Insects and Tuart health: An outline of potential threats.

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Abstract
A convenient method of defining Tuart ecosystem health is to use the health of Tuart as an indicator of ecosystem health. While this is perhaps a narrow indicator, it allows a focussed discussion of insects as threats to Tuart health in the context of broader models of ecosystem functioning.

While many species inflict damage on Tuart, few insect species could be considered as direct threats to Tuart health. These species include: Tuart bud weevil *Haplonyx tibialis*, which damages flower buds and poses a potential threat to canopy seed pools; pasture derived leaf feeders which damage young Tuart in early regeneration or afforestation plantings; and stem girdling wood and cambium feeders.

Tuart leaf area can be considered as an equilibrium between leaf area production and leaf area loss. During Tuart decline new leaf production diminishes and defoliating processes become important. The characteristics of cerambycid stem borers can result in a contribution by this group of insects to defoliation.

The difficulties of separating damaging insects from those which threaten Tuart health is explored by detailing the principle wood/cambium feeders found at Yalgorup during the Tuart decline event.

P. acanthocera. Borer of large stems and tree trunks. Rarely causes defoliation. Symptoms of stem boring more visible in stressed trees?
Bimia sp. A rarely collected branch borer common at Yalgorup. Rarely causes defoliation.
P impavida. Borer of saplings and branches. Probably contributes to net leaf area loss when new leaf production rate is slow.
P. semipunctata. Stress opportunist: preferentially attacks stressed and felled *Eucalyptus spp*. Variation in both susceptibility and attractiveness of stressed hosts. Little evidence of mass attack by *P. semipunctata* at Yalgorup.

There is an undefined role played by the Tuart longicorn *Phoracantha impavida* as a stem girdler in canopies under environmental stress such as has occurred at Yalgorup. Definition of the role of *P. impavida* in Tuart decline requires suitably replicated population studies and definition of interaction between tree vigor and feeding damage.

Introduction
Before elaborating on those insects that are potentially threatening to Tuart health it is worthwhile considering what is meant by threats to Tuart health. A convenient method of defining Tuart ecosystem health is to use the health of Tuart as an indicator of ecosystem health. While this is perhaps a narrow indicator, it allows focussed discussion of insects as threats to Tuart health in the context of broader models of ecosystem functioning.

For this presentation I am regarding threats within vegetation systems that contain Tuart as those deriving from threats to the persistence of Tuart within those systems. This allows definition of threat at 3 levels: At a generalized level, identifying from reports and collections those insect species that are found on Tuart and which might be pests. In more detail, identifying species that are damaging to Tuart according to reports of damage. At the most specific level examining whether there are contexts in which these damaging species are a threat to the persistence of Tuart. This 3 tiered examination will be used to describe a suite of wood and cambium feeding insects present in the Yalgorup Tuart decline event.

Insects found on Tuart

One way of defining potential threats is to look at the suite of insect species that feed on Tuart. The information for such an examination is contained in insect collections held at the W.A. Department of Agriculture and CALM. These collections are electronically databased, and it is anticipated that the CALM collection will soon become internet accessible, as is already the WADA collection.

It is possible to classify the insects recorded as being found on Tuart by the type of tissue on which they feed. A superficial examination of Table 1 indicates a numerical importance of wood or cambium feeders. However, these numbers reflect the historical importance of economic damage to timber in regard to the collection priorities. They also reflect the difficulties of canopy sampling for leaf chewer species. There are likely to be many tens of leaf chewing species that remain uncollected. (Majer *et al.* 1994, Abbott and Wills 2000).

Reports of damage and threat to Tuart health

A further source of information about potential threats to Tuart health are reports of damage. Few primary accounts are available which identify damaging agents and extent of damage (Newman and Clarke 1924, Keene and Cracknell 1972, Fox and Curry 1980). Those reports that exist report 3 groups of insects whose feeding extends beyond usual damage (Table 2).

