National Reserves System
Sustainable Fire Management for Conservation of Biodiversity Across Northern Australia: On and Off Reserves
Kimberley

An Assessment of the Distribution and Status of Arnhem Cypress Pine *Callitris intratropica* (R. T. Baker & H. G. Sm.) in the Kimberley Region, Western Australia.

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DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

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INTRODUCTION

THE STUDY

This project was undertaken as part of the Kimberley component of the 'Sustainable Fire Management for Conservation of Biodiversity Across Northern Australia: On and Off Reserves' and was part funded under the National Reserves System. The primary aim was to contribute to an understanding of the impact of existing fire regimes on fire sensitive communities in the Kimberley.

Recent research, general observations and expressed concerns by land managers have indicated that stands of Arnhem Cypress Pine *Callitris intratropica* are being damaged by the prevailing fire regime. The outcomes relate to several linked lines of investigation;

- Assess the current distribution of *C. intratropica* in the Kimberley describing general soil and associated vegetation characteristics. Comment should also be made on the plant's past distribution.

- Assess the extent to which *C. intratropica* could be used as an indicator of the health and structure of the broader vegetation community.

- Assess the occurrence and structure of plant species found in the savannah landscape by way of comparison with *C. intratropica* along with any particular characteristics of the species involved.

This report focuses on the results pertaining to *C. intratropica*. Other papers look at the data gained for a variety of plant species recorded at the survey sites.

STUDY LOCATION.

Most of the Kimberley study area falls within the 800-1200 mm/annum rainfall zone with a few sites in the 1200-1600 mm zone and one in the 600-800 mm/annum zone. The basic characteristic of the climate of northern Australia is that there is a strong seasonality, in the broadest terms, differentiated between a warm dry season with little or no rainfall between May to October and a hot humid wet season in the remainder. The rains of the wet season vary between intense localised thunderstorm events to constant widespread rain associated with the movement of the monsoon trough. What is most obvious is the highly variable rainfall between areas and from one season to the next. With the generally high temperatures experienced, evaporation rates are likewise high.

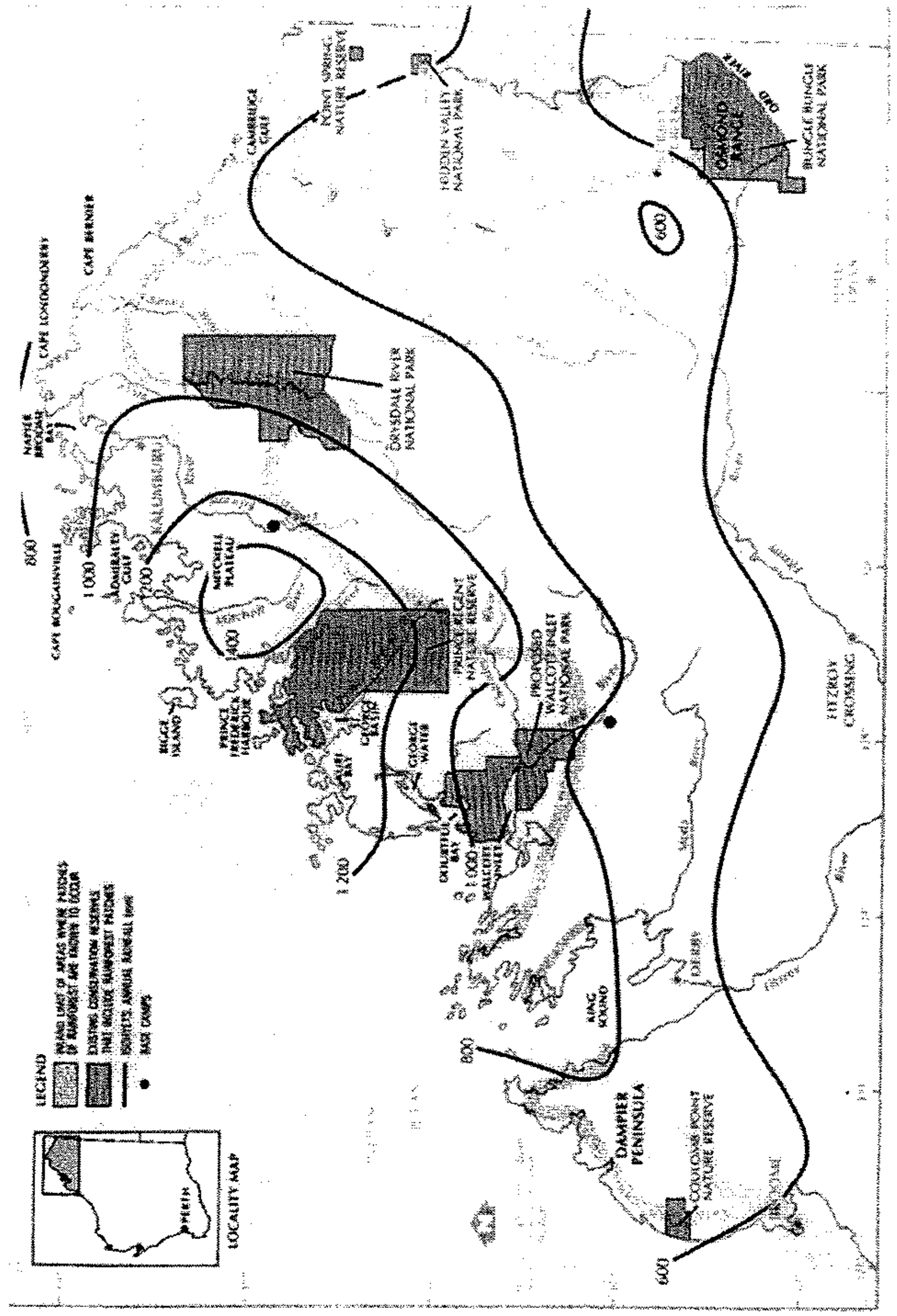

Figure 1. Rainfall isohyets of the Kimberley Region.

The study sites are primarily within the North Kimberley, Central Kimberley and Victoria Bonaparte biogeographic regions (bioregions) as defined by IBRA. A small number of study sites are at the edge of the Dampierland and Ord-Victoria Plains bioregions. The landforms where the majority of the survey sites are located are described as the Kimberley Plateau, which is the land north of the King Leopold and Durack Ranges (Kimberley Foreland), and the Cambridge Gulf lowlands. This country is dominated by sandstone escarpments and skeletal sandy soils.

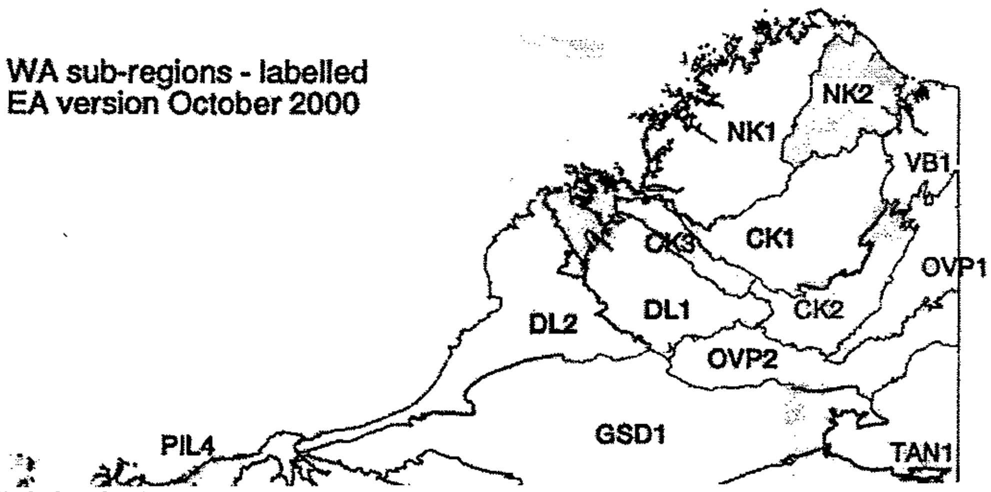

Figure 3. Kimberley subregions.

The study area encompassed most of the known or reported distribution of *C. intratropica*. Due to access and time constraints there remain large tracts where this plant is known to occur (or once occurred) that were not studied. Most noticeably this includes several large island populations, areas near the northwest Kimberley coast and north of Wyndham to Cape Londonderry. Importantly the majority of sites that had been selected at random, had *C. intratropica* either growing on or near the site, or showed evidence of being present in the past. Two sites did not appear to have had *C. intratropica* in the vicinity.

THE PLANT

Callitris intratropica R. T. Baker & H. G. Sm. is a member of a group of closely related, Australian endemic species that includes *C. columellaris*, *C. preissii* and *C. verrucosa*. In the past a number of authors have not recognised it as a distinct species with it being previously referred to as *C. columellaris* F. Muell (e.g. Stocker, 1966; Bowman and Latz, 1993). It is one of seven species of the genus *Callitris* found in Western Australia with *C. glaucophylla* in the Pilbara region being the nearest species in distribution. There is no overlap in the distribution of the two species.

In the Northern Territory flowering commences at the start of the 'wet' season around September or October. With maturity only being attained after about twelve years. There is a significant variation between the amounts of seed produced from one year to the next as well as between trees of apparently similar production capability. The amount of seed that actually germinates is very low (0.1%) and all seed able to germinate does so within a period of six weeks and is not viable after about 4 months on the forest floor. Studies have shown that the winged seed has a somewhat limited dispersal from the parent tree (Stocker 1966).

Investigations on the distribution of this species have tended to focus on Queensland and the Northern Territory. Hammer (1981) describes it as having a 'scattered distribution over large areas within 350 km of the northern coast of the Northern Territory'. Bowman and Harris (1995) mapped two primary areas of distribution of this species with one in Queensland and one in the Northern Territory and there were no indications of its presence in the Kimberley. The Department of Conservation and Land Management's online "Florabase" maps the location of voucher collections of this species in Western Australia and shows a general distribution from northern and north western coastal areas south to around 17° 30'S and approximately 300 kilometres inland. It is not found on the Pindan soils of Dampierland bioregion in the west of the Kimberley.

Bowman, Wilson and Davis (1988) referring to the work of Clayton-Green (1981) stated that its spatial pattern of generally occurring in small patches throughout its range and the poor seed dispersal might mean that the species was once more widespread. The scattering in clumps was considered to correspond to sandy soils, however Bowman and Harris (1995) reported that the genus *Callitris* is found on a wide range of soil types but is not found on cracking clays[1]. The continuing presence of these clumps has been reported to be due to a fragile balance between soils, the structure of the understorey in the clump and the pressure of fire impact from the surrounding savannah (Stocker and Mott, 1981).

In the Northern Territory the usual occurrence of *C. intratropica* has been described variously as in open forest dominated by *Eucalyptus tetrodonta* (Darwin stringybark) and *Eucalyptus miniata* (Northern woollybutt) (Hammer, 1981) and 'skeletal soils on sandstone escarpment to well drained moist monsoon forests in sandstone gorges' (Bowman, Wilson and Davis, 1988). It is an easily established plantation species and at one time was considered the most important species in the Northern Territory (Hammer, 1981).

The plant's relationship with the rainforests of the Kimberley has not been investigated, however there are no reports of its presence in the small rainforest patches of the Kimberley. In a number of coastal locations it has been reported as abutting patches of rainforest and mangrove communities. It is known to be growing well on northwest coastal islands and other mainland fire protected habitats near the coast (T. Willing pers. comm.).

It is considered that since non-Aboriginal colonisation of the Northern Territory less than 150 years ago there has been little destruction of the natural environment. This is in spite of the introduction of weeds, feral animals and altered fire regimes (Bowman and Panton, 1993; Williams, Cook and Ludwig, 1997). This same scenario could be argued for the Kimberley; however, the continuity of that situation may be under threat. Increasingly changes are being recorded from the small scale (e.g. rainforest patches) to the landscape level.

Through observation it is generally felt that the application of traditional Aboriginal burning practices only occasionally employed the use of high intensity fires. An example of this was in the driving of game at certain times of the year (Stocker and Mott, 1981; Saint and Russell- Smith 1997). The lack of traditional Aboriginal burning practices on the Arnhem Plateau in the Northern Territory has been suggested as a reason for the decline in the occurrence of *C. intratropica* in this area Bowman and Panton (1993). Evidence concerning traditional Aboriginal fire practices during the 1940's in the Murgenella area of the Northern Territory indicated that regular early dry season burning was undertaken for a number of purposes including thinning out the regeneration of *C. intratropica* that formed around stands of this species (Bowman, Wilson and Davis, 1988). This presents a more focussed view of the intent of traditional burning practices with respect to *C. intratropica* than is presented by others, where the maintenance of clumps of *C. intratropica* is considered a consequence of traditional burning practices rather than an aim (Price and Bowman, 1994). Traditional management of *C. intratropica* at Maningrida was a consequence of burning practices preventing the development of late, dry season fires (Haynes, 1985). The way in which traditional information is transferred from one culture to another, needs to be treated with caution.

As a generalisation, late dry season fires, which currently occupy large tracts of the landscape and appear to be more common than in the traditional burning situation, are significantly more intense than early dry season fires (Williams, Gill & Moore 1998). Most land management agencies see the need to shift to early dry season burning as an important management goal (Williams, Cook and Ludwig, 1997). With the use of satellite imagery it has been documented that large areas of northern Australia, including the Kimberley, are burnt by hot wildfires on an annual basis. One result is that the patchiness of fire in the landscape resulting from Aboriginal burning practices has been largely lost (Russell-Smith et al, 1997).

[1] This soil selection was also found in the study.

FIRE IMPACT

As a result of the perceived potential for a timber industry in the East Kimberley region of Western Australia earlier in the 20th Century a report was prepared for the then Forests Department of Western Australia for an area north of what is now Kununurra (Easton, 1922).

> 'The ground is very fertile, and carries most luxuriant crops of grass, some of which attain 15 feet in height. ... The black loamy country is lightly timbered, principally with messmate, woollybutt, bloodwood and ironbark, while on the light, sandy rises grows the cypress pine. This I found to my dismay, was quickly being burned out, and will before many years be entirely wiped out..'
>
> 'As none of these belts were many chains wide and are bounded on either side by the messmate country carrying tall grass, and as this grass is burned by the cattlemen every year, you will readily see how gaps have been burned through the belts. Then, where hitherto there was a clean forest floor owing to the dense canopy, sunlight is let in, and the seed of the tall grasses takes root and flourishes. ... Amongst those that are still standing, for every living tree there are 10 or 20 dead ones, in various stages of being burned up completely.[2]

Within the broad savannah landscape *C. intratropica* is considered to be one of the most fire sensitive plants. It is an obligate seeder in that it is re-established only from seed and not by sprouts from rootstock, as do many other savannah tree species. Adult trees are fire resistant to some extent, but small trees, saplings and seedlings are very fire sensitive usually being killed outright by any type of fire (Stocker, 1966; Stocker and Mott, 1981). Severe fires usually kill adult trees. The corollary to this is that the removal of fire results in the rapid establishment of dense regeneration growth (Stocker, 1966) with the populations of *C. intratropica* becoming stocked with small size classes (Price and Bowman, 1994). *C. intratropica* has been proposed as a climax species for some locations in the absence of fire (Bowman, 1986).

Bowman and Wilson (1988) reviewed the process behind the dynamic maintenance of coastal monsoon forests where *C. intratropica* was mentioned. In that review the previously hypothesized 'fire-vegetation-soil interaction where edaphic factors, particularly soil and water relations, control vegetation type which in turn influences fire frequency' was re-iterated. In the case of *C. intratropica*, being a widespread, fire-sensitive species, it may be that the type of fire regime may play a significant role when compared to other factors (Bowman and Panton, 1993). This may also be linked to the dynamics of the vegetation community of which *C. intratropica* is a part or is surrounded by. Bowman and Panton (1993) support the view that many populations of cypress can be considered as relicts of their former distribution.

For clumps of *C. intratropica* and individual trees it appears that they directly influence the fire fuel structure in their immediate vicinity because of the suppression of grass growth under the canopy and the trees provide little fuel for 'normal' fires. The result is that low to medium intensity fires often go out at the edge of the clumps (Stocker, 1966). Bowman and Harris (1995), in summarising the work of other authors, stated that '*C. intratropica* stands are characterised by a more compact, slightly moister litter layer which typically is a barrier to the entry of fire. However, canopy openings result in increased fine fuels, more grasses and less moisture'.

The finding of *C. intratropica* mostly in conjunction with sandy soils might be explained through the fire-vegetation-soil interaction. One process is that poor soils are less productive thereby producing less grass to fuel fires and thus any fires are of lower intensity when compared to good soil areas (Bowman,Wilson & Davis, 1988)

[2] No 'belts' of *Callitris intratropica* 'chains' wide have been recently found north of Kununurra.

Bowman and Panton (1993) showed that *C. intratropica* occupied a small part of its potential range but 'the distribution does not correspond to specific and equally patchy environmental factors'.[3] It was considered that topographic fire protection is important in controlling the distribution of this plant. Bowman and Harris (1995) reported that topographic fire protection had been found to be important for a number of *Callitris* populations.

INDICATOR

For a number of reasons associated with the characteristics of *C. intratropica* the plant has been suggested as a useful bio-indicator of changes in fire regime. Under existing fire regimes stands of dead trees are considered to show a local range contraction of the species and Aboriginal people in central Arnhem Land believed that stands of dead *C. intratropica* indicated poor land management and a breakdown of traditional burning associated with the increase in destructive wildfires (Haynes 1985).

Bowman and Panton (1993) outlined the characteristics of *C. intratropica* that made it a valuable indicator species;

> '(a) It is a long-lived tree (> 200 years) spanning the transition from pre- to post-contact times (Hammer, 1981);
> (b) It remains in the landscape for many years after it has died, due to its termite resistant timber (Gay & Evans, 1968);
> (c) Trees are undamaged by low intensity fires, but are scarred or killed by intense fires (Stocker, 1966a; Haynes, 1985; Bowman, Wilson & Davis 1988);
> (d) Stands occur in a range of different environments (e.g. laterite soils, Bowman & Wightman, 1985; coastal sand sheets, Bowman, Wilson & Davis, 1988; sandstone ranges, Bowman, Wilson & Fensham 1990) throughout the northern part of the Northern Territory (Gay & Evans, 1968). Typically the stands are several ha in area (Stocker, 1966a), although *C. intratropica* is also a co-dominant tree in some large tracts of *Eucalypts* savannah (Wilson *et al.* 1991).'

With respect to (b) above it has been estimated that upright, dead trees would not remain in the natural landscape for more than 50 years with a frequent burning pattern (Bowman and Panton, 1993). The fact that the tree is a long-lived obligate seeder contributes to its value as an indicator species.

This value of *C. intratropica* as an indicator of fire management (or the lack of) within the landscape warrants emphasis. It has the potential to be used as a type of monitor of fire impacts with the rapid loss of living plants from the landscape under a frequent 'hot' fire regime evidenced by an increase in the number of dead plants found in the landscape. Equally it could monitor the also unacceptable removal of fire from the landscape with the rapid establishment of seeds and saplings. It may well be possible to design a balance in fire management by looking at what is happening to *C. intratropica*.

