Skull, Stephen David (1998) ***The ecology of tropical lowland plant communities with particular reference to habitat fragmentation and Melaleuca viridiflora Sol. ex Gaertn. dominated woodlands.*** **PhD thesis, James Cook University**

CHAPTER 3 - *MELALEUCA VIRIDIFLORA* SOL. EX GAERTN.

OPEN WOODLANDS OF THE WET TROPICS:

THEIR DISTRIBUTION, STRUCTURE AND CONSERVATION STATUS

The smokey-green stands of the paperbark have a quiet appeal all of their own
(Thorsborne & Thorsborne 1987).

3.1 INTRODUCTION

There is a relative dearth of even baseline community ecology information for most vegetation types of the tropical lowlands of north-eastern Queensland. This is despite wide acknowledgment that they continue to be the most impacted by development and remain the most poorly represented communities in conservation reserves. In contrast, generally well protected upland plant communities (especially rainforests) have been extensively researched by a wide range of ecological disciplines.

Having examined the patterns of habitat loss in a selected region of tropical lowlands, this study sought to examine aspects of the ecology of one tropical lowland plant community (*Melaleuca viridiflora* woodlands) now considered to be vulnerable for the WTBR. This begins with a review of the woodland's distribution, significance and conservation status, along with a synthesis of past research conducted on this vegetation type. The review is followed by a detailed assessment of *M. viridiflora* community structure and composition, which relates observed community patterns to climate, soil type and fire history. The response of this community to a range of ecological attributes and processes (disturbances) is then examined in the subsequent chapters of this thesis.

3.1.1 General distribution and physiognomy

The Broad-leaved or Stunted tea-tree, *Melaleuca viridiflora*, is widely distributed throughout eastern and north-western Queensland (Queensland Herbarium 1994). It also occurs in the Northern Territory, Western Australia and Papua New Guinea (Hnatiuk 1990). In his description of the vegetation of the humid tropical region of north Queensland, Tracey (1982) noted that stunted paperbark forest dominated by *M. viridiflora* was the main component of what he defined as vegetation Type 20 (texture-contrast soils with impeded drainage on coastal plains). Now classified as open woodland (Walker & Hopkins 1990), stunted paperbark communities were also listed by Tracey (1982) as a minor component of vegetation Types 17, 18, and 19, which all comprise part of the tropical lowland habitat mosaic.

Tracey (1982) defined these woodlands as having a relatively simple tree layer, with a complex understorey comprising many sedges, grasses and other herbs (a typical community is presented in Plate 1). Non-graminaceous herbs are particularly abundant in the wet, hot summer months. Gillison and Walker (1981) also documented that these communities are usually two-layered with a ground layer (10-50 cm) of graminoids. The authors described the structural variation that can occur in these woodlands, ranging from stunted, twisted trees (3-7 m) to more "pole" forest-like proportions in swampy areas (18-20 m). Tracey (1982) noted that epiphytes in the canopy trees were often conspicuous and that weed invasion was likely following disturbance. Lavarack (1994) described the wide range of terrestrial and epiphytic orchids that collectively flower almost year round in this vegetation type.

Melaleuca viridiflora also occurs in a variety of eucalypt-dominated medium and low woodland and open woodland communities throughout Queensland, usually indicating heavily textured, poorly drained soils. The predominantly low moisture and nutrient status of the soils usually means that these woodlands only carry very mild fires as a result of low fuel loads (Gillison & Walker 1981). This species is tolerant of a wide range of soil salinities, prefers seasonally saturated soils, and readily coppices (Tweddell 1982). These features, together with fire tolerant bark and the capacity to establish profusely from seed, ensure that this species is a highly effective coloniser and competitor (Gillison & Walker 1981).

Stanton and Godwin (1989) classified the plant communities of the WTBR into 119 "themes" based on controlling environmental factors (including soil type), constant canopy species and commonly associated species. Seven themes of *M. viridiflora* were described for the region (Themes 13-19), the most unique of which was Theme 16 (Table 3.1).

Plate 1 Typical *M. viridiflora*-dominated open woodland habitat (Site 5 on Hinchinbrook Island National Park).

Table 3.1 **The seven themes of *M. viridiflora* woodlands identified by Stanton and Godwin (1989).**

[1] M.v.=*Melaleuca viridiflora*, C.b.=*Carallia brachiata* Lour. (Merr.), D.a.=*Dillenia alata* (R.Br. ex DC) Martelli, L.s.= *Lophostemon suaveolens* (Sol.ex Gaertn.) Peter G. Wilson & J.T. Waterh., and G.p.=*Grevillea pteridifolia* T.Knight.

[2] L.s.=*Lophostemon suaveolens*, G.p.=*Grevillea pteridifolia*, B.a.=*Buchanania arborescens* (Blume) Blume, R.s.=*Randia sessillis* F. Muell., M.q.=*M. quinquenervia* (Cav.) S.T. Blake, A.c.= *Acacia crassicarpa* A.Cunn ex Benth., A.l.=*Allocasuarina littoralis* (Salisb.) L.A.S. Johnson, A.m.=*Acacia mangium* Willd., I.a.=*Ischaemum australe* R.Br., M.a.= *Melastoma affine* D.Don, G.s.=*Gahnia sieberana* Kunth, B.p.=*Banksia plagiocarpa* A.S. George, C.c.=*Corymbia clarksoniana* (D.J. Carr and S.G.M. Carr) K.D. Hill & L.A.S. Johnson, and X.j.=*Xanthorrhoea johnsonii* A.T.Lee.

Theme number	Constant species[1]	Commonly associated species[2]	Features	Soils (classified after Stace *et al.* 1968)
13	M. v.	L. s., G. p.	Small areas in eucalypt forest, occupying run-on areas or patches of heavier soil.	Mostly podzolics of heavy texture with silty surface horizons and strong mottling at shallow depths (approx. 40 cm).
14	M.v.	Nil	Open forests of M.v. developed on recent marine alluvium. Ground cover variable.	High water tables are maintained for most of the year by constantly outflowing freshwater.
15	M.v., D.a. C.b.	B.a., R.s	Medium to tall forests of paperbarks on silty loam soils of poor internal drainage. They occupy low areas and suffer seasonal inundation.	It is likely that soils of this theme are old solonchaks, now in a constructional position.
16	M.v.	Nil	Monospecific low forest and woodland developed on a shallow mantle of sand over mangrove mud.	Water tables are frequently high (20-35 cm depth) but the lack of surface peat indicates that this is not a permanent feature.
17	M.v., L.s.	M.q., A.c., A.l., A.m., I.a.	Small low areas on sand plain. Seasonal swamp.	Soils are lightly textured podzolics and gleyed podzolics. Water tables fluctuate widely (from above surface to greater than 150 cm).
18	M.v.	M.a., G.s., B.p.	Low forest dominated by M.v. Seasonal swamp.	Gleyed podzolic soils.
19	M.v., L.s. G.p.	C.c., X.j., C.l.	Grassy low woodlands of extensive plains.	Poorly drained yellow podzols.

Many *M. viridiflora* woodlands have been classified as wetlands. In fact, in an assessment of the freshwater wetlands of Australia, Briggs (1981) placed these communities at the dry end of an environmental gradient (defined as being covered by 15-30 cm of water when flooded) used to classify wetland types. Furthermore, as discussed in Section 3.1.2, several *M. viridiflora* open woodlands are now listed in the Directory of Australia's Important Wetlands (Blackman *et al.* 1996).

3.1.2 Ecological significance and conservation status of the woodlands

As early as 1966, a sub-section of the WTBR between Ingham and Tully was recognised as being important for the conservation of highly diverse coastal plant communities (Webb 1966). In his assessment of this area, Webb (1966) recommended that certain areas within this region be proclaimed as conservation reserves due to the "unique biological complexity of the area". He added that this was all the more important as the area represents the southern limit of several vegetation associations in the wet tropics of Australia.

Stanton and Morgan (1977) conducted a survey of key and endangered sites throughout Queensland (the RAKES project). This survey identified 12 natural regions according to the dominant vegetation, landform and soil type. The existing conservation status of the dominant vegetation types of each of these regions was assessed, and key areas were defined as optimum locations (outside the existing reserve system) for the preservation of the natural diversity of a region. Preservation of these key areas at the time would have ensured the long-term representation of the remaining major plant communities and typical or outstanding landforms within a minimum reserve size. The area most relevant to this study was that defined as the wet tropical lowlands (Region 7) which contained four Coastal Key Areas including Coastal Key Area 13 (Rockingham Bay/Cardwell coastal region). At the time, this area contained the most diverse range of plant communities of the remnant coastal plain regions, and today still contains some of the most significant, unprotected mainland remnants of *M. viridiflora* open woodlands originally referred to by Tracey (1982).

Stanton and Godwin (1989) re-assessed the adequacy of existing national parks within the wet tropical lowlands, and once again formulated recommendations to overcome any existing deficiencies that were identified. The authors concluded that two new national parks were required to adequately conserve themes of *M. viridiflora* woodlands (Themes 16 and 19) not currently represented in the conservation reserve system. These parks would also have ensured an increase in representation for other *M. viridiflora* themes. Regrettably, only one small extension of a single national park (Hinchinbrook Channel National Park) has resulted from this and other previous QDEH report recommendations, despite the poor representation of many lowland vegetation types within the existing conservation system (Stanton & Godwin 1989; ESS 1993; Perry 1994; Tait 1994).

In his assessment of lowland habitats within the Tully and Murray River catchments, Tait (1994) identified *M. viridiflora* woodlands as one of several communities warranting particularly high conservation status. He noted that:

- at least 15 species of terrestrial orchids, two of which are rare, two vulnerable and two endangered, occur in these woodlands, as does the endangered epiphyte *Myrmecodia beccarii* J.D. Hook. (Lavarack 1994); and
- at least two threatened, and four seriously at risk species of butterfly inhabit this vegetation type (Braby 1992).

Additionally it is now known that the recently re-discovered Mahogany glider (van Dyck 1993) utilises this habitat as part of its usual home range, and also as an important food source (nectar and insects) when resources are low elsewhere (Mr S. Jackson in prep.).

In a more recent assessment of the conservation status of Queensland's bioregional ecosystems, *M. viridiflora* woodlands are listed as a vulnerable regional ecosystem within the WTBR (QDEH 1995a). Vulnerable was defined in this report as indicating that only 5-10% of the pre-European extent of a community remains in an intact condition in a region. Given recent trends in landuse, these communities were considered at risk of disappearing from the landscape over a period longer than 20 years through continued depletion.

Specht *et al.* (1995) have considered the conservation status of all plant communities in Australia. Their report provides a detailed assessment of *M. viridiflora* woodlands (± eucalypt species) although it defines biogeographic regions based on floristics. This approach produced biogeographic regions with slightly different boundaries to those based on more traditional parameters including landform, climate and soil type (that are more widely accepted for use, ANCA 1995). These woodlands, listed by Specht *et al.* (1995) as Community 361, are represented in existing conservation reserves around Australia (Table 3.2). Their report considers *M. viridiflora* open woodlands to be "adequate" in terms of their reservation, which indicates that the plant community is well conserved in several large reserves which represent the range of biogeographic regions from which it is recorded. The report, however, provides no figures of the actual areas of *M. viridiflora* conserved, listing only the number of reserves in which the community occurs and the total number of vegetation types recorded from each reserve (Table 3.2).

Table 3.2 **Summary of the conservation status of *M. viridiflora* (± eucalypt species) open woodlands in Australia (Specht *et al.* 1995).** Region NE3 includes a major section of coastal Queensland from south of Townsville to Cooktown, and three additional small coastal areas further to the south. In contrast, the WTBR is a much smaller area and does not extend nearly as far to the west as the main section of NE3.

State/Region	No. of reserves in which *M. viridiflora* communities occur	Total no. of all plant communities in the reserves	Approx. total area (ha) of all reserves
WA	2	11	1.15×10^5
NT	19	149	2.60×10^6
QLD	24	236	1.75×10^6
NE3	7	72	1.86×10^5
WTBR	4	39	1.72×10^5

Four *M. viridiflora* sites within the WTBR are listed in the Queensland section of the Directory of Australia's Important Wetlands (Blackman *et al.* 1996). Except for the Sunday Creek Area, the listings were all nominated for a variety of reasons including the presence of *M. viridiflora* woodlands. The first listing is the Cowley Area (Queensland Wetland No. 142) which contains small areas of *M. viridiflora* woodlands growing on dune swales. A site within the extensive dune complex was investigated during this study (Site 23). The second listing is the Edmund Kennedy Wetlands (Queensland Wetland No. 143) which only contain small areas of *M. viridiflora* woodlands within a highly significant lowland mosaic of other rare wetland types. The third of these areas is the Hinchinbrook Channel (Queensland Wetland No. 148) site. Two of the reasons for this listing are the extensive areas of Broad-leaved tea-tree woodland that occur to the west of the channel, and the variety of threatened plant species within these areas (Lavarack 1994). Two study sites (Sites 17 and 18) were assessed within this area. The final listing (Queensland Wetland No. 160) is 39 hectares of *M. viridiflora* woodland near Sunday Creek, south of Cardwell. The significance of this site (Site 16 in this investigation) is that it provides a good example of a diminishing lowland wetland community, and is a habitat containing three locally endemic orchid species (Blackman *et al.* 1996).

The conservation status of remnant *M. viridiflora* woodlands has been improved with the relatively recent gazettal of Lumholtz National Park. Lumholtz National Park is part of the WTWHA between Ingham and Cardwell, just to the north of the Cardwell Range. Although this park is relatively large, only a small fraction of its total area protects the tropical coastal lowland habitat mosaic (including *M. viridiflora* woodlands). In addition, the park is dissected by the Bruce Highway, which exacerbates problems such as weed invasion and increased fire frequencies. Annual fires ignited by landholders and altered hydrological patterns in the region are also cause for concern.

Perhaps the most significant example of this community within the existing conservation system occurs on the northern end of HINP. Here the undisturbed habitat occurs both as large, convoluted, interconnected patches and small, isolated patches of varying shapes and sizes. Since the early 1980's, the QDE has conducted prescribed burning in the majority of these communities once every ten years as part of the fire management plan for the park (QDEH 1995b). It is believed that differences in soil formation processes between these sites and the adjacent mainland render these communities unrepresentative of their mainland counterparts (Mr P. Stanton, pers. comm.). Other *M. viridiflora* communities are protected within Edmund Kennedy National Park to the north of Cardwell and Hull River National Park near Mission Beach.

Small areas of *M. viridiflora* woodland are also conserved within the state forest reserve system to the west of Cardwell. These communities are small isolated fragments, largely unconnected with other lowland habitats. Their conservation value is therefore somewhat diminished, particularly given the recent invasion of exotic pine trees that has occurred in most of the woodlands (see Chapter 6).

Coastal urbanisation and other large-scale developments (e.g. the SIIP, ESS 1993) continue to place increasing pressure on remnant habitat in all tropical lowlands. Critical habitats that had been identified during some planning processes (e.g. Tait 1994) have already been lost, and large-scale clearing that is a significant threat to biological diversity is still occurring in the lowlands of north-eastern Queensland (DEST 1995a). Current developments occurring on tropical floodplains therefore remain ecologically unsustainable. There is an urgent need for scientific data to support management concerns and assist the revision of current habitat management practices where necessary (Mr P. Stanton, pers. comm.).