The earliest reports were damage to flower buds by the Tuart bud weevil *Haplonyx tibialis* (Newman and Clark 1924, Jenkins 1972). Female weevils lay single eggs on each of the buds in developing inflorescences then chew through the twig carrying the buds so that it falls to the ground, thus preventing the full development of flowers and seed within the canopy.

This species is not a direct threat to Tuart health. However, in the context of wildfire that results in the death of mature trees, or use of fire to initiate a regeneration cohortof seedlings, shortage of seed in the canopy as a result of weevil activity could affect population densities of regenerating seedlings.

A second type of damage is that done to seedlings and saplings by pasture derived leaf feeders (Keene and Cracknell 1972, Fox and Curry 1980). Silviculturalists familiar with tree planting in old pastures, or into situations where there are existing populations of leaf-feeders, would have encountered this problem to some extent.

A third type of damage is stem girdling in mature trees by wood and cambium feeders. Larvae of stem girdlers ringbark branches, which prevents movement of sugars and essential solutes via the phloem (part of the living tissue of bark), leading to the death of affected branches.

How does damage by stem girdlers translate to a threat to Tuart health? To answer this it is useful to look at some sort of integrating model including insects and other processes affecting Tuart health.

Tuart leaf area in such a model (Fig. 1) could be regarded as in equilibrium between new leaf area production and leaf area loss. There is also a feedback loop between tree leaf area, tree photosynthetic capacity and new leaf area via carbohydrate partitioning. The feedback loop acts as an amplifier of effects on leaf area, and it is more sensitive to those factors limiting photosynthetic capacity such as soil water and nutrient availability.

Effects of leaf area loss due to insects are usually buffered because there is a luxury of leaf area so that leaf area itself doesn't limit photosynthetic capacity across annual time scales. Leaf area loss becomes important when environment limits such as soil water and nutrient availability increase in effect to the detriment of leaf area production. The relative effects of leaf area loss become greater and are in turn amplified by the feedback loop if there is no relief from environmental limits.

Do stem borers contribute to defoliation of Tuart?

How does this model translate to real insects and a real decline in Tuart health? The problem is to differentiate physical damage from contribution to decline. For example, damage by the Bullseye Borer *Phoracantha acanthocera* is cryptic on living trees (Fig. 2) but the bark can be taken off dead trees to reveal characteristic horizontal and vertical phases of gallery excavation and areas of excavation around bullseye pupal chambers. This species is found on nearly all mature Tuarts at Yalgorup, but damage is not likely to be a major contribution to foliage loss.

A second species common at Yalgorup is the undescribed *Bimia sp.*. L.J. Newman, the Government Entomologist 1918-38, noted this species on Tuart (Newman 1922) but did not define its pest status. The cogeneric *Bimia femoralis* was noted in French's Handbook of the Destructive Insects of Victoria (French 1909), again without specifying extent of damage.

In the field, damage is characterized by circular feeding areas which reach the surface of bark and which have a central gallery connecting to a gallery along the interior of the branch (Fig. 3.). By dissecting a Tuart branch it was possible to recover the orange, elongated larvae of this species and identify them to an unidentified species of *Bimia* (Duffy 1963). The course of feeding was traced within the branch and a series of cambium feeding areas are connected by a gallery running along the interior of the branch, apparently within heartwood. The small extent of the cambium feeding area relative to branch diameter (Fig. 4.), denoted here by a broken line within the solid outline indicates *Bimia sp.* probably doesn't cause branch girdling. The feeding areas appear to be confined to branches and stems containing heartwood.

Phoracantha impavida is known to be capable of stem girdling and possibly contributing to the decline of Tuart canopies (Fox and Curry 1980). Damage by this species on Tuart is characterized in part by presence of pupation chambers along with a paired false chamber within the feeding area (Fig.5.). This is not a unique identifier and other species within the range of Tuart may have similarly paired chambers.

