Crown decline in Wandoo
Supplement 2001

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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. Causes of initial foliage thinning at Talbot forest block were unclear though most likely related to below average winter rainfall in the winter of 1997.

A series of Wandoo crowns in open woodland in the north end of Talbot forest block (31° 53.103' S, 116° 30.511' E) 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 (see Wills et al. 2000 for summary of observations to winter 2000). A recently published system for rating eucalypt canopy decline (Stone et al. 2000) was used to classify declining stands.

Wandoo stands in Talbot Block exhibit a range of decline of individual tree crowns (see cover Plate and Plates 1-10). In general, continued decline of crowns is exhibited by those trees severely affected in the initial period of visible decline (ie already severely affected in 1999). Decline has not developed in trees not visibly affected in 1999. While decline has not stabilized in some crowns (see plate 6), there seems to be stabilization in many crowns where loss of foliage is more or less equalized by development of new foliage. It seems likely that some trees weakened by loss of foliage will die, though given normal rainfall conditions in the future, most have potential to survive and rebuild their canopies, resulting in a net thinning of the number of stems.

Foliage chloride concentrations indicate that increasing soil salinity does not appear to be a factor in canopy decline at the Talbot Block site. The lerp *Creis periculosa* was present in low numbers on Wandoo (average <1 per leaf) and it is not believed to be a direct agent in deterioration of Wandoo crowns in Talbot Block.

Some declining Wandoo crowns will probably continue to decline resulting in some tree deaths. Most trees will probably survive and rebuild their canopies should favorable rainfall conditions prevail. The net result is likely to be a thinning of stand density in the most severely affected stands. The extent of thinning is dependent on future rainfall. Below average winter rainfall in much of southern Western Australia during winter 2000 and 2001 (see appended Bureau of Meteorology maps) is likely to impact on remnant native vegetation.

Wandoo canopy decline is now visible in many areas in southwest Western Australia. We recommend that Wandoo water use physiology, stand responses to site conditions and regeneration ecology be investigated in Talbot Block by a university based project.

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 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 in July 2000. Extensive crown decline was only observed on Wandoo.

Causes of initial foliage thinning at Talbot forest block were unclear though most likely related to below average winter rainfall in the winter of 1997 evident in the appended series of Bureau of Meteorology maps (Bureau of Meteorology 2001, Appendix 1). Bureau of Meteorology data (pink and red areas on the maps) show that winters 1997 and 2000 lie within the range of driest 30% of all recorded winters in the region of the Talbot Block site.

Leaf insect populations were not unusually high, and were not considered important contributors to the severe Wandoo 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 open woodland in the north end of Talbot forest block (31° 53.103' S, 116° 30.511' E) 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 (see Wills et al. 2000 for summary of observations to winter 2000). A recently published system for rating eucalypt canopy decline (Stone et al. 2000) was used to classify declining stands. An extract from the article is appended (Appendix 2). We report here further observations taken on 23 May 2001.

Observations Talbot Block July 2000-May 2001

Wandoo stands in Talbot Block exhibit a range of decline of individual tree crowns (see cover Plate and Plates 1-10). In general, continued decline of crowns is exhibited by those trees severely affected in the initial period of visible decline (ie already severely affected in 1999). Decline has not developed in trees not visibly affected in 1999. While decline has not stabilized in some crowns (see plate 6), there seems to be stabilization in many crowns where loss of foliage is more or less equalized by development of new foliage. It seems likely that some trees weakened by loss of foliage will die, though given normal rainfall conditions in the future, most have potential to survive and rebuild their canopies, resulting in a net thinning of the number of stems. It should be noted that stands in the north end of Talbot forest block are the worst affected by decline symptoms. Stands further south, along Wundabiniring and Helena Roads, generally have greater proportions of trees not showing visible decline symptoms.

The spatial variation in severity of crown decline in Talbot Block appears to be related, to some extent, to topography. The landscape is gently undulating and canopy decline appears most severe in broad shallow valleys and less severe in upper parts of the landscape in Talbot Block, though we have not quantified this.

In some cases, shallow saline soils associated with valleys may contribute to the susceptibility of sites to winter rainfall drought by restricting rooting depth and accessibility of soil water (e.g. Hatton et al. 1998, their Fig. 8 data points for *E. occidentalis* and other species along a soil salinity gradient). In other cases, increasing soil salinity may lead to toxic concentrations of salts in foliage.

Table 1. Foliage concentrations (as percent of dry leaf weight) of macro-nutrients (totals N, P, K) and Chloride.

Site	Sample	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Chloride (%)
Monitored site	Healthy Wandoo (see Plate 1)	1.02	0.025	0.59	0.96
	Wandoo with crown contraction	0.62	0.027	0.68	0.99
	Wandoo with premature loss of new foliage	1.13	0.035	0.45	0.76
	Riparian *E. rudis* with crown contraction	1.30	0.046	0.54	0.66
Unmonitored site Wundabiniring Rd	Riparian Wandoo dead foliage	1.21	0.040	0.38	1.11
Thompson (1983) glasshouse seedling pot trial	*E. wandoo* (Julimar SW provenance: no added salt in irrgation)				1.27
	E. wandoo (Nundedine provenance: no added salt in irrigation)				0.71
	E. wandoo (Julimar SW provenance: watered with 0.16M NaCl)				2.39
	E. wandoo (Nundedine provenance: watered with 0.16M NaCl)				2.43

Foliage samples were tested for macro-nutrient (total N, P, K) and Chloride content (Table 1). Foliage Chloride from two provenances of *E. wandoo* seedlings subjected to elevated soil water concentrations of NaCl are provided for comparison (data recalculated as a percentage of leaf dry weight from mean data in Thompson 1983, Tables 2a and 6). Foliage chloride concentrations indicate that increasing soil salinity does not appear to be a factor in canopy decline at the Talbot Block site.

The lerp *Creis periculosa* was abundant (average >25 individuals per leaf) on *Eucalyptus rudis* along Wundabiniring Brook, and it is likely that poor *E. rudis* canopies in Talbot forest block are the result of repeated defoliation by this lerp. *C. periculosa* was present in low numbers on Wandoo (average <1 per leaf) and it is not believed to be a direct agent in deterioration of Wandoo crowns in Talbot Block.

Other observations in Talbot Block
Long stretches of the bed of Wundabiniring Brook appear to be frequently used by off-road motorcyclists and have water scoured areas, which may have resulted from destabilization by this means. There was also much evidence of feral pig activity within the month or two prior to the inspection in moist riparian areas along the brook.

