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Crown decline in Wandoo 1999-2000

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July 2000

Summary

Foliage death in an extensive area of Wandoo (*Eucalyptus wandoo*) woodland in Talbot forest block became visible from the York road in early 1999. Public concern prompted inspection of the site by CALM personnel and samples were taken to try to determine the cause. A broad scale survey was undertaken in June 1999 and repeated in July 2000 covering a region from Talbot forest block, to the east of York to Wallaby Hills Nature Reserve, south to Dryandra National Park and northwards along Metro Road to Brookton Hwy.

Several sites were inspected for insect and pathogen activity. Roadside and farmland stands of Salmon Gum (*Eucalyptus salmonophloia*), York Gum (*Eucalyptus loxophleba*) and Brown Mallet (*Eucalyptus astringens*) were also examined. Extensive crown decline was only observed on Wandoo.

Causes of initial foliage thinning at Talbot forest block were unclear though most likely related to two years of below average rainfall prior to winter 1999. Leaf insect populations were not unduly high, and were not considered important contributors to the severe defoliation observed in 1999. Fungal cankers were observed on partially or completely defoliated twigs and branches, but absence of cankers on some branches with recently desiccated leaves indicated that fungal cankers were not a primary cause of initial leaf deaths.

A series of Wandoo crowns in the open woodland in the north end of Talbot forest block were photographed on 9 June 1999 then rephotographed on 4 July 2000 to facilitate a more rigorous and objective assessment of changes in crown condition.

Overall, the condition of Wandoo crowns at the site appeared to be stabilizing after an initial severe loss of leaf biomass prior to winter 1999. Subsequently there was a slight loss of net leaf biomass in the overall canopy since. Changes in Wandoo crowns conform to a generalized model of canopy decline in eucalypts as a response to environmental stress.

Loss of leaf biomass does not inevitably lead to the death of affected trees. Some environmental stresses are cyclical on an annual or multi-annual basis (drought), or of short duration (frost and high temperature). In these cases, leaf biomass in tree crowns stabilizes after initial losses then recovers.

Management actions to deal with the consequences of relatively short-term climatic stress are unnecessary in the Wandoo woodland system. Of greater importance is remediation of stresses imposed by soil salination. Effective actions are possible, but involve identifying areas with high conservation values that are tractable to remediation or protection, and capable of attracting the community support and capital needed to apply the landscape scale modifications required. At smaller scales, prevention of bark damage by farm livestock and provision of regeneration opportunities for replacement of senescent and dead trees are also important.

Introduction

Foliage death in an extensive area of Wandoo (*Eucalyptus wandoo*) woodland in Talbot forest block became visible from the York road in early 1999. Public concern prompted inspection of the site by CALM personnel and samples were taken to try to determine the cause. A broad scale roadside survey was also undertaken to the east of York to Wallaby Hills Nature Reserve and south to Dryandra National Park then north along Metro Road to Brookton Hwy.

Several sites were inspected for insect and pathogen activity. Roadside and farmland stands of Salmon Gum (*Eucalyptus salmonophloia*), York Gum (*Eucalyptus loxophleba*) and Brown Mallet (*Eucalyptus astringens*) were also examined. Extensive crown decline was only observed on Wandoo (*Eucalyptus wandoo*). Initial findings were presented and discussed in an earlier report by Francis Tay of the Vegetation Health Service at Como. The contents of the initial report were additionally presented and discussed at a York LCDC meeting by F. Tay on Wednesday 17 May 2000.

Wandoo crowns in Talbot forest block were predicted to stabilize in a reduced condition within one or two years and then recover over a longer period, depending on adequate rainfall and low insect populations.

The sites were again inspected on 4 July 2000 and the progression of crown decline or recovery noted along with evidence of insect and pathogen activity. We report here observations made on 4 July 2000 and describe changes in the Wandoo crowns since 9 June 1999.

Observations on Wandoo crown decline in Talbot forest block

Initial observations June 1999

Causes of initial foliage thinning at Talbot forest block were unclear though most likely related to two years of below average rainfall prior to winter 1999. Leaf insect populations were not unduly high, and were not considered to be important contributors to the severe defoliation observed in 1999. Fungal cankers were observed on twigs and branches previously defoliated by unknown causes or carrying foliage dead from unknown causes. However, some branches and twigs carrying dead foliage showed no evidence of canker activity. Subsequent to initial thinning of crowns, it is not unusual that canker fungi develop in newly defoliated twigs and branches, though stem cankers may only be a contributory rather than a primary cause of canopy decline. Cankers may progress downwards and kill newly formed epicormic shoots.

