Nature Conservation Leaders Field Trip
Wheatbelt Region
June 2011

Pls rescan.

Tree Decline in the Wheatbelt Understanding the Causes and the Consequences

Great Southern District

Department of
Environment and Conservation

Our environment, our future

To:	**Director Nature Conservation**	**File Ref:2009/002 351**
From:	**Peter White Nature Conservation Officer**	
Date:	**13 June 2011**	
Subject:	**Tree health monitoring and recording**	

Through: District Manager Great Southern District & Regional Manager Wheatbelt & Director Regional Services.

Introduction

There is a significant decline occurring in many forest and woodland species within the Wheatbelt Region and other DEC Regions (e.g. Albany Highway observed in 2011). This is likely to be the result of climate change, particularly rainfall decline resulting in a significant soil moisture deficit. Attempts to monitor and record decline issues appear fragmentary, both within the Dept and allied organizations (e.g. Centre of Excellence for Climate Change, Woodland and Forest Health). The recent debate that is occurring in the media and on differing blog sites indicates a need for a systematic approach to monitoring plant health. The Department needs to champion this issue with Regions, including the Wheatbelt. It would mean supporting this through systematic observation and recording, with provision for more intense data collections if necessary. The Department also needs to develop strategies to address the predicted loss of canopy cover and the possible effects to plant and animals through habitat loss.

Background

Over the past several years, it has been evident that many tree species / plant communities are under stress and in a state of decline. This may have been as the result of damaging agents such as Phytophthora, which affects many species in relatively confined areas through to insects that attack a single species across it's entire range e.g. Wandoo Crown Decline. Appendix 1 is a brief summary of the species and damaging agents. Some examination of the decline problem has occurred at a local level e.g. *Eucalyptus marginata* deaths at Dryandra Woodland, which is thought to be drought. Some investigation was done on a decline in the Nangeenan area – this was the focus of an ABC television broadcast – though there is no clear understanding of the cause or the extent of the problem. A preliminary investigation was carried out (in conjunction with VHS) of a major crown decline in the North Bannister area; a problem which was mis-diagnosed by subsequent commentators, hence never adequately understood or recorded.

There has been some discussions with the Wheatbelt Science Division representative and through other groups (e.g. the Wandoo Recovery Group) about how tree declines could be reported, monitored and where information may be stored. These have been inconclusive.

In the last few months, the death of forest trees in the Gleneagle / Mt Cooke area has become very noticeable. The trees were observed to be under stress before this, but there is now significant tree death and subsequent leaf loss. Significant leaf loss has occurred on the outlier Jarrah stand at Jilakin Rock and in a high value biodiversity asset (yate community) in the Lake Bryde Natural Diversity Recovery Catchment.

The concerns from the Great Southern District are the limited capacity to have problems investigated properly and the lack of a coordinated response within the Department. Any information that is collected is only stored locally, there is no system to map the extent of any problem and that there is no assessment of the affects that the events are having on the surrounding ecosystems. The existing tools used to assess vegetation health e.g. Vegmachine, do not detect problems at their onset, nor can a cause be distinguished.

Discussion
This issue would probably best be developed at a Departmental level. However, there may be some inertia to overcome and valuable time may be lost if there is a protracted discussion over which section of the Dept has the corporate responsibility for the work.

What needs to be done in the Wheatbelt Region is:

Consideration (and time allocation) to the development of a Regional scale assessment of

- The number of woodland species and the % of the Wheatbelt flora (both on and off DEC land)
- The number of biotic / abiotic causes of declines
- The area of each species / ecosystem affected by each cause of decline
- The severity of each causal agent and its capacity to spread
- The affects on the other organisms in the ecosystem

It would require the development of:

- A recording system for systematic information gathering
- An information storage and retrieval system
- Mapping capacity

It also needs the issue to be communicated effectively to the public.

This monitoring and investigation work fits within the Wheatbelt Region Nature Conservation Service Plan, Landscapes, Target (T1); it is mentioned at being in the top 10 Nature Conservation Priorities for the next five years; however, there is nothing specific in the plan to cover monitoring and investigation of general ecosystem health or declines in vegetation due to climate change or other causes. There is no direct funding attached to this.

Recommendations

The Wheatbelt Regional Operations Manager tables the issue for discussion at the forthcoming Nature Conservation Program Leaders meeting as a potential serious issue developing for the South-West land Division and that the Department supports the development for monitoring of general ecosystem health and declines in vegetation due to climate change within Science Division.

The Wheatbelt Region also seeks funding opportunities for an officer to investigate and collate data directly relating to tree and habitat decline in the Wheatbelt Region. This initiative is to be supported by including it in the Wheatbelt Region's Nature Conservation Plan.

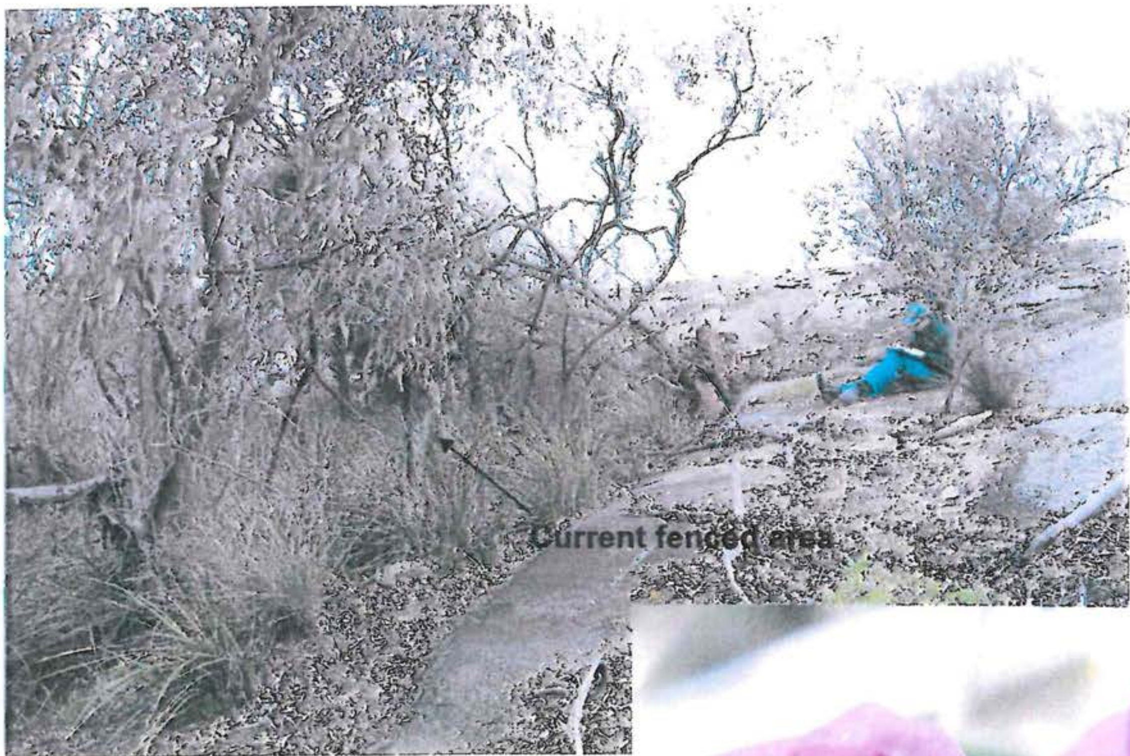
Peter White
Nature Conservation Officer

			Biotic															Abiotic							
			Fungi						Insects								Unnamed	Environmental				Poisoning	Unknown		
Genus	species	Forest, Woodl'd, Mallee, Heath	Armillaria	Marri CD	Phytophthora sp.	Phytophthora cinnamoni	Quambalaria	Uromycladium tepperianaum	Cossid moth	Galls	GLS	Lerps	locusts	Spring beetle	Tip damage	WCD and other flagging	Mundulla Yellows	Drought / climate change	Heat stress	Salinity	Waterlogging	Herbicide	Growden road decline	Freq.	Species distribution in Region
Acacia	*acuminata*	W						*										*						2	*widespread / common*
Acacia	*saligna*	F/W/M						*																1	*widespread / common*
Allocasuarina	*fraseri*	F				*									*			*						3	*western side / common*
Allocasuarina	*huegeliana*	W											*					*						2	*widespread / common*
Casuarina	*obesa*	W													*					*	*			3	*widespread / frequent*
Corymbia	*calophylla*	F	*	*			*											*						4	*western side / common*
Eucalyptus	*accedens*	W																						0	*western side / frequent*
Eucalyptus	*argyphea*	W																						0	*central / eastern / scattered*
Eucalyptus	*astringens*	W																						0	*western / scattered*
Eucalyptus	*camaldulensis*																*							1	*introduced*
Eucalyptus	*capillosa*	W																					*	1	*eastern / frequent*

Eucalyptus	*gardneri*	W														*	*					*		3	*central / eastern / scattered*
Eucalyptus	*kondininensis*	W																		*	*	*		3	*central / eastern / scattered*
Eucalyptus	*longicornis*	W						*											*			*		3	*widespread / common*
Eucalyptus	*loxophleba*	W															*		*					2	*western / southern / frequent*
Eucalyptus	*marginata*	F				*					*					*	*	*	*					6	*western / common*
Eucalyptus	*myriadena*	W																						0	*northern / central / scattered*
Eucalyptus	*occidentalis*	W										*				*	*	*						4	*southern / frequent*
Eucalyptus	*patens*	F																						0	*western / scattered*
Eucalyptus	*rudis*	W										*				*	*			*	*			5	*western / southern / frequent*
Eucalyptus	*salmonophloia*	W						*										*	*				*	4	*widespread / common*
Eucalyptus	*salubris*	W															*						*	2	*central / eastern / scattered*
Eucalyptus	*sargentii*	W																			*			1	*central / scattered*
Eucalyptus	*spathulata*	W																						0	*western / central / scattered*
Eucalyptus	*urna*	W																						0	*eastern / scattered*
Eucalyptus	*wandoo*	W	*									*				*			*	*	*	*		7	*western / southern / frequent*
		species affected	2	1	0	2	1	2	2	0	1	3	1	0	2	5	7	7	5	4	5	4	3		

Tetratheca deltoidea – Mt Caroline NR
Central Wheatbelt District

This species was known from 3 locations during the late 1880-90's. Thought be to extinct until 1988 it is only known from 2 small locations on top of Mt Caroline. Plants numbers have declined since re-discovery in 1988 by S Hopper (then approx 150 plants) but remaining plants seemed to be doing well until summer 2010-11. The last year has been of record low rainfall and the entire reserve is showing signs of extreme stress.
Seed collection and plans to replace fencing is in progress.



Myriophyllum lapidicola – Central Wheatbelt District

M. lapidicola is a poorly understood ephemeral aquatic herb found in gnamma holes (20-50 cm deep) on granite outcrops. First discovered by R. Cranfield in 1989, the species has since been recorded from 7 populations in the CW and Goldfields District. Recent monitoring has however failed to relocate 2 populations (at Yanneymonning and De-Eranning NR's) recorded from within the CWD. Survey for this species is difficult as it can remain dormant for some time after rain especially after extended dry periods.

Arid Bronze Azure Butterfly (*Ogyris subterrestris petrina*)

Barbalin NR, Central Wheatbelt District

The only extant population of the critically endangered Arid Bronze Azure butterfly is within and adjacent to Barbalin Nature Reserve in the northern wheatbelt of south-west Western Australia. The only other known, but now extinct, site where the butterfly occurred was at Lake Douglas, 12 km SW of Kalgoorlie.

In order to reproduce, the butterfly has an obligate association with the sugar ant *Camponotus terebrans*. The larvae are obligate myrmecophiles, feeding on or being fed by the ants, and living entirely within the ant's nest during their development. The ants also protect the butterfly larvae from predators, while the ants are thought to be rewarded with secretions produced by the larvae. Thus the survival of this butterfly depends on the continued existence of strong colonies of its host ant.

The most critical factor for habitat occupancy by the butterfly is the presence of large populations of the pale-coloured or 'Goldfields' form of the sugar ant *Camponotus terebrans*. Only large ant colonies can support the butterfly, because as a parasitic species, the butterfly requires large numbers of host ants. Similar ant-dependent species have ratios of ants to butterflies as high as 500:1. Hence the habitat critical for the butterfly is effectively the best, or optimal habitat for the host ant. Another critical habitat requirement is disturbance. The preferred level, type and age since disturbance is still being investigated but what is known is that *C. terebrans* is one of the first ant species to colonise disturbed sites.

The host ant also supports populations of the sap-feeding leafhopper *Pogonoscopus myrmex*. It is unknown to what degree the ants rely on the hopper's honey-dew as a resource, but if *P. myrmex* is critical to maintain large colonies of *C. terebrans* then a eucalypt's morphology will be of consequence.

There is inadequate data and research to comprehensively detail threats to the butterfly. However, changes to fire regimes, fragmentation, private collection and human disturbance are likely to cause future changes in the species' distribution and viability. The preference of males for open spaces in which to establish territories may increase the chance of roadkill. Any catastrophic events, such as flooding, hot burns associated with severe winds could be a risk to the species given that currently only a single population is known in a relatively small area. The species distribution, if more extensive than presently known, is undoubtably severely fragmented principally through human-induced land clearing for agriculture.

Mature (pre-pupal) larva attended by a sugar ant worker (x6). (Photo S. Brown and T.Gamblin).

The dispersal ability of the species is limited, which increases its fragmentation. Typically in lycaenid butterflies, each female lays more than half of her eggs in the original colony and dispersal commences thereafter. If successful in locating another ant population these dispersals may result in the establishment of new butterfly colonies. Typical dispersal distances are not known for females of *O.* Australia, *Hypochrysops halyaetus*, found that of over 1000 marked individuals the longest dispersal distance was 810 m for one female, but averaged less than 200 m.

Petrogale lateralis lateralis – Mt Caroline NR & others Central Wheatbelt District

This species is known from 18 populations scattered across much of western WA.

Mainland populations occur east of the Fortescue River Roadhouse, Cape Range NP, Ningaloo Station, Calvert Range, the Durba Hills (but may have declined), Nangeen Hill NR, Mount Caroline NR, Mount Stirling NR, Sales Rock, Querekin Rock and Tutakin (Gundaring) NR, Kokerbin Rock NR, Sales Rock, Cape Le Grand NP, Avon Valley NP and Paruna Sanctuary.

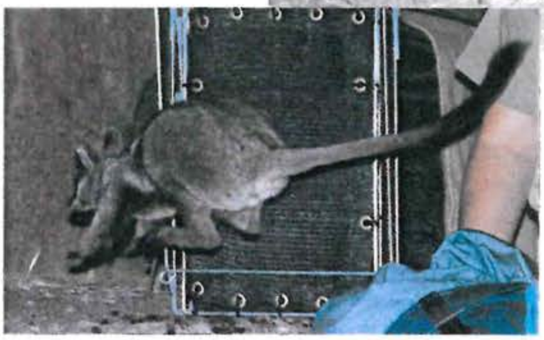
Two island populations occur on Barrow Island and on Salisbury Island.

Subfossil remains are known from Devil's Lair Cave [as *Petrogale penicillata*] and other granite outcrops within the CWD.

WWF

Previously extant colonies at Depuch Island, Gairdners Rock and Mount Ragged in Cape Arid National Park are now extinct.

Recent dramatic population declines at Nangeen Hill and Mt Caroline (founder colonies for several translocations) combined with the unknown fate of the translocated pops and the small and fragmented nature of the other colonies suggests that the current listing doesn't truly reflect the status vulnerability of this species.



Eucalyptus marginata subsp. *marginata*: Dryandra

DRY_1Eb_260209

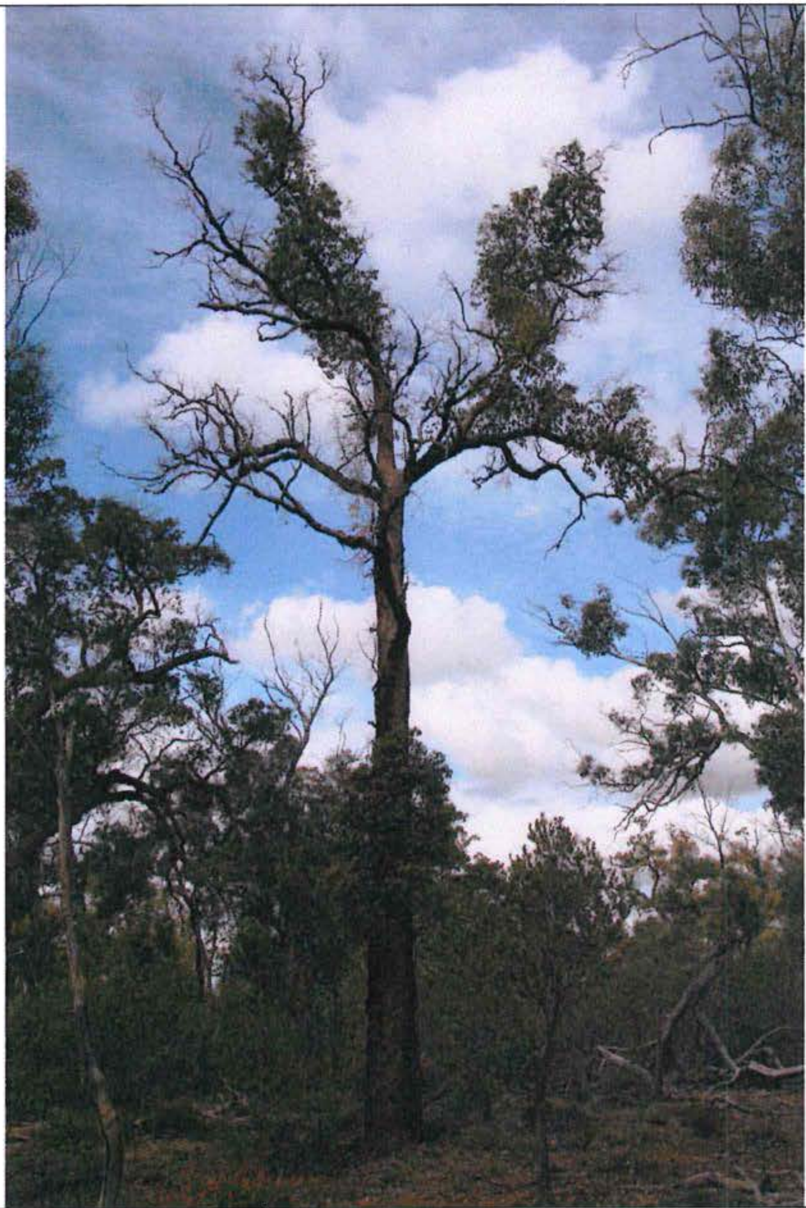
DRY_1Ed_260209

Eucalyptus marginata subsp. *marginata*: Dryandra

NK_2a_040209

NK_1a_040209

Corymbia calophylla: Marri Decline, Dryandra

	
26th Aug 2008 Dryandra SF	26th Aug 2008 Dryandra SF

Acacia acuminata NR10672 16th April 2010

Great Southern District

Department of
Environment and Conservation
Our environment, our future

To: **Greg Durell** **File Ref:**

From: **Nature Conservation Officer**

Date: **13 June 2011**

Subject: **2011 assessment of E. marginata at Jilakin Rock**

Through: Peter Lacey

On the afternoon of 13th May 2011, Peter Lacey and I inspected the health of the *Eucalyptus marginata* population at Jilakin Rock. Unfortunately, it was very late in the afternoon so time for a comprehensive assessment was limited. However, we were able to count and measure the live stems on the southern side of the road, using the size classes outlined by Kim Whitford (DEC Dwellingup).

Since you and I visited the site on 26th August, there has been a sharp decline in the number of trees alive on the site. We were able to count 14 live trees and 4 live seedlings, compared with the 41 live trees noted by Whitford in 2006 and the 74 counted by Abbott in 1981.

Site observations:

- All trees west of parking area appeared to be dead (some with old brown leaves still present in the canopy)
- many trees here and on the remainder of the site have put out a series of epicormics which have persisted for varying lengths of time, but still perished
- some of the trees near old toilet where still carrying a good crown
- the leaves on some trees appear to have died recently - there still may be some recovery from lignotubers if there is significant rainfall in the next few months
- there didn't appear to be a correlation between size classes and survival (table 1), more that it was site related with the trees closer to the drainage line being in better condition
- the *Acacia*, *Allocasuarina* and other *Eucalyptus* spp are apparently unaffected

As discussed, though there was some speculation about the cause of the decline in Whitfords 2008 report, the trend of decreased rainfall and higher average temperatures (fig 1) make drought and competition for moisture by the surrounding vegetation the most likely causes of tree death.

Given the scientific and public interest in this site, it would be worth periodic monitoring of any further decline or recovery at this site. These measurements will be sent to Kim Whitford, but it may be worth sending a copy to Colin Yates at the Depts. centre for Biodiversity and Climate Change as well as the Centre of Excellence for Climate Change, Forest and Woodland Health.

