Age distribution of Slender Cypress-pine (*Callitris gracilis*) within Pine Plains, Wyperfeld National Park

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Executive summary

In semi-arid north-west Victoria, Slender Cypress-pine (*Callitris gracilis*) is an important tree hollow forming species for hollow dependent fauna, particularly the Major Mitchell's Cockatoo (*Lophocroa leadbeateri*). Long-term management of the Major Mitchell's Cockatoo must be based on an understanding of the age distribution of Slender Cypress-pine within important habitat areas and the age at which the trees form suitable nesting hollows.

This project involved an investigation of the Slender Cypress-pine population within the Pine Plains section of Wyperfeld National Park, north-west Victoria. The objectives of the project were to determine the relationship between stem diameter and age of Slender Cypress-pine, and investigate the age distribution of the Slender Cypress-pine population within Pine Plains. Determination of the relationship between stem diameter and stem age will enable the determination of the number of years trees require to start forming hollows, and to form large hollows suitable for Major Mitchell's Cockatoo breeding.

Fifty sections were cut from recently dead fallen trees. Where possible, these sections were cut at the equivalent of breast height (1.4m). Sections were analysed using dendrochronology, to calculate the age of the tree, and hence determine the relationship between age and stem diameter. The relationship between stem diameter and number of growth rings was not strong, with considerable variation in the number of rings found in sections of similar diameter. Additionally, determination of the relationship is hampered by a scarcity of informative samples from trees of over 50cm in diameter.

The point-quarter transect method was used to sample the density and diameter distribution of a range of Slender Cypress-pine stands throughout the Pine Plains area.

The assessment of population structure within Pine Plains was limited to nine transects, in which 188 trees were assessed, 63 of which were dead. This assessment indicated that most trees within the area are between 20cm and 50cm in diameter, corresponding with an approximate age range of 70 – 110 years of age, subject to the assumptions and limitations of the study. Very few trees with a diameter of over 70cm were recorded. Estimation of the age of these larger trees is difficult, due to the lack of samples analysed over 50cm in diameter. These large (70+cm) trees are likely, however, to be at least 130 years old. Hollows suitable for use by Major Mitchell's Cockatoo have been recorded in trees as small as 34cm in diameter, which are likely to be approximately 80 years old.

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1. Introduction

The Major Mitchell's Cockatoo (*Lophocroa leadbeateri*), also known as the Pink Cockatoo, is restricted to arid and semi-arid inland areas of Australia (Walker *et al.* 2004). Within Victoria the species occurs within the north-west region. The species is considered vulnerable in Victoria and is listed as threatened under the *Flora and Fauna Guarantee Act* 1988 due to a decrease in its abundance and distribution (Emison *et al.* 1987; Walker *et al.* 2004). This decrease is attributed to the loss and degradation of their preferred habitat. Some of the practices that have led to the reduction and modification of these habitats include timber harvesting, clearing, thinning, burning and grazing. These practices have reduced the number of hollows suitable for nesting and reduced the regeneration of woody perennial flora which provides shelter and food for the species (Walker *et al.* 2004). Major Mitchell's's Cockatoo depend on tree hollows as they cannot build a nest (Walker *et al.* 2004) and often nest in hollows of veteran cypress pines (Emison *et al.* 1987; Walker *et al.* 2004). An ongoing study lead by VG Hurley, DSE NW has monitored the fate of 63 Major Mitchell's Cockatoo nest trees (all Slender Callitris Pine) from 1992 to 2007 (Hurley 2006a and b). From 1995 to 2007 52.8% (34) of these are no longer suitable for nesting, due to trees falling down or permanent hollow loss from other causes (*VG Hurley unpublished data*).

The Department of Sustainability and Environment (DSE), North West Region, and the Mallee Catchment Management Authority (CMA) commissioned this project to survey the cypress pines on Pine Plains, Wyperfeld National Park, and investigate the time frame it takes for a tree to reach its capacity to form hollows suitable for Major Mitchell's's Cockatoo. This species is known to use hollows in trees as small as 34cm DBH and the average nest tree DBH is 71cm (VG Hurley *pers comm*.).

The focus of the study is the Slender Cypress-pine (*Callitris gracilis*) population in the Pine Plains region of Wyperfeld National Park, north-west Victoria.

1.1 Aims and Objectives

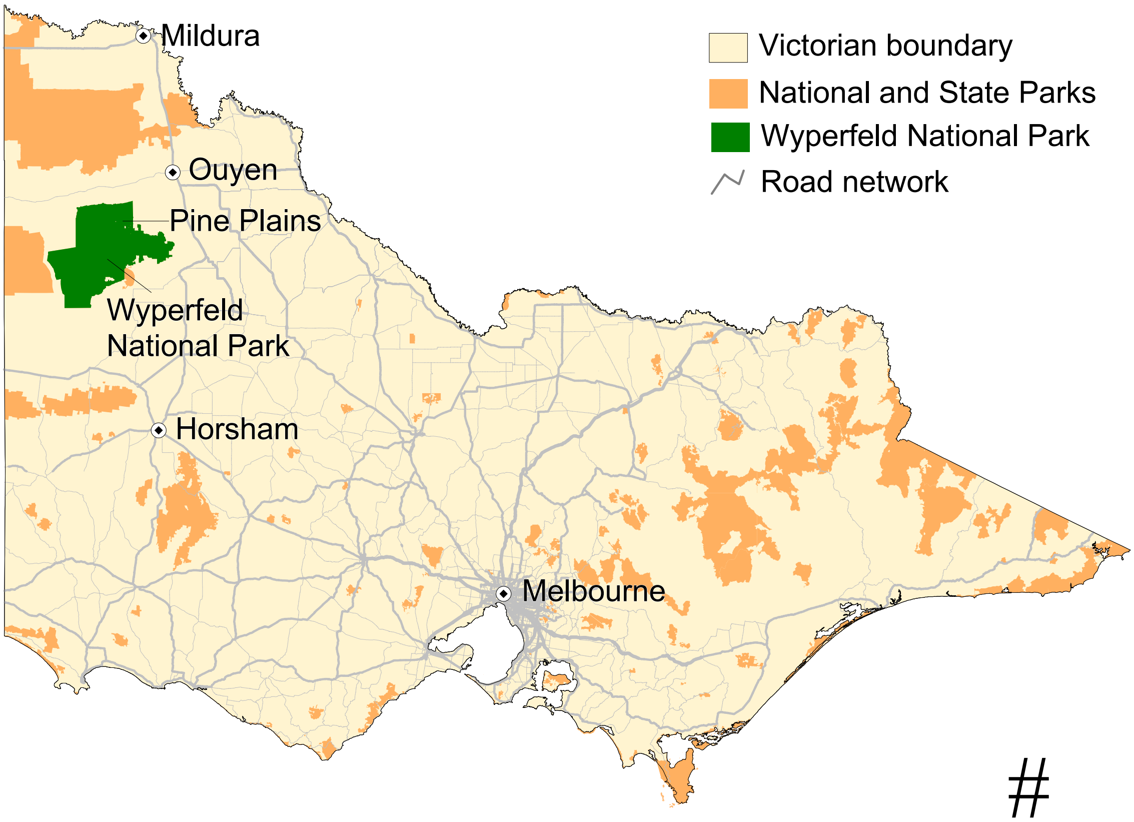
The aim of the project was to determine the relationship between tree diameter and age of Slender Cypress-pine to predict when hollows may become available for use by the Major Mitchell's Cockatoo.

This will be achieved via the completion of the following objectives:

- Determine the age of first hollow formation in Slender Cypress-pine at Pine Plains, Wyperfeld National Park.
- Determine the time frame for Slender Cypress-pine to form hollows suitable for Major Mitchell's's Cockatoo reproduction.
- Determine the age classes of Slender Cypress-pine at pine Plains in Wyperfeld National Park.

1.2 Study Area

The study was undertaken within the Pine Plains region of Wyperfeld National Park, north-west Victoria (see map 1). The locations of tree assessment transects and uprooted trees from which sections were cut are shown in maps 2 and 3 respectively.



Map 1. Location of Pine Plains, Wyperfeld National Park

Figure 1. Example of Slender Cypress-pine woodlands within Pine Plains, showing the impact of recent storms

2. Methods

2.1 Permits

This research was undertaken according to the conditions of research permit 10004381. This permit was issued by the Biodiversity Branch of DSE, pursuant to the provisions of the *Flora and Fauna Guarantee Act* 1988 and the *National Parks Act* 1975.

The permit granted the project team permissions to:

- Take horizontal cross-sections of trunks of up to fifty dead and fallen Slender Cypress-pines (*Callitris gracilis* subsp. *murrayensis*).
- Take core samples from live *C. gracilis* subsp. *murrayensis* (when dead specimens not available); and
- Take measurements, mark transects and conduct visual surveys of *C. gracilis* subsp. *murrayensis*.