The other advantages in using *C. intratropica* from a manager's viewpoint are that it is a readily identifiable species in the landscape (including dead plants) and evidence shows that it is or was found widely across the landscape. The plant ranges from 'pure' stands to being a single component of a generally Eucalypt dominated savannah woodland. Through this a wide range of savannah woodlands can be looked at and changes to the associated plant communities might be more readily identified.

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[3] The PATN analysis tends to support this in the case of this study.

METHODS

BASE CAMPS AND STUDY SITES SELECTION

Base camp locations were selected from maps with ease of access and possible representativeness being important selection factors. Most of these locations were along or near to the main access roads; the Gibb River Road and Kalumburu Road. Others were accessed by clearly defined tracks servicing popular tourist destinations (Mitchell Plateau, Drysdale River National Park) or pastoral land (Carlton Hill).

A total of 14 base camps were selected and the locations and dates visited are shown in Table 1 (See also Figure 2).

Base Location	Dates worked	Quadrat Numbers
East of Durack River Homestead	23 April 1998	1,2
Russ Creek	15-16 June 1998	3-5
Mitchell Plateau	16-17 May 1999	6,7
Gibb River Road / Mt Hart Station track	10 June 1999	10-12
Rifle Point Track	8 June 1999	8,9
Phillips Range	11 June 1999	13,14
Old Mt Elizabeth	22 – 25 June 1999	15-20
Kalumburu Road / Gibb River intersection	3-5 August 1999	21-26
Drysdale River	6 August 1999	27,28
King Edward River / Mitchell River track	11-12 August 1999	29-31
Morgan Falls – Drysdale River National Park	31 August 1999 – 2 September 1999	32-39
Purnululu National Park	17 September 1999	40
North of Kununurra	30 September, 5, 8, 12 October 1999	41-45
Kimbolton (Yampi)	2-4 August 2000	Y1,Y2

Table 1. Location of Base Camps and dates surveyed.

The base camp locations straddle a significant rainfall gradient from the lower rainfall areas of the central Kimberley to the higher rainfall northern Kimberley. The most southern of the base camps were selected because there are herbarium records for the presence of *Callitris intratropica* at or near these locations. In general terms all the locations are within the expected distribution of *C. intratropica*.

From each base camp a series a specific survey sites were selected at random. To achieve this a disc was placed on a 1:100 000 topographical map, the centre on the base camp location, with holes in the disc spaced at a scale to give 1-kilometre intervals. This was spun and the selected location was marked on the map. The number of sites selected was dependant on the time available for survey. No two sites were selected at the same distance from the base camp. For the sake of safety the maximum distance selected from the base camp was 10 kilometres.

The map grid references for each were placed in a GPS unit (Garmin GPSII Plus) and each survey point was either walked to or driven to using a quad bike. At each of the study sites between two to five quadrats were established, with the most frequent number being three.

A total of 47 survey sites were visited and 143 quadrats were established. On average 2 survey sites were surveyed each day. Generally each site comprised of three continuous quadrats with the latitude and longitude being recorded at the start of the first quadrat. Table 2 presents the location and position data for each of the survey sites and these are shown on Figure 1.

Quadrats	Location	Latitude	Longitude
1/1-1/5	18 km. East of Durack River homestead Gibb River Rd.	15^{O} 48' 43"S	127^{O} 33' 26"E
2/1-2/3	29.6 km. East of Durack River h/stead Gibb	15^{O} 46' 48"S	127^{O} 38' 14"E

	River Rd.		
3/1-3/4	2 km. West of Russ Creek Gibb River Road.	16° 03' 04"S	126° 41' 49"E
4/1-4/4	7.5 km.. West of Russ Creek Gibb River Road.	16° 03' 19"S	126° 38' 45"E
5/1-5/4	11.5 km. West of Russ Creek Gibb River Road.	16° 05' 56"S	126° 36' 12"E.
6/1-6/3	Little Mertens Campsite - Mitchell Plateau.	14° 49' 13"S	125° 43' 17"E
7/1-7/3	Mitchell Plateau access road - 22 km. Southeast of old mining camp.	14° 55' 09"S	125° 59' 35"E
8/1-8/3	4 km. Southeast of Rifle Point - King Leopold Ranges.	17° 10' 53"S	125° 24' 05"E
9/1-9/3	12 km. South-southeast of Rifle Point - King Leopold Ranges.	17° 16' 53"S	125° 24' 05"E
10/1-10/3	4 km. along Lennard River Gorge Track.	17° 09' 53"S	125° 12' 49"E
11/1-11/3	2 km. East of Mt Hart Homestead track 4 km in.	17° 03' 31"S	125° 11' 31"E
12/1-12/3	2 km. North of Gibb River Road near Lennard Gorge access.	17° 07' 52"S	125° 13' 20"E
13/1-13/3	2 km. South of Gibb River Road Phillips Range.	16° 53' 21"S	125° 49' 17"E
14/1-14/3	6 km. South of Gibb River Road Phillips Range.	16° 54' 26"S	125° 50' 30"E
15/1-15/3	Approx 5 km. West of the Mt Elizabeth access road.	16° 30' 13"S	126° 10' 01"E
16/1-16/3	13 km. East of old Mt Elizabeth Homestead.	16° 19' 31"S	126° 18' 24"E
17/1-17/3	12 km. East of old Mt Elizabeth Homestead.	16° 18' 22"S	126° 18' 41"E
18/1-18/3	4 km. Northeast of old Mt Elizabeth homestead.	16° 16' 38"S	126° 13' 19"E
19/1-19/3	4 km. Northeast of old Mt Elizabeth Homestead.	16° 16' 34"S	126° 12' 21"E
20/1-20/3	3 km. West of old Mt Elizabeth Homestead.	16° 18' 06"S	126° 10' 24"E
21/1-21/3	3.5 km. North of Gibb River/Kalumburu Rd intersection.	16° 04' 10"S	126° 31' 26"E
22/1-22/3	5.5 km. North of Gibb River/Kalumburu Rd intersection.	16° 03' 42"S	126° 31' 18"E
23/1-23/3	7 km. Southeast of Gibb River/Kalumburu Rd intersection.	16° 08' 55"S	126° 32' 32"E
24/1-24/3	9 km. South of Gibb River/Kalumburu Rd intersection.	16° 10' 27"S	126° 31' 16"E
25/1-25/3	6.5 km. Northwest Kalumburu Rd/Gibb River.	16° 04' 23"S	126° 27' 26"E
26/1-26/3	11.5 km. Northwest Kalumburu Rd/Gibb River.	16° 02' 06"S	126° 25' 21"E
27/1-27/3	8.5 km. North of Drysdale River.	15° 36' 35"S	126° 23' 32"E
28/1-28/3	11.5 km. North of Drysdale River.	15° 35' 11"S	126° 23' 01"E
29/1-29/3	King Edward River Crossing – old Mitchell River Station access track.	15° 07' 08"S	126° 07' 36"E
30/1-30/3	3 km. West of King Edward River/old Mitchell River Station access track.	15° 06' 53"S	126° 05' 51"E
31/1-31/3	4.5 km. East of King Edward River/old Mitchell River Station access track.	15° 07' 29"S	126° 10' 12"E
32/1-32/3	Drysdale River National Park (DRNP) - Morgan Falls.	15° 01' 53"S	126° 39' 31"E
33/1-33/3	2 km. Northwest of Morgan Falls – DRNP.	15° 01' 49"S	126° 38' 59"E
34/1-34/3	4.5 km. Southwest of Morgan Falls – DRNP.	15° 03' 56"S	126° 39' 19 "E
35/1-35/2	5 km. Southeast of Morgan Falls – DRNP.	15° 04' 00"S	126° 41' 36 "E
36/1-36/3	5 km. Southwest of Morgan Falls – DRNP.	15° 03' 07"S	126° 37' 33"E
37/1-37/3	8.0 km. Southwest of Morgan Falls – DRNP.	15° 03' 39"S	126° 36' 12"E
38/1-38/3	5.5 km. Northwest of Morgan Falls campsite.	15° 01' 02"S	126° 36' 59"E
39/1-39/3	4.5 km. Northwest of Morgan Falls campsite.	15° 00' 46"S	126° 37' 47"E
40/1-40/2	26 km. Northeast of ranger station Purnululu National Park.	17° 13' 50"S	128° 26' 17"E
41/1-41/3	14 km. Northeast of Ningbing Bore.	15° 11' 15"S	128° 47' 32"E

42/1-42/3	13 km. Northeast of Ningbing Bore.	15° 09' 54"S	128° 45' 51"E
43/1-43/3	20 km. Northeast of Ningbing Bore.	15° 07' 33"S	128° 49' 16"E
44/1-44/3	19 km. Northeast of Ningbing Bore.	15° 07' 41"S	128° 48' 44"E
45/1-45/3	25 km. Northeast of Ningbing Bore.	15° 05'21"S	128° 50' 38"E
Y/1/1-Y/1/3	Trent River - Yampi Defence – Kimbolton.	16° 36'12"S	123° 40' 08"E
Y/2/1-Y2/2	Trent River - Yampi Defence – Kimbolton.	16° 38' 45"S	123° 43' 30"E

Table 2: Quadrat Locations

It was originally intended that several other base camps would be included being: East of Kalumburu, Berkeley River, North of Ellenbrae Station, Saw Ranges, Tableland Station. Of these the three that are priorities for study are; Kalumburu - as it is considered that the area has been little impacted by pastoral activities, traditional Aboriginal knowledge is available and the area has been the subject of other studies (Vigilante, Wightman and Chambers); Berkeley River – likewise this is an area that has not been allocated for pastoral use in the past and is primarily accessed by Aboriginal people; Tableland Station – this is apparently toward the most southern distribution of *C. intratropica* and the plant is known to still occur in the area.

One of the main factors preventing these areas being surveyed ~~to-date~~ was an extended 1999-2000 wet season and a 'good' 2000-2001 wet season affecting field access.

QUADRAT PHYSICAL CHARACTERISTICS.

Data collection was undertaken within a quadrat 50 metres by 10 metres. A 50-metre tape was laid out along a randomly selected compass alignment with this tape defining the centre-line of the quadrat. For the quadrats the following was recorded.

1. Site Type.

   The location of the quadrat in the landscape was placed in the categories of; Slope, Valley (floor), Ridge and Plain.

2. Aspect.

   Eight points of the compass were selected to estimate the dominant aspect of each of the sites; North, Northwest, West, Southwest, South, Southeast, East, Northeast.

3. Slope.

   The categories recorded for slope were; Flat (<1°), Gentle slope (1-5°), Moderate Slope (5-30°), Steep Slope (>30°), Cliff.

4. Soil Type.

   A simple approach was adopted for the categories in this section with an assessment of the dominant structure of the soil. The categories were; Sand, Clay/sand (a predominantly clay soil with a distinct sand component), Sand/clay (a predominantly sand soil with a distinct clay component), Sand/loam (sand soils with a humus component) and Clay.

   Clearly some of these categories graded in with others requiring a subjective decision in a number of cases.

5. Soil Depth.

Hammering a steel rod into the ground at a minimum of four points along the centre line of the quadrat and roughly averaging the results obtained determined soil depth. Each of the points were evenly spaced along the centreline regardless of the substrate at that point (for example a boulder may have been at the selected point). The categories employed were; <10 cm., 10-30 cm., 30-45 cm. and >45 cm.

6. Soil Colour.

A soil sample was taken at the start of the centre line of each quadrat from a depth of at least 2 centimetres in order to remove surface layer material. Standardising the records for soil colour was made by using the Munsell Soil Colour Charts to which the soil sample (dry) was compared. This produced a wide range of soil colours primarily yellow through orange to browns, red-browns and red. For the purposes of assessment these were further categorised to Pale Soils, Mid Soils and Dark Soils as this may differentiate soils depauperate in nutrients from richer soils.

7. Rock Type.

Once again a simple approach was adopted in the determination of rock type. The categories employed were; Sandstone, Granite, Laterite, Limestone and Other.

8. Rock Size.

The categories were; Gravel (<2 cm.), Stony (2-10 cm.), Rocky (10-50 cm.), Boulders (>50 cm.) and bedrock.

9. Rock Cover.

This assessment was through a subjective visual assessment of the average broad percentage of exposed rock throughout the quadrat. Categories were; 0-30%, 30-70% and 70-100%.

10. Fire Age.

The recording of fire age was based on a visual assessment that included the immediate surrounds of the quadrat. The categories used were; Recent – cool, Recent – moderate, Recent – hot, Previous year, 2-3 years previous and Long unburnt. The determination of what constituted cool/low intensity, moderate or hot fire/high intensity was based on;

Cool/low intensity	Very patchy burnt area, no overstory leaf scorch and minimal trunk scorch.
Moderate intensity	Most of the burnt area affected, some removal of understorey species and scorch height affecting up to half the total height of the overstory foliage.
Hot/high intensity	All of the burnt area affected, most or all of understorey removed and scorch extending to top of overstory foliage.

11. Fire Exposure.

The three categories used were; Sheltered, Moderate and Exposed. This related to a subjective assessment of the amount of natural protection the quadrat had from fire. Generally speaking quadrats with a very large percentage of exposed rock or with natural barriers nearby that would prevent the progress of a fire were described as sheltered. At the other end of the scale were quadrats found on a valley floor without exposed rock in a very grassy landscape. These were rated as exposed.

GRASSES

In order to assess the dominance of a major fuel class in the savannah landscape three broad types of grass were assessed at each quadrat; cane grass (i.e. annual *Sorghum spp.*), hummock or bunch grasses (eg. *Triodia spp.*) and other grasses[4]. The same categories were assessed for each group being;

1. Density.

   This was a visual assessment of the average cover of each grass fuel component considered present over all the quadrat. The criteria were; Sparse (<5%), Light (5-25%), Moderate (25-50%), Dense (50-75%) and Very Dense (75-100%).

2. Pattern.

   This category was intended to give an assessment of the distribution of each grass fuel component through the quadrat. The two criteria were; Uniform – where there was an even spread through the quadrat, and Patchy – obviously where the grasses tended to grow in clumps or were scattered through the quadrat in an uneven manner.

3. Height.

   The average height of the grass fuel component was measured and placed in the criteria of; <0.5 m., 0.5-1 m., 1-2 m. and >2 m.

4. Status.

   The category related to the relative abundance of each grass fuel component in comparison to other grasses and categorised as; Dominant, Co-dominant, Significant, Sparse and Absent

Cypress and other species.

Total numbers of plants were recorded for each quadrat within the growth form categories of seedling, re-sprout, sapling, mature, dead. These categories were also used for other plant species and whilst generally self explanatory they were defined as;

1. Seedling

   Young plant that develops after the germination of a seed.

2. Re-sprout

   The plant has re-developed from rootstock or by re-shooting from a stem following the disturbance of the original plant. It was also recorded as being prior to the development of plants that exhibit 'normal' growth form with this being defined as the form exhibited by other plants of the species unaffected by re-sprouting.

3. Sapling

   Non-mature plant showing no indications of being a re-sprout. Considered to be pre-reproductive.

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[4] Mention concerns about the apparent increase in the amount of cane grass in the landscape in the discussion section.

4. Mature

   Adult, reproductive plant.

5. Dead

Plants were also placed in height categories with, after an initial period of measuring to check the accuracy of estimates, the plants assigned to 1-metre groupings. For those plants over 2 metres in height the diameter at breast height (DBH) was recorded to the nearest centimetre. The DBH for all dead plants is the under bark diameter. A further requirement was to identify those plants where the height could not be determined. This occurred for plants that had lost part of the crown structure, had fallen over or where only stumps were recorded. The recording of height and DBH information was introduced from quadrat 15 onwards.

Other plant species recorded in the quadrat were those that were capable of growing to greater than 2 metres in height.

All information was placed on the database Microsoft Access as well as on Microsoft Excel with plant vouchers retained at the Kununurra offices of the Department of Conservation and Land Management.

ANALYSIS OF PATTERN.

In order to explore the environmental relationships of assembled floristic data, pattern analysis was undertaken on a data matrix describing the presence/absence of plant species occurring at 5 or more quadrats across the 143 quadrats. Unidentified taxa were omitted from analysis. Pattern analysis was undertaken using the PATN software package (Belbin 1987), using a standard classificatory procedure (Bray-Curtis Association) and a conservative hierarchical fusion procedure (UPGMA with default settings). The environmental relations of resultant floristic groups were explored further using other procedures contained within the PATN package.

RESULTS

QUADRAT PHYSICAL CHARACTERISTICS.

Table 3 presents the summary of the physical variables of all quadrats. Figures are expressed as the percentage of the number of quadrats with a particular characteristic out of the total (n = 143). The figures in brackets are the percentage figures for the total number of quadrats where *C. intratropica* was recorded from within the quadrat (n = 83). The dominant category in each of the characteristics is presented in bold.

Soil Colour	**Pale**	**Mid**	**Dark**	
	44.1 (34.9)	37.8 **(42.2)**	18.2 (22.9)	
Fire Exposure	**Exposed**	**Moderate**	**Sheltered**	
	73.4 **(79.5)**	21.0 (15.7)	5.6 (4.8)	
Slope	**Flat**	**Gentle slope**	**Mod Slope**	**Steep Slope**
	53.1 **(61.4)**	39.9 (30.1)	4.9 (6.0)	2.1 (2.4)
Soil Depth	**<10 cm.**	**10-30 cm.**	**30-45 cm.**	**> 45 cm.**
	25.9 (27.7)	10.5 (13.3)	14.0 (13.3)	**49.7** **(45.8)**

Rock Cover	0-30%	30-70%	70-100%	n/a
	18.9 (26.5)	13.3 (15.7)	11.2 (8.4)	**56.6** **(49.4)**

Soil Type	Sand	Clay/sand	Sand/clay	Sand/loam	Clay
	70.6 **(63.9)**	9.1 (12.0)	9.1 (9.6)	8.4 (10.8)	2.8 (3.6)

Rock Type	Sandstone	Laterite	Gravel	Granite	Absent
	26.6 (27.7)	8.4 (10.8)	0.7 (1.2)	7.7 (10.8)	**56.6** **(49.4)**

Rock Size	Gravel	Stony	Rocky	Boulders	N/a
	7.7 (10.8)	6.3 (9.6)	10.5 (12.0)	18.9 (18.1)	**56.6** **(49.4)**

Fire Age	Burnt 2-5 yrs	Previous year	Recent - cool	Recent - moderate	Recent - hot
	43.4 **(49.4)**	21.0 (12.0)	5.6 (6.0)	23.8 (26.5)	6.3 (6.0)

Site Type	Plain/slope	Plain	Ridge	Slope	Valley	Valley/ridge	Valley/slope
	0.7 (0.0)	**46.9** **(56.6)**	9.1 (8.4)	23.8 (16.9)	16.8 (15.7)	0.7 (0.0)	2.1 (2.4)

Aspect	e	n	ne	nw	s	se	sw	w	none
	6.3 (9.6)	21.7 (22.9)	7.0 (7.2)	4.9 (2.4)	9.1 (7.2)	9.8 (3.6)	4.9 (1.2)	8.4 (8.4)	**28.0** **(37.3)**

Table 3. Percentage records of physical characteristics for quadrats.

