Insect Scouting Techniques: A survey of insect damage to foliage in *E. globulus* plantations in the Albany, Collie and Manjimup areas.

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Abstract

A method was designed to survey for insect damage in plantations of *Eucalyptus globulus* from establishment and throughout the plantation cycle and allow meaningful comparisons between regions, individual stands and different ages of trees.

Expanding foliage in the upper 1/3 of the canopies of 50 representative stands were rated for damage by leaf chewing arthropods and the principal chewers present recorded. Most stands had trivial (0-10%) levels of insect damage. Regional patterns in amount of leaf damage were found. A high proportion of stands in the Albany area older than 3 years experienced leaf damage by *Catasarcus* spp and *Gonipterus* sp. weevils.

Crude growth modelling of damaged and undamaged stands indicated no significant effect on height growth. The economic importance of the damage is unknown, as several factors may buffer stem wood production from the effects of apparent leaf damage.

Introduction

Early detection of potentially damaging populations of insects is essential for pest management in plantations of young *E. globulus*. Amelioration of damage by intervention with pesticides is possible for some species as damage to trees is affected by the scale of tree biomass relative to pest populations moving from relict pastures in the plantation system. Destruction of these populations allows the plantation to outgrow the effect of the pests. A second type of pest establishes populations based on immigrants from nearby remnant or plantation eucalypts and prefers the juvenile foliage of young trees. Control of this type is also possible as discontinuity in presence of preferred foliage ultimately limits populations of the pest (Abbott et al. in press).

Little is known of the effects of phytophages on growth in older plantations and observations of leaf damage are restricted to opportunistic records. To redress this, a method was designed to survey for insect damage from plantation establishment and throughout the plantation cycle and allow meaningful comparisons between regions, individual stands and different ages of trees. We report here the results of a minimum application of the survey method, interpretation of the observations and comment on limitations of the method.

Methods

Selection of stands

Fifty stands were chosen, mostly on the basis of accessibility to motor vehicle but also to provide representative coverage of a range of tree ages within the Albany area. There were no young plantations managed by CALM in the Manjimup area, so stands between 5 and 10 years old were selected there. Stands in the Collie area were confined to the property "Coolangatta" and near environs.

Stands in the Albany area were measured between 13 November and 5 December 1997, in the Collie area between 10 and 11 December 1997, and in the Manjimup area between 3 and 5 February 1998.

Sampling of trees within stands
Stratified random sampling involved *ca.* 220 trees per sampled stand. At 4 x 2 tree spacing the nominal stand size was 40m x 40m with every 5th tree and 5 trees per row, every 2nd row assessed. Allowing 25m buffers gave a minimum assessable stand size of slightly less than 1ha in square dimensions. Thirty trees were assessed per stand.

Assessment of tree crowns
Expanding and fully expanded foliage in the upper 2/3 of crowns (for trees up to 3 years old) and only expanding foliage of upper 1/3 of crowns (for trees 4 years and older) were assessed. Binoculars were used for trees 4 years and older.

Variables recorded

Location:	Latitude, longitude, elevation. Year planted. Distance from remnant eucalypts. Species of remnant eucalypts. Distance to edge of plantation.
Tree size (three trees only):	Height, DBHOB of one dominant tree in third, fifth and seventh rows of the stand.

Repeated measurements of 30 trees per plot:

A) Trees less that 4 years old.

Canopy stratification:	The top 1/3 and middle 1/3 of the canopy were examined. In each third there was a class of expanding leaves and a class of fully expanded leaves. (There may be more than one age cohort in the latter class.)
Leaf morphology classes:	Not produced Juvenile Mixed Adult Gone (by abscission or unknown causes)
Apparent damage classes:	<10% leaf area removed or damaged. 11-25% 26-50% 51-75% >75%

Visible insects or identifiable insect damage in whole canopy including:
Leafblister sawfly, Chrysomelids, Weevils, and other chewing or sapsucking insects

B) Trees 4 or more years old.

Canopy stratification:	Expanding leaves in the top 1/3 of the canopy.
Leaf morphology:	As above.

Apparent damage: As above.

Visible insects or identifiable insect damage:
Whole canopy as above.