2.2 Determining the age of *Callitris gracilis* using dendrochronology

2.2.1 Selection of samples

DSE staff (VG Hurley) identified the locations and approximate diameter at breast height over bark (DBHOB) of recently fallen trees suitable for sectioning. Trees were selected to enable sectioning of a wide range of diameters, and where possible trees with obvious splits or basal hollows were avoided. Most trees selected were recently dead, having been blown over in storm events less than 12 months prior to sampling. The distribution of trees from which samples were taken is shown in map 2.

2.2.2 Cutting of samples

Sections were cut on 20 December 2007 by DSE staff, while CEM researchers recorded relevant information on the location and diameter of the cut stems (Figure 2). Where possible, the DBH (over bark) of the fallen stem was measured at 1.4m along the stem, equivalent to 1.4m above ground if the stem had been standing. To avoid sections splitting as they dried, thick sections of approximately 10-20cm width were cut. Most sections were cut at the 1.4m position, however, if a hollow was present (e.g. Figure 3), additional sections may have been cut further along the stem.

For all sections, the following information was recorded:

- A unique number representing the tree;
- The geographic location of the tree (map coordinates);
- The diameter of the tree (DBHOB) at 1.4m, measured using a diameter tape;
- The diameter of the section (DBHOB), measured using a diameter tape; and
- The height at which the section was cut.

In many cases, DBHOB could not be accurately measured at 1.4m, as stems were damaged at this height as they fell (e.g. Figure 3).

Sections were labelled and transferred to plastic bags, and then transported to Ballarat for analysis.

Samples were also extracted using a Suunto 5mm Increment Borer (Figure 2). The corer was used to extract samples from either:

- Trees with a stem diameter less than could be found in uprooted trees.
- Large trees with no internal rot, which were also poorly represented in windthrown areas.

(a) Chainsawing of fallen dead trees

(b) Coring standing live trees

Figure 2. Methods used to extract samples for analysis

(a) Central rot extended several metres up many of the larger diameter stems

(b) A rot-free sample was extracted from several metres up this stem, but an accurate DBH measurement could not be obtained

Figure 3. Examples of sampling difficulties

2.2.3 Sample preparation

Sections were sanded with a belt sander, and then a random orbital sander using several grades of sandpaper to achieve a fine finish. Following fine sanding with 240 grade sandpaper, the sections were deemed smooth enough for analysis, and no further preparation (such as diluted polyurethane coatings or beeswax polish) were considered necessary.

2.2.4 Assessment of bark thickness

As all field-based stem diameter measurements were made using a diameter tape over bark, it is important to assess variation in bark thickness in relation to stem diameter. This was done by measuring the bark thickness of 23 of the stem section samples. For each section, two diameter measurements (over bark) were made using a ruler, and the bark thickness was measured in four positions, as illustrated in Figure 4. These measurements were averaged to calculate a single diameter estimate and a single bark thickness estimate for each section.

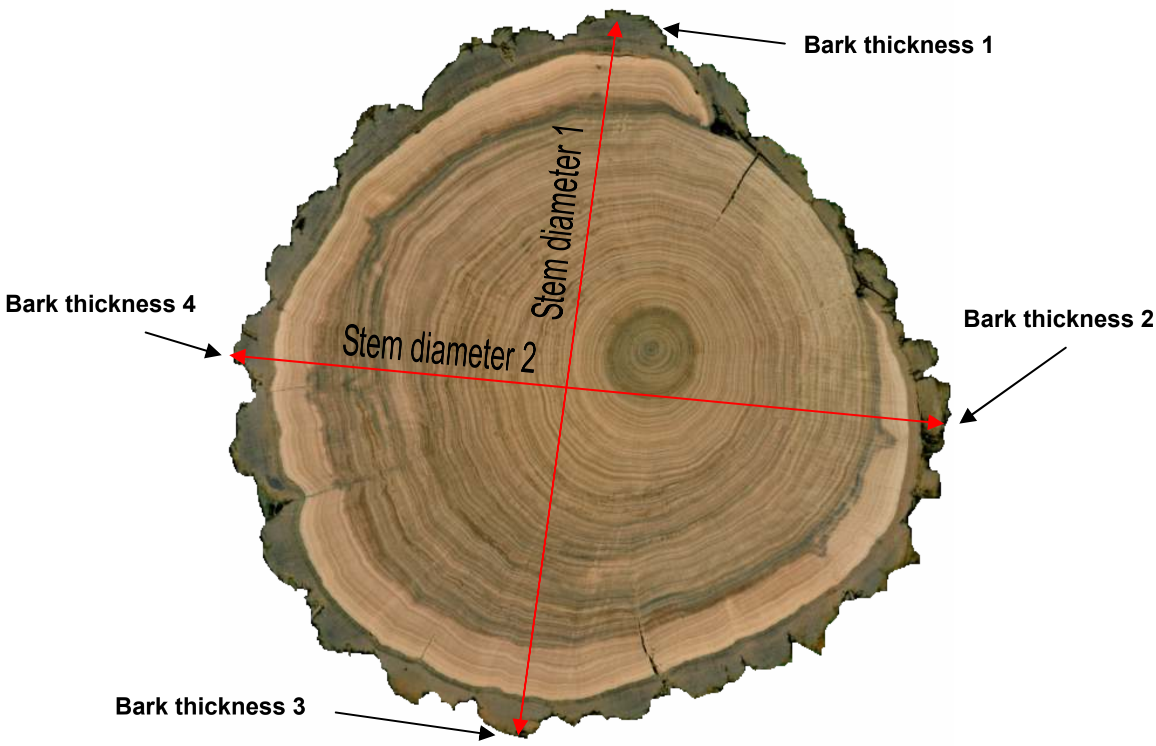


Figure 4. Measurement of stem diameter and bark thickness

2.2.5 Dendrochronological analysis

Studies have shown that while in arid Australia results of dendrochronological studies have been variable (Lange 1965, Read 1995). *Callitris* spp. have been found to show good rings (Enright & Hill 1995) compared to other species such as *Casuarina* (Schweingruber 1992).

Growth rings were counted on each sample under an Olympus™ (Model SZ-PT Sz40) compound microscope following the technique used by Hughes (1992). Pseudo growth rings were identified and excluded, as described below.

The study incorporates two assumptions:

- Slender cypress-pine produce one growth ring/year.
- Sufficient samples are taken to cover local variation.

In a study of *Myoprum platycarpum* ssp. *platycarpum* in the Victorian Mallee and adjacent areas, Westbrooke (1999) confirmed that observed growth rings were produced annually.

Identification of pseudo-rings

Many species are known to produce pseudo-rings, which cannot be considered to be annual growth rings (Hughes 1992). These pseudo-rings must be excluded from ring counts, in order to provide accurate estimates of age. Observed rings were considered to be pseudo-rings if they were not completely continuous, or if they passed through resin ducts.

2.3 Determining the age structure of *Slender Cypress-pine* within Pine Plains

Transect sampling was used to determine the diameter and age structure of the Slender Cypress-pine populations within selected areas of Pine Plains.

2.3.1 Transect assessment method

The Slender Cypress-pine population was assessed using the point-quarter transect method. The point quarter method involves the selection of regularly spaced sample points (along a transect line). At each sample point, the closest tree in each of the four quadrats are selected for sampling. The following information was recorded for each tree:

- The distance from the sample point to the tree was measured using a tape measure or laser-rangefinder;
- The diameter at breast height over bark (DBHOB) was measured at 1.4m;
- The presence of hollows was noted;
- A categorical condition score was assigned; and
- The proportion of foliage remaining on the tree was estimated.

The recording sheet used for the transect assessment is presented in Appendix 2.

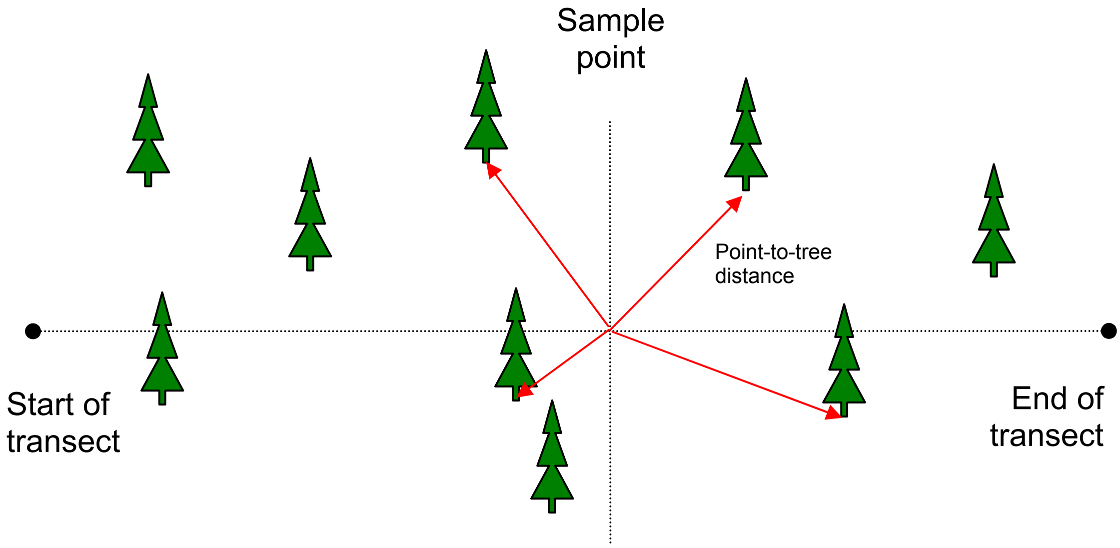


Figure 5. Point-quarter transect method

A diagrammatic representation of the point quarter transect is shown in Figure 5. In this transect, only a single sample point is shown. The direction (compass bearing) of each transect was chosen to allow transects to remain within the stand for several hundred metres. Sample points were typically spaced at 100m intervals along transects. A spacing of 50m was used within some small stands, provided that no individual tree was sampled from more than one sample point.