Peter White
Nature Conservation Officer

					diam			
	tree	stems	<10	10_29	30_49	50_69	70_90	comments
	1	2	9.1	16				two epicormics on an extremely old stump
	1	2			46	66		
	1	4	10		46			near road / main culvert
					35			
					41			
	1	2			42	66		
	1	1			30			
	1	1		20				
	1	1		20				
	1	1			45			
	1	1		27.3				
	1	1		20				
	1	6		14.1	42	55		
				18.2				
				20				
				19.2				
	3	multiple						abundant regrowth from stumps, too many to count
advance growth	4							
total	18							

Table 1 – *E. marginata* survival according to size classes

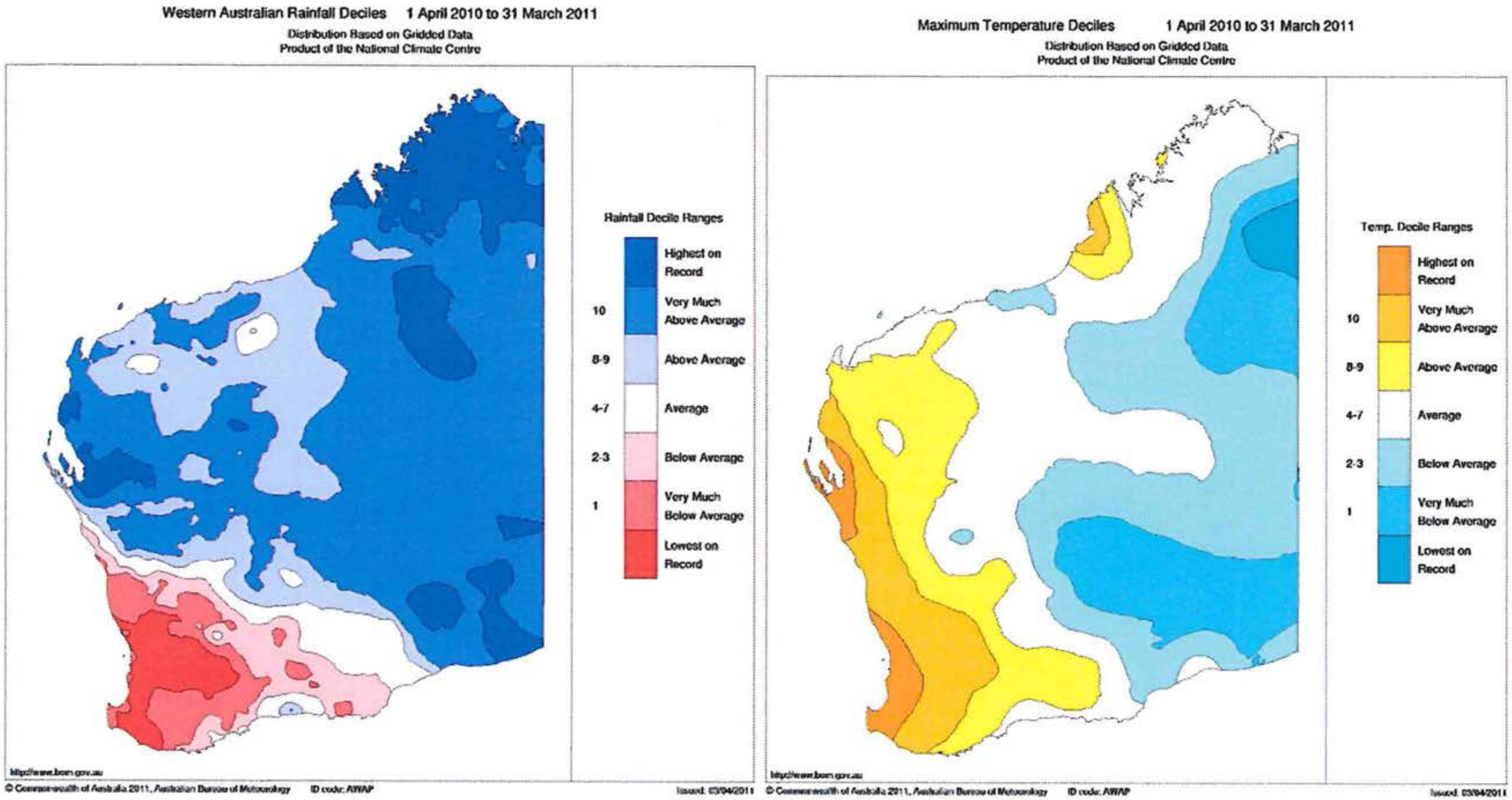
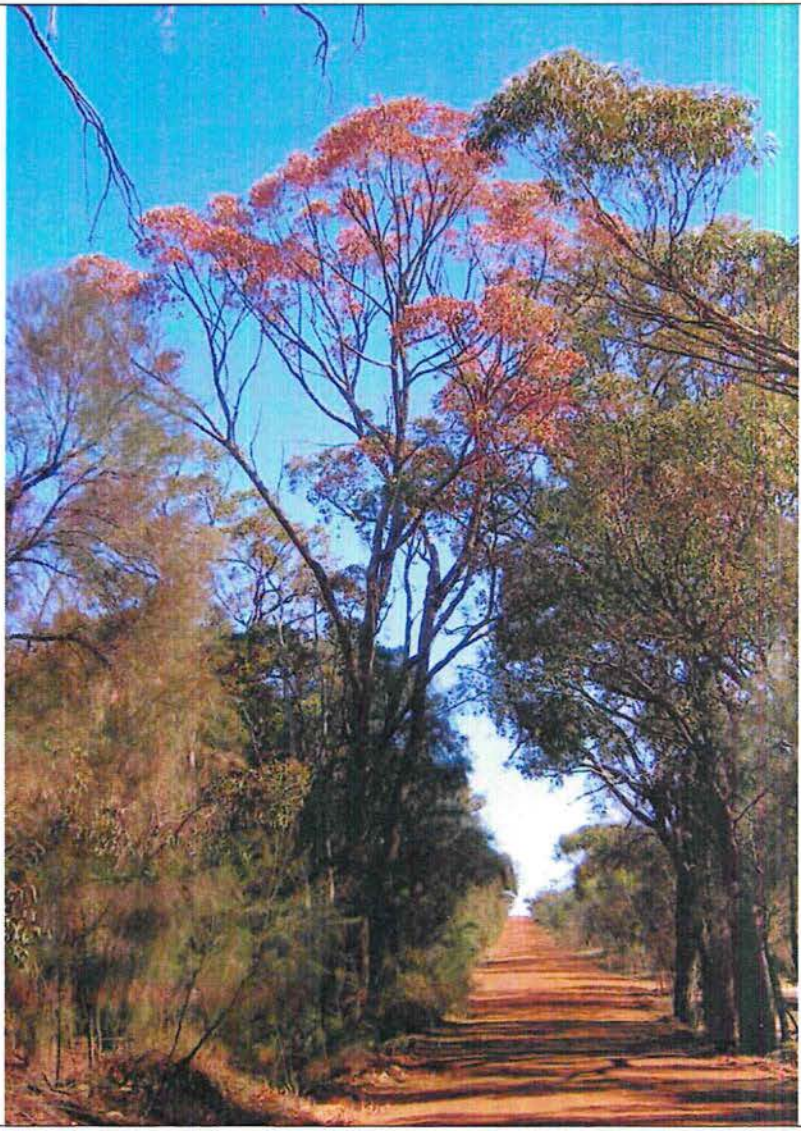


Fig 1 variation in average rainfall and temperature 1 April 2010 to 20 March 2011

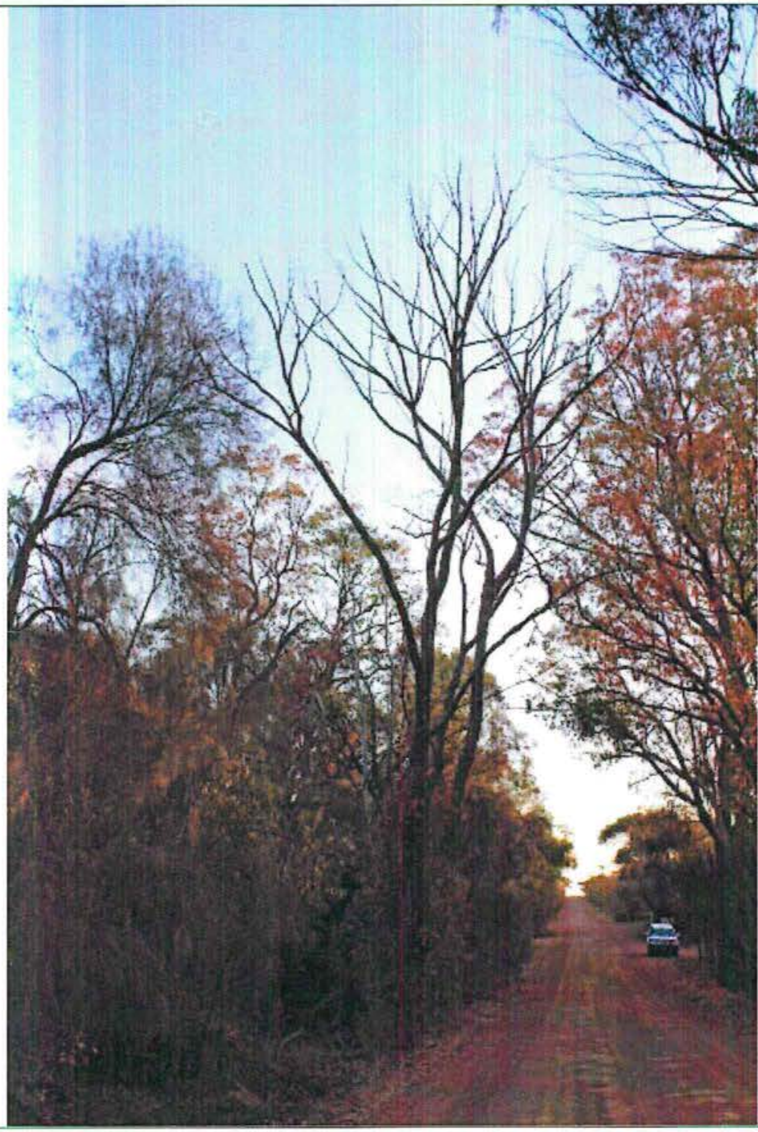
E. marginata, Nth / W side of shelter 2008

E. marginata, Nth / W side of shelter 2011

Fig 2. Progression of canopy decline, *E marginata* on northern and western side of the Jilakin Rock picnic site



E. marginata, Jilakin Rock rd 2008



E. marginata, Jilakin Rock rd 2011

Fig 3. Progression of canopy decline, *E marginata* near main culvert along Jilakin Rock rd

Great Southern District

To:	**Greg Durell**	**File Ref:**
From:	**Nature Conservation Officer**	
Date:	21/4/11	
Subject:	**Yate Swamp tree decline**	

Through: Peter Lacey

Greg

As requested, attached is the report of my initial observations of the *Eucalyptus occidentalis* decline at Yate Swamp.

Ken Wallace's memo of 6th April suggests that unless substantial rain occurs in the future that further vegetation collapses are likely. There is evidence of this occurring at several other sites already in the District and a recording and monitoring strategy should be devised whilst the symptoms are still obvious.

Peter White
Nature Conservation Officer

Eucalyptus occidentalis Endl. decline

Yate Swamp

Lake Bryde Natural Diversity Recovery Catchment

Background

Yate Swamp is a 34ha wooded lake within the LBNDRC

On 31 March 2011, Greg Durell (Gt Sthn District manager) reported significant leaf loss and tree death in the two dominant species on the lake floor; *Eucalyptus occidentalis* and *Melaleuca strobophylla.*

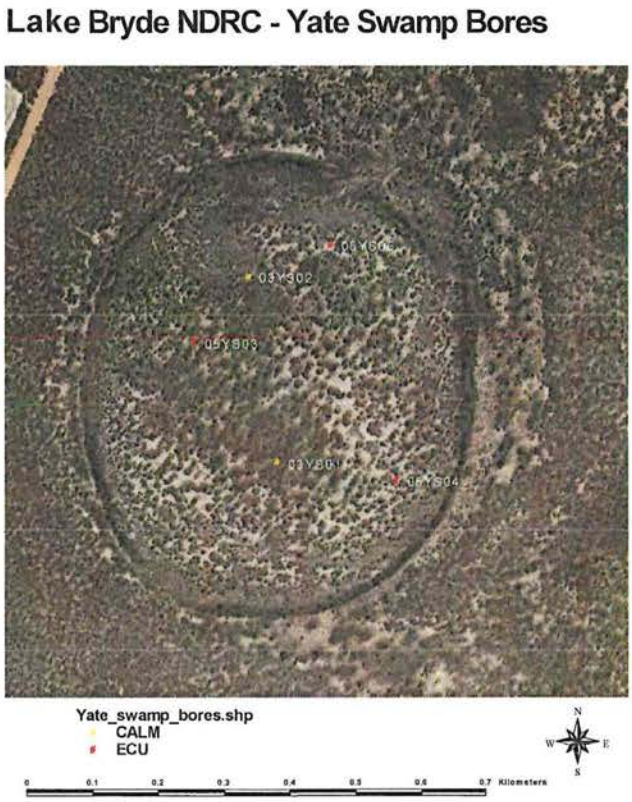
On 6^{th} and 12^{th} April 2011, I visited Yate Swamp to examine the trees and the site in detail. In conjunction with this initial report, drilling is occurring on the lake floor to determine soil depth, moisture availability and salinity. These preliminary observations may be modified depending on the outcome of the drilling work.

Brief site description

Yate Swamp is located within the Shire of Kent, approx 35 SE of Lake Grace townsite. Details of the vegetation and previous hydrological work can be found in reports by Syrinx (2003) and Boyd et al (2008).

The site can be roughly divided into three sections; the fringing strand line plants, the taller *E. occidentalis* in the central portion of the lake and the shorter, more open stands towards the edges on the lake, which has a much higher proportion of *Melaleuca strobophylla.* There is a considerable variation in the density and height range of both species across the lake floor. Though the site is described as a swamp, it only fills intermittently and has no reed beds

There is an access track on the NW side and 5 bores on the lake floor



Description of symptoms

The condition of the trees (both species) ranged from apparently unaffected to recently dead, through to plants that had been dead for (probably) two years. There are parts of the lake where there are numerous stags, but this appears to be from an unrelated cause (fire) and happened many years ago.

Fig 1: aerial photo of Yate Swamp and bore locations

The affected trees were not distributed evenly across the lake floor. The taller *E. occidentalis* in the central section of the lake were less affected than the trees around the periphery. The symptom expression varied though the fringing vegetation, with additional species such as *Melaleuca acuminata* and *M. atroviridis* being affected.

Affected trees where characterised by the dying and eventual loss of foliage. Many trees appeared to be mildly affected, with intact canopies of yellowing foliage. This progressed to the point where the leaves died completely, eventually turning grey and falling to the ground. On many of the *M. strobophylla,* the branchlets had browned off, giving the impression that the plant was dead, but a closer inspection revealed that many parts of the inner canopy were still green. There was very little sign of epicormic shoots on either species. Though the Syrinx report mentions resprouting of trees there was no evidence on this in any of the trees examined.

The foliage appeared to be desiccated; there was no sign of salinity (i.e. dying back from the tip) nor of any insect damage. There were no signs of sap running down the branches or on the trunks that would indicate insect attack. A large number of broken branchlets were observed under the trees but there was no indication that these stems had been weakened by insects.

Other observations
Populations of *Eucalyptus occidentalis* at Lake Bryde, East Lake Bryde, Silver Wattle Nr and Dumbleyung Lake were examined as part of this inspection. Affected trees were noted at Lake Bryde and East Lake Bryde, but not at the other two sites, which may indicate it is more site related rather than a species issue.

Consideration was also given to other forms of damage that may have caused these symptoms, such as the potential for chemical drift from neighbouring farmland, frost and fungi; however, these appeared improbably causes of the decline.

Rainfall and temperature
As noted by Greg Durell, the rainfall for the past seasons has been very much below average. Significant rainfall occurred in 2006 which resulted in Yate Swamp filling and maintaining water till May 2007. It has remained dry since then. See Appendix 1

Previous deaths in LB
Durells report of 30th March noted that DEC officers previously visited Yate Swamp in January 2011 and did not notice any significant leaf loss. However, by comparing the current state of leaf loss of the trees on this site against *E. occidentalis* that had died on the shores of Lake Bryde, I think that this decline started many months ago. However, many of the affected trees in the Yate Swamp would have been away from the bores which the staff would have been monitoring.

Outline of investigation
Initially, the perimeter of the lake was traversed – this was to see if the symptoms ranged off the site and to use the extra height from the top of the lunette to get a better view of tree crowns.

The bores on the lake floor were then used as observation (and photo) points as watertable data may have helped correlated observed plant health. (Appendix 2)

Photos were taken to the north, east, south and west, with a general assessment made of the plant health. Note that this was an initial assessment which can be followed up with more detailed measurement of tree sizes, basal area, etc. However the aim in the first instance was to look for patterns in plant health, which was achieved.

Site 1: 03YS01
Predominantly tall *Eucalyptus occidentalis*, occasional *Melaleuca strobophylla*

Species	% dead	% dying	% unaffected
Eucalyptus occidentalis	5	25	70
Melaleuca strobophylla			100

Abundant seed capsules noted in tree crowns
Very little regeneration from 2006

Site 2: 03YS02
Mixed *E.* and *M. strobophylla*, more open with smaller sized trees. More affected trees the north.

Species	% dead	% dying	% unaffected
Eucalyptus occidentalis	40	60	
Melaleuca strobophylla	30	60	10

Open seed capsules evident in tree canopies.
Regeneration from 2006 evident, up to 80% dead

Site 3: 05YS03
Predominantly *E. occidentalis*, occasional *M. strobophylla* (none affected)

Species	% dead	% dying	% unaffected
Eucalyptus occidentalis	5	25	70
Melaleuca strobophylla			100

Abundant seed capsules noted in tree crowns
Very little regeneration from 2006 present

Dead and dying trees visible, particularly to the East.

Note that the trees on the access track into the site were badly affected with many large *M. strobophylla* having recently died.

Site 4: 05YS04
Mixed *E. occidentalis* and *M. strobophylla*, more open with smaller sized trees. More affected trees to the north.

Species	% dead	% dying	% unaffected
Eucalyptus occidentalis	80	15	5
Melaleuca strobophylla	20	20	60

Open seed capsules evident in tree canopies
Regeneration from 2006 evident, up to 80% dead

Site 5: 05YS05
Mixed *E. occidentalis* and *M. strobophylla*, more open with smaller sized trees. More affected trees the north.

Species	% dead	% dying	% unaffected
Eucalyptus occidentalis	40	60	
Melaleuca strobophylla	20	40	40

Open seed capsules evident in tree canopies
Regeneration from 2006 evident, up to 80% dead

Salinity and water table data
Not available at the time of writing, Blaire Copeland's work will provide the detail on this

Discussion
Note that in the absence of other data, much of what is presented below is speculation – these notions can be firmed up once other information is received.

Several observation of water flow were made in the 2003 Syrinx report, however these were thought to have little affect on the lake and to a large degree have been discounted (P Lacey pers comm.) Comments on the flooding events (i.e. 4 times per decade) similarly seem at odds with local experience and it is though more likely that the lake hold fill only at time when lake Bryde floods. There would be a certain amount of in-situ rainfall collection on the lake floor.

The most recent and dramatic events that are likely to have affected the trees on the lake floor are the 2006 flood, followed by a series of drier season culminating in the driest year on record. Discussion with Dr. Stuart Crombie (Dept of Food and Agriculture) indicated that the trees may have been able to withstand their roots being inundated for periods of 4 – 5 months, but may have suffered root damage after that. There would have been sufficient soil moisture available to trees in the years following the flooding to maintain growth and even for the root systems to partially recover. However, a continual reduction in soil moisture (over such as has occurred over the last two years) could have left many trees unable to cope with the demand for increased transpiration over summer.

Most of the dead and dying trees are towards the edges of the lake, possibly on shallower soils with less available moisture. Assuming the soil profile in the lake is deeper in the centre, this could be why the trees there are better able to survive – or that what ever minimal rainfall has run off has concentrated under these trees.

Given the degree of salt tolerance of these two species and the lack of any visual symptoms, salinity as a cause is being discounted at this stage as factor in decline.

Both the Syrinx and the Boyd et al report made reference to regeneration events being linked to flooding – and whilst this certainly can be seen in several places, there are signs of regeneration which are more likely to be as a result of fire (Appendix 3). The Syrinx report makes mention of fire, but discussion on the issue is very limited. However, there is evidence of a severe fire having burnt the fringing vegetation as well as the trees on the lake floor. Several standing stags can be observed in the centre of the lake with numerous specimens on the northern and western sides of the lake. The present distribution of trees across the lake floor appears to be different to what was there before the fire.

Conclusion and recommendations

Based on visual observations, the indication is that the prolonged hot and dry conditions are the major cause of the decline in the health of the woodlands on the lake floor. However, these observations will need to be compared with the results from the soil and hydrologic assessment. There have probably been many changes to the vegetation density and composition on the lake floor; both to flood and fire, and its likely its distribution expands and contracts based on climatic conditions. However, whilst the vegetation may struggle in a drying climate, given the abundance of seed in the canopies and adjacent fringing woodland, it's still likely to persist.

It would be valuable to include the Yate Swamp in any other ongoing vegetation monitoring work in the Lake Bryde RC, and the use of Vegmachine to determine longer term changes should be considered.

