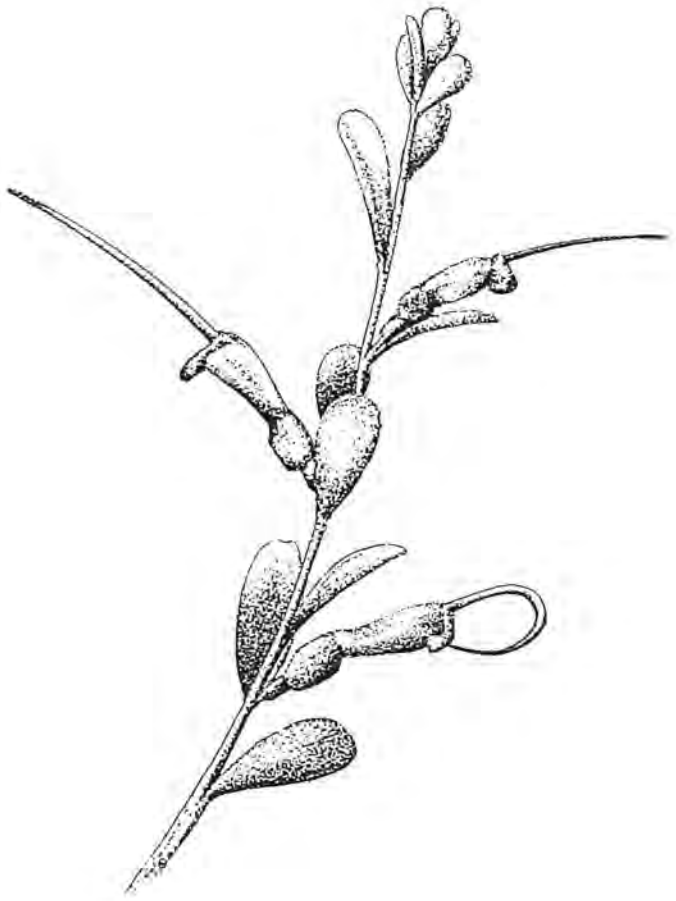
Leaves: Leaves almost opposite, thin and linear, 4-8 cm long. Pale green in colour.

Bark: Stem hairy when young.

Flower: Bright red in colour, 2-2.5 cm long. Jug shaped flowers, hence the name Jugflower. Flowers from March to November.

REF: Marchant *et al.* (1987) Part 1: 311.

Adenanthos obovatus **Basket Flower**



Height: Erect shrub with many stems, 70 cm high.

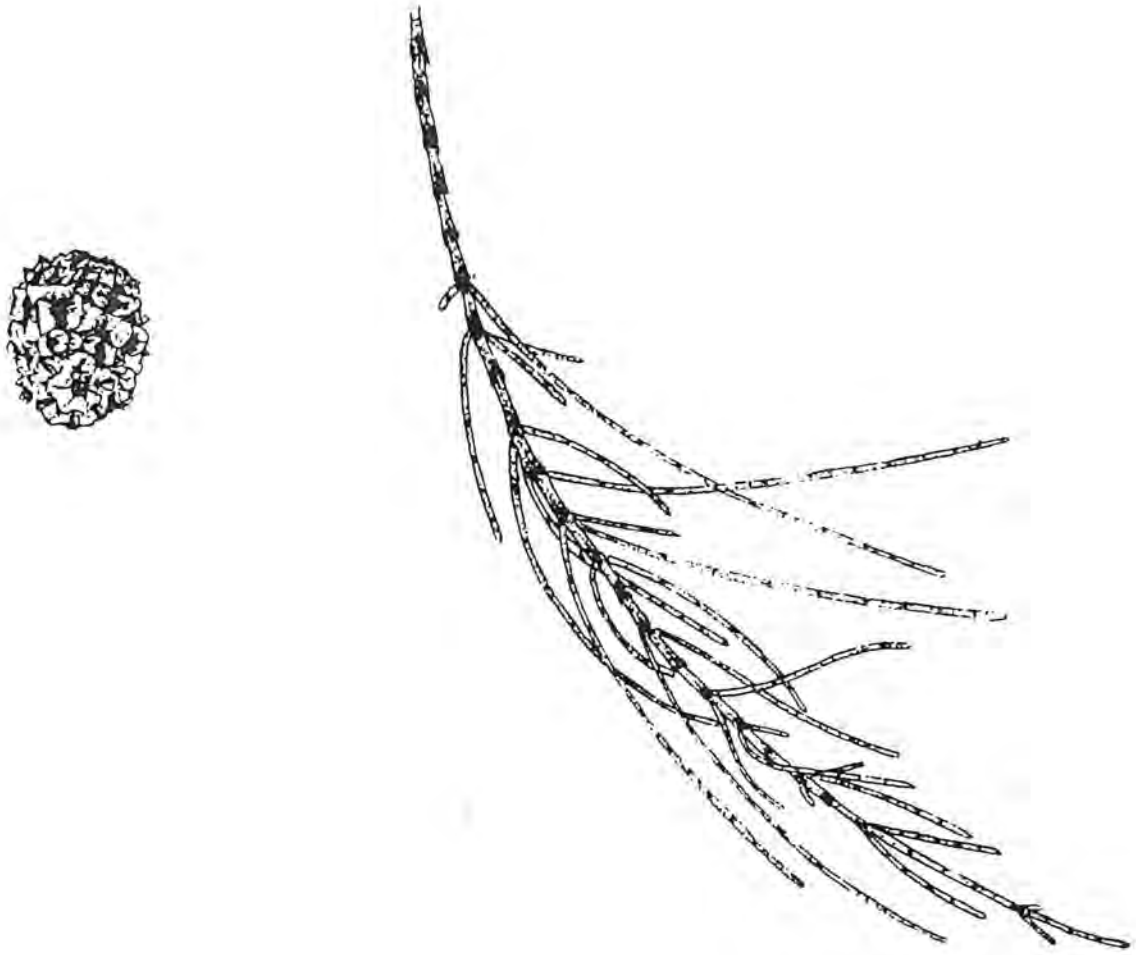
Leaves: Alternate light green, round to oval shaped leaves, 1-2 cm long.

Bark: Not applicable.

Flower: Jug shaped flowers. Red to orange in colour, 1.5-2 cm long. Flowers for most of the year.

REF: Marchant *et al.* (1987) Part 1: 313.

Allocasuarina fraseriana **Sheoak**



Height: Tree up to 10-15 metre high.

Leaves: Allocasuarinas have long needle like green branchlets which act as leaves. The true leaves are tiny teeth like scales which encircle the branchlets at intervals forming segments.

Bark: Loose and flakey, somewhat "corky" in appearance. Fawny grey in colour.

Flower: The male and female parts are carried on separate trees. The male flowers appear as small terminal spikes at the end of the branchlets and are a rusty brown colour. On the female trees they are small, red coloured, cone shaped, and are attached to the main branchlets by a stalk. Flowers May-October.

REF: Marchant *et al.* (1987) Part 1: 73.

Baeckea camphorosmae **Camphor Myrtle**

Height: Small prostrate ground cover.

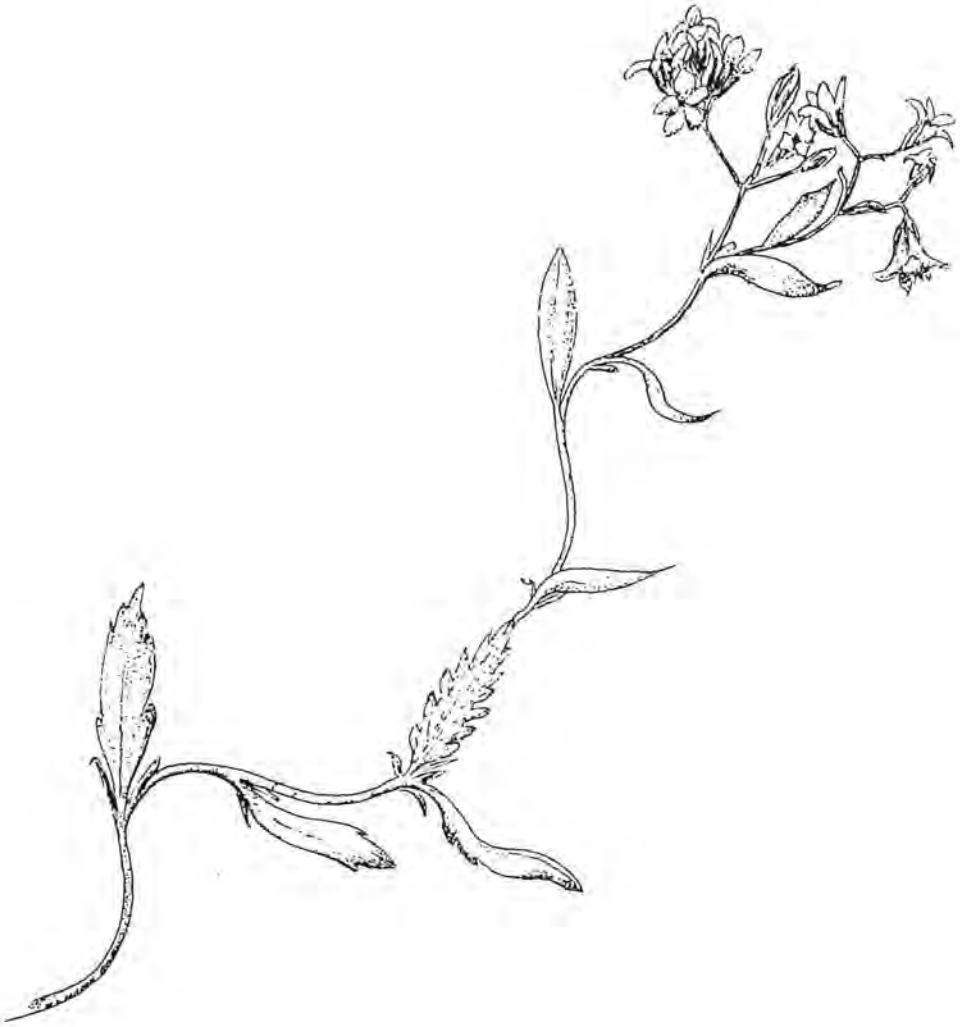
Leaves: Very small dark green leaves, 2 mm long.

Bark: Not applicable.

Flower: Very small 5 petalled flowers. White to pink in colour. Flowers from July to February.

REF: Marchant *et al.* (1987) Part 1: 382.

Billardiera drummondiana **A Billardiera**



Height: A vine or creeper.