A number of modifications to the categories were made during the survey as well as a result of the data collected. For Site Type several other categories were added as it was not possible to distinctly separate several categories. This was usually in the event of a quadrat running from one particular category to another, for example, from a plain to a slope or from a valley floor to a slope at the side of the valley. For Slope and Rock Size the categories 'cliff' and 'bedrock' respectively have been deleted from the final assessment as no quadrats were recorded for these.

The dominant type of quadrat was a plain with a flat to gentle slope with 'deep', sandy, pale to mid dark soils without rocks. For those sites where rocks are present sandstone was the most common with rock size tending to be in the larger categories. There appeared to be a relatively even spread in the percentage cover of rocks across these quadrats. The greatest numbers of quadrats were in the category of fire-exposed sites.

For quadrats with *C. intratropica* present once again the dominant type of quadrat was a plain with a flat to gentle slope with 'deep' sandy, pale to mid dark soils without rocks. For those sites where rocks are present sandstone was again the most common however there appeared to be a more even spread of rock sizes. As for the overall quadrat situation there appeared to be a relatively even spread in the percentage cover of rocks and the greatest number of quadrats were in the category of fire-exposed sites.

Appendix 1 presents the information on soil colour for the quadrats according to the Munsell Soil Colour Chart.

GRASSES

Table 4 presents the grass fuel category results expressed as a percentage for quadrats over all quadrats. The figures in parentheses, ( ), are the percentage figures for the total number of quadrats where *C. intratropica* was recorded from within the quadrat and the figures in brackets, [ ] are where *C. intratropica* was not recorded in the quadrat. The dominant category for each fuel characteristics is presented in bold.

DENSITY	**Sparse**	**Light**	**Moderate**	**Dense**	**Very Dense**	**Absent**
Sorghum	30.1 (31.3) [28.3]	11.9 (7.2) [18.3]	9.8 (2.4) [0.0]	2.1 (1.2) [3.3]	2.1 (1.2) [3.3]	**44.1 (56.6) [26.7]**
Hummock	11.2 (9.6) [13.3]	18.9 (18.1) [20.0]	17.5 (14.5) [21.7]	3.5 (3.6) [3.3]	0.7 (0.0) [1.7]	**48.3 (54.2) [40.0]**
Other	7.0 (9.6) [3.3]	1.4 (0.0) [3.3]	8.4 (9.6) [6.7]	11.9 (14.5) [8.3]	7.7 (8.4) [6.7]	**63.6 (57.8) [71.7]**

PATTERN	**Patchy**	**Uniform**	**Absent**
Sorghum	41.3 (39.8) [43.3]	14.7 (3.6) [30.0]	**44.1 (56.6) [26.7]**
Hummock	23.1 (21.7) [25.0]	28.7 (24.1) [35.0]	**48.3 (54.2) [40.0]**
Other	9.1 (10.8) [6.7]	27.3 (31.3) [21.7]	**63.6 (57.8) [71.7]**

HEIGHT	**< 0.5 m.**	**0.5 – 1 m.**	**1 – 2 m.**	**> 2 m.**	**Absent**
Sorghum	0.0 (0.0) [0.0]	9.8 (8.4) [11.7]	32.9 (21.7) [48.3]	13.3 (13.3) [13.]	**44.1 (56.6) [26.7]**
Hummock	15.4 (10.8) [21.7]	34.3 (32.5) [36.7]	2.1 (2.4) [1.7]	0.0 (0.0) [0.0]	**48.3 (54.2) [40.0]**
Other	6.3 (6.0) [6.7]	21.7 (25.3) [16.7]	8.4 (10.8) [5.0]	0.0 (0.0) [0.0]	**63.6 (57.8) [71.7]**

STATUS	**Sparse**	**Co-dominant**	**Dominant**	**Significant**	**Absent**
Sorghum	30.8 (30.1) [31.7]	12.6 (7.2) [20.0]	7.0 (3.6) [11.7]	5.6 (2.4) [10.0]	**44.1 (56.6) [26.7]**
Hummock	11.9 (8.4) [16.7]	11.9 (6.0) [20.0]	21.0 (24.1) [16.7]	7.0 (7.2) [6.7]	**48.3 (54.2) [40.0]**
Other	4.9 (6.0) [3.3]	0.7 (1.2) [0.0]	26.6 (30.1) [21.7]	4.2 (4.8) [3.3]	**63.6 (57.8) [71.7]**

Table 4. Percentage presence of grass characteristics by quadrats for all sites.

Cane grass (annual *Sorghum spp.*) was recorded on 80 quadrats in total (55.9%) with 36 of the 83 quadrats (43.4%) where *C. intratropica* was recorded having cane grass present. Of these cane grass was recorded as being dominant at 10 quadrats for all quadrats and 3 for quadrats where *C. intratropica* was recorded.

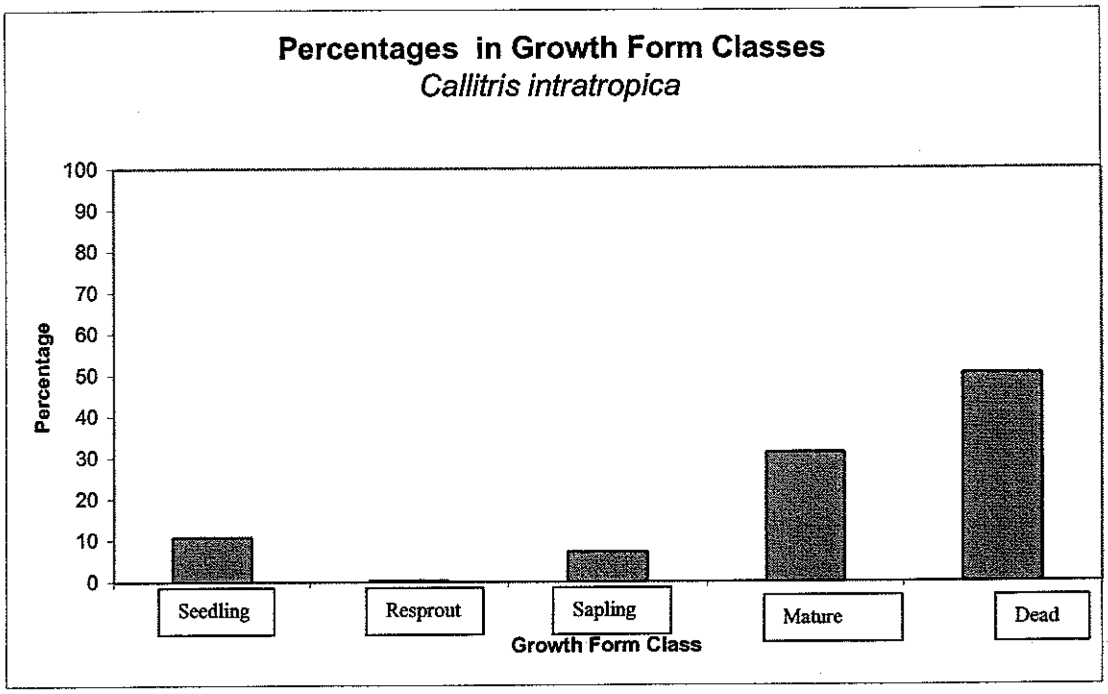
Hummock grasses were recorded on 74 quadrats in total (51.7%) with 38 of the 83 quadrats (48.5%) where *C. intratropica* was recorded having cane grass present. Hummock grasses were recorded as being dominant at 30 quadrats for all quadrats and 20 for quadrats where *C. intratropica* was recorded.

When comparing the various categories between those quadrats where *C. intratropica* wasn't recorded with those where it was, there appears to be a trend to an increase in the percentage of cane grass present for those quadrats where *C. intratropica* wasn't recorded. There also appears to be an increase in the light to moderate coverage, the cover is more uniform and there is an increase in the percentage of where it is dominant and co-dominant. The same situation is not apparent for hummock grasses.

Cypress

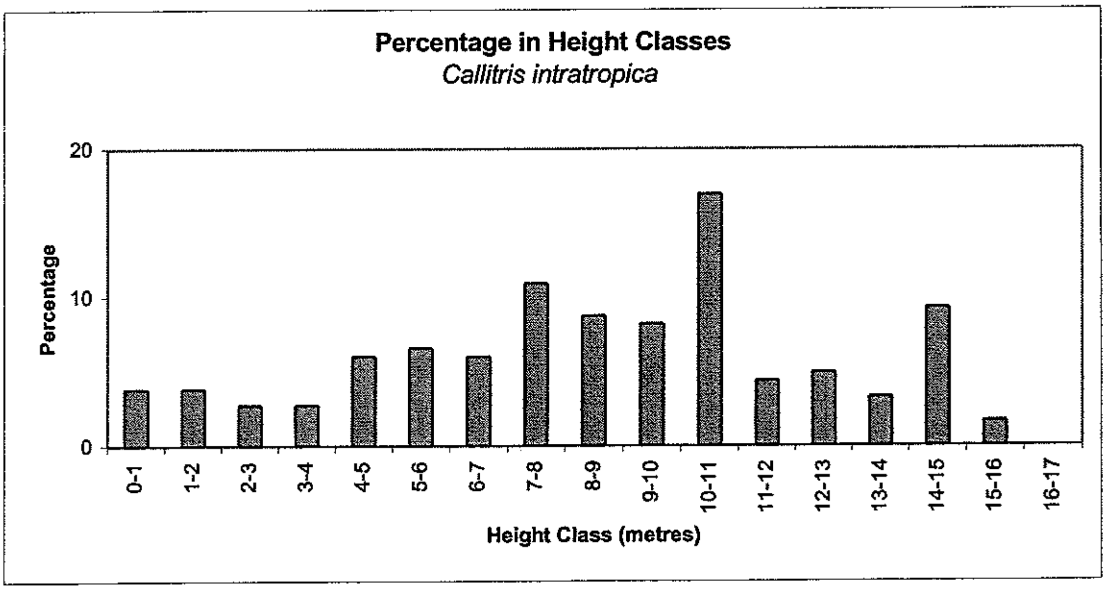
As has been previously reported *C. intratropica* was recorded at 83 of the total 143 quadrats. A total of 516 individual plants were counted. It is important to note that no quadrats were located within pure stands of *C. intratropica*. In all cases *C. intratropica* was a component of a broader savannah community. Of all the plants recorded approximately 50% in total were dead with very few plants showing signs of re-sprouting and limited numbers of saplings.

A summary of the growth classes across all transects where *C. intratropica* was recorded is given in Graph 1.



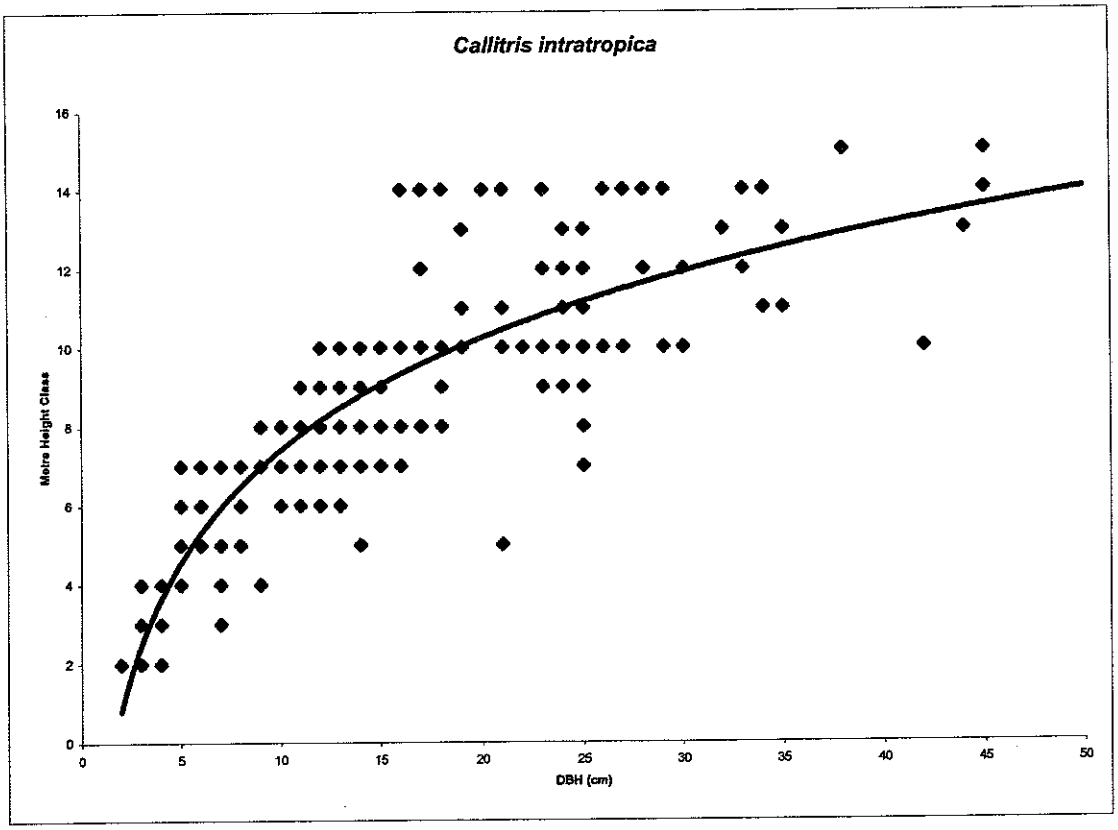
Graph 1. Percentage of C. intratropica *plants recorded for each growth form class across all quadrats where the plant was recorded for seedlings, resprouts, saplings, mature and dead.*

Likewise Graph 2 shows the percentages of the plants found in various height classes.



Graph 2. Percentage of C. intratropica *found in each height class (Living and dead plants).*

Graph 3 shows the relationship between the height and DBH for *C. intratropica* recorded from the quadrats. The line on the graph is a polynomial trendline fitted as an option from the Microsoft Excel program where the equation for the trendline is 4.1191Ln(x) – 3.0731 (R^2=0.7413).



Graph 3. Relationship between height and DBH for C. intratropica.

For Graph 3 plants were allocated to height classes on the basis that the two metre height class was for plants ranging in height from two to three metres, three metre height class was for plants ranging in height from three to four metres and so on.

Other Species

116 plant species were identified from 29 families (See Appendix 2). Apart from *C. intratropica* the next most common species were *Petalostigma pubescens* and *Eucalyptus tetrodonta* with each being found at 66 and 63 sites respectively.Identification of a number of plants was not possible because not enough material was available for identification or the plant was either dead or burnt. Table 5 presents the number of collections for which full identification was not possible. The table also indicates the number of sites where the plants were dead (in parentheses)

Specimen	No of Sites
Acacia sp.	25 (15)
Brachychiton sp.	5 (2)
Calytrix sp.	7
Eucalyptus sp.	87 (38)
Gardenia sp.	3
Grevillea sp.	4 (1)
Jacksonia sp.	1
Verticordia sp.	2
Unknown	37 (8)

Table 5. Collections not able to be identified.

The results of numerical classification of a data matrix comprising species found at 5 or more quadrats across 143 quadrats are presented in the tables below and associated appendices. Ten floristic groups were defined through numerical classification. The floristic composition for the key species of each of the groups is given in Table 6. The classification dendrogram is presented in Appendix 3 and the quadrat composition in each of the ten groups is given in Appendix 4.

Table 6 shows the groups, a listing of key species within each of the groups and the frequency of occurrence of these species expressed as a percentage of the total number of sites the species is recorded in within a group. The figures in parentheses indicate the number of sites within a group. Where no percentage is shown within the table no records for that species were made within the group. Key species were defined as those species occurring at 20% or more sites within any one group. The result is that key species are carried through to all groups they occur even if they do not exceed the 20 % threshold within a particular group.

Species	**Group 1 (31)**	**Group 2 (54)**	**Group 3 (10)**	**Group 4 (10)**	**Group 5 (1)**	**Group 6 (5)**	**Group 7 (16)**	**Group 8 (5)**	**Group 9 (6)**	**Group 10 (5)**
Callitris intratropica	100.0	74.1		70.0	100.0	20.0	6.25		16.7	
Acacia colei		5.5							50.0	
Acacia dictyophleba	3.2	5.6								20.0
Acacia difficilis		3.7	10.0	30.0					33.3	
Acacia hemignosta									16.7	20.0
Acacia multisiliqua	6.4	1.8				20.0				
Acacia neurocarpa		.6	10.0						33.3	
Acacia platycarpa	3.23	29.6		60.0						
Acacia retinervis			30.0	10.0						
Acacia retivenea								20.0	16.7	
Acacia sericata	3.23								33.3	
Acacia stipuligera										20.0
Acacia tumida	9.7	46.3							16.7	
Atalaya hemiglauca										40.0
Bauhinia cunninghamii		1.8						100.0	100.0	40.0
Bossiaea bossiaeoides	51.6	55.6								
Brachychiton diversifolius	25.8	9.3					25.00			100.0
Brachychiton tuberculatus		5.6	30.0	10.0						
Brachychiton viridiflorus	32.3	11.1		10.0						
Brachychiton viscidulus	3.2	5.6						20.0		
Buchanania obovata	16.1	51.8	70.0	20.0			12.5			40.0
Cajanus pubescens							12.5	20.0		
Calytrix achaeta	6.45	11.1	20.0	20.0			12.5			
Canthium sp. A	25.8	57.4		20.0					33.3	
Carissa lanceolata		5.6							83.3	20.0
Celtis philippensis										20.0
Clerodendrum floribundum		3.7								80.0
Cochlospermum fraseri	3.23	7.4		70.0			25.0	20.0		
Crotalaria cunninghamii										20.0
Distichostemon hispidulus		11.1	20.0							
Dodonaea physocarpa									100.0	60.0

Dolichandrone heterophylla		3.7		10.0			18.7	20.0		60.0
Erythrophleum chlorostachys	51.6	40.7	60.0	30.0					16.7	20.0
Eucalyptus aspera		5.6								40.0
Eucalyptus bigalerita	6.4					20.0				
Eucalyptus collina	12.9	5.6		50.0						
Eucalyptus confertiflora	3.23	1.8								40.0
Eucalyptus dichromophloia	22.6									
Eucalyptus ferruginea		9.26		20.0						
Eucalyptus grandifolia	9.68	11.1		20.0			6.2			
Eucalyptus miniata	12.9	42.6	10.0				12.5		16.7	
Eucalyptus tectifica	9.68	27.8	10.0	10.0		20.0	100.0	40.0	100.0	20.0
Eucalyptus tetrodonta	16.1	64.8	80.0	50.0		40.0	31.2			40.0
Flueggea virosa		1.8						20.0		40.0
Gardenia resinosa	16.1	16.7	40.0				6.2			
Grevillea agrifolia	6.4	25.9	60.0							
Grevillea mimosoides	3.2	20.4	70.0	10.0				20.0		20.0
Grevillea parallela	3.2	16.7							66.7	
Grevillea pteridifolia	12.9	3.7			100.0	40.0				
Grevillea refracta	3.23	22.2		40.0						
Grewia retusifolia									66.7	
Hakea arborescens		3.70					12.5		83.33	20.0
Jasminum didymum										40.0
Owenia vernicosa	19.3	3.70	30.0		100.0					
Persoonia falcata	19.3	18.5		10.0	100.0					
Petalostigma pubescens	77.4	53.7	70.0				12.5		66.7	
Petalostigma quadriloculare		3.7		10.0						20.0
Phyllanthus reticulatus		1.8	20.0							
Planchonia careya		46.3	70.0	20.0			12.5			
Terminalia canescens	3.2	16.7		10.0			25.0	80.0		
Terminalia grandiflora	9.7	1.8	50.0							
Terminalia latipes	29.0	7.4		20.0						
Wrightia saligna		11.1							33.3	20.0
Total No. of Key Species	**35**	**49**	**19**	**24**	**3**	**6**	**16**	**10**	**20**	**24**

Table 6. Percentage frequency of occurrence of species occurring at 20 percent or more sites within a group.