Observation of a declining Salmon Gum York-Northam Road
A declining Salmon gum just north of the Goldfields Road junction was also photographed (Plate 11). The tree had been sampled and photographed by Dagmar Hanold and Mike Stukely in October 2000 as part of an investigation of Western Australian trees exhibiting unusual symptoms including chlorotic foliage and crown dieback.

Early detection and characterization of emerging biotic threats to remnant Salmon Gum and other wheatbelt woodland trees is vital, as they exist in much of their former range only as remnant farm trees and roadside vegetation. As such, they are disconnected from ecological processes necessary for regeneration, and even low mortality rates will ensure loss of remnant stands in the long term. It is likely that the causes of decline in this Salmon Gum are different than those operating on Wandoo in Talbot Forest Block.

Conclusions
Recent publication of a system for evaluating the condition of eucalypt canopies (Stone et al. 2000) provides an objective method for evaluating canopy decline. According to the system, known as Eucalypt Canopy Condition Index (ECCI), all levels of the index including the most severe are exhibited within the stands at the Talbot Forest Block site.

Some declining Wandoo crowns will probably continue to decline resulting in some tree deaths. Most trees will probably survive and rebuild their canopies should favorable rainfall conditions prevail. The net result is likely to be a thinning of stand density in the most severely affected stands. The extent of thinning is dependent on future rainfall. Below average winter rainfall in much of southern Western Australia during winter 2000 and 2001 (see appended Bureau of Meteorology maps) is likely to impact on remnant native vegetation.

Wandoo canopy decline is now visible in many areas in southwest Western Australia. We recommend that Wandoo water use physiology, stand responses to site conditions and regeneration ecology be investigated in Talbot Block by a university based project.

Acknowledgements
We thank Lin Wong for performing the foliage nutrient analysis, and Trevor Butcher for providing a copy of the unpublished report by L.A.J. Thompson.

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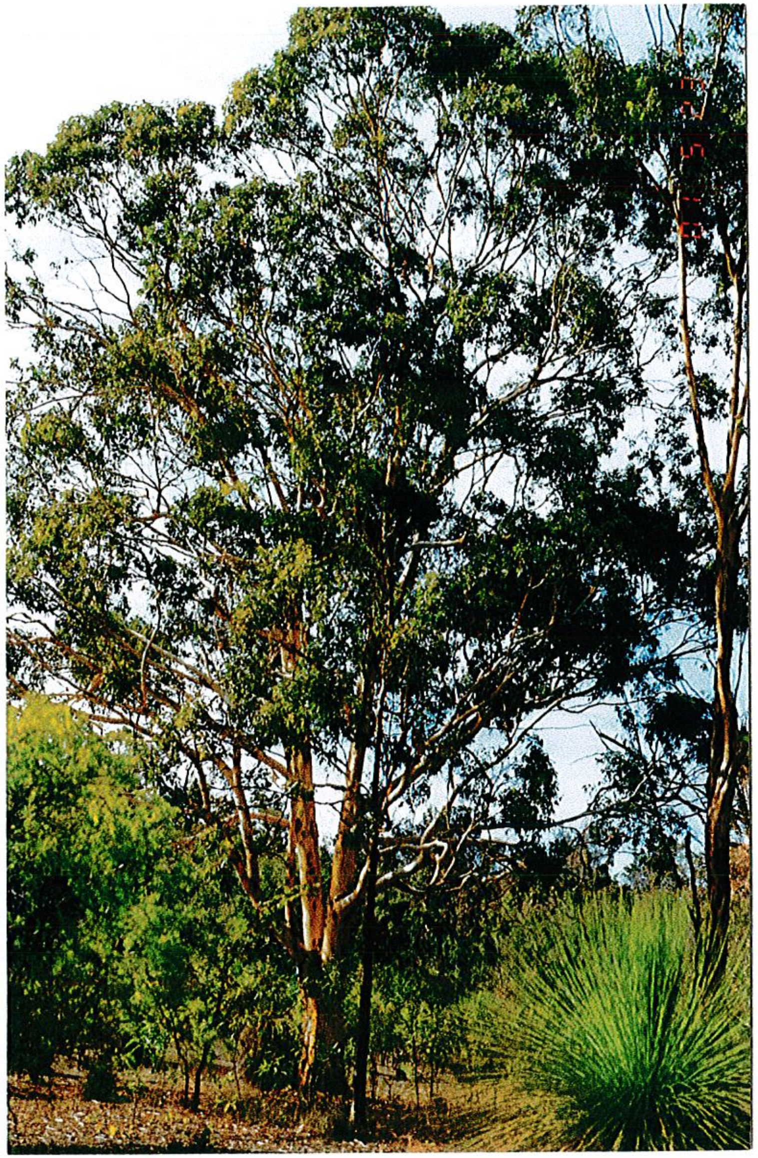
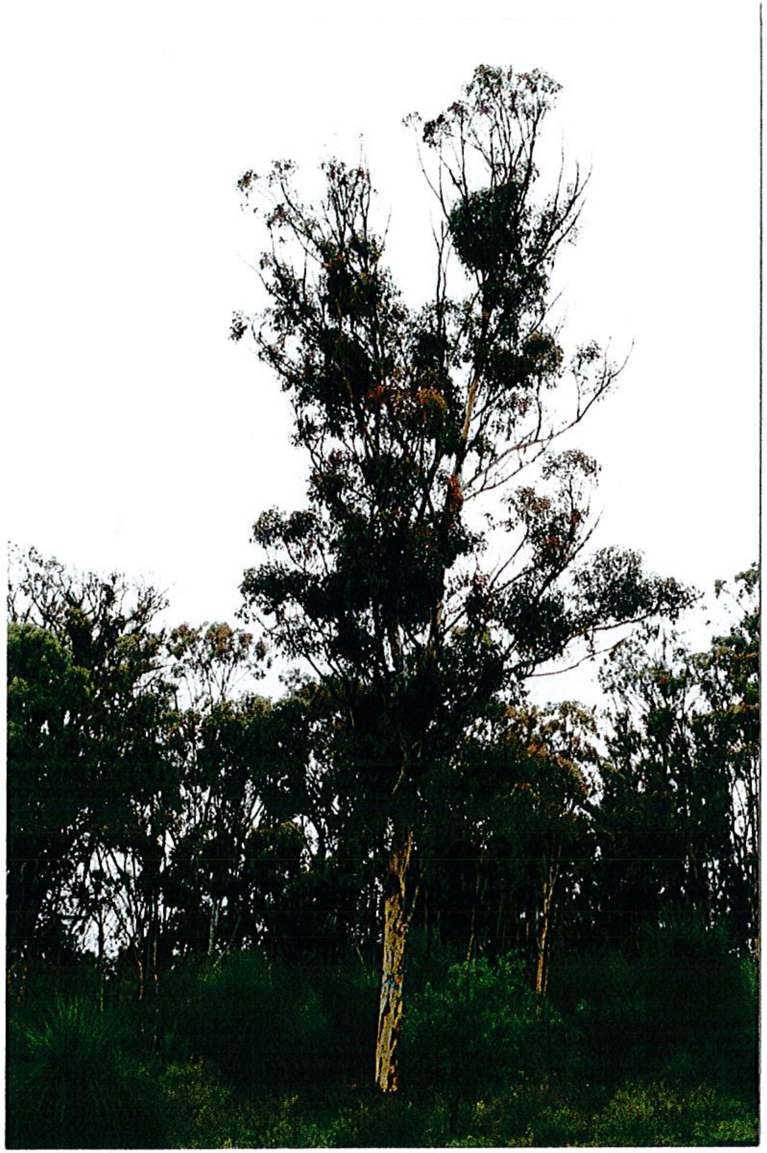
Left: Plate 1
4 July 2000.