Selection of crowns for monitoring

A series of Wandoo crowns in the open woodland in the north end of Talbot forest block was photographed 9 June 1999 then rephotographed 4 July 2000 to facilitate an objective assessment of changes in crown condition (Plates 1-10). The initial series was selected to show a range of crown conditions from unaffected to severely affected. The second series allowed examination of the changes in these crowns to give an overall indication of the change in crown conditions at the site.

Observations June 1999 - July 2000

Observations in July 2000 continued to indicate that stem borers, leaf-eating or sap-sucking lerp insects (*Creiis periculosa* on average <1 per leaf, and leaf damage by insects 10-15% of remaining leaf area) were apparently not major contributors to the type of defoliation observed at Talbot block.

The changes shown in the pairs of photographs are summarized in the captions for each pair (Plates 1-10). Damage occurring prior to winter 1999 was inferred from the positions of leaf loss, branch death and development of epicormic shoots.

Overall, the condition of Wandoo crowns at the site appeared to be stabilizing after an initial severe loss of leaf biomass prior to winter 1999. There was a slight loss of net leaf biomass in the overall canopy since winter 1999. The canopies have greatly changed in appearance: initially most foliage was held on twigs at branch terminals, now most foliage is held on epicormic branches. In some crowns there has been continued foliage loss, while in others there has been no net foliage loss.

Left: Plate 1
9 June 1999. Healthy and intact crown with very few dead branches. No foliage thinning or twig death in crown during summer and autumn 1999. Note balga skirt and accumulation of bark shed, indications of a long period since the last fire (probably not burnt in fuel reduction fire in Spring 1996).

Right: Plate 2
4 July 2000. No twig death during summer and autumn 2000. No epicormic shoots. **No noticeable change to net crown biomass.**


Left: Plate 3
9 June 1999. Some recent twig death and older dead branches. Possible twig death during summer and autumn 1999 indicated by dead leaves still held in canopy. Epicormic shoots (spring/summer 1998 leaf cohort) below dead branch terminals (see lower right branch on Plate 3).

Right: Plate 4
4 July 2000. Twig death in summer and autumn 2000 indicated by dead leaves in discrete epicormic clusters held in canopy (Plate 4). Thinning of upper canopy and development of some lush epicormic clusters clearly evident. **Probably a decrease in net leaf biomass in this canopy since winter 1999.**

Left: Plate 5
9 June 1999. Possibly some recent twig death, initially thinly foliated branches and very few older dead branches. Diffuse leaf area loss prior to spring/summer 1998/99. No epicormic shoots by winter 1999. Branch terminals mostly not dead. Twig death during summer and autumn 1999 indicated by dead leaves still in canopy.

Right: Plate 6
4 July 2000. Twig death in summer and autumn 2000. Continued thinning of upper canopy and some branches now clearly dead. Good development of epicormic clusters. **Probably no change or slight increase in net leaf biomass in this canopy since winter 1999.**

Left: Plate 7
9 June 1999. Diffuse leaf loss, some recent twig death, some older dead branches and a few small long-dead limbs. Diffuse leaf loss prior to spring/summer 1998/99 indicated by thinly foliated live branches. Some epicormic twigs already present in canopy (Plate 7 upper left). Possible twig death during summer and autumn 1999 indicated by completely bare twigs (Plate 7 top), and some apparently live twigs carry few leaves.

Right: Plate 8
4 July 2000. Boxed area denotes previously photographed canopy. Twig death in summer and autumn 2000 indicated by dead leaves in discrete epicormic clusters held in canopy (brown patches centre left of Plate 8). Upper canopy branches now clearly dead as indicated by absence of leaves. Development of epicormic clusters continued particularly in what would formerly have been the middle and lower canopy. **Probably no change in the net leaf biomass of this particular tree since winter 1999.**

Note, for a contrast, the extensive twig death during summer and autumn 2000 in the cluster of trees in the right of Plate 8. The foreground of Plate 8 illustrates the sparse understorey and patchy distribution of dense clumps of Wandoo stems in multiple aged stands at this site. A range of severity of defoliation and differences in timing of defoliation between trees within stands is illustrated by Plate 8.

