

12 JAN 1994

**HEALTH AND STRUCTURE OF *EUCALYPTUS*  
COMMUNITIES ON CHOWILLA AND  
MONOMAN ISLANDS OF THE  
RIVER MURRAY FLOODPLAIN,  
SOUTH AUSTRALIA**

by

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Divisional Report 93/3  
CSIRO  
Institute of Natural Resources and Environment  
Division of Water Resources

August 1993

**National Library of Australia Cataloguing-in-Publication Entry**

Health and structure of Eucalyptus communities on Chowilla  
and Monoman Islands of the River Murray floodplain, South  
Australia.

ISBN 0 643 05551 7.

1. Eucalyptus - South Australia - Renmark Region - Ecology.
  2. Eucalyptus - Murray River (N.S.W. - S. Aust.) - Ecology.
- I. Eldridge, Stephen R. II. CSIRO. Division of Water  
Resources. (Series : Divisional report (CSIRO. Division of  
Water Resources); 93/3).

583.420994233

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## ABSTRACT

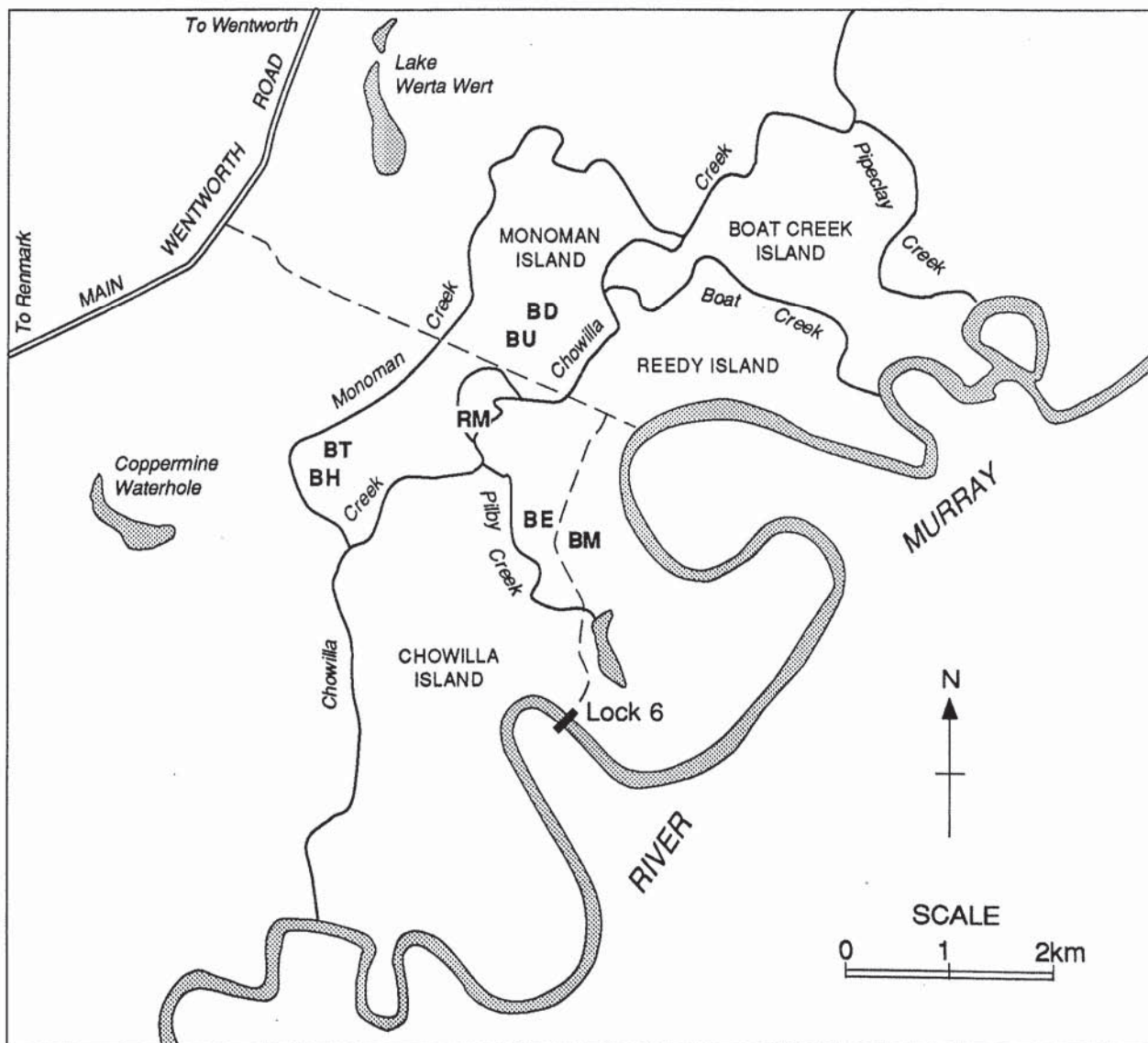
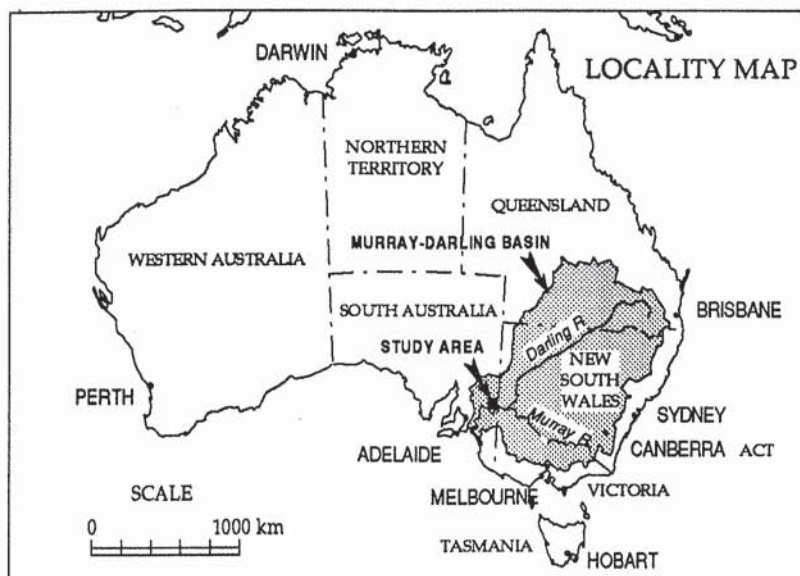
Considerable variation exists in the health and structure of *Eucalyptus largiflorens* (black box) communities in the Chowilla anabranch region of the River Murray floodplain, near Renmark in South Australia. This project quantified black box health and structure at seven sites on part of the floodplain, and provided an initial investigation into causes of the variation. The sites included a range of black box health states and landform types. A site supporting *E. camaldulensis* (river red gum), another common eucalypt on the floodplain, was included for comparison with the black box.

On a 4 (dead) to 20 (healthy) point scale, black box health varied from 4 to 16. The healthier black box communities were classified as closed forests, with the less healthy being woodlands or, where trees were dead, grasslands.

Relationships were found between health and environmental characteristics such as soil chloride concentration, soil osmotic and matric suction, groundwater salinity and pre-dawn leaf water potential, suggesting that high soil salinities present on the floodplain are affecting tree health by increasing the soil water suction, causing water stress in the trees. The causes of variation in health may be more complex however, as health and soil salinity were also related to site elevation, which determines the frequency of inundation by flood waters.

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**Fig. 1.** Location of the study area, and the seven sites.

## 1. INTRODUCTION

Two tree species are dominant on the floodplain of the River Murray in the Chowilla anabranch region, South Australia; *Eucalyptus largiflorens* (black box) and *E. camaldulensis* (river red gum). Variation in health and structure within these communities, particularly in black box communities, has already been observed (Hollingsworth *et al.* 1990; Eldridge 1991). Whereas in some areas black box is in good health with a dense canopy, in others the trees are either in a state of severe decline or dead. Soil and water characteristics, e.g. groundwater depth and salinity, soil chloride concentration and flood frequency, also vary widely throughout the floodplain, and have

previously been associated with eucalypt health and structure in the region (Eldridge 1991; Jolly *et al.* 1992).

This project aimed, firstly, to describe the health and structure of black box and red gum communities in an area of the Chowilla floodplain in which previous hydrological (Jolly *et al.* 1991 and 1993; Thorburn *et al.* 1993) and ecological (Thorburn *et al.* 1992; Thorburn and Walker 1993; Mensforth *et al.* 1993) studies had been conducted. Secondly, the project aimed to determine the causes of the health and structure variation in the black box trees at these sites, by comparing these parameters with soil and plant physiological factors.



## 2. MATERIALS AND METHODS

### 2.1 Study Area

The sites were located on Monoman and Chowilla Islands (Fig. 1), and were specifically selected to include a range of black box health conditions and landform types. On Monoman Island, two sites supported apparently healthy black box (sites BT and BM) and two supported unhealthy or dead black box (sites BU and BD). For both healthy and unhealthy vegetation, one site of each pair was of relatively high elevation (sites BH and BD) and one was of relatively low elevation (Table 1). Black box at the two sites on Chowilla Island were also apparently healthy. These sites were in an area known as the 'flushed zone', where the rise in river level associated with Lock 6 (a weir situated immediately downstream of the study site on the River Murray, Fig. 1) has recharged the aquifer with fresh river water. The two sites in this area also had different elevations, one relatively high (site BM) and one low (site BE), similar to the sites on Monoman Island. Site RM, which supported red gum, was included for comparison with the black box. Generally, red gum is in good health in the area of this study.

### 2.2 Measurements

A quadrat of at least 400 m<sup>2</sup> was marked at each site and characteristics of the vegetation, soil and groundwater in the quadrat were measured.

The vegetation characteristics consisted of:

- Location in the quadrat
- Canopy type
- Percentage crown cover
- Foliage cover
- Structural formation
- Health
- Girth (over bark) at breast height
- Height and
- Leaf area

which were measured on all trees, and

Pre-dawn and midday water potential  
Foliar Na<sup>+</sup> and Cl<sup>-</sup> concentrations, and  
Sapwood area,

measured on selected trees. Tree diameter at breast height, tree sapwood area and plot leaf area index were then calculated from these measurements.

During the late 1930s and early 1940s many trees in the area were cut at ~40 cm above the ground for fire wood (Jack Seecamp, pers. comm.). These trees produced coppice shoots, and now generally have two to four narrower stems. Individual stems were treated separately for determination of diameter and sapwood areas; whole trees were considered for other parameters, i.e. height, health, canopy projection, etc.

The soil and groundwater parameters measured were:

- . Soil matric suction (the absolute value of matric potential)
- . Soil gravimetric water content
- . Soil and groundwater chloride concentration, and
- . Groundwater depth.

Osmotic potential of the soil solution was estimated from soil chloride concentrations (i.e. osmotic potential = 0.125 \* chloride concentration). This conversion assumed all salts were present in the soil as NaCl. The elevation of each site was also surveyed.

All parameters were measured in March and April 1992, and selected measurements were repeated in September 1992. Repeated measurements were made of variables likely to vary seasonally; tree health, pre-dawn and midday tree water potential, soil gravimetric moisture content and matric suction.

Further details of the measurement methods follow.



### 2.2.1 Vegetation

At each site the location of trees and shrubs was mapped. Tree height was also measured using a clinometer, measuring the angle of incline of the tree top relative to the ground.

Canopy type, percentage crown cover in each quadrat, and foliage cover in the quadrat were measured according to Walker and Hopkins (1990, Appendix A). Canopy type is a density measure of individual tree crowns, estimated by matching the actual tree crown with standard photographs given by Walker and Hopkins (1990). Crown cover percentage is the percentage of the quadrat area within the vertical projection of the periphery of the crowns. The estimation of crown cover percentage assumes an opaque crown and, to convert to foliage cover, requires that the crown type (density) be considered. Percentage foliage cover is equal to the product of percentage crown cover and crown type.

Vegetation type was derived from growth form and crown separation. Closed forest is defined as a community where the upper storey of vegetation consists of tree species whose crowns are touching or overlapping. In an open forest, crowns are touching or slightly separated, and in a woodland crowns are clearly separated. Percentage foliage cover is not used in the assignment of vegetation type. It is assumed that the vertical crown projection is opaque, and no consideration is made of the actual crown density.

The upper storey of vegetation was classified by the structural formation of its dominant species, using trinomial codes for growth form, height class, and crown separation (cover) class in that order (Appendix A). Structural formation classes of the upper storey of vegetation can be defined by the growth form and crown separation.

Health was measured using a four component scaling system, based on that described by Grimes (1987, Appendix B). This was used successfully in a previous study of black box dieback (Eldridge 1991). The index consisted of four components; crown size, crown density, epicormic growth and dead branches.

Each component was scored on a five point scale (1-5). The four scores were then summed to calculate the index of health. Health was scored in March and September to assess seasonal variation.

Sapwood area of ~7 trees at each site was measured by physically removing a small portion of the tree trunk at breast height with a hammer and chisel. The width of sapwood, the width of bark and the outer circumference of the trunk were then determined and used to calculate the sapwood area at breast height. Sapflow measurements had been previously used to determine the inner and outer boundaries of the sapwood. The outer boundary sapwood was taken as the cambium, while the inner boundary was marked by a colour change in the wood (from cream to dark red). Relationships between sapwood area and tree size were also determined. These were then used to estimate sapwood area of each tree within the quadrats. A 'sapwood area index' was then calculated for each site, as the ratio of the total sapwood area in a quadrat to the quadrat area.