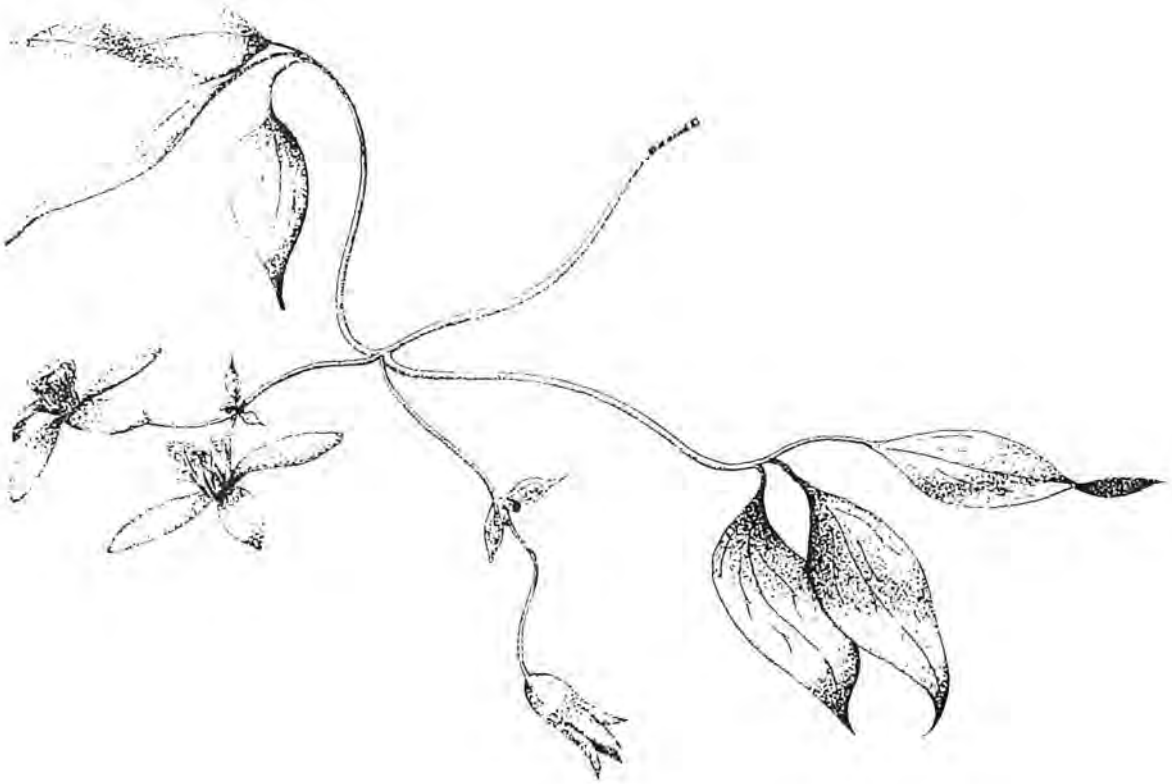
Leaves: Dark green on the top and pale green on the underside. The leaves are fringed with serrations.

Bark: Brown vine.

Flower: Dark blue flowers that mature to form leathery seed capsules. Flowers from August to October.

REF: Marchant *et al.* (1987) Part 1: 200.

Clematis pubescens **Old Mans Beard.**



Height: A vine or creeper that climbs over rocks and shrubs, 2-3 metre high.

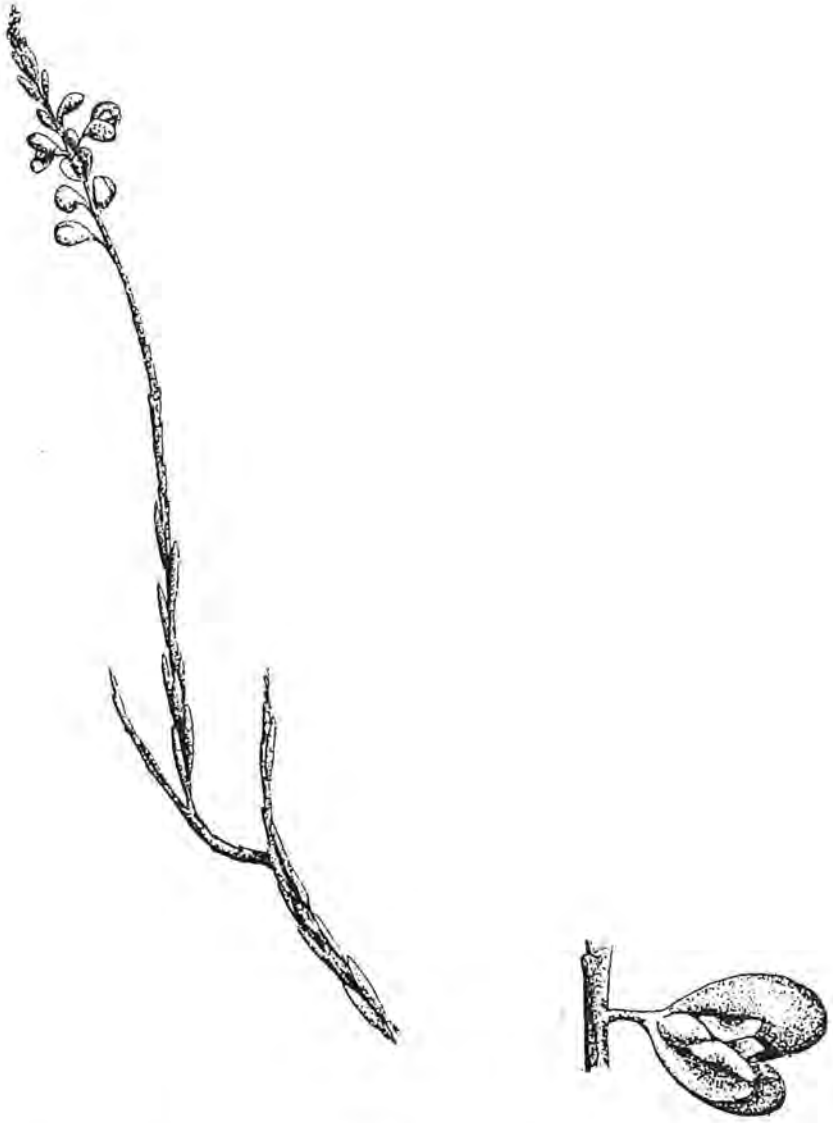
Leaves: Heart shaped, lush green leaves, 5-8 cm long.

Bark: A soft woody vine.

Flower: A large starry flower, white to cream in colour. Has 4 large petals, approximately 5 cm across. Flowers from September to October.

REF: Marchant *et al.* (1987) Part 1: 64.

Comesperma virgatum **A Comesperma**



Height: Tall spindly erect shrub, about 1 metre high.

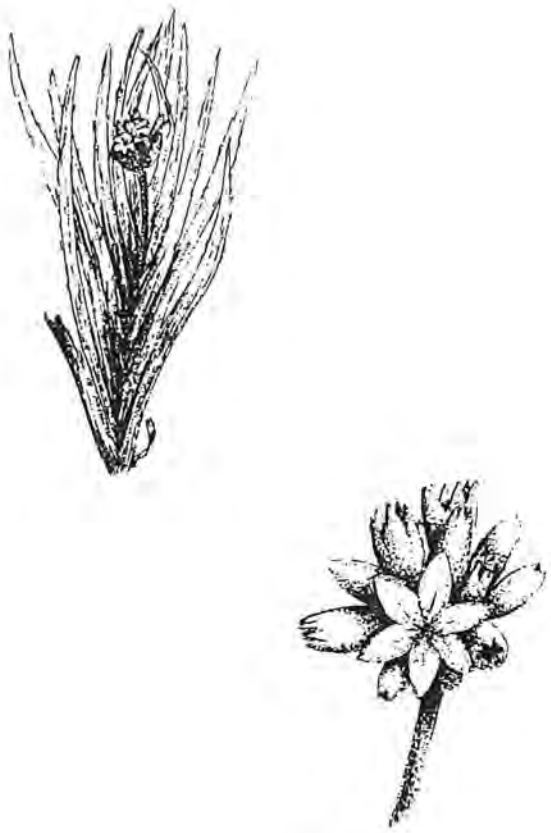
Leaves: Narrow oval leaves, 1 cm long.

Bark: Not applicable.

Flower: Many small flowers grouped together to form one large flower head at the end of the wand like stem. Flowers are pink to mauve in colour and are produced from August to January.

REF: Marchant *et al.* (1987) Part 1: 471-472.

Conostylis pusilla **Bristly Cottonheads.**



Height: Small distinct tufts, 2-5 cm high.

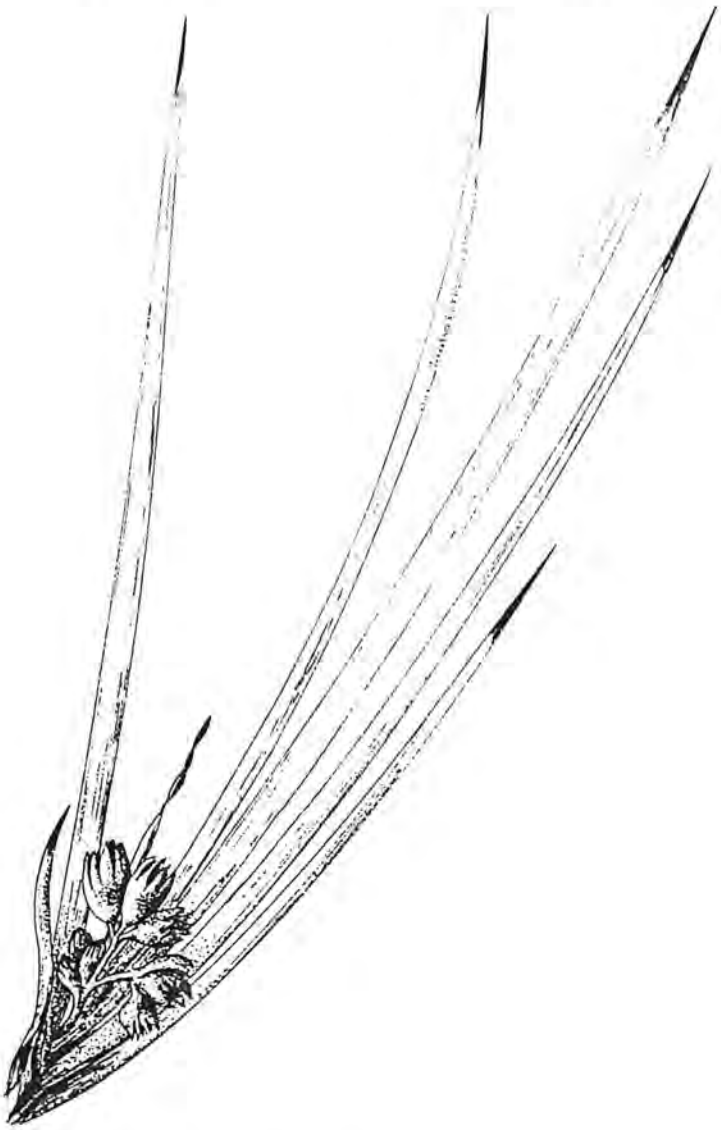
Leaves: Silvery green in colour, 1.5-5 cm long. The most striking feature are the thin hairy leaves.

Bark: Not applicable.

Flower: Pale yellow flower heads that stick out on long thin stalks, approximately 5 cm long. Flowers are 2-3 cm across. Flowers from August to December.

REF: S. Hopper (*personal communication*)

Conostylis serrulata **Woolly Conostylis**



Height: Grows in small tufts, 20-30 cm high.

Leaves: Thin, flat leaves 20-30 cm long. The leaves are fringed with small woolly hairs.

Bark: Not applicable.

Flower: Creamy yellow flower heads clustered together on short flower stalks, 5-8 cm high. Flowers from August to October.

REF: Marchant *et al.* (1987) Part 2: 851.

Conostylis setosa

Height: Grows in small tufts, 15-20 cm high.

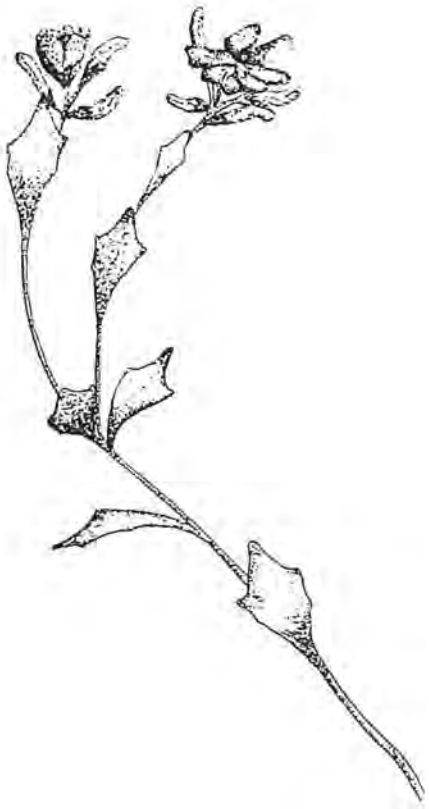
Leaves: Flat thin leaves 10-30 cm long with soft, slender white spines on each margin.