Feeding areas are typically large relative to branch diameter. Stems and branches up to 15cm diameter can be girdled when there is a coalescence of feeding areas. There is variable effect between trees and some trees with large populations of this borer exhibit little apparent girdling of branches.

Damage by *Phoracantha semipunctata* is reasonably common at Yalgorup. This species feeds on dead wood and is sensitive to the moisture content of wood and bark. Overseas, *P. semipunctata* can kill drought stressed trees (Paine *et al.* 1985), but it is not a cause of death in trees at Yalgorup. Instances of *P. semipunctata* damage at Yalogrup usually precede the decline event and are associated with other unrelated events. In the case shown (Fig. 6), feeding has taken place on an area of stem killed by fire more than a decade previously (marked by the dotted lines in Fig. 6). There are other instances at Yalgorup of this species exploiting fire killed trees and green fallen branches unrelated to the decline event. Interestingly, this species hasn't exploited the large amount of dead material available following the decline event, because the material is either unattractive or unsuitable for their development.

The four common species of wood feeding longicorn beetles present at Yalgorup that are easily identified by their larval damage can be classified into 3 groups (Table3). One way is to divide them between living wood feeders and dead wood feeders. *P. semipunctata* falls into the dead wood feeder category. Other species such as *Phoracantha recurva*, from the northern range of Tuart, and *Coptocercus rubipes* also fall into this category.

Living-tree feeders, such as *Bimia sp.* and *P. acanthocera* might show increased expression of symptoms of their damage but contribute little to loss of foliage in Tuart canopies as they are associated with large branches and stems.

Amongst the living tree feeders it is *P. impavida* that is of interest in the Tuart decline event at Yalgorup. The relationship between Tuart decline and *P. impavida* populations is unclear at present although a series of hypotheses can be articulated.

Population fluctuation hypothesis: This hypothesis proposes two things. Damage to Tuart has increased due to increased populations of *P. impavida*. Populations have increased because natural limiting processes such as predators and parasitoids have diminished (Longman and Keighery 2002).

Damage and tree vigor hypothesis: *P. impavida* populations fluctuate independently of tree vigor. The effect of damage increases as Tuart vigor declines because cambium growth is less vigorous and the mechanical effects of *P. impavida* feeding are greater. In particular, there is hypothesized to be an increased incidence of branch and stem death by girdling or structural failure of branches in less vigorous trees.

P. impavida population and drought stress hypothesis: *P. impavida* populations and consequent damage increase as drought stress increases. There is much evidence from studies of *P. semipunctata* that bark conditions greatly affect survival rates of larvae (Hanks *et al.* 1999). Trees subject to water stress have decreased bark moisture content and increased concentrations of soluble sugars in the bark (Caldeira *et al.* 2002). Survivorship of *P. semipunctata* larvae in stressed trees is inversely correlated with bark moisture content. It is not unreasonable to speculate that stress induced changes to bark qualities might affect all bark feeding cerambycids, including *P. impavida.*

There are constraints to testing these hypotheses due to difficulties in resolving populations of *P. impavida* larvae in the field. *P. impavida* is found high in tree canopies, is not readily visible from its damage and damage is variable in expression between trees. Suitable equipment is required for safe access and replicated observations.

A second area of difficulty relates to differentiation of effects of borer damage from effects of other organisms that may be active in and responsive to declining canopies (Stukeley, these proceedings). In the short term, borer effects might be coincident with, and difficult to distinguish from, symptoms common to most declining eucalypt canopies. In the longer term, the feeding sites of each of the cerambycid species discussed here might provide access for fungal infections. In Karri, Farr *et al.* (2000) found significant associations between insect galleries and incipient rot in timber billet faces, although presence of rot and insect galleries were apparently not mutually dependent.