The significance of the entire lowland habitat mosaic has long been recognised by government agencies and biologists. Funding programs, research initiatives and media attention, have, however, traditionally focused on relatively well protected, upland plant communities (in particular rainforests). This previous bias, coupled with the ecologically unsustainable development of lowland regions, has resulted in:

- the ecology of a significant proportion of the plant communities of lowland ecosystems remaining poorly understood;
- extremely fragmented lowland ecosystems (the patterns of habitat fragmentation in this region are considered in Chapter 2); and
- the communities of lowland regions remaining poorly represented in the existing conservation reserve system.

3.1.3 Review of previous research

A synopsis of the research conducted in *M. viridiflora*-dominated woodlands has not previously been compiled. A summary of the available literature is presented in Table 3.3. Management-related investigations that have been discussed above are not re-iterated here. From Table 3.3 it can be seen that other than the collection of baseline taxonomic and distribution information, research has focussed on a select number of plant species (particularly orchids), even fewer animals and rarely on entire communities.

The only study to assess these woodlands within the WTBR was conducted during an honours thesis (Tweddell 1982). This study showed that *M. viridiflora*:

- reached its highest densities on duplex soils;
- was capable of tolerating a wide range of salinities; and
- was dominant where sites dried out markedly during the dry season.

The physical structure of these woodlands has only been investigated in two other biogeographic regions of Australia (Top End Coastal and Cape York Peninsula). These investigations have primarily focussed on changes to fire regimes since European occupation, and their subsequent effects on woodland and adjoining grassland structure. A brief synopsis of these projects is outlined below. More detailed reference to these studies will be made in further sections of this chapter where appropriate.

On Cape York Peninsula, *M. viridiflora* is invading grassland habitats resulting, in some cases, in irreversible habitat changes and therefore a reduction of overall habitat diversity (Stanton 1992; Crowley & Garnett 1995). An analysis of two sets of aerial photographs taken 20 years apart has recorded a reduction in grassland habitat of approximately 10 %. This work was supported by ground-truthing which indicated an 11% increase in the presence of *M. viridiflora*, with four sites of an earlier CSIRO survey having been completely converted from grassland to woodland (Crowley & Garnett 1995).

Table 3.3 **Synopsis of research relevant to *M. viridiflora*-dominated woodlands.** Research topics are presented in chronological order.

Table 3.3 is presented on the next two pages.

Reference	Topic of research	General notes
Blake (1968)	Taxonomy and distribution.	Provided detailed information with respect to known locations of this and other *Melaleuca* species.
Tweddell (1982)	Hydrological investigations, germination responses (salinity) and flowering studies.	Listed 38 plant species from woodlands near Cardwell.
Barlow (1989)	Taxonomy and evolution.	Outlined patterns of differentiation in tropical species of *Melaleuca.*
Sommer (1990)	Ant plant (*Myrmecodia beccarii*) ecology.	Described the ecological role of ants in the survival, dispersal and nutrition of this epiphyte.
Braby (1992)	Butterflies and conservation.	Recorded 36 butterfly species from woodlands near Cardwell, including several listed as rare or threatened.
Winter *et al.* (1992)	Terrestrial vertebrate survey.	Surveyed vertebrate diversity in woodlands near Rollingstone north of Townsville (33 species recorded).
Anderson (1993)	Leaf litter and soil fauna.	Twelve orders of macro-invertebrates recorded from woodland habitat near Cardwell.
Lawler (1993)	Orchid conservation.	Cited concern over depletion of Tea-tree orchid (*Dendrobium canaliculatum*) and makes management recommendations for woodland habitat.
van Dyck (1993)	Taxonomy, distribution, ecology and conservation status of the Mahogany glider.	Confirms woodland habitat (with eucalypt emergents) is utilised by Mahogany glider as an important food source.

Reference	Topic of research	General notes
Bartareau and Skull (1994)	Effects of fire on epiphyte distribution.	Fire responses of two epiphytes documented.
Lavarack (1994)	Orchid and habitat conservation.	Management recommendations for orchid conservation proposed.
Skull (1994a)	Exotic species invasion.	Invasion of plantation pine (*Pinus caribaea* Morelet var. *hondurensis* Barrett and Golfar (Pch)) into woodlands first documented.
Jobson (1995)	Orchid taxonomy.	Geographic variation exhibited by the *Dendrobium canaliculatum* R.Br. species complex.
Balciunas and Burrows (1995)	Biological control of *M. quinquenervia.*	Recorded 79 species of insects feeding on the sap, flowers, leaves and fruit of *M. viridiflora.*
Crowley and Garnett (1995)	Invasive potential of *M. viridiflora* into significant Cape York grassland habitat.	Management recommendations outlined to preserve Golden shouldered parrot habitat.
Bartareau (1995)	Pollination and breeding systems of *Dendrobium canaliculatum*.	Taxonomic status of the species discussed.
Blackman *et al.* (1996)	Directory of important wetlands in Australia.	Two woodland habitats near Cardwell listed in directory as significant.
Williams (in prep.)	Aspects of the ecology of *Myrmecodia beccarii.*	MSc thesis in progress.
Roberts (in prep.)	Effects of fire on *Melaleuca* woodlands.	PhD thesis in progress based on work conducted in the Northern Territory.
Jackson (in prep.)	Socio-ecology of the Mahogany glider.	PhD thesis in progress that identifies woodland as habitat for the Mahogany glider both as a food resource and as part of the glider's home range.

The authors concluded that these habitat changes correspond to changes in fire regimes as a result of the cessation of Aboriginal burning, a finding supported by Stanton (1992). Hotter fires towards the end of the dry season (traditionally avoided by graziers) are now less common, enabling the Tea-tree suckers which were presumably kept in the ground layer by relatively frequent Aboriginal burns, to establish through to maturity (Crowley & Garnett 1995).

In the Northern Territory, fire frequencies are considered to be higher than those of the WTBR with extremely large areas burnt annually (Russell-Smith 1993). It is estimated that sandstone and floodplain *Melaleuca* communities experience fire every 4-5 years and 14-15 years respectively (Dr J. Russell-Smith, pers. comm.). In this region, field observations have included heavy mortality of mature paperbark stands and the invasion of *Melaleuca* species into other wetland habitats. This invasion has recently been documented for the first time in the WTBR (QDEH 1996b).

The lack of an understanding of regenerative processes following disturbance in *Melaleuca* communities is a management concern (Dr J. Russell-Smith, pers. comm.). Work in progress (Roberts in prep.) is examining the effects of fire on the structure of some of the Kakadu *Melaleuca* communities, including those dominated by *M. viridiflora.* Finlayson *et al.* (1993) have published results on the structure of a mixed *Melaleuca cajaputi* Powell/*M. viridiflora* community on the Magela floodplain near Jabiru. The community exhibited a typical bell shaped distribution curve across the DBH size classes. Importantly, the site has remained unburnt for at least the past 20 years (Dr M. Finlayson, pers. comm.). General reductions in *Melaleuca* tree density across the same floodplain have also been documented and attributed to a combination of fire, buffalo grazing and wind (Williams 1984).

Comparisons of the research results from other regions with those recorded in this study are confounded by significant differences in:

annual fire regimes (including fire frequency, season and intensity);

- the scale of the habitats and the subsequent areas that are burnt on an annual basis;
- management practices (traditional vs. grazier vs. natural resource management); and
- environmental attributes such as rainfall, relative humidity and soil type (Dr J. Russell-Smith, pers. comm.).

Consider the examples of rainfall and relative humidity. Figures 3.1a and 3.1b present this data for five locations relevant to either this project (Townsville, Cardwell and Cooktown) or previous research (Coen and Jabiru). Rainfall patterns for the five locations are essentially similar, with only the magnitude of falls differing between areas (Figure 3.1a). The occurrence of significant rain throughout the dry season (May, June and even July) for Cardwell and Cooktown is the most notable difference between the locations. The overall pattern of relative humidity is, however, markedly different in both Townsville and Jabiru (Figure 3.1b). These two locations (particularly Jabiru) experience highly reduced relative humidities throughout the dry season (April-October). This often means fire could carry much earlier in the year compared with the other locations where relative humidity does not drop significantly until much later (August-September).

3.1.4 Aims of this investigation

This section of the thesis had the following objectives:

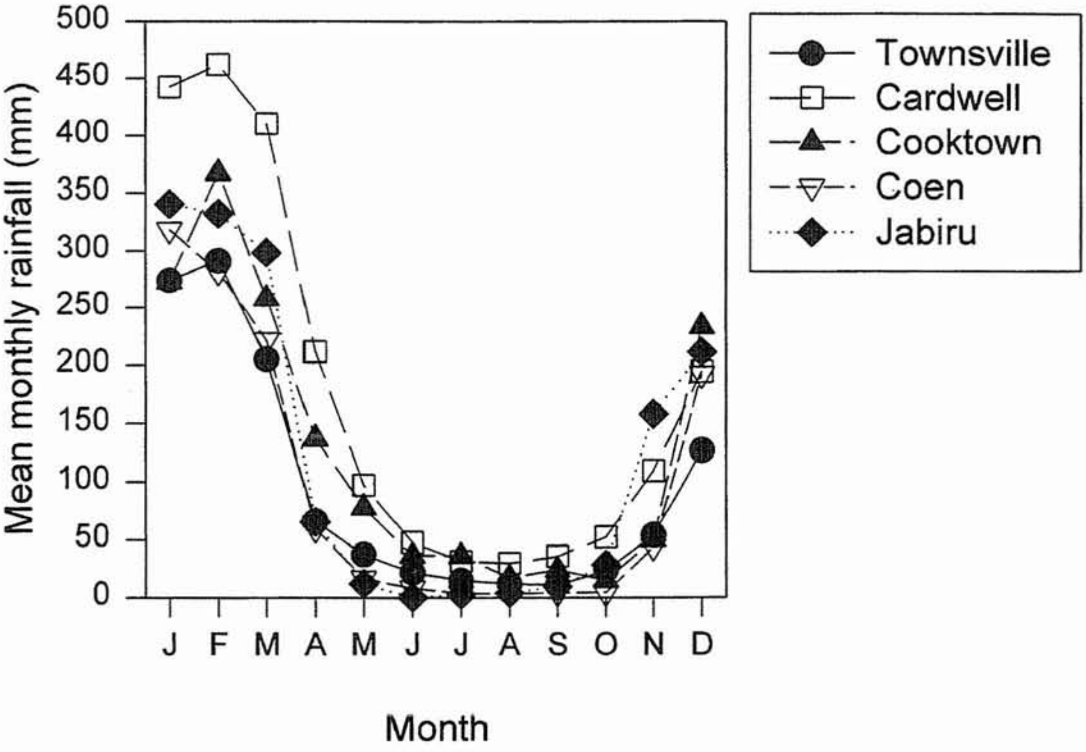
(i) to conduct a detailed analysis of the structure of *M. viridiflora* woodlands within the WTBR; and

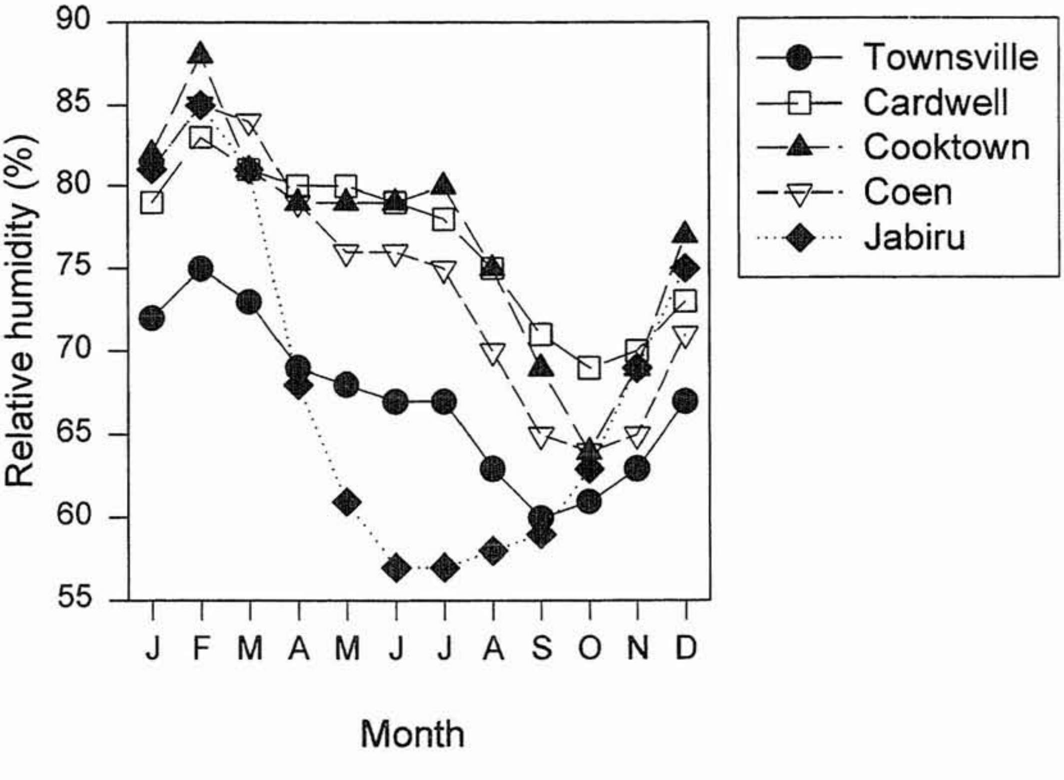
(ii) to assess the communities in terms of species composition, soil type, fire history and climate (predicted).

Figure 3.1 **Climate data for locations studied either during this investigation (Townsville, Cardwell & Cooktown) or for previous research conducted on *M. viridiflora* woodlands (Coen & Jabiru).** Data sourced from the Bureau of Meteorology. All available data (varying time periods for each site) from the Bureau was utilised in the analysis.

(a) **Mean monthly rainfall (mm).**

(b) **Mean monthly relative humidity (%).**


Mean monthly rainfall (mm)
500
450
400
350
300
250
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D
Month
Townsville
Cardwell
Cooktown
Coen
Jabiru


Relative humidity (%)
90
85
80
75
70
65
60
55
J
F
M
A
M
J
J
A
S
O
N
D
Month
Townsville
Cardwell
Cooktown
Coen
Jabiru

3.2 METHODS

3.2.1 Site selection

A combination of topographic maps, aerial photographs, previous vegetation surveys and consultation was used to select possible study sites. This study only investigated *M. viridiflora* communities that satisfied the following selection criteria:

- the community was located within the coastal lowlands of the WTBR {defined by Stanton & Morgan (1977) and re-iterated by ANCA (1995)} between Cooktown and Townsville; and
- *M. viridiflora* comprised more than 70% of the canopy trees.

The general location of the study sites on the north-eastern Queensland coast (a key guide to the other site location figures) is presented in Figures 3.2a-b. Sites 1-4 were chosen to represent communities at the southern extremity of the WTBR (Figure 3.2c). In the central section of the WTBR, sites were primarily selected within HINP (Sites 6-11) and the WTWHA (Sites 16-21), as this is where a majority of these woodlands occur (excluding privately owned freehold land)[1] (Figure 3.2c). Hinchinbrook Island National Park provided unique opportunities to study *M. viridiflora* communities in detail as it is isolated from the mainland and therefore subject to far less disturbance in terms of habitat fragmentation, high fire frequencies, and exotic plant and feral animal invasion.

Central WTBR sites were also located on the mainland in the State Forest and adjoining private land west of Cardwell (Sites 12-15). Northern WTBR mainland sites included Sites 22, 23 and 24 which were located in the Mission Beach, Cowley Beach and Cape Tribulation areas respectively (Figures 3.2d, 3.2e and 3.2f respectively).