Bark: Not applicable.

Flower: Creamy white flower heads on stalks 10-15 cm high. Flowers from October to November.

REF: Marchant *et al.* (1987) Part 2: 852.

Dampiera linearis **Diamond Dampiera**



Height: Small erect shrub, 10-15 cm high.

Leaves: Dark green leaves that are diamond or wedge shaped and serrated on the margin.

Bark: Smooth green bark.

Flower: Small blue to purple flowers that are covered in soft silky hairs. Flowers from August to November.

REF: Marchant *et al.* (1987) Part 2: 629.

Daviesia decurrens **Thorny Bitter Pea**

Height: Prickly erect shrub, 60 cm high.

Leaves: Flat hook shaped leaves that have a sharp spike on the end of each leaf.

Bark: Not applicable.

Flower: Very small pea shaped flowers that grow in clusters at the stem and leaf junction. Dark red and orange in colour. Flowers from June to November.

REF: Marchant *et al.* (1987) Part 1: 250.

Dianella revoluta **Spreading Flax Lilly**

Height: When in flower this species produces a large flower stalk, 1m in height.

Leaves: Pale green with a bluish tinge. Long rush like leaves, 70-90 cm long.

Bark: Not applicable.

Flower: Small blue flowers that are formed on a large branching stalk. The flowers mature to form small brown berries. Flowers from September to November.

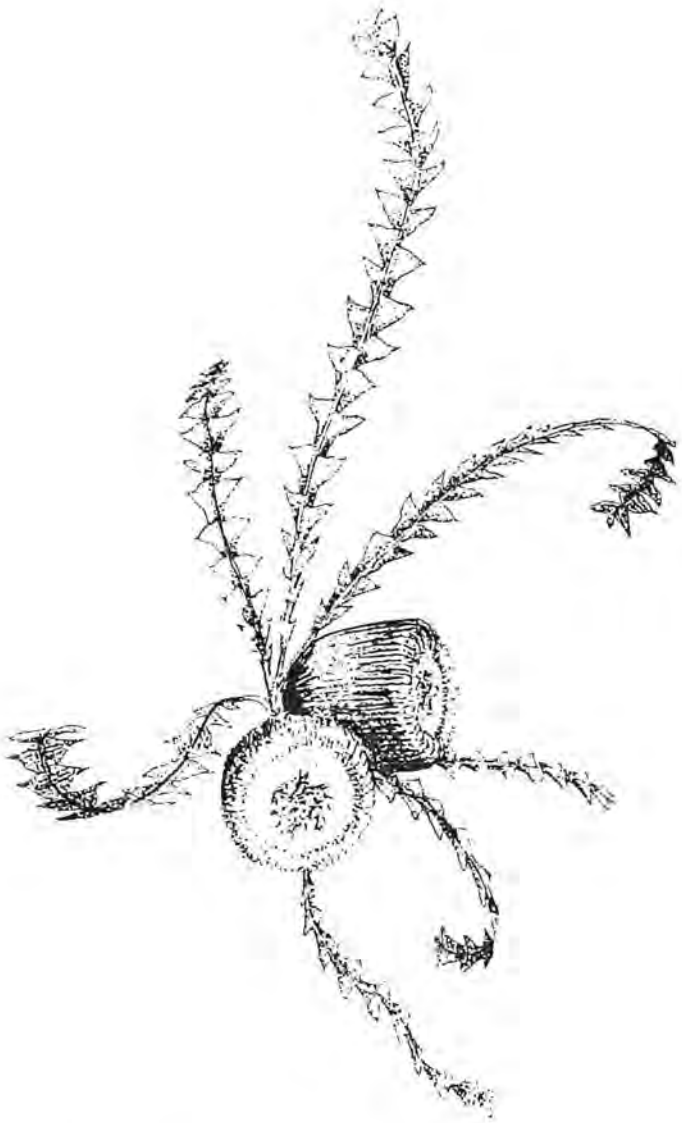
REF: Marchant *et al.* (1987) Part 2: 756-757.

Drosera species **Sundews**

There are many sundews which are very difficult to identify. In general they are; small insectivorous plants.

REF: Marchant *et al.* (1987) Part 1: 147-154.

Dryandra nivea **Couch Honeypot**



Height: Prostrate, spreading ground cover 10 cm high.

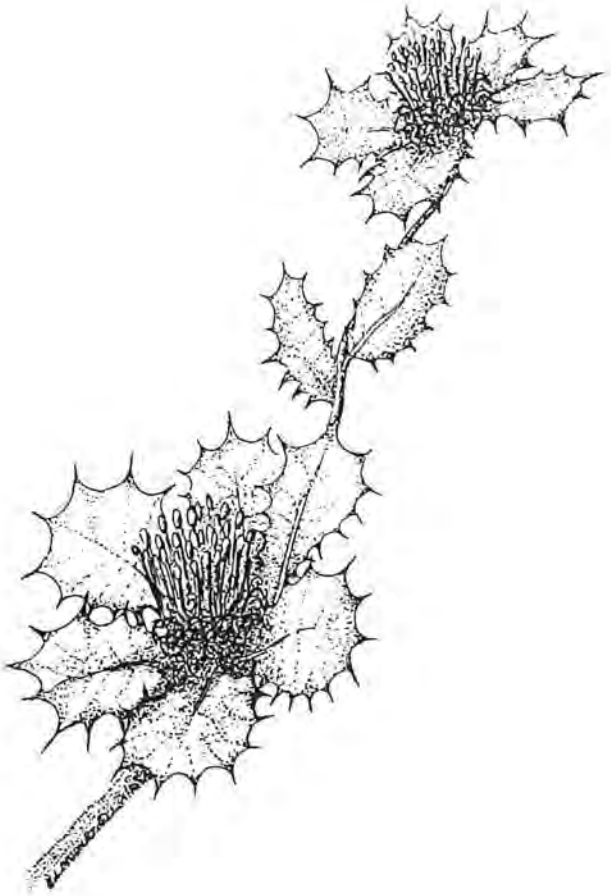
Leaves: The most striking feature is the long thin serrated leaves. They are glossy green on the top, pale green on the underside.

Bark: Not applicable.

Flower: Flower brown pot shaped flowers, hence the name honeypot. Small flower approximately 5 cm long and wide. Flowers from May to August.

REF: Marchant *et al.* (1987) Part 1: 326.

Dryandra sessiles **Parrot Bush**



Height: A small tree growing up to 6 metre high.

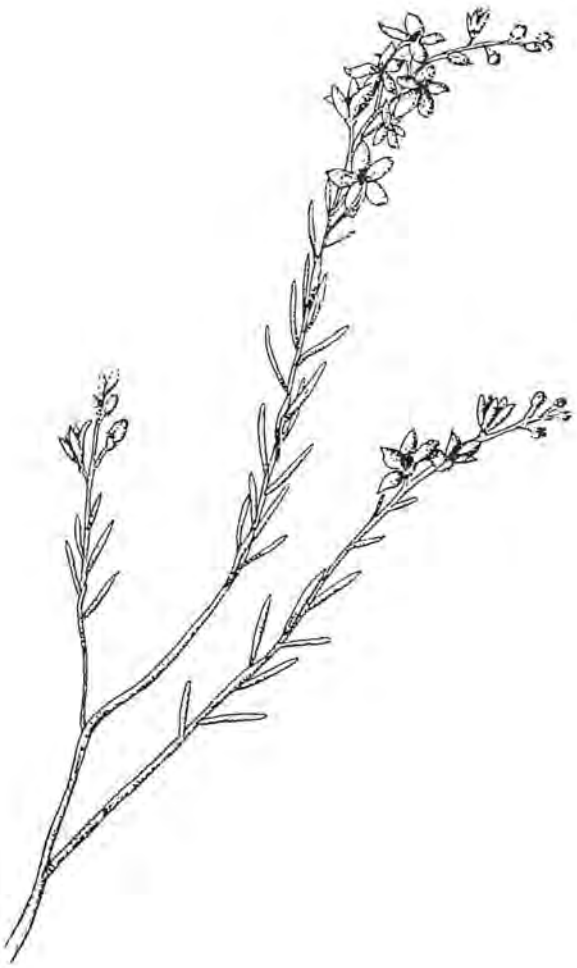
Leaves: Wedge shaped and fringed with very sharp spikes. Pale green in colour, 3 cm long.

Bark: Pale brown.

Flower: The flowers are yellow and sea urchin shaped. Flowers from May to October.

REF: Marchant *et al.* (1987) Part 1: 327.

Eriostemon spicatus **Pepper and Salt**



Height: Spindly, woody shrub, 0.5 metre high.

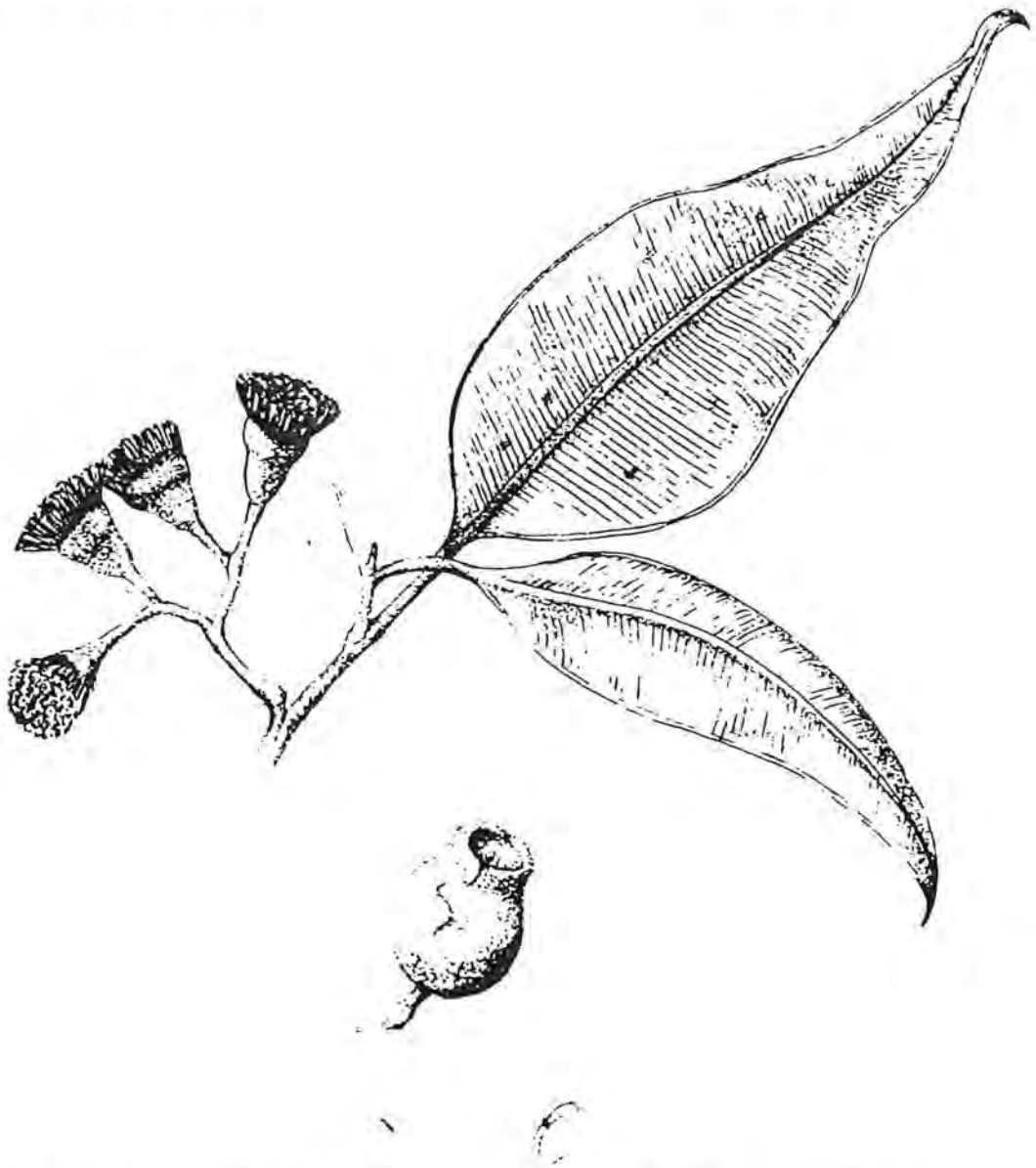
Leaves: Small soft linear leaves, 1 cm long. A light green to grey in colour.