Adequacy of visual estimates of damage
Visual estimates of damage are subjective and suffer from considerable variation between observers. To minimize this complication , a single observer was used for this data set. Acuity of observation is also subject to degradation as subject distance from the observer increases. We tried to minimise this by using a compact pair of 7 x 15-25mm zoom binoculars for observations, only assessing readily observable parts of the canopy and categorizing according to broad damage classes.

Analysis
An average damage for a stand was estimated using class midpoints to approximate the percent damage of individual trees. Differences between regions were tested by Fisher's exact test.

We used a height–age model and compared heights of damaged stands with that expected. Several existing models for growth are available: a) An empirical age-height model for expected height from Inions (1992, Table 6) with regional modifiers from Edwards and Harper (1996); b) physiologically based models that require parameters for individual stands e.g. Hingston et al. (1994), Battaglia and Sands (1997).

The independently derived height-age model using data in Inions (1992) was potentially most suitable as no site-specific parameters other than stand age were needed. The model is as follows:

$$\text{mean ht for age class} = 2.83(\text{age}) - 1.2 \text{ for age} \leq 3$$
$$\text{and ht} = \exp(3.30605 - 3.959758/(\text{age})) \text{ for age} \geq 3 \text{ and} \leq 8 \text{ years.}$$

Variation within age classes could be estimated from the relationship:

$$S = 0.92137 + 0.1416(\text{mean ht for age class}).$$

The height-age model tended to underestimate expected heights up to age 3 when compared with heights from least damaged stands. This necessitates within-age-class comparisons, for which there are too little data (*cf* Fig.3).

To overcome this a height-age model was generated from stands with <10% damage. Heteroscedasticity was controlled be using natural logarithm of height. The model was used to generate a standardized residual variation from expected height and allow comparison of residuals from damaged and undamaged stands. The model used was:

$$\ln(\text{ht}) = 2.4494 + 0.01152(\text{age}) - 3.1065(\text{age})^{-2}, \; r^2 = 0.82, \; n = 17.$$

The latter model should not be used in any other context as the sample from which it was derived was small and most of the sample was less than 4 years old while most of the damaged stands were older than 3 years. Stands less than 1 year old were excluded.

Results

Damage to leaves
Twelve of the 50 stands assessed for damage to expanding foliage in the upper 1/3 of tree crowns showed average leaf area missing greater than 25% and 5 stands showed leaf area missing greater than 50% (Table 1.). Only a single stand averaged in the 11-25% damage

class for expanding leaves. Thus, least damaged stands were in all but one case distinctly different from most damaged stands.

Table 1. Number of stands surveyed in each age and damage class.

	AVERAGE DAMAGE TO EXPANDING LEAVES			
AGE CLASS (years)	0-10%	11-25%	26-50%	>50%
0-1	5	0	0	0
1-2	5	0	1	0
2-3	6	0	0	0
3-4	4	0	1	2
4-5	4	0	3	1
>5	13	1	2	2
TOTAL	37	1	7	5

While these observations do not necessarily indicate severe damage, as chewer activity and leaf production may be seasonal and out of phase, the nearly direct relationship between amount of damage to expanding foliage and fully expanded foliage (Fig. 1) suggests that current chewer activity continued prior levels of leaf area removal relative to leaf production. It is assumed here that the principal chewers observed, *Catasarcus* spp and *Gonipterus* sp., prefer expanding foliage. That is, damage greater than about 25% leaf area loss in the upper 1/3 of the stands was chronic damage by these weevils.