Nine transects were sampled, with either five or seven sample points per transect. In total, 188 trees were sampled.

Density calculation

Stand density is calculated for each transect using the following procedure:

Calculate the average distance between sample points and trees:

Mean point-to-tree dist (m) = (Sum of all point-to-tree distances) / (number of trees sampled in transect)

Calculate the mean area covered per tree:

Mean area per tree (m^2) = (Mean point-to-tree dist)^2

Convert this to trees per hectare:

Total tree density (trees / ha) = 10,000 / (Mean area per tree)

Error bars were calculated to provide an indication of the precision of density estimates. These error bars were derived by calculating the standard error of the point-to-tree distances, and then calculating upper and lower density estimates by adding and subtracting the standard errors to the mean point-to-tree distance, and following the above procedure.

Once a total density estimate has been calculated, density of various age/size classes and condition classes can be calculated using the proportions of these classes within the trees assessed at each transect.

2.3.2 Selection of transect locations

Transects locations were selected in consultation with DSE staff. Transects were positioned in dune and inter-dune situations. Generally, large stands were chosen, and sampling was conducted in areas where Major Mitchell's's Cockatoos have been recorded breeding in previous seasons. The locations of transects sampled are shown in map 3.

Transect sampling was conducted from 18-21 Dec 2007.

2.4 Data storage and analysis

Transect data and the details of the tree sections were entered into a Microsoft Access database. The database was designed to store the transect data, and to generate the summary data presented in most of the tables and appendices included in this report. A copy of the database can be found on the CD supplied with the report.

3. Results

3.1 Diameter of trees sampled

Fifty-seven *Callitris gracilis* cross sections were cut from 47 recently uprooted trees. The DBHOB distribution of the trees sampled is shown in Figure 6. Trees ranged from 9.8cm to 70.0cm in diameter.

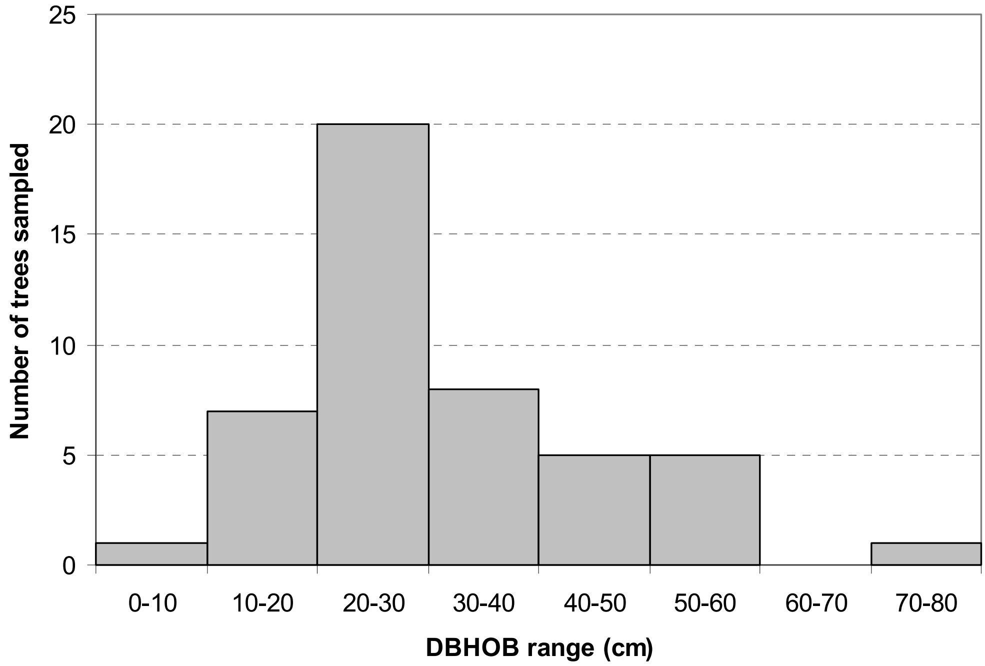


Figure 6. Diameter distribution of sampled trees

Very few trees larger than 50cm in diameter were available, and most of the sections taken from these larger trees had rot within the centre, making these sections unsuitable for analysis. A large proportion of the fallen trees were between 20 and 30cm in diameter, and 20 samples were taken within this size class. Only one of the trees sampled was less than 10cm in diameter.

3.2 Bark thickness

The relationship between stem diameter and bark thickness was assessed for 23 sections (Figure 7). Bark thickness was found to be positively correlated with stem diameter (R^2 = 0.83), with increasing variability in bark thickness as stem diameter increases. According to this relationship, bark thickness can be predicted by:

Bark thickness (mm) = 0.0481 x DBHOB (mm)

This equation can be used to estimate bark thickness of trees sampled in the field, and hence DBH (under bark).

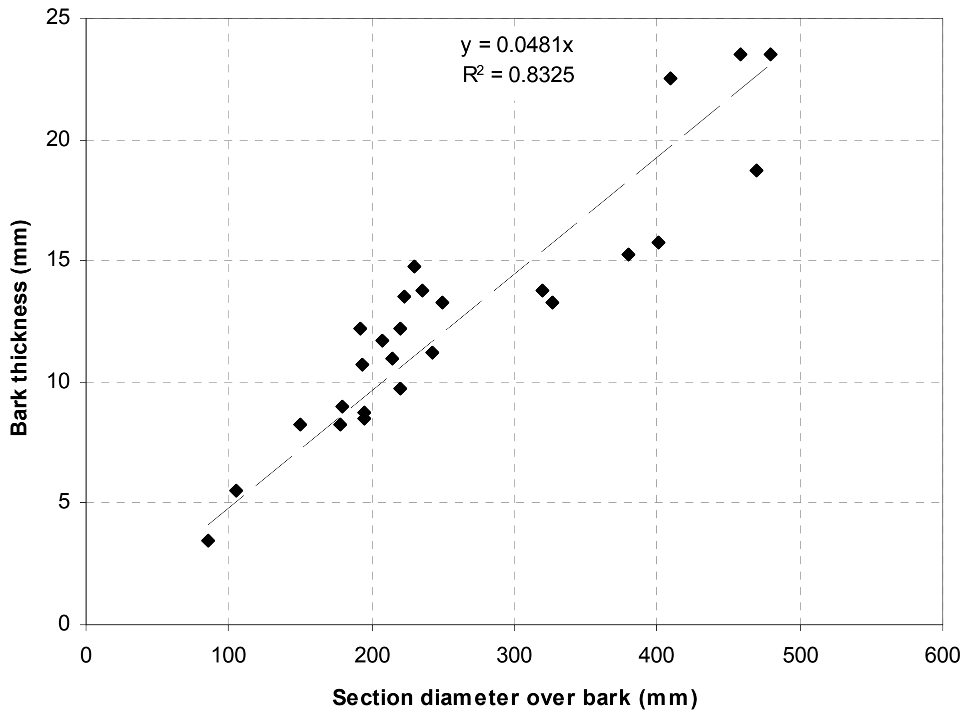


Figure 7. Relationship between bark thickness and stem diameter

3.3 Relationship between diameter and age

Growth rings were counted on 37 sections and one core sample. The number of growth rings counted in these samples is presented in Table 1. Seven of these samples are of less value in this analysis, as they were either cut from high up the stem (> 3m, 3 samples) or did not have an accurate DBHOB measurement (four samples), or both (two samples). DBHOB values assigned to trees with inaccurate DBHOB measurements were measured either at the base of the tree, or higher than 1.4m. Two samples cut from large (> 50cm DBHOB) trees higher than 4m were used in the analysis, as very few rot free samples were available in this size class.

Of the samples taken at breast height (1.4m), the smallest was 9.0cm in diameter (a core sample) and the largest was 52.5cm in diameter. The number of rings counted ranged from 5 to 105.

Table 1. Number of growth rings observed in section and core samples

*Shaded cells represent samples not used to determine the age vs. diameter relationship.

DBHOB (cm)	Rings	DBHOB (cm)	Rings	DBHOB (cm)	Rings
9.0	5*	24.0	75	33.0	86
9.8	19*	24.0	67	33.0	86
10.2	38	24.2	67	34.2	99
16.0	56	25.0	74	36.3	84
16.2	83	25.2	79	38.0	89
17.0	93	25.5	66*	49.0	67*
20.2	64*	25.7	89	50.5	98
21.0	74	26.3	67	52.5	105
21.0	70	27.8	87	55.7	63*
22.3	48	28.0	86	59.5	104*
23.6	52	33.0	96	70.0	88*
23.9	77	33.0	94		
24.0	94	33.0	87		

The relationship between DBHOB and number of growth rings is plotted in Figure 8. The figure includes both valid data points and growth ring counts taken from problematic samples (those highlighted in Table 1). The dataset includes three valid ring counts for sections over 40cm DBHOB.