Right: Plate 2
No twig death during summer and autumn 2000. No epicormic shoots. Stone et al. (2000) ECCI rating =1 (Symptoms previsual). **No visible change since July 2000.**



Left: Plate 3
4 July 2000.

Right: Plate 4
23 May 2001. Twig death in summer and autumn 2001 indicated by dead leaves in discrete epicormic clusters held in canopy (ECCI Phase 2: Foliar discolouration). Continued thinning of upper canopy and leaves on terminal branches (ECCI Phase 3: Defoliation). Some crown contraction to lower parts of canopy (ECCI Phase 4: Crown contraction) although this is offset to some extent by development of some lush epicormic clusters clearly evident in lower parts of crown. Overall Stone et al. (2000) ECCI rating = 4 (Defoliation and crown contraction). **Probably no change or slight net decrease in leaf biomass since July 2000.**



Left: Plate 5
4 July 2000.

Right: Plate 6
23 May 2001. Terminal branchlets now all dead (ECCI Phase 4: Crown contraction). Crowns left of centre more or less unchanged. Crown immediately right of centre shows continuing death of epicormic clusters to the extent that the tree is probably close to death (ECCI Phase 5: Dead crowns). Overall Stone et al. (2000) ECCI rating = 5 (Dead crowns). **Probably a net decrease in leaf biomass in this stand.**

Plate 7
4 July 2000.

Plate 8
23 May 2001. Continued death of epicormic clusters in upper part of largest tree and some loss of epicormic clusters throughout (ECCI Phase 4: Crown contraction). Probably a net loss of leaf biomass in this particular tree since July 2000. In the stand generally, terminal branches now clearly dead and continued death of epicormic clusters in most crowns (ECCI Phase 4: Crown contraction). One or two crowns completely dead (ECCI Phase 5: Dead crowns). Overall Stone et al. (2000) ECCI rating = 5 (Dead crowns). **Probably a net loss of foliage biomass in this stand since July 2000.**

Note the death of a small balga in left centre foreground.

Left: Plate 9
4 July 2000.

Right: Plate 10
23 May 2001. Development of epicormic clusters continuing, particularly in what would formerly have been the middle and lower canopy. Development of foliage on remaining live terminal branches. Overall Stone et al. (2000) ECCI rating = 4 (Crown contraction). **Probably a slight net increase in leaf biomass of this particular tree since winter 2000.**

Notes: One difficulty presented by the Stone et al. (2000) index system is that historical symptoms of crown contraction remain present, even when the physical condition of the crown stabilizes or improves. Crown contraction from branch apices (ECCI Phase 4: Crown contraction) may continue while net foliage biomass remains the same or increases due to development epicormic foliage. In some cases of decline there may be partial independence between crown contraction under defoliation and branch mortality agents and the development of epicormic clusters after epicormic release has been initiated.

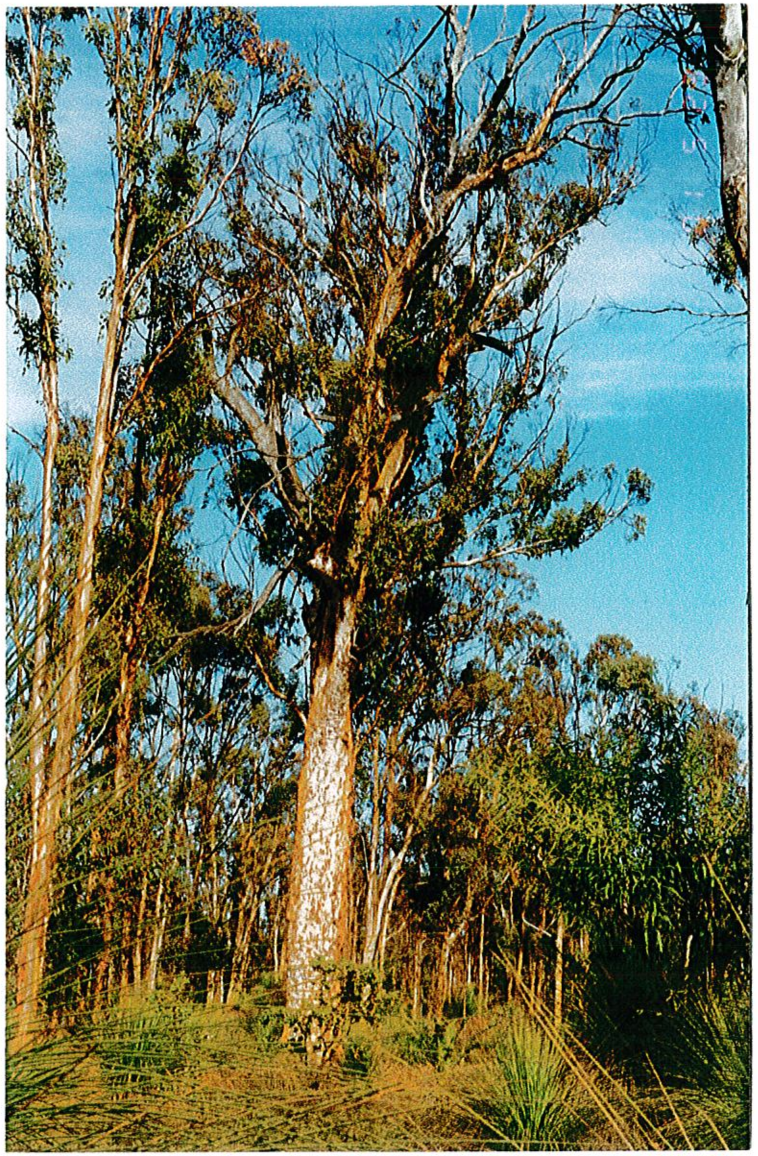


Plate 11
23 May 2001. A visibly declining Salmon Gum located 150m north of Goldfields Rd junction on Northam-York Road.