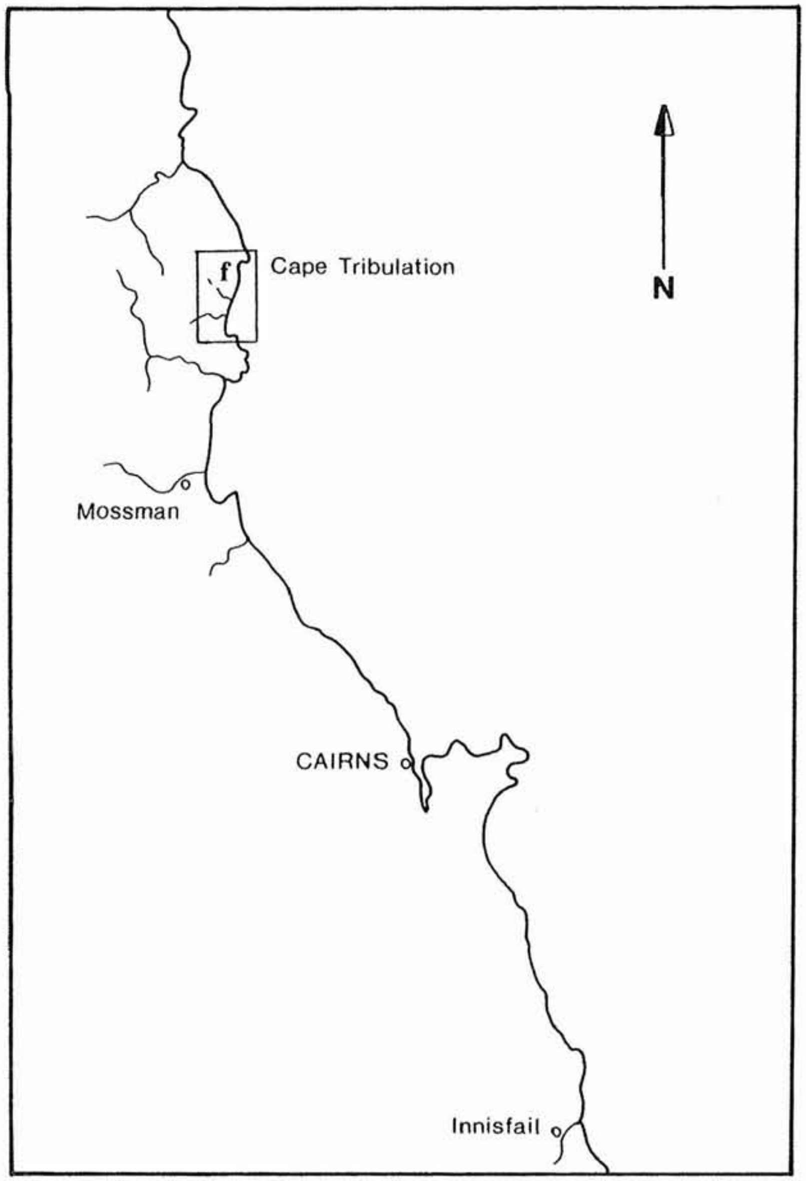
[1] Additionally, both the WTMA and the QDE provided the majority of funding for this research

Figure 3.2 **Location of study sites within the Wet Tropics Biogeographic Region.** Letters (c-f) indicate the location of other site figures that are referred to in the text (Figures 3.2c-f).

(a) **Location of the only site in the Cape Tribulation region.**

(b) **Location of sites in the Townsville-Cardwell, Tully and Mission Beach regions.**

(a)


N
Cape Tribulation
f
Mossman
CAIRNS
Innisfail

(b)

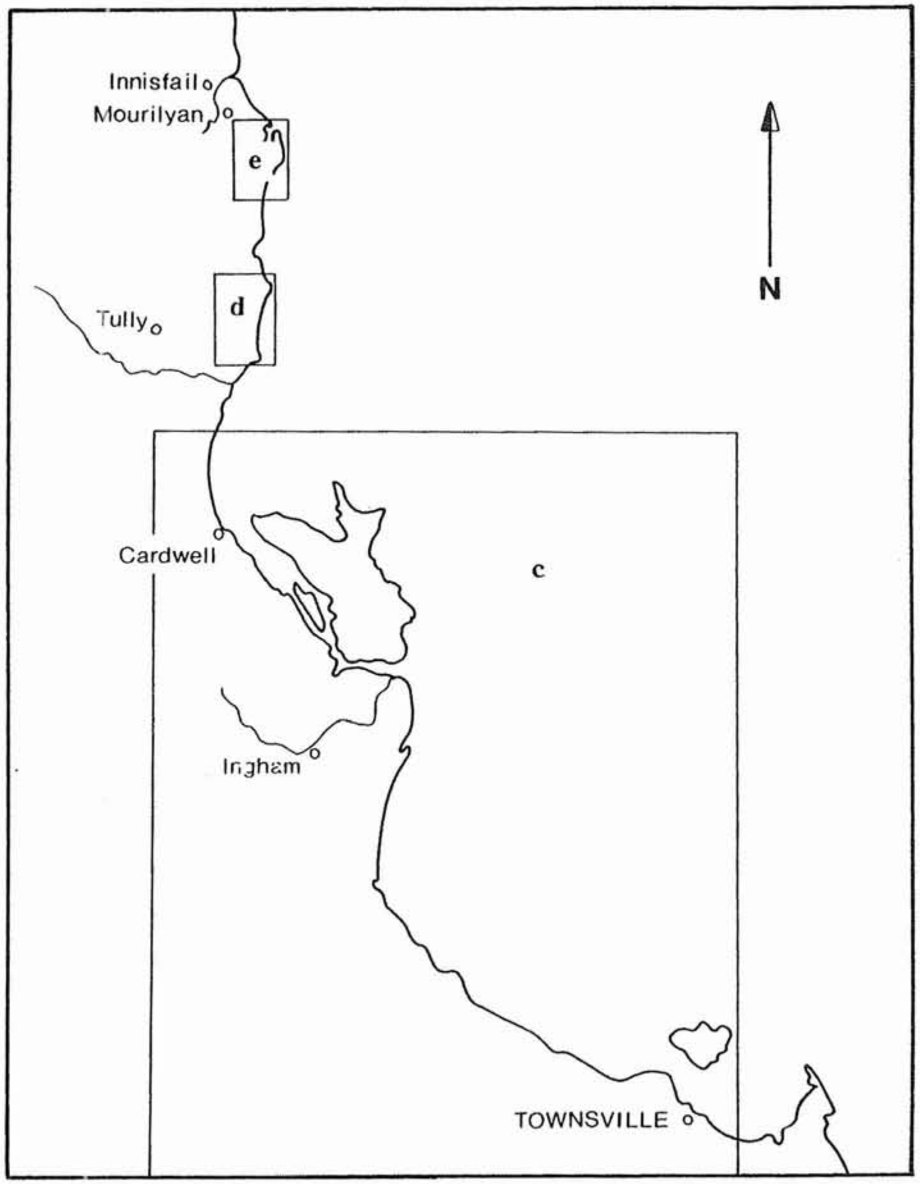

N
Innisfail
Mourilyan
e
Tully
d
Cardwell
c
Ingham
TOWNSVILLE

Figure 3.2 **Location of study sites within the Wet Tropics Biogeographic Region.**

(c) Location of Sites 1-21.

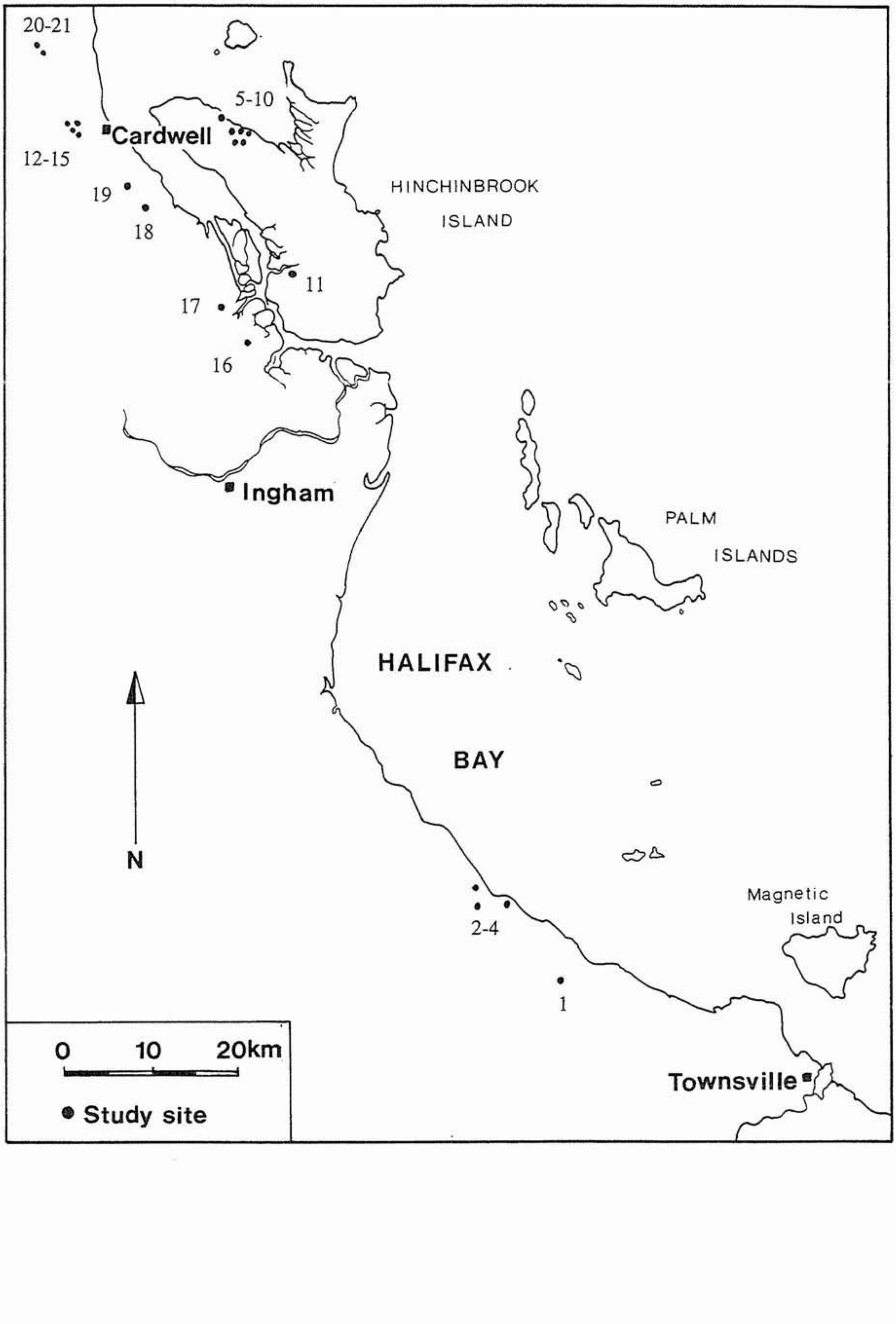

20-21
5-10
Cardwell
12-15
HINCHINBROOK
ISLAND
19
18
11
17
16
Ingham
PALM
ISLANDS
HALIFAX
BAY
N
Magnetic
Island
2-4
1
0
10
20km
Townsville
● Study site

Figure 3.2 **Location of study sites within the Wet Tropics Biogeographic Region.**

(d) **Location of Site 22 in the Mission Beach area.**

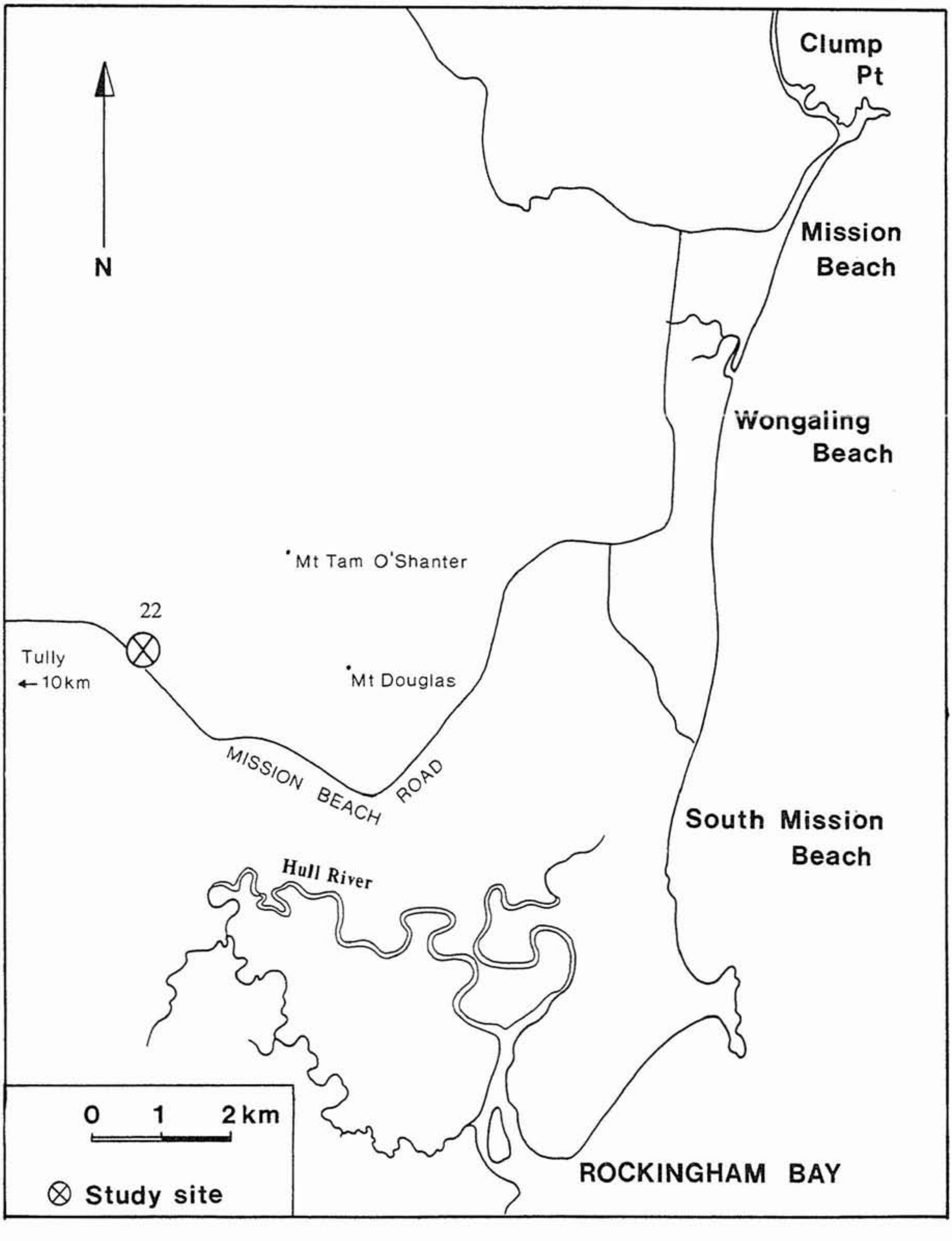

Clump Pt
Mission Beach
Wongaling Beach
South Mission Beach
ROCKINGHAM BAY
N
Mt Tam O'Shanter
Mt Douglas
22
Tully ← 10km
MISSION BEACH ROAD
Hull River
0 1 2 km
⊗ Study site

Figure 3.2 Location of study sites within the Wet Tropics Biogeographic Region.

(e) Location of Site 23 in the Cowley Beach area.