Within Group 1 60% of the *C. intratropica* was recorded as dead; in Group 2 40% was recorded as dead and in Group 4 22% was recorded as dead. The singleton site (7/1) of Group 5 had a large proportion of seedlings of *C. intratropica* (46% of the total). *C. intratropica* was recorded at one site only in each of groups 6,7 and 9.

Table 7 shows the families for the key species found within each group. The column figures give the number of key species recorded for each family.

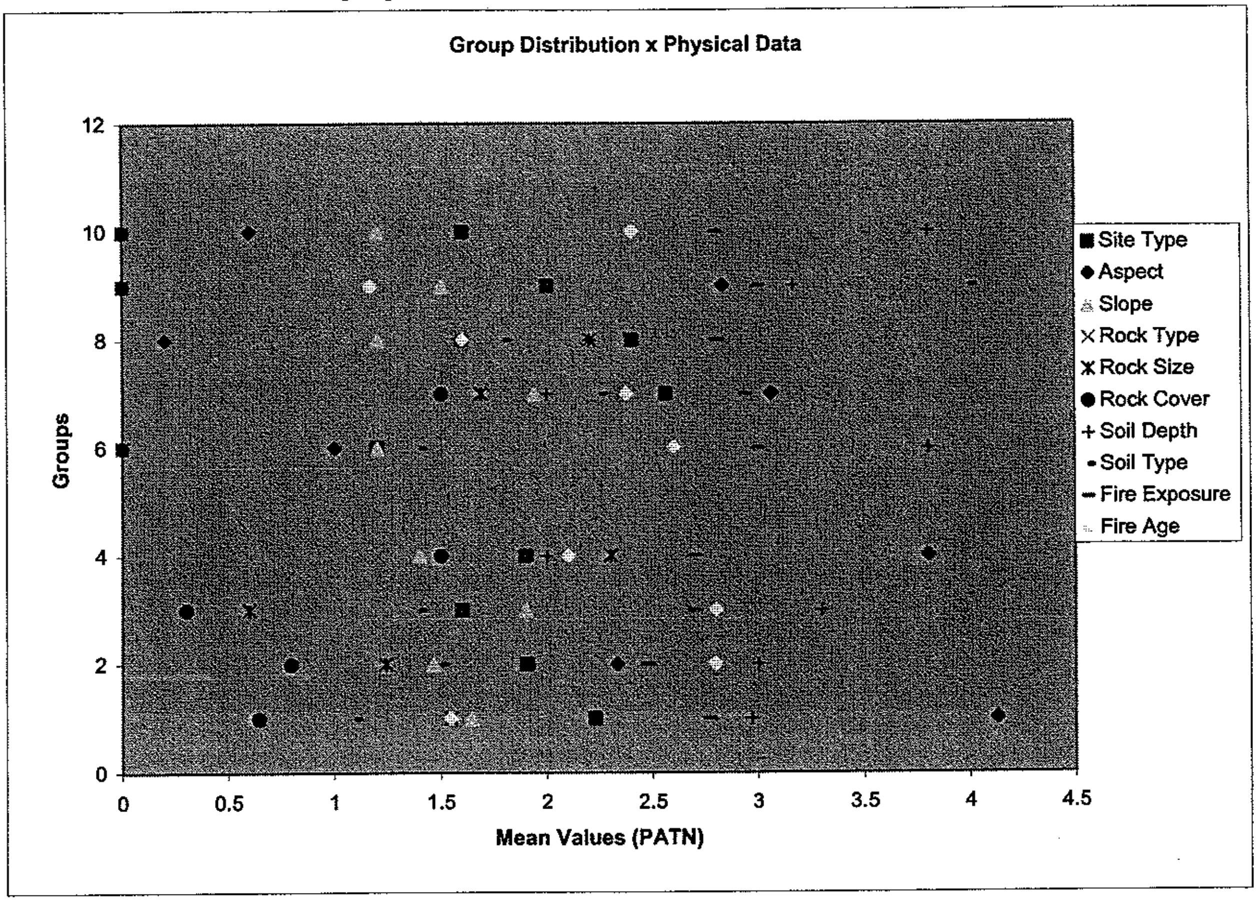
Family	Group									
	1	2	3	4	5	6	7	8	9	10
Cupressaceae	1	1	0	1	1	1	1	0	1	0
Mimosaceae	5	7	3	3	0	1	0	1	7	3
Papilionaceae	1	1	0	0	0	0	1	1	0	1
Sterculiaceae	3	4	1	2	0	0	1	1	0	1
Anacardiaceae	1	1	1	1	0	0	1	0	0	1
Myrtaceae	9	9	4	6	0	3	5	1	2	4
Rubiaceae	2	2	1	1	0	0	1	0	1	0
Bixaceae	1	1	0	1	0	0	1	1	0	0
Caesalpiniaceae	1	2	1	1	0	0	0	1	2	2
Proteaceae	7	6	2	3	2	1	1	1	3	2
Meliaceae	1	0	1	0	1	0	0	0	0	0
Euphorbiaceae	1	4	2	1	0	0	1	1	1	2
Combretaceae	3	3	1	2	0	0	1	1	0	0
Apocynaceae	0	2	0	0	0	0	0	0	2	2
Verbenaceae	0	1	0	0	0	0	0	0	0	1
Sapindaceae	0	1	1	0	0	0	0	0	1	2
Bignoniaceae	0	1	0	1	0	0	1	1	0	1
Lecythidaceae	0	1	1	1	0	0	1	0	0	0
Ulmaceae	0	0	0	0	0	0	0	0	0	1
Oleaceae	0	0	0	0	0	0	0	0	0	1

Table 7. Families for key species found in each group.

The number of families within each group and the families with the greatest number of species are as follow;

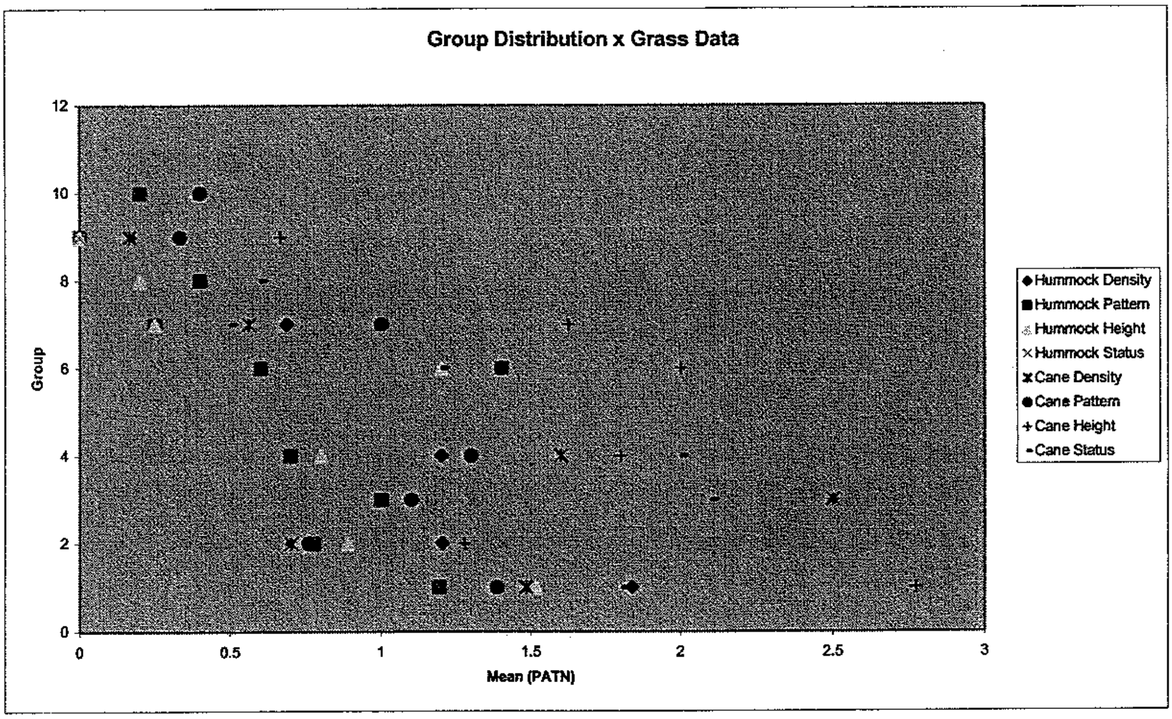
Group 1	13 families, Myrtaceae and Proteaceae;
Group 2	17 families, Myrtaceae and Mimosaceae;
Group 3	12 families, Myrtaceae and Mimosaceae slightly more species than others;
Group 4	13 families, Myrtaceae, Mimosaceae and Proteaceae;
Group 5	3 families;
Group 6	4 families, Myrtaceae;
Group 7	12 families, Myrtaceae;
Group 8	19 families, no family with significantly more species than others;
Group 9	9 families, Mimosaceae;
Group 10	14 families, no family with significantly more species than others.

Graphs 4 and 5 present the mean similarity values from the PATN analysis for the physical and grass fuel characteristics for each of the ten groups



Graph 4. Mean PATN similarity values for the physical characteristics for each group.

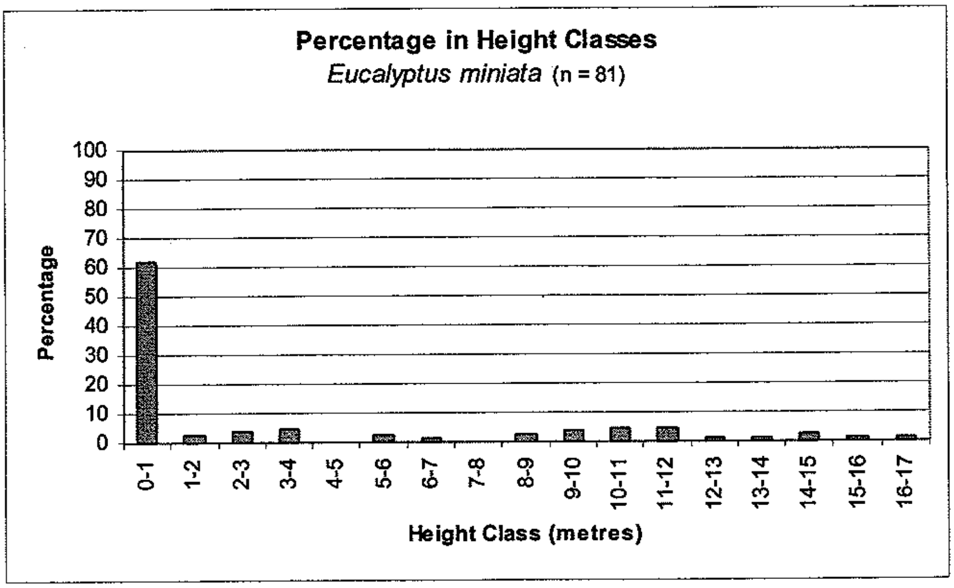
In all comparisons the singleton group 5 (Site 7/1) has been ignored. There is a relatively even spread of groups for site type, the two most dissimilar groups being six and seven. *C. intratropica* is found in both groups. Group six sites are plain locations whereas group seven has a variety of site types but valley locations are dominant. For aspect there appear to be an even spread of groups with groups one and eight being the most dissimilar. *C. intratropica* is found in group one but not in group eight. It is difficult to differentiate the two groups for aspect excepting that group 1 has a wide variety of aspects and group eight has three of the five sites with no aspect. For slope, groups three and seven are most dissimilar to groups six, eight and 10. *C. intratropica* is found in groups six and seven but not in groups three, eight and 10. Sites in groups three and seven are flat (excepting for one site) and sites in groups six, eight and 10 mostly have a gentle slope. For groups six, nine and 10 rocks are not recorded. *C. intratropica* in not found in group 10. Of the remaining groups three and eight are the most dissimilar. *C. intratropica* is not found in either group. Group three is comprised of sites where rocks are mostly absent except for two where laterite is found. Group eight are all granite rock sites. For rock size the two most dissimilar groups are three and four. *C. intratropica* is found in group four but not group three. Group three is comprised of sites where rocks are mostly absent and group four shows an even spread of rock size from stony (2-10 centimetres) to boulders (>50 centimetres). Rock cover once again shows the greatest dissimilarity between groups three and eight. *C. intratropica* is not found in either group. Group eight is different to group three in that it has a rock cover of 0-30 %. The groups most dissimilar for soil depth are groups four and seven from groups six and 10. *C. intratropica* is not found in group 10. Groups four and seven are predominantly shallow soils of less than 10 centimetres whereas groups six and 10 have soils in the categories of 30-45 centimetres and greater than 45 centimetres. Groups one and nine are the most dissimilar for soil type. *C. intratropica* is found in both groups. Group one is comprised solely of sand soils whereas group nine is comprised solely of sandy loam. There appears to be a minimum amount of difference between the groups for fire exposure and it is not possible to identify the differing criteria between the most dissimilar groups. For fire age the most dissimilar groups are groups two and three and group nine. *C. intratropica* is not found in group three. Once again it is not possible to identify the differing criteria between the most dissimilar groups.



Graph 5. Mean PATN similarity values for grass fuel characteristics.

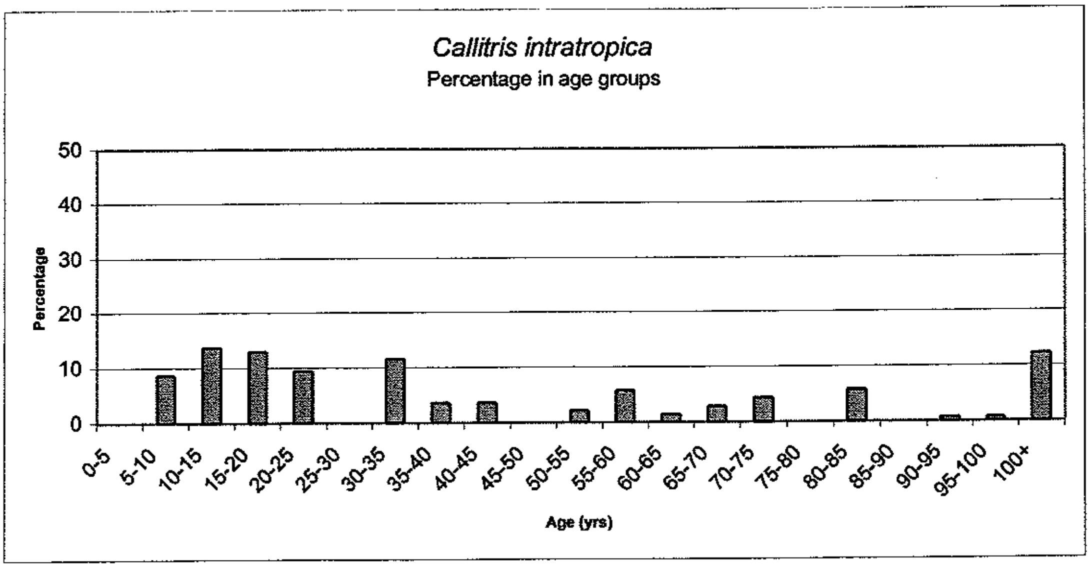
Hummock grass is not recorded within group eight, nine and ten. The greatest dissimilarity for hummock grass density is between group one and group nine. *C. intratropica* is found in group one but not within groups eight and 10. Similar distributions exist for hummock grass pattern, height and status. The dominant density of hummock grass within group one is light to moderate, for pattern it is predominantly uniform, for height the class 0.5-1 metre and status is primarily dominant. The most dissimilar groups for cane grass density are groups three and nine. *C intratropica* is not found in group three. Group three has cane grass density ranging from moderate to very dense. The density within the sites for group nine was mostly absent. For cane grass pattern the most dissimilar sites are within groups six and nine. *C. intratropica* is found in both groups. The reasons for the dissimilarity are not immediately apparent excepting that group six has slightly more patchy cane grass sites than cane grass absent sites than group nine. For cane grass height the main dissimilarity is between group one and groups eight and 10. *C. intratropica* is not found in groups eight and 10. Group one has a cane grass height of primarily 1-2 metres followed by > 2 metres. Groups eight and 10 have cane grass absent to 1-2 metres. For cane grass status the main dissimilarity is between group three and group nine. *C. intratropica* is not found in group three. The cane grass status within group three is co-dominant to dominant whereas within group nine it is primarily absent within the sites.

The condition of the *C. intratropica* across the quadrats is further emphasised when looking at the representation in the various height classes. There is a lack of numbers of plants in the smaller height classes that indicates a lack of replenishment stock. By way of comparison Graph 6 shows the height structure for *Eucalyptus miniata*.