There are obvious signs of tree decline around Lake Bryde and East Lake Bryde which should be documented (Appendix 4).

There are several recommendations from Boyd et al report which should be adopted to improve understandings of this ecosystem.

References

Boyd, T., Bertuch, M., Ogden, G., & Froend, R. Investigation of Eucalyptus occidentalis Hydroperiod Requirements at Yate Swamp. CEM Report No. 2008 – 14. June 2008.

Syrinx Environmental PL: Assessment of Hydrologic Retirements of Yate Swamp, technical report No. RPT 0302-004. December 2003

Appendix 1: Variation in average rainfall and temperature 1 April 2010 to 20 March 2011
Appendix 2: Photo point images
Appendix 3: Fire damage images
Appendix 4: Tree decline Lake Bryde

Appendix 1

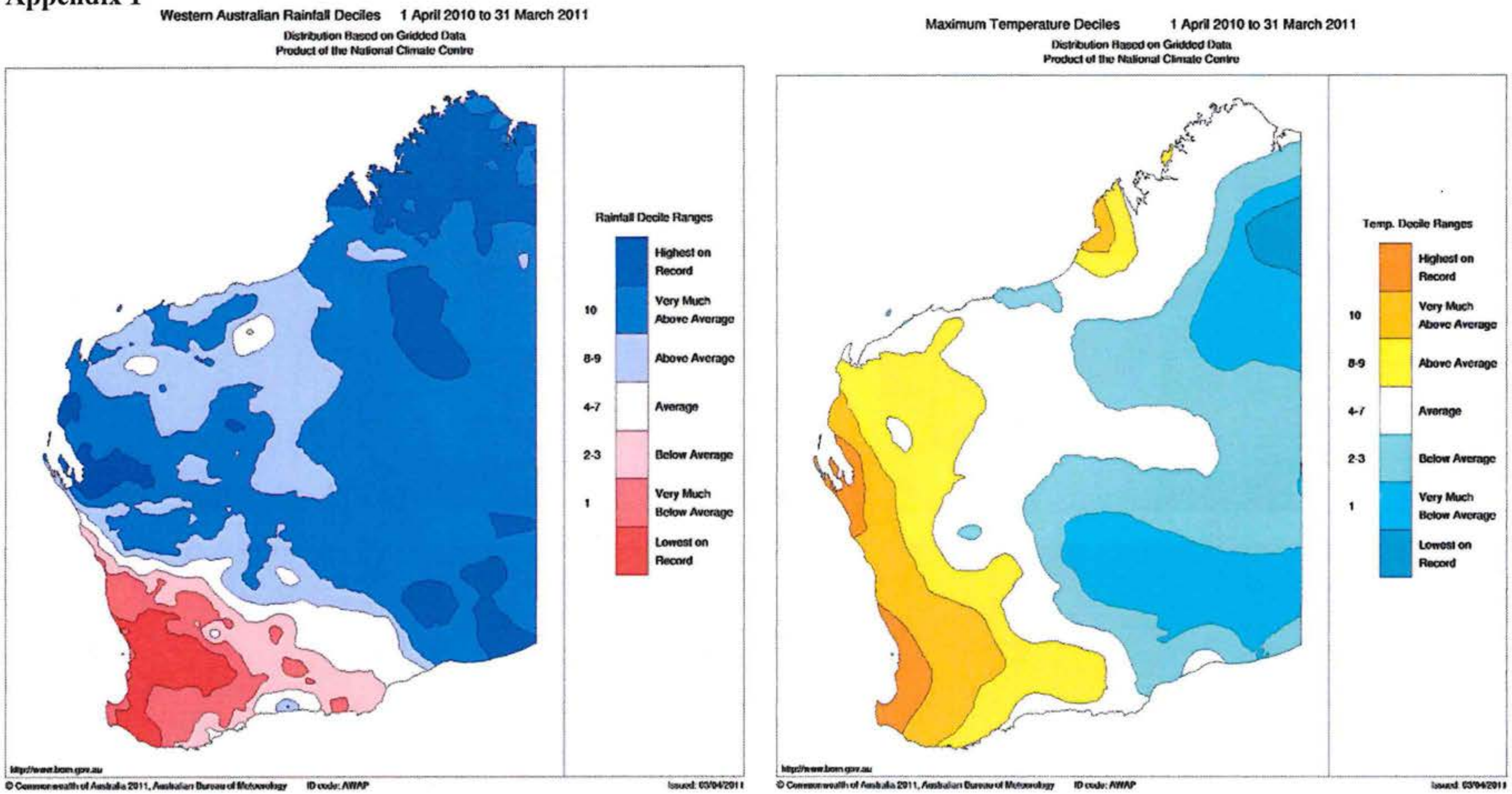


Fig 2: Variation in average rainfall and temperature 1 April 2010 to 20 March 2011

Appendix 2: Photo points and tree condition assessment
Site 1: 03YS01

North

East

South

West

Site 2: 03YS02

North	East
	
South	West
	

Site 3: 05YS03

North	East
	
South	West
	

Site 4: 05YS04

North	East
	
South	West
	

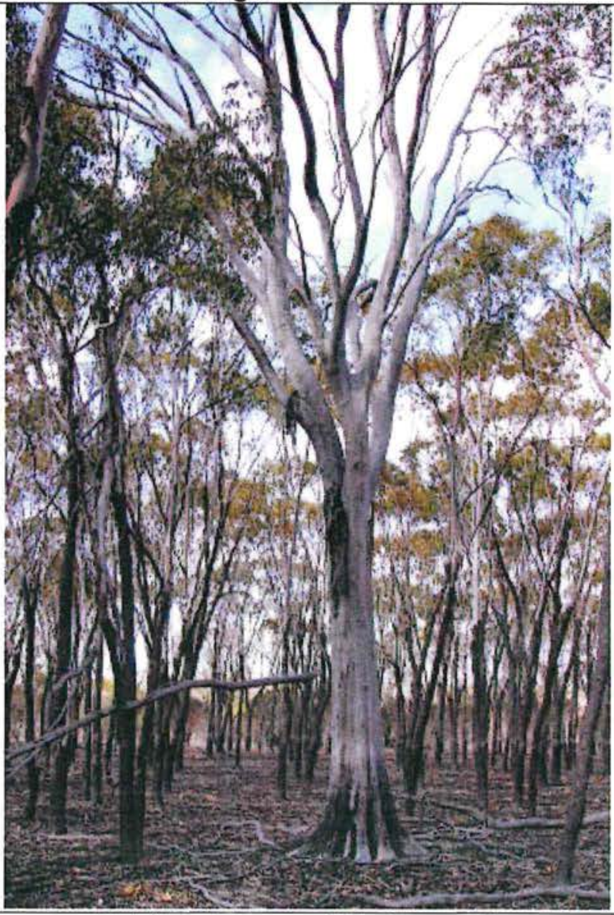
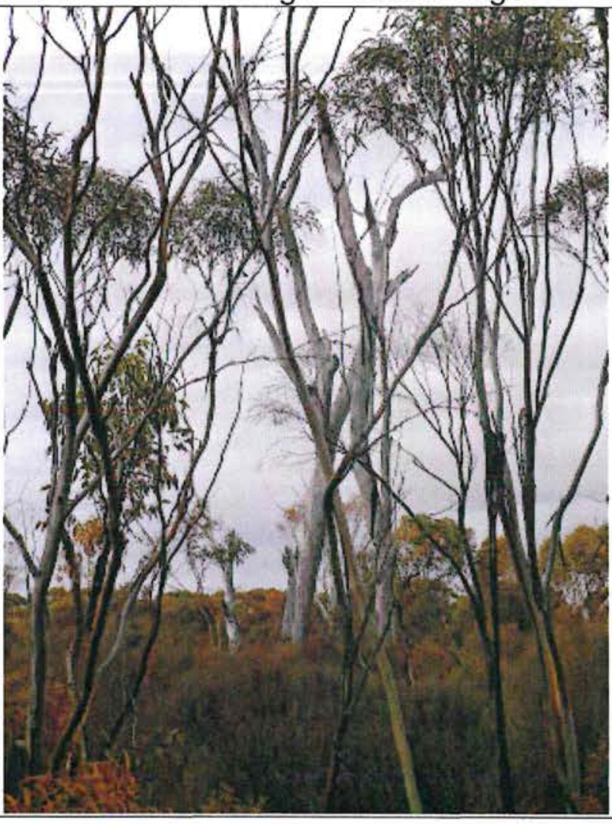
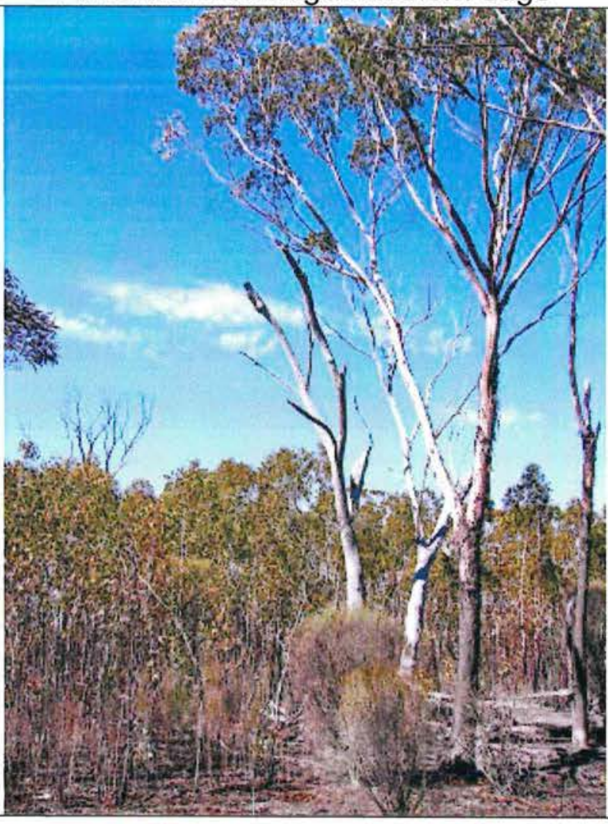
Site 5: 05YS05

North	East
	
South	West
	

Appendix 3
Fire damage

Old fire damage Western side	Post fire regen (?) lake floor Eastern side
	
Fallen stages North western edge	Fallen stages North western edge
	

Fire damage

Stag on lake floor	Veteran on northern edge
	
Old fire damage Western edge	Recent fire damage Northern edge
	

Appendix 4:
Tree Decline Lake Bryde

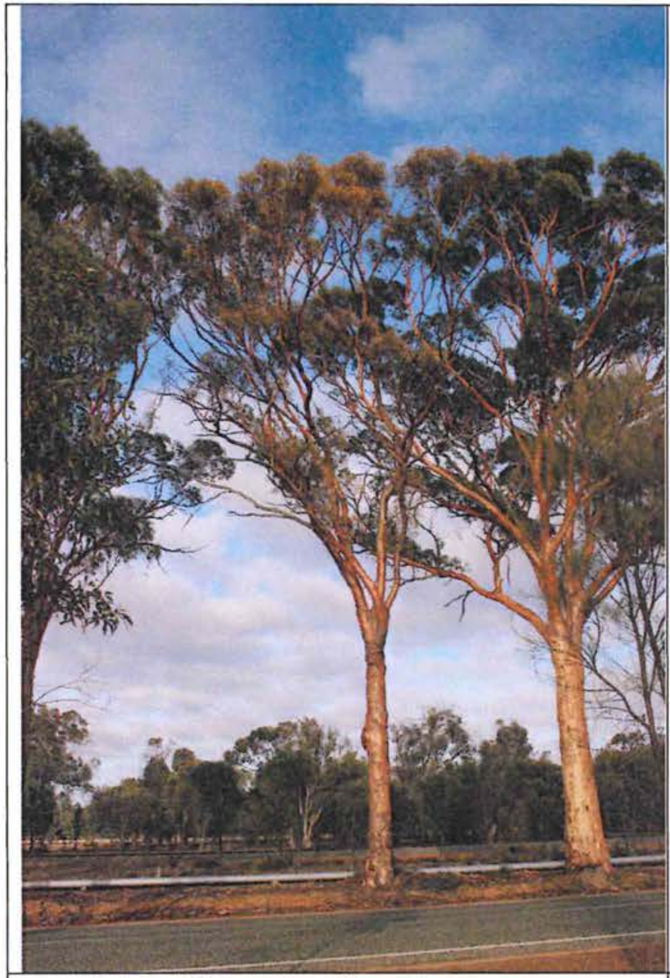
Fringing vegetation showing trees that have died over the last two years

SE side of Lake Bryde showing death and decline in range of size class trees

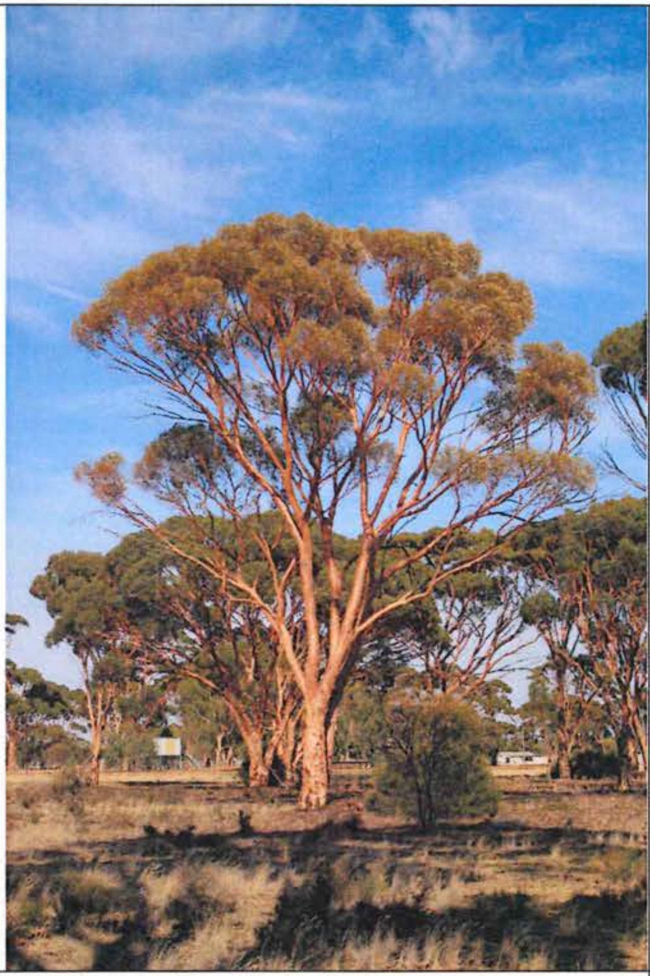
Photo1: Flat-Topped Yate crown collapse Lake Bryde March 30, 2011

Photo 2 & 3: Flat-Topped Yate crown collapse Lake Bryde March 30, 2011

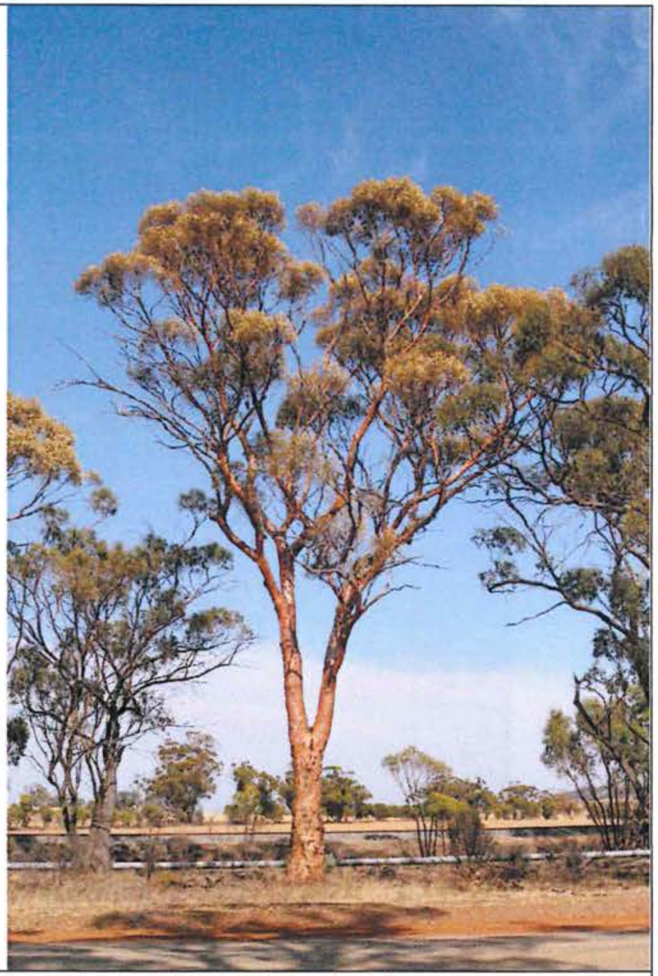
Heat Stress: Great Southern Highway: February 2007



E. salmonophloia: Pingelly

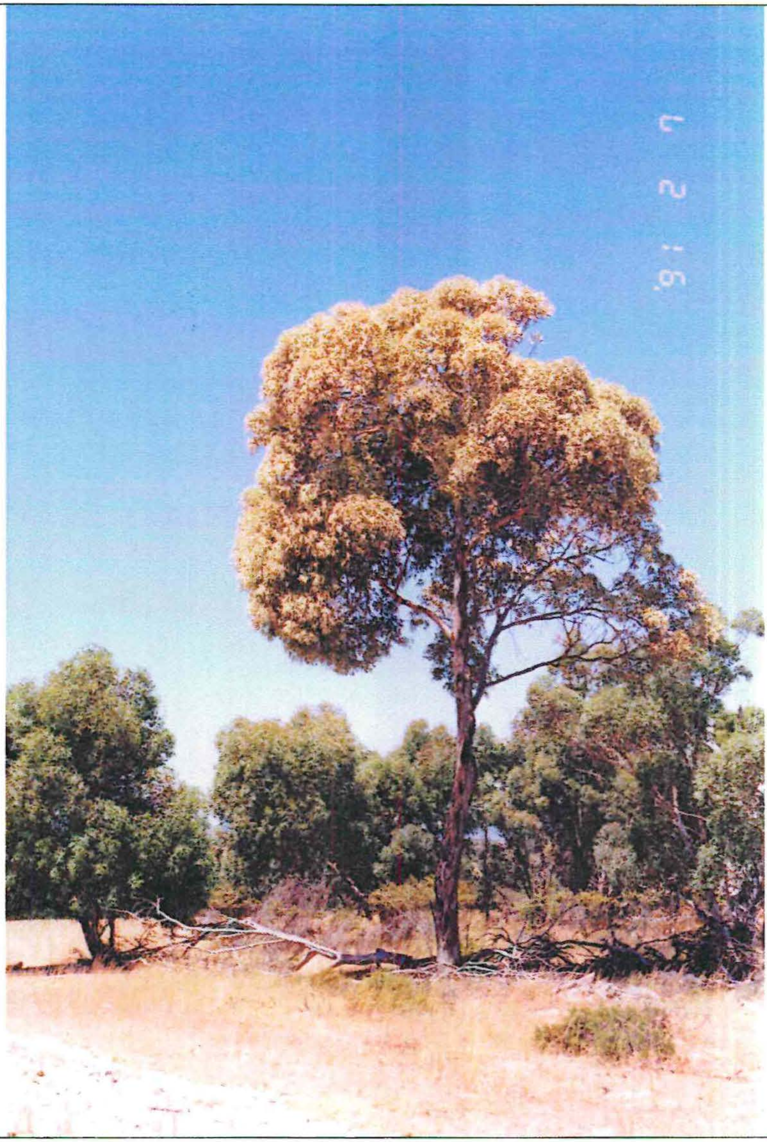
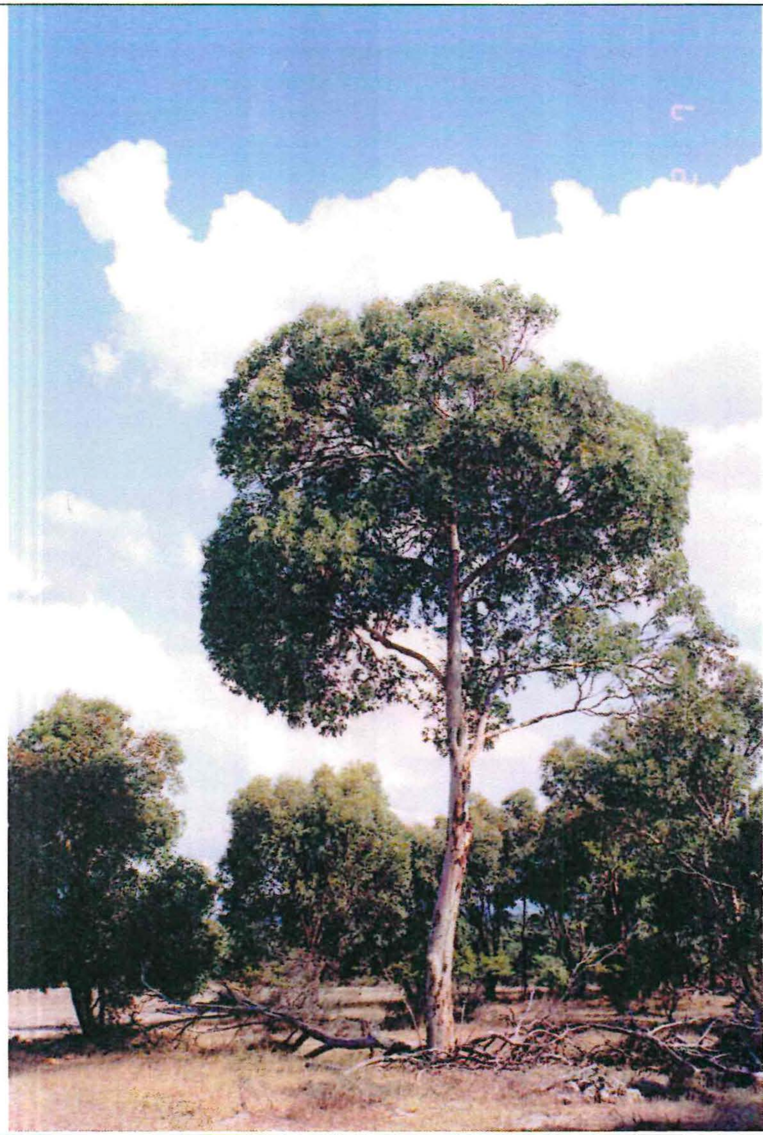