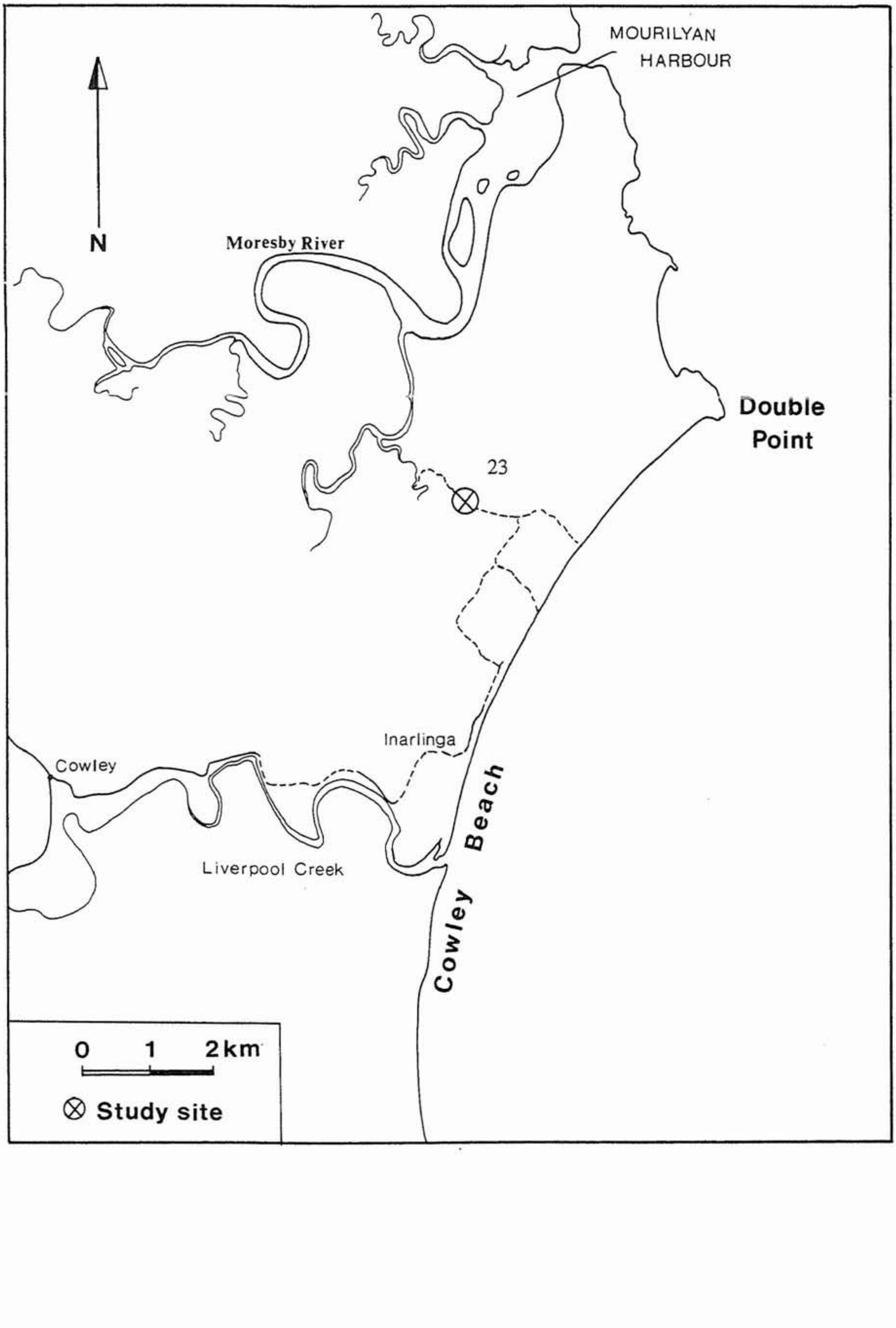
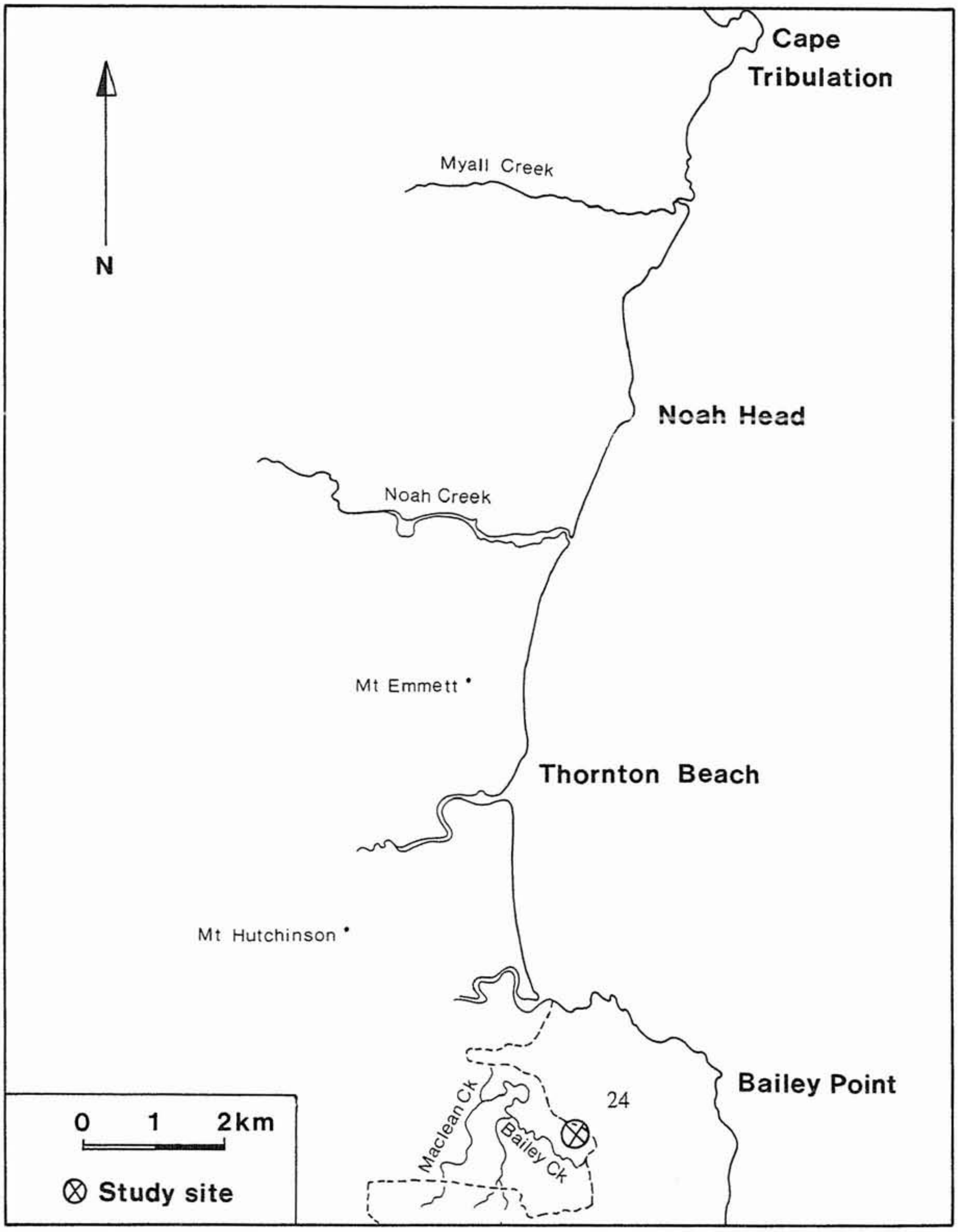

MOURILYAN
HARBOUR
N
Moresby River
Double
Point
23
Inarlinga
Cowley
Liverpool Creek
Beach
Cowley
0 1 2 km
⊗ Study site

Figure 3.2 **Location of study sites within the Wet Tropics Biogeographic Region.**

(f) **Location of Site 24 in the Cape Tribulation area.**


Cape
Tribulation
Myall Creek
N
Noah Head
Noah Creek
Mt Emmett
Thornton Beach
Mt Hutchinson
Bailey Point
24
Maclean Ck
Bailey Ck
0 1 2km
⊗ Study site

3.2.2 Plot data collection

The location of each site was recorded with a handheld *Garmin 100* GPS unit. Altitude was determined from topographic maps. Recent fire histories were assessed using past fire records (predominantly for sites within conservation reserves) or determined following discussions with local authorities and landholders.

Most of the woodland populations sampled were small and irregularly shaped. To ensure sample units were not located too close to ecotones, a transect was established through the middle of each population. Five 10 x 10 m plots (spaced 10 m apart) were established along the transect, with the starting point for the first plot of the transect selected at random. Plots were marked permanently to enable re-examination following fire. Steel pegs were used to mark the corners of the plots, with aluminium tags (labelled with date and plot number) nailed into a reference tree close to a pre-determined corner of every plot, and above previous fire scars.

To provide an estimate of species richness, all species within each community were recorded and an herbarium (reference) collection compiled. Species were collected at all sites throughout the range of tropical seasons (excepting remote sites), so as to obtain a complete reference collection. Sampling effort (the number of visits to each site) was also monitored to examine its relationship with species richness.

All mature *M. viridiflora* trees taller than 1.5 m were counted and their height and diameter at breast height (DBH) recorded. Heights were estimated visually and diameters recorded with a DBH measuring tape at a fixed height (waist level) above the ground. Individual *M. viridiflora* plants (hereafter woody sprouts) less than 1.5 m were counted. This process was repeated for all dominant species present in the plot. In addition, the number of dead *M. viridiflora* individuals present in each plot was recorded to provide an estimate of mortality. Due to their predominance in the understorey, Grasstree (*Xanthorrhoea johnsonii* A.T.Lee) densities were also recorded.

A single soil profile to a depth of 1 m was dug (as close as possible to the site centre) at each site using a 7.5 cm diameter auger. A representative sample of each horizon sub-section was collected, systematically stored in a compartmentalised tray and subsequently classified according to Cannon *et al.* 1992.

To enable climate comparisons to be made with other regions where this community has been studied, mean monthly rainfall and relative humidity data for Townsville, Cardwell, Cooktown (all within the WTBR), Coen (Cape York Peninsula) and Jabiru (Top End Coastal) were obtained from the Bureau of Meteorology. The climate prediction system BIOCLIM (Busby 1991) was also used to predict climate parameters, including rainfall and temperature profiles for each of the study sites based on longitude, latitude and altitude.

3.2.3 Data analyses

Linear regressions and Pearson correlation coefficients were used to investigate the relationship between height and DBH at all sites collectively and then for individual sites. An ANCOVA was used to compare the relationship between DBH and height at all sites. The height (m) and DBH (cm) data were then sub-divided into size classes. Seven height ($0<x\leq2$, $2<x\leq5$, $5<x\leq8$, $8<x\leq11$, $11<x\leq14$, $14<x\leq17$, $x>17$) and nine DBH ($x\leq2$, $2<x\leq5$, $5<x\leq10$, $10<x\leq15$, $15<x\leq20$, $20<x\leq25$, $25<x\leq30$, $30<x\leq35$, $x>36$) size classes were chosen. Only *M. viridiflora* data was included in subsequent DBH analyses. The distribution of both sets of size class data was very similar (Figure 3.3), so analyses of community structure concentrated on the more precisely measured DBH data only.

A cluster analysis was conducted on the *M. viridiflora* DBH data matrix to determine sites with similar structures using a Bray-Curtis (Czekanowski) association measure followed by flexible unweighted, pair group arithmetic averaging (UPGMA). This technique is a hierarchical, agglomerative clustering process available in the PATN software package (Belbin 1995a, 1995b). All analyses closely followed the recommended procedure outlined by Belbin (1991).

Figure 3.3 *M. viridiflora* size class data across all study sites.

(a) Tree DBH (cm) size class data.

Tree DBH (cm) data classes are as follows:

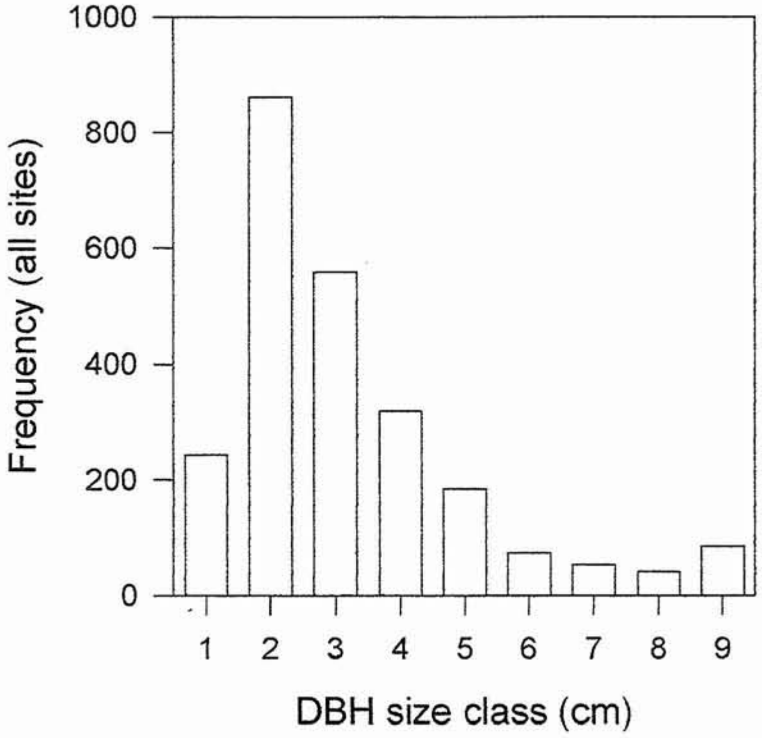
$1 = x \leq 2$
$2 = 2 < x \leq 5$
$3 = 5 < x \leq 10$
$4 = 10 < x \leq 15$
$5 = 15 < x \leq 20$
$6 = 20 < x \leq 25$
$7 = 25 < x \leq 30$
$8 = 30 < x \leq 35$
$9 = x > 36$

(b) Tree height (m) size class data.

Tree height (m) classes are as follows:

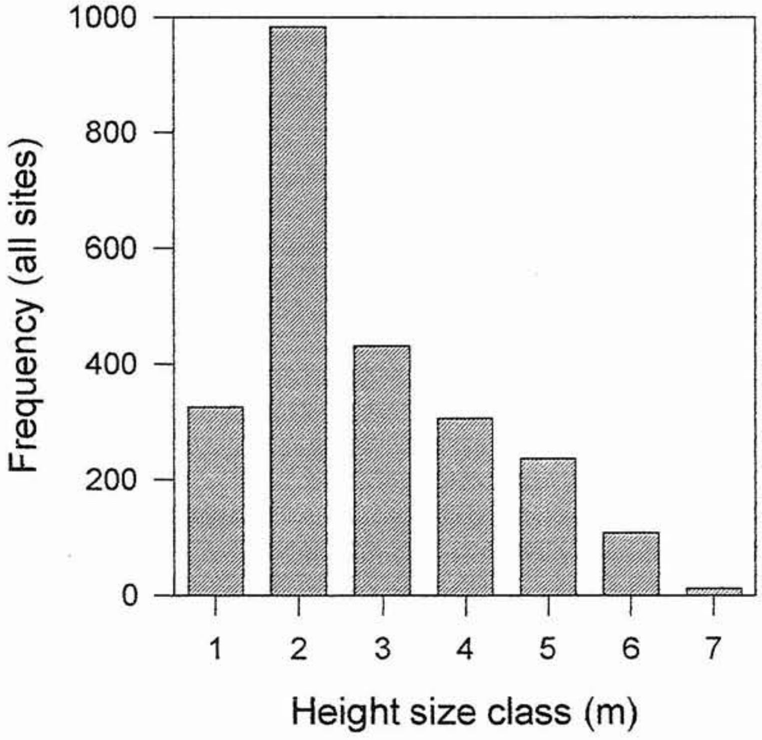
$1 = 0 < x \leq 2$
$2 = 2 < x \leq 5$
$3 = 5 < x \leq 8$
$4 = 8 < x \leq 11$
$5 = 11 < x \leq 14$
$6 = 14 < x \leq 17$
$7 = x > 17$

(a)



1000
800
600
400
200
0
Frequency (all sites)
1
2
3
4
5
6
7
8
9
DBH size class (cm)

(b)



1000
800
600
400
200
0
Frequency (all sites)
1
2
3
4
5
6
7
Height size class (m)

This classification technique was tested against the polythetic divisive approach of TWINSPAN (two-way indicator species analysis). Originally developed by Hill (1979), this technique is now a useful addition to the PATN package. The analysis of DBH data used six cut levels (set at 0, 5, 10, 20, 30 and 50) with the minimum group size for division and maximum number of divisions set at two and five respectively. This additional analysis was employed to determine which DBH groups (or species in the case of the species presence/absence data matrix) were responsible for producing divisions/groupings of sites within the data matrix.