Appendix 1

Bureau of Meteorology southern rainy season (April to November) maps from 1996 to month to date in 2001. Position of Talbot Forest Block site marked with black spot.

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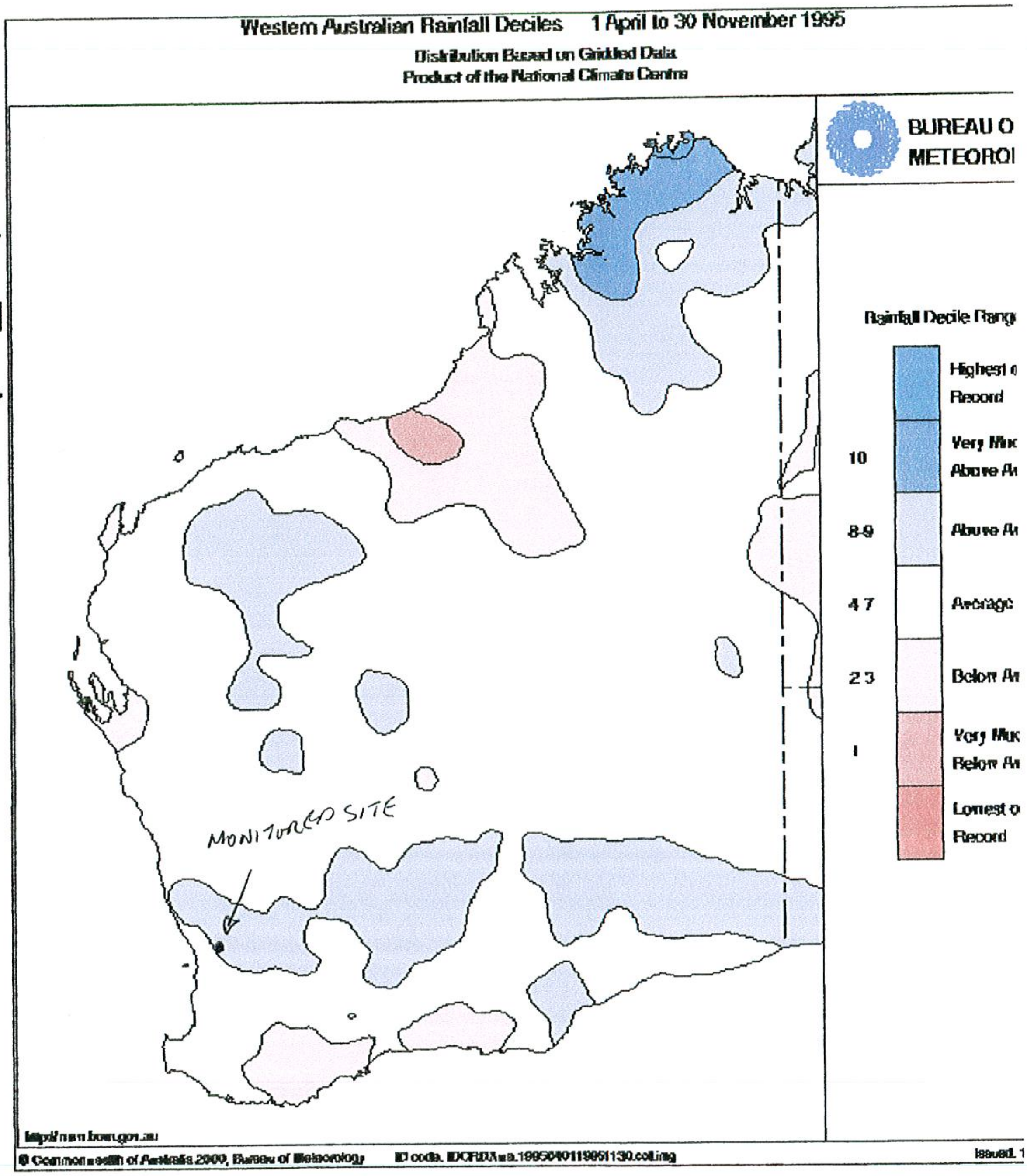

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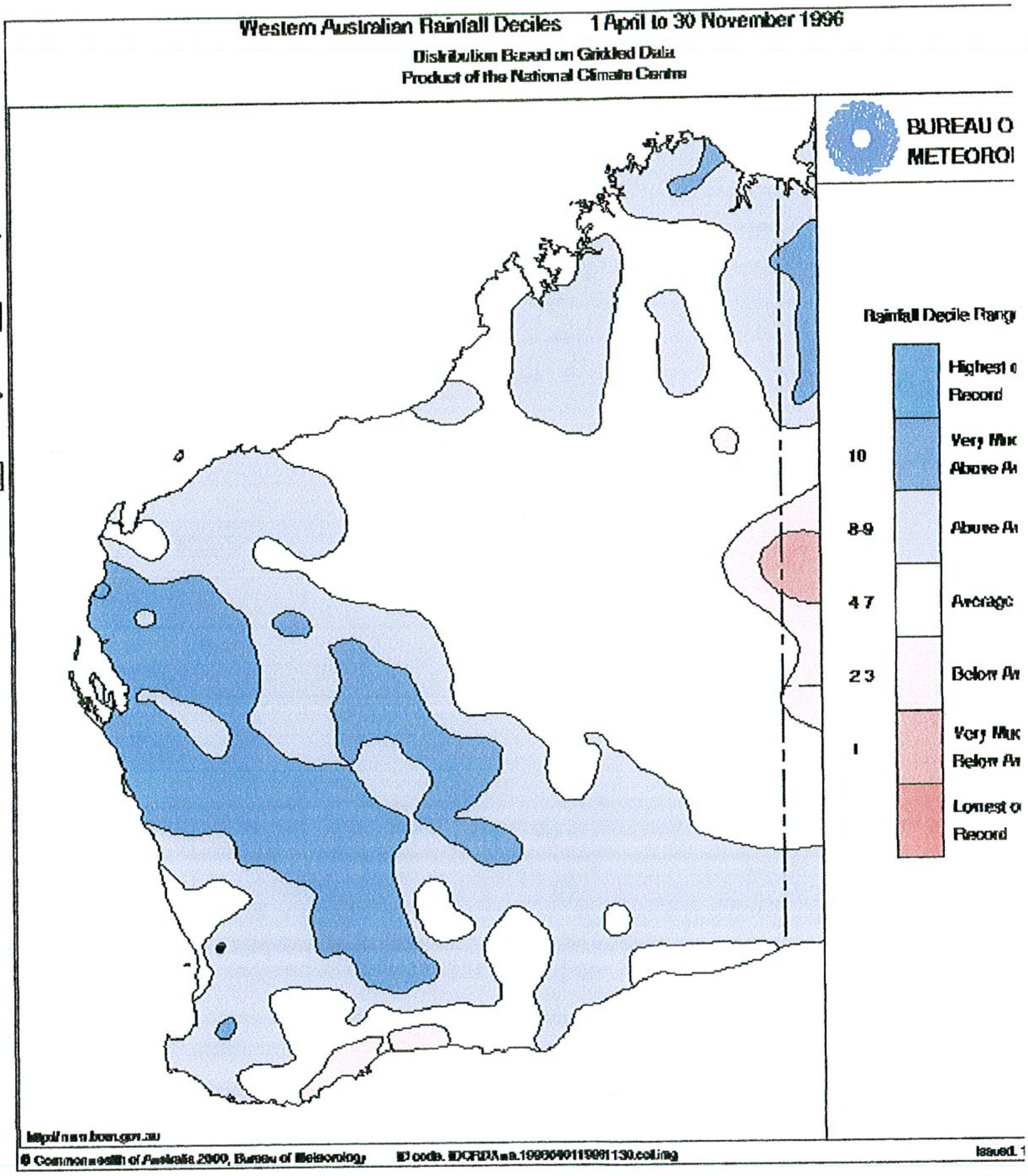