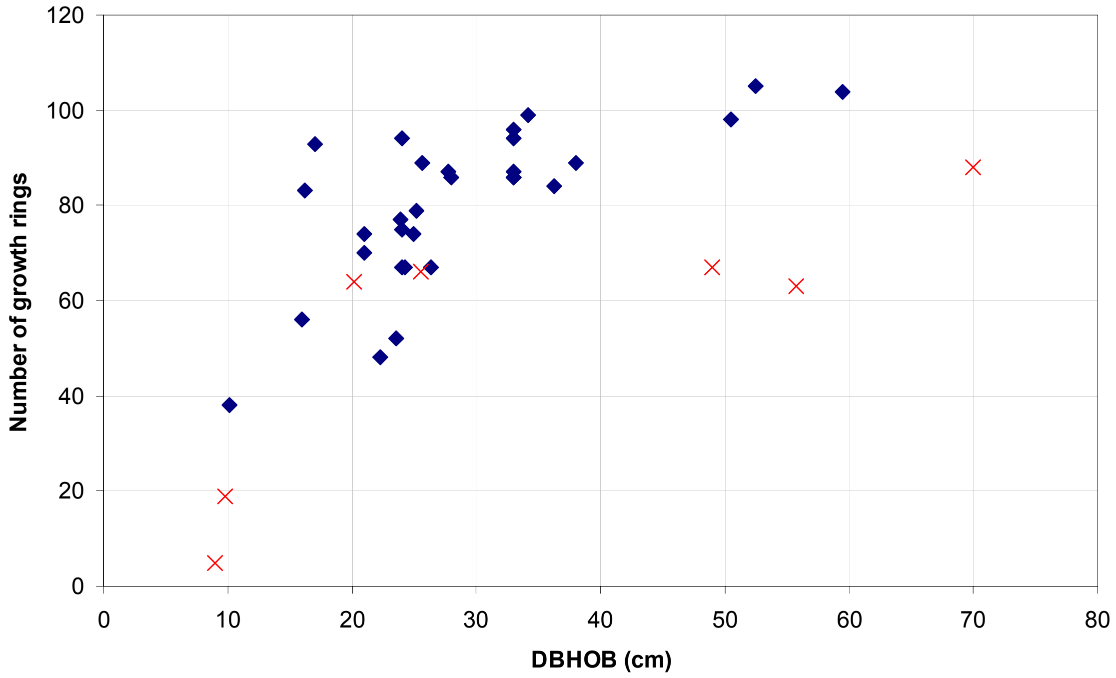


Figure 8. Relationship between DBHOB and number of growth rings

Blue diamonds represent samples cut at or near 1.4m, with known DBHOB. Red crosses represent samples cut above 4m, or samples from trees of unknown DBHOB.

Within 10cm diameter classes, there is considerable variation in the number of rings counted (Table 2). For 20-30cm size class, in which 12 sections were studied, the number of rings ranged from 48 to 94, with an average of 74. There was less variation (and fewer samples) in the 30-40cm size class, with ring counts ranging from 84 to 99, with an average of 90. Three valid samples were included in the 50-60cm size class, with ring counts ranging from 98 to 105, with an average of 102.

Table 2. Average number of growth rings in relation to 10cm size classes

Size class	DBHOB size range (cm)	Number of valid samples	Average number of rings	Standard error
1	10-19.9	4	68	13
2	20-29.9	15	74	3
3	30-39.9	8	90	2
4	40-49.9	0	-	-
5	50-59.9	3	102	2

3.3.1 Type of relationship

Logarithmic and linear trend lines were fitted to the valid data points (Figure 9). The logarithmic trend line had a slightly stronger fit to the data points, but equation is heavily influenced by potential outliers, particularly the sample with DBHOB of 10.2cm, and has a negative intercept:

Number of rings = 33.1 Ln(DBHOB) – 28.8 (R^2 = 0.53)

A linear regression, based on valid points, produces the following relationship:

Number of rings = 1.1 (DBHOB) + 49.4 (R^2 = 0.48)

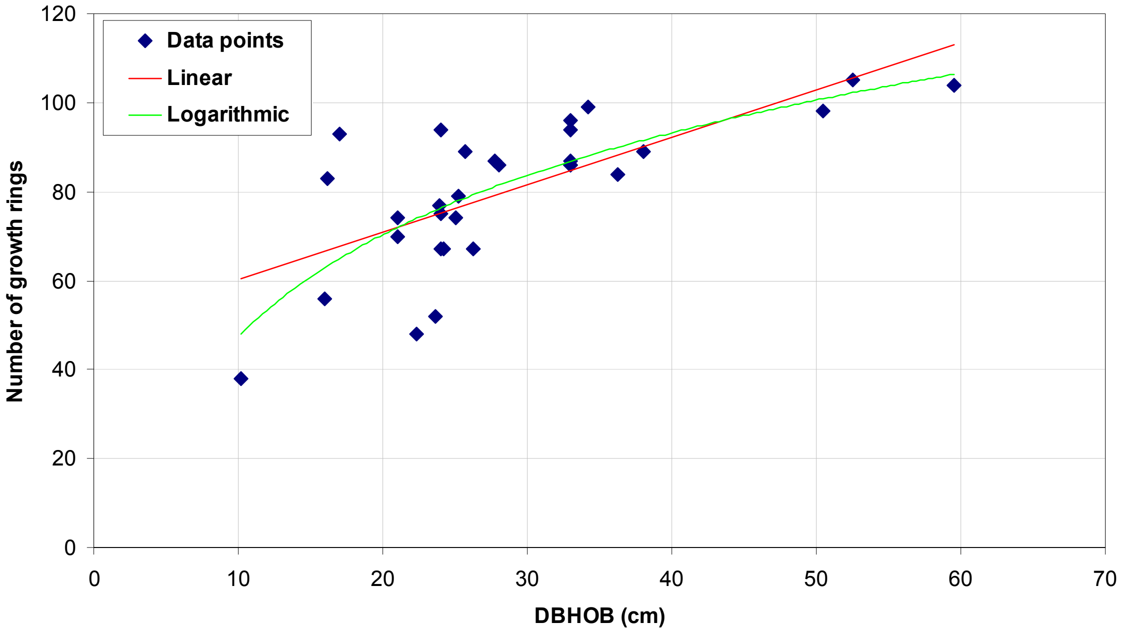


Figure 9. Alternative models relating the number of growth rings to DBHOB.

3.3.2 Age estimation

None of these models provide strong predictive ability, and the models deviate significantly when predicting the number of rings in trees of over 50cm DBHOB, where very few samples were available. Most of the sections greater than 50cm DBHOB could not be analysed due to rotten centres. In the transect assessment presented in section 3.4, trees were recorded with DBHOB ranging from under 10cm to approximately 90cm. The modelled age estimates across this DBHOB range are presented in Table 3.

Table 3. Age predictions using the alternative models

DBHOB (cm)	Model predictions of number of growth rings	
	Linear	Logarithmic
10	60	47
20	71	70
30	81	84
40	92	93
50	103	101
60	114	107
70	124	112
80	135	116
90	146	120
100	156	124

3.4 Tree density and age class distribution on Pine Plains

The point-quarter transect method was used to assess stand density, age/size class distribution and tree condition at nine locations within the Pine Plains area.

3.4.1 Stand density

Stand density was highly variable (Figure 10), ranging from approximately 12 trees per hectare at transects 4, 5, 6 and 8 to over 120 trees per hectare at transects 3, 7 and 9. Transect three was a high-density stand, in a protected location near the eastern boundary of the park, with most trees in good condition, ranging from 30-40cm DBHOB. Similarly, transect 7 was in a protected location, with similar sized trees (Figure 11). Transect 9, located on a dune, was also a dense stand, but approximately half of the trees were young regeneration, less than 10cm in DBHOB.