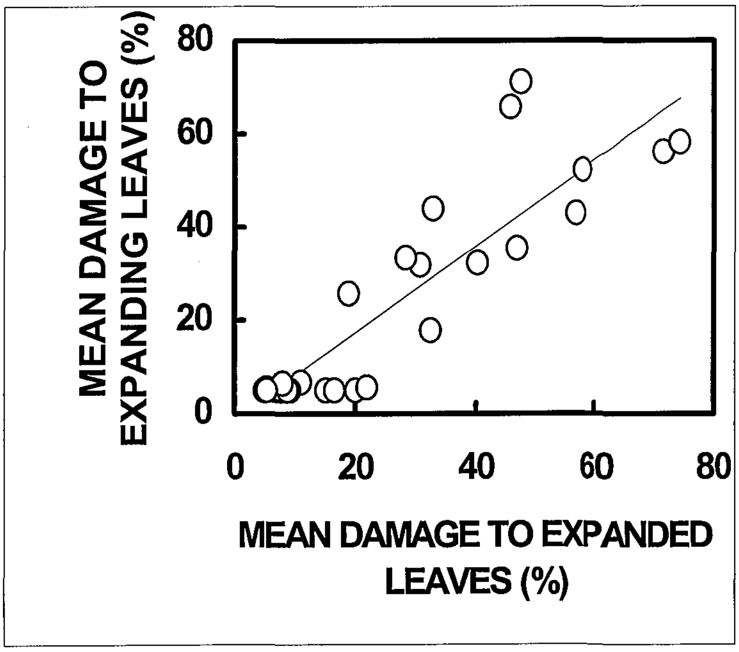

Fig. 1. Relationship between damage to expanding leaves and damage to fully expanded leaves in the upper 1/3 of stand canopies. Fitted regression: y=0.09253(x)-1.1745, r^2=0.82, n=35.

Regional variation in amount of damage

Western (west of 116°30') and eastern (east of 117°) clusters of stands were assessed for damage, and the western stands were compared with equivalent aged stands in the eastern cluster. While small sample sizes preclude sophisticated analysis, it is clear that for older

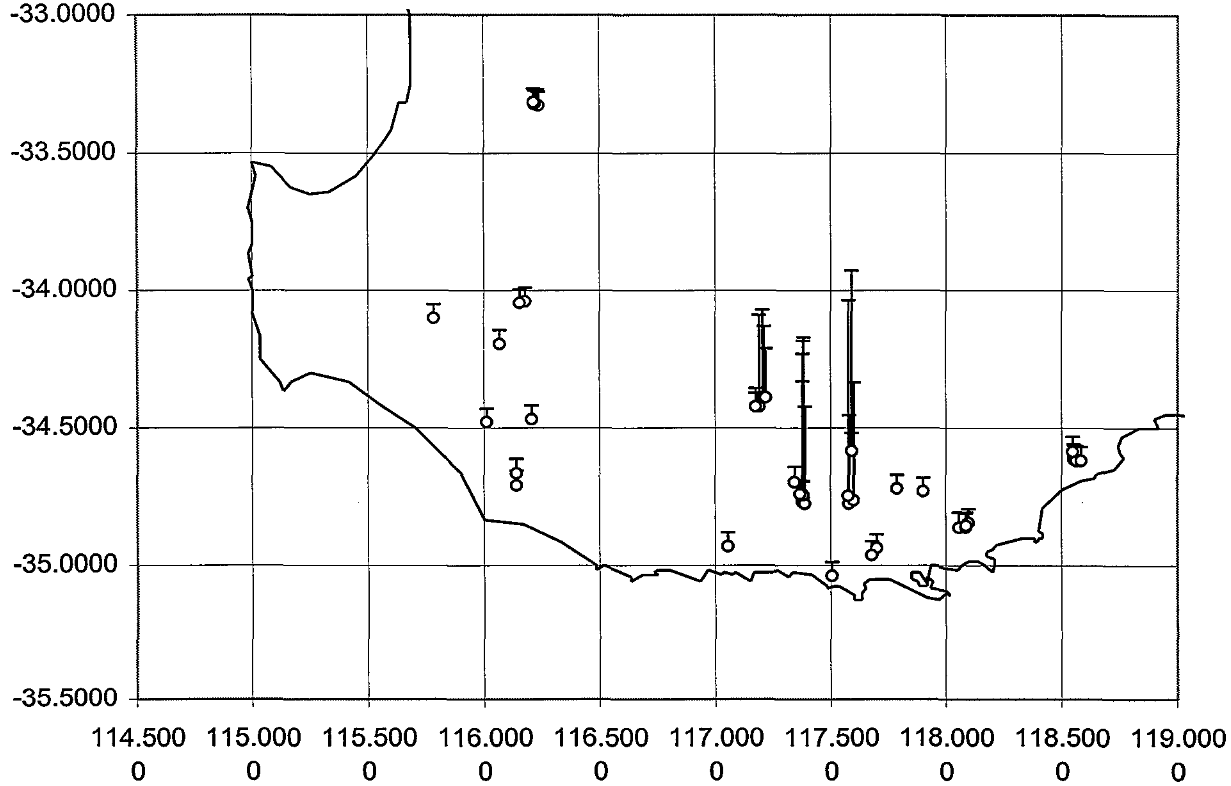

Fig. 2. E. globulus stands in southwest Western Australia surveyed for insect damage to foliage. Bars above each location indicate amount of damage to expanding leaves in upper 1/3 of canopy. Shortest bars indicate average of 5% leaf area missing.