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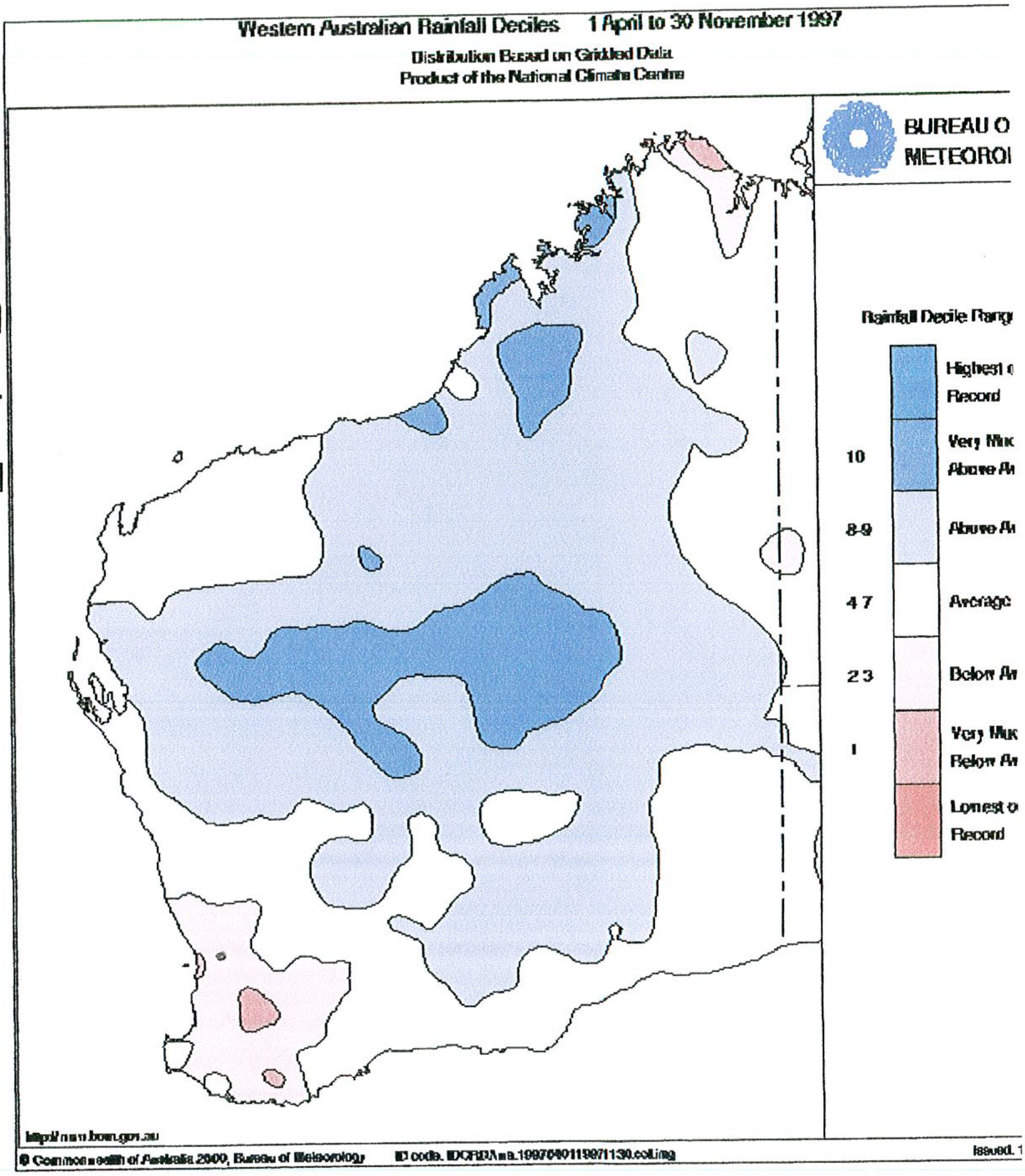