Conclusions

In conclusion it is possible to say that general knowledge of the roles of insects in Tuart health exists in the form of collections and written form. While the suite of potential pest species is broad, 3 types of pest species have been noted to constitute a threat to Tuart health:

- There exists a potential threat to the canopy seed pool by the Tuart bud weevil *Haplonyx tibialis.* This is important in the context of regeneration after wildfire or use of fire to promote seedling regeneration.
- There is a threat to young or regenerating Tuarts by pasture derived leaf feeders. This threat exists in regeneration of old pastures or areas with poor weed control.
- There is an undefined role played by the Tuart longicorn *Phoracantha impavida* as a stem girdler in canopies under environmental stress such as has occurred at Yalgorup. Definition of the role of *P. impavida* in Tuart decline requires suitably replicated population studies and definition of interaction between tree vigor and feeding damage.

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Table 1. Numbers of species in feeding guilds of potential pests of Tuart based on Abbott (1985) and additional reports and observations.

Consumer group	Number of species
Wood or cambium feeders	19
Leaf chewers	11+
Sapsuckers	4+
Flower or bud feeders	1

Table 2. Published reports of damage

Source	Damage	Species
Newman and Clark (1924)	Damage to flower buds	*Haplonyx tibialis*
Fox and Curry (1980)	Stem girdling by wood/cambium feeders	*Phoracantha impavida* *Cryptophasa unipunctata* *Culama sp.*
Fox and Curry (1980)	Damage to young trees or foliage	Pasture derived species: grasshoppers and geometrid loopers. Native leafminer: *Nepticula sp.*

Table 3. Types of host-insect interaction among Cerambycidae feeding on Tuart..

Indications	Dying and dead tree feeders	Living tree feeders	
Host selection	Adult beetles attracted to dying and dead stems.	Populations normally present on at least some to most trees in mature or multi-aged stands.	
Extent of damage	Extensive damage always in dying or dead trees or stems.	Damage normally slight or without consequence to overall tree health.	
Effect of damage	Death of trees and stems related primarily to environmental stress.	Effect of damage increases as tree vigor declines. Increased incidence of branch and stem death by girdling or structural failure in less vigorous trees?	Visual symptoms of damage may increase as tree vigor declines but damage rarely contributes to change in tree health at the time scale of annual growth cycle.
Example species from Tuart	*Coptocercus rubipes* *Phoracantha semipunctata* *Phoracantha recurva*	*Phoracantha impavida*	*Bimia sp.* *Phoracantha acanthocera*