To test the discreteness of the groupings formulated by the cluster analysis, an ordination was performed using semi-strong hybrid multi-dimensional scaling (SSH). This is a robust ordination technique which combines metric and non-metric multi-dimensional scaling (Faith 1991). Recently, it has been described as probably the most robust of ordination techniques currently available (Jackson & Fox 1996). This analysis is also available within the PATN package. Three dimensions were chosen on the basis of the stress parameter (lack of fit), and for the third dimension 100 random starts were utilised to minimise the likelihood of local minima (Faith 1990). Site variables which appeared to be important with respect to site groupings (soil type, rainfall and fire history), were then superimposed on plots of the ordination vectors.

The species presence/absence data was analysed according to the procedure outlined above for the DBH data matrix, except that:

- two cut levels (0 & 1) and a maximum number of four divisions were used in the TWINSPAN analysis; and
- four dimensions were required to produce sufficiently low stress in the ordination.

Species with a frequency of < 5% for all study sites were not included in the analysis. As a result, 75 species were selected from the original list of 127.

Site groupings from selected multi-variate analyses were then tested for significant differences with respect to other parameters using one-way ANOVA. For the species presence/absence data, species richness and predicted total annual rainfall were tested for significant differences between groupings of the Bray-Curtis classification. Groupings from both classifications based upon the DBH size class data were tested for significance based upon the raw DBH data for each site and predicted total annual rainfall. Tukey's HSD test was employed to determine which pairs of groups (if any) were significantly different at the 5% significance level. All uni-variate analyses were conducted using the SPSS software package (SPSS 1993).

3.3 RESULTS

3.3.1 General characteristics of the sites

A total of 24 *M. viridiflora* populations were investigated during this project. A summary of the data collected at each site is provided in Tables 3.4a-b. This includes physical data (altitude, soil type and the rainfall predicted by BIOCLIM), structural data (theme, mean DBH and heights, the percentage of *M. viridiflora* in the canopy, and the abundance of *M. viridiflora* in two different size classes) and other site information (fire history, species richness and sampling effort). Means of site parameters and their standard errors are also provided where appropriate. The following text in this section relates to data presented in Tables 3.4a-b.

Altitude ranged from five metres above sea level to 30 m, with the majority of sites 10-15 metres above sea level. Four sites (1-4) had predicted annual rainfalls of less than 1500 mm, with most sites between 2000 and 2300 mm. Three sites were predicted to register more than 3000 mm annually (Sites 22-24).

Of the seven themes identified by Stanton and Godwin (1989), six were recorded during this survey. Fifty-four percent of the sites were classified as Theme 19 with Theme 13 the next most abundant (21%). No Theme 15 (*M. viridiflora* associated with *Dillenia alata* (Sol.ex Gaertn. DC) Martelli and *Carallia brachiata* (Lour.) Merr. was recorded.

Table 3.4(a) **Summary of site data.** Standard errors are given in parentheses where appropriate. Soil types after Cannon *et al.* (1992) and themes after Stanton and Godwin (1989).

[1] Plant community theme number.

[2] Soil type (C=Cudmore, Po=Porter, R=Rungoo, L=Lugger, T=Thorpe, M=Malbon & Pr=Prior). Duplex (texture contrast) soils are indicated with an asterisk. All other soils are gradational.

[3] Fire frequency (1=1 fire every year, 2=1 every 1-2 years, 3=1 every 5 years, 4=1 every 10 years and 5=1 every 20 years).

[4] Number of site visits.

Table 3.4(a) is presented on the next two pages. Overall site means are provided on page two of this table where appropriate.

Site	Latitude	Longitude	Altitude (m)	Annual rainfall (mm)	Theme[1]	Soil type[2]	Fire frequency[3]	Species richness	Sampling effort[4]
1	19° 06' 00"	146° 27' 00"	10	1351	13	C	3	30	2
2	19° 05' 06"	146° 18' 00"	10	1402	13	Po*	4	18	2
3	19° 05' 06"	146° 26' 00"	30	1394	13	C	3	38	1
4	19° 04' 00"	146° 26' 00"	15	1410	13	C	3	33	1
5	18° 16' 00"	146° 10' 30"	10	2320	19	R*	4	49	13
6	18° 14' 48"	146° 08' 00"	10	2300	19	R*	4	20	6
7	18° 16' 00"	146° 09' 30"	10	2301	13	R*	4	14	3
8	18° 16' 30"	146° 10' 18"	20	2310	18	R*	4	10	6
9	18° 16' 30"	146° 10' 24"	20	2310	18	R*	4	15	6
10	18° 16' 30"	146° 10' 12"	15	2311	19	L	4	14	6
11	18° 25' 30"	146°13' 30"	5	2205	16	T	4	16	2
12	18° 15' 06"	145° 58' 00"	10	2055	19	C	4	25	2

Site	Latitude	Longitude	Altitude (m)	Annual rainfall (mm)	Theme[1]	Soil type[2]	Fire frequency[3]	Species richness	Sampling effort[4]
13	18° 15' 18"	145° 58' 12"	10	2038	19	C	4	11	2
14	18° 15' 12"	145° 57' 48"	10	2055	19	C	4	17	2
15	18° 15' 18"	145° 57' 36"	10	2038	19	C	4	18	2
16	18° 30' 00"	146° 10' 48"	5	2144	19	T	4	17	3
17	18° 27' 30"	146° 09' 00"	5	2134	19	L	1	15	2
18	18° 20' 12"	146° 03' 42"	10	2099	19	Po*	2	13	1
19	18° 19' 42"	146° 02' 36"	15	2076	19	M	3	27	8
20	18° 11' 30"	145° 57' 06"	10	2163	14	R*	3	16	1
21	18° 10' 42"	145° 56' 12"	10	2147	19	Pr	3	24	1
22	17° 56' 00"	146° 01' 30"	10	3262	19	R*	3	15	2
23	17° 39' 30"	146° 39' 30"	10	3213	17	T	5	15	1
24	16° 13' 00"	145° 26' 30"	15	3515	18	L	3	11	1
Mean	-	-	11.9 (1.1)	2189 (110.3)	-	-	-	20 (2)	3 (1)

Table 3.4(b) **Summary of site data.** Standard errors are given in parentheses where appropriate.

[1] Number of individuals 500 m^{-2}

Table 3.4(b) is presented on the next two pages. Overall site means are provided on page two of this table where appropriate.

Site	Mean DBH (cm)	Mean height (m)	*M. viridiflora* > 1.5 m[1]	*M. viridiflora* < 1.5 m[1]	% *M. viridiflora* in canopy	*Xanthorrhoea johnsonii*[1]
1	8.6 (0.7)	9.2 (0.5)	54	341	74	107
2	13.1 (0.6)	13.3 (0.4)	46	89	98	14
3	10.8 (1.2)	10.0 (0.4)	85	45	97	0
4	13.7 (0.7)	12.5 (0.6)	32	330	86	0
5	19.3 (1.3)	5.9 (0.3)	128	158	99	504
6	19.2 (1.3)	4.9 (0.2)	107	84	98	705
7	5.0 (0.3)	4.0 (0.2)	88	79	72	540
8	4.3 (0.3)	3.3 (0.2)	53	154	95	175
9	5.9 (0.3)	4.2 (0.2)	142	154	96	725
10	13.2 (0.6)	9.5 (0.6)	55	94	74	30
11	7.6 (0.5)	6.2 (0.3)	114	44	71	139
12	10.4 (1.0)	7.3 (0.5)	43	75	77	242

Site	Mean DBH (cm)	Mean height (m)	*M. viridiflora* > 1.5 m[1]	*M. viridiflora* < 1.5 m[1]	% *M. viridiflora* in canopy	*Xanthorrhoea johnsonii*[1]
13	11.5 (0.8)	10.3 (0.2)	62	50	100	0
14	9.8 (0.7)	6.7 (0.5)	83	123	73	0
15	9.5 (0.4)	6.4 (0.2)	74	53	89	130
16	21.2 (1.6)	5.6 (0.4)	80	275	99	466
17	34.7 (1.9)	11.2 (0.4)	48	360	96	368
18	32.4 (1.8)	10.4 (0.4)	57	65	99	307
19	9.6 (0.6)	7.6 (0.5)	51	276	78	397
20	3.1 (0.1)	2.7 (0.1)	215	900	75	333
21	5.4 (0.4)	5.8 (0.3)	182	298	75	390
22	5.1 (0.3)	4.6 (0.2)	149	3	73	97
23	5.2 (0.2)	2.7 (0.7)	255	149	84	6
24	12.7 (0.8)	9.6 (0.4)	87	0	82	0
Mean	10.4 (0.2)	6.0 (0.1)	95 (12)	175 (39)	86 (2)	237 (47)

The seven soil types recorded during the survey were all derived from acid igneous rock (Cannon *et al.* 1992). Gradational soils were more predominant (63%) than duplex soils, although Cudmore (gradational) and Rungoo (duplex) series soils were equally abundant (30%).

Recent fire histories varied from annual fires at Site 17 to relatively low frequencies (Site 23), with most sites averaging a fire once every 5-10 years. This moderate fire frequency was particularly common for sites on HINP.

Community structure varied markedly for every parameter recorded. Average DBH was lowest at Site 20, low for two other groups of sites (7-9 and 21-23) and high at Sites 17 and 18. Mean tree heights largely reflected the trends exhibited by the DBH data, although several sites (5, 6 and 16) had very low tree heights despite relatively high mean DBH's.

The number of *M. viridiflora* individuals per 500 m^2 in the >1.5 m size class varied from 32 at Site 4 to 255 at Site 23. Understorey parameters (the number of *M. viridiflora* sprouts <1.5 m and Grasstrees) also had wide ranging densities. Canopy dominance of *M. viridiflora* was lowest at Site 11 (71%) and highest at Site 13 (100%). Species richness and sampling effort were not significantly correlated (Pearson correlation coefficient = 0.40, $p>0.05$). Sampling effort was particularly high at Site 5 as this was where detailed responses to prescribed and simulated fires were documented (Chapter 5).

The density of *Xanthorrhoea johnsonii* in the understorey also varied greatly across the range of sites examined. Whilst absent at some sites (Sites 3, 4, 13 and 14), this species reached very high densities at others (Sites 7 and 9) (Table 3.4b). Variations in soil type and fire history may account for some of the differences noted; the response of this species to fire is documented in more detail in Chapters 5 and 6.

3.3.2 Relationships between tree DBH and tree height

The data from all sites were pooled and initially suggested the existence of two main linear relationships (b~0.25 and b~0.7-calculated from a line of best fit analysis) with intercepts close to zero (Figure 3.4). Regression analysis results for each individual site and all sites pooled are presented in Table 3.5.

Figure 3.4 ***M. viridiflora* tree height (m) and DBH (cm) data for all study sites.** Approximate positions of main data trends are indicated with estimated regression lines.

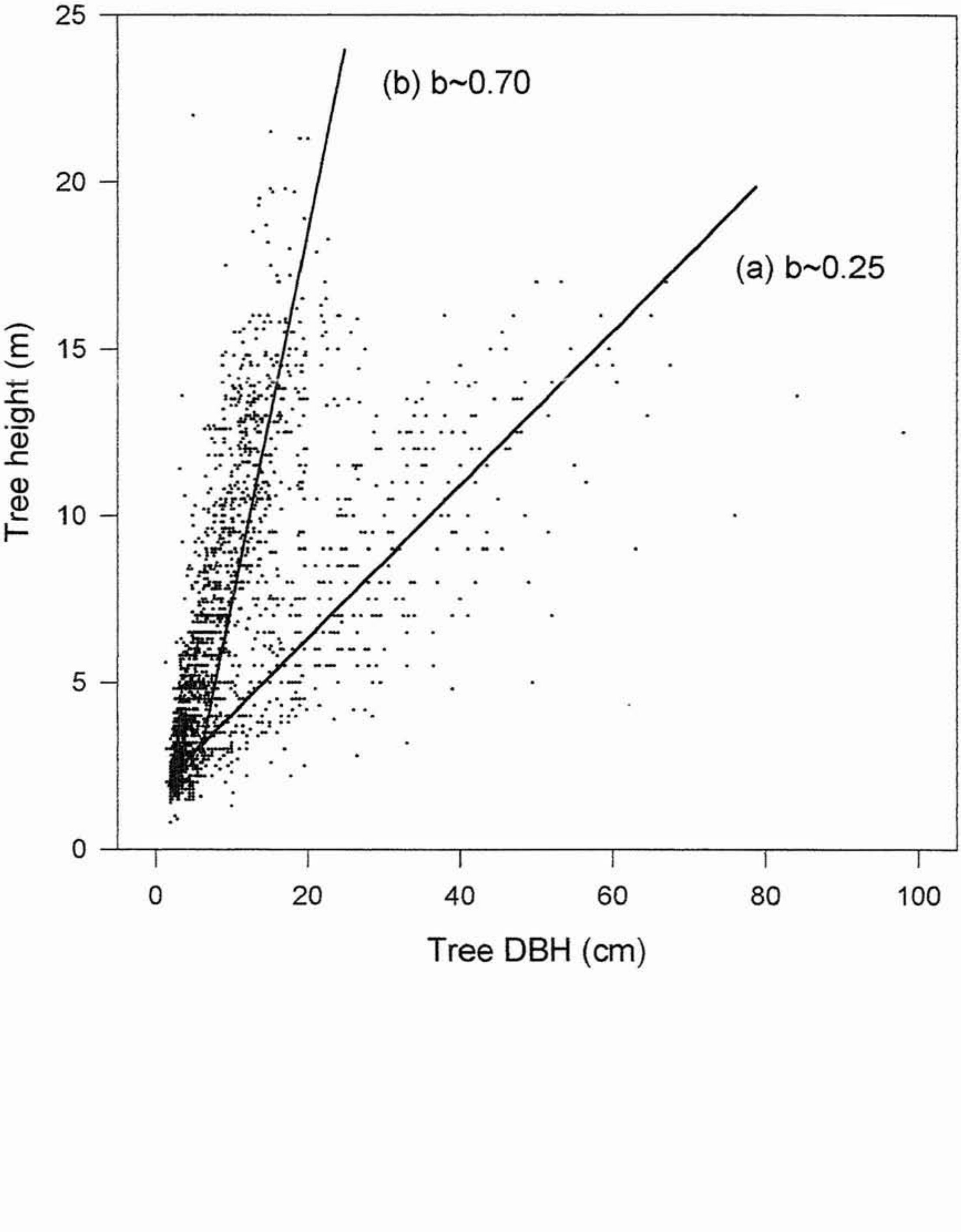

25
20
15
10
5
0
0
20
40
60
80
100
Tree height (m)
Tree DBH (cm)
(b) b~0.70
(a) b~0.25

Table 3.5 **Linear regression and Pearson correlation coefficient results for tree height (dependent variable) and tree DBH at each site (ie. height = a + bDBH where b=slope and a=intercept of the regression line).** All regressions and correlations were significant ($p< 0.000$).