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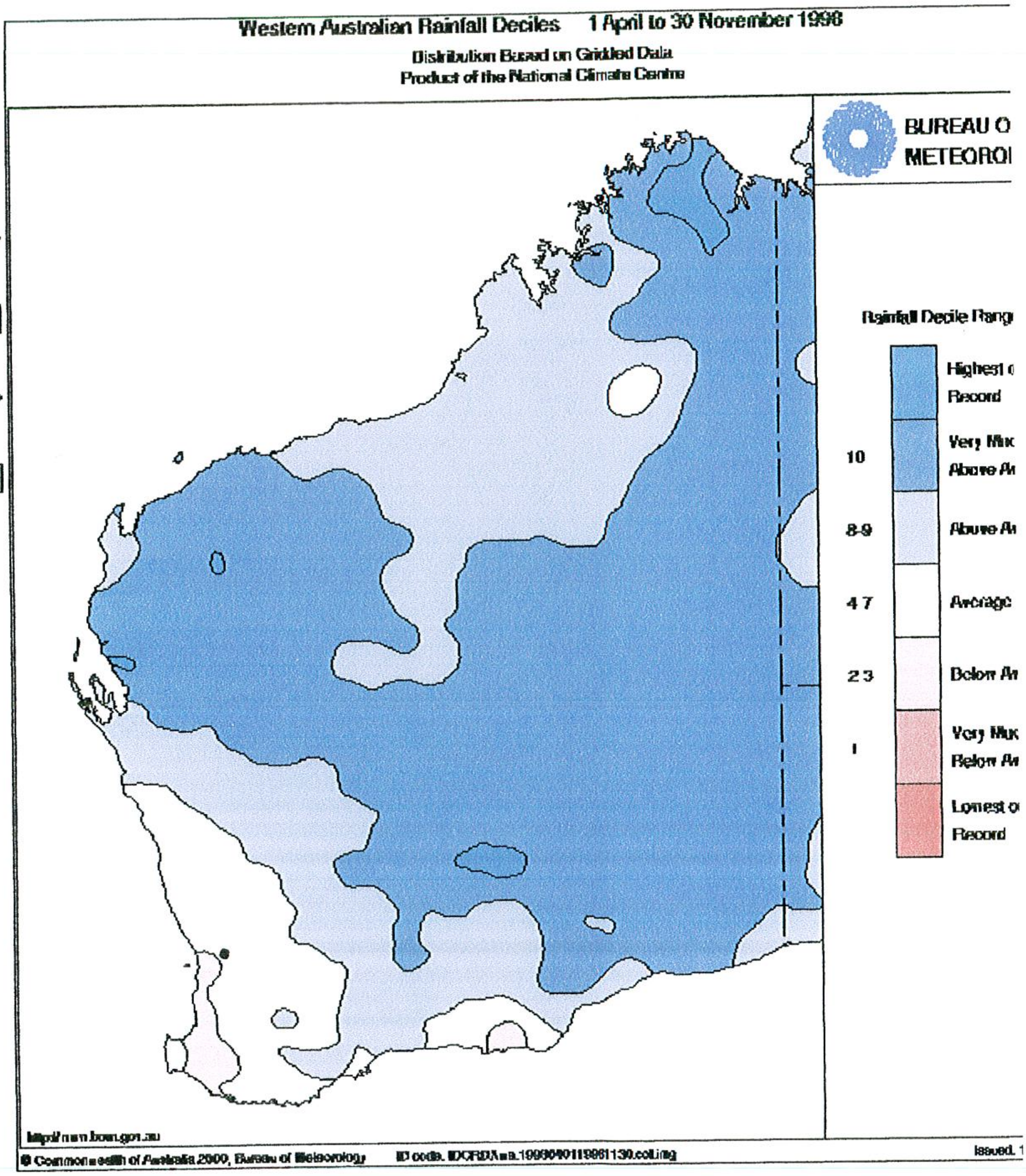

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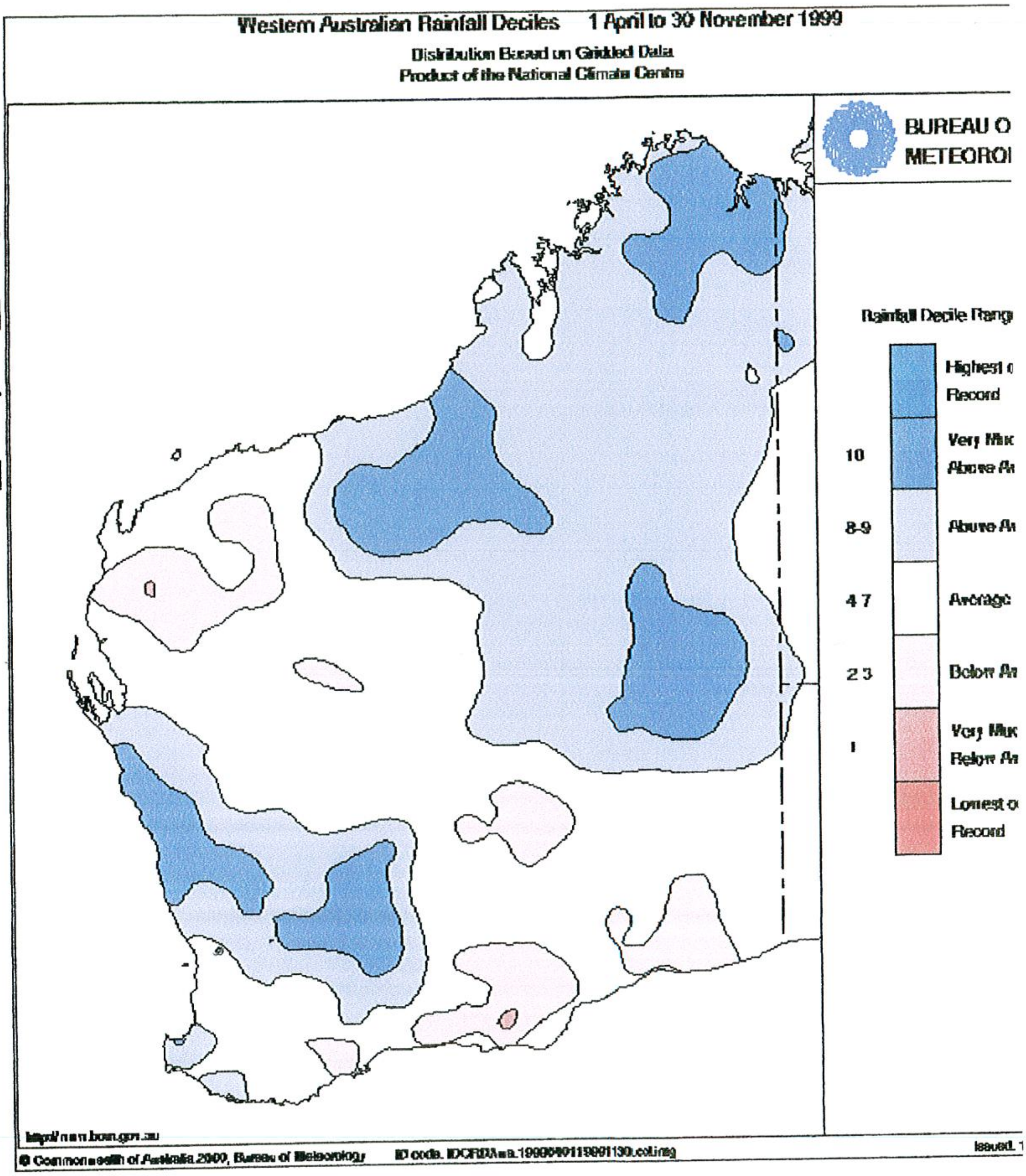

