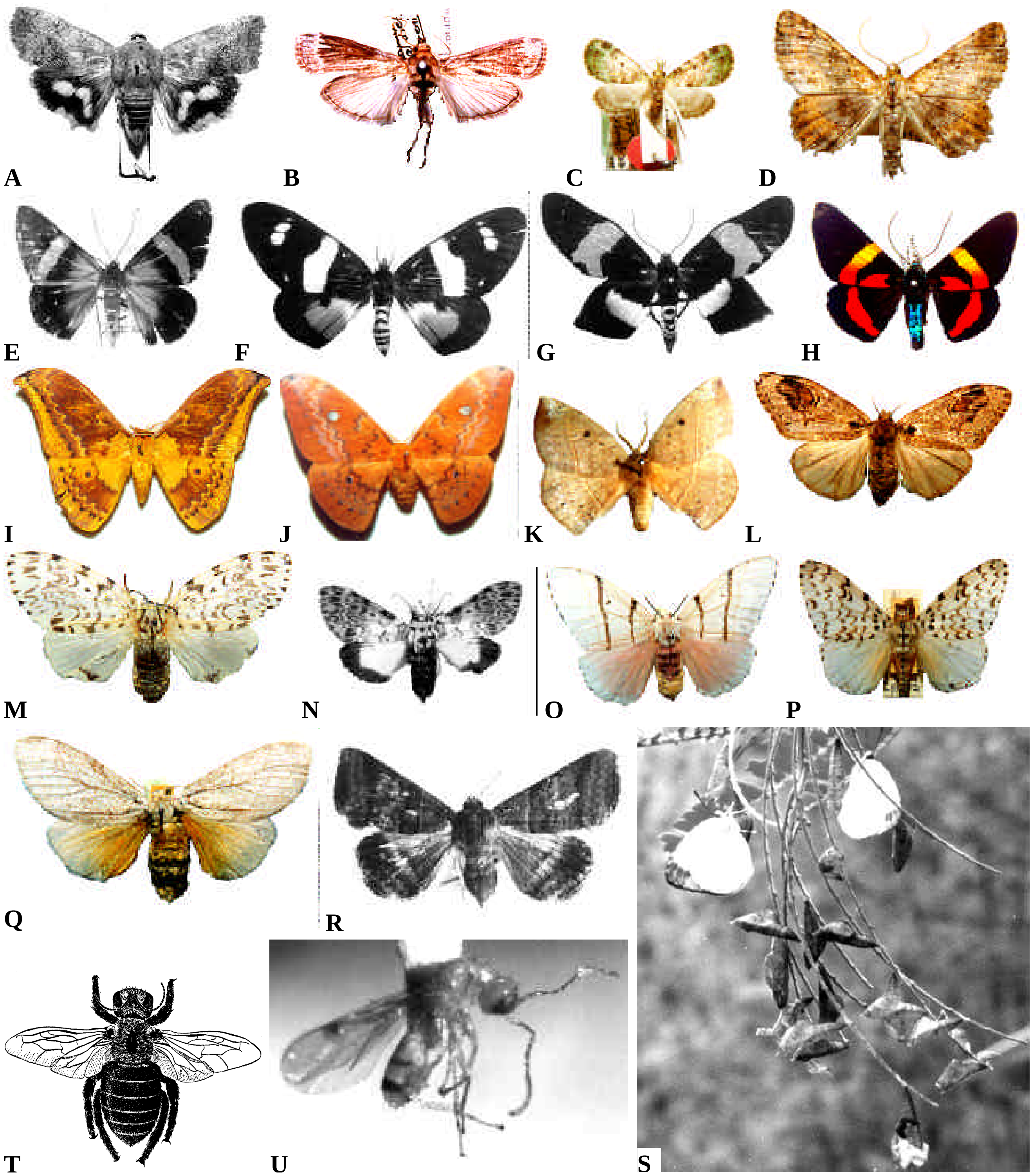

Fig. 6-4: Forest Insect Pests of PNG: (A) *Hyblaea puera* (Hyblaeidae), (B) *Hypsipyla robusta* (Pyralidae), (C) *Alcis papuensis* (Geometridae), (D) *Paradromulia nigrocellata* (Geometridae), (E) *Milionia isodoxa* (Geometridae), (F) *Milionia sp.* (Geometridae), (G) *Milionia sp.* (Geometridae), (H) *Milionia sp.* (Geometridae), (I) *Syntherata sp.* (Saturniidae), (J) *Syntherata janetta* (Saturniidae), (K) *Anthela ekeikei* (Anthelidae), (L) *Dasychira mendosa* (Lymantriidae), (M) *Lymantria ninayi* ♀ (Lymantriidae), (N) *Lymantria ninayi* ♂ (Lymantriidae), (O) *Lymantria rosa* (Lymantriidae), (P) *Lymantria novaguinensis* (Lymantriidae), (Q) *Calliteara queenslandica* (Lymantriidae), (R) *Mocis trifasciata* (Noctuidae), (S) pupae and emerging adults of *Eurema blanda* (Pieridae), (T[†]) *Xylocopa aruana* (Anthophoridae), (U) *Megastigmus sp.* (Torymidae) (photos Schneider, M.F.; drawing reproduced from Gray, B. and Wylie, F.R., 1974[†])

Pest Insect	Host Species	Signs of Damage/ Effects of Infestation	Occurrence/ Remarks	Control Measures
ISOPTERA (see chapter 6.2.1)				
Rhinotermitidae				
Coptotermes elisae (**figs. 5-17 A**, **6-3 C**, **D**)	*Araucaria cunninghamii* and many other hosts	bore wood of living trees causing death of host	severe pest at Bulolo and Wau	site preparation, cultural methods
Schedorhinotermes spp. (**figs. 5-17 B**, **6-3 A**, **B**)	various hosts	decompose dead wood; do not attack living trees but timber products	minor pest all over PNG	wood preservation
Termitidae				
Nasutitermes novarum-hebridarium (**figs. 5-17 C**, **6-3 E**)	*Eucalyptus deglupta*, *Acacia mangium* and other hosts	bore wood of living trees causing timber degrade or death of host	severe pest in Gogol area and New Britain Island	site preparation, cultural methods
Pericapritermes spp. (**figs. 5-17 D**, **6-3 H**)	various hosts	decompose dead wood; do not attack living trees but timber products	minor pest all over PNG	wood preservation