Bark: Not applicable.

Flower: Very small flowers , 6 mm across with 5 small petals shaped like a star. The deep pink to mauve colour flowers are in clusters on slender spikes. Flowers from June to December.

REF: Marchant *et al.* (1987) Part 1: 488-489.

Eucalyptus calophylla **Marri**



Height: A very tall tree that can grow up to 30-40 metre in height. Average height approximately 25 m.

Leaves: Glossy green on the top and a dull green on the underside. The leaf venation is very close.

Bark: Chunky, brownish grey in colour.

Flower: Creamy white in colour, grouped in clusters of 3 to 7. The most distinguishing feature of the marri tree are the large woody nuts commonly called "Honky Nuts". Flowers from February to March.

Eucalyptus patens **Yarri (Blackbutt)**

Height: A tall tree can grow to heights of 40-45 metre. Average height approximately 35 metre.

Leaves: A dull green to bluish green colour on both top and bottom, 10-16 cm long.

Bark: A thick, corky bark which is grey in colour. Commonly black due to burning after bushfires.

Flower: Creamy white in colour grouped in clusters of 4-8 flowers. Flowers from November to February.

Gompholobium capitatum **A Gompholobium**

Height: A small spindly shrub, 30 cm high.

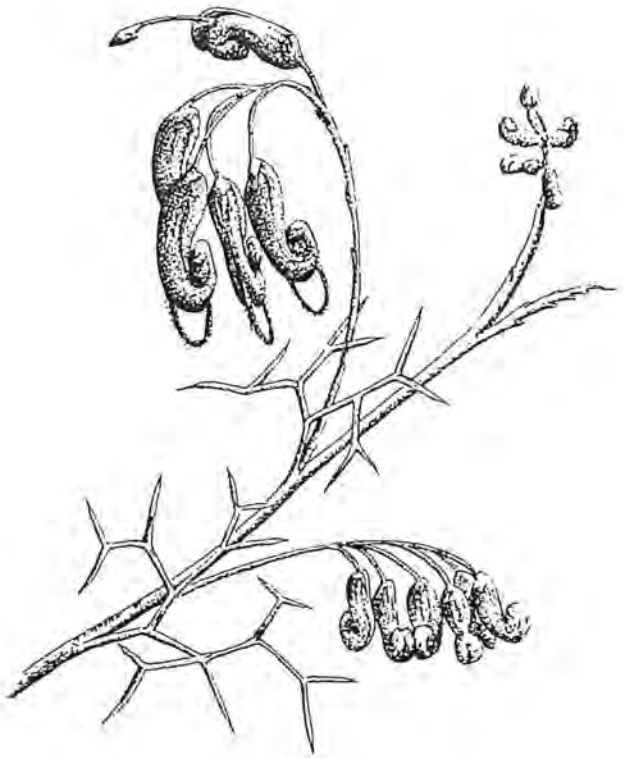
Leaves: Pinnate or feather shaped leaves, dark green in colour.

Bark: Not applicable.

Flower: Dense flower heads on the tip of each branch. Bright yellow pea shaped flowers. Flowers from September to October.

REF: Marchant *et al.* (1987) Part 1: 263.

Grevillea wilsonii **Wilsons Grevillea**



Height: A dense bushy shrub, 1.5 m heigh.

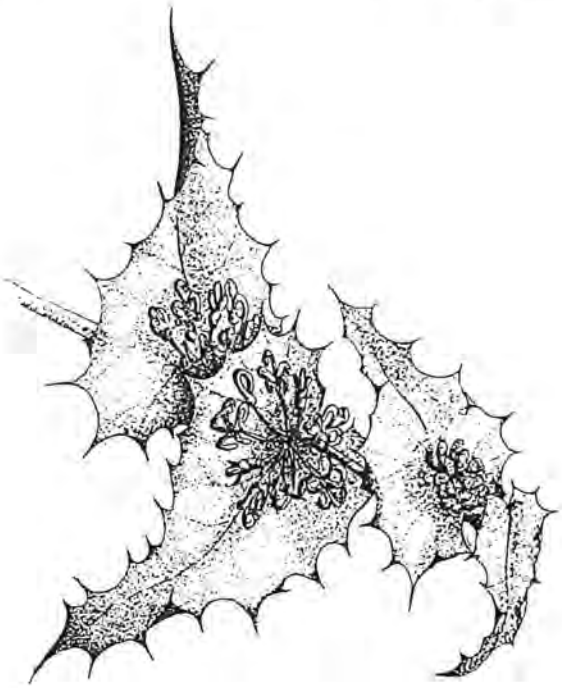
Leaves: Finely divided, sharply pointed leaves. The leaves are very harsh to touch or walk through. A distinguishing feature of this plant is the high proportion of dead foliage that is retained on the shrub.

Bark: Not applicable.

Flower: A deep red colour, 12-15 mm long. The flowers are formed from September to December in clusters and are tube shaped.

REF: Marchant *et al.* (1987) Part 1: 335.

Hakea amplexicaulis **Prickly Hakea**



Height: Prickly spreading shrub, 1-3 m high.

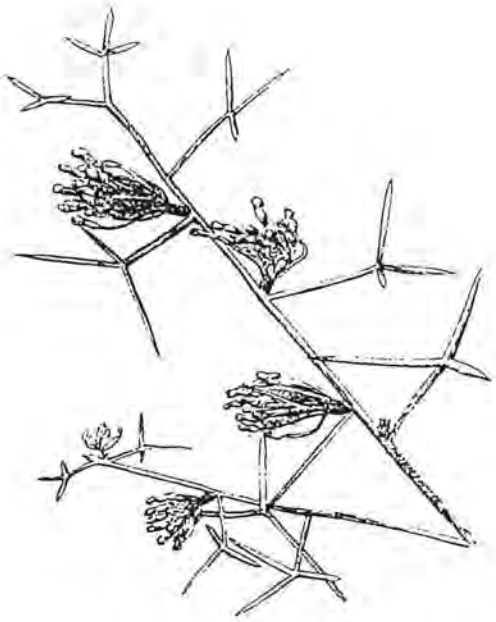
Leaves: Stem clasping leaves, 10-20 cm long. The leaf is fringed with sharp course spikes.

Bark: Smooth brown bark.

Flower: Small clusters of white to cream flowers which grow at the stem and leaf junction. The flowers mature to form beaked hard woody nuts or fruit.

REF: Marchant *et al.* (1987) Part 1: 336.

Hakea lissocarpha **Honeybush**



Height: Spreading shrub, 1-1.5 m in height.

Leaves: Finely divided, sharp pointed leaves that are dark green in colour. The leaves are very harsh to touch or walk through.

Bark: Smooth reddish-brown bark.

Flower: Creamy yellow flowers that are tube shaped, 3-4 mm long. The sweetly scented flowers mature to hard woody fruits or nuts. These nuts persist on the shrub until burning or drying of the plant. Flowers from June to July.

REF: Marchant *et al.* (1987) Part 1: 341-342.

Hemigenia curvifolia **A Hemigenia**

Height: Small woody plant, 60-90 cm high.

Leaves: Dark green leaves folded flat together and recurved, 1 cm long.

Bark: Not applicable.

Flower: Blue flowers, 1 cm across. The flowers mature to form "Hop" shaped seed pods. Flowers during September.

REF: Blackall and Grieve (1974) Parts 1-3: 585.

Hibbertia hypericoides **Yellow Buttercup**

Height: Low bushy shrub, 60 cm high.

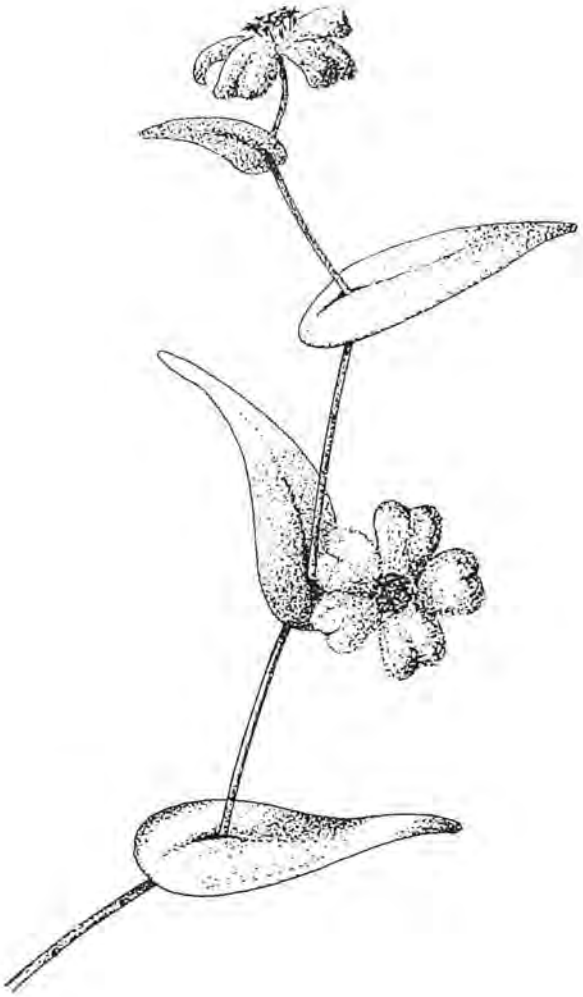
Leaves: Small linear leaves, 5-15 mm long. Dark green in colour.

Bark: Not applicable.

Flower: Prolific bright yellow flowers, approximately 2 cm across. Has 10 petals which are deeply notched. Flowers from May to November.

REF: Marchant *et al.* (1987) Part 1: 125.

Hibbertia perfoliata **Collared Hibbertia**



Height: A low spreading shrub, 10 cm high.

Leaves: Dark green on the top and pale green on the underside. A distinct feature is the way the stem appears to pass through or perfoliate the leaf. Large broad leaf 5-6 cm long.

Bark: Not applicable.

Flower: Yellow buttercup flowers, 3-4 cm across. Flowers from August to March.

REF: Marchant *et al.* (1987) Part 1: 128.

Hibbertia pilosa **Hairy Guinea Flower**

Height: Semi prostrate shrub, 10 cm high.