	Regression				Correlation
Site	r^2	b	a	F	r
1	0.42	0.42	5.85	38.06	0.65
2	0.35	0.42	7.78	23.74	0.59
3	0.24	0.16	8.31	25.87	0.49
4	0.45	0.40	7.35	24.87	0.67
5	0.69	0.20	2.00	278.44	0.83
6	0.70	0.16	1.91	236.53	0.83
7	0.68	0.49	1.71	172.32	0.83
8	0.75	0.63	0.95	293.04	0.87
9	0.76	0.55	1.40	379.63	0.87
10	0.61	0.53	4.46	83.10	0.78
11	0.68	0.55	2.56	238.28	0.82
12	0.70	0.40	4.04	124.18	0.83
13	0.50	0.59	3.82	57.07	0.70
14	0.73	0.60	2.16	167.06	0.85
15	0.47	0.36	2.97	63.49	0.68
16	0.41	0.15	2.51	53.50	0.64
17	0.68	0.17	5.25	94.31	0.82
18	0.74	0.19	4.36	149.43	0.86
19	0.68	0.58	3.04	103.09	0.82
20	0.27	0.62	0.93	76.31	0.54
21	0.74	0.81	2.15	440.96	0.86
22	0.71	0.72	1.14	331.79	0.84
23	0.44	0.23	1.81	152.32	0.67
24	0.66	0.44	4.09	162.38	0.81
All data	0.35	0.23	4.07	1146.40	0.59

The slopes and intercepts of the regression equations varied markedly, with the regression coefficient lowest at Site 3 (r^2=0.24) and highest at Site 9 (r^2=0.76). The strength of the relationship was also highly variable, suggesting only trees at some sites increase height proportionally with diameter (e.g. Sites 5, 6, 17 & 18). Results from the ANCOVA are presented in Table 3.6. The relationship between DBH and tree height varied significantly between sites.

Table 3.6 **Analysis of co-variance (ANCOVA) results for the regression equations.** Significant results are highlighted in bold.

Source of variation	d.f.	F ratio	p
Co-variate	1	1641.49	**0.000**
Site	23	575.28	**0.000**

3.3.3 Community analyses of study sites

Species presence/absence data matrix

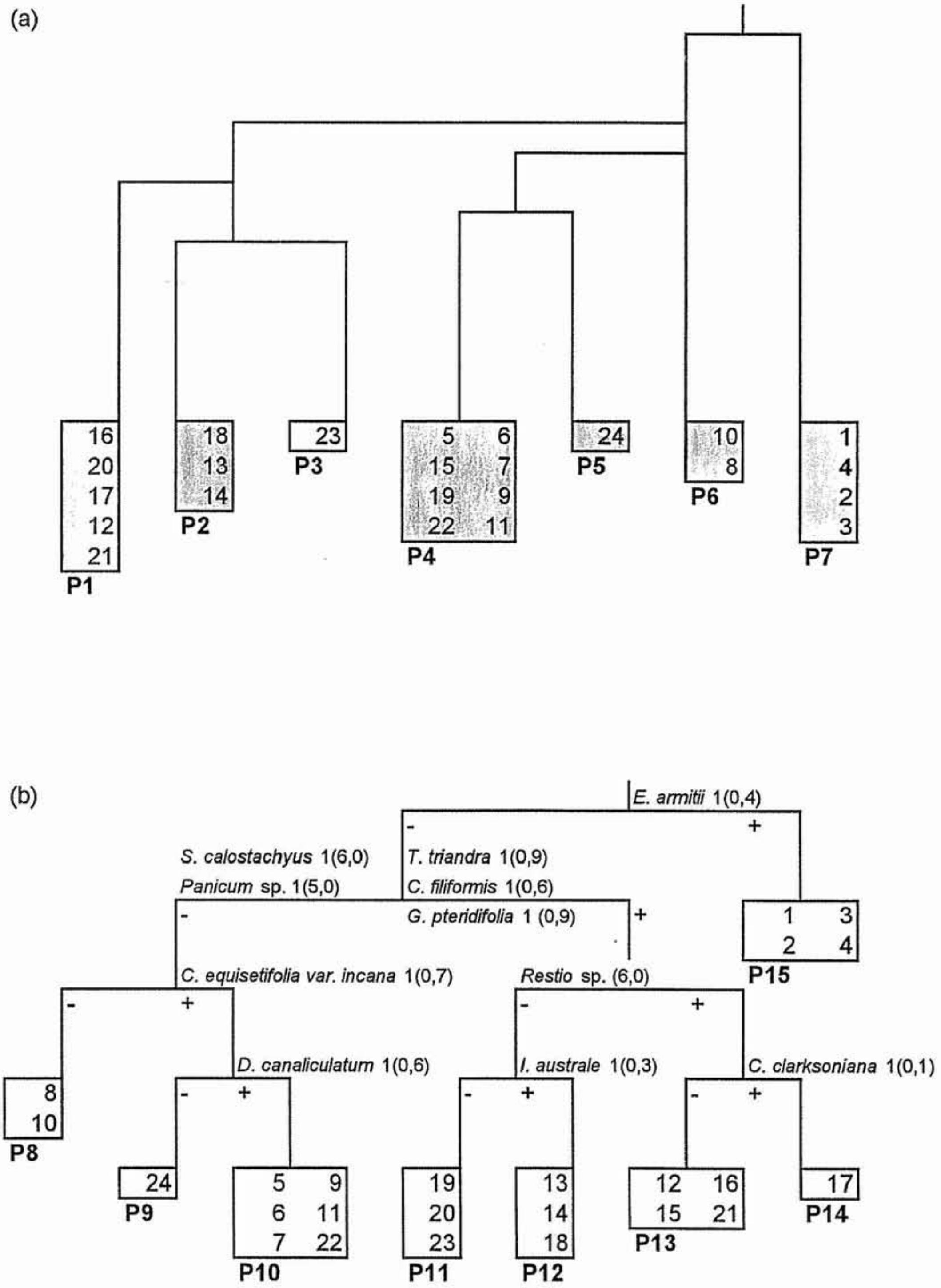
The reduced species presence/absence matrix utilised in the multi-variate analyses is presented in Appendix B. Results from the Bray-Curtis and TWINSPAN classification techniques are presented in Figures 3.5a and 3.5b respectively. The Bray-Curtis clustering technique produced seven groupings (P1-P7) and TWINSPAN eight (P8-P15). The two approaches generally produced similar groupings.

The initial Bray-Curtis division produced two groups, the first of which (P7) separated the four sites at the southern extreme of the WTBR (Figure 3.5a). These sites had few understorey native herbaceous species and midstorey shrubs. Native grasses and introduced pasture species dominated the understorey, contributing to a high species richness at Sites 3 and 4. These four sites shared several species in common, including *Themeda triandra* Forsskal (Kangaroo grass), *Dendrobium canaliculatum* (Tea-tree orchid), *Pandanus* sp. and

Figure 3.5 **Classifications of the species presence/absence data.**

(a) **Classification of the species presence/absence data matrix utilising the Bray-Curtis association measure.** End groups of sites are identified by codes (P1-P7). Groups of sites and their respective colours have been used to show the similarity of the SSH ordination results in Figure 3.6a.

(b) **Classification of the species presence/absence data matrix utilising TWINSPAN.** Cut levels of 0 and 1. Indicator taxa, their abundance level and number of sites at which they occurred are given at each division. End groups of sites are identified by codes (P8-P14).


(a)
16
20
17
12
21
P1
18
13
14
P2
23
P3
5
6
15
7
19
9
22
11
P4
24
P5
10
8
P6
1
4
2
3
P7
(b)
E. armitii 1(0,4)
-
+
S. calostachyus 1(6,0)
Panicum sp. 1(5,0)
T. triandra 1(0,9)
C. filiformis 1(0,6)
G. pteridifolia 1 (0,9)
-
+
1
3
2
4
P15
C. equisetifolia var. incana 1(0,7)
Restio sp. (6,0)
-
+
-
+
D. canaliculatum 1(0,6)
I. australe 1(0,3)
C. clarksoniana 1(0,1)
8
10
P8
-
+
-
+
-
+
24
P9
5
9
6
11
7
22
P10
19
20
23
P11
13
14
18
P12
12
16
15
21
P13
17
P14

a species of wattle. Conversely, the absence of species present at many other sites including *Casuarina equisetifolia* L. var. *incana* (Benth.) L.Johnson, *Dianella* spp. and a range of other herbaceous species was also a noticeable feature of this first group. The TWINSPAN classification also distinguished these sites from all others based on the presence of the grass *Eriachne armitii* Benth. (Figure 3.5b).

The second group from the first Bray-Curtis division included Sites 8 and 10 (P6). These sites are at the two extremes of the soil moisture gradient investigated in Chapter 4. It is therefore interesting that despite significant differences in terms of soil moisture, the sites are grouped according to species presence/absence. Similarly, the TWINSPAN classification grouped these sites (P8-after three divisions) based upon the absence of the sedge *Schoenus calostachyus* (R.Br.) Poiret, a species of Panic grass and the tree *Casuarina equisetifolia* var. *incana* (Figure 3.5b).

The next Bray-Curtis division produced a further two groups (Figure 3.5a). The first of these (P5) contained only one site, the most northern site investigated during this project (Site 24). This site had an understorey almost completely dominated by the giant sedge *Gahnia sieberiana* Kunth and *Melastoma affine* D.Don. Apart from other canopy trees (the most unusual being *Dillenia alata* which was only recorded from one other site, on HINP (Site 11), few other species were recorded. The second group (P4) contained eight sites, including all the remaining sites located on HINP (Sites 5, 6, 7 and 9). Three mainland sites were also included in this group, two from the Cardwell region and the only one investigated in the Mission Beach region. The TWINSPAN classification also placed site 24 on its own (P9), separated from six other sites at the fourth division based on the absence of the Tea-tree orchid *Dendrobium canaliculatum*. The six sites that comprise P10 were all contained within a similar grouping produced by the Bray-Curtis approach (P4). Apart from Site 22 (located at Mission Beach), all sites were located on HINP.

The final division of the Bray-Curtis classification produced three groupings (P1-P3), with P1 relatively similar to P2. The P1 group contained the majority of mainland sites in the Cardwell region, with the remainder in P2. The P3 group contained a single site (Site 23) which was the only one situated on an old sand dune system. Furthermore, this site was located near Cowley Beach, nearly 100 km to the north of Cardwell. Although this site contained no unique species, it had several (including *Melaleuca nervosa* (Lindley) Cheel) that were only documented at one other site. The TWINSPAN analysis produced a group identical to P2 (P12) at the fourth division based upon the presence of the grass *Ischaemum australe* R.Br. The P11 group matched none of those from the Bray-Curtis classification, whilst P13 contained three of the five members of the P1 group. Site 17 stood alone in the TWINSPAN classification based on the presence of *Corymbia clarksoniana* (D.J. Carr. & S.G.M. Carr) K.D. Hill & L.A.S. Johnson (previously *Eucalyptus clarksoniana* D.J. Carr & S.G.M. Carr), which separated it from those sites in group P13 (Sites 12, 15, 16 and 21).

The groupings defined by the Bray-Curtis classification were re-iterated by a plot of the first and second vectors from the ordination of the presence/absence data (Figure 3.6a). Some overlap occurred between the P1 and P4 groupings of the classification, particularly Sites 16 and 19. These sites are both on the mainland and, although on different soil types, experience relatively infrequent fires. Soil types (especially gradational and duplex soils when pooled) and fire history did not produce distinct patterns when overlaid on the ordination (Figures 3.6b and 3.6c respectively). Rungoo soils tended to clump together with Cudmore soils predominantly falling to the left of the origin for Vector 1.

Sites with fire histories of 1/5 or 1/10 years formed a large group. Interestingly, although Sites 23 and 17 are very close together in the ordination space, they actually have the most different recent fire histories. Rainfall data overlaid on the species presence/absence ordination produced some more definitive groupings (Figure 3.6d). High rainfall sites (Sites 22, 23 & 24) were arranged in a diagonal, linear fashion. Nearly all sites with either moderate or moderate-high rainfall fell below this diagonal and low rainfall sites above it. The exceptions to this were two sites with moderate-high rainfall (Sites 8 and 10) which formed a separate group above the linear diagonal.

*DBH size class data matrix (*M. viridiflora *data only)*

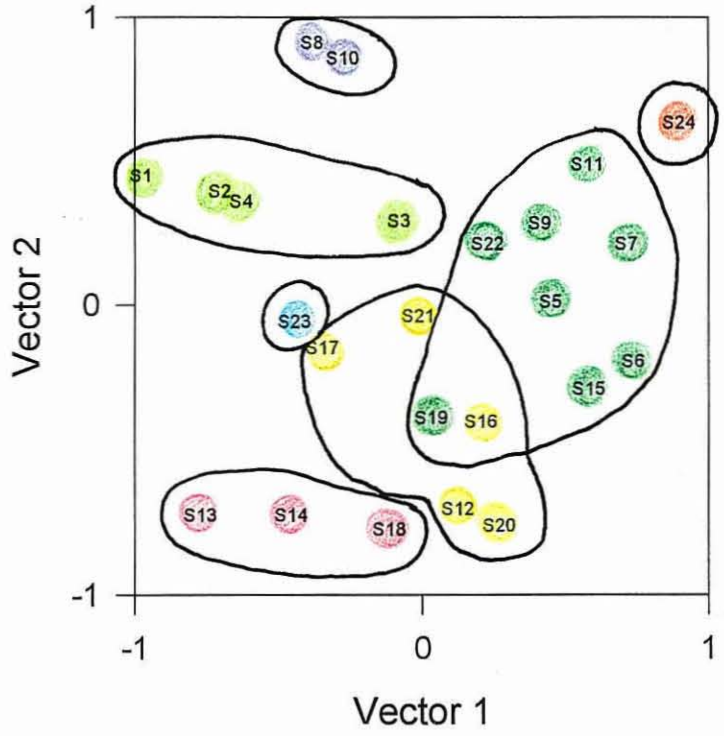
The DBH data matrix is presented in Appendix C. The Bray-Curtis and TWINSPAN classifications of DBH size class data are presented in Figures 3.7a and 3.7b respectively. The former analysis produced six species groups whilst the latter produced seven. In both cases the first group to separate was that containing Sites 17 and 18 (D6 and D13).