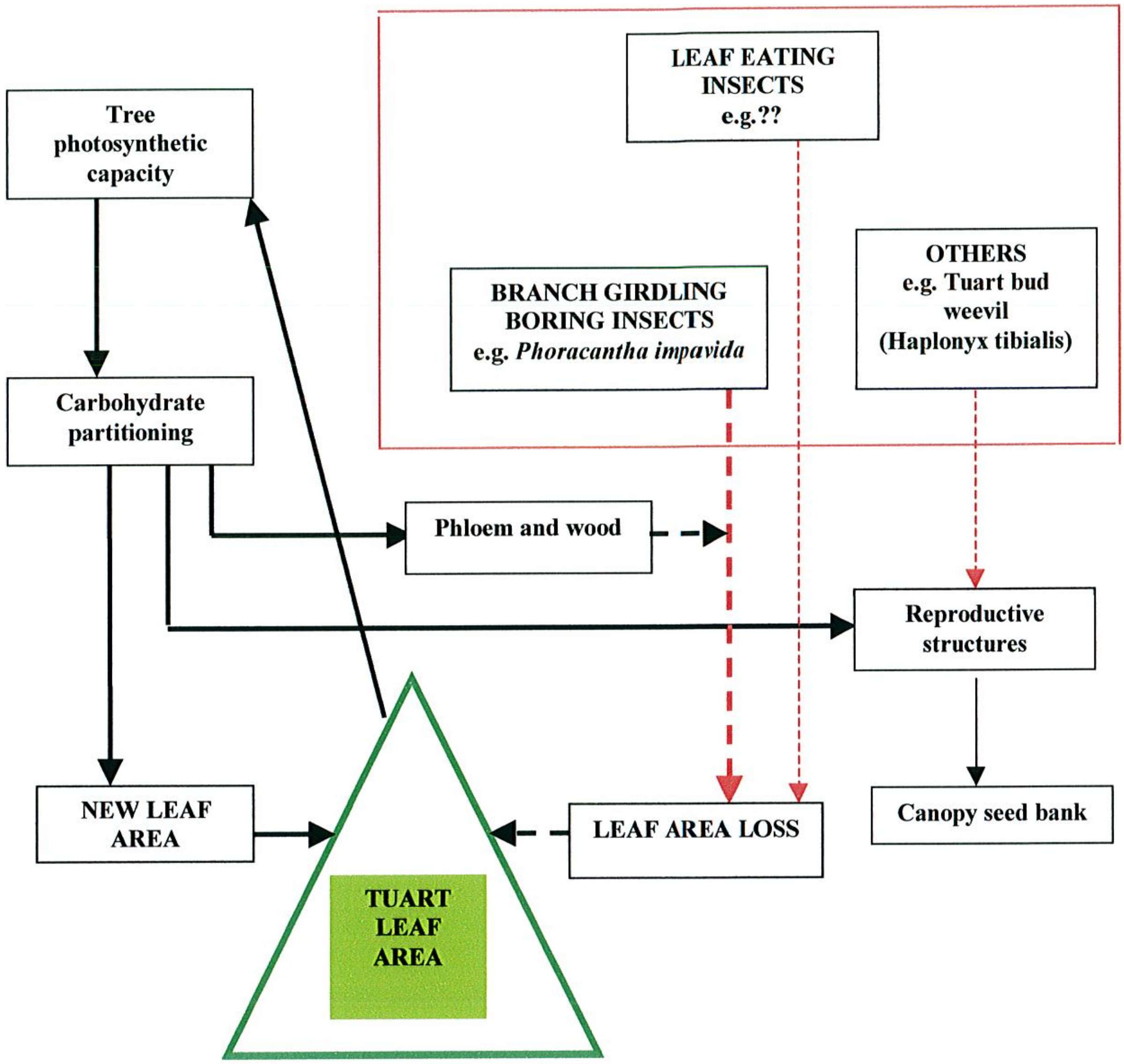

Fig.1. Schematic representation of effects of insect populations on Tuart health via their effects (dotted lines) on components of tree biomass. Environmental variables (soil water and/or nutrient availability) have primary effects on tree photosynthetic capacity and new leaf area production, while insects affect leaf area by contributing to leaf area loss.