E. salmonophloia: Kokerby

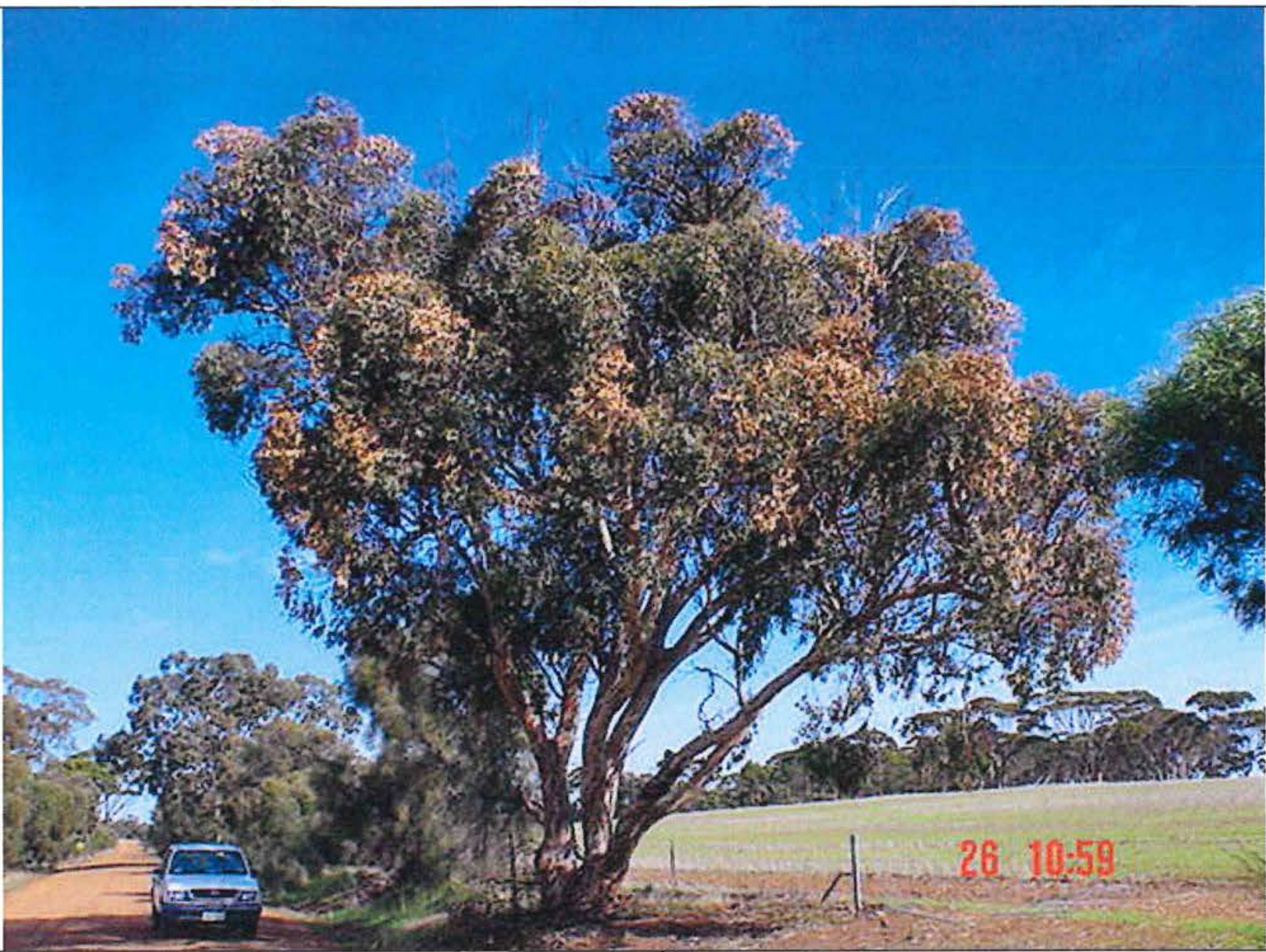


E. salmonophloia: Gwambygine

Heat Stress: Tambellup: February 1991/92

	
7th Feb 1991	7th Feb 1992

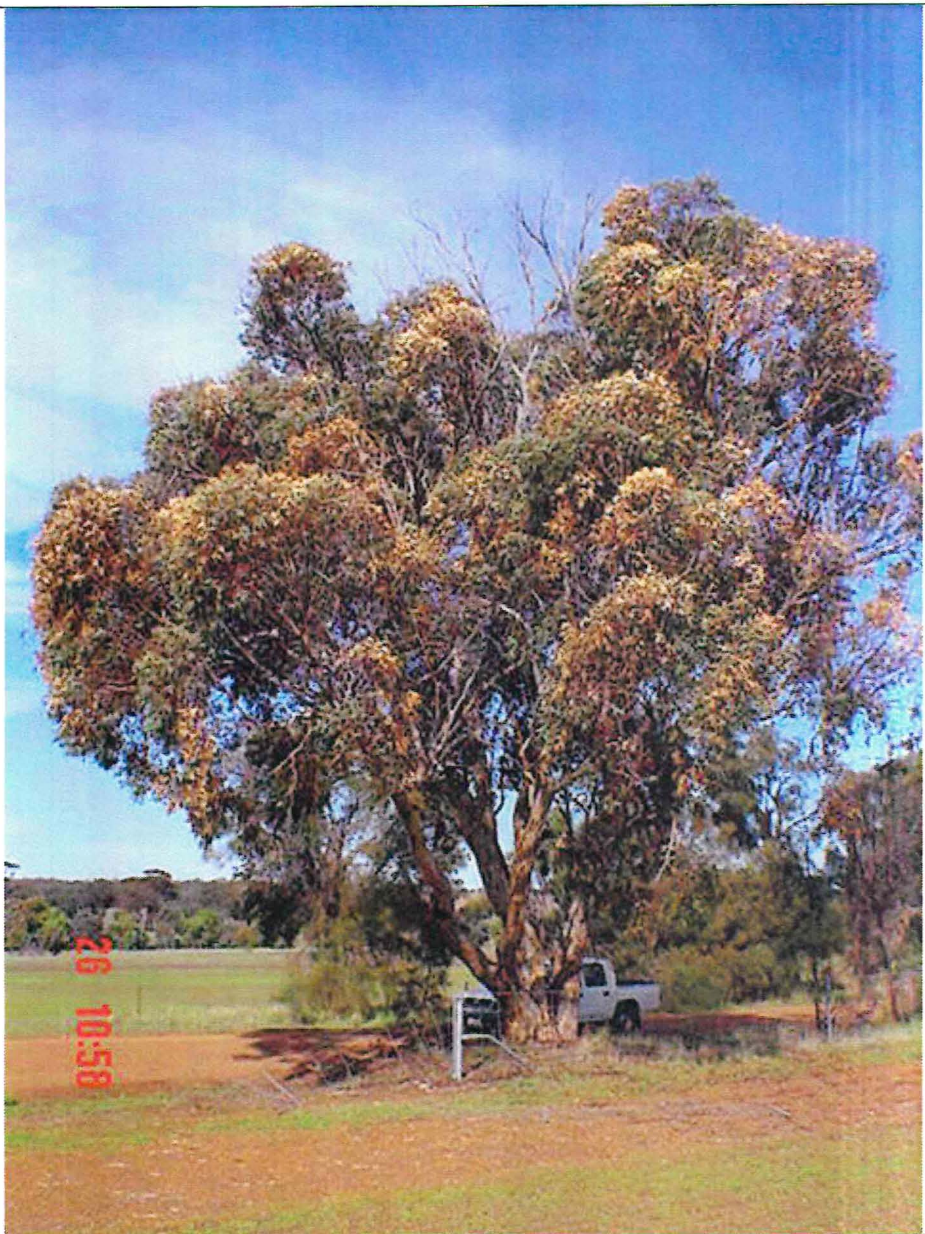
Eucalyptus wandoo subsp. *wandoo*: WCD 2006 - 2010



Doradine rd 26th May 2006

Doradine rd 19th March 2010

Eucalyptus wandoo subsp. *wandoo*: WCD 2006 - 2010

	
Doradine rd 26th May 2006	Doradine rd 19th March 2010

Department of Conservation and Land Management
Conserving the nature of WA

Wandoo Recovery GROUP

Bulletin No.2 March 2005

Introduction

The Wandoo Recovery Group (WRG) was formed in February 2003 by the Minister for the Environment, Dr Judy Edwards, in response to community concern about wandoo's failing health. The WRG's role was to investigate the causes of crown decline and develop appropriate strategies and actions. This bulletin provides an overview of research into wandoo health, which includes studies of borers and cankers.

Members of the WRG include representatives from the Department of Conservation and Land Management, the York and Cranbrook Land Conservation District Committees, the Department of Environment, Greening Australia WA, the Water Corporation, Beverley Naturalists Club, World Wide Fund for Nature (Woodland Watch), The University of Western Australia, the Forest Products Commission, Western Power and the general community.

Background

Wandoo (*Eucalyptus wandoo*) is found across much of south-western Australia.

It is a common component within conservation reserves but also of remnant bushland vegetation and paddock trees within the agricultural areas of the western Wheatbelt.

In recent times the onset of a severe crown decline has been observed in many wandoo trees throughout its natural range. There is undocumented evidence that decline events have occurred previously.

Crown decline characteristics

Crown decline is a syndrome affecting wandoo and occasionally some other eucalypt species.

Symptoms can be expressed in a number of ways but most commonly it is the process known as 'flagging' that occurs. Flagging is where the upper and outer branchlets in the tree crown die. The tree responds by sending up epicormic shoots as the tree attempts to recover. These epicormic shoots may eventually die, resulting in progressive downward movement of the tree crown and redistribution of the canopy. Over several years there can be a noticeable decline in the tree canopy, sometimes resulting in death of the tree.

Another form of decline is expressed in the death of large branches and main stems. The onset of symptoms is often quite rapid and can result in sudden death of the entire tree.

The Wandoo Recovery Group

The WRG aims to raise the profile of wandoo crown decline through the coordination of government and community-based actions and building partnerships with stakeholders and interest groups.

A declining stand of wandoo trees.

Flagging (above) is where the upper branchlets in the tree crowns die.

The WRG is focussing on three key areas. These are:

• **research**, to promote, support and coordinate research into wandoo decline and recovery, to better understand the nature and causes of the decline;

• **mapping**, to accurately assess the extent of wandoo's distribution, its present health and the history of the wandoo crown decline through a coordinated vegetation mapping survey, with the benefit of local community knowledge about previous decline events; and

• **communication**, to raise awareness of the severity of wandoo crown decline and the need for sustained action, while continuing to provide feedback on the WRG's progress.

Likely causes of wandoo crown decline

There is some evidence that insects and fungal pathogens are likely causes of the crown decline. Rainfall deficit, salinity, waterlogging, altered fire regimes and changes in agricultural practices are thought to be contributing factors toward wandoo decline.

CURRENT RESEARCH

The WRG is working closely with The University of Western Australia, which is conducting the principal research into wandoo crown decline.

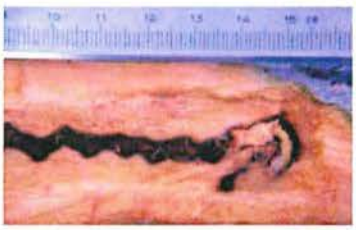
Based on the link between pests and pathogens and their environment, new research will focus on the relationships between climate, tree physiology and the wood-boring insect/fungal pathogen relationship as a priority.

Insects and fungal studies (Phytopathological research)

In 2003, Ryan Hooper from UWA completed an honours project that aimed to assess the nature of damage to wandoo canopies and determine links with foliage loss and the organisms involved. Hooper (2003) developed a model describing the relationship between a wood-boring insect (Type-one) and fungal pathogens causing canker likely to be responsible for the damage found in declining wandoo canopies.

Two borers and their effect on wandoo

Two borers were identified in wandoo. Type-one borers and associated fungal cankers (infected lesions) were found to cause the most common localised patches of flagging occurring in declining stands of wandoo. In addition, ring-barking borers were found to cause broad regions of flagging and considerable canopy loss.



Type-one larvae burrowing beneath the branch surface.

Canker development

Canker types including fusiform, cracking and permanent cankers are always associated with Type-one borer invasion.

Fusiform cankers form shortly after invasion by Type-one borer and look like a narrow scar that meanders down the length of the branch, following Type-one borer corridors beneath the surface.

Insects and fungal studies (Phytopathological research) continued

These cankers are often located on one side of the branch. The combination of a number of fusiform cankers leads to the cracking and flaking of bark tissue. Cracking type cankers have a black colour, generated from extensive regions of cracking and flaking bark tissues on large twigs and branches. These eventually result in a permanent canker with a broad region of severe decay causing flagging by affecting the wandoo tree's ability to take up water and nutrients, which ultimately results in the branch death and canopy decline.

Type-one borer corridors (dark brown lines) associated with the decayed region (brown) and adjacent healthy tissue. Photo - Ryan Hooper.

The research identified an association between Type-one borers and fungal cankers on every declining branch sampled, but never on healthy trees.

Although many trees did not show signs of flagging throughout 2003, Hooper's study found evidence that healthy branches had been subject to the same type of damage in previous decline events. This evidence suggests that fungal pathogen dispersal mechanisms and/or the population dynamics of the Type-one borer may hold the key to where the crown decline syndrome is expressed from year to year.

The findings were presented to the American Phytopathological Society's annual conference in 2004. Hooper is currently submitting a scientific paper *The characterisation of damage and biotic factors associated with the decline of wandoo in South Western Australia*, to the *Canadian Journal of Forest Research*, NRC Research Press.

Future research directions

The next stage in Hooper's research is to undertake a PhD project to identify the Type-one borer, describe its biology and life history, and clarify the interactions between the wood-borer and fungal pathogen(s) in relation to environmental change that result in the decline of tree health.

Environmental studies (Ecophysiological research)

In May 2004, Dr Pieter Poot from UWA led a research survey team to gain some insight into the geographic extent of wandoo crown decline and the possible underlying environmental causes.

Sample sites were selected where:

- wandoo was the dominant tree species;
- the population of wandoo was relatively large; and
- the sites chosen were evenly spread across wandoo's known distribution range.

These criteria excluded single paddock trees or relatively small populations.

At each of the 30 sites, health ratings were given to 12 randomly selected average-sized trees, with a maximum rating of 100 per cent. The ratings were based on six tree characteristics – previous canopy damage, recent canopy damage, recent canopy growth, crown size, crown density and epicormic growth. Where possible, one co-occurring eucalypt species (jarrah, marri, powderbark, salmon gum) was included in the analysis.

The results confirmed the field observation that the average health of other eucalypt species (64 per cent) at the sample areas is better than that of wandoo (48 per cent). Figure 1 indicates there is no clear regional pattern of the health status of wandoo.

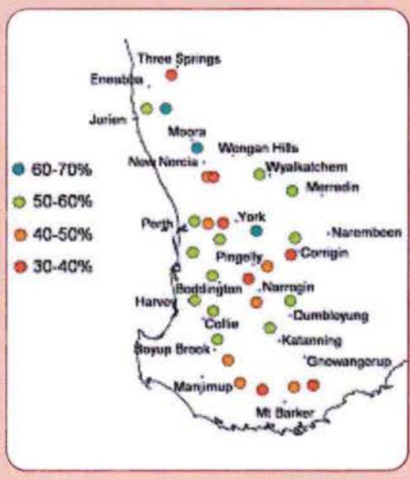


Figure 1. Health status (percentage of maximum possible score) and approximate location of 30 wandoo sample populations.

Environmental studies (Ecophysiological research) continued

Leaf and soil samples were taken at each site for each tree for subsequent chemical analysis and may provide clues on whether individual tree health or average site health is related to salinity stress, drought stress or nutrient imbalance.

Another line of the research is screening the tolerances of wandoo populations (seedlings grown in glasshouse) to salinity, drought and waterlogging.

Data will provide information on the genetic and physiological variation within and among populations of wandoo for these stress factors. This could be important for future rehabilitation projects.

CALM's Wheatbelt Rural Advisory Officer, Peter White, and WRG Executive Officer, Liz Manning.

Future direction

The research team believes that drought conditions over the last two decades may be partly responsible for wandoo decline by weakening the tree and making it more vulnerable to insect attack. A continuing drought could start to affect other species in the future. Therefore much of the research to be undertaken in the coming year will focus on the water relations of wandoo and some of the co-occurring eucalypt species at a few core sites.

The research team will be seeking funding and collaborative support to better understand the consequences of long-term drought on a catchment scale from a hydrological and a vegetation perspective.

The UWA research team (from left) is Ryan Hooper, Lotte Westerhof, Dr Pieter Poot, Dr Erik Veneklaas, Professor Hans Lambers and Eleftheria Dalmaris.

More information

Government and community based action is under way to map the extent of decline, and monitor trends, in the health and condition of wandoo forests. For further information on the work of the WRG and how you can help, contact Executive Officer Liz Manning on 0427 441 482 or Chairman Alan Sands on (08) 93684399.

Ryan Hooper can be contacted on (08) 6488 7346 or at hooper01@tartarus.uwa.edu.au.
Dr Pieter Poot can be contacted on (08) 6488 2491 or at pieterp@cyllene.uwa.edu.au.

2005014-03-3000

Wandoo Recovery GROUP

Department of Environment and Conservation

Bulletin No. 5 **October 2008**

This is the fifth bulletin developed by the Wandoo Recovery Group (WRG) to provide information about the progress of research and the improvements in understanding of wandoo crown decline.

Background

Wandoo *(Eucalyptus wandoo*, Blakely) is a widespread and ecologically valuable tree species of south-western Australia. Endemic to the area, the species is important for wildlife, is a source of high-quality honey, yields first-class structural timber and plays an important role in watershed protection and amenity. Most of the eastern or high salinity risk areas of Perth's forested water supply catchments are dominated by wandoo.

Wandoo is under threat from the phenomenon of 'wandoo crown decline', which expresses itself in the decline of the tree canopy. In its earliest stage there is foliage death on terminal branches (flagging). Usually affected trees produce epicormic branches that can help to rebuild the crown. But if the condition of the tree is poor, or the problem persists, these will also die. In some cases, the entire tree will eventually succumb.

Wandoo crown decline occurs on a regional scale across a range of climatic zones and landscapes and is a cause for significant concern. Although the cause is unclear, climate change, altered land use and management, and pest populations appear to be relevant factors.

The government's Wandoo Recovery Group (WRG) was formed in 2003 to investigate the causes of decline and develop appropriate strategies and actions. The WRG focuses on four priorities:

- research – to identify the causes of decline;
- mapping – to better understand the extent, frequency and severity of decline;
- communication – to be achieved through an ongoing public education program; and
- building partnerships with other organisations and community groups.

The Department of Environment and Conservation (DEC) provides technical and administrative support to the WRG.

Right: Ryan Hooper installs monitoring equipment in wandoo in the Helena catchment. Photo – Liz Manning

Research

Insects and fungal studies (Phytopathological research) Research by The University of Western Australia (UWA) PhD student Ryan Hooper has found that wood boring insects and fungal pathogens are constantly associated with branch death. A wood-boring insect (known as Type-1 borer) has been found to exist in higher populations in wandoo woodlands of declining health. The environmental factors driving population dynamics of Type-1 borer require further investigation. Monitoring phenology (development of bud formation, flowering and seed set) and growth in the wandoo forest is under way and will aid in this understanding.