Left: Plate 9
9 June 1999. Some recent twig death, some older dead branches and long-dead massive limbs. Weathered limbs in this canopy have been dead for perhaps 5 or more years. These dead limbs are witness marks of much earlier crown declines. Thinly foliated live branches and some epicormic twigs are already present in the canopy by winter 1999 (Plate9 right central). Possible twig death during summer and autumn 1999 indicated by dead leaves still in canopy (Plate 9 right central).

Right: Plate 10
4 July 2000. Upper canopy branches now clearly dead and development of epicormic clusters continued, particularly in what would formerly have been the middle and lower canopy. Continued thinning of leaves on remaining live terminal twigs. **Probably no change, or a slight decrease in the net leaf biomass of this particular tree since winter 1999.**

Note the sapling canopies in lower right and left background showing a slight thinning of leaf biomass since winter 1999, with much foliage still held on terminal twigs. A range of severity of defoliation and differences in timing of defoliation between trees within stands is illustrated by the background trees in Plate 10. Young acacia in lower right understorey is a fire interval indicator (grown since last fuel reduction fire in Spring 1996).


Observations made in the regional survey

Wambyn Nature Reserve
Open Wandoo woodland and heath. Last fire unknown, but probably > 40 years since last fire.
Not surveyed 1999.
Observations July 2000: An area adjoining a gully on the western side of this reserve is apparently becoming salt affected and there appears to be some deterioration of Wandoo crowns in this part of the reserve, as well as parts of the reserve that are not salt affected.

Mokine Road about 3-5 km from York
Roadside Wandoo and Marri (*Corymbia calophylla*).
Not surveyed 1999.
Observations July 2000: Evidence of repeated epicormic branching over may years. Many dead branches and strong epicormic branching in crowns of both Marri and Wandoo indicating approximately stable leaf biomass in crowns with high leaf and branch turnover.

Wallaby Hills Nature Reserve Goldfields Road (31°50.830'S 116°59.261'E)
Scattered small trees in sparse shrubland on shallow soils over granite. No significant crown damage seen in June 1999 or July 2000.
Chewing insect damage 1999: Estimated 15-25% leaf area lost.
Insect damage 2000: Estimated 10-15% leaf area lost. *Creiis periculosa* estimate average <1 per leaf.

Mt Kokeby near town reservoir
One tree with severe branch girdling by borers. No other evidence of unusual foliage loss.
Insect damage 1999: *Creiis periculosa* estimate 4-10 per leaf.
Insect damage 2000: Estimated 5-10% leaf area lost. *Creiis periculosa* estimate average <1 per leaf.

Road and rail reserve south of Brookton
15 December 1997: Very extensive and hot fire completely defoliated trees. 20,000 ha farmland and remnant native vegetation affected.
4 July 2000: Lush epicormic branches on fire affected trees.

Dryandra NP
Site affected by *Armillaria* not inspected July 1999.
Site not affected by *Armillaria* (32° 47.2425'S 116° 59.605'E). Trees with lush crowns June 1999 and July 2000.
Chewing insect damage 1999: Estimated 10-20% leaf area lost.
Chewing insect damage 2000: Estimated 10-15% leaf area lost. *Creiis periculosa* estimate average <1 per leaf.

Metro Road, Wandoo in several valleys crossing southern part of road
Drive by inspection, old stag limbs and dead branches emerging from currently healthy canopy. No changes to canopy condition July 2000.

Metro Road, Flint forest block (32°18.256'S 116°27.143'E)
Healthy crowns June 1999 and July 2000.
Chewing insect damage 1999: Estimated 10% leaf area lost.
Chewing insect damage 2000: Estimated 20-25% leaf area lost. *Creiis periculosa* estimate average 4 per leaf.

Trees in farm parkland and roadside strips
Damage 1999: Isolated trees on farms showed severe crown recession and death of branches.
Damage 2000: Widespread instances of individuals and clumps of roadside trees showing more or less severe crown recession or death of branches. No Mundulla Yellows-like symptoms seen in roadside or farmland trees, nature reserves or forest blocks.

Overview of Wandoo decline in the context of general tree decline models.

Crown decline can originate from a variety of processes, and quite different processes can culminate in very similar symptoms. The following discussion briefly outlines how the complex interaction between environmental stresses and biotic factors such as insect feeding and fungi contributes to crown decline.