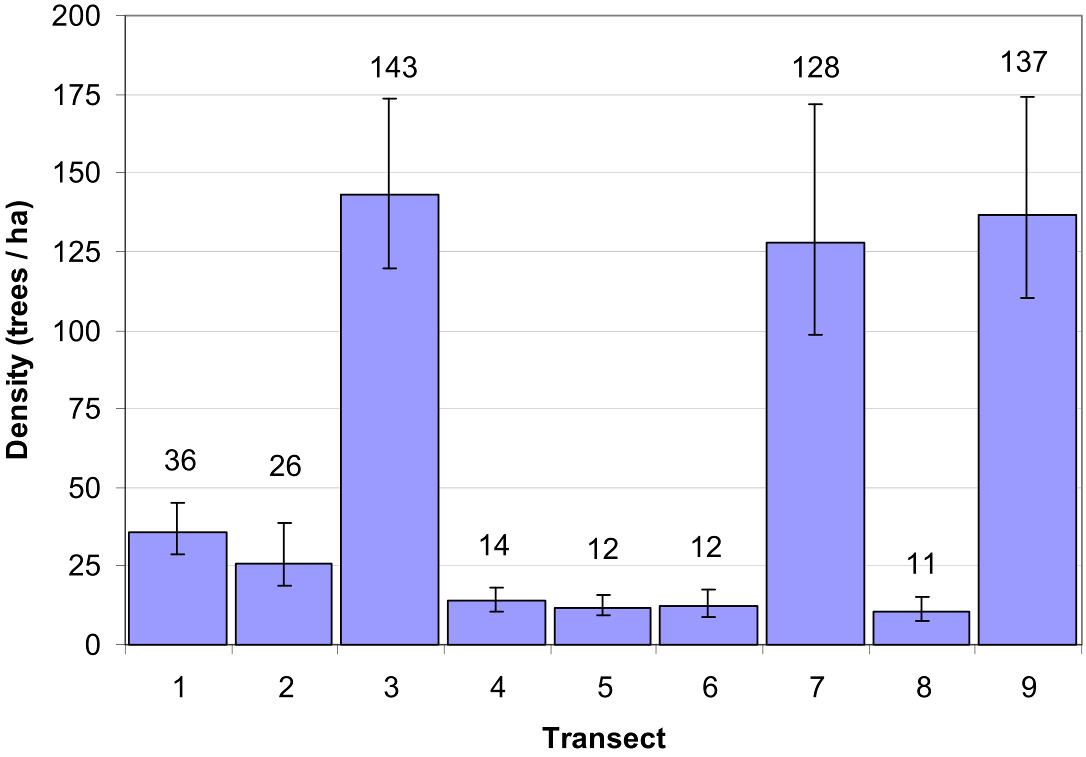


Figure 10. Density of stands assessed by point-quarter transects

Error bars represent ± one standard error. Numbers above the bars represent the density estimate for each transect (trees / ha). Density estimates include both live and dead trees.

(a) Dune with very few live trees remaining. (Transect 8)

(b) Higher density stand with many recently windthrown trees.

(d) Flat area with high density of trees in good condition. (Transect 7)

(c) Dune with mixture of dead, senescing, mature and regenerating trees. (Transect 5)

(e) Dune area dominated by dead trees. (Transect 2).

Figure 11. Examples of Slender Cypress-pine stands

3.4.2 Stem diameter distribution

The mean diameter of live and dead trees assessed in point-quarter transects is presented in Figure 12. The size class distribution (10cm classes) of trees recorded in each transect is presented in Table 4 (number of individual trees in each size class) and Table 5 (density of each size class). For live trees, the mean DBHOB ranged from 20cm at transect eight to 50cm at transect five.

Dead trees were recorded in all transects except transects five and six. Trees with a DBHOB of over 60 were recorded at transect one (one dead tree), transect two (two dead trees), transect five (seven live trees), transect six (three live trees), transect seven (one live tree) and transect eight (one dead tree).

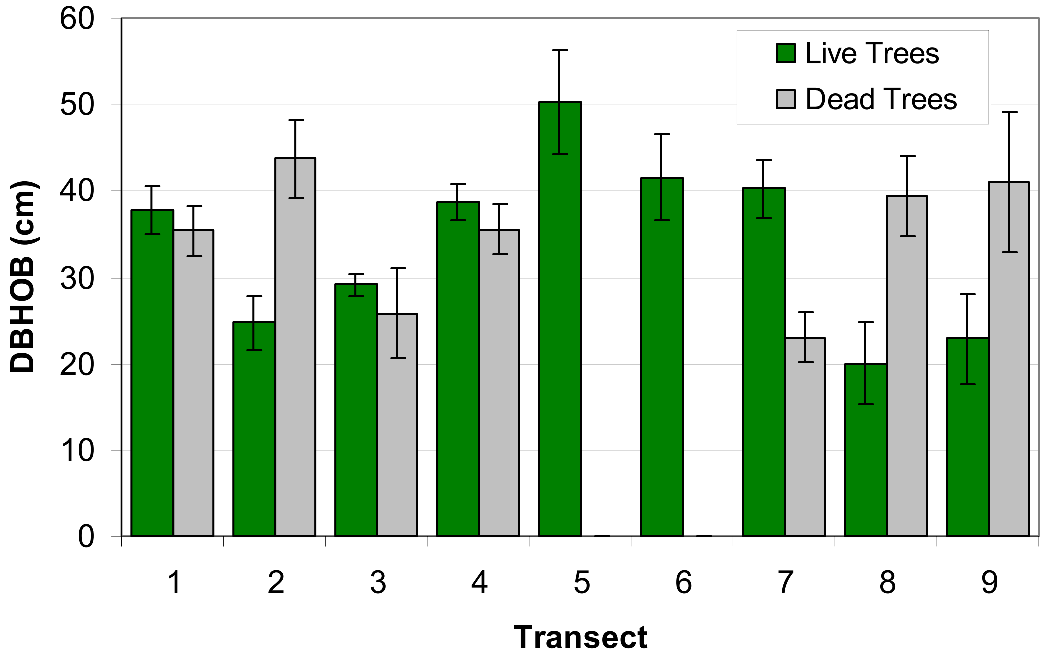


Figure 12. Mean stem diameter (DBHOB) of live and dead trees assessed in point-quarter transects

Error bars represent ± one standard error.

Table 4. Size class distribution of live and dead trees recorded in point-quarter transects – number of trees

Trans	Tree status	Number of trees	Density (trees/ha)	Number of trees recorded within 10cm diameter classes Number shown indicates the lower boundary of each class.									
				0	10	20	30	40	50	60	70	80	90
1	Dead	16	29		1	3	8	2	1	1			
	Live	4	7				3	1					
	Total	20	36		1	3	11	3	1	1			
2	Dead	13	17		1	2	3	2	3	1	1		
	Live	7	9	1		4	2						
	Total	20	26	1	1	6	5	2	3	1	1		
3	Dead	5	26		1	2	1	1					
	Live	23	118			14	7	2					
	Total	28	143		1	16	8	3					
4	Dead	9	6			2	4	2	1				
	Live	11	8				6	4	1				
	Total	20	14			2	10	6	2				
5	Dead	0	0										
	Live	20	12	4			2	3	4	1	3	2	1
	Total	20	12	4			2	3	4	1	3	2	1
6	Dead	0	0										
	Live	20	12	3		2	4	4	4	1	1	1	
	Total	20	12	3		2	4	4	4	1	1	1	
7	Dead	7	45		3	2	2						
	Live	13	83			2	4	4	2	1			
	Total	20	128		3	4	6	4	2	1			
8	Dead	11	6			3	4	1	2	1			
	Live	9	5	4		3	1	1					
	Total	20	11	4		6	5	2	2	1			
9	Dead	2	14				1	1					
	Live	18	123	9			2	6	1				
	Total	20	137	9			3	7	1				
Total	Live	125	39	21		25	31	25	12	3	4	3	1
	Dead	63	20		6	14	23	9	7	3	1		
	Total	188	59	21	6	39	54	34	19	6	5	3	1

Table 5. Size class distribution of live and dead trees recorded in point-quarter transects – tree density

Trans	Tree status	Number of trees	Density (trees/ha)	Density (trees/ha) of trees recorded within 10cm diameter classes Number shown indicates the lower boundary of each class.									
				0	10	20	30	40	50	60	70	80	90
1	Dead	16	28.5	-	1.8	5.3	14.3	3.6	1.8	1.8	-	-	-
	Live	4	7.1	-	-	-	5.3	1.8	-	-	-	-	-
	Total	20	35.6	-	1.8	5.3	19.6	5.3	1.8	1.8	-	-	-
2	Dead	13	16.9	-	1.3	2.6	3.9	2.6	3.9	1.3	1.3	-	-
	Live	7	9.1	1.3	-	5.2	2.6	-	-	-	-	-	-
	Total	20	26.0	1.3	1.3	7.8	6.5	2.6	3.9	1.3	1.3	-	-
3	Dead	5	25.6	-	5.1	10.2	5.1	5.1	-	-	-	-	-
	Live	23	117.6	-	-	71.6	35.8	10.2	-	-	-	-	-
	Total	28	143.2	-	5.1	81.8	40.9	15.3	-	-	-	-	-
4	Dead	9	6.2	-	-	1.4	2.8	1.4	0.7	-	-	-	-
	Live	11	7.6	-	-	-	4.1	2.8	0.7	-	-	-	-
	Total	20	13.8	-	-	1.4	6.9	4.1	1.4	-	-	-	-
5	Dead	0	0.0	-	-	-	-	-	-	-	-	-	-
	Live	20	11.9	2.4	-	-	1.2	1.8	2.4	0.6	1.8	1.2	0.6
	Total	20	11.9	2.4	-	-	1.2	1.8	2.4	0.6	1.8	1.2	0.6
6	Dead	0	0.0	-	-	-	-	-	-	-	-	-	-
	Live	20	12.3	1.8	-	1.2	2.5	2.5	2.5	0.6	0.6	0.6	-
	Total	20	12.3	1.8	-	1.2	2.5	2.5	2.5	0.6	0.6	0.6	-
7	Dead	7	44.7	-	19.2	12.8	12.8	-	-	-	-	-	-
	Live	13	83.0	-	-	12.8	25.5	25.5	12.8	6.4	-	-	-
	Total	20	127.7	-	19.2	25.5	38.3	25.5	12.8	6.4	-	-	-
8	Dead	11	5.9	-	-	1.6	2.1	0.5	1.1	0.5	-	-	-
	Live	9	4.8	2.1	-	1.6	0.5	0.5	-	-	-	-	-
	Total	20	10.7	2.1	-	3.2	2.7	1.1	1.1	0.5	-	-	-
9	Dead	2	13.7	-	-	-	6.8	6.8	-	-	-	-	-
	Live	18	123.1	61.6	-	-	13.7	41.0	6.8	-	-	-	-
	Total	20	136.8	61.6	-	-	20.5	47.9	6.8	-	-	-	-
Total	Live	125	39.0	6.5	-	7.8	9.7	7.8	3.7	0.9	1.2	0.9	0.3
	Dead	63	19.6	-	1.9	4.4	7.2	2.8	2.2	0.9	0.3	-	-
	Total	188	58.6	6.5	1.9	12.2	16.8	10.6	5.9	1.9	1.6	0.9	0.3