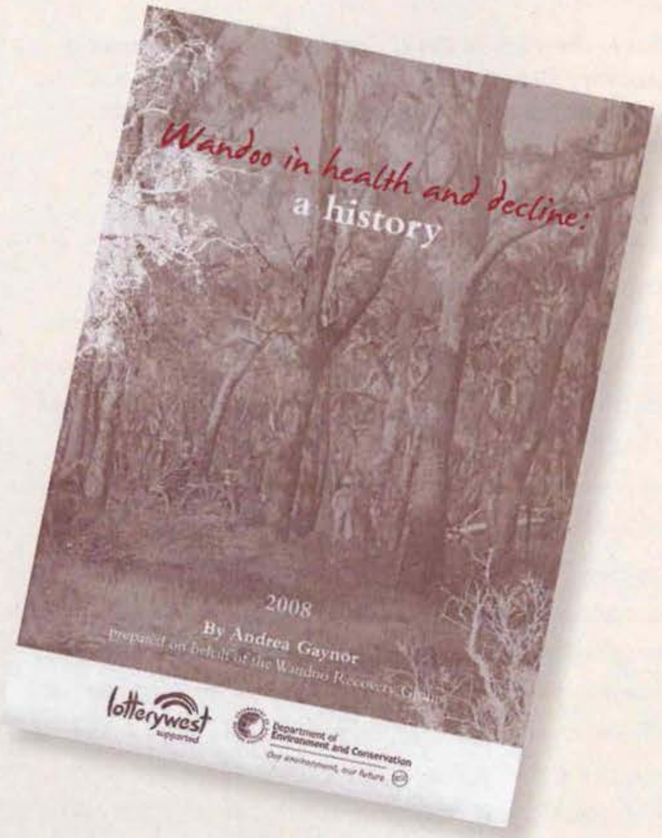
Environmental studies (Ecophysiological research)

Early research revealed important differences in the way wandoo handles drought conditions, compared to other eucalypts like jarrah and marri. While wandoo is able to continue to take up water from soil that is quite dry, it does so by developing enormous tensions in its sapwood. Such tensions can lead to failure of the tree's hydraulic system if soils dry out too much. UWA's, Erik Veneklaas, Pieter Poot and visitor Fabiano Scarpa are investigating whether the tensions previously observed in the different species are likely to cause embolisms (air bubbles that render vessels useless for water transport) of the trees' vessels. Such embolisms would reduce the capacity of trees to supply the foliage with water, causing leaves to rapidly dry out.

Historical review of wandoo

Dr Andrea Gaynor, from UWA has undertaken historical research to determine whether the current decline episode is historically unique or cyclical. She has canvassed possible causes and built a record of the past relationships between people and wandoo. The research involved interviews with people who have lived and worked in wandoo areas and includes photographic, archival and other documentary sources. Although this review sought evidence of crown decline anywhere in the range of wandoo, two focus areas were chosen for more detailed study: Kojonup and surrounds, and the areas north and east of Mundaring (including Julimar). While there's no unequivocal evidence of prior occurrence of wandoo crown decline, the testimony of many keen observers, together with the documentary record, strongly suggests that it has only emerged at a significant level since the 1980s.

The study unearthed fascinating insights into wandoo and its woodland settings, which may provide a useful context for further research. A booklet – *Wandoo in health and decline: a history* – has been produced that brings together the results of historical research (Gaynor, 2008).



(Left to right) DEC Director General Keiran McNamara, WWF-Australia Land Program Leader Richard McLellan, DEC Manager Swan Region and WRG Chairman Alan Sands, WRG Executive Officer Liz Manning, and former Environment Minister David Templeman at the Lotterywest grant presentation for the Woodland Recovery Project, Photo – R. Harris

Surveying and mapping

To better understand when and where the decline occurs, WRG is coordinating a Woodland Recovery Project, assisted by DEC, WWF-Australia, and a $71,295 Lotterywest grant. The two-year project includes an historical review of wandoo, community surveys to record and monitor wandoo health and an education campaign to promote knowledge relating to the conservation of woodland species with a focus on wandoo.

Community surveys

Volunteers, local environment groups and TAFE colleges are helping the WRG record and monitor wandoo health at several sites across its range. The collaborative nature of the project unites research with community knowledge and is underpinned and strongly supported by DEC.

Crown assessment training workshops are conducted each year to instruct community volunteers on the survey technique and to help ensure a consistent standard in the results. Swan, Challenger and Great Southern TAFE have incorporated wandoo surveys in their Conservation and Land Management studies. Students and volunteers learn practical skills in on-ground monitoring and assessment.

Twenty-two monitoring sites have been established since 2006 on a range of land tenures. Results give information on stand structure (number and density of trees), extent of recent branch death and current crown health at each site.

During 2008, 70 transects were surveyed across 21 of the sites. Additional sites, spread across areas such as Cranbrook, Stirling Range National Park, North Dandalup and Collie have helped fill gaps in the mapping project, as identified in the WRG preliminary report *Baselining Wandoo Crown Condition*. Continued monitoring will improve understanding of decline and recovery cycles of wandoo crowns. Reports covering the results from the 2006 and 2007 surveys can be viewed on DEC's website (www.dec.wa.gov.au).

Above: The location of wandoo crown condition survey sites across the south-west of Western Australia. Colours of the markers indicate the relative outlook for the trees at each site (green = good, red = poor) based on the amount of flagging observed.

Below: Swan TAFE students survey wandoo health at Wundabiniring Brook with DEC entomologist Allan Wills (far right). Photo – Liz Manning

Review of wandoo decline across the Wheatbelt and State forest

In 2002, a survey of wandoo decline created a snapshot of wandoo health across three broad transects covering 600 kilometres, including 129 sites and spanning wandoo's east-west range (Mercer, 2003). The decline pattern was found to be broad-scale, variable and not continuous across the landscape. In 2008 a second survey was undertaken to build on the data, investigate factors thought to predispose wandoo trees to decline and establish trends in wandoo health over the intervening six years (Mercer, 2008). Results found that although wandoo decline continues to occur, recovery is evident at some sites. Recovery is most noticeable on the northern transect around York, becoming less so along the central and southern transects respectively.

This project was coordinated by the WRG and undertaken by private contractor Jack Mercer. The Avon Catchment Council, South West Catchments Council, South Coast NRM Inc, and DEC funded the project. Funding provided by the NRM councils was through the State and Federal governments' Natural Heritage Trust and the National Action Plan for Salinity and Water Quality Program. WWF-Australia assisted the WRG with the administration of funds provided by project partners. Support from these organisations extends the existing collaborative efforts between government and non-government organisations and raises appreciation of the importance of healthy woodlands.

References

Gaynor, A (2008). *Wandoo in health and decline: a history.* Prepared on behalf of the Wandoo Recovery Group, August 2008. Department of Environment and Conservation, Kensington, Western Australia.

Mercer, J. (2003). *Survey of Eucalyptus wandoo decline.* A report on wandoo decline in the Western Australian Wheatbelt on behalf of the Department of Conservation and Land Management (CALM), Western Australia.

Mercer, J. (2008). *Second survey of Eucalyptus wandoo decline - Final report June, 2008.* A report on wandoo decline on behalf of the Wandoo Recovery Group, Department of Environment and Conservation and WWF-Australia.

Future directions

Tree decline has been recorded in a number of important woodland species such as wandoo and tuart. The newly approved Centre of Excellence for Climate Change, Woodland and Forest Health will do much to unite the research into these declines. Research activities are embodied in four programs:

- climate change, woodland and forest declines
- decline ecology
- restoring biodiversity values
- policies and action for woodland restoration.

In addition to five years of State Government funding, contributions from universities, many government, non-government organisations and community groups will enable a concerted effort in addressing the issues of woodland decline. A recent three-day field trip, hosted by the centre, toured State forest and woodlands between Helena Catchment, Dryandra, Collie and Bussleton. The field trip combined site visits and workshops to familiarise researchers and forest managers, sponsors and other stakeholders with the nature and scale of the problem and align them to build strong and collaborative projects.

DEC's Nature Conservation Advisory Officer and WRG member Peter White discusses declines occurring at Dryandra Nature Reserve during the recent Centre of Excellence field trip. Photo – Liz Manning

More information

Copies of reports and information about wandoo, WRG projects and research are available electronically from DEC's website at www.dec.wa.gov.au.

For more information on the WRG or to join the mailing list, contact Executive Officer Liz Manning on 0427 441 482 or email lizmanning@bigpond.com.

2008442-1008-

Wandoo Crown Decline

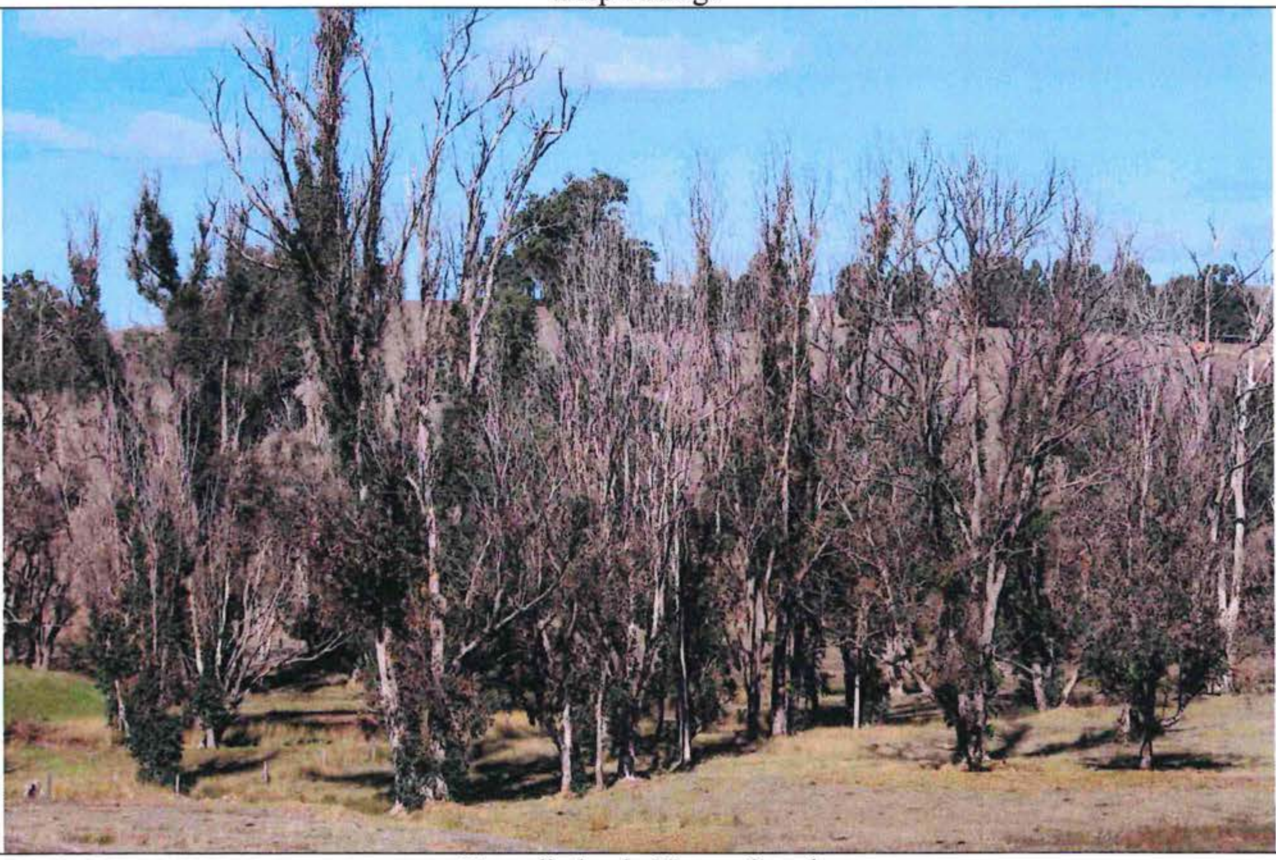
Dongolocking Reserves July 2010

Wandoo Crown Decline

Wunderabinning Brook May 2001

Eucalyptus rudis subsp. *rudis*: Flooded Gum decline

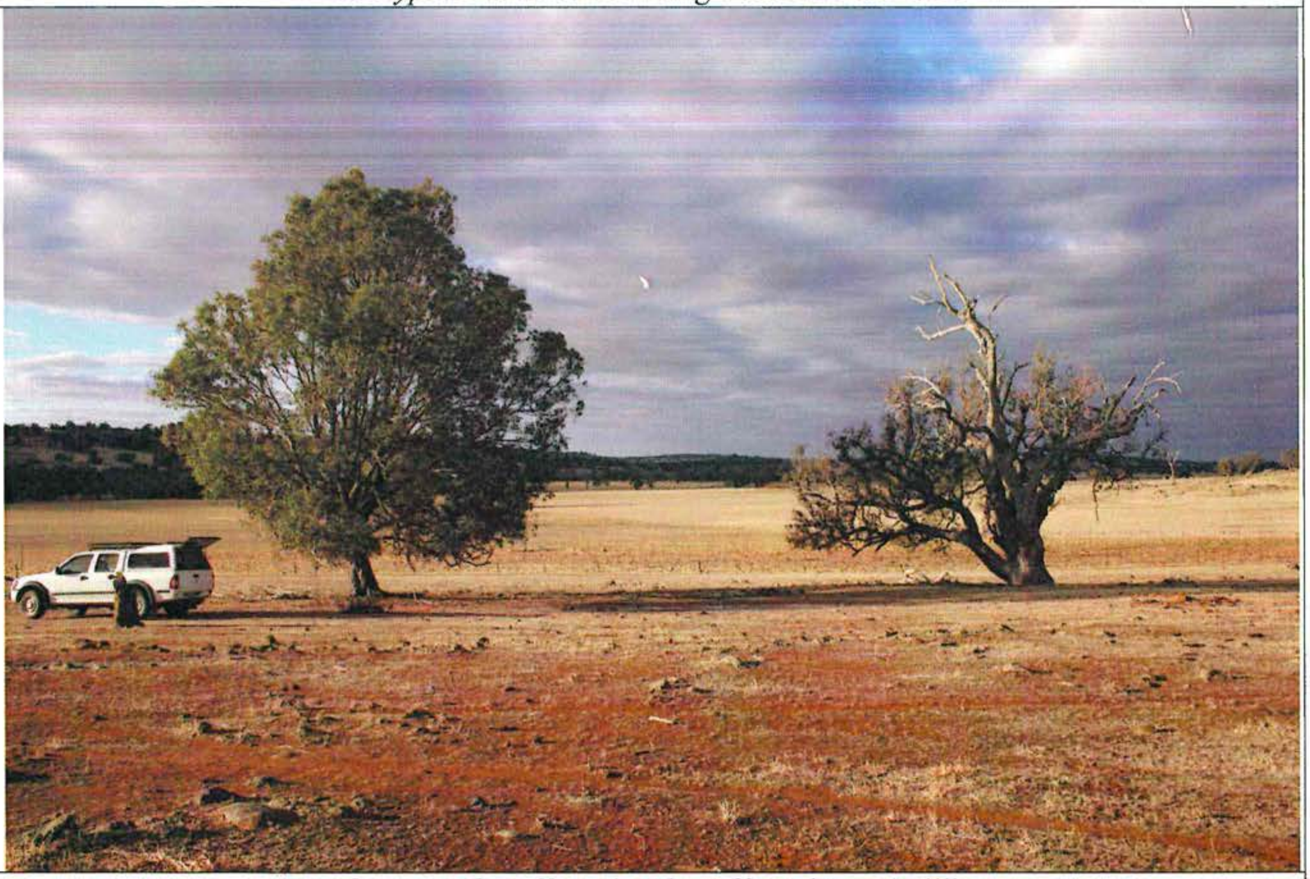
Lerp damage



Tree die back, Upper Capel

Eucalyptus rudis subsp. *rudis*: Flooded Gum decline

Eucalyptus rudis: surrounding Toolibin Lake TEC



Eucalyptus rudis: affected and unaffected trees Williams

Heteronyx / Lipretrus (Spring Beetle) damage to revegetation works 2009

Lipretrus damage August 2009 Wallatin Creek

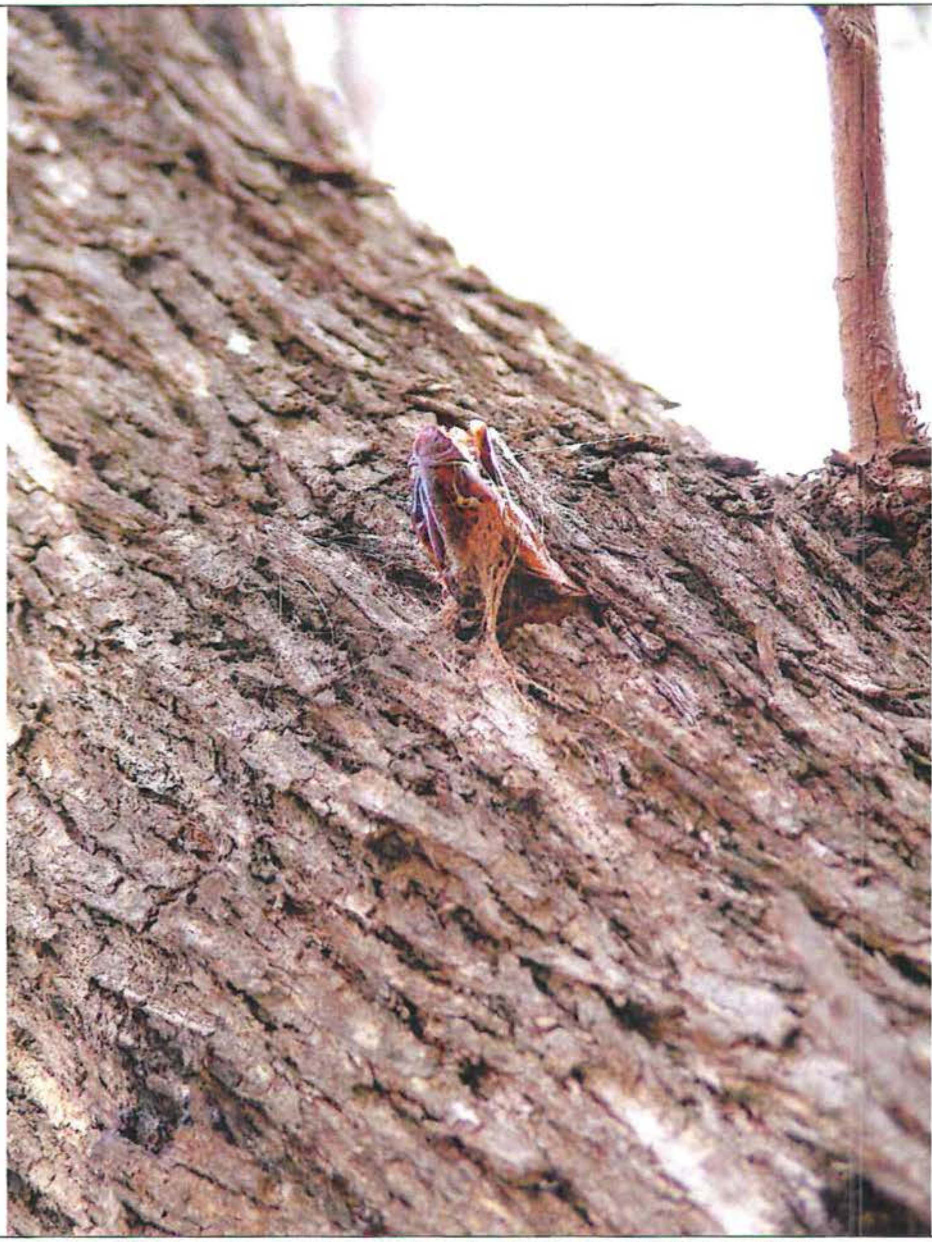
Lipretrus sp on *Calothamnus quadrifidus*