Factors contributing to canopy decline in eucalypts interact in complex ways.[1, 2, 3, 4] A simplified explanation of some of the processes can be outlined using flow diagrams. Deterioration of eucalypt crowns may be induced by any of several environmental stresses (Figure 1). These stresses could act through physiological strains either damaging or disrupting photosynthesis (e.g. heat or frost shocks), reducing the production of photosynthate due to prolonged stomatal closure to avoid water loss (e.g. drought), or restricting plant growth (e.g. nutrient deficiencies or toxicities). The overall effect can result in a net loss of leaf biomass in the canopy as leaves are killed or lost to senescence without equivalent replacement.

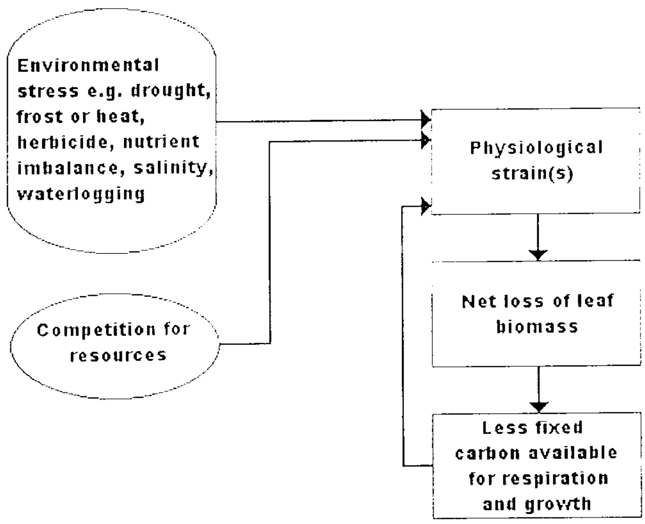

Figure 1. Simplified relationship between environmental stresses and loss of leaf biomass in open woodland tree crowns.

Closed forest canopies usually contain more than sufficient leaf biomass so that to some extent, depending on initial leaf area index, changes in the amount of leaf biomass do not greatly affect the amount of sunlight intercepted and, consequently, the amount of tree growth.[5, 6] In closed canopies, losses of canopy leaf biomass can to some extent be tolerated at little cost to growth.[6] In open woodland canopies, such as those of the Wandoo at Talbot forest block and in remnant roadside and farm trees, the amount of light intercepted and the amount of carbon fixed would be expected to be closely linked to the amount of canopy leaf biomass.[7] Reduction in canopy leaf biomass would cause a directly proportional reduction in the amount of carbon fixed by photosynthesis and reduction or cessation of tree growth in the absence of stored reserves of carbohydrate. Net loss of foliage results in a less vigorous tree or remobilization of stored carbohydrate reserves.

In open woodland canopies loss of leaf biomass could be expected to lead to less fixed carbon available for new leaf biomass, thus providing a potential feedback amplification of the effect of the initial loss if it were a large enough loss. Loss of foliage biomass in individual trees could possibly continue via feedback amplification if the environmental stress continued, partitioning of fixed carbon between respiration and growth was affected, or competitive interactions for resources within stands were altered.

Environmental stresses are not the only cause of loss of leaf biomass in tree canopies. Leaf–feeding insects[8] and leaf spot fungi can sometimes remove or damage leaf biomass at a greater rate than it is produced resulting in a net loss of leaf biomass (Figure 2). Stem girdling borers and stem cankers[9] can also cause foliage death.