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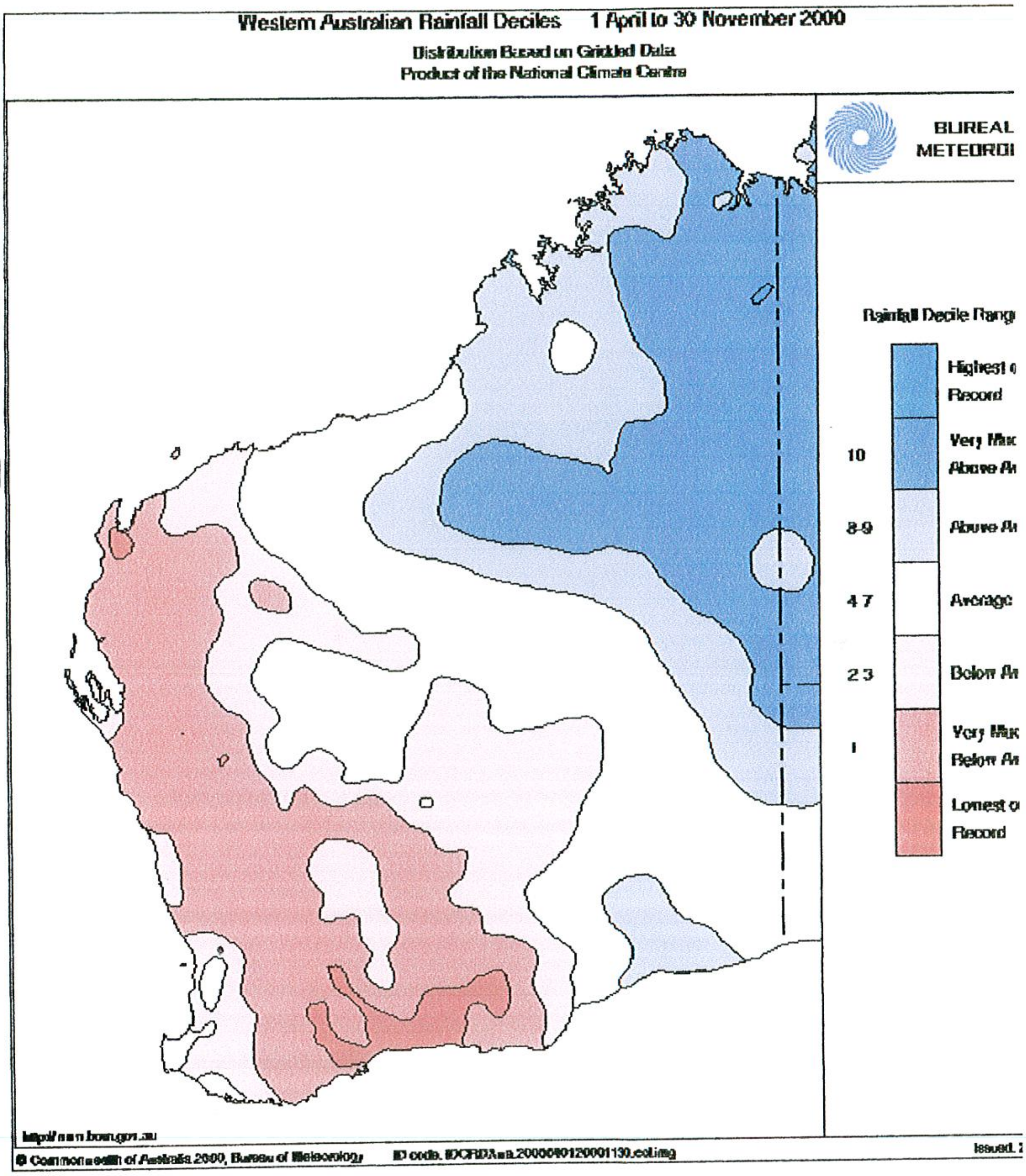