Insect damage: Woodland species

Borer damage: *Acacia acuminata* 2005

Insect damage: Woodland species

Borer damage: *Eucalyptus salmonophloia*: Lake Bryde 2011

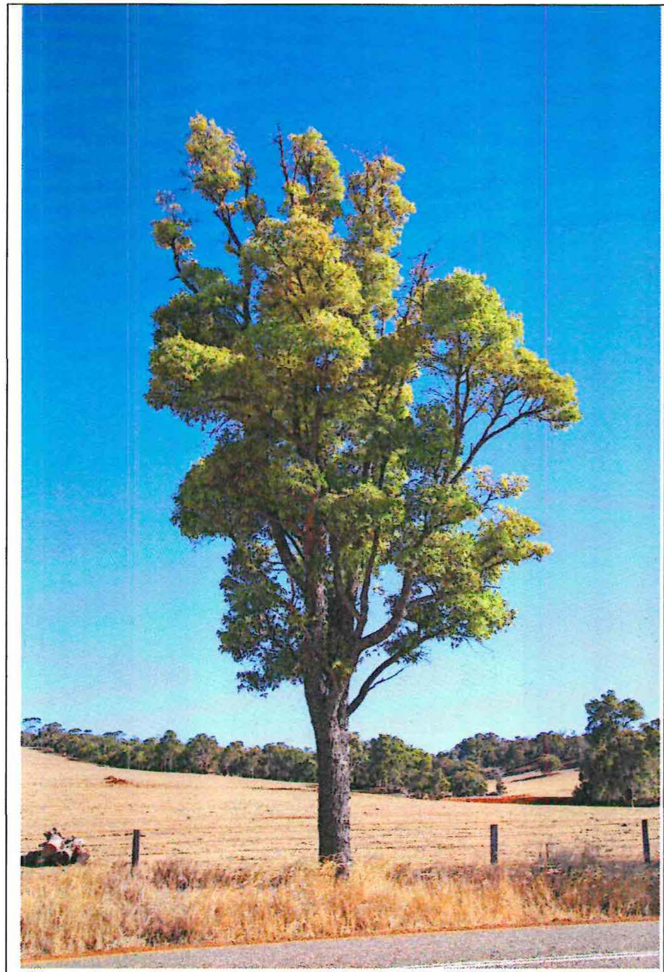


Borer damage: *Eucalyptus longicornis*: Highbury 2006

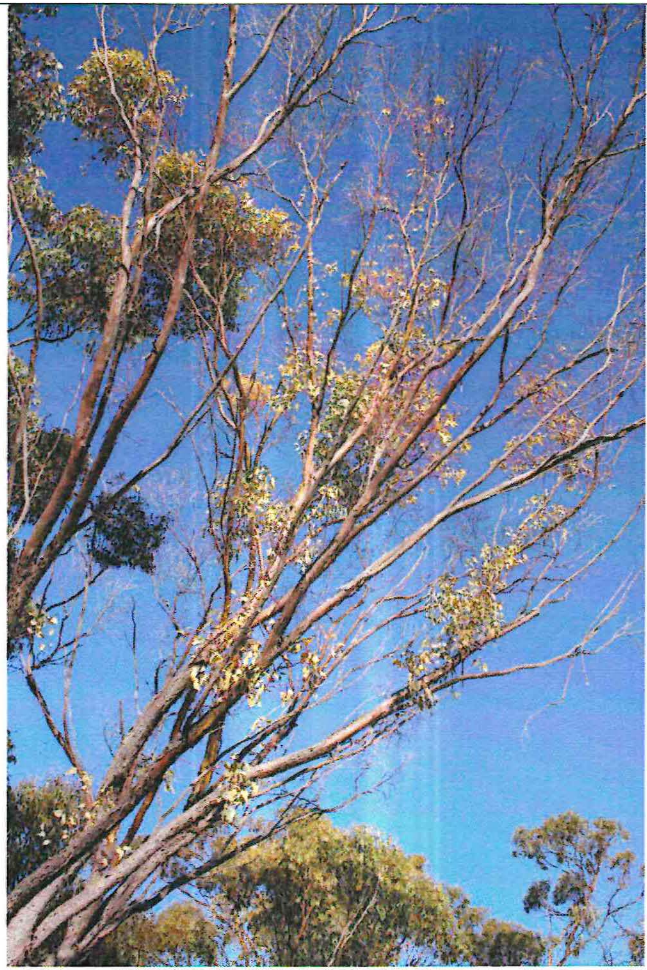
Mundulla Yellows

MY *Eucalyptus rudis*, Tonkin Highway 2009

Mundulla Yellows



Eucalyptus marginata: Wandering: 2009



Eucalyptus loxophleba: Wagin: 2006

Eucalyptus wandoo: Pootenup road: 2009

Mundulla Yellows — a new tree-dieback threat

A recently described tree-killing disease, Mundulla Yellows, has been found in Western Australia. It has the potential to seriously affect a number of our native plant species. What is Mundulla Yellows and what can be done to combat the disease?

by Dagmar Hanold, Mike Stukely and John W Randles

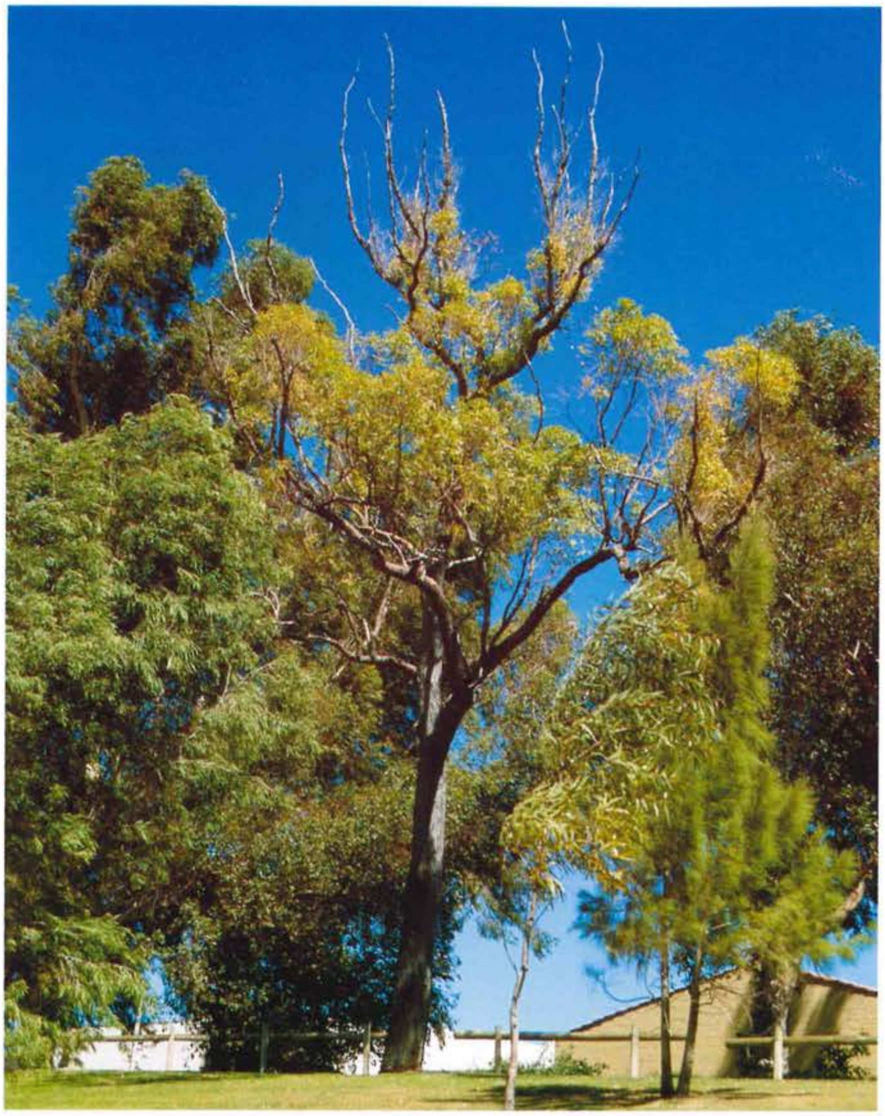
In Western Australia, the term 'dieback' generally refers to the devastating disease of many native plants, caused by the root-rotting water mould *Phytophthora cinnamomi*. But there are other diseases of trees, caused by a variety of living organisms or environmental factors, that also cause tree crowns to die back. A little-known and only recently described disease, Mundulla Yellows, has the potential to seriously affect a number of our native plant species, as well as revegetation plantings on farms and possibly some eucalypt plantations. Mundulla Yellows is a progressive slow dieback and yellowing disease of many varieties of eucalypts, now suspected of being caused by a virus-like agent. It has been reported in trees of all ages. Once symptoms appear, the affected trees do not recover, and die within a few years.

Research is in progress to identify the cause of Mundulla Yellows, to develop a rapid diagnostic test, and to determine its distribution and how it is spread, so that strategies can be developed to manage the disease.

WHERE IS IT?

Mundulla Yellows was first reported in the late 1970s in the south-east of South Australia, by bee keeper Geoff Cotton. There is evidence that the disease also occurs in other States, including Western Australia, but typical Mundulla Yellows symptoms have not been reported outside Australia. In South Australia, Mundulla Yellows is present in scattered sites throughout an area estimated to exceed 25,000 square kilometres—and it is spreading! Many of the sites show high incidence of the disease.

Mundulla Yellows is named after the town of Mundulla in South Australia (see box). Its symptoms have been observed in a wide range of eucalypts growing in modified landscapes, as well as in remnant natural vegetation. Sheoaks (the *Allocasuarina* spp.), banksias (*Banksia* spp.) and wattles (*Acacia* spp.) show similar symptoms, which suggests that the disease may not be confined to eucalypts. Mundulla Yellows has so far been observed mainly in sites that have undergone significant disturbance, such as farmland, roadsides and urban parks. However, it has been seen occasionally in natural forest in eastern Australia.



Previous page
Main: A jarrah leaf showing interveinal yellowing—a sympton of Mundulla Yellows.
Photo – Mike Stukely
Inset: Salmon gum with medium stage Mundulla Yellows symptoms on a roadside in the WA Wheatbelt.
Photo – Allan Wills

Above: A jarrah (*Eucalyptus marginata*) showing medium to late stage Mundulla Yellows symptoms, in a Perth suburban park. Dead branches can be seen at the top, while the dense epicormic shoots that have sprouted lower down are clearly yellow. Only a small amount of green foliage remains. The other nearby eucalypts still appear healthy.
Photo – Mike Stukely

The first sightings of Mundulla Yellows in WA were made by Frank Podger (see box). Recent surveys by the Department of Conservation and Land Management in WA have located additional species with Mundulla Yellows symptoms. They include river redgum (*Eucalyptus camaldulensis*) and lemon-scented gum (*Corymbia citriodora*)—both of which are cultivated—as well as the WA natives salmon gum (*E. salmonophloia*) and York gum (*E. loxophleba*). Affected trees occur in a scattered distribution, and mostly in coastal areas, although Mundulla Yellows symptoms have been observed as far inland as York, Williams and Boyup Brook. In the Perth area, sheoaks also appear to be affected by Mundulla Yellows. The declines of wandoo (*E. wandoo*) and flooded gum (*E. rudis*) in the Wheatbelt and of tuart (*E. gomphocephala*) south of Perth do not, however, appear to be associated with Mundulla Yellows.

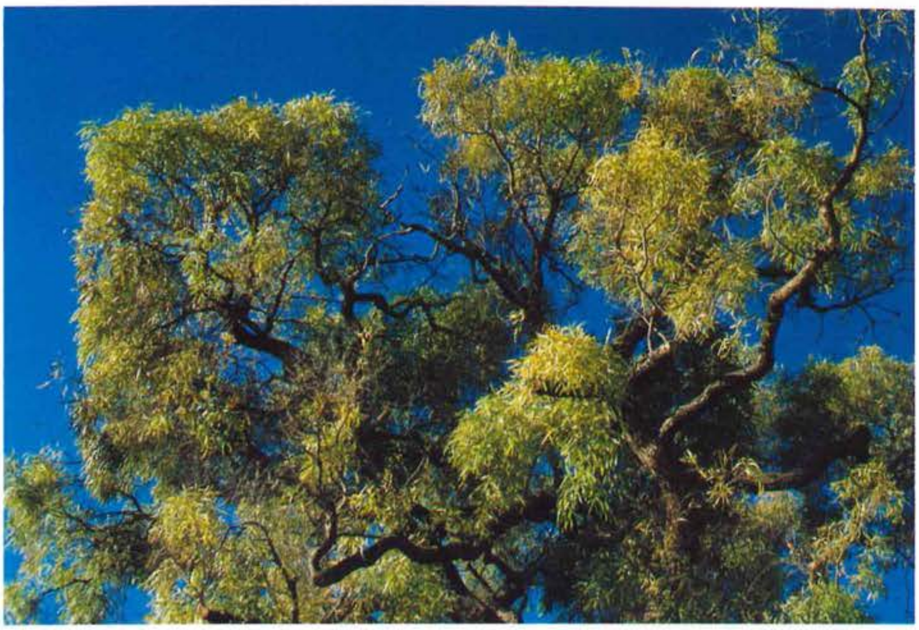
AN ENVIRONMENTAL CONCERN

The origin of Mundulla Yellows is unknown. Is Mundulla Yellows an exotic disease that has only recently

Right: Pricklybark (*Eucalyptus todtiana*) with Mundulla Yellows symptoms in a Perth suburban park. Dead limbs have been removed for safety reasons, but this treatment does not stop the disease, and clear yellowing is now spreading to other parts of the crown.
Photo – Mike Stukely

Centre right: Buckingham Old Coach Road, South Australia, showing healthy river redgums photographed during a flood in 1906.
Photo – Courtesy Mr Adrian Packer

Below right: The same site in 1999 with tree deaths due to Mundulla Yellows.
Photo – Courtesy The Border Chronicle



arrived in Australia? If so, where did it come from, and why is it already so widespread when its rate of spread appears slow? Alternatively, has the disease been present for a long time as a latent infection in some plants, causing little or no damage, and has its recent increase been caused by environmental changes favouring disease development or perhaps due to mutations in the pathogen(s)? Further investigation is needed.

Mundulla Yellows is now acknowledged as a threat of national significance to natural biodiversity and ecological sustainability. It causes the irreversible loss of natural vegetation, including ancient gum trees. Since a wide range of eucalypts and other species of native flora, which comprise natural Australian ecosystems, appear to be affected, it poses potential danger to natural wildlife habitats and, thus, the conservation of threatened plant and animal species. It has evoked considerable public concern, as well as much speculation as to its cause.

The potential of Mundulla Yellows to cause damage to our native flora may be exacerbated by climatic changes predicted for the coming decades. It is potentially detrimental to a number of industries and parties, including commercial tree growers, bee keepers, tourism, native cut flowers, public amenity, land and forest managers, and local government. It could jeopardise revegetation programs, salinity and groundwater level control, and input on the international carbon credits policy,

MUNDULLA YELLOWS: A SHORT HISTORY (BY FRANK PODGER)

In 1979, bee keepers and farmers Geoff Cotton, Bill Hunt and Sandy Mathison, from the Tatiara district of South Australia, noticed abnormal patches of bright yellow foliage in small numbers of large river redgums (*E. camaldulensis*) around Mundulla and in South Australian blue gum (*E. leucoxylon*) near Keith, close to the border with Victoria.

It is these magnificent old trees that lend an essential Australian character to the landscape, forever captured in the art of Hans Heysen. These ancient trees slowly declined and, over the next decade, died. Neighbouring trees also became affected, and discrete new centres of disease gradually appeared elsewhere in the landscape.

Despite Cotton's growing apprehension, most landholders took little notice of the problem until 1991, when Cotton first showed examples of Mundulla Yellows to David Paton of Adelaide University. In 1992, vital though modest research grants from the Honey Bee Research Council and from the Save the Bush Fund allowed Paton and his students to begin a disease monitoring program. Over the next five years, this work showed greater than expected rates of deterioration within affected trees, and further spread of the disease to healthy neighbours was much greater than expected.

The name 'Mundulla Yellows' was adopted in 1997 by Podger, Cotton, Choate and Randles, and is now in general use. The name refers to the small and lovely rural town of Mundulla (the name given by indigenous people)—the place where the disease was first recognised and where strong support for subsequent action originated—and the disease's distinctive and striking set of symptoms, particularly the early appearance of small clusters of bright yellow leaves in otherwise healthy crowns.

The connection with Western Australia first emerged soon after a conversation I had with Stan Bellgard in early 1993. He was then researching *Phytophthora megasperma* for the WA Department of Conservation and Land Management. He told me of a report from South Australia of the possible involvement of *P. megasperma* with widespread deaths of river redgum. To me, however, it seemed that several features of Mundulla Yellows, and of the climatic regime at Mundulla, did not fit the published requirements of *P. megasperma*. In August 1993 I visited the Tatiara district for the first time and was directed to Geoff Cotton. We took soil samples at five diseased sites around Mundulla, none of which yielded any species of *Phytophthora*. Most importantly, no evidence of rot in even the smallest secondarily thickened roots was observed in five excavated saplings of diseased river redgums.

Upon my return to Perth, I saw that Mundulla Yellows was widely established there. However, the degree of damage and the stages of symptom development seemed to indicate a later arrival in Perth than at Mundulla, perhaps by a decade or more. Soon afterwards, I encountered a report of work in Italy, which described somewhat similar symptoms in young eucalypts. The authors had attributed that disease to a phytoplasma. This led me to contact with Adelaide University's distinguished plant virologist John Randles at the Waite Institute. His subsequent interest has led to the first significant funding to support the assignment of Dagmar Hanold to research the possible role of phytoplasmas and viruses, and to the advances reported in this article.

In the course of private surveys from 1993, over more than 20,000 kilometres, I have encountered Mundulla Yellows at many places across the length and breadth of Australia. The principal features of distribution of the disease, noted throughout these travels, are:

- it is rarely seen in essentially undisturbed natural vegetation, and then at the very margin with cleared land and roadways;
- in WA it occurs in a broken pattern that extends northward from Walpole in the far south-west to include infested sites in Bunbury, Perth, Geraldton, and on to the wet-dry tropics at Broome, Derby, Kununurra and, only in the last two years, Wyndham; and
- in country towns and cities, where it is most commonly encountered, it is most frequent in well-watered parks, road verge plantings subject to run-off, and well-cared-for home gardens. It is very uncommon at places where dry season moisture status is not ameliorated by some source of supplementary water.

Twenty-three eucalypt species native to Western Australia have been recorded as affected by Mundulla Yellows. Within Western Australia, these include tropical species such as long-fruited bloodwood (*Corymbia polycarpa*), woollybutt (*Eucalyptus miniata*) and Darwin stringybark (*E. tetrodonta*), which are highly susceptible, as are the southern temperate marri, red-flowering gum (*C. ficifolia*), jarrah, blackbutt (*E. patens*) and pricklybark (*E. todtiana*). Some other species natural to semi-arid areas of WA, and used in exotic plantings here and elsewhere, are also affected. A great many more eastern Australian native species are often severely damaged in exotic cultivation around Australia.

A group of river redgums planted alongside Perth's Mitchell Freeway, and affected by Mundulla Yellows. Some have died, others are near death, but some still appear healthy. Photo – Mike Stukely

and could impact on quarantine practices.

Mundulla Yellows has symptoms different from those of previously reported diseases of eucalypts. To define the problem—and to distinguish Mundulla Yellows from yellowing due to other factors—symptoms have been described in *A Field Guide to Mundulla Yellows* by D Hanold and J W Randles, published in 1999 by the University of Adelaide. The disease passes through three stages: early, medium and late.

FINDING THE CAUSE

When investigations into the cause of Mundulla Yellows using molecular methods began, in January 2000, a living organism was thought to be the cause (see box on page 47). This was because affected trees occurred in mixed stands with, or immediately adjacent to, unaffected trees. If environmental factors—such as nutrient imbalances, herbicide spraying and high soil salinity—were the cause, they would be more likely to affect most trees in an area. Also, some disease symptoms had developed in previously healthy plants grafted with patches of bark taken from Mundulla Yellows-affected trees. This method is used widely by plant pathologists to see if a contagious agent is present.

Unlike *Phytophthora*-induced dieback, there was no evidence to suggest that disease-causing organisms such as fungi, bacteria or nematodes were associated with Mundulla Yellows. So researchers began to investigate the hypothesis that Mundulla Yellows was caused by a micro-organism that could not live or replicate outside the host cells (obligate intracellular pathogen).

Plant pathogens in this category can belong to the virus, viroid or phytoplasma groups. So far, more than 1000 viruses, 30 viroids and about 200

Top photos: Stages of Mundulla Yellows symptom development in river redgum.
Top left: Early stage. Uneven yellowing affects the outer parts of one limb or a segment of the crown. These zones comprise fully expanded leaves with interveinal yellowing (chlorosis).
Top centre: Medium stage. Dieback of affected shoots occurs with progression of yellowing inwards towards the centre of the crown. Flowering and seed production decline on the affected branches. Neighbouring limbs subsequently develop the same symptoms. Part of the crown is still unaffected.
Top right: Late stage. Yellow 'panic growth' (epicormic shoots) below the dying zones gives a denser appearance. Seed production ceases. Dieback progresses. Eventually the whole crown shows dieback and the tree dies.
Photos – Dagmar Hanold

Right: A jarrah leaf showing interveinal yellowing (top) compared with one that is healthy.
Photo – Mike Stukely

phytoplasmas are known to infect plants. Phytoplasmas and viroids do not vary much in their structure, but viruses can be very diverse. They can vary in the structure and biochemical properties of their genome (consisting of nucleic acids, i.e. DNA or RNA), and the composition, shape and size of their particles (consisting of proteins). Consequently, there is a vast range of potential candidates for this investigation.

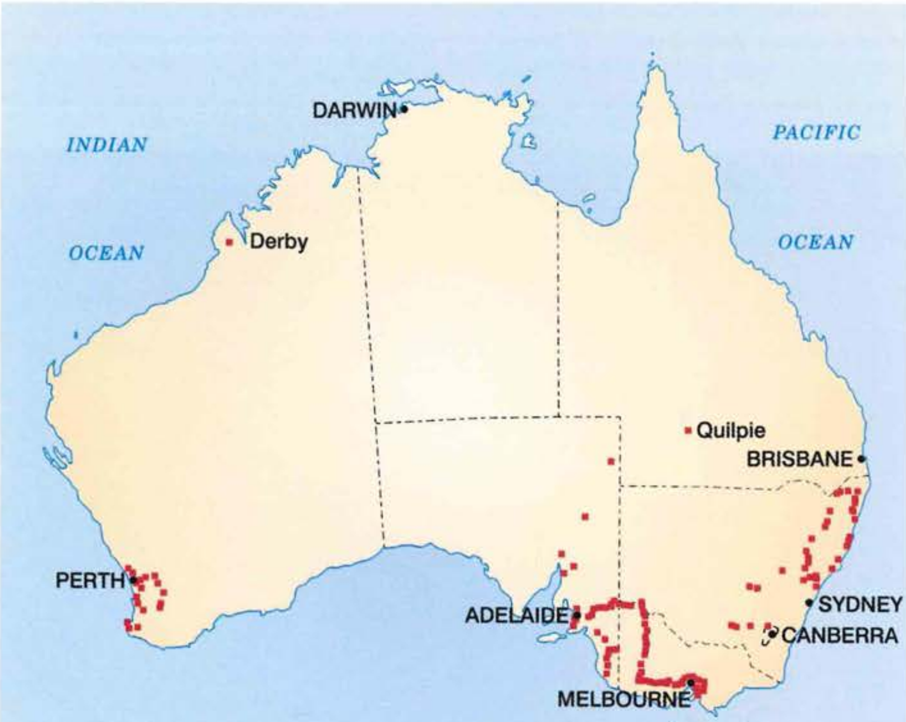
Obligate intracellular plant pathogens cannot spread independently, but need either biological vectors or mechanical means of transmission. Sap-sucking insects, nematodes, fungi, pollen, seed and plant sap carried on tools are examples identified in the past as possible modes of spread.