Leaf area was measured using the 'Adelaide' method (Andrew *et al.* 1979). A single branchlet was chosen as a reference 'module', and the number of modules in the canopy of each tree was estimated. Leaf area of the reference module was then determined. From this, total leaf area at each site was estimated. Leaf area index was calculated by dividing the total leaf area in each quadrat by the quadrat area.

Leaf water potential was measured using a Scholander pressure-bomb (Scholander *et al.* 1969). Measurements were made prior to dawn, in the period of lowest diurnal water stress in the plants. Measurements were also made at midday in the period of greatest water stress. Leaf water potential could not be measured at the BD site as there were no leaves on the trees. However, measurements were made on the closest trees to the site which did have leaves. These trees were ~50 m south of the site.

Foliage samples for leaf ion concentrations were taken from 'young' and 'mature' leaves.



Young leaves were the terminal leaves on branches, and in many cases had grown over the preceding 6 months. Mature leaves were those closest to the trunk, and were probably a number of years old. Approximately 15 leaves of each age were taken from each of five trees in each plot. Leaves were dried at  $\sim 70^{\circ}\text{C}$  for 48 hr then finely ground. Soluble foliar  $\text{Na}^{+}$  and  $\text{Cl}^{-}$  were determined on water extracts, using a method described by Heffernan (1985). The dried, ground leaf tissue (0.2 g) was boiled in 20 ml of water and filtered through Whatman No. 54 filter papers. Chloride concentrations in the extract were determined by silver chloride titration, and sodium concentrations were measured by atomic absorption spectrophotometry. Results are expressed relative to the mass of dried leaf.

### 2.2.2 Soil

Soil was sampled by hand auger, and taken at 10 cm increments to 80 cm depth, then 20 cm

increments to 200 cm, then 50 cm to the water table. Matric suction of each sample was measured using the filter paper method (Greacen *et al.* 1989). Soils were dried at  $105^{\circ}\text{C}$  for 24 hr to determine gravimetric water content.

Chloride was extracted from the dry soil by barium nitrate extraction. Chloride concentration in the extract was determined colorimetrically (Taras *et al.* 1975) and converted to the concentration in the soil solution using the gravimetric water content.

### 2.2.3 Groundwater

Groundwater depth was assumed to be the depth beyond which soil samples were saturated. Groundwater chloride concentration was assumed to be the soil chloride concentration of the most shallow saturated soil sample.



### 3. RESULTS AND DISCUSSION

Results of all measurements are given in Appendix C, and means of many variables in Table 1. These results will be discussed in more detail below.

#### 3.1 Tree Health Index

Average tree health at each of the sites ranged from the lowest possible index of 4, at site BD where all trees were dead, to 16 (Table 1). The meaning of these indexes can be visualised by referring to the figures in Appendix B, depicting the various factors contributing to the index value. The reduction in health index, from the maximum possible of 20 to 16, was due to some trees showing minor signs of stress, such as epicormic growth, although considerable regrowth had occurred. There were no significant differences in health between the two seasons.

#### 3.2 Community Structure

Relatively healthy eucalypt communities on the Chowilla floodplain were classified as 'closed forest' (i.e. tree crowns touching or overlapping), except in the case of site BE, where the vegetation was classified as 'open forest' due to its lower crown density (Table 1). Site BU, where eucalypt health was poor, was classified as a woodland as the crown separation term was 'sparse', compared with 'dense' and 'mid-dense' at healthier sites. The vegetation at site BD was classed as grassland as no live trees remained in the area.

The vegetation at site BH was described as 'closed forest' despite the leaf area index (LAI) being less than that for the vegetation at site BE, which was described as 'open forest' (Table 1). The black box at site BH were larger, and probably older than those growing at other sites (as discussed in the following paragraph). As the tree stem density was also lower compared with the other plots, their canopies, while touching, were relatively sparse and the values of foliage cover and LAI were lower (Table 1).

Black box stem diameter varied considerably between the sites (Table 2). The largest trees were at site BH. These were probable the oldest stems at the study sites, and had not been previously felled. The smaller stem diameter and higher stem number at the other sites is a result of coppicing after the tree felling in the 1930s and 1940s. The dead trees at site BD had smaller diameters than the trees at the other sites, presumably due to the reduction in growth in stressed conditions.

Mean height for each site is shown in Table 1, and the frequency distribution of tree heights at each site, and for all trees, in Table 3. The 'unhealthy' live trees at site BU tended to be shorter than trees at the other sites, while the larger, healthier trees at site BH were taller. The height of the trees at each site is represented in the structural formation classification (Table 1, Appendix A).

The river red gums at site RM had health indexes as high as the healthiest black box sites (Table 1). Site RM also had fewer, bigger trees than the black box sites. The trees were 0.4 to 2.0 m in diameter, and 24 to 34 m tall. None of the red gums appeared to have been previously cut down.

#### 3.3 Sapwood Area

Sapwood area increased with tree size (Fig. 2), and was generally well related to tree diameter (Table 4). The black box trees tended to be smaller, and have lower sapwood areas for a given tree diameter than the red gums. This difference in sapwood area-tree diameter relationship was reflected in the regressions between these two variables for each species (Table 4, eqns 1 and 2). The regression for the red gums was similar to that for both species combined (eqn. 3). Although the constants in the regression equations were less than zero, they were not significantly different from zero. This is reasonable as all trees (or twigs), regardless of size, will have some conducting tissues. Thus regressions, forced through the origin, were



Table 1. Vegetation health and structure, and summary of soil, water and plant physiological measurements made at the study sites.

Site	BE	BM	BH	BT	BU	BD	RM
Site no. from McEwan et al. (1991)	7	4	5	3	2	1	6
Tree species	black box	black box	black box	black box	black box	black box	red gum
Canopy type (%)	60	60	50	50	40	0	60
Crown cover (%)	73	100	90	98	38	0	100
Foliage cover (%)	44	60	45	49	15	0	60
Structural formation - upper story	ET7M	ET7D	T7D	T8D	T6S	G1M	T8D
Leaf area index ( $m^2 m^{-2}$ )	0.9	1.0	0.6	1.0	0.6	0.0	1.5
Vegetation type	open forest	closed forest	closed forest	closed forest	woodland	grassland#	closed forest
Health - summer (se)	15 (0.4)	13 (0.8)	16 (0.5)	13 (0.7)	10 (0.5)	4 (0.0)	16 (1.1)
Health - winter (se)	14 (0.4)	12 (0.4)	16 (0.5)	13 (0.6)	11 (0.5)	4 (0.0)	17 (0.9)
Tree density (stems $ha^{-1}$ )	550	675	75	350	300	200#	50
Mean tree diameter (cm)	14	14	61	24	21	10	103
Mean tree height (m)	8.1	8.6	11.6	9.0	5.9	nd@	28.6
Sapwood area index ( $m^2 ha^{-1}$ )	2.7	4.7	1.5	3.1	2.8	nd@	2.7
Pre-dawn leaf water potential (MPa)							
summer (se)	-2.9 (0.09)	-2.5 (0.08)	-2.4 (0.07)	-2.7 (0.05)	-3.1 (0.03)	-3.2 (0.09)*	-1.7 (0.12)
winter (se)	-2.2 (0.04)	-2.3 (0.06)	-2.0 (0.08)	-2.2 (0.05)	-2.8 (0.02)	-2.2 (0.08)*	-1.2 (0.10)
Midday leaf water potential (MPa)							
summer (se)	nd@	-3.3 (0.05)	-3.6 (0.02)	-3.1 (0.07)	nd@	nd@	-2.5 (0.07)
winter (se)	-3.0 (0.11)	-3.0 (0.08)	-3.0 (0.16)	-3.1 (0.13)	-4.0 (0.15)	-3.3 (0.25)*	-1.9 (0.02)
Young leaf [Cl <sup>-</sup> ] ( $mg g^{-1}$ )	3.4 (1.8)	4.0 (2.0)	7.5 (1.7)	5.6 (1.2)	0.6 (0.1)	nd	3.4 (2.6)
Mature leaf [Cl <sup>-</sup> ] ( $mg g^{-1}$ )	1.8 (1.1)	2.0 (1.5)	3.5 (0.9)	1.9 (1.1)	0.8 (0.2)	nd	0.8 (0.1)
Young leaf [Na <sup>+</sup> ] ( $mg g^{-1}$ )	4.7 (0.5)	6.3 (0.5)	4.1 (0.3)	4.6 (0.6)	4.2 (0.8)	nd	2.6 (0.2)
Mature leaf [Na <sup>+</sup> ] ( $mg g^{-1}$ )	5.1 (0.8)	6.3 (0.6)	4.1 (0.4)	4.8 (0.4)	4.1 (0.8)	nd	3.0 (0.3)
Site elevation (m above AHD)	19.9	20.2	20.6	20.3	20.4	21.1	19.3
River flow for inundation ( $GI day^{-1}$ )	62-77	77-82	98-101	77-82	77-82	98-101	47-62
Flood frequency (1 in X to Y yr)	7.7-9.5	9.5-12.9	>12.9	9.5-12.9	9.5-12.9	>12.9	3.9-7.7
Groundwater [Cl <sup>-</sup> ] ( $g l^{-1}$ )	7.7	3.2	7.8	10.4	19.9	18.6	3.4

# all trees at this site were dead

\* from live trees as close as possible to the plot

@ nd = not determined



**Table 2. Frequency distribution of the diameter of all trees at the study sites, and for individual black box sites.**

Size class (diameter > X m)	Site					
	All trees	BE	BM	BH	BT	BU
0.05	1	1	0	0	0	0
0.10	29	3	13	0	4	9
0.15	55	13	25	0	5	12
0.20	23	5	10	0	7	1
0.25	7	2	4	0	0	1
0.30	8	0	0	3	2	3
0.35	3	0	0	1	1	1
0.40	4	0	0	1	2	0
0.50	3	1	0	1	1	0
0.60	0	0	0	0	0	0
0.70	0	0	0	0	0	0
0.80	1	0	0	1	0	0
0.90	1	0	0	1	0	0
> 0.90	3*	0	0	0	0	0

\* All these trees are red gums

**Table 3. Frequency distribution of the height of all trees at the study sites, and for individual black box sites.**

Size class (height > X m)	Site					
	All trees	BE	BM	BH	BT	BU
4	5	1	2	0	0	2
5	5	1	1	0	1	2
6	10	2	3	0	3	2
7	5	3	1	0	0	1
8	11	4	3	0	1	3
9	8	3	3	0	1	1
10	13	4	4	2	3	0
12	14	4	6	1	3	0
14	5	0	1	2	2	0
16	2	0	1	1	0	0
24	0	0	0	0	0	0
>24	4*	0	0	0	0	0

\* All these trees are red gums

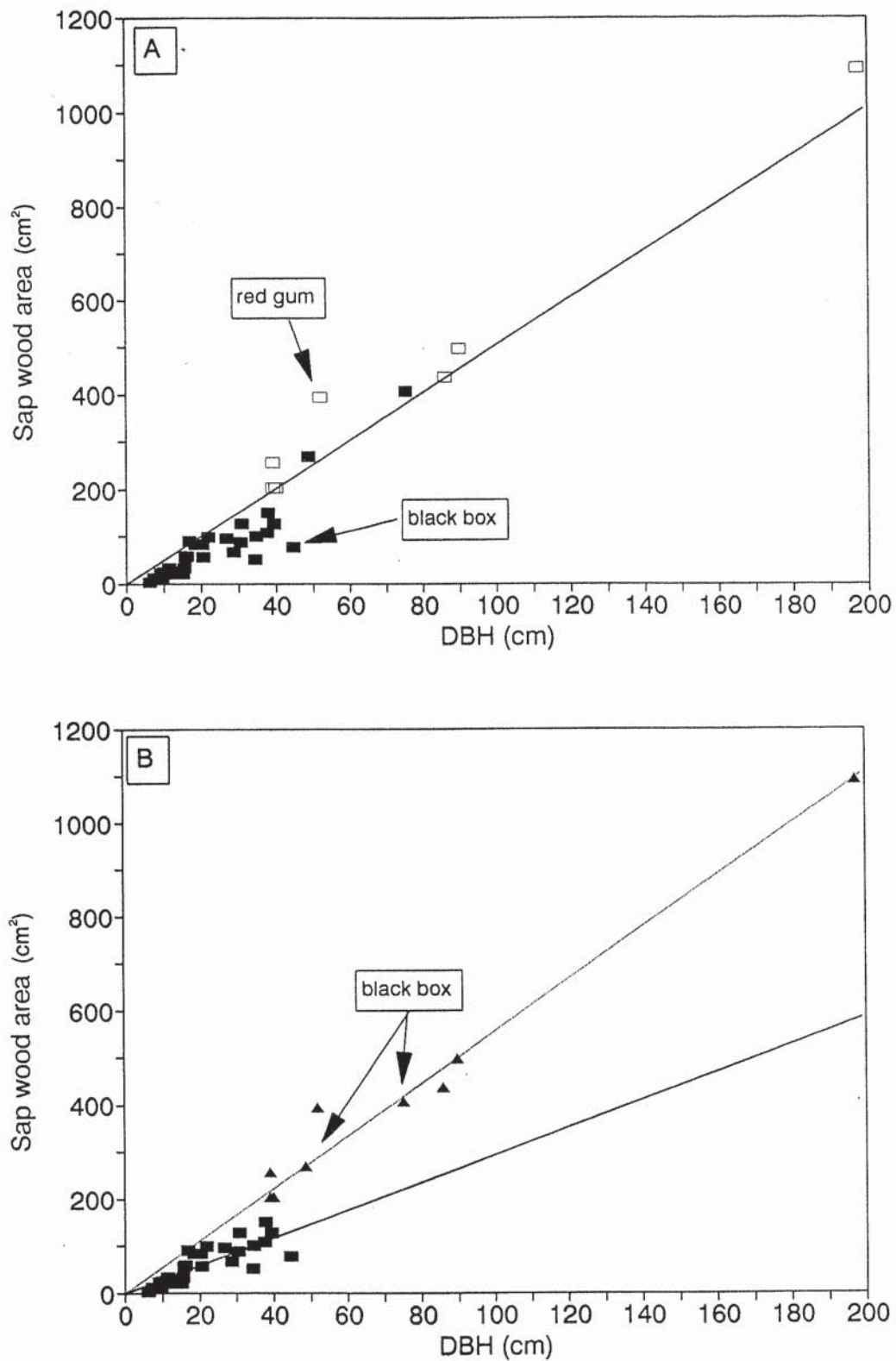


Fig. 2. Relationships between tree diameter at breast height (DBH) and sapwood area: A. for the two tree species shown separately, with the line being the regression of all data. B. for large trees ( $\blacktriangle$ , all red gums and two black box  $<50$  cm DBH) and small trees ( $\blacksquare$ , black box with DBH  $<50$  cm) shown separately, with the lines indicating the regressions through each class of tree.

calculated for both species (eqns 4 and 5) and for all trees (eqn. 6, this curve is shown in Fig. 2a).