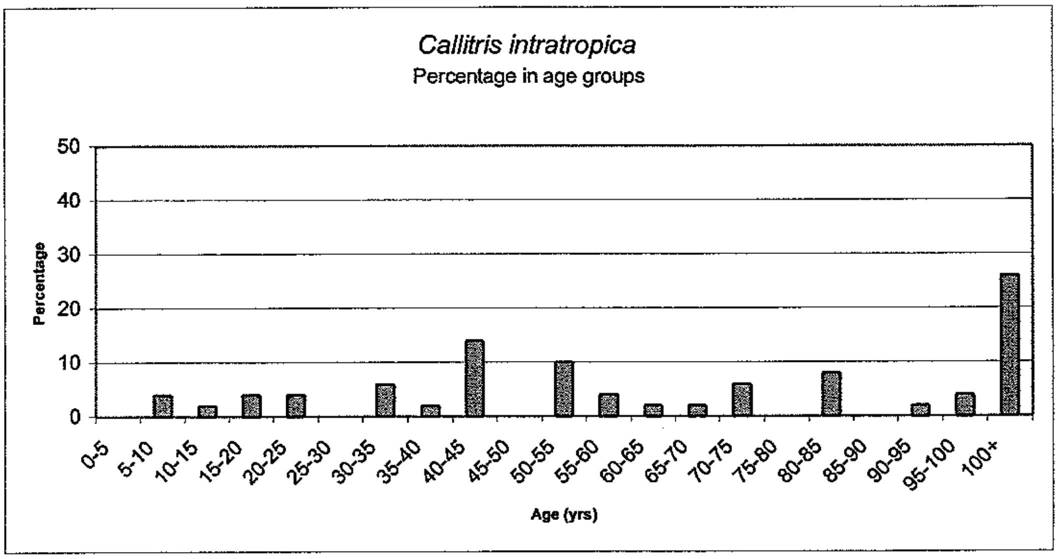


Graph 6: Percentages of Eucalyptus miniata *found in each height class.*

Using the data obtained for the height and DBH records a direct application of the DBH/age relationship determined for Hammer (1981) gives an approximate age structure of the plants measured during the project. This age structure gives two sets of data one for the "best" growth curve of Hammer and one for his fitted curve [$D = 36.99(1-e^{-0.0144A})$ where D is diameter in centimetres and A is age in years]. Hammer discusses the fitted curve as being the average for the population. This is further subdivided to separate the age classes for live versus dead cypress. In applying this here no differentiation in the growth rates between sites is made. The reality may be that different locations in the landscape may produce different growth rates for *Callitris intratropica*. The results of this assessment are given in Graph 7 for live *Callitris intratropica* and Graph 8 for dead *Callitris intratropica.*



Graph 7. Hammer's fitted (average) age structure for live C. intratropica.



Graph 8. Hammer's fitted (average) age structure for dead C. intratropica.

Tables 8, 9, 10 and 11 show the percentage of particular species found in various growth form classes across all transects for those species where more than 50 individuals were counted. There appears to be four distinct trends in the growth form structures. The results are presented on that basis.

The first trend was for a high percentage of either saplings or re-sprouts and low or very low percentages for other classes.

Species	**Seedling**	**Re-sprout**	**Sapling**	**Mature**	**Dead**
Acacia dictyophleba	0.00	**97.60**	0.80	1.20	0.40
Acacia difficilis	1.16	5.20	**89.02**	4.62	0.00
Acacia neurocarpa	0.79	3.94	**92.13**	3.15	0.00
Acacia retinervis	0.00	8.99	**82.01**	8.47	0.53
Acacia stigmatophylla	0.00	2.47	**81.48**	16.05	0.00
Acacia tumida	2.07	16.07	**75.84**	5.72	0.30
Dodonaea physocarpa	0.19	**97.51**	0.00	2.30	0.00
Eucalyptus bigalerita	10.38	**77.36**	12.26	0.00	0.00
Eucalyptus tetrodonta	0.97	**81.18**	8.81	8.41	0.63
Grevillea mimosoides	0.00	36.17	**53.19**	10.64	0.00
Grewia retusifolia	0.00	**100.00**	0.00	0.00	0.00
Melaleuca nervosa	0.00	**99.64**	0.00	0.36	0.00

Table 8. Species showing a trend for high percentages of either saplings or re- sprouts.

The second trend was for a high percentage of re-sprouts, a much-reduced percentage of saplings and a higher percentage of mature plants.

Species	**Seedling**	**Re-sprout**	**Sapling**	**Mature**	**Dead**
Acacia nupperima	0.00	**39.39**	6.67	**47.88**	6.06
Bauhinia cunninghamii	0.74	**69.63**	13.33	**16.30**	0.00
Bossiaea bossiaeoides	1.72	**45.79**	13.48	**36.65**	2.35
Brachychiton diversifolius	0.00	**44.44**	22.22	**31.48**	1.85
Calytrix achaeta	0.00	**50.29**	6.94	**36.42**	6.36
Carissa lanceolata	0.00	**72.09**	13.02	**14.42**	0.47
Distichostemon hispidulus	0.00	**74.03**	10.50	**15.47**	0.00

Erythrophleum chlorostachys	1.64	**81.93**	6.78	**9.24**	0.41
Eucalyptus collina	2.27	**61.36**	13.64	**22.73**	0.00
Eucalyptus grandifolia	4.35	**66.67**	11.59	**17.39**	0.00
Eucalyptus miniata	2.24	**54.48**	11.19	**30.60**	1.49
Gardenia resinosa	0.00	**55.70**	11.39	**31.65**	1.27
Grevillea parallela	1.10	**65.93**	14.29	**16.48**	2.20
Grevillea striata	0.00	**78.85**	7.69	**13.46**	0.00
Petalostigma pubescens	1.12	**50.40**	10.24	**36.32**	1.92
Terminalia canescens	0.91	**30.91**	9.09	**58.18**	0.91

Table 9. Species showing a trend for high percentages of re- sprouts and mature plants.

The final trend was for a high percentage of re-sprouts, this then steps down to a lower percentage of saplings and a lower percentage of mature plants.

Species	**Seedling**	**Re-sprout**	**Sapling**	**Mature**	**Dead**
Acacia platycarpa	0.46	**74.77**	22.48	2.29	0.00
Buchanania obovata	2.16	**51.72**	30.60	15.52	0.00
Canthium sp. A.	3.94	**76.31**	16.93	2.74	0.08
Erythroxylum ellipticum	2.44	**70.73**	14.63	10.57	1.63
Grevillea agrifolia	4.44	**51.78**	32.54	10.95	0.30
Grevillea refracta	0.00	**75.91**	15.33	8.76	0.00
Melaleuca viridiflora	0.00	**82.02**	12.41	4.73	0.84
Owenia vernicosa	0.00	**59.70**	25.37	14.93	0.00
Phyllanthus reticulatus	0.00	**52.31**	27.69	20.00	0.00
Planchonia careya	0.00	**70.94**	18.72	10.34	0.00
Stenocarpus acacioides	0.00	**81.54**	10.77	4.62	3.08

Table 10. Species showing a trend for gradually reducing percentages from a high percentage for re-sprouts.

Finally there were a number of species that did not fit any of the trends. This data is presented in Table 11.

Species	**Seedling**	**Re-sprout**	**Sapling**	**Mature**	**Dead**
Acacia humifusa	16.44	6.85	**43.84**	13.70	19.18
Cajanus pubescens	0.00	0.00	0.00	**100.00**	0.00
Callitris intratropica	10.85	0.39	7.17	31.20	**50.39**
Cochlospermum fraseri	0.00	15.73	8.99	**74.16**	1.12
Eucalyptus tectifica	29.44	**34.75**	6.07	27.31	2.43
Terminalia grandiflora	0.00	10.53	26.32	**53.95**	9.21

Table 11. Species not fitting any particular trend in growth percentages.

PATN.

In testing for physical differences between species groups it may not be showing significant differences because of something that has happened over time rather than what is obvious on the day.

Based on the finding that the PATN analysis did not find a strong correlation for the differences between sites based on either fire history obvious on the day of observation or fire protection afforded by the site it may well be that this snapshot view has not been successful. What is being looked at is an accumulated change due to a regime over time.

Further analysis of, primarily, the age class structure components of the vegetation and an assessment of the status of the population based on that, has the potential to be developed in a management tool for land managers. By this the model is that a land manager could establish a quadrat, and without necessarily knowing the species within the quadrat, undertake an assessment by recording basic grasses and counting the numbers of plants within various age classes for individual species. (S1, S2 etctera). This could then be used to give an assessment of the status of the plants in terms of available replenishment stock and the future of the quadrat under the current land management regime.

DISCUSSION

Representativeness of Sample Sites.

Sites to be studied were identified in a random manner from selected base camps. The selection of sites constituted a stratified random sample and there is a lot of confidence in the representativeness of the sites selected. These data have general application within the existing and previous distribution of *Callitris intratropica* within the Kimberley region of Western Australia.

It soon became apparent that it is difficult to estimate fire age as fire impacts are soon masked by new growth from one season to the next. This has been commented on by other authors (Craig, 1997). Whilst it is highly unlikely that any of the sites could be considered as long unburnt (a category that was in the original matrix) it is also unlikely that field estimates of age greater than two years are accurate.

The recording of fire age is complicated by the time that records were undertaken. If the model of the landscape being primarily affected by late dry season fires is accepted then the frequency of quadrats affected by fire would be expected to be greater for survey times later in the year. Likewise it is more likely that later records where fire is present will be recorded as being subject to hot recent fires. It is unlikely that satellite imagery is accurate enough to assist in fire history mapping at the scale required to assess particular quadrats. Satellite imaging may provide assistance, however, in determining the types of landscape most likely to have been or be affected by a particular type of fire.

The reason behind why two grass 'types' in particular have been focussed on are as a result of observations concerning the apparent spread and increase in dominance of cane grass (annual *Sorghum sp.*). The speculation is that due to an increase in the frequency of intense, large fires (usually associated with the end of the dry season) and the concomitant reduction in the amount of burning during the cooler times of the year (wet season and early dry season burning) the cane grass has become favoured over existing grass types, particularly hummock grass assemblages both annual and perennial species. This change would result in a change of fuel loads and flammability with associated eventual changes to the structure of the understorey and potentially a change in the overstory because of increased fire impacts.

The results concerning cane grass appear to indicate that there is a higher frequency of this grass on sites where cypress is not present. It would be of interest to focus on cypress stands of varying 'health' to determine whether there is a trend in the presence of cane grass for they various stands. As mentioned previously the quadrats were selected from a landscape where *C. intratropica* was either present nearby or likely to have been present. On that basis it may be that the higher incidence of cane grass in quadrats not recording *C. intratropica* has resulted in the loss of the plant from that location. There are several locations on the Gibb River Road that appear to support this.

There is some degree of subjectivity in the recording of grass types particularly for 'other' grasses. It is considered, however, that the categories are robust enough to pick up any clear trends.

Obviously one of the factors determining the number of quadrats where grasses were recorded has to do with recent fires. There would be a change in the recordings of grasses toward the end of the dry season because of the increased occurrence of fire in the landscape. At the end of the dry season large tracts of the Kimberley landscape have been affected by extensive, 'hot' fires meaning that grasses would not be present.

Cypress

The results show that *C. intratropica* is very common within the study area with it being recorded at 83 out of 143 sites. This is worthy of note given that the actual quadrat selection had a high degree of randomness. Given that its status is believed to have deteriorated then this plant would have been even more common and widespread in the past. Under the current fire regime the fate of *C. intratropica*, and the communities that it is, or was, a component, is cause for concern. In the areas studied it is unlikely that fire free conditions would be sustained long enough for *C. intratropica* to be able to establish it own understorey fire fuel characteristics (Bowman, Wilson and Davis, 1988) *C. intratropica* is very fire sensitive at the seedling and saplings stage, requires at least 12 years before it is mature, has a limited seed dispersal from the parent tree and has a short term of seed viability. Given these factors the re-introduction of the species to areas it was present is difficult to imagine given the current fire conditions.

The dominant type of quadrat found in this survey conformed to the general descriptions of the Kimberley Plateau. The use of the term 'deep' soils in the survey is a local description when compared to the soils of other regions, in that Kimberley soils are generally described as skeletal and shallow. The fact that all the quadrats where *C. intratropica* was found were primarily shallow soils is of particular interest. This would open up the line of enquiry as to whether this soil of this depth has different growing conditions to other locations and whether the conditions are affecting cypress or other species. For example are the shallow soils consistently found in a topography that affords protection from grass establishment or perhaps there may be different soil moisture dynamics and productivity for these soils that affects the establishment of grasses. Further work is required to differentiate sites for the presence or absence of *C. intratropica* based on other physical characteristics.

Some authors have stated that the biota of Northern Australia is still relatively intact since colonisation. This could be certainly argued to be the case when compared to large areas of southern Australia. What should not be dismissed however is that there may well have been a significant change in the occurrence of a variety of species across the landscape at the community level. With the recognition of the changed fire regime that has taken place this change in the landscape would still be occurring.

Around 50% of all the *C. intratropica* plants counted were dead. For some quadrats this was 100% of all the plants found on the quadrat. This high percentage accords with reports by other authors where it has been considered that high intensity and high frequency fires have been causing the loss of the species from the landscape. The low percentage within the re-sprout category is in keeping with the fire sensitive nature of the species where all but the lowest in intensity of fires cause the death of most plants.

Bowman and Panton (1993) placed *C. intratropica* stands studied in the Northern Territory into four groups depending upon the broad growth structure identified. These were;

Group I.
Verge of local extinction – stands with very few living stems and many dead trees.
Group II.
Depressed – stands with few young or mature trees and a large number of dead trees.
Group III.
Healthy – stands with large numbers of young and mature trees.
Group IV.
Locked – stands with few mature trees and a very large number of young trees.

A comparison of this grouping with the records for the 83 quadrats where *C. intratropica* was recorded showed that in the broadest context approximately 52% of the sites were in the depressed category, 42% were on the verge of local extinction and only 6% could be considered as healthy. There were no 'locked' stands.

From graph 5 and graph 6 it is apparent that a greater proportion of older plants are within the dead as compared to the live grouping. This is likely to be a function of the plant remaining in the landscape after it has been killed. Smaller plants, such as saplings, are likely to be quickly removed from the landscape either as a result of the fire that causes their death or by subsequent fires. The height and bulk of the larger trees are likely to give them some resistance to subsequent fires.

If it is assumed that Hammer's modelling is applicable to the Kimberley then a great proportion of the existing live plants are in the age groups from 5 to 25 years.

It is to be emphasized that the direct application of Hammer's modelling needs to be viewed with caution and may well be indicative only. It is clear that there are a range of parameters that affect the growth form and rates of *C. intratropica*. These include climatic effects, such as rainfall, location in the landscape, depth of soil, fire history and soil moisture dynamics. The measuring of growth rings may be subject to significant error.

For the most part the disturbance that led to the re-sprouting of a plant in the quadrats was the impact of fire however in certain locations the impact of stock grazing and trampling should not be dismissed.

There has been a significant reduction in the distribution of *Callitris intratropica* as a component of the savannah landscape. There is evidence that the removal of the plant from the landscape became more rapid after the 1960's. For example at a number of locations where Western Australian Herbarium collections were made in the 1970's no evidence of *C. intratropica* can be found at those locations nor in the vicinity. Further study of the trend of loss of *C. intratropica* is warranted.

It is suggested that under current land management regimes operating at the landscape scale there will be further substantial removal of this species over the next 10 to 15 years. In many places the evidence for the existence of *C. intratropica* is the presence of large numbers of dead trees. Whilst the plant remains for a long period of time after it has been killed by fire, eventually it is lost.

The reproductive methods of the plant would suggest that it is extremely difficult for it to be re-introduced to an area under current regime of disturbance factors. The seed is not distributed far from the base of parent trees and parent trees are becoming less and less prevalent in the landscape. This is also coupled to the low seed viability and highly fire sensitive nature of the plant..

A number of other 'common' bush and tree species appear to be of concern with respect to their continued presence in the landscape under the current management regimes. Looking at the structure of the population of the species can generally assess the level of fragility of the population. Generally those species that are exhibiting high numbers of seedlings in a population and where mature plants are in low numbers or are not present there is a reason for concern.

Where there are low numbers of seedlings but high numbers of resprouts and low numbers of mature plants or mature plants are absent then there is less concern until all the root stock supporting the resprouting process are lost. This latter process is a potentially long term process as the resources stored within the root stock are gradually depleted. Several locations located during the study where species considered fire tolerant are to be found could be studied to assess the extent of this process. The species involved are predominantly eucalyptus species.

There are indications that the 'health' in the structure of a community can be used to determine the 'health' in what is happening to the total community.

BIBLIOGRAPHY

(Presentation is as per Pitson, John. *Style Manual for Authors, Editors and Printers of Australian Government Publications*. 3rd edn. Australian Government Publishing Service, Canberra. (1978))

Anon. *Country in Flames - Proceeding of the 1994 symposium on biodiversity and fire in North Australia, Darwin, Northern Territory.* Department of the Environment, Sport and Territories and the North Australia Research Unit, The Australian National University. (1994)

Baird, A.M. *The Life History of Callitris.* Phytomorphology – Vol. 3, No.3 (1953)

Bowman, D. M. J. S. *Response of* Eucalyptus *Forest and Woodland to Four Fire Regimes at Munmarlary, Northern Territory, Australia.* Journal of Ecology 76. pp. 215-232. (1988)

Bowman, D. M. J. S. & Fensham R. J. *Response of a monsoon forest-savanna boundary to fire protection, Weipa, northern Australia.* Australian Journal of Ecology 16. pp. 111-118. (1991)

Bowman, D. M. J. S. & Harris S. *Conifers of Australia's Dry Forests and Open Woodlands.* Ecology of the Southern Conifers. N. J. Enright and R. S. Hill, Melbourne University Press. pp. 252-270. (1995)

Bowman, D.M.J.S. & Latz, P.K. *Ecology of* Callitris glaucophylla *(Cupressaceae) on the MacDonnell Ranges Central Australia.* Aust. J. Bot. Vol 41 (1993)

Bowman, D. M. J. S. & Panton W. J. *Decline of* Callitris intratropica *R.T. Baker & H.G. Smith in the Northern Territory: implications for pre- and post-European colonization fire regimes.* Journal of Biogeography 20. pp. 373-381. (1993)

Bowman, D. M. J. S. & Panton W. J. *Munmarlary revisited: Response of a north Australian* Eucalyptus tetrodonta *savanna protected from fire for 20 years.* Australian Journal of Ecology 20. pp. 526-531. (1995)

Bowman, D. M. J. S. & Wilson B. A. *Fuel characteristics of coastal monsoon forests, Northern Territory, Australia.* Journal of Biogeography 15. pp. 807-817. (1988)

Bowman, D. M. J. S., Wilson B. A., et al. *Response of* Callitris intratropica *R.T. Baker & H.G. Smith to fire protection, Murgenella, Northern Australia.* Australian Journal of Ecology 13. pp. 147-159. (1988)

Braithwaite, R. W. & Estbergs J. A. *Fire Patterns and Woody Vegetation Trends in the Alligator Rivers Region of Northern Australia.* Ecology and Management of the Worlds Savannas. J. C. Tothill and J. J. Mott. Canberra, Australian Academy of Science.

Craig, A. B. *A review of information on the effects of fire in relation to the management of rangelands in the Kimberley high-rainfall zone.* Tropical Grasslands 31: 161-187. (1997)

Easton, R. *Report on the North Kimberley District of W.A.* Forests Department. (1922)

Gill, A. M., Moore P. H. R., et al. *Fire weather in the wet-dry tropics of the World Heritage Kakadu National Park, Australia.* Australian Journal of Ecology 21. pp. 302-308. (1996)

Ginsberg, J. R. *Perspectives on Wildfire in the Humid Tropics.* Conservation Biology 12(5). pp. 942-943. (1998)

Hammer, G. L. *Site classification and tree diameter-height-age relationships for cypress pine in the Top End of the Northern Territory.* Australian Forestry 44(1). Pp. 35-41. (1981)

Head, L. & O'Neil A., et al. *A Comparison of Aboriginal and Pastoral Fires in the North-West Northern Territory.* Conservation and Development in North Australia. I. Moffatt and A. Webb, NARU.