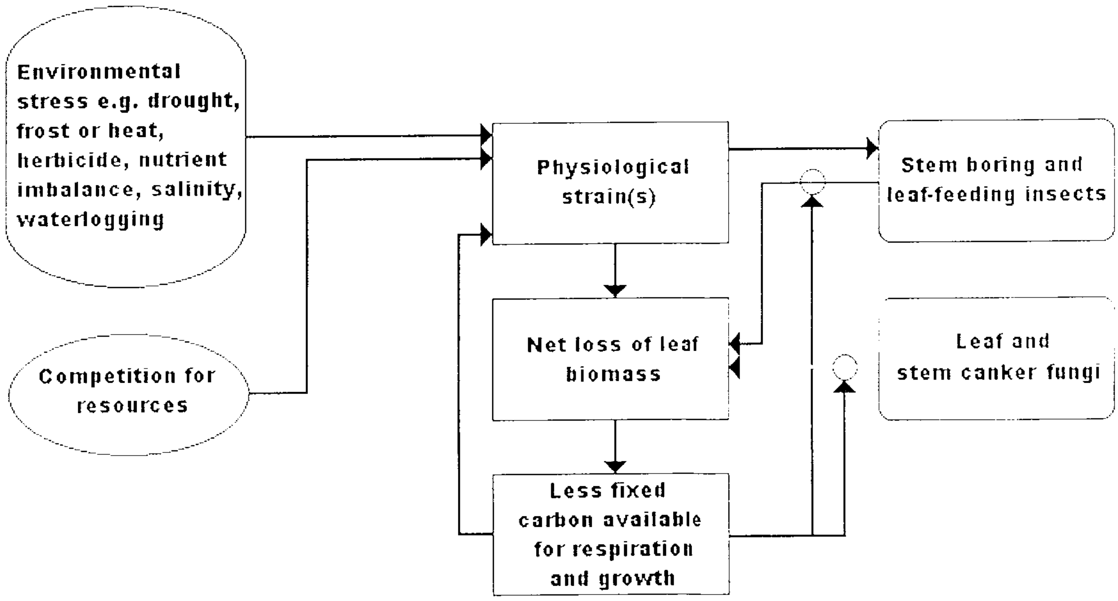

Figure 2. Simplified relationships between defoliating insects and fungi and leaf biomass loss in open woodland tree canopies.

Trees under physiological strain lose vigour and become more susceptible to damage by insect populations[10] and canker infections[11, 12] which would normally impose no damaging effects on healthy trees despite their presence. Pathogens can be present as endophytes undergoing asymptomatic growth, or as latent infections prior to development of symptoms.[13] Symptoms are actuated by physiological changes in the host. Feedback amplification of leaf loss could continue without environmental stress simply from the effect of leaf loss to pathogens and insects. As tree vigour deteriorates, susceptibility to further damage would increase.