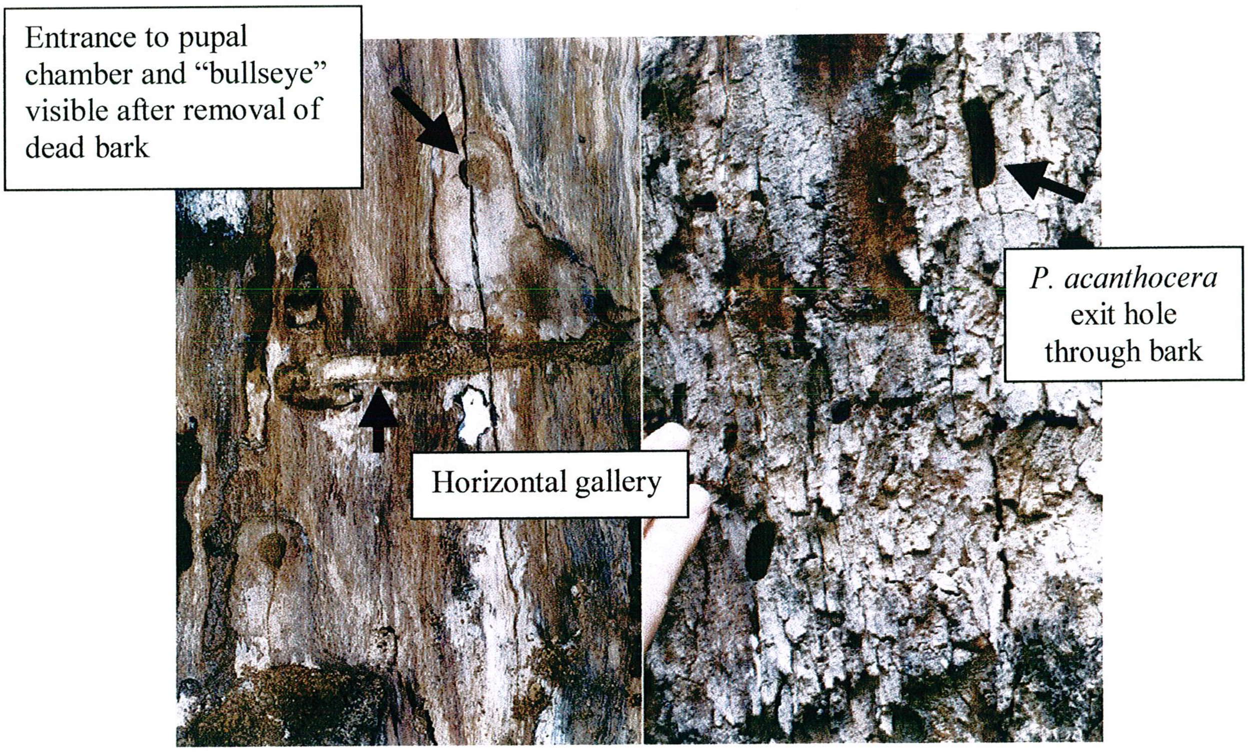

Figure 2. *P. acanthocera* exit holes in bark of dead Tuart (right photograph). The same are after removal of bark showing underlying galleries, "bullseyes' and openings to pupal chambers (left photograph).