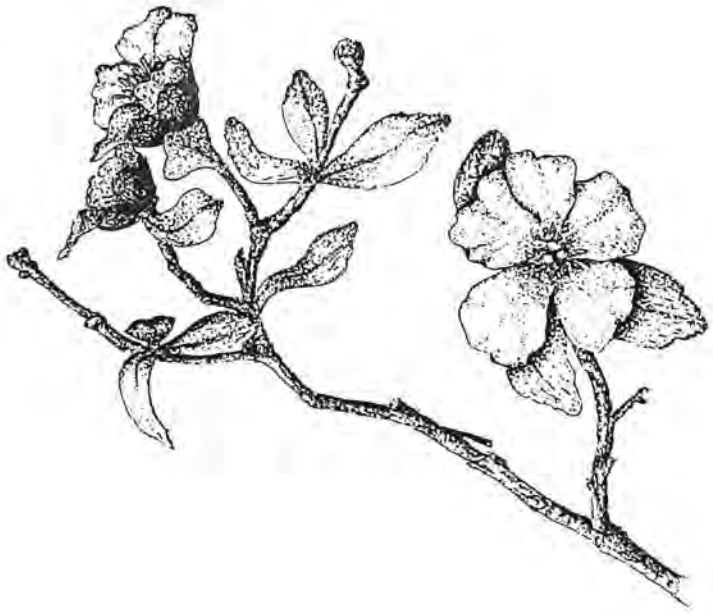
Leaves: Dark green leaves that are covered in silky grey hairs. Lance shaped, 1-2 cm long.

Bark: Not applicable.

Flower: Yellow buttercup flowers, 10-15 mm across. Flowers During October.

REF: Blackall and Grieve (1974) Parts 1-3: 379.

Hibbertia quadricolor **Mountain Primrose**



Height: Small prostrate shrub, to 0.5 metre high.

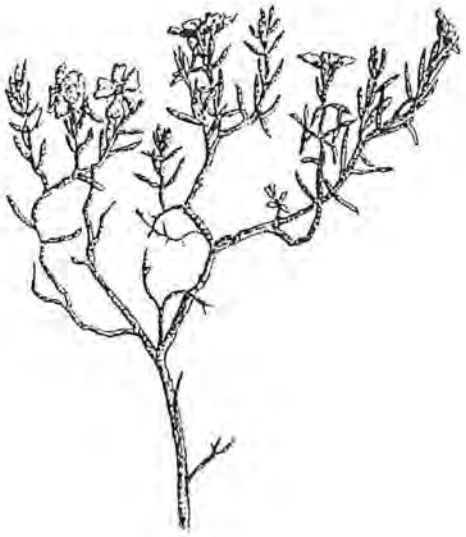
Leaves: Broad, oval leaves up to 2 cm long. Upper surface dark green sparsely hairy, lower surface greyer and sparsley hairy.

Bark: Not applicable.

Flower: Bright golden yellow buttercup shaped flowers. Has 5 large petals, 4-5 cm across. Flowers from July to November.

REF: Marchant *et al.* (1987) Part 1: 128-129.

Hibbertia silvestris **A Hibbertia**



Height: Low semi prostrate shrub, 25-30 cm high.

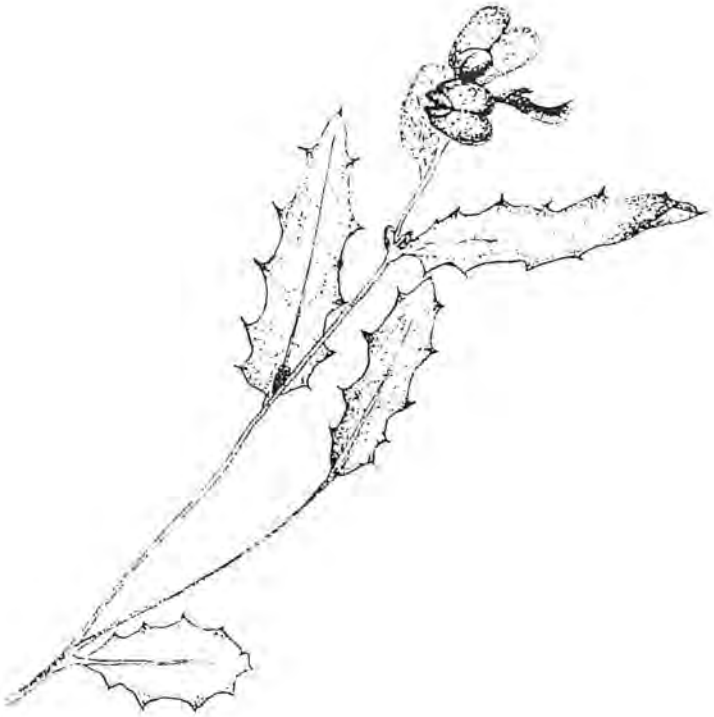
Leaves: Small elliptical shaped leaves, 1 cm across. Dark green on the top and pale green on the underside and covered with silky grey hairs.

Bark: Rough brown bark.

Flower: Small yellow buttercup flower, 1 cm across. Flowers from August to October.

REF: Marchant *et al.* (1987) Part 1: 131.

Hovea chorizemifolia **Holly leaved Hovea.**



Height: Has 3 to 4 stems up to 70 cm high.

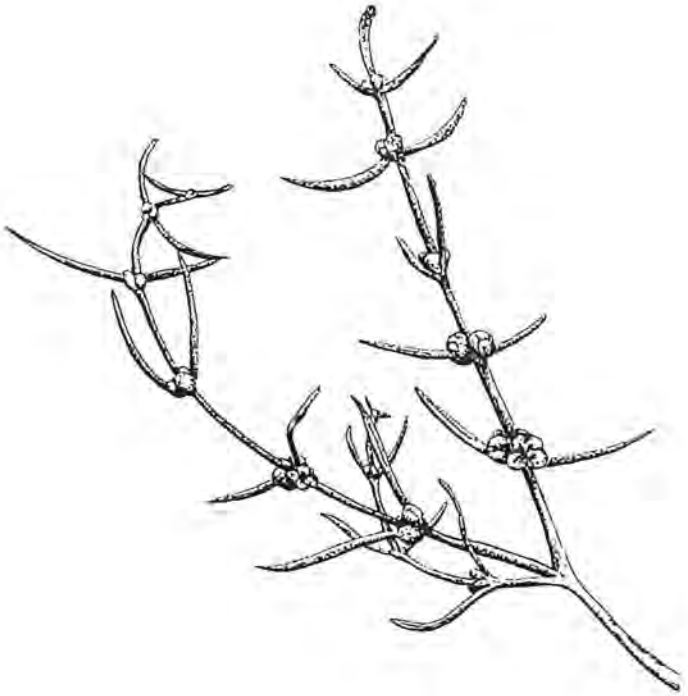
Leaves: Dark green in colour, the leaves are "holly" shaped and are fringed with sharp prickly spikes.

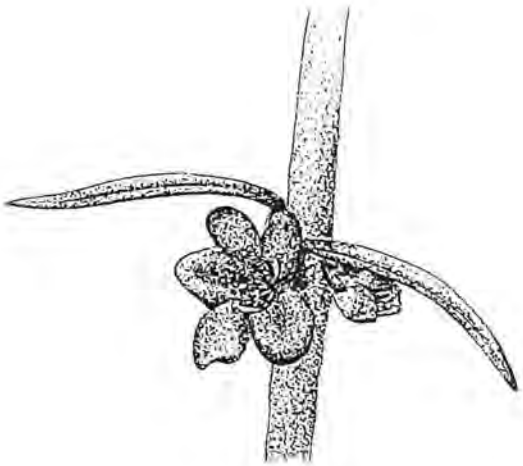
Bark: Not applicable.

Flower: Pea flower, dark blue to violet in colour. Flowers from May to September.

REF: Marchant *et al.* (1987) Part 1: 268-269.

Hypocalymma angustifolium **A Hypocalymma**





Height: A multi-stemmed shrub, 0.5-1 metre across.

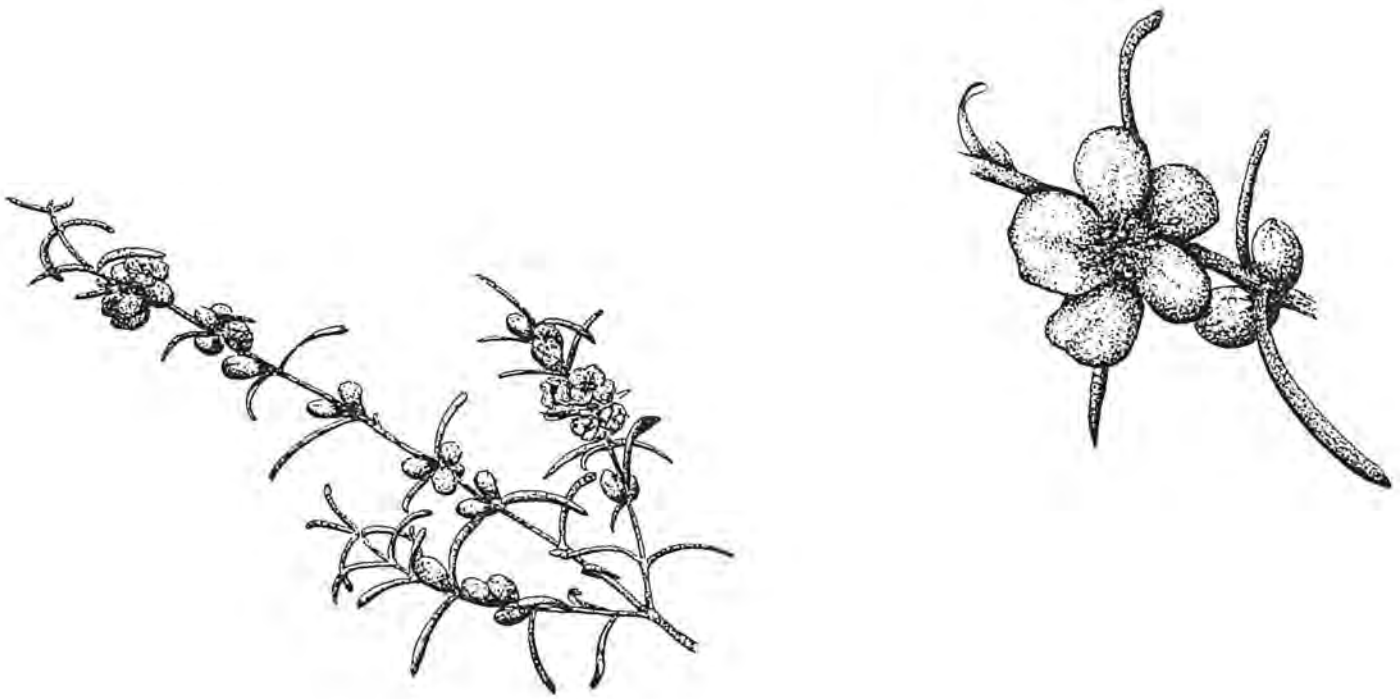
Leaves: Green needle shaped leaves, 1-3 cm long opposite each other on the stem.

Bark: Rough grey bark.

Flower: Small white flowers often with a pink tinge, 1 cm across. Flowers from July to October.

REF: Marchant *et al.* (1987) Part 1: 408-409.

Hypocalymma robustum **Swan River Myrtle**



Height: A many stemmed shrub, 1 metre high

Leaves: Dark green linear leaves, 10-15 mm long, opposite each other on the stem.

Bark: Not applicable.

Flower: The flowers have 5 petals and a number of fluffy stamens. Pinkish flowers which have a pleasant scent, 1 cm across. Flowers from June to January.

REF: Marchant *et al.* (1987) Part 1: 409.

Isopogon sphaerocephalus **Drumstick Isopogon**

Height: An erect shrub, 1-2 metre high.