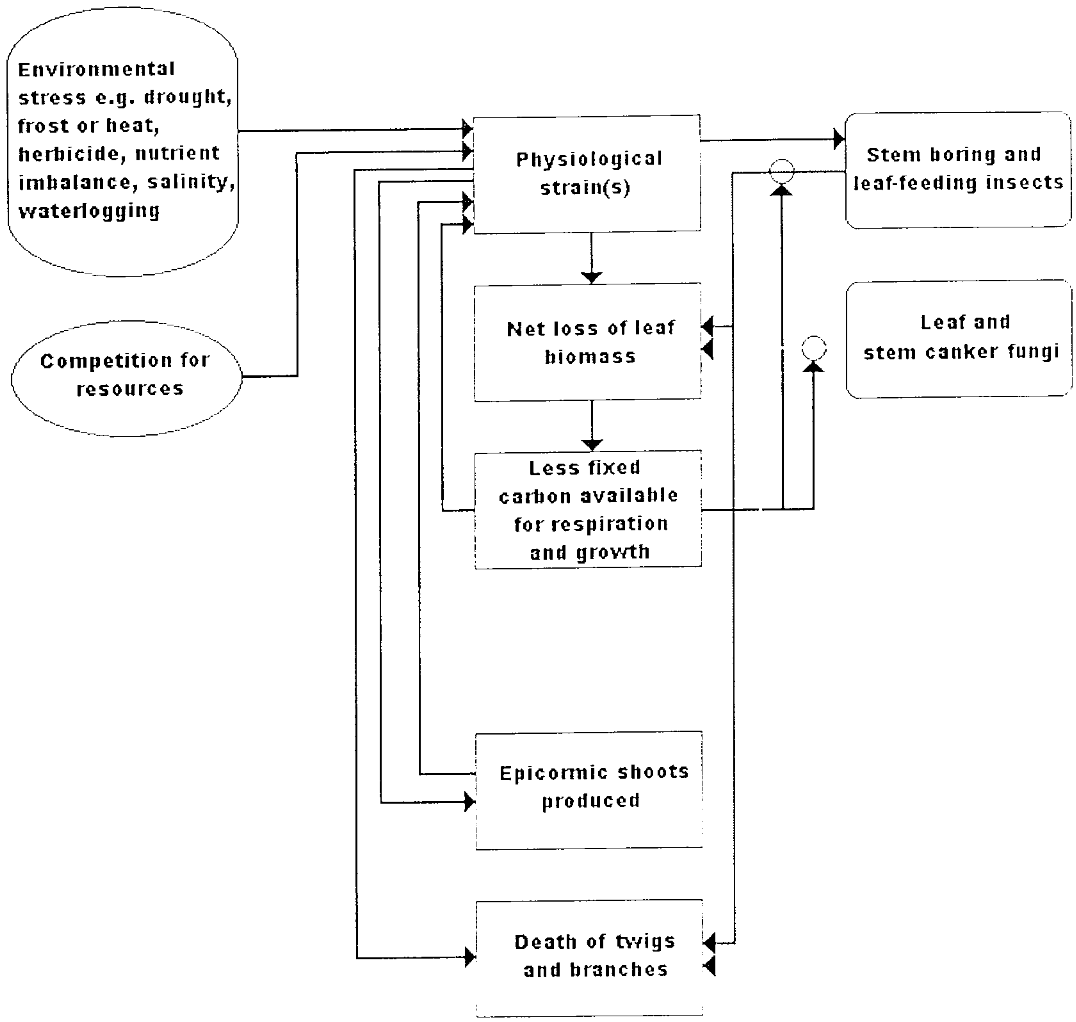

Figure 3. Simplified relationships between environmental stress, loss of leaf biomass in woodland canopies, insects and cankers, formation of epicormic shoots and death of twigs and branches.

Foliage loss is sometimes severe enough to remove the physiological dominance of branch apices, and epicormic buds become released from suppression and grow from branches and limbs (Figure 3). Onset of death of defoliated terminal twigs and branches can be accelerated as the epicormic shoots develop as competing and dominant sinks for resources. Stem boring insects and stem cankers may contribute to the toll.

Thus, canopy decline can be viewed as a series of phenomena contributing to loss of canopy biomass. Changes in the crown structure of affected tree canopies can be viewed as responses to more or less severe defoliation over a period of time.

Causes of Wandoo crown decline in the York area

In other investigations,[14, 15] crown decline in Wandoo has been attributed to several causes including increasing soil salinity, insect or fungal attack, fire damage, or drought. From each of these origins, foliage loss may culminate in the same manifestations of crown decline. Evidence for the causes of crown declines in the York area is reviewed below.

Canopy decline in eucalypts associated with high populations of insects is not uncommon in Western Australia.[8] Extensive areas of *Eucalyptus rudis* are currently declining under defoliation by the sap sucking psyllid *Creiis periculosa* and *Perthida sp.* leafminer.[16] The leafminer *Perthida glyphopa* is a well known contributor to long term decline of jarrah (*Eucalyptus marginata*) crowns.[17] The stem girdling borer *Phoracantha impavida* is an important contributor to foliage loss in declining Tuart (*Eucalyptus gomphocephala*) south of Mandurah.[18] Flat Topped Yate (*Eucalyptus occidentalis*) suffers periodic outbreaks of the defoliating psyllid *Cardiaspina jerramungae*.[19] Wandoo can carry high populations of the sap sucking psyllid *Creiis periculosa* that cause defoliation, but populations of this insect are not considered a significant contribution to the Wandoo decline around York.

Fire is an important pathway for nutrient cycling in some vegetation systems especially on nutrient poor soils. Fire exclusion can affect the balance of competitive interactions between tree species by exacerbating the effects of nutrient deficiencies or interacting with differences in fire sensitivity between species.[18, 20] Fire history may play a role in determining the composition of mixed species stands including Wandoo, and the stocking density of regrowth stands of Wandoo, since it is easily killed by fire.[21, 22] However, in the single species stands of Wandoo woodland examined in this survey, fire exclusion was probably not a contributor to environmental stress as crown decline was observed in both old open stands and dense regrowth stands subject to regular fuel reduction burning, and open stands of mature trees probably unburnt for several decades.

Trees within a small area of woodland showed a wide variation in the expression of the effects of environmental stress. Factors such as stand age structure, density of stems within stands, tree genotype, and localized soil conditions probably make important contributions to differences in the degree of exposure to environmental stress within and between stands of Wandoo. Differences in expression of canopy decline relate to differences between trees in the time scale of development of a sequence of symptoms. That is, progression from initial foliage losses, through development of epicormic shoots and death of defoliated branches. Increased activity of canker fungi following initial foliage losses was also indicated by repeated deaths of epicormic shoots on previously affected trees.