Microcerotermes biroi (**figs. 5-17 E**, **6-3 F**, **G**)	*Eucalyptus deglupta*, *Acacia mangium* and other hosts	introduction of heart rot into living host causing timber degrade	severe pest in Gogol area and New Britain Island	site preparation, cultural methods
ORTHOPTERA (see chapter 6.2.2)				
Acrididae				
Valanga irregularis	*Eucalyptus spp.* and other hosts	eat leaves, shoots and ring-bark young seedlings	pest in nurseries all over PNG	cultural methods, chemical methods
HEMIPTERA (see chapter 6.2.3)				
Adelgidae				
Pineus pini (**fig. 6-3 I**) (pine woolly aphid)	*Pinus spp.*	affect terminal buds causing stunted growth	minor pest in Bulolo	chemical methods
Coccidae				
Ceroplastes rubens (red wax scale, **box 6-1 I**)	*Pinus caribaea*	sparse and dark foliage of host, loss of increment	minor pest in Bulolo	chemical methods
Psyllidae				
Glycaspis spp. (**fig. 6-3 J**)	*Eucalyptus spp.*	leaves with white fibrous lerps that defoliate host	minor pest in some areas	chemical methods
Cardiaspina spp. (**fig. 6-3 K**, **L**)	*Eucalyptus spp.*	leaves covered with brown lerps that defoliate host	minor pest in some areas	chemical methods
Flatidae (**fig. 6-3 M**)				
Paratella errudita	*Eucalyptus deglupta*	defoliation and loss of increment	minor pest in natural stands	
Coreidae				
Mictis profana (crusader bug, **fig. 6-3 N**)	*Acacia auriculiformis*	shoot tip wilt due to piercing action of the bug	minor pest in some areas	
Leptoglossus australis (**fig. 6-3 O**)	*Eucalyptus deglupta*	defoliation, deformation of stem, loss of increment	minor pest in natural stands	
Pternistria levipes	*Tectona grandis*	piercing of stem causes wilt and lesions	minor pest in natural stands	
Pternistria macromera	*Tectona grandis*	piercing of stem causes wilt and lesions	minor pest in natural stands	
Pentatomidae				
Austromalaya sp.	*Eucalyptus deglupta*	piercing causes defoliation and loss of increment	minor pest in natural stands	