Lacey, C.J. *Factors influencing occurrence of white cypress pine regeneration in New South Wales.* Technical Paper 21 – Forestry Commission N.S.W.

Munsell. *Soil Colour Charts*. GretagMacbeth New York. (1994)

O'Neill, A. L. & Head L. M., et al. *Integrating remote sensing and spatial analysis techniques to compart Aboriginal and pastoral fire patterns in the East Kimberley, Australia.* Applied Geography 13. pp. 67-85. (1993)

Price, O. & Bowman D. M. J. S. *Fire-stick forestry: a matrix model in support of skilful fire management of* Callitris intratropica *R.T. Baker by north Australian Aborigines.* Journal of Biogeography 21. pp.573-580. (1994)

Russell-Smith, J. *Pre-contact Aboriginal and contemporary fire regimes of the savanna landscapes of northern Australia: patterns, changes and ecological responses.* Unpubl.

Russell-Smith, J., Lucas, D., Gapindi, M., Gunbunuka, B., Kapirigi, N., Namingum, G., Lucas, K., Giuliana, P., & Chaloupka, G. *Aboriginal resource utilization and fire management practice in western Arnhem Land, monsoonal northern Australia: notes for prehistory and lessons for the future.* Human Ecology 25. pp. 159-195. (1997)

Russell-Smith, J. and Ryan P. *Establishing a photo-point monitoring system in Kakadu National Park: rationale and protocol.* Kakadu National Park: 6.

Russell-Smith, J.& Ryan P. G., et al. *A Landsat MSS-Derived Fire History of Kakadu National Park, Monsoonal Northern Australia, 1980-1994: Seasonal Extent, Frequency and Patchiness.* Journal of Applied Ecology. (1995)

Russell-Smith, J. & Ryan P. G., et al. *Fire regimes, fire-sensitive vegetation, and fire management of the sandstone Arnhem Plateau, monsoonal northern Australia.* Journal of Applied Ecology. (1998)

Saint, P. & Russell-Smith, J. Eds. *Malgarra: Burning the Bush. Report of the Fourth North Australia Fire Manager's Workshop, Kalmuburu WA, June 1997.* Bush Fire Service WA, WA Lotteries Commission, Cooperative Research Centre for Tropical Savannas. (1998)

Stocker, G. C. *Aspects of the Seeding Habits of* Callitris Intratropica. Commonwealth of Australia, Department of National Development, Forest Research Institute (Leaflet No. 97). (1966)

Stocker, G. C. & Mott, J.J. *Fire in the tropical forests and woodlands of northern Australia.* Fire and the Australian Biota. A. M. Gill, Australian Academy of Science. pp. 425-439. (1981)

Thackway, R. & Cresswell, I.D. Eds. *Toward An Interim Biogeographic Regionalisation For Australia: A Framework For Setting Priorities In The National Reserves System Cooperative Program.* Proceedings of a technical meeting held in Adelaide at the South Australian Department of Environment and Natural Resources between 7 – 11 February 1994.

Williams, R. J. & Cook G. D., et al. *Torch, trees, teeth and tussocks: disturbance in the tropical savannas of the Northern Territory (Australia), Disturbance in the tropical savannas of the Northern Territory.* Chapter 5 (2000)

Williams, R.J., Gill, A.M. & Moore, P.H.R. *Seasonal changes in fire behaviour in a tropical savanna in northern Australia.* International Journal of Wildland Fire, 8, pp. 227-239. (1998)

Vigilante, T. *An assessment of the effects of fire regime on plant species, plant communities and indigenous natural resources around Kalumburu, North Kimberley, Western Australia.* Centre for Indigenous Natural and Cultural Resource Management and Cooperative Research Centre for the Sustainable Development of Tropical Savannas. Darwin, Northern Territory University. (1998)

APPENDICES

Appendix 1

Munsell Soil Colour Chart Records.

site/quad	soil colour	site/quad	soil colour	site/quad	soil colour
1/1	pale yellow	13/1	dark brown-orange brown	26/3	Brown 7.5YR 5/3
1/2	pale yellow	13/2	dark brown-orange brown	27/1	Olive 5Y 4/4
1/3	pale yellow	13/3	yellow brown	27/2	Olive 5Y 4/4
1/4	pale yellow	14/1	pale brown	27/3	Olive Brown 2.5Y 4/4
1/5	pale yellow	14/2	brown	28/1	Yellowish Red 5YR 5/6
2/1	pale brown	14/3	brown	28/2	Light Yellowish Brown 2.5Y 6/3
2/2	pale brown	15/1	orange/brown	28/3	Brownish Yellow 10YR 6/6
2/3	pale brown	15/2	orange/brown	29/1	Strong Brown 7.5 YR 5/6
3/1	orange/red	15/3	red	29/2	Red 2.5 YR 5/6
3/2	yellow/orange	16/1	Light yellowish-brown 2.5Y 6/4	29/3	Red 2.5 YR 5/6
3/3	pale orange	16/2	Olive yellow 2.5Y 6/6	30/1	Greyish Brown 10 YR 5/2
3/4	orange	16/3	Olive yellow 2.5Y 6/6	30/2	Olive 5Y 5/3
4/1	brown	17/1	Reddish brown 5YR 4/4	30/3	Pinkish White 5YR 5/2
4/2	brown	17/2	Reddish brown 5YR 4/3	31/1	Light Yellowish Brown 2.5 Y 6/4
4/3	orange/brown	17/3	Reddish brown 5YR 4/3	31/2	Dark Reddish Grey 5 YR 4/2
4/4	pale yellow/brown	18/1	Brown 7.5YR 5/4	31/3	Yellowish Brown 10 YR 5/4
5/1	pale cream	18/2	Yellowish brown 10YR 5/4	32/1	Not Recorded
5/2	pale cream	18/3	Greyish brown 2.5Y 5/2	32/2	Not Recorded
5/3	pale brown	19/1	Reddish yellow 5YR 6/8	32/3	Not Recorded
5/4	pale cream/brown	19/2	Reddish yellow 5YR 6/8	33/1	Not Recorded
6/1	yellow/orange	19/3	Reddish yellow 5YR 6/8	33/2	Not Recorded
6/2	pale orange	20/1	Reddish yellow 7.5 YR 7/6	33/3	Not Recorded
6/3	yellow/brown	20/2	Reddish yellow 7.5 YR 7/6	34/1	Not Recorded
7/1	orange/red	20/3	Reddish yellow 7.5 YR 7/6	34/2	Not Recorded
7/2	red	21/1	Yellowish red 5YR 4/6	34/3	Not Recorded
7/3	red	21/2	Red 2.5YR 4/8	35/1	Not Recorded
8/1	red-brown	21/3	Red 2.5YR 4/8	35/2	Not Recorded
8/2	red-brown	22/1	Dark Reddish Brown 5YR 3/3	36/1	Not Recorded
8/3	red	22/2	Dark Reddish Brown 5YR 3/3	36/2	Not Recorded
9/1	red-brown	22/3	Reddish Brown 5YR 4/4	36/3	Not Recorded
9/2	red-brown	23/1	Light Olive Brown 2.5 Y 5/4	37/1	Not Recorded
9/3	red-brown	23/2	Light Brownish Grey 2.5 Y 6/2	37/2	Not Recorded
10/1	grey	23/3	Light Brownish Grey 2.5 Y 6/2	37/3	Not Recorded
10/2	grey	24/1	Reddish Grey 10R 6/1	38/1	Not Recorded
10/3	grey	24/2	Light Yellowish Brown 10YR 6/4	38/2	Not Recorded
11/1	light brown	24/3	Light Yellowish Brown 10YR 6/4	38/3	Not Recorded
11/2	light brown-pale	25/1	Light Olive Brown 2.5Y 5/6	39/1	Pale Yellow 2.5YR 7/4
11/3	light brown-pale	25/2	Yellowish Brown 10Y 5/6	39/2	Pale Yellow 2.5YR 7/4
12/1	pale brown	25/3	Yellowish Brown 10Y 5/6	39/3	Pale Yellow 2.5YR 7/4
12/2	pale brown	26/1	Brown 7.5YR 5/2	40/1	Brown 10YR 4/3

12/3	pale brown	26/2	Brown 7.5YR 5/3	40/2	Dark Grayish Brown 10YR 4/2
41/1	Pale Yellow 2.5 YR	43/3	Yellowish Brown 10 YR 5/4	Y/1/2	Brown 5/3
41/2	Pale Yellow 2.5 YR	44/1	Brown 10 YR 5/3	Y/1/3	Brown 5/3
41/3	Pale Yellow 2.5 YR	44/2	Light Brown 7.5 YR 6/4	Y/2/1	Gray 6/1
42/1	Light Red 2.5 YR	44/3	Pale Brown 10 YR 6/3	Y/2/2	Gray 6/1
42/2	Red 2.5 YR 5/8	45/1	Very Pale Brown 10 YR 7/3		
42/3	Red 2.5 YR 5/8	45/2	Very Pale Brown 10YR 7/3		
43/1	Yellowish Brown	45/3	Very Pale Brown 10 YR 7/3		
43/2	Yellowish Brown	Y/1/1	Red 5/8		

Appendix 2 – Flora Species Recorded

The following is a list of all species identified during the project along with the total number of plants counted within each species (in brackets [ ]), total number of quadrats where the species was recorded (in parentheses ( )) and a list of quadrats where they were recorded.

Cupressaceae

Callitris intratropica R. T. Baker & H. G. Sm. **Arnhem Cypress Pine**

[516] (83) 1/1, 1/2, 1/3, 1/4, 1/5, 2/1, 2/2, 3/1, 3/2, 3/3, 3/4, 4/1, 4/2, 4/3, 4/4, 5/1, 5/2, 5/3, 5/4, 7/1,13/1, 13/2, 13/3, 14/1, 14/2, 15/1, 15/3, 16/1, 16/2, 17/1, 17/2, 18/1, 18/2, 18/3, 19/1, 19/2, 19/3, 20/1, 20/2, 20/3, 23/1, 24/1, 24/2, 24/3, 25/1, 25/2, 25/3, 26/1, 28/1, 29/1, 29/2, 29/3, 30/1, 30/3, 31/1, 31/2, 32/1, 32/2, 32/3, 33/1, 34/1, 34/3, 35/1, 35/2, 36/1, 37/1, 38/1, 38/2, 38/3, 39/1, 39/2, 41/1, 41/2, 41/3, 42/1, 42/2, Y/1/1, Y/1/2, Y/1/3, Y/2/1, Y/2/2.

Ulmaceae

Celtis philippensis Blanco

[1] (1) 40/1

Moraceae

Ficus opposita Miq. **Sandpaper Fig**

[2] (1) 2/2

Tiliaceae

Grewia retusifolia Kurz

[76] (4) 21/3, 26/1, 26/2, 26/3.

Sterculiaceae

Brachychiton diversifolius R. Br. **Northern Kurrajong**

[54] (22) 4/3, 4/4, 5/1, 5/2, 8/1, 8/2, 9/1, 19/3, 20/1, 20/2, 20/3, 22/1, 22/2, 22/3, 27/3, 31/1, 31/2, 33/1, 40/1, 40/2, Y/1/2, Y/1/3.

Brachychiton tuberculatus Guymer **Largeleaf Kurrajong** (Priority 3)

[39] (7) 41/1, 41/2, 41/3, 42/2, 42/3, 43/2, 43/3.

Brachychiton viridiflorus Guymer (Previously *Sterculia viridiflora*)

[48] (17) 4/3, 4/4, 5/1, 5/2, 5/3, 5/4, 13/1, 14/2, 15/1, 15/2, 15/3 20/1, 20/2, 20/3, 29/2, 35/2, 38/1.

Brachychiton viscidulus Guymer (Previously *Sterculia viscidula*)

[19] (5) 12/3, 14/2, 32/1, 32/2, Y/1/3.

Lecythidaceae

Planchonia careya Kunth **Cocky Apple, Mangaloo** (Previously *P. australis*)

[344] (36) 6/1, 6/2, 7/3, 13/1, 16/3, 25/1, 28/2, 28/3, 30/2, 30/3, 31/1, 31/2, 32/1, 32/2, 32/3, 33/1, 33/2, 33/3, 34/1, 34/2, 34/3, 35/1, 35/2, 37/1, 39/1, 39/2, 41/1, 41/2, 41/3, 42/1, 42/3, 43/1, 43/3, 45/2, 45/3, Y/2/1.

Bixaceae

Cochlospermum fraseri Planch. **Kapok Tree, Cotton Tree**

[88] (17) 8/2, 9/1, 9/2, 9/3, 12/1, 12/2, 12/3, 13/1, 13/2, 13/3, 14/1, 14/2, 14/3, 15/2, 29/2, 31/1, 31/2.

Mimosaceae

Acacia acradenia F. Muell.

[2] (1) 45/1.

Acacia colei Maslin & L. Thomson

[48] (6) 21/1, 21/2, 21/3, 30/2, 30/3, 37/3.

Acacia dictyophleba F. Muell.

[250] (5) 36/1, 37/1, 38/3, 40/2, 41/1.

Acacia difficilis Maiden

[173] (8) 13/1, 13/2, 15/3, 21/2, 21/3, 41/3, 42/1, 42/3.

Acacia dunnii Turrill **Dunn's Wattle, Elephant Ear Wattle**

[3] (1) 32/3.

Acacia hemignosta F. Muell. **Club-leaf Wattle**
[6] (2) 21/2, 22/2.
Acacia humifusa A. Cunn. Ex Benth.
[73] (9) 4/1, 4/2, 5/1, 5/2, 5/3, 17/1, 17/2, 17/3, 38/3.
Acacia humilis ms
[7] (1) 18/3.
Acacia kelleri F. Muell.
[1] (1) 39/1.
Acacia leptophleba F. Muell.
[1] (1) 42/2.
Acacia multisiliqua Maconochie
[16] (4) 18/2, 18/3, 23/1, Y/2/2.
Acacia neurocarpa A. Cunn. ex Hook. (Previously *A. pellita* Kimb Flora)
[126] (6) 21/2, 21/3, 45/3, Y/1/1, Y/2/1, Y/2/2.
Acacia nupperima Baker
[165] (9) 17/1, 17/2, 17/3, 32/1, 32/2, 34/1, 34/2, 34/3, 39/1.
Acacia pellita O. Schwarz
[5] (1) 45/2.
Acacia platycarpa F. Muell. **Ghost Wattle**
[238] (23) 3/2, 13/1, 13/2, 14/1, 14/3, 15/1, 15/2, 16/1, 16/2, 34/1, 34/3, 34/3, 35/2, 36/1, 36/2, 37/1, 37/2, 38/1, 39/1, 39/2, 41/3, 42/1, 42/2.
Acacia plectocarpa A. Cunn. Ex Benth. (Subspecies plectocarpa previously known as *A. numerosa*)
[14] (5) 18/1, 18/2, 18/3, Y/2/1, Y/2/2.
Acacia retinervis Benth.
[189] (4) 42/2, 43/1, 43/2, 43/3.
Acacia retivenea F. Muell.
[6] (2) 10/1, 21/3.
Acacia sericata A. Cunn. Ex Benth. (Priority 3)
[8] (3) 4/2, 21/1, 21/3.
Acacia stigmatophylla A. Cunn. Ex Benth.
[81] (8) 9/3, 17/3, 29/2, 38/3, 39/1, 39/2, 39/3, Y/2/1.
Acacia stipuligera F. Muell.
[4] (1) 22/1.
Acacia tumida F. Muell. Ex Benth. **Pindan Wattle**
[1054] (29) 2/1, 2/2, 4/1, 6/3, 7/2, 7/3, 15/1, 15/2, 15/3, 21/3, 24/1, 24/2, 24/3, 25/1, 25/2, 25/3, 29/1, 29/2, 29/3, 30/2, 30/3, 31/1, 31/2, 37/2, Y/1/1, Y/1/2, Y/1/3, Y/2/1, Y/2/2.

Albizia sp.
[1] (1) 10/2.

Caesalpiniaceae

Erythrophleum chlorostachys Baill. **Cooktown Ironwood**
[494] (49) 1/2, 1/3, 1/4, 3/1, 3/2, 3/3, 3/4, 4/1, 4/2, 4/3, 6/1, 6/2, 6/3, 13/2, 13/3, 14/2, 14/3, 16/2, 16/3, 18/1, 18/2, 18/3, 21/3, 22/1, 29/1, 29/2, 29/3, 30/1, 31/1, 32/1, 32/2, 32/3, 33/1, 33/2, 33/3, 35/1, 36/3, 38/1, 38/2, 38/3, 39/1, 41/1, 41/2, 41/3, 45/1, 45/2, 45/3, Y/1/1, Y/2/1.

Bauhinia cunninghamii de Wit. **Beantree, Bauhinia** (Previously *Lysiphyllum cunninghamii*)
[135] (14) 8/3, 10/1, 10/2, 10/3, 12/3, 21/1, 21/2, 21/3, 26/1, 26/2, 26/3, 40/1, 40/2, Y/1/1.

Papilionaceae

Bossiaea bossiaeoides Court

[1104] (46) 1/1, ½, 4/1, 4/2, 4/3, 4/4, 6/1, 14/2, 15/1, 15/3, 17/1, 17/3, 18/1, 18/3, 19/1, 19/2, 20/1, 20/2, 20/3, 24/1, 24/2, 24/3, 25/2, 25/3, 30/1, 30/2, 31/1, 32/1, 32/3, 33/1, 34/1, 34/2, 34/3, 35/1, 35/2, 36/1, 36/2, 37/1, 37/2, 37/3, 38/1, 38/2, 38/3, 39/1, 39/2, 39/3.

Cajanus pubescens Maesen

[220] (3) 12/1, 12/2, 12/3.

Crotalaria cunninghamii R. Br. **Green Birdflower, Parrot Pea**

[6] (1) 40/2.

Jacksonia argentea C. A. Gardner

[1] (1) 29/1.

Jacksonia forrestii F. Muell. **Broombush** (Previously *J. thesioides* Kimb Flora)

[8] (2) 18/3, 37/1.

Proteaceae

Grevillea agrifolia A. Cunn. ex R. Br. **Blue Grevillea**

[341] (22) 18/2, 18/3, 20/3, 24/1, 25/1, 25/2, 25/3, 32/1, 33/1, 33/2, 34/3, 35/1, 36/1, 36/2, 36/3, 37/1, 37/3, 43/2, 45/1, 45/2, 45/3, Y/2/1, Y/2/2.

Grevillea erythroclada W. Fitzg. **Needleleaf Grevillea**

[1] (1) 20/3

Grevillea heliosperma R. Br. **Rock Grevillea**

[30] (2) 36/2, 36/3.

Grevillea mimosoides R. Br.