Two black box trees with diameters >50 cm (marked in Fig. 2b) had sapwood area-diameter relationships similar to those of the red gums. The inclusion of these two trees in the red gum regression had little effect on the equation (eqn. 7, also shown in Fig. 2b). However, exclusion of these trees from the black box data lowered the slope of that regression (eqn. 8, also shown in Fig. 2b). (When calculated, the constants in these regressions were also not significantly different from zero, so are not given.)

Equations 7 and 8 were used to estimate the sapwood area of all trees in each quadrat. Equation 7 was used for all red gums and black box trees >50 cm diameter, and eqn. 8 was used for all other black box trees. The estimated sapwood areas were summed and expressed relative to the quadrat area, i.e. as a 'sapwood area index' (Table 1). Sapwood area index increased with increasing tree stem density at all black box sites, except BE. The red gum site, RM, had a similar sapwood area index to sites BE, BT and BU, although the tree density was much lower.

### 3.4 Leaf Water Potential

The pre-dawn leaf water potentials of the healthy black box forests ranged from -2.9 to -2.4 MPa in summer, but were lower (-3.1 MPa) at the BU site (Table 1). A similar pattern occurred in winter, although potentials were generally 0.4 to 0.6 MPa higher than in summer (Table 1). It is likely that part of this increase is due to decreased surface soil matric suction (and hence total suction) in winter associated with seasonal rainfall (as described below).

Pre-dawn water potential generally decreased with decreasing health index in both seasons (Fig. 3). The lower leaf water potentials at the less healthy sites indicate that these trees were suffering greater water stress in both seasons.

The midday leaf water potentials in the black box were between -3.0 and -3.6 MPa at all sites, except site BU in summer (Table 1). This site had a lower potential (-3.9 MPa), indicating the level of stress trees at this site were under. For example, Sinclair (1980) found similar pre-dawn water potentials (as low as -4.4 MPa) in highly stressed *E. obliqua*.

**Table 4.** Coefficients (and standard errors) of regression equations between sapwood area (cm<sup>2</sup>), the dependent variable, and tree diameter at breast height (cm). 'Large trees' are defined as red gums and black box >50 cm in diameter, while 'small trees' are black box <50 cm in diameter. The line from equation 3 is shown in Fig. 2, and the lines from equations 7 and 8 are shown Fig. 2b. All regressions were significant (P < 0.001).

Equation no.	Species	Slope	Constant	n	R <sup>2</sup>
<i>Intercept calculated</i>					
1	Black box	4.8 (0.43)	-34.2 (35.8)	32	0.81
2	Red gum	5.4 (0.38)	-23.3 (52.4)	7	0.98
3	Both spp.	5.8 (0.22)	-48.3 (45.2)	39	0.95
<i>Regression forced through the origin</i>					
4	Black box	3.8 (0.26)		32	0.76
5	Red gum	5.6 (0.20)		7	0.97
6	Both spp.	5.1 (0.19)		39	0.92
7	'Large trees'	5.5 (0.16)		9	0.98
8	'Small trees'	2.9 (0.32)		30	0.68



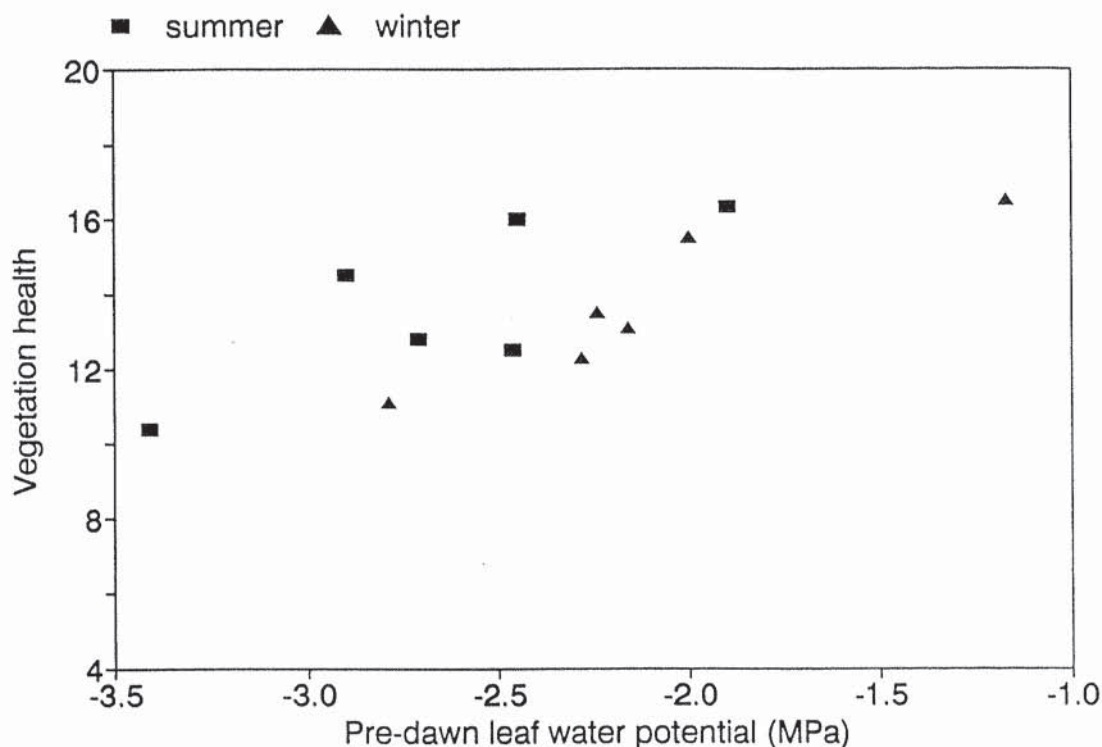


Fig. 3. Variation in mean vegetation health index with leaf water potential for each site in two seasons.

In the red gums, both the pre-dawn and midday leaf water potentials were significantly higher than in the black box, in both seasons (Table 1).

### 3.5 Soil Water Suction and Chloride

In summer, the surface soil matrix suctions were very high ( $>10$  MPa) at all sites, except site BD (Fig. 4). The difference in suction between site BD and the other sites suggests that the presence of live trees at the other sites was having an impact on the suction profiles in summer: The suction profile at site BD is consistent with discharge of groundwater from bare soil (Gardner and Fireman 1958; Jolly *et al.* 1993), while the high surface soil matrix suctions at the other sites would be due to tree water extraction.

The matrix suctions were lower in the surface of all sites in winter (Fig. 4), presumably due

to infiltration of 20 mm of rain that fell in the week prior to sampling. Wetting occurred to a depth of ~30-40 cm at sites BD, BT, BE and RM, and to a depth of ~20 cm at site BU where a relatively thick surface clay layer occurs (McEwan *et al.* 1991). At sites BM and BH, wetting occurred to greater depths than the other sites (i.e. ~90-110 cm). These two sites are on levees, and have low surface clay contents allowing rainfall to penetrate to greater depths.

At sites BH and BT, matric suction was higher in winter than in summer at depths of ~50 to 200 cm (Fig. 4). This increase in suction may have been due to extraction of water from these areas of the profile by trees.

Maximum soil chloride concentrations ranged between 16 and 24 g l<sup>-1</sup> at most black box sites (Fig. 5). These chloride concentrations were equivalent to osmotic suctions of ~2 and 3 MPa, which were greater than matric

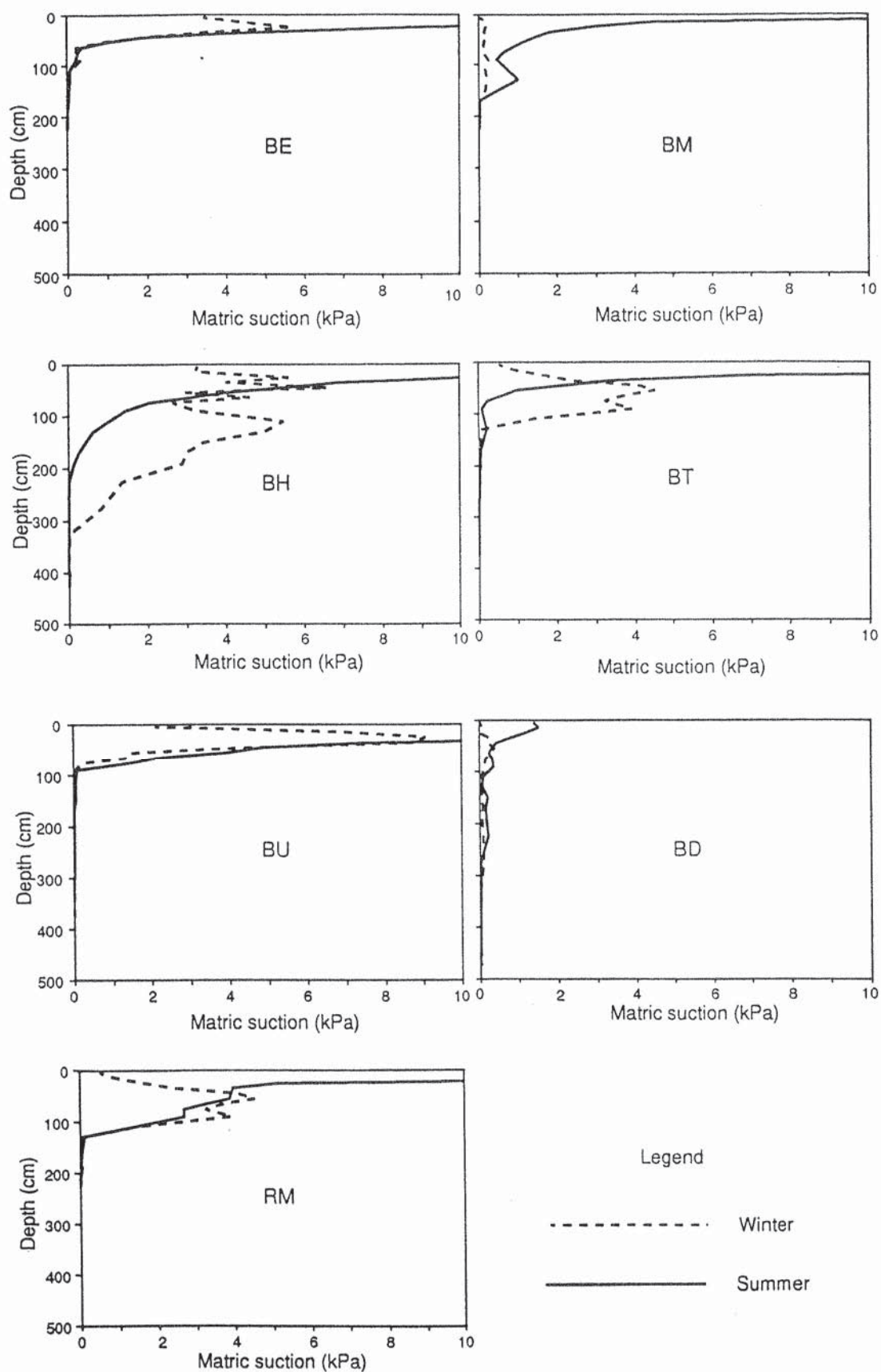


Fig. 4. Soil matric suction profiles at each site in two seasons.