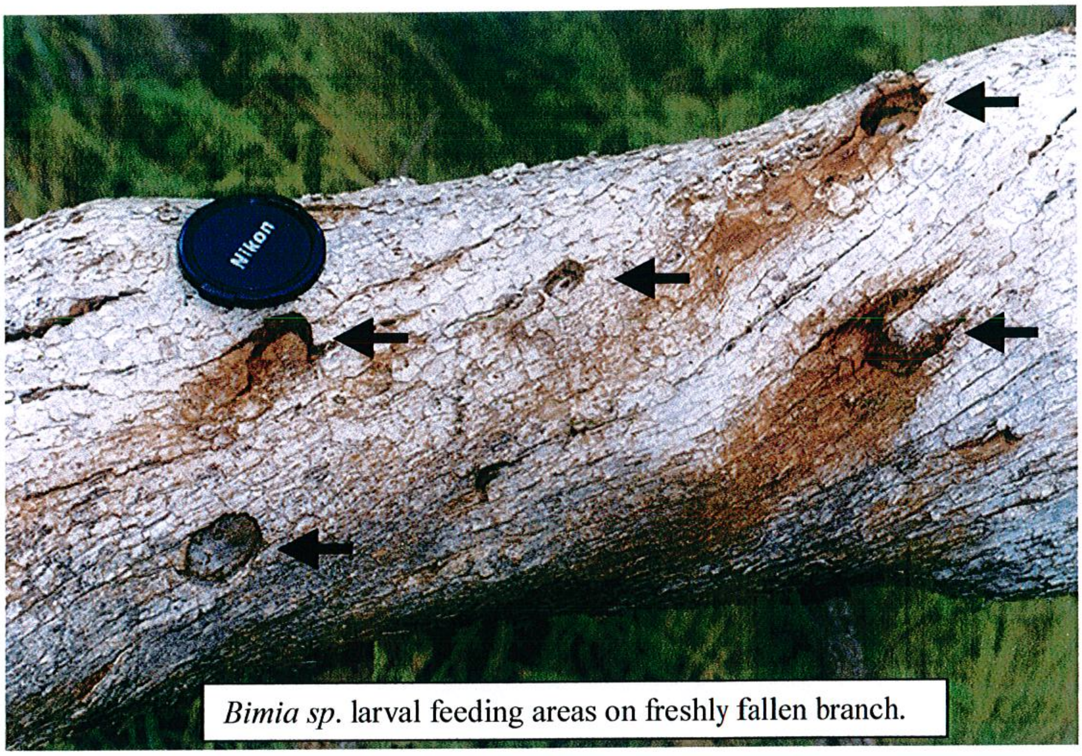

Figure 3. Cluster of *Bimia sp.* larval feeding areas on a recently fallen branch.

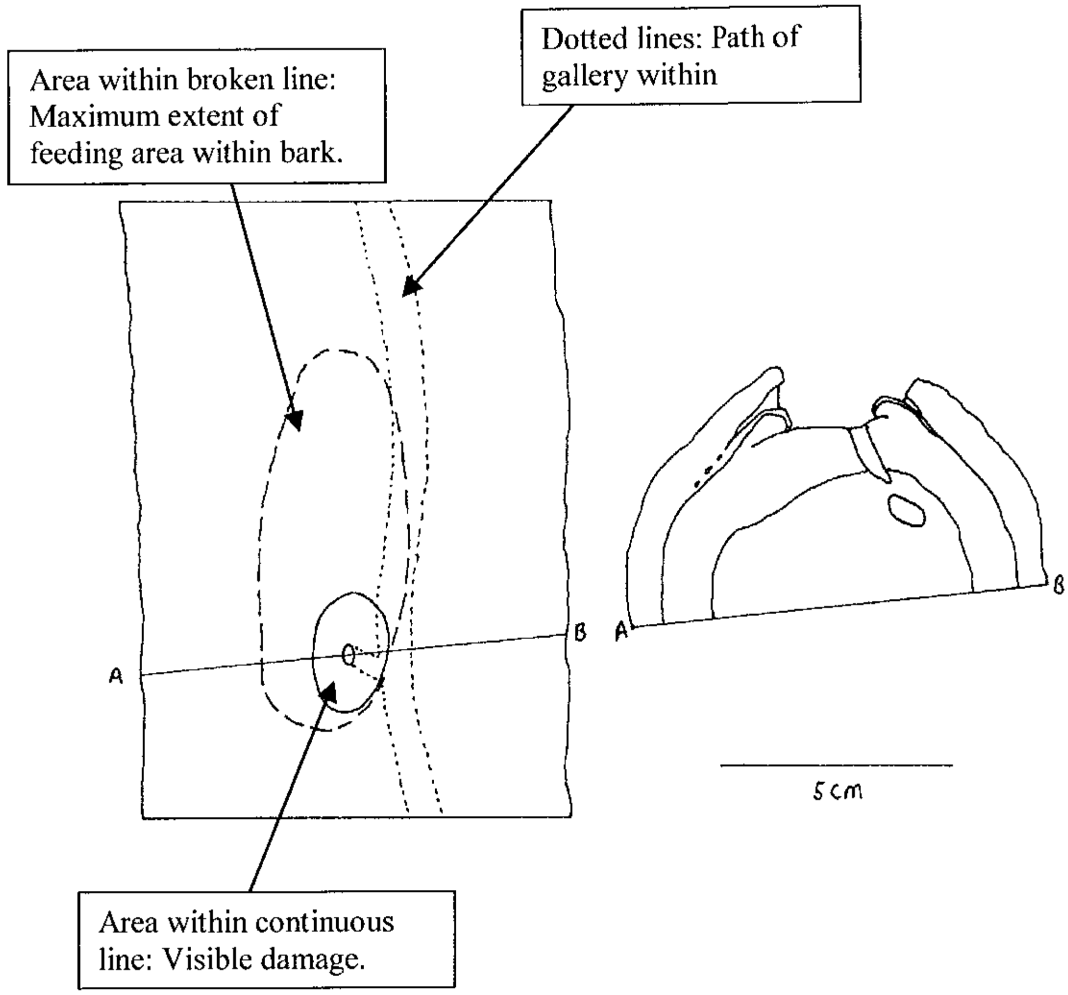

Figure 4. Drawing of stem of Tuart showing surface and interior feeding areas of *Bimia sp.*