The overall diameter class distribution for live and dead trees recorded within transects is presented in Figure 13, and Figure 14 presents the relationship between mean DBHOB of live trees, and density of live trees. Figure 13 also indicates the size class distribution of known Major Mitchell's Cockatoo nest trees (Victor G Hurley, unpublished data). The average diameter of known nest trees is approximately 71cm, significantly larger than the average diameter of trees recorded in transects (35cm, t-test $p < 0.001$).

No dead trees of less than 10cm DBHOB were recorded, and only one standing dead tree was measured with a DBHOB of greater than 70cm. The most frequently recorded size classes of live trees were between 20 and 50cm, with 30-40cm being the modal class for both live and dead trees. No live trees in the 10-20cm class were recorded.

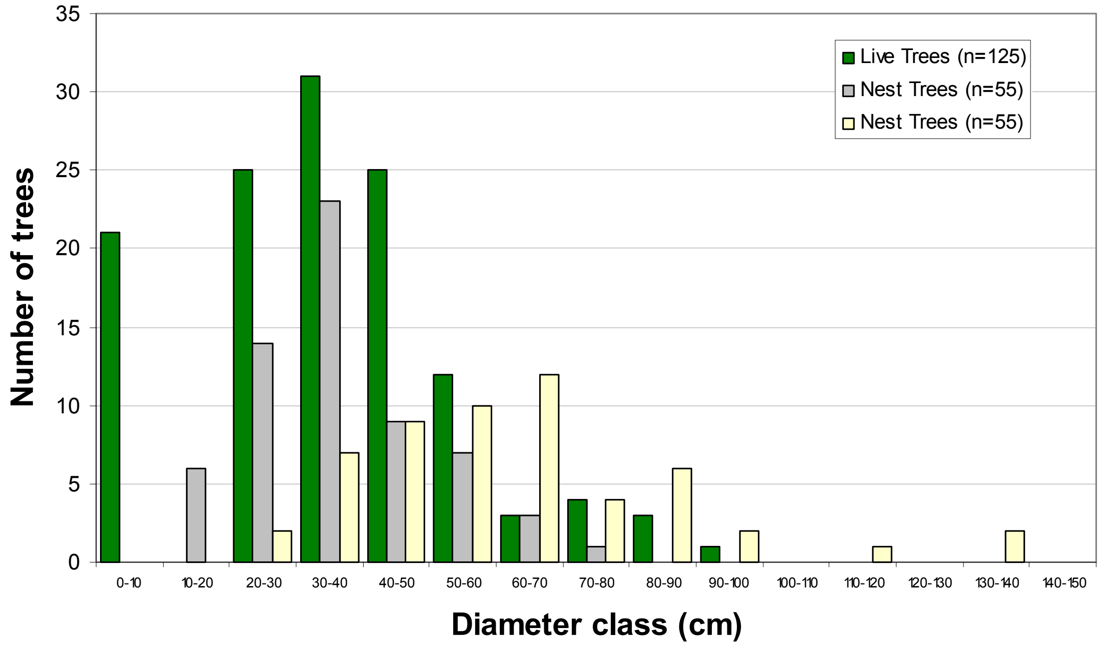


Figure 13. Size class distribution of live and dead trees recorded in point-quarter transects

Nest tree data supplied by Victor G Hurley (unpublished data).

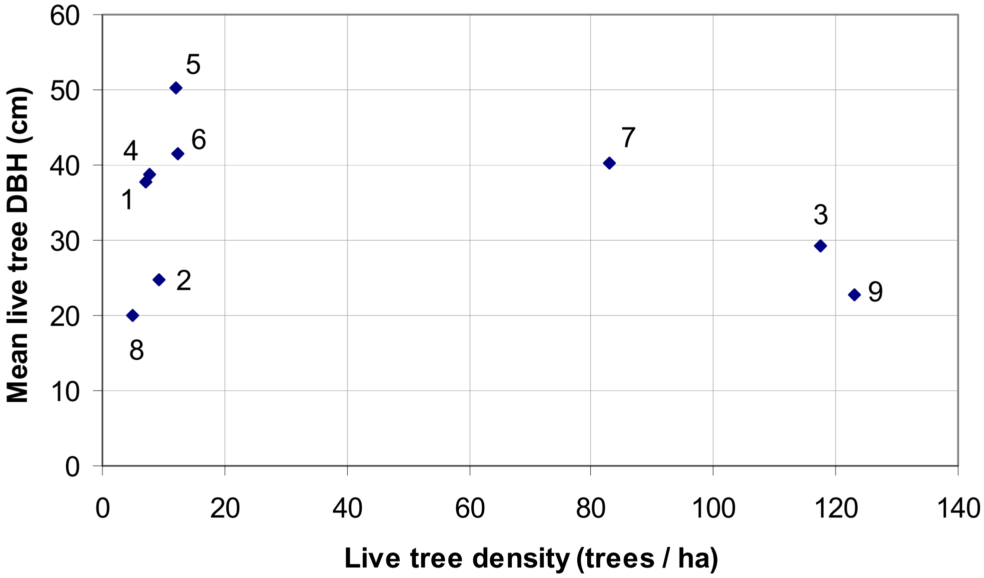


Figure 14. Relationship between density and mean DBH of live trees
Transect numbers are indicated adjacent to each data point.

4. Discussion

The assessment of population structure within Pine Plains was limited to nine transects, in which 188 trees were assessed, 63 of which were dead. This assessment indicated that most trees within the area are between 20cm and 50cm in diameter, corresponding with an approximate age range of 70 – 110 years of age, subject to the assumptions and limitations of the study. Few trees were recorded below 20cm DBH confirming the view that there has been limited recruitment in the last 50-60 years. Of concern, dead trees were also found in these smaller (younger) size classes. Very few trees with a diameter of over 70cm were recorded. Estimation of the age of these larger trees is difficult, due to the lack of samples analysed over 50cm in diameter. These large (70+cm) trees are likely, however, to be at least 130 years old.

In a study of trees with hollows used by Major Mitchell's Cockatoo on Pine Plains, Hurley (2006a) found that the DBHOB of utilised trees ranged from 34cm to 149cm, with an average diameter of 73cm. Using the linear relationship between DBHOB and age developed in this project, trees with a DBHOB of 34cm are likely to be approximately 80 years old.

Determination of the relationship between diameter and age of Slender Cypress-pine trees in this project is subject to several assumptions and limitations:

- It is assumed that trees produced a single growth ring each year.
- Samples were collected at several locations within the study area, and these samples are assumed to adequately represent variation within the Pine Plains area. Growth rates (incremental diameter growth per year) may vary throughout the study area.
- Similarly, samples collected from both dune and inter-dune situations have been pooled for analysis. It is possible that growth rates may also vary in different landscape positions, due to differences in water availability, nutrient availability and light.
- Very few large trees without rot were available for sectioning (fallen dead trees only). This results in limited ability to assess and predict the number of rings, and hence age, of trees over 50cm in diameter.
- Within the samples analysed, there is considerable variability in the number of rings counted in similar sized specimens, possibly due to variation in site conditions.
- Many pseudo-rings were identified in sections during analysis. While identified rings were excluded from ring counts, it is possible that a proportion of pseudo-rings were not identified, and this would introduce an error factor, leading to an overestimate of tree age.
- To date, no sampling of trees of known age has been undertaken. If analysable cores can be extracted from known-age trees of a broad range of diameters, the resulting growth ring counts would provide valuable information for validating the relationship between DBHOB and age.