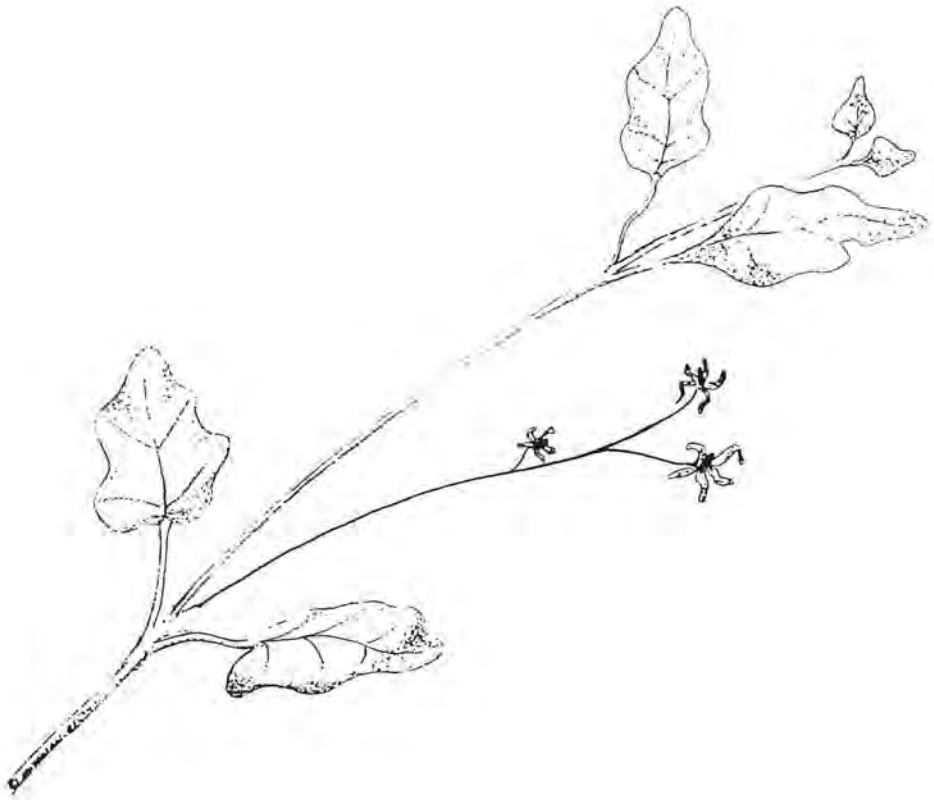
Leaves: Long linear leaves, 5-10 cm long, dull green colour and covered in soft small hairs.

Bark: Not applicable.

Flower: The most distinguishing feature are the creamy yellow colour and coned shaped flower heads, 3-4 cm across. Flowers from December to February.

REF: Marchant *et al.* (1987) Part 1: 347.

Lasiopetalum floribundum **Lasiopetalum**



Height: Grows to a height of 1.5 metre.

Leaves: Triangular leaves, dark green on the top, pale green on the underside with small hairs.

Bark: The stem is a brown colour and is also covered in small hairs

Flower: Small groups of tassel flowers approximately 1 mm long. The flowers are pink or white and are produced from August to January.

REF: Marchant *et al.* (1987) Part 1: 136.

Leschenaultia biloba **Blue leschenaultia**

Height: Spindly stem grows up to 70 cm high.

Leaves: Soft small linear leaves less than 1 cm long.

Bark: Not applicable.

Flower: Various shades of blue, 2-3 cm wide. Has 5 evenly spaced petals. Flowers from June to August.

REF: Marchant *et al.* (1987) Part 2: 633.

Leptosperma angustatum **A Lepidosperma**

Height: Medium to tall sedge, 50-60 cm high.

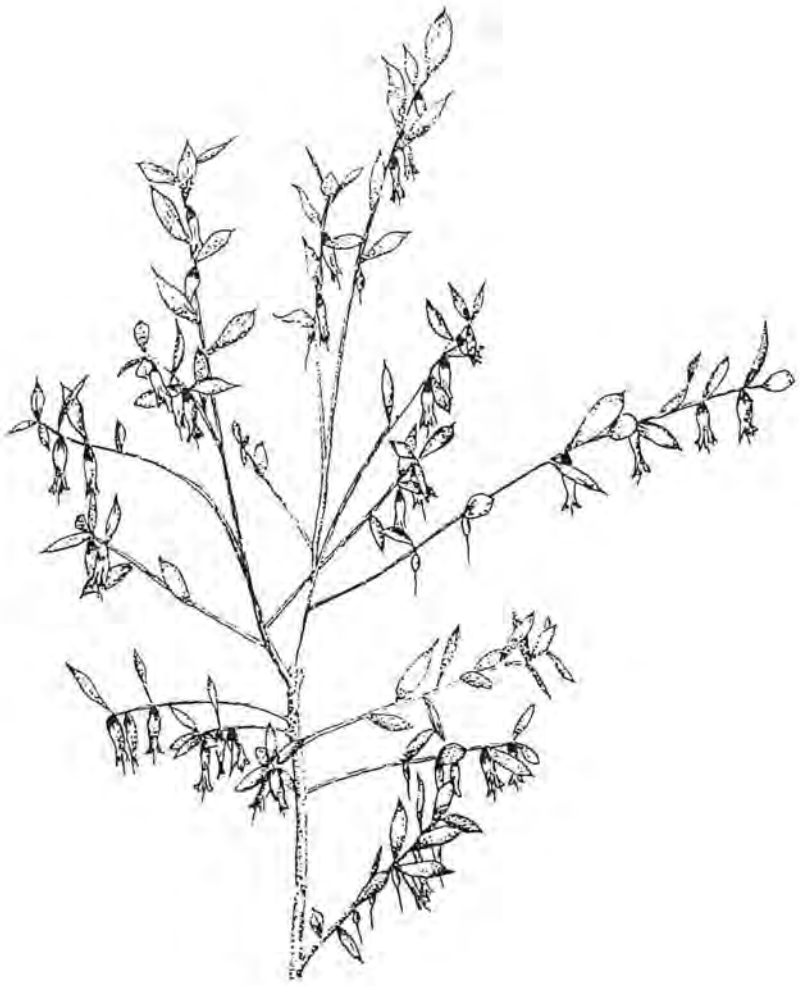
Leaves: A true grass or sedge characterized by many stems, with sheathing leaves. The leaves are small flat growths sheathing the base of each stem.

Bark: Not applicable.

Flower: Brown to black flower spikelets and fruit consisting of a seed like grain.

REF: Marchant *et al.* (1987) Part 2: 887.

Leucopogon nutans **A Leucopogon**



Height: A medium, bushy shrub, 0.5-1 metre high.

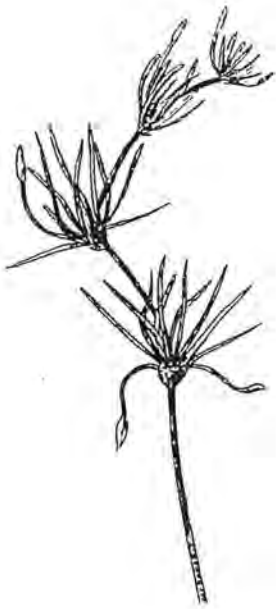
Leaves: Light green leaves tapering to a sharp point. The leaves are close together which have a tendency to point downwards.

Bark: Light brown in colour.

Flower: Very small tube like white flowers with a pink tinge. Flowers from March to June.

REF: Marchant *et al.* (1987) Part 1: 187.

Loxocarya fasciculata **Kerosene Grass**



Height: Small straggling herb, 20-30 cm high.

Leaves: A leafless species that has many small branches covered in soft small hairs.

Bark: Not applicable.

Flower: Produces male and female spicklets from simple branchlets, also reproduces vegetatively by underground runners or rhizomes.

REF: Marchant *et al.* (1987) Part 2: 918.

Melaleuca preissiana **Moonah (Paper Bark)**

Height: Small tree, 5-8 metre high.

Leaves: Small dark green lanceolate leaves, 1 cm long.

Bark: White deciduous paper bark which is the most distinguishing feature of this species.

Flower: White bottle brush shaped flowers. The flowers are produced in dense spikes at the end of the branches.

REF: Marchant *et al.* (1987) Part 1: 416-417.

*Opercularia echinocepha*la **Prickly Headed Stink Weed**

Height: Small dense herb, 50 cm high.

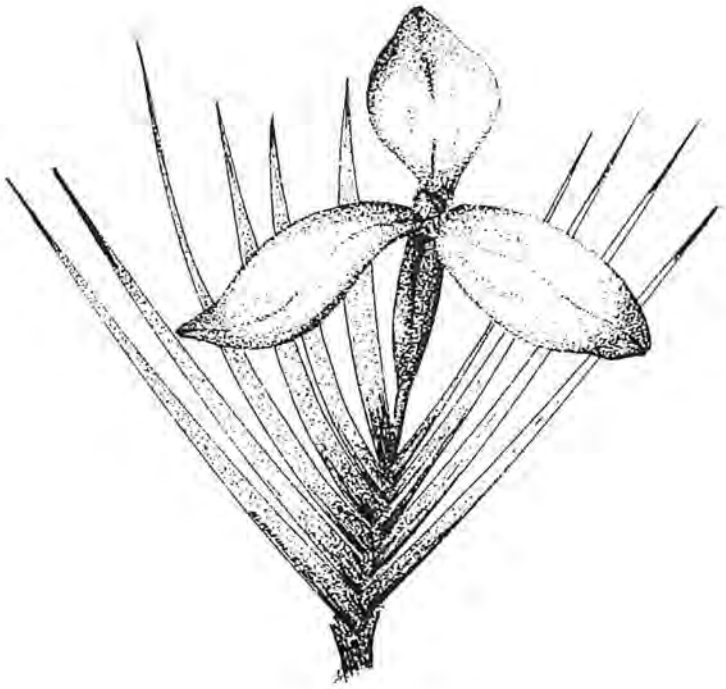
Leaves: Small lance shaped leaves that grow opposite each other on the stem. Light green in colour, 1 cm long. The leaves and stem are covered in small soft hairs. When the leaves and stem are crushed they give off a terrible smell.

Bark: Not applicable.

Flower: Small white flower that resembles clover bur, approximately 1 cm in diameter. Flowers from September to December.

REF: Marchant *et al.* (1987) Part 2: 644-645.

Patersonia pygmaea **Pygmy Wild Iris**



Height: Compact small dense herb, 50cm heigh.

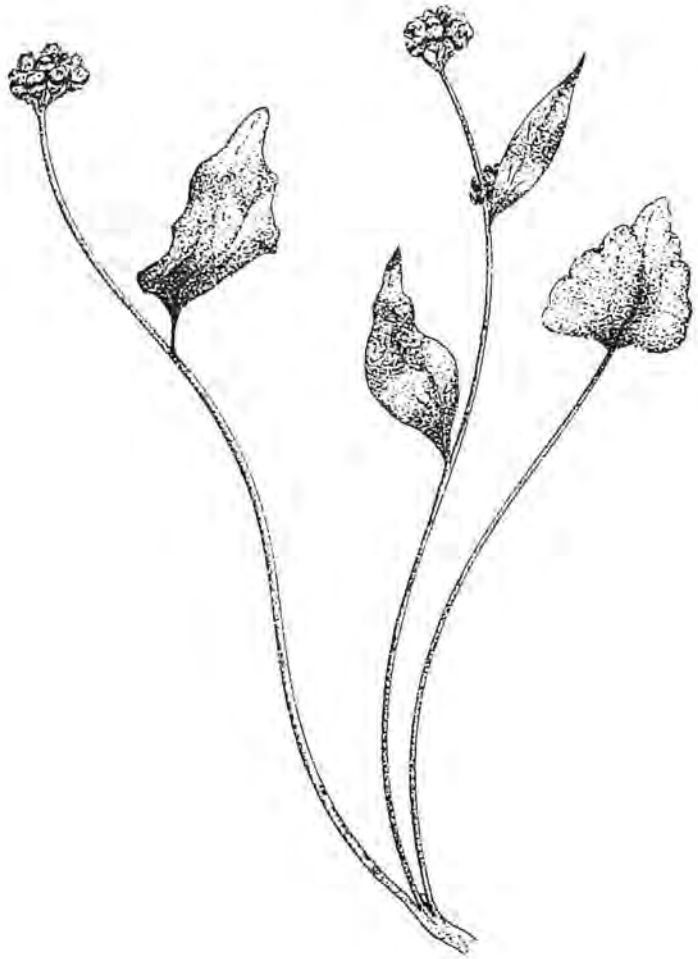
Leaves: Small lance shaped flat leaves, hairy only on margins. Dark green, 4.5-5 cm long.