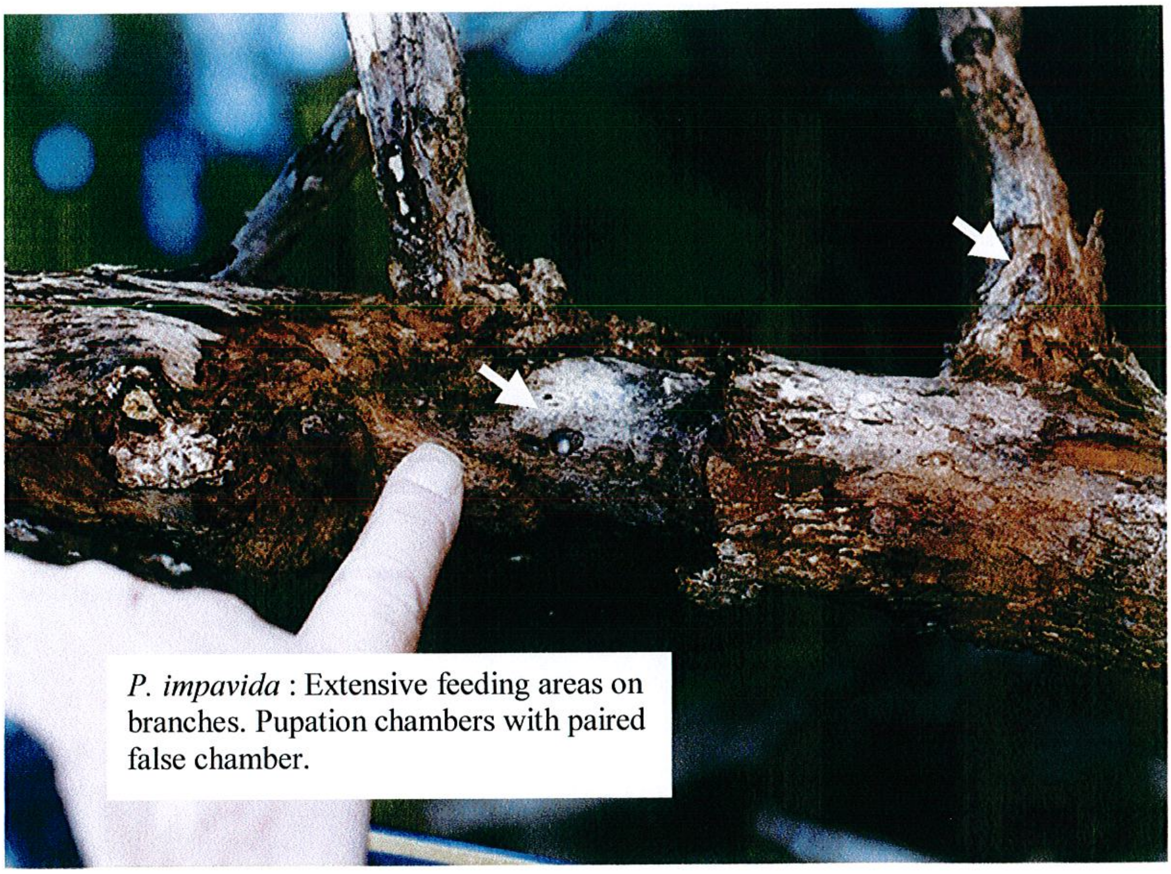

Figure 5. Feeding area of *P. impavida.*

Figure 6. Scorch scar on Tuart bole. *P. semipunctata* galleries cover the area killed by heat within the dotted line.