stands (>5 years old), stands with more than 10% leaf area missing were significantly ($P<0.05$, Fisher's Exact test) more likely to be encountered in the eastern part of the area sampled (Fig. 2).

The sample, and Fig. 2 in particular, should not be regarded as representative of regional distribution of damage in plantations less than 3 years old. Some plantations in the Albany area <3 years old and not under CALM administration were known to be heavily infested with leafblister sawfly, though none of the stands assessed for this study were infested. Heavy infestations of leafblister sawfly on young plantations carrying foliage of juvenile morphology have been noted in the past in the Augusta area on plantations administered by Bunnings, though these plantations have now grown to support well developed canopies of adult morphology.

Effect of leaf damage on stem growth
Height growth was not affected by the amount of damage to the upper 1/3 of stand canopies (Fig. 3). The relationship between stem height and diameter at breast height for individual trees was not significantly affected by >10% leaf damage to expanding leaves within stands. Thus, leaf damage in the upper 1/3 of canopies appeared to have no effect on either height or diameter growth. It must be emphasized here that the dimensions of three trees per stand may not adequately measure stand performance.

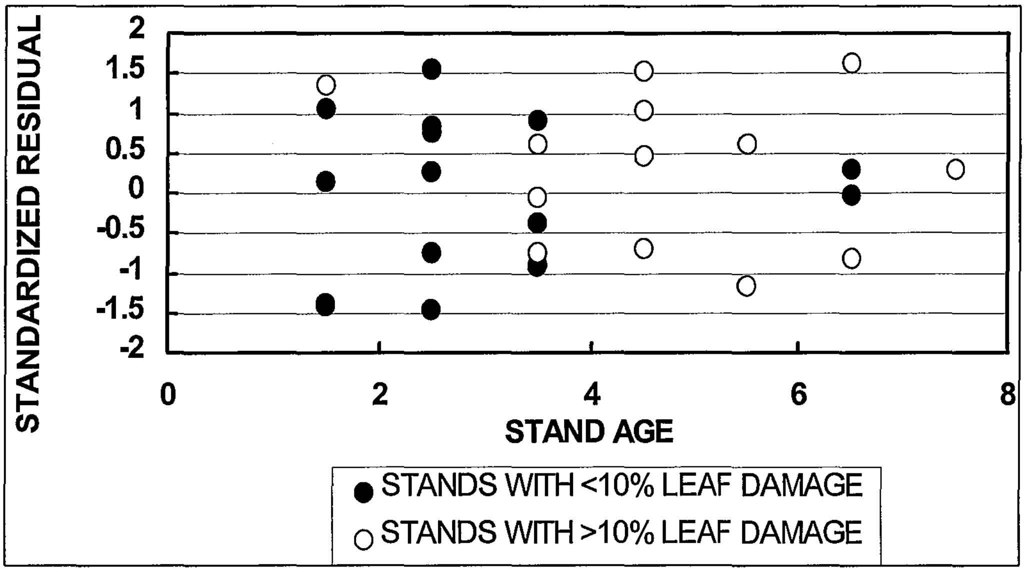

Fig. 3. Standardized residuals from fitted Age-Height model for stands with least damaged and damaged leaves. Residual heights for damaged stands all fall within 2 standard deviations of expected height.

Discussion

Populations of *Gonipterus scutellatus* are known to develop on both juvenile and adult foliage of *E. globulus*, although the species is not a preferred host in mixed species stands in Tasmania (Clarke *et al.* 1998). Host preferences for *Catasarcus* spp. are unknown but the genus is widespread and endemic in southern Western Australia on many eucalypt species. *Catasarcus* sp. damage on *E. globulus* foliage is known from the Esperance area. *E. globulus* plantations may provide a preferred food source for *Gonipterus* sp. and *Catasarcus* spp in the context of nearby remnant native eucalypts in Western Australia.