Figure 3.6 **Ordination of presence/absence data by SSH, Vector 2 vs. Vector 1 (S = site).**

(a) Sites (colours taken from groupings produced by Bray Curtis classification of species presence/absence data, Figure 3.5a)

(b) Sites with soil types (by colour) superimposed (C=Cudmore, Po=Porter, R=Rungoo, L=Lugger, T=Thorpe, M=Malbon & Pr=Prior)

(a)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S10
S24
S1
S2
S4
S3
S11
S9
S22
S7
S5
S23
S21
S17
S6
S15
S19
S16
S12
S20
S13
S14
S18
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-1
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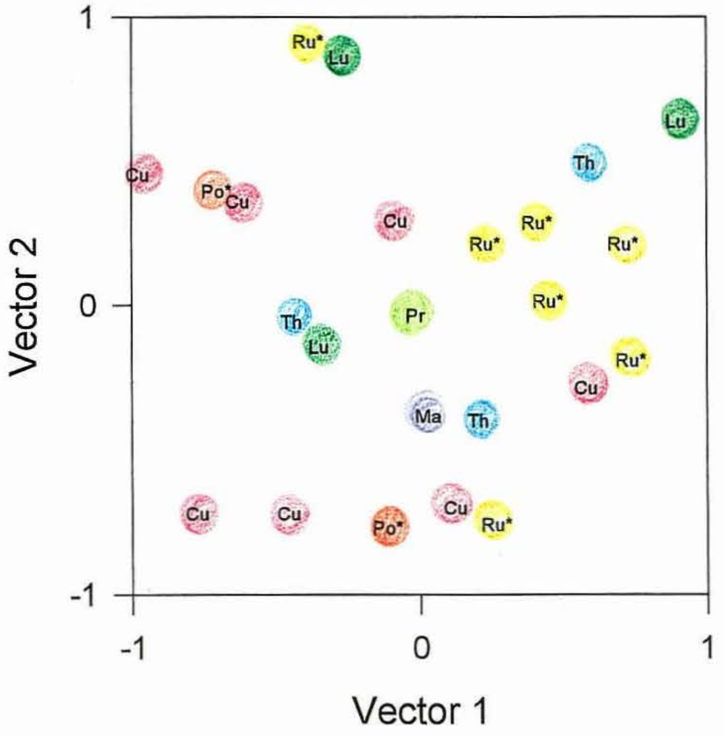
Vector 2
Vector 1

(b)


Ru*
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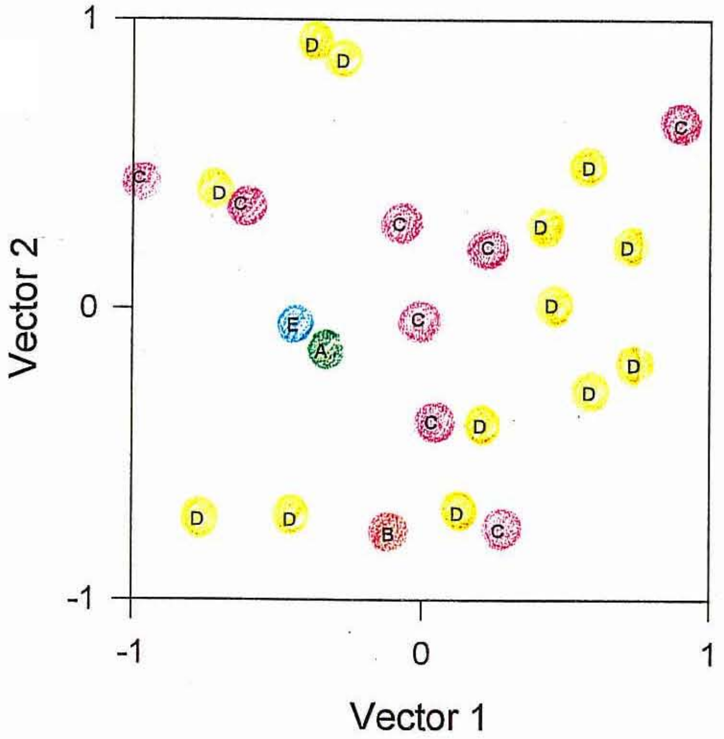
Cu
Cu
Po*
Cu
Ru*
1
0
-1
-1
0
1
Vector 2
Vector 1

Figure 3.6 Ordination of presence/absence data by SSH, Vector 2 vs. Vector 1 (S = site).

(c) Sites with fire frequency (by colour) imposed (A=1 fire every year, B=1 every 1-2 years, C=1 every 5 years, D=1 every 10 years and E=1 every 20 years).

(d) Sites with rainfall (by colour) superimposed (L=low: 1300-1700 mm, M=moderate: 1701-2100 mm, MH=moderate-high: 2101-2300 and H=high: > 2300).

(c)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-1
0
1
D
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C
C
D
C
C
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C
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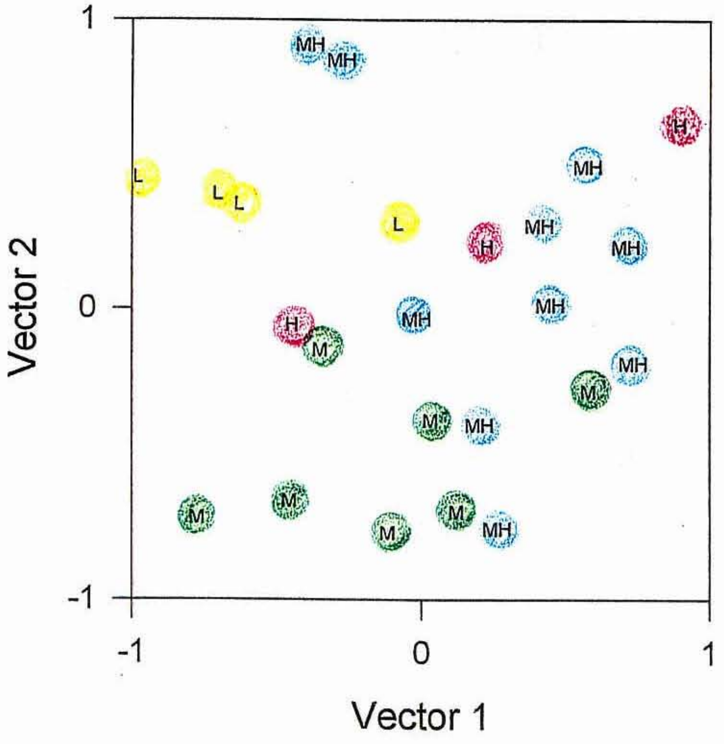
D
D
B
C

(d)


Vector 2
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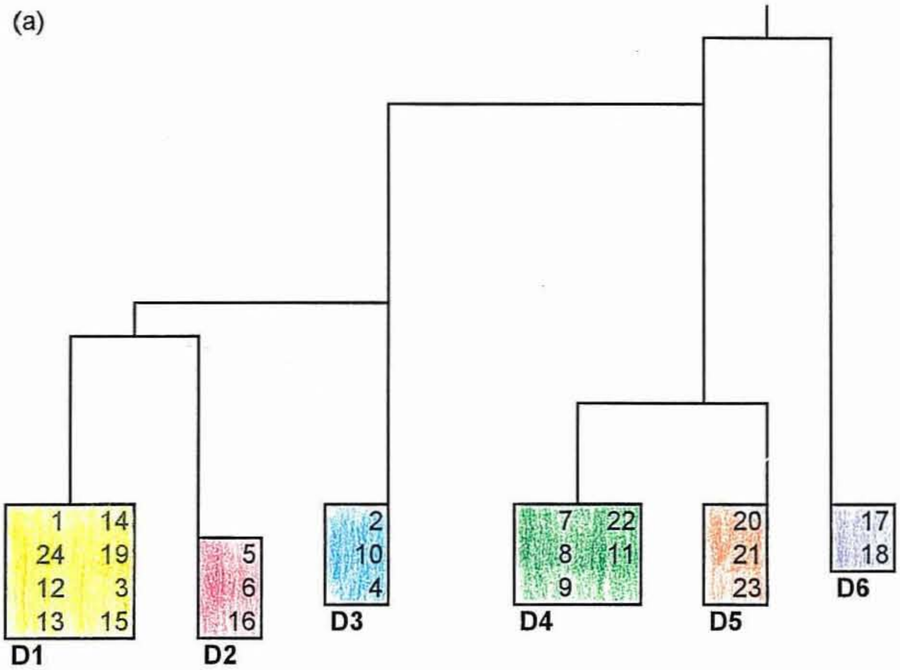
MH

Figure 3.7 **Classifications of the DBH size class data matrix.**

(a) **Classification of the *M. viridiflora* DBH size class data matrix utilising the Bray-Curtis association measure.** End groups of sites are identified by codes (D1-D6). Groups of sites and their respective colours have been used to show the similarity of the SSH ordination results in Figure 3.8a

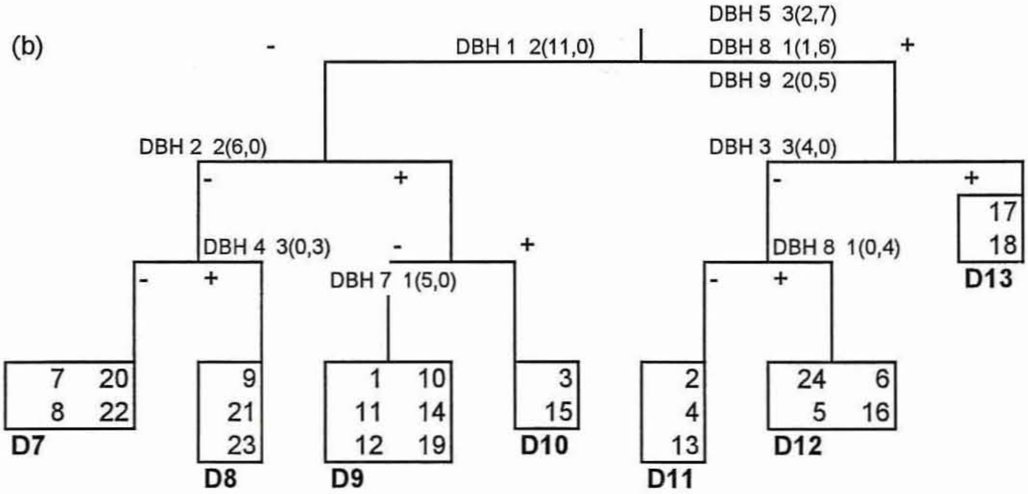
(b) **Classification of the *M. viridiflora* DBH size class data matrix utilising TWINSPAN.** Cut levels of 0, 5, 10, 20, 30 and 50. Indicator groups, their frequency and the number of sites at which they occurred are given at each division. End groups of sites are identified by codes (D7-D13).

(a)



1 14
24 19
12 3
13 15
D1
5
6
16
D2
2
10
4
D3
7 22
8 11
9
D4
20
21
23
D5
17
18
D6

(b)



DBH 5 3(2,7)
-
DBH 1 2(11,0)
DBH 8 1(1,6)
+
DBH 9 2(0,5)
DBH 2 2(6,0)
DBH 3 3(4,0)
-
+
-
+
DBH 4 3(0,3)
-
+
DBH 8 1(0,4)
17
18
D13
-
+
DBH 7 1(5,0)
-
+
7 20
8 22
D7
9
21
23
D8
1 10
11 14
12 19
D9
3
15
D10
2
4
13
D11
24 6
5 16
D12

These sites had the highest recent fire frequencies and lacked any individuals in the DBH 1 category (< 2 cm), had one each in the DBH 2 category (2-5 cm) and frequencies less than 10 for all other categories except DBH 7 (26-30 cm) and DBH 8 (31-35 cm). The woodland structure is therefore simple, characterised by varying densities of sprouts and high mean DBH's (Table 3.4b).

The first division of the Bray-Curtis classification also separated eight other sites which eventually split into two groups of five and three sites respectively (D4 and D5). Group D4 contained four of the six HINP sites, which had very similar soil types, annual rainfall totals and fire histories (Table 3.4). Group D5 contained two sites near Edmund Kennedy National Park and the site at Cowley Beach near Innisfail (Site 23). Despite being situated on a range of soil types, all three sites had low tree heights and DBH's (Table 3.4b). The TWINSPAN classification also separated seven of these sites (second division) based upon a lack of individuals in the DBH 2 category. The group was then further divided depending on the presence or absence of individuals in the DBH 4 (11-15 cm) category. These final two groups (D7 and D8) were very similar to those of the Bray-Curtis classification (D4 and D5).

The second division of the Bray-Curtis classification separated Sites 2, 4 and 10 (D3, Figure 3.7a) from the remainder. Two of these sites are in the southern section of the WTBR (Sites 2 and 4), with the third (Site 10) located on HINP at the end of a soil moisture gradient (high moisture) investigated in Chapter 4. TWINSPAN produced a similar grouping (but here Site 13 replaces 10) based on the absence of DBH 8 (31-35 cm) at the third division (D11, Figure 3.7b). The positive side of this division (D12) forms a grouping nearly identical to one of those from the final division of the Bray-Curtis classification (D2). Sites 5, 6 and 16 are identical themes identified by Stanton and Godwin (1989). Furthermore, they have identical fire histories and very similar mean DBH's, heights and soil types (Tables 3.4a-b).

The remaining eight sites from the Bray-Curtis classification (D1) are a similar group to those produced at the third division of TWINSPAN based upon the presence or absence of DBH 7 (26-30 cm) (D9 and D10). Group D 1 contains a diverse group of sites from either end of the WTBR, that belong to different themes and with very different soil types and fire histories (Table 3.4a).

The SSH ordination produced groups identical to those of the Bray-Curtis classification (Figure 3.8a). Cudmore and Rungoo soil types were grouped together, with less pattern evident for other soil types (Figure 3.8b). Fire histories were well separated when overlaid on the ordination vectors (Figure 3.8c). Sites experiencing recent fire frequencies of either 1/5 or 1/10 years were grouped together, with those having lower or higher frequencies positioned on either side of the ordination space. Discernible patterns were less evident when the total annual rainfall data was superimposed on the ordination space (Figure 3.8d). Although some grouping of moderate and moderate-high sites occurred, sites with either low or high rainfall did not group particularly well.

3.3.4 Variation in community parameters among classification/ordination groups

As the results from the two classification procedures and the subsequent SSH ordinations for both the species presence/absence and DBH size class analyses were very similar, the following results refer only to the Bray-Curtis classification groupings.

Species presence/absence data matrix

Species richness did not differ significantly among the classification groups ($p=0.19$), but predicted total annual rainfall based on latitude, longitude and altitude did ($p<0.001$) (Table 3.7). The four southern WTBR sites (Group P7) were significantly different in terms of rainfall from all other groups (Table 3.8). Group P3 (Site 23 near Cowley Beach, Innisfail) was separated from the majority of mainland sites in the Cardwell region (P2 and P1), and Site 24 (closest to Cooktown) was statistically different to all other sites except Site 23.