Bark: Not applicable.

Flower: Purple flowers from September to December.

REF: Marchant *et al.* (1987) Part 2: 800.

Pentapeltis silvatica.



Height: Semi prostrate perennial herb.

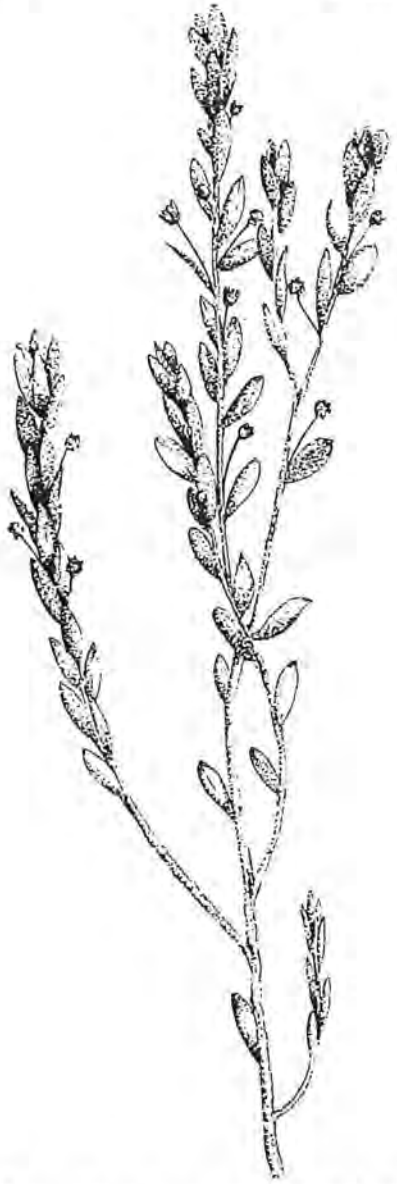
Leaves: Dark green elongated. The edges of the leaf are thickened and bluntly toothed.

Bark: Not applicable.

Flower: A very small white flower, 1cm across. Flowers from April to June.

REF: Blackall and Grieve (1974) Parts 1-3: 488.

Phyllanthus calycinus **False Boronia**



Height: Small shrub, about a metre high.

Leaves: Very small ovate leaves light green in colour, 1 cm long.

Bark: Smooth and brown in colour.

Flower: A creamy yellow flower which resembles that of the sweet scented brown Boronia. Male flowers about half the size of female flowers. Flowers from July to January.

REF: Marchant *et al.* (1987) Part 1: 451-452.

Pimelea ciliata

Height: Erect single stem shrub, 0. 5-1 m high.

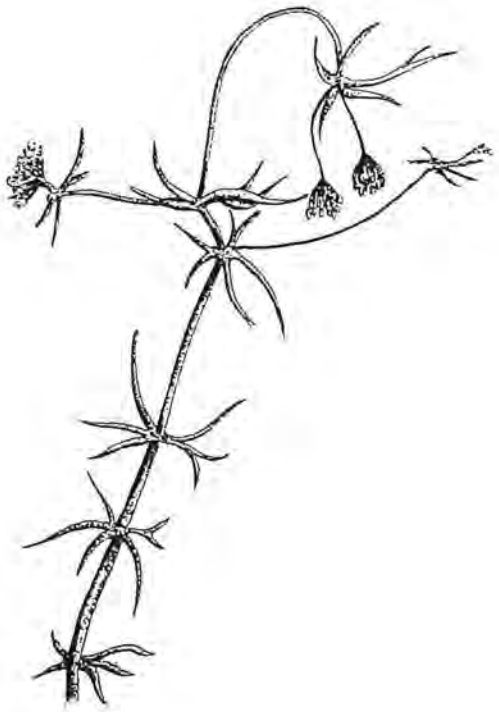
Leaves: Opposite dark green lanceolate leaves, 2-3 cm long. The leaves are recurved or hooked at the tip.

Bark: Dark brown smooth bark.

Flower: Attractive rose pink to white flowers clustered together in one large attractive flower head. Flowers from August to January.

REF: Marchant *et al.* (1987) Part 1: 370.

Platysace tenuissima **Three Leaf Platysace**



Height: Very small spindly shrub, 2-3 cm across.

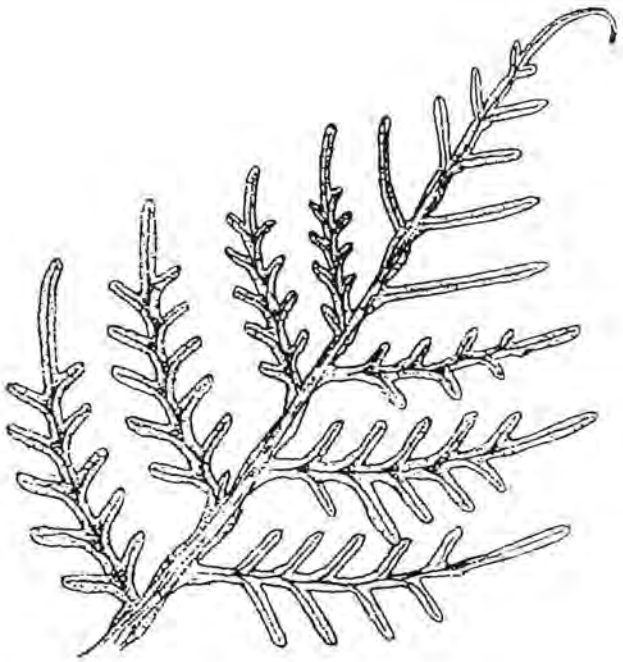
Leaves: Very small leaves, 2-3mm across. Each leaf is evenly divided into 3 separate sections.

Bark: Not applicable.

Flower: A very small brown flower. The flower matures to form a small fleshy seed pod. Flowers from September to November.

REF: Blackall and Grieve (1974) Parts 1-3: 486.

Pteridium esculentum **Bracken Fern.**



Height: Can grow to 2 metres high.

Leaves: Large green fronds, 2 metres long.

Bark: Not applicable.

Flower: Bracken is a fern and does not produce flowers. The fern reproduces from spores, these can be seen on the underside of each frond as small brown spots during the winter months. Also reproduces vegetatively from rhizomes.

REF: Marchant *et al.* (1987) Part 1: 51-52.

Sollya heterophylla **Australian Blue Bell**

Height: A twining shrub, 60-90 cm high. Dark green in colour.

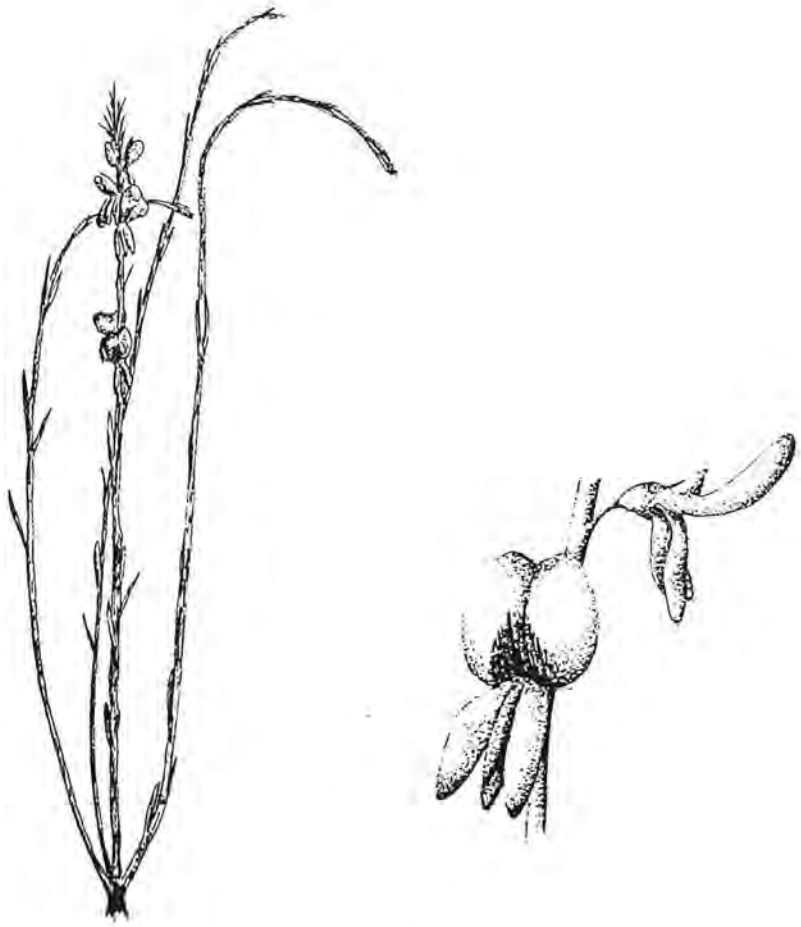
Leaves: Lance shaped leaves, 5-6 cm long. Dark green in colour.

Bark: A twining stem that is light brown in colour.

Flower: A very attractive blue, bell shaped flowers that hang down in clusters. The flowers mature to form long black seed capsules, 4-5 cm long. Flowers from June to January.

REF: Marchant *et al.* (1987) Part 1: 202.

Sphaerolobium medium



Height: Erect, apparently leafless, multi-stemmed shrub to 60 cm high.

Leaves: Linear leaves up to 1 cm long almost opposite.

Bark: Not applicable.

Flower: Yellow to orange and red pea flowers in whorls along flowering branch. Flowers from August to November.

REF: Marchant *et al.* (1987) Part 1: 296-297.

Stylidium species **Trigger Plants**

There are many trigger plants that are difficult to identify without flowers. In general they are; Attractive pink or white flowering plants with a motile style.

REF: Marchant *et al.* (1987) Part 2: 608.

Styphelia tenuiflora **Common Pin** Heath

Height: A spindly erect shrub, 0.50-1 m high.