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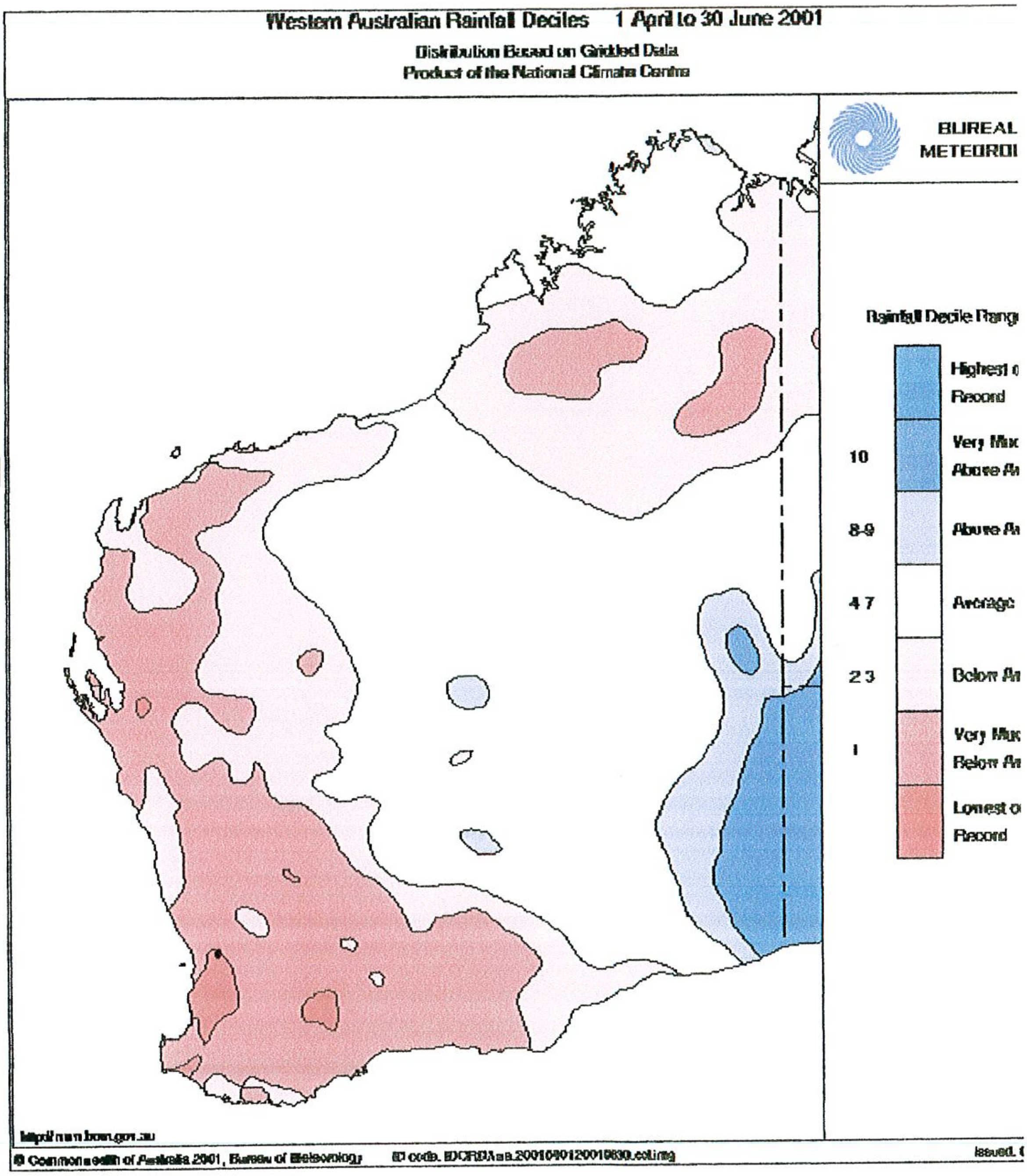
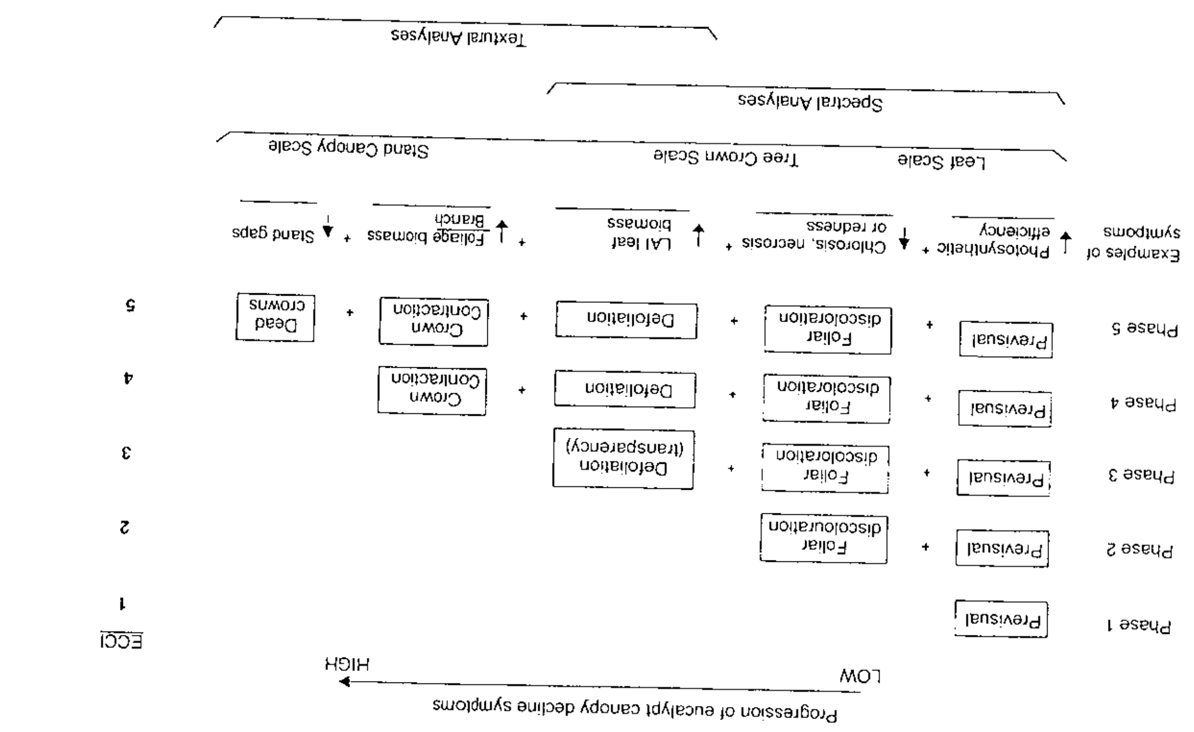


Appendix 2

Stone et al. (2000) Fig. 1, p. 28. Phases of canopy decline are a series of conditions developing from Phase 1 where symptoms are not visible to casual observation but may be visible by spectral analysis. Previsual signs of canopy decline at the Talbot Block site may be present in archival satellite telemetry. Onset of visible foliage discoloration may be very rapid in Wandoo and be very transient prior to leaf death. Phases 3, 4 and 5 are the most readily visible phases of decline. For full discussion of the ECCI see Stone et al. (2000). The ECCI system universally applies to many origins and development of canopy decline in eucalypts.

FIGURE 1. A conceptual model illustrating the structural hierarchy of the Eucalypt Canopy Condition Index (ECCI)



stances (e.g., intensity of damaging agent and initial host vigor). The actual condition of a tree is the culmination of symptoms from initial exposure to the stress-inducing agents up to the time of observation. Therefore a score of each progressive decline attribute is added together to produce an overall score that is stratified into a number of categories that we have termed the *Eucalypt Canopy Condition Index* (ECCI). The ECCI is then used as our indicator of forest health.

As an example, a eucalypt tree, with a relatively dense canopy that is damaged and discolored from psyllid feeding would have a lower ECCI score (2; previsual + foliar discoloration) than trees that have started to shed damaged leaves (3; previsual + foliar discoloration + defoliation). It is anticipated that a comparison of two average ECCIs for a particular forest stand, obtained at different times, would form the basis of a forest health surveillance program. This is similar to the approach proposed for the Forest Condition Rating system in Ontario, Canada (Mohammed et al., 1997).

A major task in the development of the ECCI is to identify the optimal combination of spectral, radiometric and spatial (scale) features from remotely sensed data that most accurately correlate with each of the five levels or phases of severity in canopy decline (Figure 1), and then to develop these features into computer-based algorithms. It is expected that different sensors and platforms may be applicable in the development of the ECCI, progressing from hyperspectral imagery at the pre-visual phase to high spatial resolution sensors to help identify dead canopy crowns (Figure 2).

How this may be achieved for each of the five key phases of eucalypt canopy decline, as identified in Figure 1, is described below.

Previsual

Early effects of stress are often manifested as previsual symptoms at the finest structural scale, for example, disruption of cellular function and organization in young leaves or in the fine root system. These responses have been detected in laboratory and near-range studies of reflectance spectra of stressed plants. Using spectral radiometers Ahern (1988), Rock et al. (1988), Carter et al. (1996) and others have demonstrated that certain regions of the reflected electro-magnetic spectrum of leaves, such as a blue shift at the inflection point between the red and near infrared (NIR) wavelengths (0.690-0.740 μm) and at the NIR shoulder and plateau (0.75-1.30 μm), are sensitive to changes