BREAKTHROUGH

Thanks to advances in biotechnology, there is a range of methods available for testing whether such a pathogen is responsible for Mundulla Yellows. Tissue samples from normal eucalypts were compared with those affected by Mundulla Yellows using different means.

Karen Gibb and Nuredin Habili carried out tests that detected phytoplasmas in eucalypts; however, they were found with similar frequency in Mundulla Yellows-affected trees and healthy trees, so did not appear to be a cause of Mundulla Yellows. Virus-like particles could be observed occasionally in leaf tissue by means of electron microscopy, but their role as a cause could not be confirmed by this method.

Left: Dieback, leaf distortion and stunting symptoms in a river redgum seedling in the glasshouse after bark patch grafting, with normal seedlings behind.
Photo – Dagmar Hanold



As no viruses or viroids of eucalypts had previously been characterised, a molecular test for virus-like agents in eucalypt tissue first had to be developed to test Mundulla Yellows-affected trees. Purified leaf extracts would be expected to comprise both general 'background' components from the host plant's cells and additional unusual components from pathogens if they were present. A breakthrough was made with this approach. Unusual nucleic acids (MY-RNAs) were found in Mundulla Yellows-affected river redgums (*E. camaldulensis*) in the south-east of South Australia. Indications from the size and biochemical characteristics of these nucleic acids pointed to a possible association with a virus or viroid.

MY-RNAs were detected in the leaf tissue of affected trees in South Australia before symptoms developed. This suggests that MY-RNAs are more likely to be associated with a cause rather than an effect of the disease. It also indicates that there may be a significant lag period between infection and appearance of disease symptoms. MY-RNAs have been detected in trees within revegetation sites and plantations less than a year after they were planted into areas previously without Mundulla Yellows. They have also been found in nursery-grown seedlings in the glasshouse. This suggests that the widely used practice of raising seedlings in one area for planting elsewhere may carry a risk of spreading Mundulla Yellows.

SURVEY

A survey conducted in the southern Australian states in 2000–2001 detected MY-RNAs in more than 30 species of eucalypts, as well as in sheoaks and bottlebrushes (*Callistemon* spp.), at a number of locations. However, it appears that symptoms may vary, perhaps due to environmental or host factors, or possibly variations in the MY-RNAs. In samples taken from trees with Mundulla Yellows symptoms in Western

Australia, MY-RNAs have so far been detected in marri (*Corymbia calophylla*), salmon gum, York gum and cultivated river redgum in the south-west, as well as in Darwin box (*E. tectifica*) from the tropical north.

There is preliminary evidence that insects may spread Mundulla Yellows. Field sites are being monitored for the development of symptoms and spread of MY-RNAs. Since symptoms take time to develop, and the spread of the disease appears to be slow, samples need to be collected regularly over at least five years.

With the above evidence, we are now investigating the hypothesis that Mundulla Yellows is caused by a virus-like agent. MY-RNAs now need to be characterised to test their association with a potential virus-like pathogen. A sensitive, specific and fast routine test suitable for screening large numbers of samples from a wide range of plant species needs to be developed. This will be essential for testing nursery material and planting stock for infected material, and to identify possible sources of genetic disease resistance for use in breeding programs. It will also be essential for investigating mechanisms of disease expression, modes of spread (such as different insect species) and other features of the disease cycle.

THE FUTURE

In the case of *Phytophthora* dieback in WA, it took more than 40 years from the first records of symptoms to the discovery of the cause—and, by then, huge areas of vegetation had been devastated. Groundbreaking advances in Mundulla Yellows research during the past two years have opened the way towards identifying the cause of this disease. Only when the disease cycle is known can specific strategies be designed to disrupt it and thus control the spread of the disease. Until more specific knowledge is available, general plant hygiene practices will help to minimise the risk through human activity of spreading diseases, including Mundulla Yellows, from plant to plant and, most importantly, into new areas. An integrated research program towards nationwide control of Mundulla Yellows has been devised, but funding still needs to be secured.

FINDING THE CAUSE OF A NEW PLANT DISEASE

Finding the cause of a new disease is rather like detective work. Evidence must be critically examined and possible suspects eliminated by means of specialised investigation methods. The approach we have used successfully in the past includes the following steps:

1. *Define the disease* and provide a range of descriptors to differentiate it from other diseases or disorders.
2. *Separate facts from fiction.* Usually a mixture of opinions and valid observations exists when starting to investigate a disease of unknown cause. It is necessary to critically assess this mixture to determine what facts are available to build on.
3. *Formulate a working hypothesis* on the most likely cause. The disease may be due to living organisms or environmental factors.
4. *Test this hypothesis* by designing experiments to establish whether it is true or false.
5. *Identify the cause of the disease* by proving or disproving the hypothesis. A set of rules established by the early microbiologist R Koch (Koch's Postulates) is used to verify whether the cause has been found. If the first hypothesis turns out to be wrong, a different one may have to be established and tested.
6. *Investigate the disease,* if the cause is a living organism, by: a) characterising its causal organism(s); b) determining the host range and the events leading to the disease's appearance and spread, i.e. the disease cycle; and c) examining the effects of environmental factors on disease expression.
7. *Design control or management strategies.* Once the disease cycle is known, strategies can be designed to disrupt it. This could involve controlling vector insects or preventing transmission by other means; identifying genetic resistance for use in breeding programs to establish resistant lines for replanting; or, in the case of some viruses, designing mild strains to inoculate host trees and thus prevent infection by virulent ones.

Depending on the nature of the pathogen and the host plants under investigation, this complete process could take many years. However, it prepares a sound base of scientific knowledge on which to build strategies to deal with a disease problem. In the long term, it saves resources from being wasted on unsuccessful trial-and-error approaches, and it may provide wider benefits by increasing our knowledge of plant pathogens. We are applying this approach to investigate the cause of Mundulla Yellows.

by Dagmar Hanold and John W Randles

Dagmar Hanold is a molecular biologist specialising in plant viruses and viroids of trees. She has been developing molecular diagnostic methods for new diseases and has conducted extensive disease surveys on palms in the Pacific area.

John W Randles is a plant virologist with a special interest in viroids and the characterisation and epidemiology of plant viruses. He has identified the viral causes of a number of new diseases in a range of plant species.

Both work at the Waite Institute (University of Adelaide), Department of Applied and Molecular Ecology, Glen Osmond, SA 5064. They can be contacted on (08) 8303 7307 or by email (dagmar.hanold@adelaide.edu.au).

Mike Stukely is a Research Scientist with the Department of Conservation and Land Management, based at Kensington. Mike can be contacted on (08) 9334 0299 or by email (mikes@calm.wa.gov.au).

Frank Podger has worked for almost 50 years on diseases of native vegetation in Australia, particularly in WA, where in 1967 he determined the cause of the devastating disease then called jarrah dieback. He later helped to develop strategies and policies for its management. He has had a keen interest in Mundulla Yellows from almost ten years ago, and maintains it in retirement. Frank can be contacted by email (frankpod@tpg.com.au).

Diseases and Pathogens of Eucalypts, published by CSIRO and edited by Keane, Kile, Podger and Brown, provides excellent further reading.

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Executive Editor: Ron Kawalilak. Editor: David Gough.
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2003221-0603-2M

Quambalaria coyrecup T.Paap

Disease: Canker disease of *Corymbia* species
Classification: K: Fungi, D: Basidiomycota, C: Ustilaginomycetes, O: Microstromatales, F: Quambalariaceae

A severe canker disease has been causing decline in *Corymbia calophylla* (marri) in south-west Western Australia for some years now. Cankers are present on marri across its natural range and occur on trunks, branches and twigs of trees of all ages. There is no evidence to indicate that infected trees are able to recove therefore the future health of marri in the south-west is of serious concern.

The pathogen:

The fungal pathogen *Quambalaria coyrecup* has been identified as the causal agent. The fungus is thought to be endemic (native) to south-west Western Australia , but the reasons for this recent disease epidemic are undetermined. Thus, it is of immediate importance to determine the factors driving this decline and develop control and management options.

Host Range:

In addition to infecting marri, *Q. coyrecup* causes severe disease in urban plantings of red-flowering gum (*Corymbia ficifolia*) in Western Australia. To date the pathogen has not been observed causing disease on other *Eucalypt* species.

Control:

While there have not yet been control or management options developed for this disease, fencing off remnant stands of trees to encourage seedling recruitment and planting understorey species is encouraged.

Identifying the symptoms:

The canker disease can easily be recognised by the following identifying features:

The bark surrounding the affected area cracks and is eventually shed. Large amounts of kino (gum) are produced, staining the limb or trunk dark red (Fig.1).

Target-like lesions are formed as a result of a 'tug-of war' between host and pathogen. The tree produces a defence response that 'walls off' the diseased area but with time the fungus penetrates this barrier and reinvades. Once the disease has progressed to the point of girdling the host it has effectively ring barked it, resulting in the death of the affected limb or the entire tree if the trunk has been girdled. Scarring as a result of the canker is evident (Fig. 2).

The pathogen *Q. coyrecup* is sometimes observed sporulating on the diseased area visible as a powdery white mass (Fig. 3), producing air borne spores. Spore production (conidiogenesis) is shown in Fig. 4.

Further Reading:

Paap *et al.* (2005) In:15th APPS conference, Geelong. P. 66. (Abstract)
Paap (2006) *The incidence, severity and possible causes of canker disease of Corymbia calophylla (marri) in the southwest of Western Australia*, PhD Thesis, Murdoch University.

Key Contact: Trudy Paap, Murdoch University. Ph: 08 9360 2619

Armillaria luteobubalina / Eucalyptus wandoo:
Popanyining 2010

Observations of Marri and Jarrah Crown Decline near North Bannister

Mike Stukely and Allan Wills, Science Division, 3 November 2005

1. Edited extracts of Reports received from Peter White, CALM Narrogin, September – October 2005:

In an area of State Forest along Albany Highway, from North Bannister to about 10-15km further north, symptoms were observed on both *Corymbia calophylla* and *Eucalyptus marginata* that are similar to the "flagging" on *E. wandoo* affected by Wandoo Crown Decline. There is a range of stages of development of symptoms present, from those where the foliage has been dead for several weeks through to very recent death. In some cases, entire trees are sporting partially dead canopies.

When branch samples were cut through at various points, borer galleries were not encountered either above or below the dead foliage line. There was some, what appeared to be, scarring on the underside of the branchlet – similar to the fusiform scarring that Ryan Hooper reported in his assessment on *E. wandoo*.

The area that is affected continues about 10 - 15km along the highway and symptoms diminish rapidly either side of this area, both to the north and south. Affected trees are not confined to the road verges, with symptoms being visible on trees several hundred metres into the bush.

2. Observations on 3rd November by Stukely and Wills:

Brief details of observations made at two sites with widespread symptoms are given below.

Site A (code MAR3 = 32° 30.421' S, 116° 22.143'E).

Location and Site – East side of Albany Highway, upper slope and onto laterite ridge-top, with outcropping granite; stand of Jarrah/Marri above wandoo gully (on west side of Highway). Generally a harsh site. Symptoms extend at least 200m into the forest.

Symptoms – Heavy flagging of dead foliage was seen on scattered ground and advance-growth Jarrah coppice and saplings (Fig.1), and marri up to small pole size (Fig.2). Some larger, mature trees had scattered flagging of mainly small twigs, but many also showed old branch dieback and extensive epicormic growth. The condition of affected foliage ranged from very freshly killed to fully brown (dead several months), and old dieback of leaders and epicormic shoots (now defoliated) was also common. Small longitudinal splits were often present in the bark of branchlets and on petioles below dead and dying foliage. The cause of these is unknown. Fresh, healthy epicormics are now emerging from live tissue below the dead wood on many trees.

Coppices showed a clear succession of symptom development dating back over several years, with the leader having been killed and replaced by adjacent branches or epicormics, which had subsequently also been killed and replaced (Fig.3). This succession appeared to be predated by fire damage, estimated to have occurred at least 5 years ago, which killed the then leaders.

Causal Agents – There was some evidence of stem damage caused by insect activity, including **borers** (frass vent) and **moths** (webbing present in frass), on only two affected trees. A small gallery beneath a split in the bark of a dead twig (jarrah) contained Dipteran (fly, possibly Cecidomyiidae) larvae. Jarrah leafminer was not present. [Note: In Wandoo, insect damage is not necessarily readily apparent on the stem surface in the early stages of gallery development.]

On Jarrah advance growth coppices, removal of the bark towards the base of branches with dead and dying foliage revealed clear evidence of downward-advancing lesions, probably caused by **canker fungi**. Type 1 galleries as described by Ryan Hooper on Wandoo were not visibly present after removing of bark of affected branches.

Site B (code MAR4 = 32° 32.227' S, 116° 24.129'E).

Location and Site – West side of Albany Highway, upper to mid slope with occasional granite boulders, stand of mostly Jarrah above a wide, wet open area. Symptoms extend at least 500m into the forest.

Symptoms – Severe flagging of dead foliage, giving the appearance of widespread crown scorch, was seen on most understorey and mid-storey Jarrah. Over-storey trees had minor flagging but often also carried extensive old branch dieback (now defoliated), and epicormic growth.

The condition of affected foliage ranged from very freshly killed to fully brown (dead several months), and old dieback of leaders and epicormic shoots (now defoliated) was also common. Small longitudinal splits were often present in the bark of branchlets and on petioles below dead and dying foliage, as at Site A. The cause of these is unknown. Fresh, healthy epicormics are now emerging from live tissue below the dead wood on many trees.

As at Site A, coppices showed a clear succession of symptom development dating back over several years, with the leader having been killed and replaced by adjacent branches or epicormics, which had subsequently also been killed and replaced. This succession appeared to be predated by fire damage, estimated to have occurred at least 5 years ago, which killed the then leaders.

Causal Agents – There was again some evidence of stem damage caused by insect activity, a longicorn **borer gallery** was present on one affected small sapling. Jarrah leafminer was not present.

On Jarrah advance growth coppices, removal of the bark towards the base of branches with dead and dying foliage revealed clear evidence of downward-advancing lesions, probably caused by **canker fungi**.

Conclusions

Canker fungi are clearly involved, and are causing damage at a level more severe than usual. The involvement of insects was apparently less consistent. Canopy dominants appear to be least affected.

Recommendations

More detailed definition of the extent and severity of crown decline is warranted as a baseline for determining the longer term spread of this problem.

Investigation of causal agents may reveal novel pathogens.

Management options for controlling the problem are probably limited.

Fig. 1(a). Jarrah ground coppice with recent flagging. Albany Highway 12 km N of North Bannister.

Fig. 1(b). Jarrah sapling with flagging. Albany Highway 12 km N of North Bannister.

Fig. 2. Branch dieback in Marri saplings. Death of terminal foliage followed by recurrent death of epicormic foliage and stems. Note weathering of dead branches indicating long term presence of this condition. Albany Highway 12 km N of North Bannister.

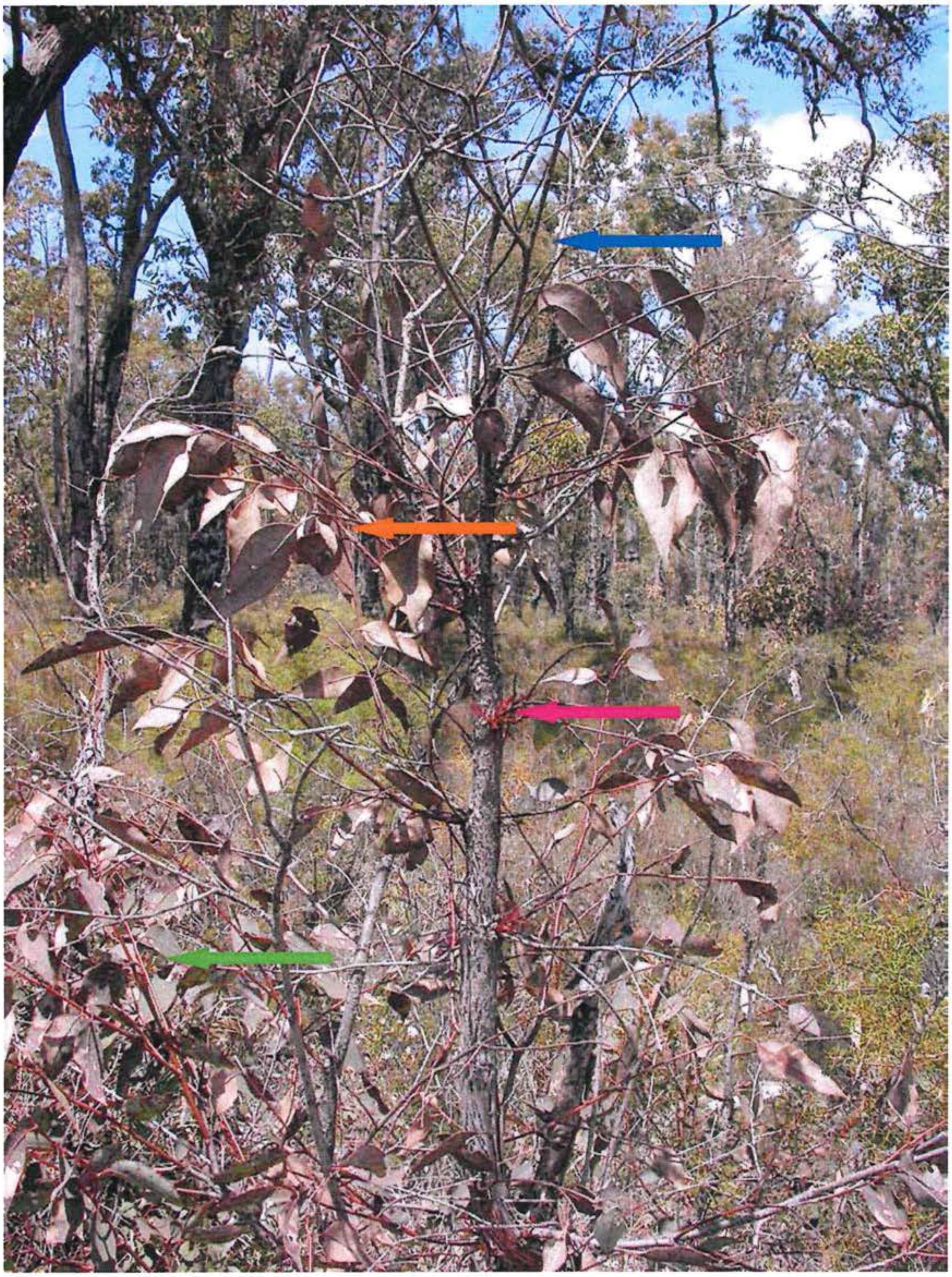
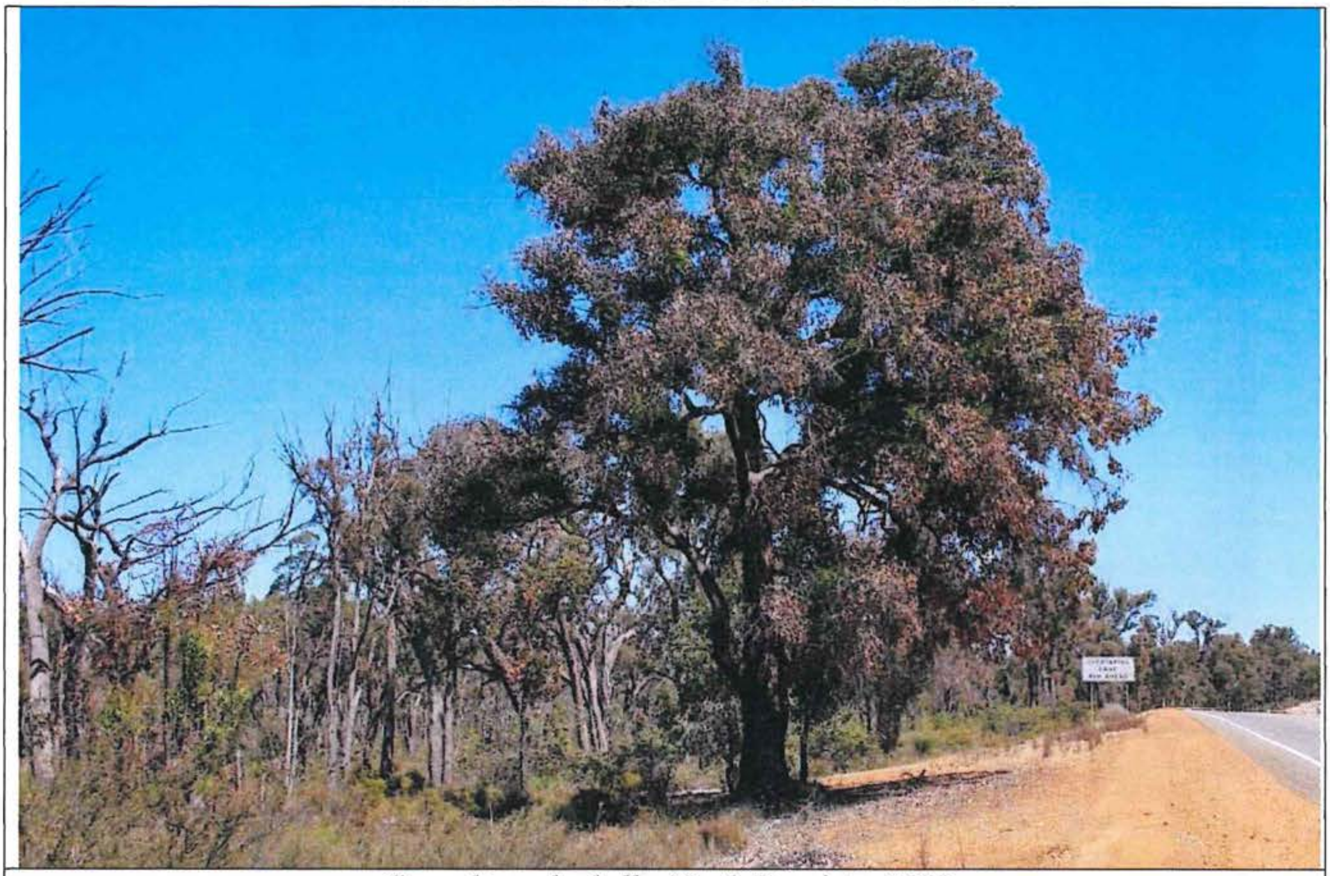


Fig. 3. Jarrah advance growth showing progressive decline. Blue arrow: Growing apex dead last year. Orange arrow: foliage dead this year. Purple arrow: Epicormic shoots. Green arrow: green foliage produced last growing season. Albany Highway 12 km N of North Bannister.