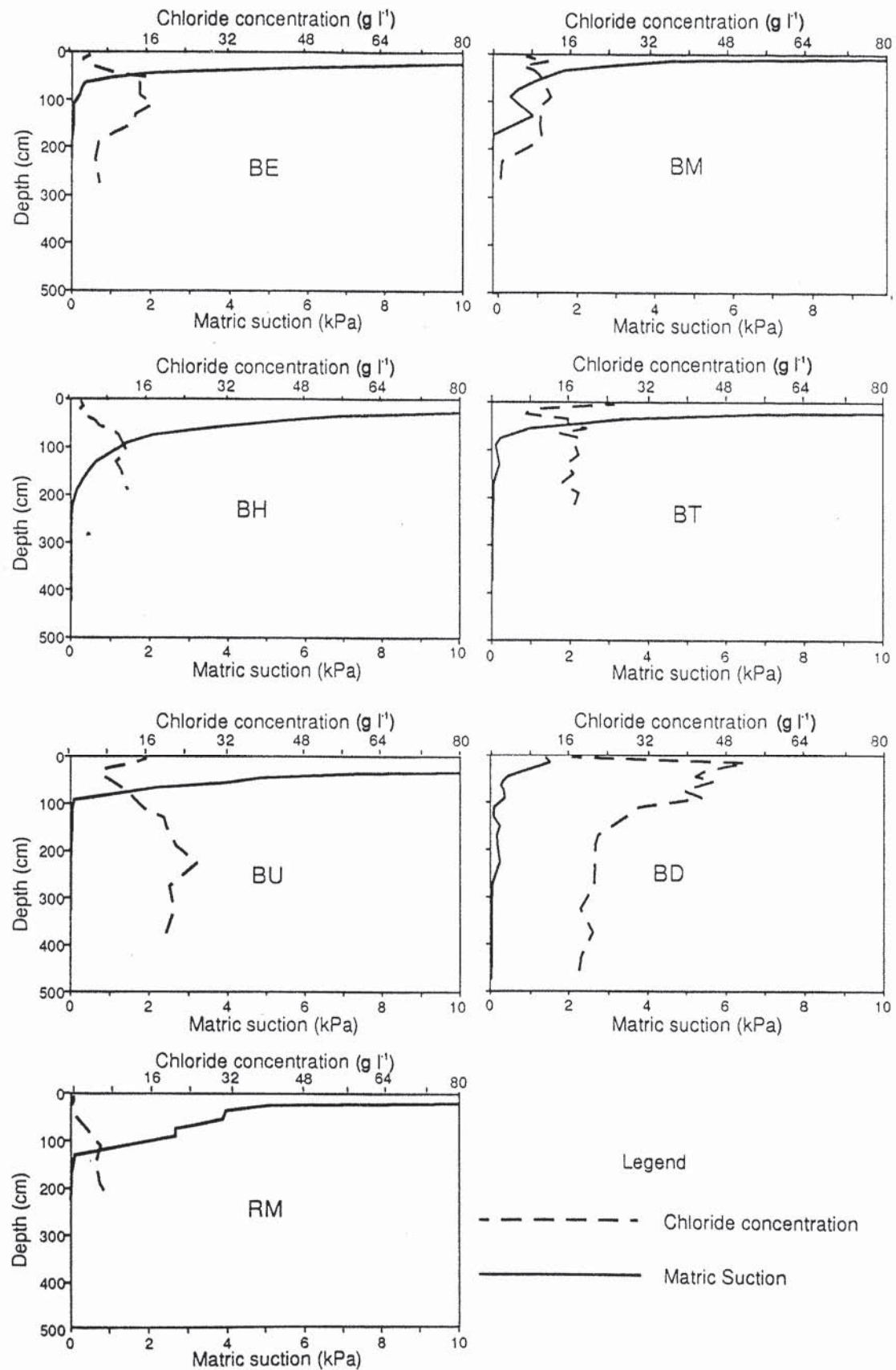


Fig. 5. Soil chloride concentration and matric suction profiles at each site in summer.



suctions at depths greater than ~1 m at all sites. At sites BH and RM, surface chloride concentrations were lower than at the other sites, suggesting a net downward flux of water at shallow depths in these soils. Chloride concentrations at site BD increased from the groundwater, reaching  $\sim 56 \text{ g l}^{-1}$  near the surface. This profile is consistent with net groundwater discharge from bare soil (as was the suction profile); i.e. water and salts moving to the soil surface by capillarity, where the water evaporated.

Mean soil chloride concentration below 40 cm depth increases with site elevation (Fig. 6). As frequency of flooding is largely determined by elevation on the floodplain (Jolly *et al.* 1992), this relationship implies that flooding is an important determinant of sub-soil salinity. Certainly flooding appeared to have a greater influence than did groundwater salinity. For example, Sites RM and BE had similar groundwater chloride concentrations (Table 1), yet site BE had almost double the sub-soil chloride concentration (Fig. 6).

The relationship between sub-soil chloride and elevation is different for sites BM and BH

than that of the other sites (Fig. 6). Sites BM and BH are both situated on sandy levees, giving their higher elevations (by 0.3 m) than nearby sites BE and BT, respectively (Table 1). These sandy levees have lower surface clay contents than do soils at the other sites (McEwan *et al.* 1991). Recharge from rainfall and floodwaters, which leach salts from the soil, would thus be expected to be higher at these sites, hence their relatively low soil salinities.

It should be noted that further detailed data on soil matric suction chloride concentrations at these sites are given by McEwan *et al.* (1991), and details of groundwater salinity (and chemistry) are provided by Jolly *et al.* (1992).

### 3.6 Foliar Sodium and Chloride Concentrations

Since the salinities of the floodplain soils are high (Fig. 5) and ions are taken up by plants with water, it is possible that variation in black box health is due to specific ion toxicity. Sodium and chloride are the dominant ions in

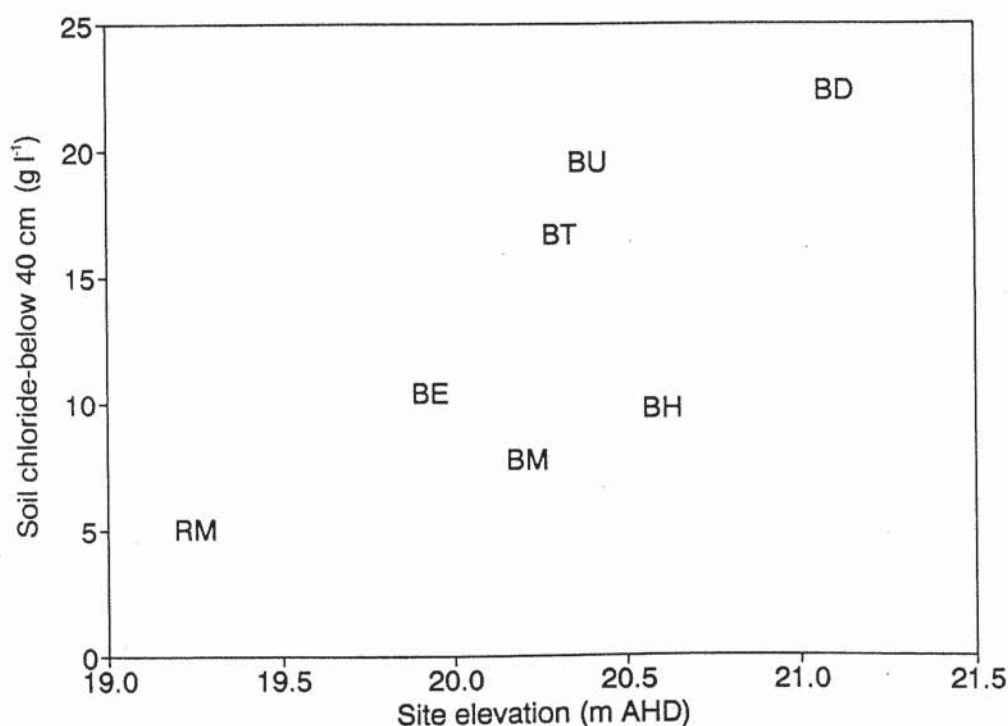


Fig. 6. Variation in sub-soil chloride concentration (mean value below 40 cm depth) in summer with site elevation.



the soil solution in these soils, so will be the only ions present in potentially toxic levels.

There was little variation in mean foliar sodium concentrations between any of the sites (Table 1). Chloride concentrations were generally higher in young leaves than mature leaves, with there being little difference in chloride between the black box sites, except for site BU. This site had markedly lower foliar chloride concentrations. The ion concentrations were similar to those previously found in *E. camaldulensis* grown in solution cultures of varying salinity (e.g. Sands 1981, Marcar and Termaat 1990).

No strong relationships were present between foliar chloride or sodium concentrations and health when all trees were considered (Fig. 7). Noteworthy in the chloride data however, are the two distinct groups of foliar chloride concentrations in both young and mature leaves (Fig. 7a). These patterns are explained by the foliar chloride concentrations in individual trees. Some trees at each site had similar (either high or low) chloride concentrations in both young and mature leaves, regardless of health. Also, in some trees mature leaves contained low chloride concentrations but young leaves contained high chloride concentrations. With the exception of site BU, black box trees at all sites exhibited this variation in foliar chloride grouping which appears to be unrelated to any of environmental characteristics measured.

Site BU had the lowest mean foliar chloride concentrations, and the lowest variability in chloride concentrations (Table 1). Trees at this site also had the lowest health indexes but the highest groundwater chloride concentrations. As chloride ions would be taken up by the plant with water, the low concentrations in leaves at this site suggest that water uptake in the trees at this site is being inhibited. This inhibition of water uptake would explain the poor health of these trees. However, it is unclear why this mechanism does not explain intra-site variations in foliar chloride concentrations at other black box sites. The foliar chloride concentrations in trees at other sites may be a result of spatial and temporal variations in

soil chloride (see McEwan *et al.* 1991), rather than the mean chloride value at the site.

While the chloride concentrations in young leaves at the red gum site were similar to those in the black box leaves, the concentrations in mature leaves were lower than at all black box sites, except site BU (Table 1). These low values may be due to both the relatively low groundwater salinity and high LAI at this site. These two factors would reduce the mass of chloride per unit leaf area moving to the red gum leaves in the transpiration stream.

### 3.7 Factors Affecting Health and Structure

Variation in the structural formation of eucalypt communities is related to tree health (Table 1). As the crown separation term in the structural formation code changes from dense to sparse, health as measured using the health index decreases. Factors affecting health and community structure are discussed below.

#### 3.7.1 Soil chloride concentration

The high soil chloride and low health index values at site BU (Table 1) suggest that soil salinity may be an important factor influencing black box health in the Chowilla region. The proportion of chloride contributing to the total dissolved salts in the floodplain soils remains relatively constant (McEwan *et al.* 1991), allowing chloride concentrations to be used as a measure of soil salinity.

There were zones of low chloride concentration in approximately the upper 40 cm of the soil at several sites (Fig. 5). To assess the importance of these zones in affecting black box health, the mean chloride concentration in the upper 40 cm of soil was related to black box health. Surface soil chloride concentrations commonly vary spatially and seasonally due to changes in soil water content, rather than because of any change in mass of salts in the soil. To prevent moisture

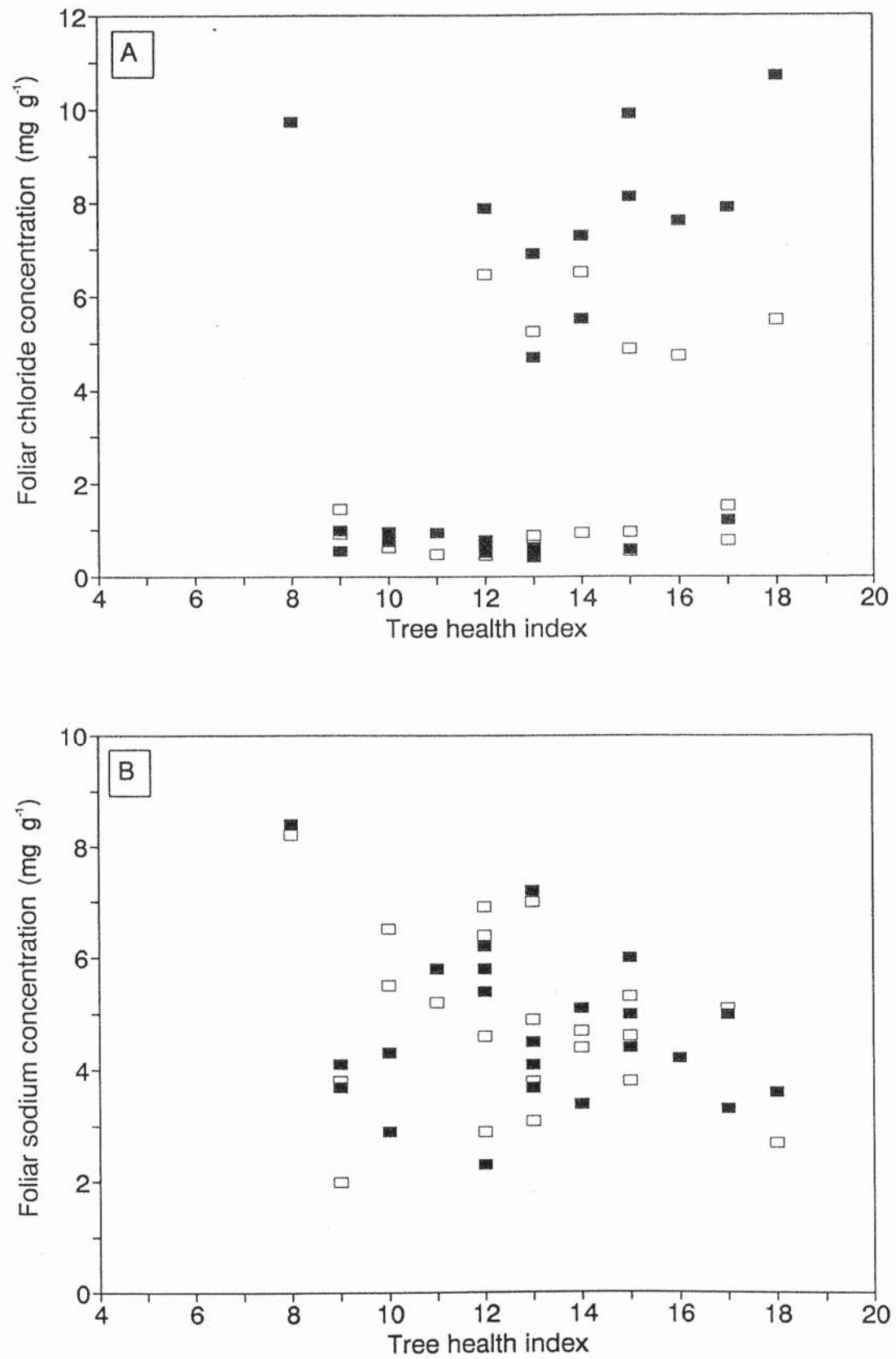


Fig. 7. Variation in foliar chloride (A) and sodium (B) concentration of both young (■) and mature (□) leaves with health index of individual trees from all sites.



variations from masking relationships between soil chloride and health, soils chloride measurements made in summer were normalised with respect to water content. The water content chosen was that corresponding to a matric suction of 2 MPa. The water content at this suction was estimated from moisture characteristics determined for the floodplain soils (given by Jolly *et al.* 1993). Normalised surface soil (0-40 cm) chloride and health (in summer) were well related (Fig. 8). However, site BU has a lower health index than expected from its surface chloride when compared with the other sites indicating that other factors were also important in determining tree health at this site.