Observations at Talbot block indicate that it will be difficult to identify Wandoo genetically resistant to the canopy decline. Insects and fungi are not implicated as primary causes of the decline and resistance to their defoliating effects is not clearly expressed. Trees examined within a small area of Talbot forest block showed wide variation in the expression of effects of environmental stress (Plates 1-10). However, it is practically difficult to separate variation in exposure to environmental stress from phenotypic variation in the expression of decline.

The progressive development of interveinal chlorosis and foliage death characteristic of the Mundulla Yellows syndrome[23] was not observed in this survey in roadside or farmland trees, nature reserves or forest blocks.

Several types of environmental stress have probably contributed to canopy declines in stands of Wandoo across the region surveyed. Canopy decline at Wambyn Nature Reserve is coincident with salinity in part of the reserve. Other parts of the reserve showing decline are apparently not saline. Canopy decline in Talbot block is not coincident with salinity or unusual insect attack and is most likely related to drought. Stem borers may play an important role in high turnover of branches on some roadside and paddock trees.

Loss of leaf biomass does not inevitably lead to the death of affected trees. Some environmental stresses are cyclical on an annual or multi-annual period length (drought), or of short duration (frost and high temperature). In these cases leaf biomass in the crowns usually stabilizes after initial losses then slowly recovers, depending on low populations of insects and sufficient rainfall. However, increasing soil salinity or nutrient imbalances impose chronic stress and the progressive loss of canopy biomass may occur over a long period and eventually result in tree deaths.

Conclusions

Canopy decline in Talbot block is not coincident with salinity or unusual insect attack and is most likely related to drought.

Increased activity of canker fungi following initial foliage losses was indicated on Talbot block.

Crown decline at Wambyn Nature Reserve is coincident with, though not necessarily caused by salinity in part of the reserve.

Stem borers may play an important role in high turnover of branches on some roadside and paddock trees.

Fire exclusion was probably not a contributor to environmental stress in extensive decline as crown decline was observed in both old open stands and dense regrowth stands subject to regular fuel reduction burning, and open stands of mature trees probably unburnt for several decades.

Mundulla Yellows syndrome was not observed in this survey in roadside or farmland trees, nature reserves or forest blocks.

It will be difficult to identify Wandoo genetically resistant to the crown decline as it is difficult to separate variation in exposure to environmental stress from phenotypic variation in the expression of decline.

The canopy declines observed in Wandoo around York, while highly visible and likely to continue to attract comment, are not unusual. The most extensive declines are probably attributable to the consequences of below average rainfall in 1997 and 1998. The crown declines can be considered as a phase in a cyclical process and the crowns will eventually stabilize and then recover over several years. The crowns will continue to carry dead branches for many years as witness marks of the present decline.

Management responses

Management actions to deal with the consequences of relatively short-term climatic stress are unnecessary in the Wandoo woodland system. Of greater importance is remediation of stresses imposed by soil salinity. Effective actions are possible, but involve identifying areas with high conservation values that are tractable to remediation or protection, and capable of attracting the community support and capital needed to apply the necessary landscape scale modifications. At smaller scales, prevention of bark damage by farm livestock and provision of regeneration opportunities for replacement of senescent and dead trees are important.[24]

Recommendations for future research and monitoring:

Document changes in Wandoo stands and provide an interpretation so that communities and landholders can identify and appropriately respond to the complex of processes occurring.

1. The Land for Wildlife scheme in CALM has an extensive community outreach and may be in a position to coordinate monitoring of Wandoo trees on farms by by rural communities. Staff of CALM's Regional Services Division need to be briefed about crown decline so that instances of sudden changes can be reported to the Vegetation Health Service in CALM**Science** Division.

2. Continue monitoring of the Talbot site and follow the fate of individual trees, branches and twigs using photography. (CALM**Science** Division)

3. Sample recent epicormic deaths in spring and summer 2000 to determine cause of death. (CALM**Science** Division)

4. Map extent of crown decline in the northern end of Talbot block and Wambyn Nature Reserve to determine changes in extent of affected area. Are fire history or geomorphic features important? (CALM**Science** Division)

5. Monitor recovery of vegetation after summer 1997 wildfire in Horne and Goodenough Nature Reserves south of Brookton. (CALM**Science** Division)

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