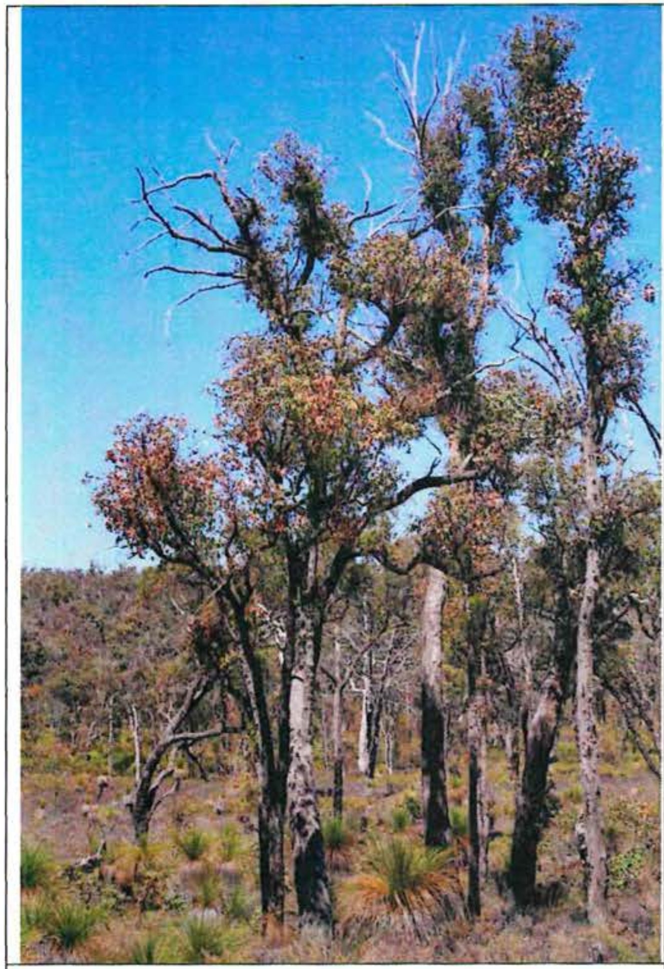
Jarrah and Marri Crown Decline



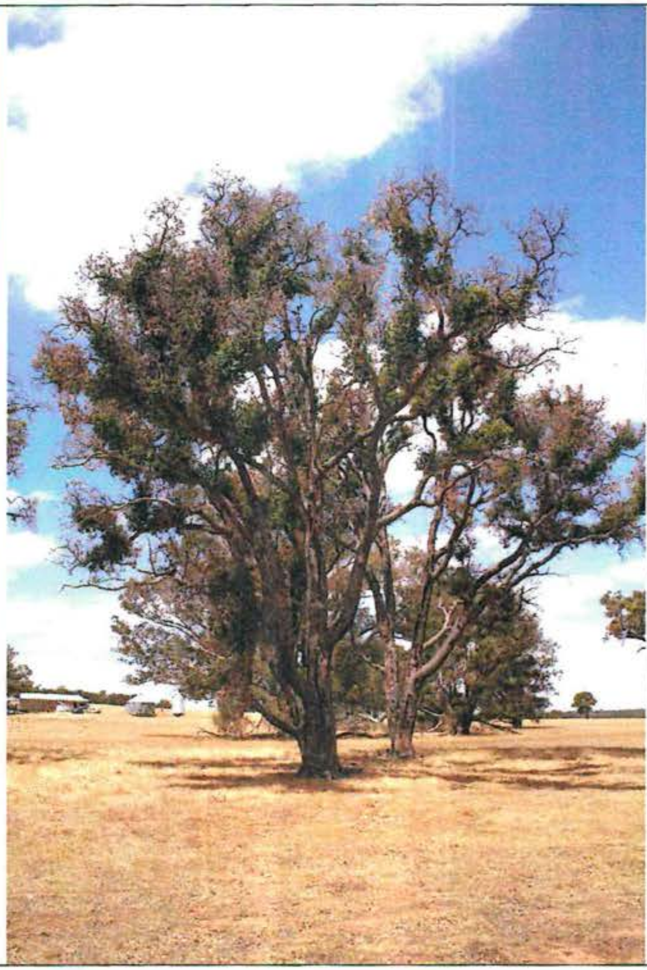
Corymbia calophylla: North Bannister 2006

Corymbia calophylla: North Bannister 2006

Jarrah and Marri Crown Decline



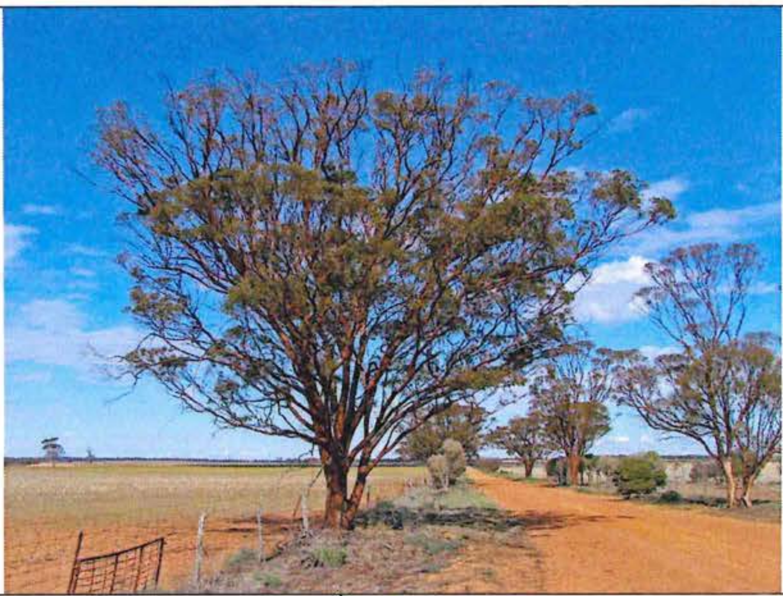
Eucalyptus marginata: North Bannister 2006



Corymbia calophylla: Jingalup 2007

Corymbia calophylla: Jingalup 2007

*Eucalyptus salubris*_1: Growden road / Nangeenan



17th May 2006

6th July 2007

1st Sept 2009

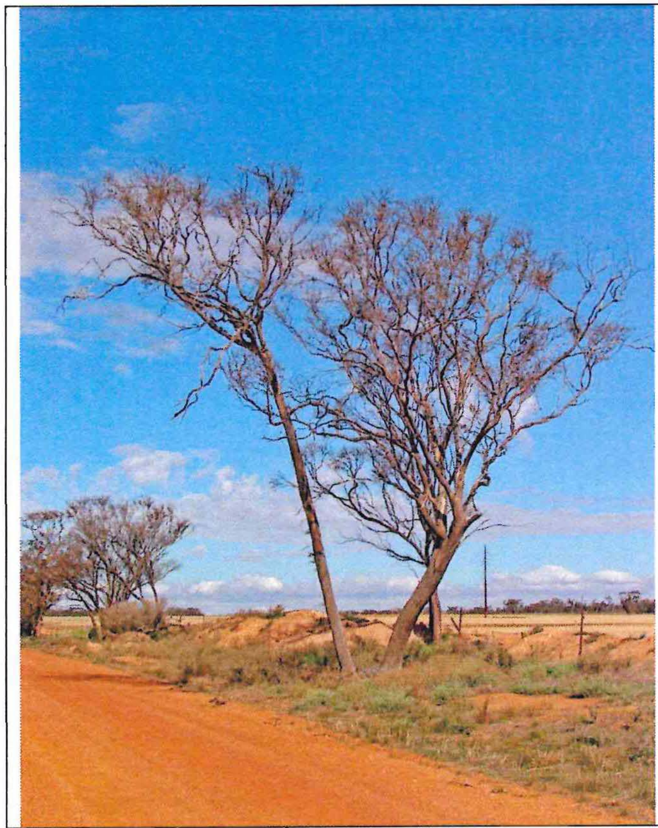
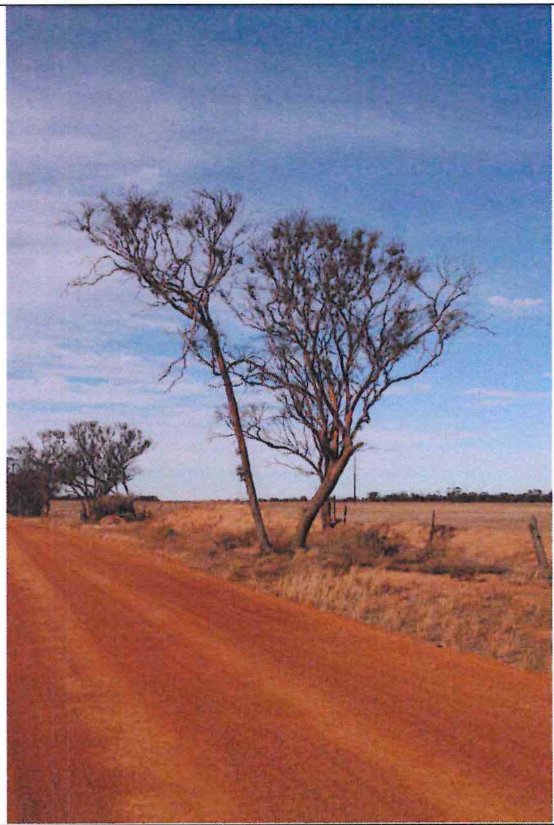
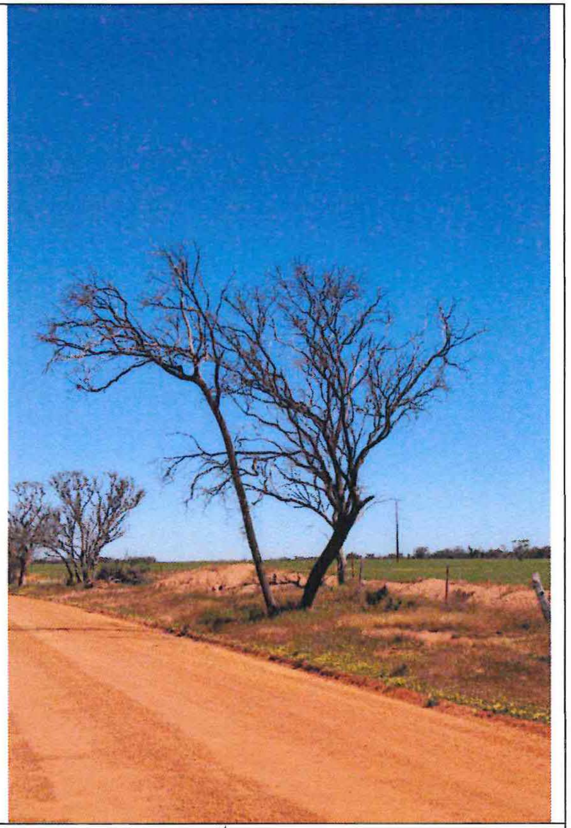
Eucalyptus loxophleba subsp. *lissophloia*_1: Growden road / Nangeenan

17th May 2006

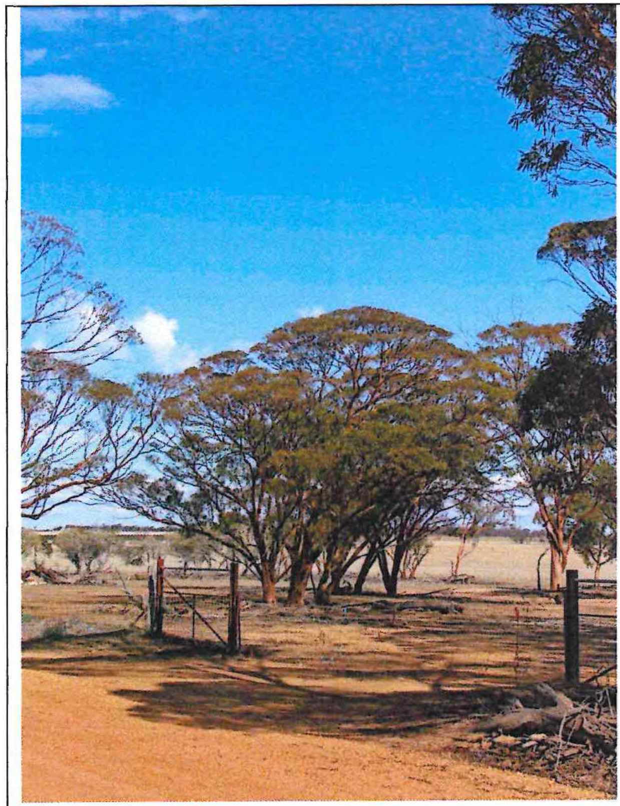
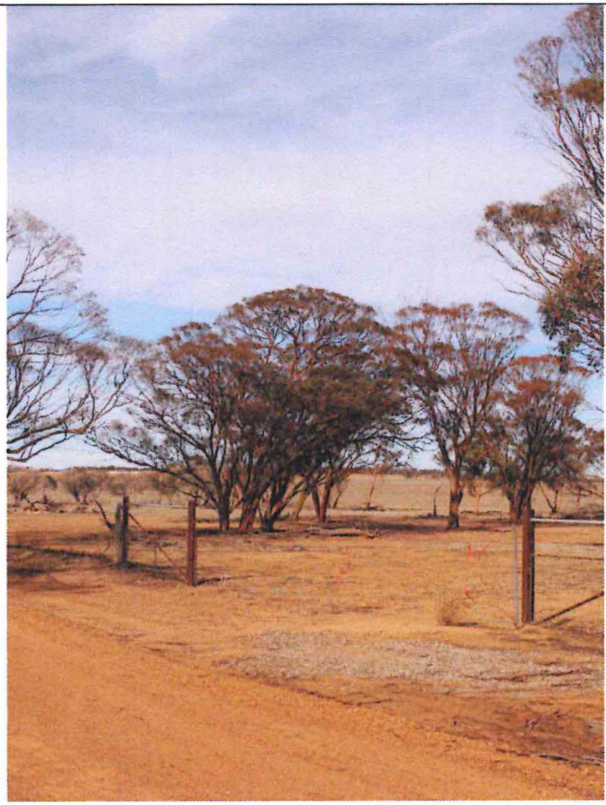
6th July 2007

1st Sept 2009

Eucalyptus moderata: Growden road / Nangeenan

		
17^{th} May 2006	6^{th} July 2007	1^{st} Sept 2009

*Eucalyptus salubris*_2: Growden road / Nangeenan

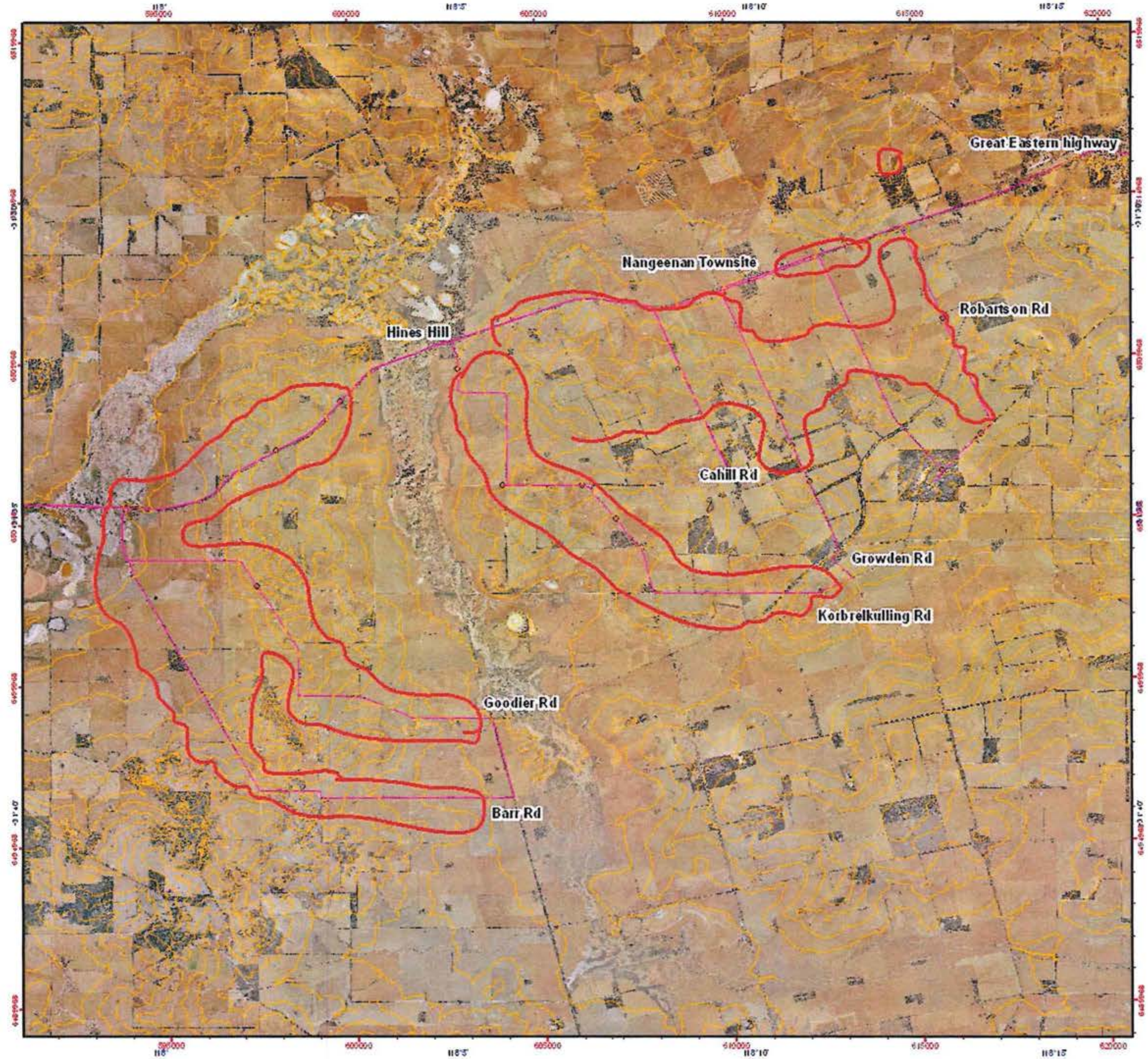
		
17th May 2006	6th July 2007	1st Sept 2009

Eucalyptus loxophleba subsp. *lissophloia*_2: Growden road / Nangeenan

17th May 2006

6th July 2007

1st Sept 2009



Nangeenan Tree Decline Occurance 2010

Approximate boundary of >70 Tree decline

N

1:120,000 (A3)

0 0.5 1 2 3 4
Kilometers

Projection: Universal Transverse Mercator
MGA Zone 50. Datum: GDA94

Department of Environment and Conservation
Our environment, our future

Produced by N. Moore
Under the Direction of
Keiran McNamara
Director General, Department of Environment and Conservation

Graticule shown at 5 minutes intervals
Grid shown at 5000 metre intervals

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Produced at 13:12pm, on February 16, 2010