There is reasonable evidence to support the assumption that Slender Cypress-pine puts down a single growth ring each year. In a study of *Myoprum platycarpum* ssp*. platycarpum* in the Victorian Mallee and adjacent areas, Westbrooke (1999) confirmed that observed growth rings were produced annually. Strong growth rings have been reported in studies of *Callitris columellaris* in north-western Australia (Cullen and Grierson 2007), and *Callitris macleayana* in the Atherton Tablelands in Queensland (Ash 1983). Both these studies found annual ring patterns, and a reasonably strong correlation between ring width and rainfall.

This study examined both logarithmic and two types of linear relationships between diameter and number of growth rings. While the logarithmic relationship provided the best fit, this is largely due to potential outlier growth counts from the smallest and largest samples. Simple linear models have been applied to a range of species, including *Callitris preisii* (O'Donnell et al. 2007), *Allocasuarina littoralis* (Burley, et al. 2007), *Eucalyptus marginata* (Whitford 2002), *Corymbia calophylla* (Whitford 2002) and *Salix fragilis* var. *fragilis* (Gray 2003). A linear model is likely to be most appropriate for *Callitris gracilis* within north-west Victoria, provided that small samples (< 10cm DBHOB) are excluded.

In a dendrochronological study of *Callitris preisii* in the semi-arid Lake Johnston region of south-west Western Australia O'Donnell et al. (2007) found that 60 year old trees ranged from 4-10cm in diameter, which approximately corresponds with the lower portion of the linear model developed in this project. O'Donnell et al. (2007) did not analyse trees greater than 10cm in diameter.

Tree age estimates could be further improved using the dendrochronological technique of cross dating. Cross dating involves the compilation of skeleton plots for each sample, and then matching ring-growth features across many samples collected from similar environmental conditions. This enables calendar years to be assigned to individual growth rings, and aids in the identification of potentially missing or additional rings, including pseudo-rings. Using this technique correlations between growth ring characteristics and environmental conditions, particularly past rainfall, can also be examined. Cross dating is a very time consuming technique, and funding for further analysis of the existing samples is currently being sought. Future research would also involve ^{14}C isotope dating of growth ring samples to further validate age calculations.

A 5mm diameter tree corer was used to extract samples from diameter classes that were under-represented in the available recently dead fallen trees. Trees with a diameter of greater than 50cm were particularly targeted, although it was not always possible to determine if these trees had internal rot. Cores were extracted with limited success, often breaking when being extracted, and it was difficult to penetrate far enough into the centre of these large stems. When examined in the laboratory, it was decided that most of these core samples were unsuitable for dendrochronological analysis, and the analysis presented in this report has focussed on the chainsawed stem sections. Burley et al. (2007) had similar problems with corers when studying *Allocasuarina littoralis* in coastal northern NSW and Queensland. Further sampling of large trees using a larger diameter chainsaw driven corer may produce more informative samples.

In order to gain a better understanding of the age class distribution of Slender Cypress-pine throughout the entire Pine Plains area, accurate mapping of stand boundaries is essential. Aerial photography or high resolution satellite imagery could be used to identify the distribution of Slender Cypress-pine and develop a comprehensive stratified random sampling strategy to assess density, size/age class distribution and tree condition. Opportunities for funding the acquisition of aerial photography or high resolution imagery should be investigated.

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Appendix 1 Details of *Callitris gracilis* section samples

Section #	Waypoint #	GDA 94 Easting	GDA94 Northing	DBHOB (cm)	Sect. Diam. (cm)	Sect. Height (m)
1	26	590467	6076734	21.0	21.0	1.40
3	27	590526	6076703	25.7	25.7	1.87
4	28	590546	6076701	33.0	26.2	5.10
2	29	590460	6076733	22.3	22.3	1.40
5	30	590181	6076026	28.8	23.5	4.95
6	31	590059	6075812	26.3	26.3	2.86
7	32	589774	6075209	42.5	38.0	4.20
8	33	589751	6075187	16.2	16.0	1.40
9	34	589773	6075181	27.8	26.6	1.75
10	35	589632	6075347	28.0	26.5	2.38
11a	36	589618	6075349	49.0 at base	33.2	3.28
11b	36	589618	6075349	49.0 at base	29.2	5.56
12a	37	589615	6075347	33.0	28.5	2.80
12b	37	589615	6075347	33.0	21.2	7.00
13	37	589615	6075347	25.0	21.6	2.54
14a	38	589436	6075280	50.5 @ 2.3	42.0	5.24
14b	38	589436	6075280	50.5 @ 2.3	39.0	6.26
15a	39	589436	6075280	Na	24.4	2.00
15b	39	589495	6075306	Na	20.2	3.05
16	40	589359	6075414	34.2 @ 1.4	32.2	2.52
17	41	589174	6075371	70.0 @ base	33.0	5.70
18A	42	589365	6075394	24.0	24.0	1.40
18B	42	589365	6075394	24.0	22.1	1.94
19A	43	590520	6075761	36.3	33.5	2.42
19b	43	590520	6075761	36.3	31.6	2.53
20a	44	590457	6075786	59.5	52.0	2.78
20b	44	590457	6075786	59.5	45.2	4.05
21a	45	590457	6075786	38.0	38.0	1.40
21b	45	590462	6075667	38.0	34.2	4.00
22	46	590451	6075648	33.0	33.0	1.30
23a	47	590495	6073999	23.6	22.0	2.70
23b	47	590495	6073999	23.6	20.5	3.70
24	48	590322	6073625	33.0	29.0	2.70
25	49	590289	6073585	55.7	32.0	8.00
26	50	590247	6073630	?	25.5	2.40
27	51	590223	6073611	51.8	33.8	5.50
28	52	588215	6073466	46.0	46.0	1.40
29	53	588188	6073441	41.6	41.4	2.47
30	54	588170	6073445	25.2	25.2	1.40
31	55	588180	6073437	26.5	23.0	2.40
62	56	588250	6073440	42.5	42.5	1.40
33	57	588281	6073444	21.0	2.0	1.40
34	58	588300	6073434	31.0	31.0	1.40
35	59	588311	6073415	24.0	24.0	1.40
36	60	588313	6073430	24.0	24.0	1.40
37	61	588339	6073426	24.2	23.0	2.90
38	62	588364	6073412	19.8	19.8	1.40
39	63	588378	6073405	19.0	19.0	1.40
40	64	588342	6073377	17.0	17.0	1.40

Section #	Waypoint #	GDA 94 Easting	GDA94 Northing	DBHOB (cm)	Sect. Diam. (cm)	Sect. Height (m)
41	65	588341	6073342	10.2	10.2	1.40
42	66	588344	6073348	16.0	16.0	1.40
43	67	588354	6073346	13.3	13.3	1.40
44	68	588564	6073618	23.9	23.9	1.40
45A	69	590487	6075104	9.8	11.0	0.50
45B	69	590487	6075104	9.8	9.8	1.40
46	70	587348	6087942	26.0	23.4	3.40
47	71	586024	6089510	52.5	46.0	2.10

Appendix 2 Transect data sheet

Date | | | **Recorders** | | GPS |

Location:

Transect location

	Easting	Northing		
Start			Bearing°:	
End			Dist b/n points (m):	

Structure – **S** = standing, **SCD** = standing canopy damaged, **SN** = Snapped, **OR** = uprooted.
Canopy % - estimate of % of canopy remaining.

Point	Tree	Dist (m)	DBH (cm)	Cond	**Structure**	Canopy %	Hollows / notes
1	1						
	2						
	3						
	4						
2	1						
	2						
	3						
	4						
3	1						
	2						
	3						
	4						
4	1						
	2						
	3						
	4						
5	1						
	2						
	3						
	4						

Notes

Appendix 3 Raw transect data

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
1	21/12/2007	MG/SF	588030	6083904	130	100	Flat. No regen, lots of rabbit warren ripping. Part of transect burnt.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	18	45	3	S	80	0	
1	2	22	33	0	SN	0	0	long dead
1	3	30	37	3	S	70	0	
1	4	9	31	0	S	0	0	rec dead
2	1	11	34	0	S	0	0	rec dead
2	2	9	32	0	SN	0	0	long dead
2	3	32	19	0	S	0	0	rec dead
2	4	10	27	0	S	0	0	rec dead
3	1	10	52	0	SN	0	0	main trk hol long dead
3	2	16	32	3	S	50	0	
3	3	8	26	0	S	0	0	long dead
3	4	16	27	0	SN	0	0	long dead no hol
4	1	20	43	0	S	0	0	long dead
4	2	37	39	0	S	0	0	long dead
4	3	15	68	0	SN	0	0	long dead
4	4	8	30	0	S	0	0	long dead no hol
5	1	10	37	3	S	60	0	
5	2	19	31	0	S	0	0	rec dead
5	3	19	32	0	S	0	0	rec dead
5	4	16	42	0	S	0	0	rec dead