The key question arising from the observed amounts of damage in the stands sampled is whether the damage is of economic importance. We attempted to answer this in general terms by comparing damaged and relatively undamaged stands for variation from an expected measure of height growth. On the whole, residuals for stands with damaged leaves were not significantly different from the null model (Fig. 3).

Despite the arguable deficiencies of this analysis (in relation to the small sample, crudeness of the model and poorly stratified division of the sample to model expected growth), there are good reasons to expect between-stand variation in height growth to be relatively insensitive to insect damage.

1) Relationships between Leaf Area Index (LAI) and Canopy Net Production (CNP).

   Modelled changes in CNP are much more sensitive to between-site differences in conditions (temperature and water stress) than changes in LAI about the LAI at which maximum CNP is achieved for a particular site (Battaglia et al. 1998, Fig. 4 therein). Indeed, reduction in LAI in some circumstances may result in an increase in CNP according to the model of these authors. Stand LAI needs to fall below 3 or 4 (depending on site conditions) for CNP to become increasingly sensitive to change in LAI. LAI of around 3 or greater appears to be usual for plantations older than 3 years in southwest Western Australia (Hingston *et al.* 1994).

2) Relationship between damage and LAI.

   There is not a direct relationship between leaf area removal by chewing and changes in LAI. The apparent amount of damage results from the difference between leaf area removal and leaf area production. Apparent damage may be small despite a large rate of leaf removal if rates of leaf production are also great (Landsberg and Cork 1997, Fig. 14.5 therein). In terms of whole canopies, extended retention of older (less palatable) leaves may compensate for loss of new foliage and buffer, to some extent, the effect of leaf chewing on LAI. The plasticity of leaf senescence is not well understood for *E. globulus*, although Battaglia et al. (1998) indicated possible responses in leaf longevity to water stress and temperature.

3) Sensitivity of height growth to reduction in CNP.

   Plants have the potential to respond to reductions in CNP by altering internal patterns of carbon allocation. Plants can maintain stem extension growth in preference to diameter growth when competition from light is important. Varanjic and Ash (1997) found production of below ground woody tissue of seedlings to be more sensitive to sapsucking scale insects than production of stem tissue. Remobilization of stored carbon is also possible. In brief, stem extension growth may be buffered from the effects of changes in CNP by changes in carbon allocation.

4) Adequacy of stem height growth as a proxy measure of economic productivity.

   Effects of phytophagy on tree form are well known and the effect of chewing on stem growth may be confounded by effect of phytophagy on tree form. Total woody biomass production may be little affected, though the economic value of sawn recoveries of wood is sensitive to stem form and branching. Because *E. globulus* plantations are intended for woodchip production stem height should be an adequate measure.

Considering these factors together, the economic effect of the observed insect damage remains unknown, although none is evident from the measurements gathered in this survey. Single defoliation events in plantations less than 3 years old involving removal of at least

50% of foliage may result in significantly smaller heights for 6 months or more (Abbott and Wills 1996). The effects of repeated removal of foliage are more severe than single defoliation events. However, in the closed canopies of older plantations it may be that the most severe damage needs to be sustained for several years (to overcome the buffering processes outlined in points 1-3) before growth is measurably affected. If attrition of LAI of stands is occurring at high levels of apparent leaf damage then some measurable effect on growth should develop if LAI decreases to about 2. Despite the limited usefulness of visual estimates of leaf damage in older canopies for providing direct information on economic effects, the method does provide early warning of possible economic damage.

Conclusions

The insect scouting technique used here has good potential to identify regional patterns in insect damage using relatively unskilled observers and collecting a limited set of observations.

Weevil damage appears to be characteristic of an area of plantations to the northwest of Albany and appears to be chronic and long term in duration. The damage may appear early in the plantation cycle and would probably recur despite initial control by application of insecticide.

In consideration of whether the damage observed is of economic consequence the following needs to be answered: Are the amounts of damage observed reducing or likely to reduce in future the canopy LAI to the extent that stem wood production is affected? To address this question, estimates of leaf damage need to be taken in the context of stand LAI measurements.

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