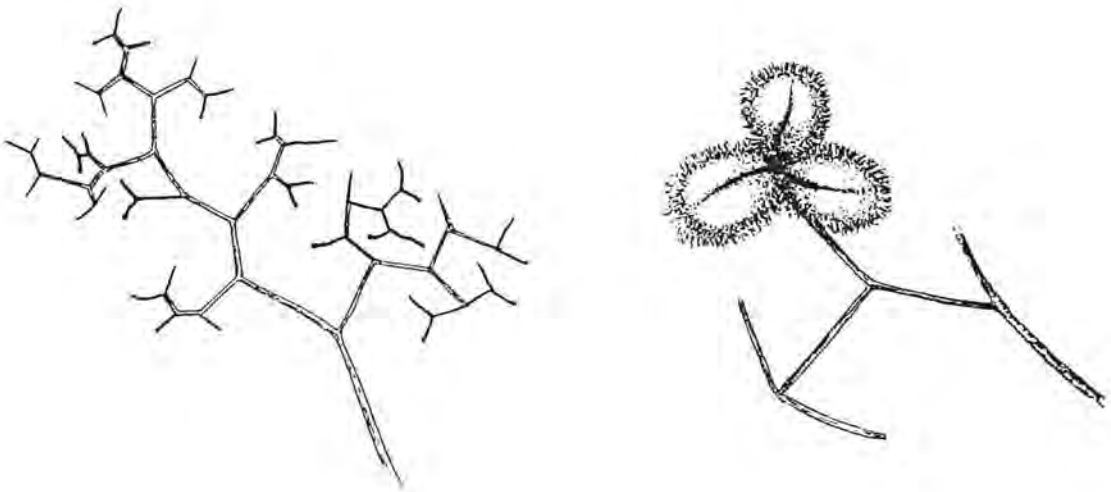
Leaves: Glossy green on the top with a thin cream to yellow band around the edge. Dull green on the underside. Very sharp spikes on the tip of each leaf. The leaves are 10-15 cm long.

Bark: Not applicable.

Flower: Long white tube flowers, 2 cm long. Flowers from April to November.

REF: Marchant *et al.* (1987) Part 1: 195-196.

Thysanotus dichotomus **Branching Fringe Lily**



Height: Small very spindly shrub, 40-60 cm hight.

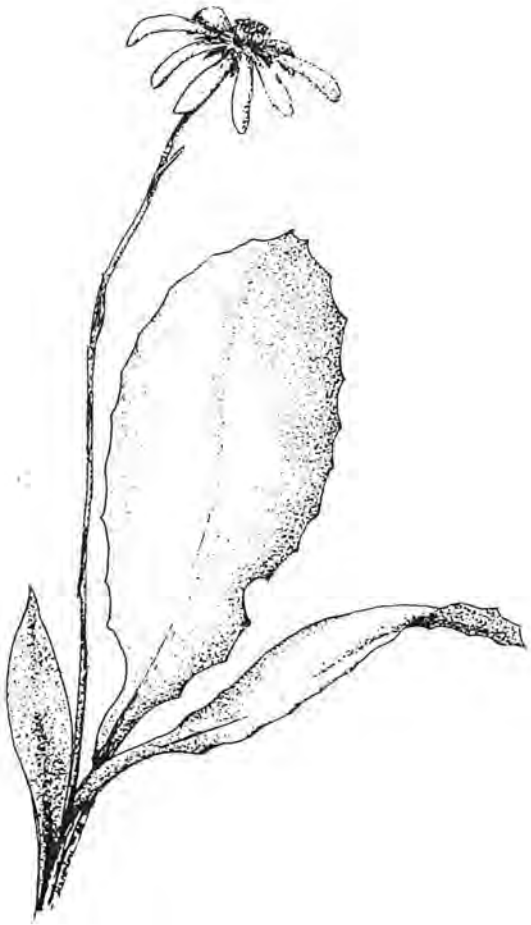
Leaves: Extremely small basal leaves that wither at an early age. The most distinguishing feature is the branches which constantly divide into 2 separate sections.

Bark: Light green stem.

Flower: Attractive mauve coloured fringed lilies. Flowers from September to January.

REF: Marchant *et al.* (1987) Part 2: 773-773.

Trichocline spathulata **Native Gerbera**



Height: Perennial herb to 1 metre.

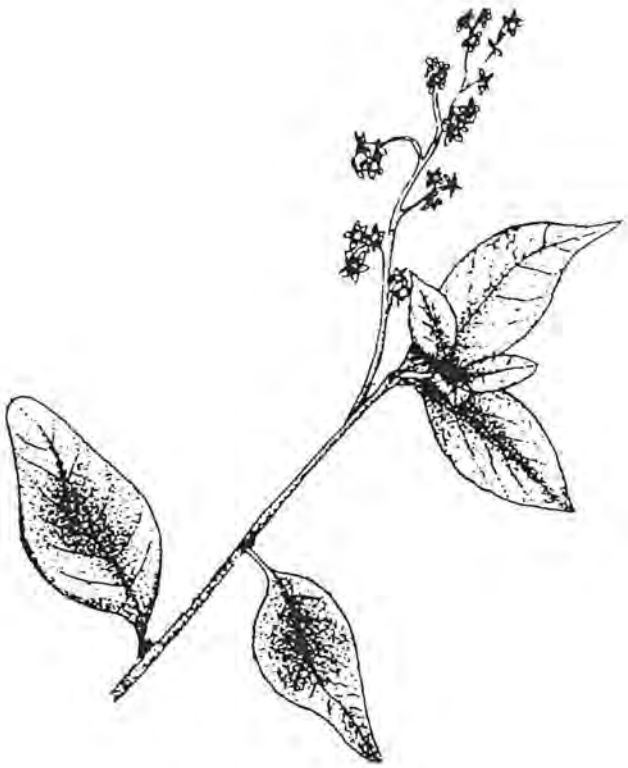
Leaves: Leaves are ovate, 5-8 cm long with white cottony-hairy undersides.

Bark: not applicable.

Flower: Solitary creamy white "gerbera-like" flowers from December to January.

REF: Marchant *et al.* (1987) Part 2: 710.

Trymalium floribundum **Karri Hazel**



Height: Can grow to heights of 10 m in the Karri forest. In the Northern Jarrah Forest the average height is approximately 2-2.5 m

Leaves: Easily identified by its leaves which are green on the top and grey to white on the underside.

Bark: Pale green in colour.

Flower: The creamy white flowers are small and grouped in clusters which hang like tassels, these tassel flowers are very strongly scented. Flowers from August to November.

REF: Marchant *et al* (1987) Part 1: 461.

Combining Hazard and Risk

Hazard maps cannot be used in isolation. The consequence of *P. cinnamomi* infection depends on interrelated factors such as the risk of infection, the intensity of the operation and factors affecting the quality of the environment like the amount of salt stored in the soil profile. The risk of infection can be obtained from maps of disease distribution and the intensity and timing of the operation.

The risk of infection and spread can be combined with hazard to determine the consequences of an operation. The cumulative experience of managers and researchers will need to be combined in the development of a set of rules that will incorporate hazard and risk in a logical way. These rules need to be continually refined with experience once hazard assessment has been put into practise and as knowledge of the factors affecting disease expression increases. Fig. 5 illustrates one way of representing various combinations of risk and hazard.

There is a better idea of the consequences of introduction of *P. cinnamomi* for extreme cases such as low and high hazard than for intermediate cases. The consequences of disease increase rapidly for high hazard sites once there is more than a very low risk of introduction of the pathogen. For low hazard sites the

consequences of disease are much less and they increase at a slower rate than for high hazard. It is more difficult to predict the consequences for intermediate than for low or high hazard sites.

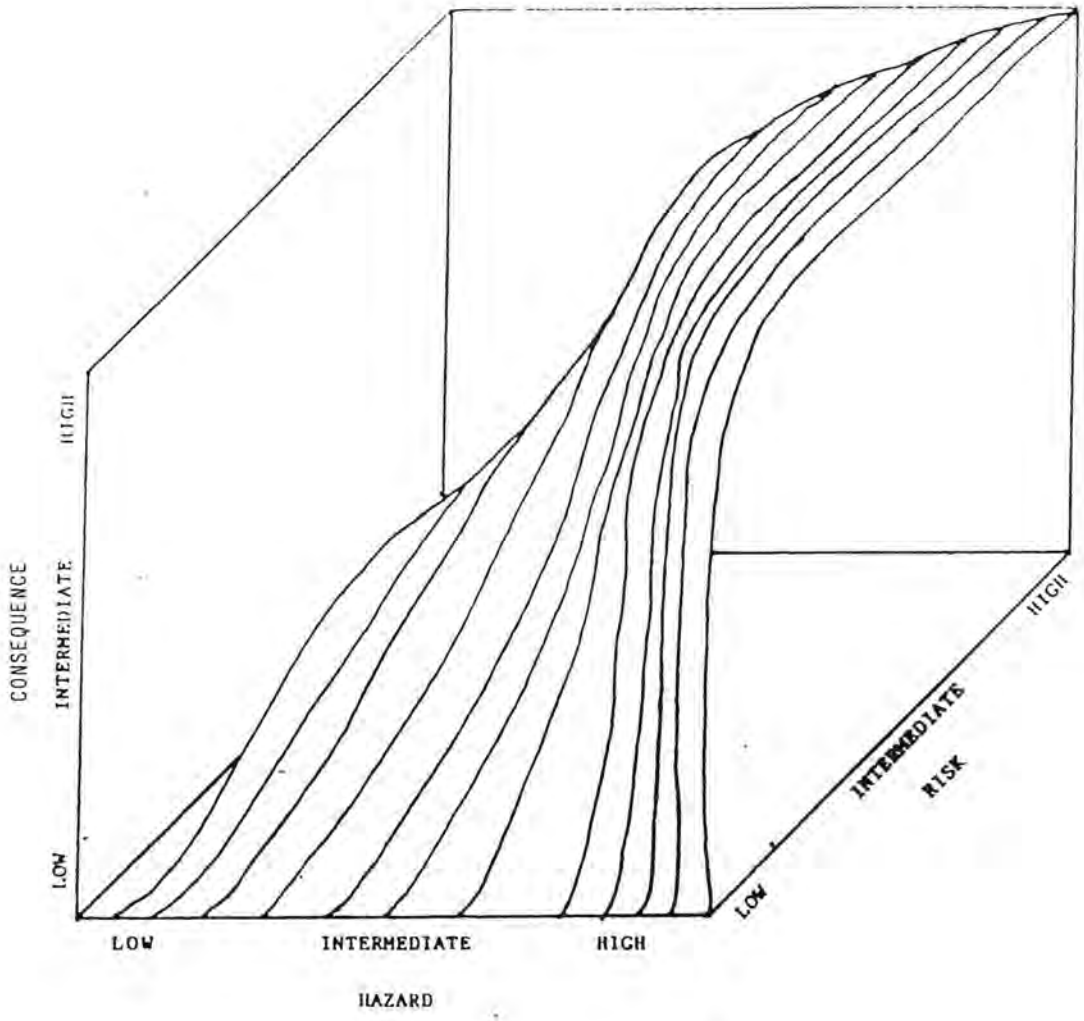


Figure 5 Combining *Phytophthora cinnamomi* hazard with risk. The surface shows the relationships between combinations of hazard and risk to the possible damage should *P. cinnamomi* be introduced into an area.

GLOSSARY

Disease: A harmful alteration of the normal physiological and biochemical development of a plant.

Fungus: One of the lower forms of plant life that lack chlorophyll and being incapable of manufacturing its own food, derives energy from dead or living plant or animal tissue.

Havel site-vegetation types: Definition of sites in the northern jarrah forest by a set of vegetation indicator species that were identified from test surveys to occurr within a corresponding range of environmental conditions. The site types are designated by letters of the alphabet.

Impact: The effect of disease on plant health.

Pathogen: Any organism or factor causing disease.

Phytophthora: (*phyton*, a plant; *phthora*, destruction) Many species in this genus are destructive parasites of economic plants. Hyphae typically branch at right angles and are often constricted at the base. Some species (e.g.) *P. cinnamomi* frequently produce hyphal swellings. Hyphae asexually produce oval shaped sporangia which germinate directly by a hypha or indirectly by segmentation of the protoplasm into zoospores. Following release, the motile ovoid biflagellate zoospores swarm for some time, come to rest, encyst and germinate. Sexual reproduction is by means of fertilisation of an oogonium by an antheridium borne on the same or different hyphae and formation of an oospore.

Risk: The probability of a site being infected.