Health was also well related to mean chloride concentration below 40 cm soil depth (Fig. 9). Soil matric suction at these depths does not have as great a temporal variation as that at shallow depths, so the chloride data were not normalised with respect to water content. It

is interesting to note that the data from site BU appear to fit the relationship between sub-soil chloride and health better than the relationship with surface soil chloride concentration.

Vegetation health is related to site elevation (Fig. 10), as expected from the relationship between soil chloride and elevation (Fig. 6).

### 3.7.2 Pre-dawn water potential

Pre-dawn water potential was well related to soil chloride (Fig. 11). Pre-dawn water potential was also related to health in both seasons (Fig. 3). As pre-dawn water potential is an indicator of plant water stress, these relationships give further evidence that the water stress observed in these black box communities is due to the elevated salinity of floodplain soils, and the increased osmotic suction due to the salinity.

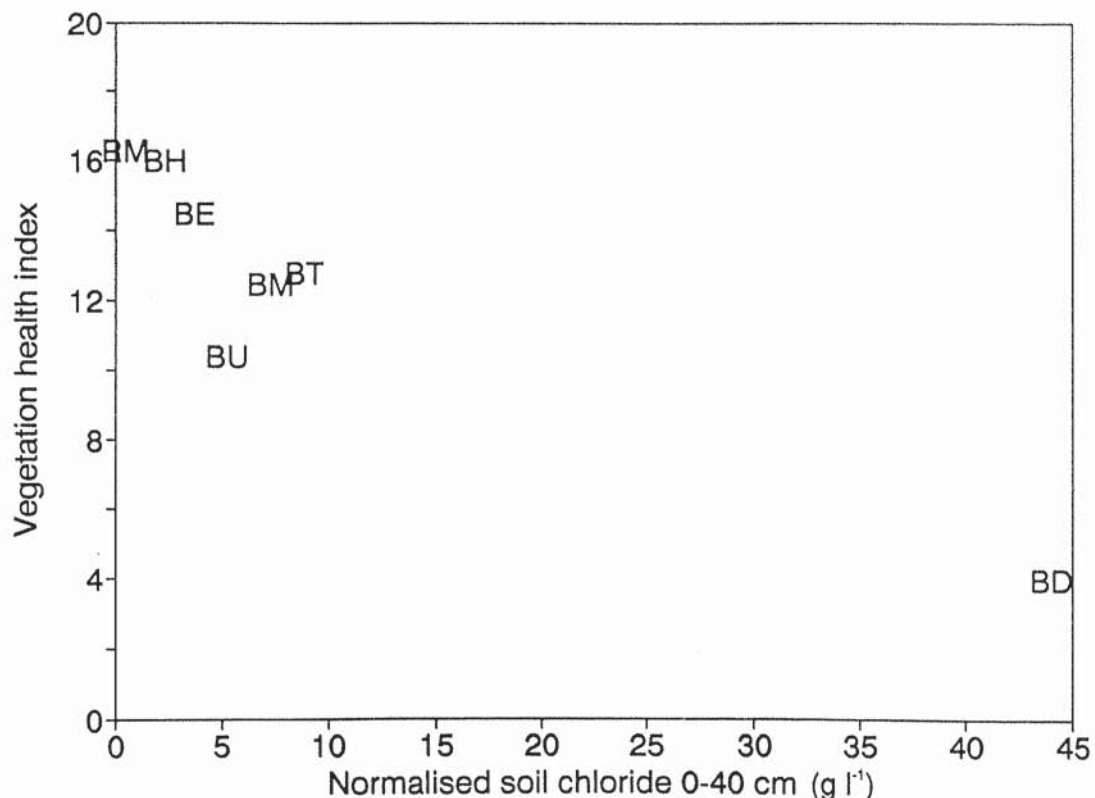


Fig. 8. Relationship between vegetation health and mean surface soil chloride concentration (above 40 cm depth) for all sites in summer. The chloride data at each site were normalised to the moisture content at 2 MPa matric suction, as described in the text.

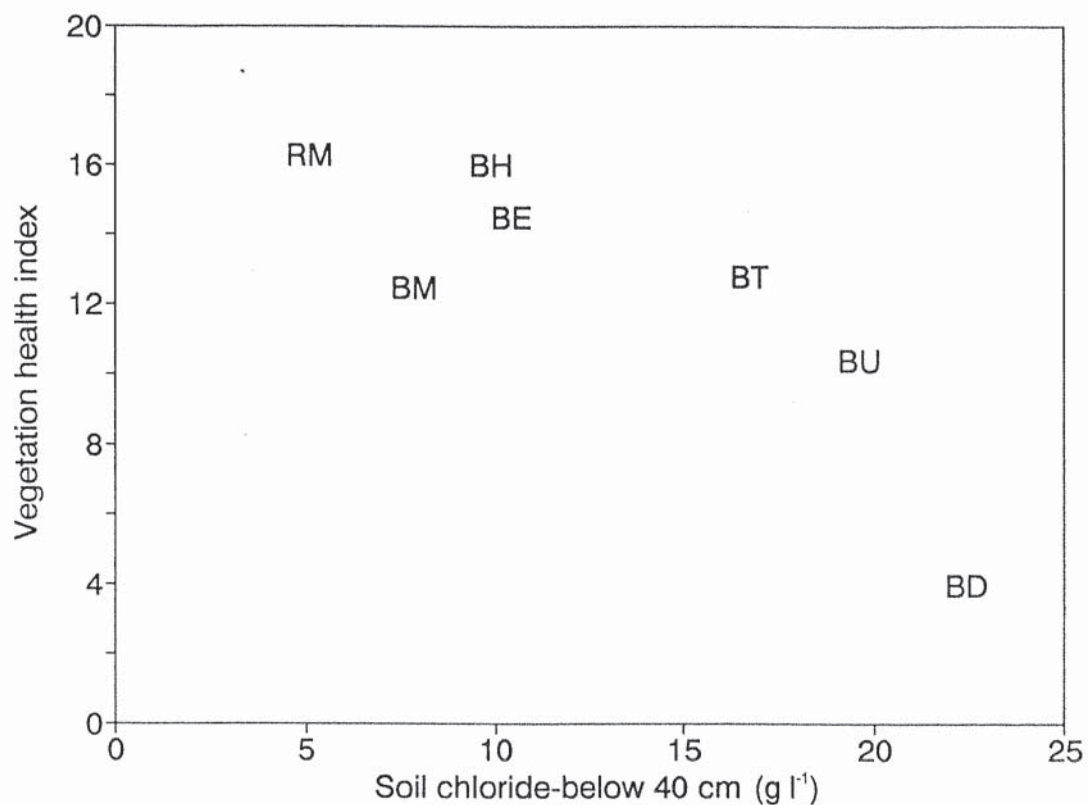


Fig. 9. Relationship between vegetation health and mean sub-soil chloride concentration (below 40 cm depth) for all sites in summer.

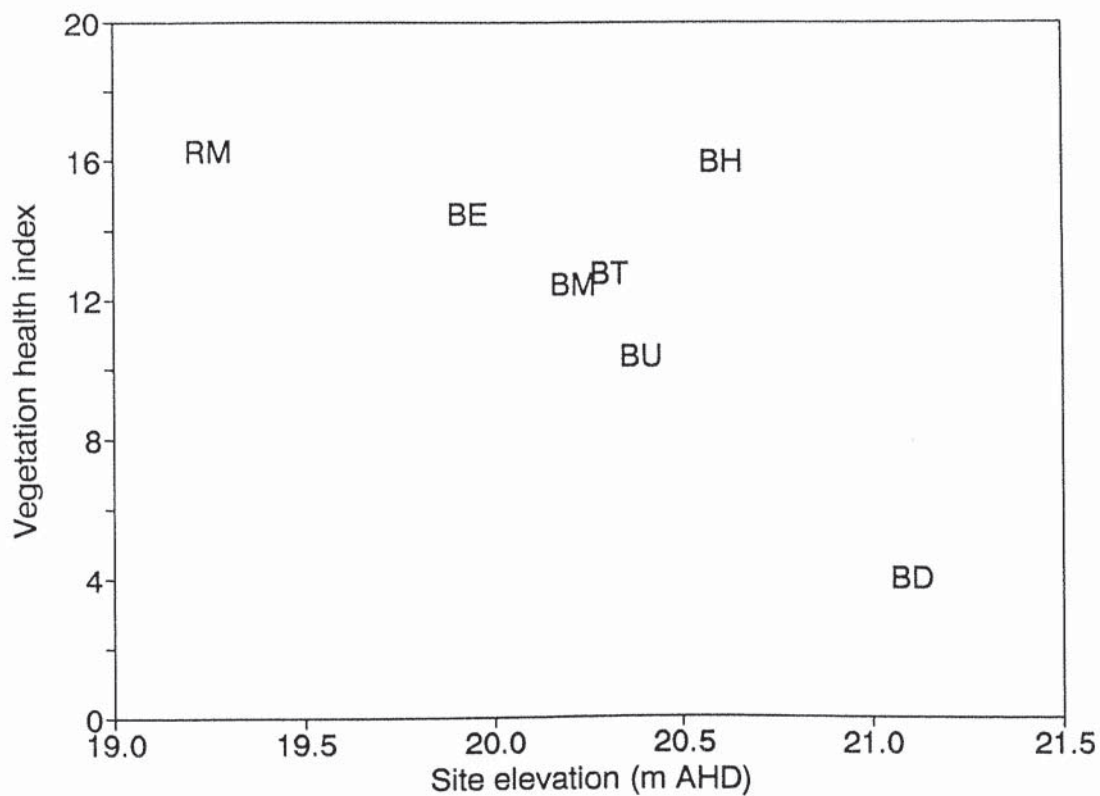


Fig. 10. Variation in vegetation health index in summer with site elevation.

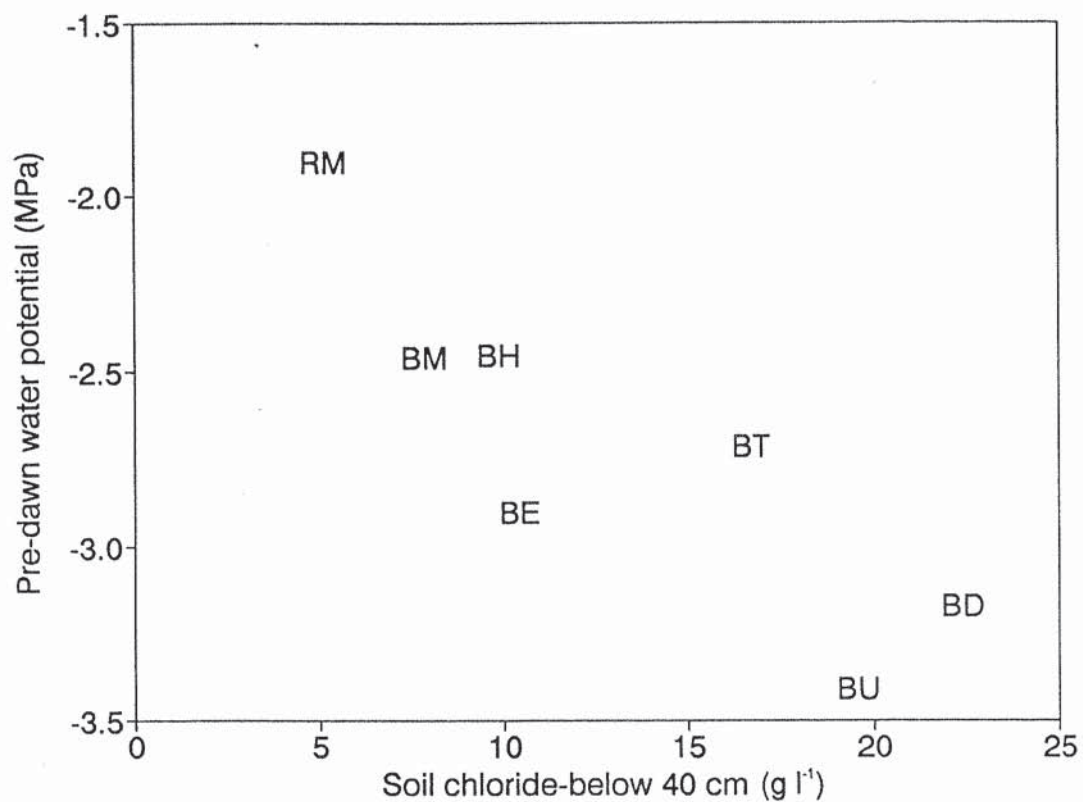


Fig. 11. Relationship between pre-dawn leaf water potential and mean sub-soil chloride concentration (below 40 cm depth) for all sites in summer.