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
2	19/12/2007	mg/sf	585894	6080280	260	100	Swale.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	9	28	4	s	100	0	
1	2	18	24	2	s	50	0	
1	3	10	18	0	sn	0	0	long dead
1	4	25	7	4	s	100	0	regen
2	1	26	27	0	sn	0	0	long dead
2	2	10	29	1	sn	50	0	
2	3	10	41	0	sn	0	0	long dead-hollow in middle
2	4	8	32	0	sn	0	0	rec dead
3	1	16	36	0	sn	0	0	hollow middle
3	2	20	32	2	sn	40	0	
3	3	28	23	4	s	100	0	
3	4	35	30	3	sn	50	0	
4	1	8	56	0	s	0	0	rec dead
4	2	75	72	0	sn	0	0	long dead split middle
4	3	11	59	0	sn	0	0	rec dead-hollow middle
4	4	12	36	0	sn	0	0	rec dead
5	1	8	57	0	sn	0	0	rec dead split mid

5	2	28	64	0	sn	0	0	long dead middle hol
5	3	3	42	0	sn	0	0	long dead mid holl
5	4	32	28	0	sn	0	0	long dead mid holl

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
3	18/12/2007	mg/sf	590451	6082662	0	50	Swale. Mixed pine and belah. Site protected from wind by adjacent dunes. Most trees in good condition.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	7	40	3	s	75	0	
1	2	10	33	3	s	80	0	
1	3	6	33	3	s	80	0	
1	4	6	22	3	s	75	0	
2	1	8	25	3	s	80	0	split
2	2	8	22	0	s	100	0	rec dead
2	3	16	25	2	s	50	0	
2	4	17	25	4	s	90	0	
3	1	2	26	4	s	60	0	one branch dead
3	2	16	26	3	s	60	0	
3	3	12	32	4	s	90	0	
3	4	13	42	0	s	0	0	long dead 2 hols
4	1	2	24	4	s	80	0	
4	2	8	27	4	s	80	0	
4	3	2	30	0	s	0	0	rec dead
4	4	2	10	0	s	0	0	long dead
5	1	10	38	4	s	90	0	
5	2	8	21	3	s	75	0	
5	3	10	29	4	s	90	0	
5	4	4	28	3	s	90	0	
6	1	7	21	3	s	80	0	
6	2	10	39	4	s	80	0	
6	3	10	33	3	s	70	0	
6	4	7	23	4	s	90	0	
7	1	11	25	0	sn	0	0	rec dead
7	2	8	27	3	s	90	0	
7	3	7	40	2	s	30	0	hollow in middle split
7	4	7	33	2	s	60	0	

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
4	21/12/2007	mg/sf	588005	6083927	290	100	Flat. Point 4 and 5 were done on the way back to the car.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	31	44	1	sn	10	0	
1	2	27	35	3	s	60	0	
1	3	8	33	0	s	0	0	long dead
1	4	18	45	0	s	60	0	
2	1	12	45	0	sn	0	0	long dead
2	2	21	45	4	s	80	0	
2	3	36	34	3	s	70	0	
2	4	13	33	2	s	25	0	

3	1	67	31	0	sn	0	0	long dead
3	2	55	37	4	s	80	0	
3	3	29	23	0	sn	0	0	long dead
3	4	38	30	2	s	40	0	
4	1	20	32	0	s	0	0	long dead
4	2	42	50	0	s	0	0	long dead trunk hol
4	3	13	33	0	s	0	0	rec dead
4	4	11	40	3	s	70	0	
5	1	23	28	0	s	0	0	long dead
5	2	24	53	3	sn	60	0	
5	3	42	32	2	sn	40	0	
5	4	8	43	2	s	30	0	

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
5	18/12/2007	mg/sf	585862	6088022	160	100	Dune. Track to kellies lookout. Most trees with a basal hollow. 5.4 has split with open hollow. Not useable by fauna.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	35	85	1	sn	30	0	1x30cm branch live
1	2	18	72	1	sn	20	0	1x30cm stem and base live
1	3	16	42	1	sn	50	0	no hols split in half
1	4	37	58	2	sn	40	0	snapped and split
2	1	10	57	1	sn	20	0	fallen no hols
2	2	28	78	2	s	50	0	1x20 some branches snapped
2	3	42	82	1	sn	20	0	no holls
2	4	17	9	4	s	100	0	yound multistemmed
3	1	40	36	1	sn	50	0	
3	2	18	47	1	sn	10	0	1x20 main trunk
3	3	10	9	4	s	100	0	regen single stem
3	4	6	58	1	sn	15	0	no hols split in half
4	1	51	3	4	s	100	0	regen
4	2	55	90	4	s	90	0	no hols good cond
4	3	55	60	1	s	20	0	basal hollow temite
4	4	19	9	4	s	100	0	regen
5	1	41	44	3	or	60	0	hollow in main trunk on gound
5	2	17	37	2	sn	60	0	no hols
5	3	10	54	1	sn	20	0	main trunk hollow
5	4	55	75	2	sn	40	0	main trunk hollow

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
6	18/12/2007	mg/sf	585574	6087960	160	100	Swale. Kelly track

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	8	38	4	s	90	0	
1	2	34	29	4	s	100	0	
1	3	32	45	1	sn	30	0	hollow in main trunk
1	4	8	47	1	sn	20	0	
2	1	53	43	2	sn	30	0	
2	2	70	34	4	s	80	0	split at base

2	3	4	76	3	s	90	0	
2	4	19	56	3	sn	50	0	25x15cm hollow on main trnk
3	1	22	2	4	s	100	0	regen
3	2	18	55	1	s	50	0	main trunk hol
3	3	21	42	4	s	100	0	no hols
3	4	24	58	3	s	30	0	split in main tnk
4	1	8	28	3	s	90	0	no hols
4	2	32	68	4	s	100	0	no hols
4	3	28	52	3	s	75	0	1 in main trnk 50x10
4	4	8	35	4	s	90	0	no hols
5	1	92	5	4	s	100	0	
5	2	28	84	1	sn	10	0	30x15 main tnk, 20x15 side tnk - used by birds
5	3	29	3	4	s	100	0	regen
5	4	33	31	2	sn	30	0	no hols

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
7	20/12/2007	mg/sf	589953	6076363	310	50	Flat.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	8	31	0	sn	0	0	long dead
1	2	4	40	4	s	100	0	
1	3	15	53	4	s	100	0	
1	4	5	42	3	s	80	0	
2	1	8	34	2	sn	25	0	trunk split
2	2	12	51	4	s	100	0	
2	3	18	67	3	sn	50	0	
2	4	18	31	0	s	0	0	long dead
3	1	14	31	4	s	90	0	
3	2	20	46	4	s	90	0	
3	3	2	15	0	s	0	0	long dead
3	4	4	29	0	sn	0	0	long dead
4	1	2	24	0	s	0	0	long dead
4	2	8	43	3	s	50	0	live
4	3	6	26	4	s	90	0	
4	4	5	15	0	s	0	0	long dead
5	1	5	30	3	s	90	0	
5	2	7	32	4	s	90	0	
5	3	8	28	4	s	90	0	
5	4	8	16	0	s	0	0	long dead

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
8	20/12/2007	mg/sf	590383	6076707	190	100	Dune.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	6	24	3	s	70	0	
1	2	8	28	0	sn	0	0	long dead mid hol
1	3	30	34	0	s	0	0	long dead mid hol
1	4	15	22	3	s	60	0	no hol
2	1	10	49	0	s	0	0	no ext hol long dead

2	2	33	9	4	s	100	0	regen
2	3	53	67	0	s	0	0	long dead mid hol
2	4	80	45	4	s	100	0	
3	1	17	36	3	s	75	0	live
3	2	6	31	0	s	0	0	long dead
3	3	6	4	4	s	100	0	regen
3	4	16	23	0	s	0	0	long dead
4	1	40	24	0	sn	0	0	long dead
4	2	42	31	0	s	0	0	long dead
4	3	84	33	0	sn	0	0	long dead
4	4	41	24	4	s	100	0	regen
5	1	44	9	4	s	100	0	regen
5	2	40	7	4	s	100	0	regen
5	3	8	57	0	sn	0	0	long dead mid hol
5	4	33	56	0	sn	0	0	long dead

TRAN.	DATE	RECORDERS	EASTING	NORTHING	BEARING	INTERVAL	NOTES
9	18/12/2007	589876	589876	6083103	140	100	Dune.

POINT	QUAD.	DIST (m)	DBH (cm)	COND.	STRUCT.	FOLIAGE	HOLL.	NOTES
1	1	8	35	3	s	80	0	
1	2	6	2	4	s	100	0	regen
1	3	11	1	4	s	100	0	regen
1	4	10	1	4	s	100	0	regen
2	1	10	36	4	s	90	0	
2	2	16	33	0	s	0	0	recently dead
2	3	8	2	4	s	100	0	
2	4	7	44	4	s	90	0	
3	1	16	1	4	s	100	0	regen
3	2	8	4	4	s	100	0	regen
3	3	15	3	4	s	100	0	regen
3	4	10	49	0	sn	0	0	dead - split
4	1	14	58	3	sn	70	0	main trunk hol 20x2
4	2	7	46	2	sn	25	0	main trunk snapped
4	3	3	42	4	s	90	0	
4	4	2	43	2	sn	60	0	
5	1	7	2	4	s	100	0	regen
5	2	3	41	2	s	25	0	main trunk snapped
5	3	8	46	3	s	80	0	
5	4	2	4	4	s	100	0	