[49] (22) 9/2, 12/3, 17/2, 17/3, 18/1, 29/2, 31/1, 34/2, 34/3, 36/3, 37/3, 38/1, 38/2, 39/1, 40/1, 41/3, 42/3, 43/1, 43/2, 43/3, 45/2, 45/3.

Grevillea parallela Knight

[90] (14) 15/2, 15/3, 16/1,16/2, 16/3,20/2, 21/2, 26/1, 26/2, 26/3, 29/1, 29/2, 29/3, Y/1/3.

Grevillea pteridifolia Knight **Silky Grevillea, Kimberley Christmas Tree**

[48] (9) 1/1, 2/2, 2/3, 5/1, 5/2, 23/1, 23/2, 30/2, 361.

Grevillea pyramidalis A. Cunn. Ex R. Br. **Caustic Tree**

[15] (5) 15/3, 17/3, 28/3, 37/1, 43/1.

Grevillea refracta R. Br. **Silverleaf Grevillea**

[137] (17) 2/1, 13/1, 13/2, 13/3, 14/1, 32/2, 34/1, 34/2, 34/3, 35/1, 35/2, 36/1, 36/2, 41/1, 41/2, 41/3, Y/2/1.

Grevillea striata R. Br. **Beefwood**

[52] (4) 8/1, 8/2, 9/1, 9/3.

Hakea arborescens R. Br.

[45] (10) 12/2, 21/1, 21/3, 26/1, 26/2, 26/3, 31/3, 39/1, 40/1, Y/1/2.

Persoonia falcata R. Br.

[34] (18) 1/1, 2/3, 3/2, 6/1, 6/2, 7/2, 13/2, 14/2, 15/1, 15/3, 16/1, 16/2, 17/2, 17/3, 18/1, 18/2, 30/1, Y/2/2.

Stenocarpus acacioides F. Muell

[62] (8) 13/2, 28/1, 28/2, 28/3, 29/1, 29/2, 31/1, 39/1.

Stenocarpus cunninghamii R. Br.

[1] (1) 18/2.

Stenocarpus sp.A.

[32] (9) 7/1, 15/1, 152, 162, 16/3, 17/2, Y/1/3, Y/2/2.

Myrtaceae

Calytrix achaeta Benth.

[173] (13) 4/2, 13/2, 14/1, 17/3, 28/2, 28/3, 29/1, 29/2, 33/2, 33/3, 39/1, 39/2, 39/3.

Calytrix brownii Craven (Previously *C. brachychaeta*)

[12] (1) 43/2

Calytrix exstipulata DC. (Previously *C. conferta, C. microphylla*)

[12] (3) 4/4, 18/3, 38/3,

Eucalyptus aspera K. D. Hill & L. A. S. Johnson. **Roughleaf Range Gum**

[28] (5) 22/1, 22/3, 29/1, 29/2, 29/3.

Eucalyptus bigalerita F. Muell. **Northern Salmon Gum**

[106] (3) 20/2, 20/3, 23/1.

Eucalyptus brachyandra F. Muell. **Tropical Red Box**

[1] (1) 39/2.

Eucalyptus cadophora K. D. Hill & L. A. S. Johnson **Twinleaf Bloodwood**

[14] (1) 12/1.

Eucalyptus collina K. D. Hill & L. A. S. Johnson **Silverleaf Box**

[88] (12) 13/1, 13/2, 13/3, 14/1, 14/2, 14/3, 17/2, 17/3, 18/1, 18/2, 18/3, 24/2.

Eucalyptus confertiflora K. D. Hill & L. A. S. Johnson **Roughleaf Cabbage Gum**

[21] (4) 30/1, 31/1, 40/1, 40/2.

Eucalyptus dichromophloia

[23] (7) 3/1, 3/2, 3/3, 3/4, 4/1, 4/2, 4/4.

Eucalyptus ferruginea K. D. Hill & L. A. S. Johnson.

[24] (7) 13/1, 13/3, 15/1, 17/1, 25/1, 25/2, 41/1.

Eucalyptus grandifolia K. D. Hill & L. A. S. Johnson **Largeleaf Cabbage Gum**

[69] (12) 5/2, 5/4, 9/1, 9/2, 13/3, 17/2, 20/1, 29/1, 30/3, 33/1, 36/2, 41/2.

Eucalyptus jensenii Maiden **Wandi Ironbark**

[16] (6) 3/2, 3/4, 21/3, 22/1, 22/2, 22/3.

Eucalyptus latifolia K. D. Hill & L. A. S. Johnson **Roundleaf Bloodwood**

[2] (2) 29/2, 30/3.

Eucalyptus lirata W. Fitzg. Ex Maiden **Kimberley Yellowjacket**

[28] (11) 3/1, 3/2, 3/3, 4/1, 4/2, 15/2, 17/1, 17/2, 17/3, 24/3, 41/1.

Eucalyptus miniata A. Cunn. Ex Schauer **Northern Woollybutt**

[143] (31) 5/1,5/2, 6/1, 6/2, 7/2, 7/3, 11/1, 16/1, 16/3, 21/1, 27/1, 29/1, 30/1, 30/2, 32/1, 32/3, 33/1, 33/2, 34/1, 34/3, 35/1, 35/2, 38/1, 38/3, 39/1, 41/1, 41/2, 41/3, Y/1/2, Y/2/1.

Eucalyptus nesophila K. D. Hill & L. A. S. Johnson. **Melville Island Bloodwood**

[35] (3) 6/2, 7/1, 7/3.

Eucalyptus oligantha Schauer **Broadleaf Box**

[12] (4) 20/1, 20/2, 34/2, 34/3.

Eucalyptus phoenicea F. Muell. **Scarlet Gum**

[11] (6) 1/2, 1/3, 1/4, 1/5, 2/1, 2/2.

Eucalyptus polycarpa K. D. Hill & L. A. S. Johnson **Longfruit Bloodwood**

[12] (3) 2/2, 19/1, 19/3, 31/2, Y2/1, Y/2/2

Eucalyptus tectifica F. Muell. **Darwin Box**

[658] (46) 8/1, 8/2, 8/3, 9/1, 11/1, 11/2, 11/3, 12/1, 12/2, 12/3, 14/1, 14/2, 15/1, 15/2, 15/3, 16/1, 20/3, 21/1, 21/2, 21/3, 22/1, 23/2, 25/1, 25/2, 25/3, 26/1, 26/2, 26/3, 27/1, 27/2, 27/3, 28/1, 28/2, 28/3, 29/2, 31/2, 31/3, 38/3, 39/1, 39/2, 44/2, 45/1, Y/1/1, Y/1/2, Y/1/3, Y/2/1.

Eucalyptus tetrodonta F. Muell. **Darwin Stringybark**

[1761] (63) 3/4, 5/1, 5/3, 5/4, 6/1, 6/2, 6/3, 7/1, 7/2, 7/3, 9/2, 11/1, 11/3, 13/3, 16/1, 16/2, 16/3, 17/2, 17/3, 19/3, 22/1, 22/3, 23/1, 23/2, 23/3, 24/2, 24/3, 25/3, 28/1, 28/2, 29/2, 31/2, 31/3, 32/1, 32/2, 32/3, 33/1, 33/2, 33/3, 34/1, 34/2, 34/3, 35/1, 35/2, 36/1, 37/1, 37/2, 37/3, 38/1, 38/2, 39/1, 39/2, 39/3, 41/1, 41/3, 42/1, 42/2, 42/3, 43/1, 43/2, 45/1, 45/2, 45/3.

Melaleuca minutifolia F. Muell.
[1] (1) 11/2.

Melaleuca nervosa Cheel
[561] (5) 34/2, 34/2, 35/2, 35/2, 45/1.

Melaleuca viridiflora Sol. Ex Gaertn.
[950] (9) 23/1, 23/2, 23/3, 26/3, 44/1, 44/2, 44/3, Y/2/1, Y/2/2.

Verticordia cunninghamii Schauer
[38] (1) 35/1

Combretaceae

Terminalia canescens Radlk. (Previously *T. bursarina.*)
[109] (19) 6/1, 6/2, 8/3, 10/2, 10/3, 12/3, 14/2, 14/3, 15/1, 27/1, 27/3, 28/3, 29/1, 31/1, 31/2, 31/3, Y/1/1, Y/1/2, Y/1/3.

Terminalia grandiflora Benth. **Plumwood, Nutwood**
[76] (9) 5/4, 19/2, 19/3, 29/1, 43/1, 43/2, 43/3, 45/1, 45/2.

Terminalia hadleyana W. Fitzg.
[10] (6) 13/3, 32/1, 39/2, 39/3, Y/1/1, Y/1/3.

Terminalia latipes Benth.
[33] (15) 1/4, 1/5, 2/2, 3/2, 4/1, 4/2, 14/1, 14/2, 14/3, 15/1, 15/2, 18/2, 18/3, 31/1, 33/1.

Opiliaceae

Opilia amentacea Roxb.
[2] (1) 14/1.

Santalaceae

Santalum lanceolatum R. Br. **Plumbush, Plumwood**
[1] (1) 14/1.

Euphorbiaceae

Breynia cernua Muell. Arg.
[2] (2) 26/1, 28/2.

Flueggea virosa F. Voight (Previously *Securinega melanthesoides*)
[39] (5) 10/2, 40/1, 40/2, Y/1/1, Y/1/3.

Glochidion disparipes Airy Shaw
[1] (1) 6/2.

Petalostigma pubescens Domin **Quinine Tree, Quinine Berry**
[846] (66) 1/1, 1/2, 1/3, 2/1, 2/2, 3/1, 3/2, 3/3, 4/1, 4/2, 4/3, 4/4, 5/3, 5/4, 6/1, 6/2, 16/1, 16/2, 16/3, 18/1, 18/2, 18/3, 19/1, 19/2, 19/3, 20/1, 20/2, 20/3, 21/3, 24/3, 25/1, 25/2, 25/3, 26/1, 26/2, 26/3, 29/1, 29/2, 29/3, 30/2, 31/1, 33/2, 34/3, 35/1, 35/2, 36/2, 36/3, 37/1, 37/2, 37/3, 38/1, 38/2, 41/2, 41/3, 42/3, 43/1, 43/2, 43/3, 45/1, Y/1/2, Y/1/3, Y/2/1, Y/2/2.

Petalostigma quadriloculare F. Muell. **Quinine Bush**
[12] (4) 16/1, 22/1, 39/1, 42/2.

Phyllanthus reticulatus Poir.
[64] (3) 33/1, 33/2, 33/3.

Erythroxylaceae

Erythroxylum ellipticum R. Br. ex Benth.
[123] (5) 4/2, 12/1, 18/1, 18/2, 18/3.

Sapindaceae

Atalaya hemiglauca F. Muell ex Benth. **Whitewood**

[46] (2) 40/1, 40/2.

Distichostemon hispidulus Baill.

[181] (8) 33/1, 33/2, 36/1, 37/2, 41/3, 42/3, Y/1/1.

Dodonaea physocarpa F. Muell.

[522] (9) 21/1, 21/2, 21/3, 22/1, 22/2, 22/3, 26/1, 26/2, 26/3,

Anacardiaceae

Buchanania obovata Engl. **Wild Mango**

[242] (46) 3/4, 6/1, 6/2, 6/3, 7/2, 91, 9/3, 13/2, 14/2, 15/1, 15/2, 15/3, 17/2, 18/1, 183, 22/2, 24/1, 25/1, 27/2, 30/1, 31/1, 31/2, 32/3, 33/1, 33/2, 33/3, 34/2, 34/3, 36/1, 36/2, 363, 37/1, 37/3, 38/1, 39/2, 39/3, 40/2, 41/1, 42/3, 43/1, 43/3, 45/1, Y/1/1, Y/1/3, Y/2/1, Y/2/2.

Meliaceae

Melia azedarach L. **White Cedar**

[2] (1) 40/1.

Owenia vernicosa F. Muell. **Emu Apple**

[67] (11) 2/1, 2/2, 2/3, 3/1, 3/2, 3/3,3/4, 39/3, 43/1, 43/2, 43/3, Y/1/1.

Apocynaceae

Carissa lanceolata R. Br. **Conkerberry, Conkleberry**

[205] (9) 21/1, 21/2, 22/2, 26/1, 26/2, 26/3, 29/1, 29/2, 29/3.

Wrightia saligna Benth.

[22] (9) 15/1, 15/2, 15/3, 21/3, 22/1, 26/1, 32/1, 32/2, Y/1/3.

Asclepiadaceae

Marsdenia stenophyllum (Previously *Gymnema stenophyllum*)

[1] (1) 93.

Boraginaceae

Ehretia saligna R. Br. **Coonta, False Cedar**

[2] (2) 6/1, 20/3

Verbenaceae

Clerodendrum floribundum R. Br.

[20] (6) 6/2, 22/1, 22/2, 38/1, 40/1, 40/2.

Premna acuminata R. Br.

[2] (2) 21/3, Y/1/1.

Premna herbacea Roxb.

[2] (1) 19/3

Oleaceae

Jasminum didymum G. Forst

[10] (2) 40/1, 402.

Jasminum molle R. Br.

[18] (1) 16/1

Bignoniaceae

Dolichandrone heterophylla F. Muell. **Lemonwood**

[39] (10) 10/2, 22/1, 22/2, 22/3, 27/1, 27/2, 27/3, 29/1, 42/2, Y/1/1.

Rubiaceae

Canthium sp. A.

[3656] (43) 3/1, 3/2, 3/3, 4/1, 4/2, 4/3, 4/4, 5/2, 6/1, 6/2, 6/3, 13/2, 14/1, 15/1, 15/3, 16/1, 16/2, 16/3, 17/1, 17/2, 17/3, 21/2, 24/1, 24/2, 24/3, 25/1, 25/2, 25/3, 26/1, 31/1, 32/1, 32/3, 34/2, 34/3, 35/1, 35/2, 36/2, 37/2, 37/3, 38/1, 38/2, Y/2/1, Y/2/2.

Gardenia dacryoides A. Cunn. Ex Puttock **Malava** (Previously *G sp B* Kimb Flora)

[1] (1) 18/3.

Gardenia megasperma F. Muell. (*G. megasperma* subsp. *arborea* = *G sp D* Kimb Flora)

[9] (5) 30/3, 38/2, 39/1, 39/2, 39/3.

Gardenia pyriformis A. Cunn. Ex Benth.

[10] (3) 18/1, 42/2, 43/1.

Gardenia resinosa F. Muell.

[79] (19) 1/1, 1/2, 2/2, 4/2, 6/1, 6/2, 14/2, 17/1, 17/2, 28/1, 33/1, 34/1, 34/2, 35/1, 35/2, 36/3, 45/1, 45/2, 45/3.

Arecaceae

Livistona eastonii C. A. Gardner

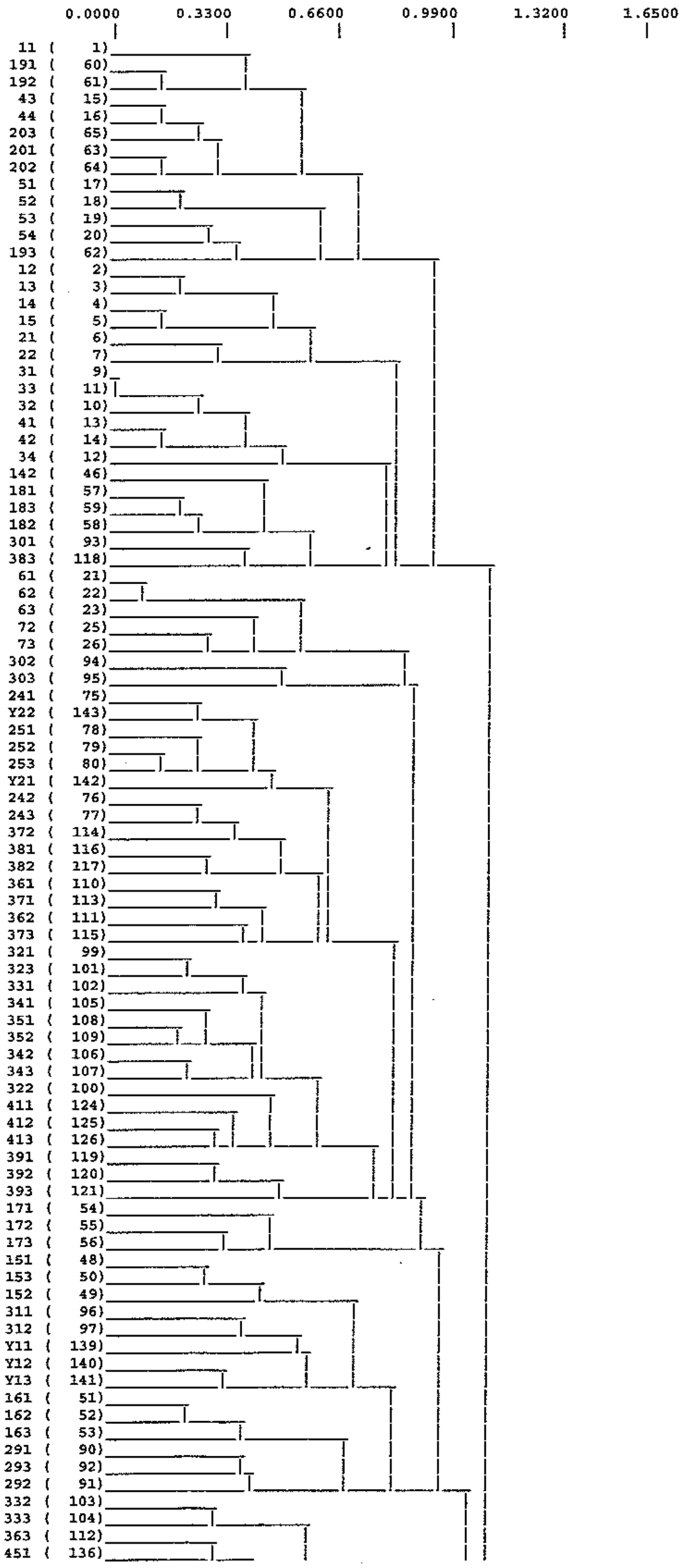
[440] (6) 6/1, 6/2, 6/3, 7/1, 7/2, 7/3.