#### 4. CONCLUSIONS

The variation in health and structure of black box communities in the study area was associated with high soil chloride concentrations. Pre-dawn (and midday) water potentials were low at sites with lower health indexes and higher soil chloride, suggesting that trees were suffering water stress caused by high soil osmotic suction (i.e. 'physiological

drought'). Soil chloride concentrations were higher at elevated sites, possibly due to the reduced frequency of flooding, so health also varies with elevation and may be linked with flood frequency. Ion toxicity was not responsible for variations in health, as there was a poor relationship between foliar chloride and sodium concentrations and tree health.

#### Acknowledgments

Part of this work was supported by funds from the Land and Water Resources Research and Development Corporation (Research Grant No. 88/44). The second author acknowledges the support of an Australian Postgraduate Priority Research Award (from Flinders Uni-

versity of South Australia, School of Earth Sciences) and a Centre for Groundwater Studies Bursary during this work, which was conducted while on leave from the Queensland Department of Primary Industries.



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## APPENDIX A

Guidelines for assigning structural formation codes to a particular stratum of vegetation  
(from Walker and Hopkins 1990).

**Growth form**

Symbol/form		Description
T	Tree	Woody plant more than 2 m tall with a single stem or branches well above the base
M	Tree mallee	Woody plant perennial usually of the genus <i>Eucalyptus</i> . Multi-stemmed with fewer than five trunks of which at least three exceed 100 mm in diameter at breast height. Usually 8 m or more tall
S	Shrub	Woody multi-stemmed at the base (or within 200 mm from ground level) or, if single stemmed, less than 2 m tall
Y	Mallee shrub	Commonly less than 8m tall, usually with five or more trunks, of which three of the largest do not exceed 100 mm in diameter at breast height.
Z	Heath shrub	Shrub usually less than 2 m tall, commonly with ericoid leaves
C	Chenopod shrub	Xeromorphic single or multi-stemmed halophyte exhibiting drought and salt tolerance
G	Tussock grass	Forms distinct but open tussocks usually with individual shoots, or if not, then forming a hummock. These are the common agricultural grasses
H	Hummock grass	Coarse xeromorphic grass with a mound-like form often dead in the middle; genera are <i>Triodia</i> and <i>Plectrachne</i>
D	Sod grass	Grass of short to medium height forming compact tussocks in close contact at their base and uniting as a densely interfacing leaf canopy
V	Sedge	Herbaceous, usually perennial, erect plant generally with tufted habit and of the families Cyperaceae and Restionaceae
R	Rush	Herbaceous, usually perennial, erect plant. Rushes are grouped in the families Juncaceae, Typhaceae, Restionaceae and the genus <i>Lomandra</i>
F	Forb	Herbaceous or slightly woody, annual or sometimes perennial plant; not a grass
E	Fern	Characterised by large and usually branched leaves (fronds), herbaceous to arborescent and terrestrial to aquatic; spores in sporangia on the leaves
O	Moss	Small plant usually with a slender leaf bearing stem with no true vascular tissue
L	Vine	Climbing, twining, winding or sprawling plant usually with a woody stem

## APPENDIX A (cont.)

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**Height class***Class Height (m)*

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9	>35.01
8	20.01 - 35
7	12.01 - 20
6	6.01 - 12
5	3.01 - 6
4	1.01 - 3
3	0.51 - 1
2	0.26 - 0.5
1	<0.25

**Crown cover***Symbol Description Crown Separation Ratio\**

D	Closed or dense	<0 m
M	Mid-dense	0 - 0.25
S	Sparse	0.25 - 1
V	Very sparse	1 - 20
I	Isolated plants	>20
L	Isolated clumps	>20

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\*The crown separation ratio is obtained by dividing the mean distance between tree canopies at a particular site by the mean diameter of canopies at that site.

**APPENDIX B****Attributes for index of eucalypt health (modified from Grimes 1978).**

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**Crown size**

5 points	The crown is wide, deep and roughly circular in plan, without any obvious faults
4 points	The crown has easily observed, but slight faults, such as lop sidedness or is partly undeveloped
3 points	Obvious deficiencies in size and/or shape are present
2 points	Small, poorly shaped crowns
1 point	Crown absent

**Crown density**

5 points	Very dense leaf clumps with even distribution of clumps over the crown. Very little light penetrating the leaf clumps
4 points	Dense leaf clumps distributed unevenly over the crown
3 points	Clumps of average density with reasonable distribution or dense clumps very unevenly spread
2 points	Clumps are sparse and poorly spread
1 points	No leaves present on the crown

**Dead branches**

5 points	No visible dead branchlets or branches in the crown apart from the thin twigs immediately inside the new leaf development, and the lowest branches in the process of being shed
4 points	On close inspection dead branchlets are evident but not over all the crown
3 points	Large and/or small branches are dead but not over all the crown. These are easily observed
2 points	Large and small branches dead over most of the crown, which is obviously dying
1 point	All branches are dead



**APPENDIX B (cont.)**

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**Crown epicormic growth**

5 points	No epicormic growth is present
4 points	Epicormic growth can be seen in part of the crown
3 points	Epicormic growth is present over most of the crown
2 points	Epicormic growth is present over all of the crown and stem
1 point	No growth present on crown

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**APPENDIX B (cont.)****Diagrams depicting vegetation health index attributes.**

Crown size



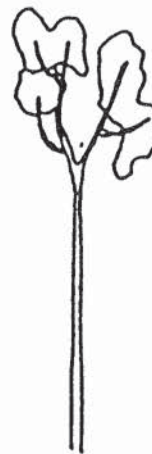
5 points



4 points

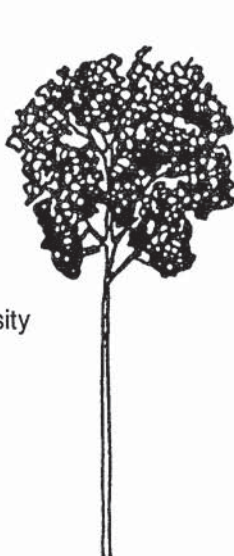


3 points

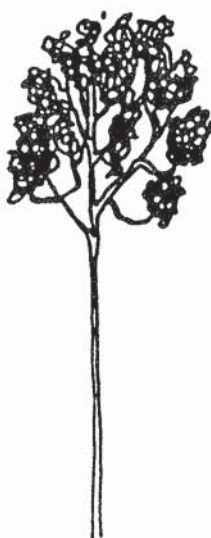


2 points

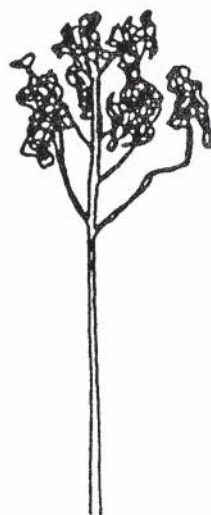
Crown density



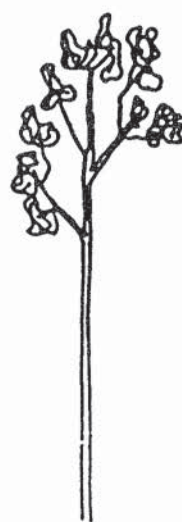
5 points



4 points



3 points

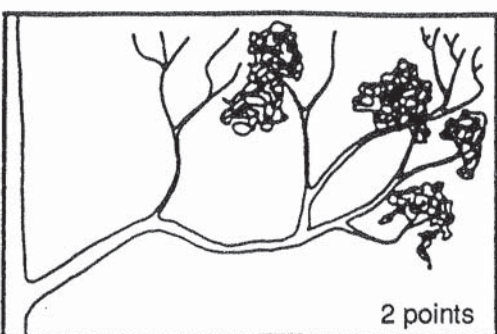
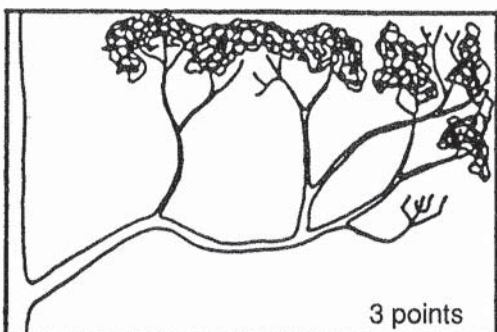
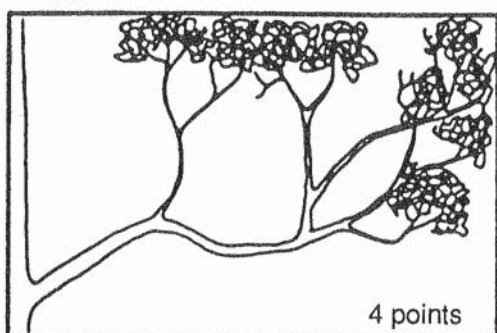
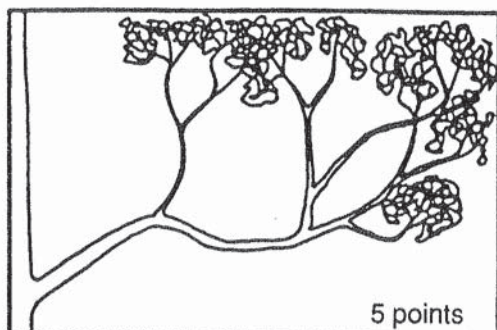


2 points

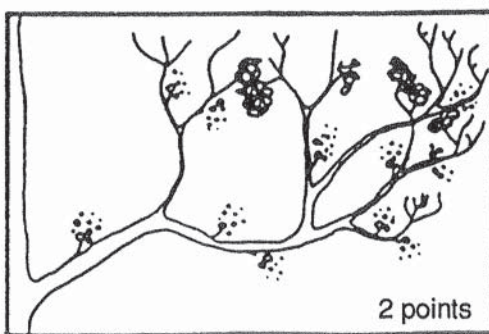
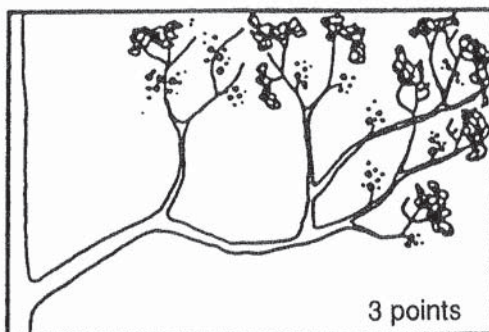
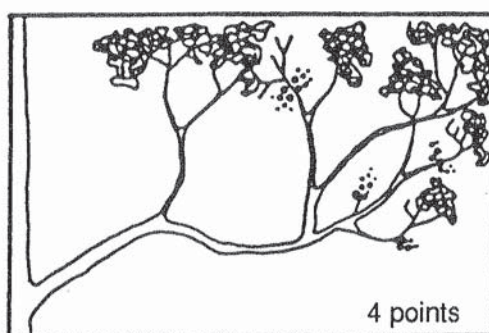
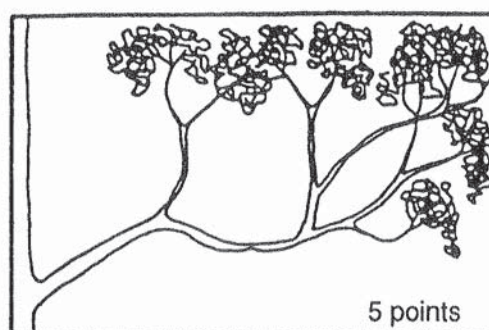


**APPENDIX B cont.****Diagrams depicting vegetation health index attributes.**

Dead branches



Epicormic growth



## APPENDIX C

### Listing of all data measured.

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#### Legend for the data

Area	Area of the quadrat established at each site
Tree	All individual trees were identified by a letter - '(em)' signifies that the tree was emergent from the canopy
Coordinate A & B	Coordinates of the base and canopy projection of each tree within each quadrat
GBH	Girth over bark at breast height - numbers separated by '+' indicate the girths of individual stems of multi-stemmed trees
DBH	Diameter at breast height (calculated from girth)
[Cl]-ldw	Chloride concentration of leaves on a dry weight basis
[Na]-ldw	Sodium concentration of leaves on a dry weight basis
Leaf water potential	Summer data given for identified trees - winter data given separately for unidentified trees.
	<b>Note - data for the BD site were obtained from live trees ~50 m from the plot, so do not actually represent the state of the trees at the site.</b>
[Cl]-ss	Chloride concentration of the soil solution, measured in summer only