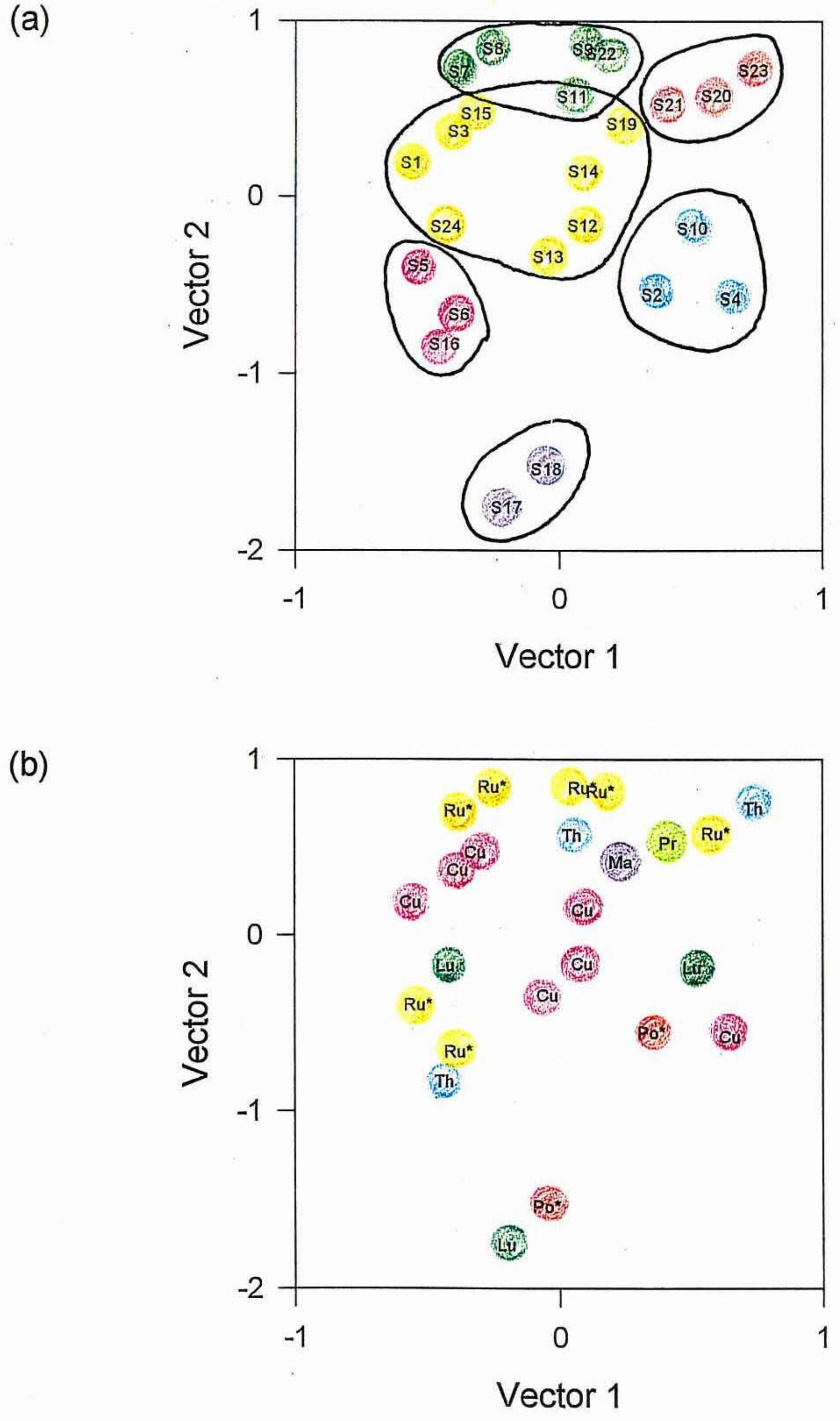
DBH size class data matrix

The results of the one-way ANOVA on the site DBH data statistically confirmed the groupings formed in the Bray-Curtis classification (Table 3.9). Group P6 was significantly different to all other groups, with Groups 2 and 3 also statistically removed from Group 1 (Table 3.10). No significant difference was recorded between Groups D4 and D5, which are located adjacent to each other in the classification dendrogram (Figure 3.8a). Rainfall did not vary significantly between the site groupings (Table 3.9).

Figure 3.8 **Ordination of the *M. viridiflora* DBH size class data by SSH, Vector 2 vs. Vector 1 (S = site).**

(a) Sites (colours taken from groupings produced by Bray Curtis classification of species presence/absence data, Figure 3.7a)

(b) Sites with soil types (by colour) superimposed (C=Cudmore, Po=Porter, R=Rungoo, L=Lugger, T=Thorpe, M=Malbon & Pr=Prior)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S20
S15
S3
S19
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S24
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S13
S10
S5
S2
S4
S6
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S18
S17
(b)
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Vector 1
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Ru*
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Ma
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Lu
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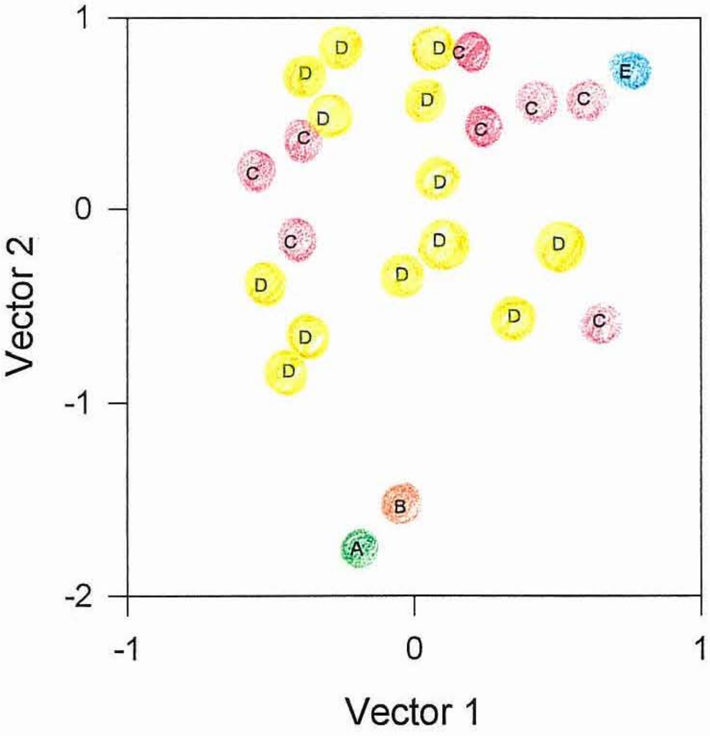
Lu
Cu
Ru*
Po*
Cu
Ru*
Th
Po*
Lu

Figure 3.8 **Ordination of the *M. viridiflora* DBH size class data by SSH, Vector 2 vs. Vector 1 (S = site).**

(c) Sites with fire frequency (by colour) imposed (A=1 fire every year, B=1 every 1-2 years, C=1 every 5 years, D=1 every 10 years and E=1 every 20 years).

(d) Sites with rainfall (by colour) superimposed (L=low: 1300-1700 mm, M=moderate: 1701-2100 mm, MH=moderate-high: 2101-2300 and H=high: > 2300).

(c)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C
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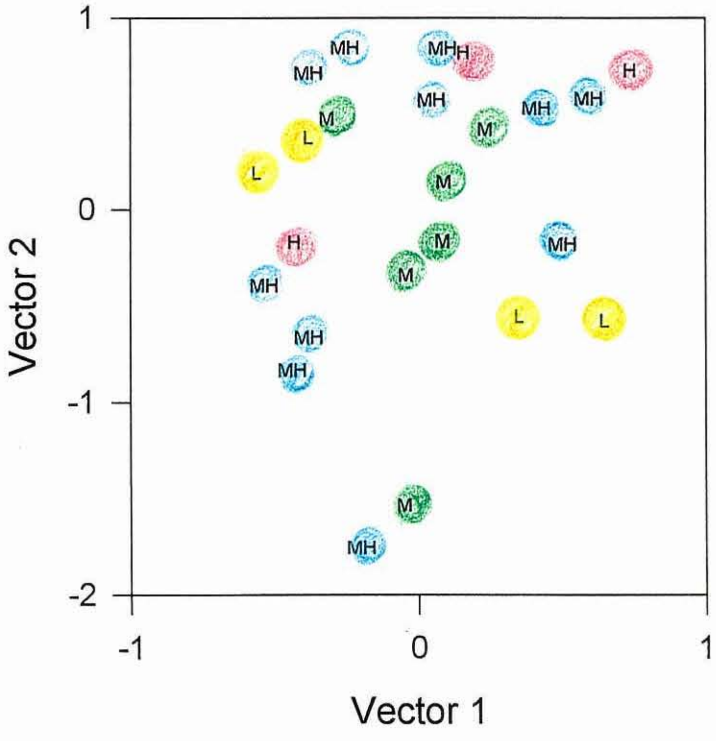
D
B
A

(d)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MH

Table 3.7 **Results of one-way ANOVA's of Bray-Curtis classification groupings with species richness and predicted total annual rainfall.** F ratios and their significance are listed. For significant results ($p \leq 0.05$ and highlighted in bold), multiple comparison test data (Tukey's-HSD) are presented in Table 3.9.

Variable	d.f.	F ratio	p
Species richness	6	1.65	0.19
Rainfall	6	15.39	**<0.001**

Table 3.8 **Results of a Tukey-HSD multiple comparison test for the Bray-Curtis species presence/absence classification groups and predicted total annual rainfall** (*significant difference, $p < 0.05$).

Mean (mm)	Group	P7	P2	P1	P6	P4	P3	P5
1389	P7	-						
2064	P2	*	-					
2128	P1	*		-				
2310	P6	*			-			
2351	P4	*				-		
3213	P3	*	*	*			-	
3515	P5	*	*	*	*	*		-

Table 3.9 **Results of one-way ANOVA's of Bray-Curtis classification groupings with site DBH data and predicted total annual rainfall.** F ratios and their significance are listed. For significant results (p≤0.05 and highlighted in bold) multiple comparison test data (Tukey's-HSD) are presented in Table 3.10.

Variable	d.f.	F ratio	p
DBH (cm)	5	415.49	**<0.001**
Rainfall (mm)	5	1.09	0.40

Table 3.10 **Results of a Tukey-HSD multiple comparison test for Bray-Curtis classification groupings and site DBH data** (*significant difference, p≤0.05).

Mean (cm)	Group	D5	D4	D1	D3	D2	D6
4.50	D5	-					
5.68	D4		-				
10.45	D1	*	*	-			
13.31	D3	*	*	*	-		
19.71	D2	*	*	*	*	-	
33.41	D6	*	*	*	*	*	-

3.4 DISCUSSION

The sites examined during this investigation varied considerably across the range of parameters recorded. Even sites considered relatively adjacent at the landscape scale sometimes exhibited marked differences in either species composition, species richness, community structure attributes, soil type or fire history. Sites essentially formed a continuum between the two extremes of this vegetation type described by Gillison and Walker (1981). Their stunted, twisted woodland (3-7 m) was recorded at several sites (Sites 7-9 and 20-23), and their "pole" forest-like community (18-20 m) at Site 10. Despite this variation in community structure, general trends in the data emerged. These are discussed in more detail below.

Plant species have long been known to form distribution patterns with respect to environmental gradients such as rainfall (Kershaw & Looney 1985). This was re-iterated in this study, with species composition of the woodlands providing a basis for classifying the study sites into five major groups. Two sites in the more northern section of the WTBR stood alone (Figure 3.5a), with the sites with the lowest predicted annual rainfall separated from the majority in the central section of the WTBR. Sites also tended to group into onshore and offshore sites in both the classification and ordination analyses (although this and other recorded similarities between the classifications and ordinations is 'comforting', they may to some degree reflect the sampling scale, the use of presence/absence data and the concentration of DBH data into too few size classes).

Following the separation of southern WTBR sites, the next primary split in the species classification analysis was, interestingly, based upon the presence of *Grevillea pteridifolia* J.Knight (and others), and in subsequent splits based upon *Casuarina equisetifolia* var *incana.* Tracey (1982) noted that both these species were indicative of disturbance in *M. viridiflora* communities. The *Casuarina* formed small but often quite dense thickets in these woodland communities, sometimes resulting in the localised exclusion of the Tea-tree. The *Grevillea* was more predominant in mainland sites, particularly where roads were close and fires relatively recent or frequent.

Although some patterns emerged with other site data superimposed on the species presence/absence ordination (fire history and soil type), these appeared to be much less distinctive. Difficulties in classifying soil types from samples collected by augur are well documented, with this method one of the least preferred for site classification (Walker & Hopkins 1990). The isolation of many sites, coupled with the number investigated precluded any more detailed methodologies (e.g. relatively large open pits) being employed. Furthermore, many of the characteristics used to distinguish the main soil types (gradational and duplex) are readily observed in auger samples. Accurately assessing the extent of these characteristics is, however, difficult. In addition, lowland soils are widely acknowledged as being highly variable over short distances (Mr M. Cannon, pers. comm.). This could result in a woodland community actually being situated on several variations of a given soil series, making classification of a site difficult at best. Future work could target this problem and ensure the soil types adopted here are accurate.

Similarly, the accuracy of the fire history data is likely to be variable. Whilst some histories were obtained from records kept on conservation reserves, many were formulated solely from discussion with land owners. The lack of accurately recorded fire histories has frustrated other researchers in tropical ecosystems (Bowman 1992), and remains a major obstacle to improved fire management of conservation reserves. An early attempt at fire dating using *Xanthorrhoea johnsonii* stem tissue scars proved unsuccessful and, furthermore, this species was not recorded at all sites. This method has been shown to be a useful method for determining past fire histories by researchers in more temperate systems (Gill & Ingwersen 1976; Bulow-Olsen *et al.* 1982). Fire history and soil type may interact with climate making detection of pattern with respect to single variables difficult. Furthermore, it is important that classification schemes are based not only on the species present, but also on measures of abundance, distribution, size and vigour (Kershaw & Looney 1985).

The most striking result from the multi-variate analyses of the structural data was the separation of those sites with annual fire regimes (Sites 17 and 18). These sites have a collective total of only 10 *M. viridiflora* individuals in the first four DBH size classes. Modal frequencies occur in the largest DBH size class (Appendix C), with moderate numbers of sprouts in the understorey. In comparison, sites with lower fire frequencies have typical bell shaped distributions across the size classes (e.g. Sites 1, 3, 6 and to a lesser extent Sites 13 and 16, Appendix C). The only other published data on the structure of similar *Melaleuca* communities also recorded a bell shaped curve and, importantly, the community had remained unburnt for at least 20 years (Finlayson *et al.* 1993). The structure of frequently burnt communities suggests that recruitment of a midstorey (and in the long-term canopy) is being prevented. This has drastic implications for the longevity of these communities and represents a large management challenge as the sites are both located outside the existing conservation reserve system.

These sites provide an ideal opportunity for future assessment, particularly if management practices can be altered. This would allow repeated monitoring to determine if a cohort of individuals can survive to the midstorey and beyond. Alternatively, if management practices are not adjusted, what is the long-term fate of these sites? Perhaps a change to grassland or alternatively woodland dominated by other species will occur. These could include species that are sometimes recorded naturally in these communities and are also known to become more prevalent following disturbances including fire (e.g. *Grevillea pteridifolia*, Tracey 1982).

The seven themes of *M. viridiflora* woodlands identified by Stanton and Godwin (1989), although taking into account soil type and a degree of floristic information, make no allowance for an assessment of community structure. This is also absent from any other floristic (e.g. Specht *et al.* 1995) or qualitative classification (e.g. QDEH 1995a) of plant community conservation status relevant to the WTBR. Specht *et. al.* (1995) consider that conservation of these open woodlands in Australian is adequate (the highest rating), whilst locally they are considered vulnerable (QDEH 1995a).

This research highlights the extensive variation in species composition and community structure exhibited by these communities, many of which have disappeared from localised areas of the landscape in the past 50 years (see Chapter 2). Although some sites are in fact situated within the existing conservation system (especially within HINP), many remain unprotected examples of either different species assemblages or structural types, which may in fact represent different successional stages of the same community type or theme. Wilson (1996) has highlighted the need some faunal groups have for structural diversity within habitat types, a parameter he considered essential for biodiversity conservation. As recently as 1989, Themes 16 and 19 (accounting for more than half of the study sites investigated) remained poorly protected in the conservation reserve system (Stanton & Godwin 1989). This situation persists in 1996 (Mr P. Stanton, pers. comm.). Until a more comprehensive range of the variation documented here becomes protected within conservation reserves and managed holistically across the landscape, the conservation status of these woodlands will remain well below ideal.

Past research efforts coupled with those of this study have recorded more than 300 plant and animal species from *M. viridiflora* open woodlands, with a further 12 orders of leaf and soil macro-invertebrates not identified to the species level (Table 3.3). This high biodiversity further underlines both the importance of these woodlands as an integral component of the

WTBR lowland habitat mosaic, and the urgent need to improve their current conservation status.