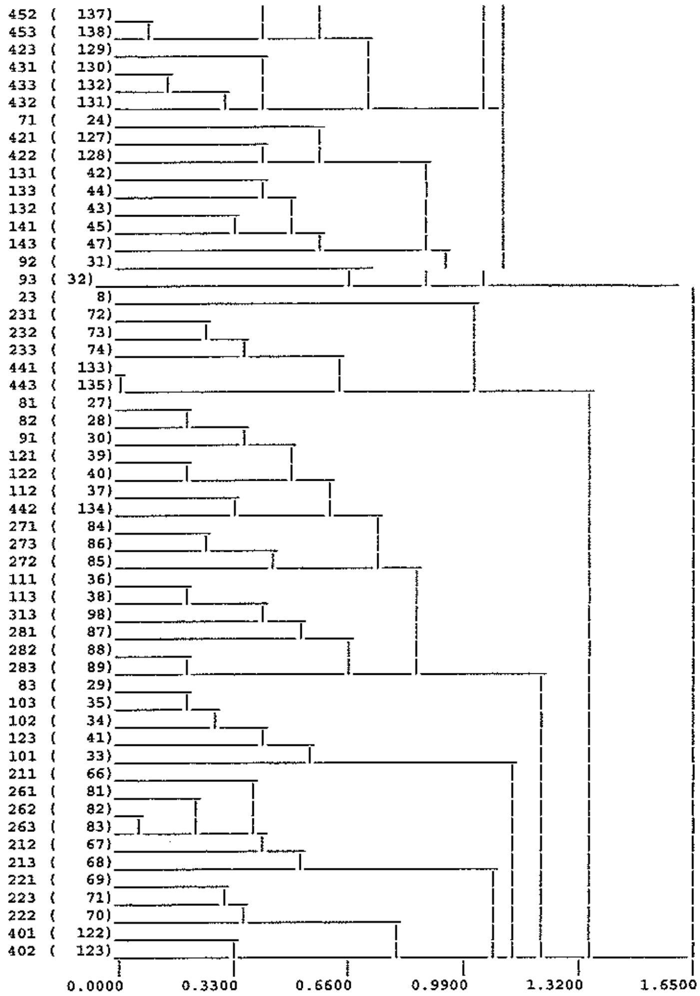
Pandanaceae

Pandanus spiralis R. Br.

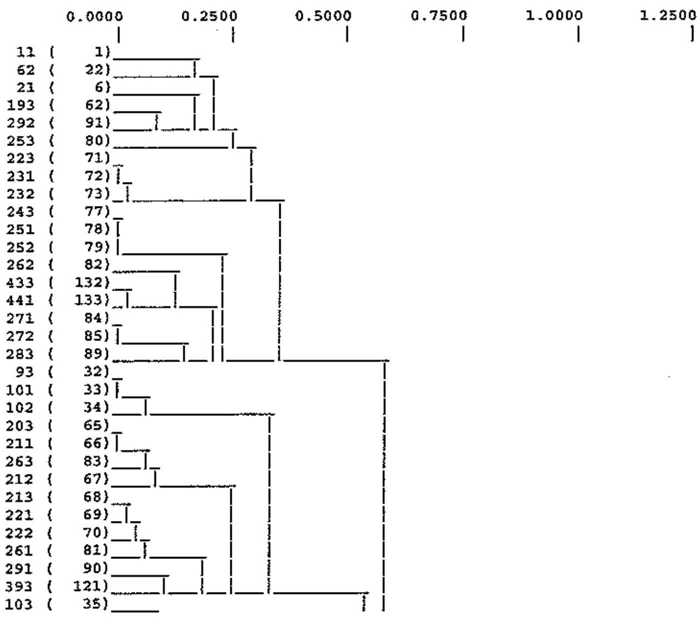
[25] (2) 37/2, 37/3.

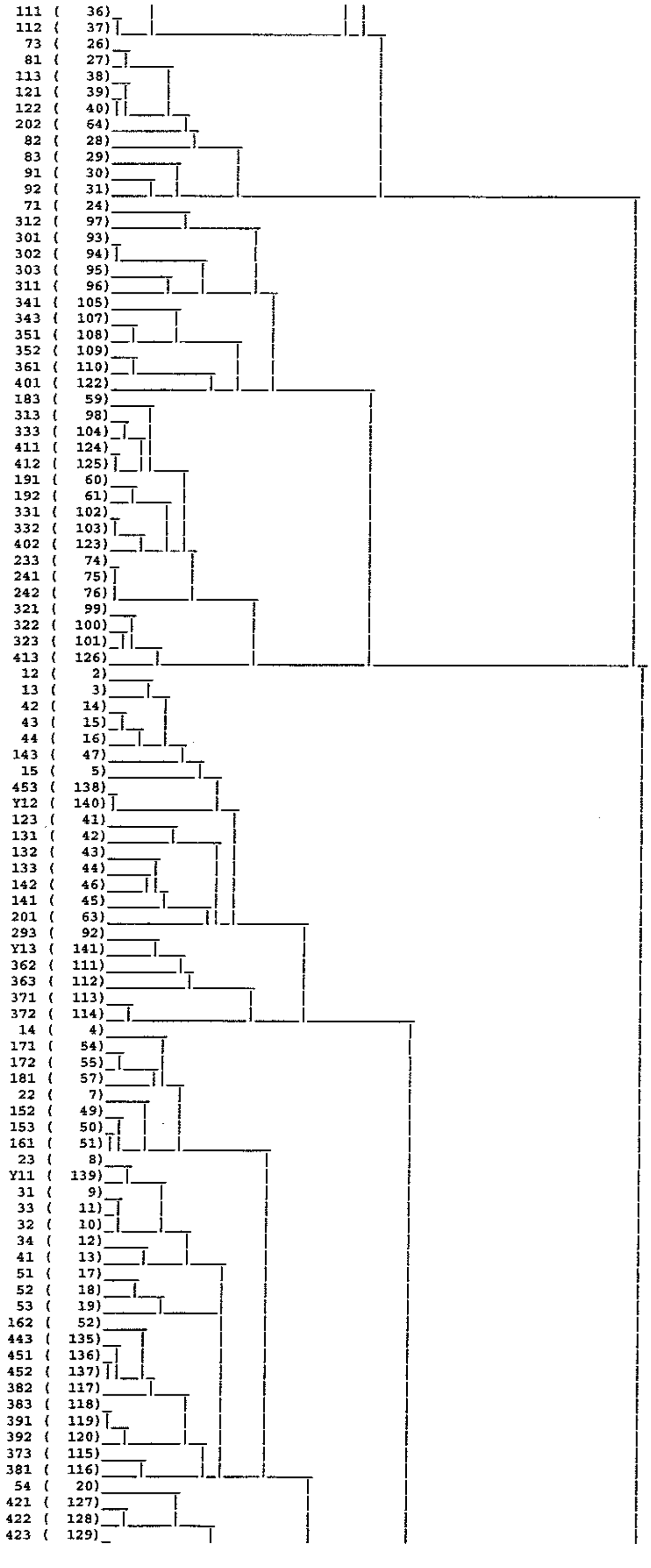
Appendix 3 Dendrograms Generated by PATN





Dendrogram for species.




111 (36)
112 (37)
73 (26)
81 (27)
113 (38)
121 (39)
122 (40)
202 (64)
82 (28)
83 (29)
91 (30)
92 (31)
71 (24)
312 (97)
301 (93)
302 (94)
303 (95)
311 (96)
341 (105)
343 (107)
351 (108)
352 (109)
361 (110)
401 (122)
183 (59)
313 (98)
333 (104)
411 (124)
412 (125)
191 (60)
192 (61)
331 (102)
332 (103)
402 (123)
233 (74)
241 (75)
242 (76)
321 (99)
322 (100)
323 (101)
413 (126)
12 (2)
13 (3)
42 (14)
43 (15)
44 (16)
143 (47)
15 (5)
453 (138)
Y12 (140)
123 (41)
131 (42)
132 (43)
133 (44)
142 (46)
141 (45)
201 (63)
293 (92)
Y13 (141)
362 (111)
363 (112)
371 (113)
372 (114)
14 (4)
171 (54)
172 (55)
181 (57)
22 (7)
152 (49)
153 (50)
161 (51)
23 (8)
Y11 (139)
31 (9)
33 (11)
32 (10)
34 (12)
41 (13)
51 (17)
52 (18)
53 (19)
162 (52)
443 (135)
451 (136)
452 (137)
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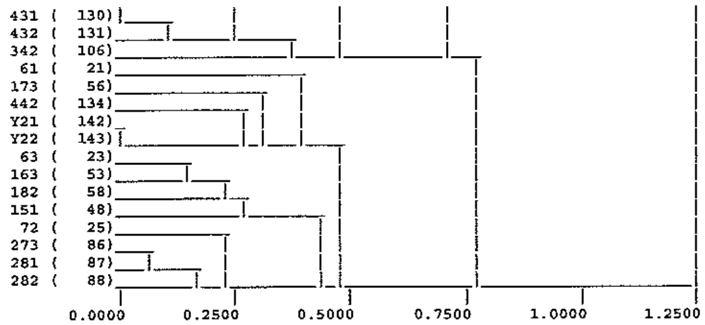
54 (20)
421 (127)
422 (128)
423 (129)



Dendrogram for physical characteristics.

Appendix 4 Site Composition from PATN

This table shows the site composition of the ten floristically defined groups from the numerical classification.

Group	No. of Members	Site Listing
1	31	1/1, 1/2, 1/3, 1/4, 1/5, 2/1, 2/2, 3/1, 3/2, 3/3, 3/4, 4/1, 4/2, 4/3, 4/4, 5/1, 5/2, 5/3, 5/4, 14/2, 18/1, 18/3, 18/2, 19/1, 19/2, 19/3, 20/1, 20/2, 20/3, 30/1, 38/3.
2	54	6/1, 6/2, 6/3, 7/2, 7/3, 15/1, 15/2, 15/3, 16/1, 16/2, 16/3, 17/1, 17/2, 17/3, 24/1, 24/2, 24/3, 25/1, 25/2, 25/3, 29/1, 29/2, 29/3, 30/2, 30/3, 31/1, 31/2, 32/1, 32/2, 32/3, 33/1, 34/1, 34/2, 34/3, 35/1, 35/2, 36/1, 36/2, 37/1, 37/2, 37/3, 38/1, 38/2, 39/1, 39/2, 39/3, 41/1, 41/2, 41/3, Y1/1, Y1/2, Y1/3, Y2/1, Y2/2,.
3	10	33/2, 33/3, 36/3, 42/3, 43/1, 43/2, 43/3, 45/1, 45/2, 45/3.
4	10	7/1, 9/2, 9/3, 13/1, 13/2, 13/3, 14/1, 14/3, 42/1, 42/2.
5	1	2/3.
6	5	23/1, 23/2, 23/3, 44/1, 44/3.
7	16	8/1, 8/2, 9/1, 11/1, 11/2, 11/3, 12/1, 12/2, 27/1, 27/2, 27/3, 28/1, 28/2, 28/3, 31/3, 44/2.
8	5	8/3, 10/3, 10/1, 10/2, 12/3.
9	6	21/1, 21/2, 21/3,26/1, 26/2, 26/3.
10	5	22/1, 22/2, 22/3, 40/1, 40/2.

Appendix 5 Percentages of Plants Found in 1 Metre Height Categories

The percentages of plants found in 1 metre height categories, where more than 50 individuals were counted, is presented in Table 10. Where the figures are highlighted in bold indicates the height class that is reported in the literature as being the mature height of the species in question.

Species	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Acacia dictyophleba	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia difficilis	91	5	2	1	1	0	0	0	1	0	0	0	0	0	0	0	0
Acacia neurocarpa	96	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia nupperima	90	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia platycarpa	90	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia retinervis	32	46	17	5	1	0	0	0	0	0	0	0	0	0	0	0	0

Acacia stigmatophylla	76	13	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia tumida	89	5	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Bauhinia cunninghamii	68	11	2	4	2	4	2	2	2	0	0	4	0	0	0	0	0
Bossiaea bossiaeoides	93	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachychiton diversifolius	60	6	0	6	6	3	6	0	3	0	6	0	3	3	0	0	0^{+}
Buchanania obovata	60	14	7	4	6	4	2	1	0	1	1	1	0	0	0	0	0
Callitris intratropica	4	4	3	3	6	7	6	11	9	8	17	4	5	3	9	2	0
Calytrix achaeta	78	14	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Canthium sp. A.	95	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Carissa lanceolata	85	8	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Cochlospermum fraseri	50	17	25	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Distichostemon hispidulus	90	9	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Dodonaea physocarpa	98	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erythrophleum chlorostachys	80	2	3	1	1	3	2	1	1	1	1	1	0	0	0	0	0
Erythroxylum ellipticum	81	8	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus bigalerita	94	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus collina	72	0	8	3	0	3	5	3	3	0	5	0	0	0	0	0	0
Eucalyptus grandifolia	70	11	2	2	2	0	0	0	2	4	2	2	2	0	0	0	0
Eucalyptus miniata	62	2	4	5	0	2	1	0	2	4	5	5	1	1	2	1	1
Eucalyptus tectifica	27	2	5	7	5	1	5	6	8	8	7	5	8	5	3	1	0
Eucalyptus tetrodonta	80	5	3	1	1	0	1	0	2	2	2	1	1	1	1	0	0
Gardenia resinosa	49	4	0	4	16	18	8	2	0	0	0	0	0	0	0	0	0
Grevillea agrifolia	64	26	8	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea mimosoides	66	16	7	5	5	2	0	0	0	0	0	0	0	0	0	0	0
Grevillea parallela	63	12	10	7	4	3	0	0	0	1	0	0	0	0	0	0	0
Grevillea refracta	86	8	2	2	3	0	0	0	1	0	0	0	0	0	0	0	0
Grewia retusifolia	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca nervosa	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owenia vernicosa	71	16	6	0	0	2	0	0	0	4	0	0	0	0	0	0	0
Petalostigma pubescens	52	9	8	17	11	3	0	0	0	0	0	0	0	0	0	0	0
Planchonia careya	77	14	1	3	2	1	0	0	0	0	0	0	0	0	0	0	0
Terminalia canescens	35	15	37	10	1	2	0	0	0	0	0	0	0	0	0	0	0
Terminalia canescens	33	20	34	9	1	2	0	0	0	0	0	0	0	0	0	0	0
Melaleuca viridiflora	78	16	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0^{+}
Phyllanthus reticulatus	65	5	12	9	9	0	0	0	0	0	0	0	0	0	0	0	0
Stenocarpus acacioides	85	3	6	0	2	0	2	2	0	0	0	0	0	0	0	0	0
Terminalia grandiflora	27	5	19	2	8	2	5	5	2	6	6	0	0	0	13	0	0

Appendix 6. Mean values from PATN analysis of physical data by group with standard deviations in brackets.

Group	1	2	3	4	5	6	7	8	9	10
Site Type	2.226 (1.313)	1.907 (1.127)	1.600 (1.020)	1.900 (1.044)	4.000 (0.000)	1.200 (0.400)	2.563 (1.116)	2.400 (1.200)	2.000 (1.414)	1.600 (1.200)
Aspect	4.129 (2.744)	2.333 (2.694)	2.800 (2.561)	3.800 (2.638)	6.000 (0.000)	1.000 (1.095)	3.063 (2.536)	0.200 (0.400)	2.833 (2.192)	0.600 (0.800)
Slope	1.645 (0.598)	1.463 (0.629)	1.900 (0.538)	1.400 (0.489)	2.000 (0.000)	1.200 (0.400)	1.938 (1.088)	1.200 (0.400)	1.500 (0.500)	1.200 (0.400)
Rock Type	0.645 (1.002)	0.666 (0.962)	0.200 (0.400)	1.200 (0.871)	0.000 (0.000)	0.000 (0.000)	1.375 (1.111)	1.600 (0.489)	0.000 (0.000)	0.000 (0.000)
Rock Size	1.548 (1.898)	1.241 (1.621)	0.600 (1.200)	2.300 (1.345)	0.000 (0.000)	0.000 (0.000)	1.688 (1.609)	2.200 (0.748)	0.000 (0.000)	0.000 (0.000)
Rock Cover	0.645 (0.863)	0.796 (1.095)	0.300 (0.640)	1.500 (0.922)	0.000 (0.000)	0.000 (0.000)	1.500 (1.225)	1.600 (0.800)	0.000 (0.000)	0.000 (0.000)
Soil Depth	2.968 (1.231)	3.000 (1.171)	3.300 (1.187)	2.000 (1.342)	4.000 (0.000)	3.800 (0.400)	2.000 (1.275)	2.200 (1.470)	3.167 (0.897)	3.800 (0.400)
Soil Type	1.097 (0.530)	1.500 (0.897)	1.400 (0.800)	1.500 (0.806)	1.000 (0.000)	1.400 (0.800)	2.250 (1.146)	1.800 (0.748)	4.000 (0.000)	2.800 (1.166)
Fire Exposure	2.774 (0.489)	2.481 (0.659)	2.700 (0.458)	2.700 (0.458)	3.000 (0.000)	3.000 (0.000)	2.938 (0.242)	2.800 (0.400)	3.000 (0.000)	2.800 (0.400)
Fire Age	1.548 (1.187)	2.796 (1.532)	2.800 (0.979)	2.100 (0.700)	1.000 (0.000)	2.600 (1.200)	2.375 (1.218)	1.600 (0.800)	1.167 (0.372)	2.400 (1.356)

Appendix 7. Mean values from PATN analysis of grass fuel data by group with standard deviations in brackets.

Group	1	2	3	4	5	6	7	8	9	10
Hummock Grass Density	1.839 (1.221)	1.204 (1.352)	1.100 (1.136)	1.200 (1.249)	3.000 (0.000)	1.400 (1.200)	0.687 (1.356)	0.400 (0.800)	0.000 (0.000)	0.400 (0.800)
Hummock Grass Pattern	1.194 (0.737)	0.777 (0.831)	1.000 (0.894)	0.700 (0.781)	1.000 (0.000)	0.600 (0.489)	0.250 (0.433)	0.400 (0.800)	0.000 (0.000)	0.200 (0.400)
Hummock Grass Height	1.516 (0.798)	0.888 (0.955)	1.100 (1.044)	0.800 (0.871)	2.000 (0.000)	1.200 (0.979)	0.250 (0.433)	0.200 (0.400)	0.000 (0.000)	0.400 (0.800)
Hummock Grass Status	2.258 (1.502)	1.407 (1.661)	1.300 (1.418)	1.700 (1.735)	4.000 (0.000)	1.400 (1.200)	1.000 (1.732)	0.600 (1.200)	0.000 (0.000)	0.400 (0.800)
Cane Grass Density	1.484 (1.074)	0.703 (1.030)	2.500 (1.910)	1.600 (1.200)	1.000 (0.000)	1.400 (1.020)	0.562 (0.609)	0.400 (0.800)	0.166 (0.372)	0.200 (0.400)
Cane Grass Pattern	1.387 (0.748)	0.759 (0.921)	1.100 (0.700)	1.300 (0.900)	2.000 (0.000)	1.400 (0.800)	1.000 (1.000)	0.400 (0.800)	0.333 (0.745)	0.400 (0.800)
Cane Grass Height	2.774 (1.337)	1.278 (1.533)	2.500 (1.360)	1.800 (1.249)	3.000 (0.000)	2.000 (1.095)	1.625 (1.654)	0.400 (0.800)	0.666 (1.491)	0.400 (0.800)
Cane Grass	1.806 (1.378)	0.685 (0.939)	2.100 (1.578)	2.000 (1.549)	1.000 (0.000)	1.200 (0.979)	0.500 (0.500)	0.600 (1.200)	0.166 (0.372)	0.200 (0.400)

Status										