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## Appendix C

Site: BE  
Area: 400m<sup>2</sup>

Tree	Coordinate A			Coordinate B			GBH (cm)	DBH (cm)	Tree Height (m)
	Base	Canopy Right	Canopy Left	Base	Canopy Right	Canopy Left			
A	16.4	11.6	18.4	4.8	8.8	1.0	140	44.6	9.0
B	11.5	8.8	13.7	2.4	5.0	-2.0	47+36		10.4
C	7.8	3.9	8.0	2.6	2.6	-2.5	48	15.3	9.3
D	6.6	1.8	6.6	1.2	2.9	-1.0	48	15.3	7.7
E	6.2	4.0	7.0	3.5	5.5	2.3	39	12.4	7.7
F	6.7	5.8	10.9	4.3	8.4	4.3	32	10.2	6.5
G	6.3	5.0	8.8	8.2	10.9	6.7	45+56+71		5.4
H	4.6	3.0	7.3	9.0	10.1	6.1	41	13.1	9.5
I	6.8	4.1	6.8	10.7	9.9	7.8	42	13.4	10.4
J	8.6	8.1	10.0	12.0	12.6	10.4	22	7.0	4.6
K	9.3	8.6	13.5	12.4	13.0	9.6	40	12.7	8.2
L	9.3	8.1	10.3	13.1	14.6	10.5	42	13.4	9.5
M	8.3	5.6	8.2	12.9	16.2	11.7	46	14.6	10.6
N	7.1	4.8	7.1	13.4	14.6	11.6	30	9.5	7.8
O	6.9	6.9	9.4	15.0	15.0	13.0	37	11.8	7.0
P	3.3	3.0	6.1	11.9	12.9	8.6	52	16.6	9.6
Q	2.8	-1.5	2.5	15.4	19.6	11.9	69	22.0	6.8
R	1.6	-1.0	3.9	18.1	20.5	17.2	40	12.7	3.3
S	5.6	1.8	5.7	19.4	20.5	17.8	35	11.1	11.4
T	14.0	11.2	17.9	15.5	17.9	11.3	48	15.3	7.7
U (dead)	17.6			19.8			30	9.5	
V	1.1	0.4	3.2	9.3	10.6	8.0	29	9.2	5.7
W	7.0	6.1	8.0	12.2	12.8	11.6	15	4.8	9.0
L1	14.0			18.3					
L2	12.2			17.4					
L3	9.1			16.6					
L4	6.4			13.7					
L5	3.3			8.9					
L6	12.8			15.8					
L7	12.2			16.7					
L8	10.3			17.0					
L9	10.3			16.2					
L10	13.1			19.0					
L11	18.0			10.0					
L12	18.0			9.4					
L13	15.1			8.6					
L14	18.3			5.6					
U1	18.9			18.1					

Tree	Summer Health	Winter Health	Leaf Area (m <sup>2</sup> )	Sapwood Thickness (cm)	Sapwood Area (cm <sup>2</sup> )	Leaf ion concentration			
						[Cl]-ldw (mg g <sup>-1</sup> )		[Na]-ldw (mg g <sup>-1</sup> )	
						Young	Mature	Young	Mature
A	15	15	46.9	0.6	77.3				
B	14	13	38.2				3		4
C	14	14	19.6						
D	17	16	21.8	0.5	20.9				
E	16	14	17.4						
F	15	15	6.5	1	23.9	1	1	6	5
G	13	10	13.1				4		4
H	16	16	13.1						
I	13	13	9.8						
J	13	12	3.3						
K	11	12	9.8						
L	12	10	4.4						
M	16	13	17.4						
N	14	14	3.3	0.5	12.1				
O	13	12	5.5			1	1	4	3
P	14	11	15.3						
Q	13	13	32.7	1.7	97.8	5	5	4	7
R	14	13	13.1						
S	17	14	8.7			8	1	5	6
T	17	16	31.6						
U (dead)									
V	17	16	5.5						
W	14	16	1.1						



## Appendix C

Site: BE (continued)

Tree	Pre-dawn leaf water potential (-kPa)			Midday leaf water potential (-kPa)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
A						
B	2800	2850	2650			
C						
D						
E	2900	3400	3400			
F						
G	3400	3650	3350			
H						
I	2300	2650	2750			
J						
K						
L						
M						
N						
O						
P						
Q						
R	2700	2650	2550			
S						
T						
U (dead)						
V						
W	2650	2700	2850			

Soil Depth (cm)	Summer Suction (kPa)	Winter Suction (kPa)	Summer Theta g (g g <sup>-1</sup> )	Winter Theta g (g g <sup>-1</sup> )	[Cl]-ss (mg l <sup>-1</sup> )	Osmotic Potential (kPa)
0-10	67078	3443	0.057	0.150	3673	459
10-20	30759	4416	0.067	0.173	2303	288
20-30	8766	5702	0.156	0.258	3329	416
30-40	4683	3396	0.163	0.169	6188	773
40-50	1922	1914	0.171	0.162	9171	1146
50-60	1002	832	0.102	0.142	15591	1949
60-70	348	218	0.119	0.123	13813	1727
70-80	263	207	0.119	0.130	13898	1737
80-100	206	308	0.127	0.132	13906	1738
100-120	57	65	0.144	0.132	16482	2060
120-140	55	51	0.130	0.139	12818	1602
140-160	51	32	0.091	0.117	12604	1576
160-180	23	15	0.104	0.044	8669	1084
180-200	9	8	0.211	0.199	5542	693
200-250	3	9	0.140	0.099	4805	601
250-300	1	1	0.234	0.207	5725	716

## Appendix C

Site: BM  
Area: 400m<sup>2</sup>

Tree	Coordinate A			Coordinate B			GBH (cm)	DBH (cm)	Tree Height (m)
	Base	Canopy Right	Canopy Left	Base	Canopy Right	Canopy Left			
A	6.1	11.2	8.0	25.0	25.0	20.1	51	16.2	10.0
B	4.1	7.0	2.6	24.0	25.9	20.2	31+35		9.7
C	1.7	5.3	-1.4	24.6	25.9	20.6	39+25+45+35		10.9
D	3.3	5.4	0.0	25.4	29.7	23.7	49+30		8.6
E	5.2	5.0	1.7	26.8	30.0	25.4	51	16.2	12.6
F	5.1	6.3	4.7	24.8	25.3	24.5	23	7.3	5.2
G	0.6	1.2	-3.0	27.6	26.8	22.5	46	14.6	8.0
H	9.8	11.3	7.9	13.9	14.5	17.3	41	13.1	7.2
I	11.1	12.0	8.2	17.8	16.8	22.8	50	15.9	4.2
J	5.9	5.9	3.9	17.8	20.6	16.4	53	16.9	8.6
K	8.5	9.0	5.5	16.0	18.3	13.7	35+33+40		11.6
L	10.7	13.0	4.6	4.2	18.0	0.0	48+65+53	16.6(53)	10.3
M	10.6	12.2	5.6	2.3	0.9	-2.0	38+50		9.3
N	6.0	7.2	3.0	4.6	4.8	2.0	39	12.4	7.5
O	3.8	5.0	3.0	5.8	5.8	4.1	23	7.3	5.5
P	3.4			6.7	30.0	30.0	43+38+34		
Q	0.7	2.5	-0.8	4.0	5.1	4.1	32+28		3.8
R	2.6	6.2	-2.0	10.1	12.5	6.4	38+42		9.8
S	0.0	0.0	-4.7	10.8	11.9	5.1	37+24+32		14.9
T	0.6	0.6	-6.5	11.9	16.3	9.9	63+48		
U	4.1	4.7	-1.0	12.4	13.4	9.3	70	22.3	11.2
V	3.3	5.6	3.3	13.9	17.5	13.9	32	10.2	5.8
W	4.9	8.0	2.9	13.5	15.4	9.2	49+37	15.6(49)	10.3
X	2.4	2.4	-3.1	16.3	17.5	14.0	28+18		6.1
Y	3.4	5.9	-0.7	16.7	20.3	16.5	23+26+36+36		8.7
T1	8.2	12.7	0.9	15.0	19.6	12.0	72+32		
A1	8.7	8.7	-1.4	10.7	12.1	9.2	25+21		

Tree	Summer Health	Winter Health	Leaf Area (m <sup>2</sup> )	Sapwood Thickness (cm)	Sapwood Area (cm <sup>2</sup> )	Leaf ion concentration			
						[Cl]-ldw (mg g <sup>-1</sup> )		[Na]-ldw (mg g <sup>-1</sup> )	
						Young	Mature	Young	Mature
A	15	12	19.6						
B	12	11	13.1						
C	15	13	27.3			1	1	5	5
D	16	16	39.2						
E	13	13	12.0	1.4	58.0				
F	8	10	1.1						
G	13	13	14.2						
H	14	12	8.2						
I	15	14	22.9						
J	15								
K	8	9	4.4						
L	11	12	56.7	1.3	55.9				
M	11	13	17.4						
N	9	9	5.5						
O	12	14	3.3	0.5	10.8	8	6	6	7
P									
Q	8	12	2.7			10		8	8
R	15	13	24.0						
S	11	11	8.7			1	0.5	6	5
T	16	16	37.1						
U	15	15	24.0						
V	12	10	3.8						
W	12	13	17.4	0.8	32.2	1	0.5	6	6
X	13	12	2.2						
Y	10	11	8.7						
T1	7/15								
A1	9/15								

## Appendix C

Site: BM (continued)

Tree	Pre-dawn leaf water potential (-kPa)			Pre-dawn leaf water potential (-kPa)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
A	2300	2500	2400	3400	3250	3250
B						
C						
D						
E	2200	2400	2400			
F						
G						
H						
I	2300	2100	2050			
J						
K						
L						
M	2400	2500	2400			
N						
O						
P						
Q	3050	2900	3000			

Soil Depth (cm)	Summer Suction (kPa)	Winter Suction (kPa)	Summer Theta g (g g <sup>-1</sup> )	Winter Theta g (g g <sup>-1</sup> )	[Cl]-ss (mg l <sup>-1</sup> )	Osmotic Potential (kPa)
0-10	16869	30	0.018	0.110	6586	823
10-20	4519	173	0.077	0.140	11328	1416
20-30	2903	180	0.098	0.167	5926	741
30-40	1812	126	0.115	0.191	8461	1058
40-50		214	0.142	1.548	9639	1205
50-60	1136	118	0.122	0.105	10056	1257
60-70		111	0.093	0.449	10020	1253
70-80	648	92	0.063	0.059	11044	1380
80-100	451	239	0.021	0.088	11733	1467
100-120		156	0.037	0.094	1694	212
120-140	1007	200		0.121		
140-160		154	0.099	0.110	9640	1205
160-180	14	18	0.073	0.029	9896	1237
180-200		11	0.048	0.055	8106	1013
200-250	7	5	0.065	0.011	1812	227
250-300	1	1	0.085	0.250	1447	181



## Appendix C

Site: BH  
Area: 952.4m<sup>2</sup>

Tree	Coordinate A			Coordinate B			GBH (cm)	DBH (cm)	Tree Height (m)
	Base	Canopy Right	Canopy Left	Base	Canopy Right	Canopy Left			
A	17.8	27.9	17.8	13.7	9.2	18.9	153	49	10.2
B	12.8	18.3	7.3	11.3	4.8	17.0	118+79		12.5
C	9.0	12.9	5.5	12.1	6.2	13.3	89+86		9.4
D	2.7	5.2	0.0	6.5	1.7	8.8	97	31	9.5
E	5.4	14.0	1.3	22.6	14.1	32.2	236	75	12.6
F	17.3	25.6	10.6	24.9	32.7	18.6	282	90	15.3

Tree	Summer Health	Winter Health	Leaf Area (m <sup>2</sup> )	Sapwood Thickness (cm)	Sapwood Area (cm <sup>2</sup> )	Leaf ion concentration			
						[Cl]-ldw (mg g <sup>-1</sup> )		[Na]-ldw (mg g <sup>-1</sup> )	
						Young	Mature	Young	Mature
A	15	17	50.1	2.2	268.2	10	10	4	5
B	17	17	122.1	1.6	108.5	1	2	3	5
C	15	15	39.2				9		3
D	15	14	36.0	1.5	127.7	8	5	5	4
E	16	15	126.4	2.1	405.7	8	5	4	4
F	18	15				11	6	4	3

Tree	Pre-dawn leaf water potential (-kPa)			Midday leaf water potential (-kPa)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
A	2200	2650	2350			
B	2650	2400	2400			
C	3100	2350	2650			
D	2500	2450	2350	3600	3650	3600
E	2100	2100	2450			

Soil Depth (cm)	Summer Suction (kPa)	Winter Suction (kPa)	Summer Theta g (g g <sup>-1</sup> )	Winter Theta g (g g <sup>-1</sup> )	[Cl]-ss (mg l <sup>-1</sup> )	Osmotic Potential (kPa)
0-10	68237	3276	0.018	0.035	1998	250
10-20	39468	3207	0.017	0.027	2613	327
20-30	11150	5596	0.063	0.068	1658	207
30-40	6915	4018	0.061	0.050	2935	367
40-50		6592	0.065	0.044	4995	624
50-60	4007	2982	0.066	0.044	5812	727
60-70		4610	0.068	0.062	8603	1075
70-80	2054	2652	0.069	0.057	9892	1236
80-100	1434	3228	0.080	0.041	10588	1323
100-120		5465	0.054	0.036	11477	1435
120-140	622	4982	0.025	0.034	9288	1161
140-160		3428	0.086	0.022	10283	1285
160-180	274	2993	0.080	0.017	10903	1363
180-200		2875	0.103	0.058	11591	1449
200-250	25	1355		0.077		
250-300	1	836		0.072		
300-350		25		0.073		
350-400		6		0.089		
400-450		12		0.212		

## Appendix C

Site: BT  
Area: 400m<sup>2</sup>

Tree	Coordinate A			Coordinate B			GBH (cm)	DBH (cm)	Tree Height (m)
	Base	Canopy Right	Canopy Left	Base	Canopy Right	Canopy Left			
A	15.6	14.3	17.4	19.1	20.0	17.4	31+35	11.1(35)	5.6
B	9.8	3.9	10.2	19.7	22.5	18.8	41+28	13.1(41)	7.3
C	11.5	6.2	16.2	17.1	22.5	13.2	37+50+54+60		10.1
D	13.6	12.5	18.5	12.5	15.2	9.9	136	43.3	9.0
E (em)	14.3	14.4	15.9	13.5	15.1	13.2	19	6.0	4.8
F	11.7	8.4	12.6	12.4	15.3	7.2	58+28		11.3
G	9.9	9.1	10.6	11.2	11.8	6.8	32	10.2	5.2
H	8.5	3.3	7.7	11.9	12.8	9.4	48	15.3	9.8
I (em)	5.8	2.8	7.3	12.7	15.2	10.6	33	10.5	5.4
J	1.3	-1.8	7.4	13.1	18.4	3.8	119	37.9	13.0
K	7.9	5.5	12.2	3.8	10.0	0.8	124	39.5	14.0
L	10.7	6.5	11.0	6.4	7.8	5.3	98	31.2	11.1
M	11.5	9.9	13.6	1.0	12.9	0.0	90	28.6	9.6
N	17.2	16.3	19.5	0.5	13.0	-1.5	105+93		9.6
O/hang	25.0	17.8	30.5	16.0	24.5	11.1			

Tree	Summer Health	Winter Health	Leaf Area (m <sup>2</sup> )	Sapwood Thickness (cm)	Sapwood Area (cm <sup>2</sup> )	Leaf ion concentration			
						[Cl]-ldw (mg g <sup>-1</sup> )		[Na]-ldw (mg g <sup>-1</sup> )	
						Young	Mature	Young	Mature
A	14	14	9.8	1.2	32.4	6	1	3	5
B	14	14	24.0	0.7	19.6				
C	14	17	83.9			7	7	5	4
D	11	17	21.8						
E(em)									
F	13	10	21.8			7	0.5	5	5
G	14	15	9.8						
H	14	12	17.4						
I(em)						7	1	7	6
J	16	15	81.8	1.2	151.5				
K	13	14	52.3						
M	8	10	8.7	1.0	88.6				
N	13	14	31.6				1		4
O/hang	9	11	26.2			1	1	4	4

Tree	Pre-dawn leaf water potential (-kPa)			Midday leaf water potential (-kPa)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
A	2900	2700	2650			
B	2450	2750	2650			
C	2400	2800	3050			
D						
E(em)						
F	2700	2900	2750			
G						
H						
I(em)						
J						
K	2500	2350	2650	3250	3100	3000
M						
N						
O/hang	2700	3050	2900			

## Appendix C

Site: BT (continued)

Soil Depth (cm)	Summer Suction (kPa)	Winter Suction (kPa)	Summer Theta g (g g <sup>-1</sup> )	Winter Theta g (g g <sup>-1</sup> )	[Cl] <sup>-</sup> ss (mg l <sup>-1</sup> )	Osmotic Potential (kPa)
0-10	52953	1676	0.378	0.099	25126	3141
10-20	22191	1635	0.077	0.083	8599	1075
20-30	6768	1665	0.131	0.106	6791	849
30-40	3363	3094	0.136	0.114	15697	1962
40-50		1615	0.154	0.137	15659	1957
50-60	948	2228	0.164	0.149	19317	2415
60-70		1085	0.191	0.148	13867	1733
70-80	222	943	0.171	0.127	18002	2250
80-100	87	221	0.159	0.090	16962	2120
100-120		271	0.124	0.077	17614	2202
120-140	192	225	0.172	0.153	15210	1901
140-160		81	0.141	0.163	16804	2100
160-180	51	47	0.027	0.214	14220	1777
180-200		45	0.120	0.114	17716	2214
200-250	26	34	0.114		16658	2082
250-300	1	20		0.175		
300-350		9		0.059		
350-400		6		0.172		



## Appendix C

Site: BU  
Area: 400m<sup>2</sup>

Tree	Coordinate A			Coordinate B			GBH (cm)	DBH (cm)	Tree Height (m)
	Base	Canopy Right	Canopy Left	Base	Canopy Right	Canopy Left			
A	2.6	1.0	5.4	4.0	6.2	1.3	43+40+43+2		7.2
B	10.5	0.6	5.9	10.1	14.0	7.9	39+34+25+3		5.7
C	4.9	2.1	5.8	14.3	16.5	13.0	31+48		4.6
D	7.7	5.4	9.1	10.6	13.4	8.0	25+31+38+3		4.5
E	11.3	7.0	8.4	19.2	22.0	18.6	84	26.7	7.5
F	12.4	10.8	13.6	18.2	20.0	15.9	23+35+37		6.5
G	19.6	18.2	19.5	20.0	20.5	19.0	20	6.4	3.3
H	17.6	15.9	20.0	16.0	18.4	13.3	108	34.4	8.7
I	16.8	13.5	16.8	6.7	7.9	5.5	75	23.9	3.4
J	13.2	10.9	16.0	2.9	5.4	0.5	90+80	25.5(80)	7.3
K	9.0	8.0	9.6	5.0	6.0	3.2	39		5.8

Tree	Summer Health	Winter Health	Leaf Area (m <sup>2</sup> )	Sapwood Thickness (cm)	Sapwood Area (cm <sup>2</sup> )	Leaf ion concentration			
						[Cl]-ldw (mg g <sup>-1</sup> )		[Na]-ldw (mg g <sup>-1</sup> )	
						Young	Mature	Young	Mature
A	10	13	46.9			1	1	3	6
B	12	13	46.9						
C	10	10	25.1			1		4	7
D	10	11	19.6						
E	9	9	12.0	1.3	96.8				
F	12	12	18.5						
G	13	12	2.7	0.2	3.7	0.4	1	7	4
H	8	9	27.3	0.5	51.7				
I	9	10	6.0			1	1	4	2
J	9	10	24.0	0.9	67.0				
K	12	13	10.9	0.8	27.2	1	1	2	3

Tree	Pre-dawn leaf water potential (-kPa)			Midday leaf water potential (-kPa)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
A	3550	3550	3500			
B						
C						
D	3550	3500	3500			
E						
F	3500	3500	3300			
G						
H						
I	3500	3350	3200			
J	3200	3200	3200			
K	3400	3500	3400			

Soil Depth (cm)	Summer Suction (kPa)	Winter Suction (kPa)	Summer Theta g (g g <sup>-1</sup> )	Winter Theta g (g g <sup>-1</sup> )	[Cl]-ss (mg l <sup>-1</sup> )	Osmotic Potential (kPa)
0-10	87087	2089	0.041	0.118	15485	1936
10-20	50549	6966	0.066	0.108	12741	1593
20-30	21280	9078	0.098	0.110	7437	930
30-40	7457	8730	0.121	0.125	6124	765
40-50	4853	4467	0.136	0.139	7185	898
50-60	3948	1469	0.139	0.154	8763	1095
60-70	2183	1390	0.132	0.149	10416	1302
70-80	1470	218	0.121	0.131	11858	1482
80-100	104	52	0.142	0.153	13089	1636
100-120	53	41	0.158		39050	4881
120-140	62	50	0.185	0.190	19006	2376
140-160	56	45	0.178	0.183	19580	2447
160-180	40	33	0.178	0.198	20684	2585
180-200	22	19	0.166	0.162	21418	2677
200-250	13	14	0.152	0.163	25811	3226
250-300	11	12	0.216	0.197	20188	2523
300-350	8	6	0.204	0.142	21096	2637
350-400	1	8	0.166	0.125	19534	2442
400-450						

## Appendix C

Site: BD (all trees dead)

Area: 400m<sup>2</sup>

Tree	Coordinate A			Coordinate B			GBH (cm)	DBH (cm)	Tree Height (m)
	Base	Canopy Right	Canopy Left	Base	Canopy Right	Canopy Left			
A	7.0			9.0			8		
B	6.7			11.8			2+2+2		
C	9.6			10.9			5+2+2		
D	8.5			16.2			2+2+2+3+2+2		
E	4.9			17.8			2+3+2+2+4+2		
F	11.8			19.5			2+4+2+3+4+4+2+4		
G	14.1			6.7			7+3+2		

Tree	Summer Health	Winter Health	Leaf Area (m <sup>2</sup> )	Sapwood Thickness (cm)	Sapwood Area (cm <sup>2</sup> )	Leaf ion concentration			
						[Cl]-ldw (mg g <sup>-1</sup> )		[Na]-ldw (mg g <sup>-1</sup> )	
						Young	Mature	Young	Mature
A	4	4							
B	4	4							
C	4	4							
D	4	4							
E	4	4							
F	4	4							
G	4	4							

Tree	Pre-dawn leaf water potential (-kPa)			Midday leaf water potential (-kPa)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
A	3000	3050	2800			
B	3600	3050	3000			
C	3200	3700	3150			

Note: these measurements were made on live trees 50m from the BD plot.

Soil Depth (cm)	Summer Suction (kPa)	Winter Suction (kPa)	Summer Theta g (g g <sup>-1</sup> )	Winter Theta g (g g <sup>-1</sup> )	[Cl]-ss (mg l <sup>-1</sup> )	Osmotic Potential (kPa)
0-10	1382	16	0.022	0.090	16325	2041
10-20	1509	45	0.069	0.080	51994	6499
20-30		23		0.098		
30-40	773	258	0.095	0.103	43303	5413
40-50	413	245	0.099	0.114	41664	5208
50-60	296	369	0.070	0.117	45639	5705
60-70	251	262	0.074	0.124	42315	5289
70-80	317	152	0.094	0.110	39381	4923
80-100	341	105	0.089	0.114	43131	5391
100-120	79	53	0.112	0.143	30256	3782
120-140	66	56	0.162	0.180	27620	3452
140-160	203	53	0.178	0.193	24538	3067
160-180	154	75	0.197	0.203	21889	2736
180-200	161	58	0.217	0.211	21312	2664
200-250	213	73	0.215	0.225		
250-300	20	91	0.158	0.175	21101	2638
300-350	15	14	0.109	0.214	18134	2267
350-400	8	6	0.233	0.244	20727	2591
400-450	10	11	0.260	0.254	18329	2291
450-475	1	17	0.236	0.246	17650	2206



## Appendix C

Site: RM  
Area: 827.2m<sup>2</sup>

Tree	Coordinate A			Coordinate B			GBH (cm)	DBH (cm)	Tree Height (m)
	Base	Canopy Right	Canopy Left	Base	Canopy Right	Canopy Left			
A	26.3	11.1	29.5	23.2	16.0	28.4	28	8.9	25.6
B	25	15.7	29.5	19.1	12.2	20.9	27	8.6	24.0
C	15.3	0.6	31.5	12.2	-6.0	16.9	62	19.7	30.5
D	9.2	0.7	9.7	7.2	3.1	10.2	13	4.1	34.1
L1	27			26.9					
L2	15.5			0.5					
L3	1.9			24.6					
L4	0.6			22.4					
L5	20.6			15.9					
L6	7.7			12.9					
L7	13.8			11.6					
L8	2.8			5.3					
L9	3.5			5.8					
L10	4.9			4.8					
L11	2.8			3.3					
L12	0.8			2.4					
L13	1.2			3.1					
L14	3.4			1.2					
L15	3.5			0.4					
L16	10.5			1.2					
L17	1.2			5.3					

Tree	Summer Health	Winter Health	Leaf Area (m <sup>2</sup> )	Sapwood Thickness (cm)	Sapwood Area (cm <sup>2</sup> )	Leaf ion Concentration			
						[Cl]-ldw (mg g <sup>-1</sup> )		[Na]-ldw (mg g <sup>-1</sup> )	
						Young	Mature	Young	Mature
A	17	17	316	1.9	494.8		1		3
B	13	14	123.7	1.7	434.2		1	2	3
C	18	18	753.4	1.8	1091.4	1	1	3	3
D	17	17	93.9	2	203.6				

Tree	Pre-dawn leaf water potential (kPa)			Midday leaf water potential (kPa)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
B	1500	1250	1900			
C	1600	2050	1700	1950	1900	1950

Soil Depth (cm)	Summer Suction (kPa)	Winter Suction (kPa)	Summer Theta g (g g <sup>-1</sup> )	Winter Theta g (g g <sup>-1</sup> )	[Cl]-ss (mg l <sup>-1</sup> )	Osmotic Potential (kPa)
0-10	57781	511	0.079	0.200	762	95
10-20	21117	881	0.114	0.202	681	85
20-30	5092	1656	0.168	0.192	317	40
30-40	3967	2377	0.183	0.188	632	79
40-50		4074	0.174	0.191	891	111
50-60	3873	4519	0.191	0.193	1591	199
60-70		3715	0.199	0.193	2619	327
70-80	2690	3228	0.198	0.189	3444	430
80-100	2677	3926	0.190	0.171	4557	570
100-120		1429	0.178	0.182	6178	772
120-140	107	77	0.167	0.168	5623	703
140-160		40	0.157	0.167	5226	653
160-180	27	31	0.187	0.192	5714	714
180-200		29	0.122	0.194	6027	753
200-250	7	9	0.199		8180	1023