Box 6-3: Common Forest Insect Pests of Papua New Guinea - An Overview (continued)

Pest Insect	Host Species	Signs of Damage/ Effects of Infestation	Occurrence/ Remarks	Control Measures
DIPTERA (see chapter 6.2.4)				
Fergusoninidae				
Fergusonina spp. (**fig. 6-3 P**)	*Eucalyptus spp.*	females induce leaf and flower galls that inhibit flower and seed production	minor pest in some areas	
COLEOPTERA (see chapter 6.2.5)				
Bostrichidae				
Xylothrips religiosus (powderpost beetle) (**fig. 6-3 S**)	*Eucalyptus torelliana* and other hosts	most common powderpost borer, especially after fire adults and larvae bore wood	common but minor pest in PNG	
Scarabaeidae				
Xylotrupes gideon (**fig. 6-3 T**)	*Toona australis*, *Pinus patula*, *Fraxinus spp.* and many other hosts	adult beetles feed on bark, causing secondary infestations and die-back	common but minor pest in PNG	mechanical methods
Buprestidae				
Agrilus opulentus (**fig. 6-3 Q**)	*Eucalyptus deglupta*	larvae bore under bark and feed on cambium; zigzag-like galleries visible on bark; loss of growth; death of host	severe pest in New Britain and Madang Province	cultural methods, chemical methods
Agrilus viridissimus (**fig. 6-3 R**)	*Terminalia brassii*	larvae bore under bark and feed on cambium; loss of-increment; death of host	severe pest in New Britain and Madang Province	cultural methods, chemical methods
Chrysomelidae				
Rhyparida coriacea	*Casuarina spp.*, *Tectona spp.*, *Terminalia spp.* *Eucalyptus spp.*	adults can cause complete or severe defoliation	common but minor pest in PNG	
Paropsis andersonae, *P. albae* (**fig. 6-8**)	*Eucalyptus spp.*	larvae and adults feed on foliage; loss of increment	minor pest around Port Moresby	
Cerambycidae				
Potemnemus spp. (**fig. 6-3 U**)	*A. hunsteinii*, *T. grandis*	larvae bore heartwood and cambium of freshly fallen logs; degrade of timber	common and severe pest in PNG	cultural methods, chemical methods
Dihammus spp. (**fig. 6-3 V**)	*A. hunsteinii*, *T. grandis*	larvae bore heartwood and cambium of freshly fallen logs; degrade of timber	common and severe pest in PNG	cultural methods, chemical methods
Hyplocerambyx severus (**figs. 6-3 W**, **6-14 B**)	*Anisoptera spp.* and other hosts	larvae bore heartwood and cambium causing timber degrade or death of host	common and severe pest in PNG	cultural methods, chemical methods
Curculionidae				
Vanapa oberthuri (**figs. 6-3 X**, **6-15**)	*A. cunninghamii*	larvae bore wood and cambium of living host resulting in death of host or timber degrade	severe pest of plantations at Wau Bulolo, Goroka, and Kainantu	cultural methods
Sympiezoscelus sp., *Aesiotes sp.* and *Illacuris laticollis* (**box 6-1 F**)	*A. cunninghamii*	larvae bore wood and cambium of living host resulting in death of host or timber degrade; often secondary pest or after fire	minor pests of plantations at Bulolo and Wau	cultural methods
Oribius destructor (**fig. 6-3 Y**)	*Eucalyptus spp.*	adults defoliate host causing loss of increment	minor pest all over PNG	
O. cruciatus	*Tectona grandis*	adults defoliate host causing loss of increment	minor pest all over PNG	

Box 6-3: Common Forest Insect Pests of Papua New Guinea - An Overview (continued)

Pest Insect	Host Species	Signs of Damage/ Effects of Infestation	Occurrence/ Remarks	Control Measures
COLEOPTERA	(continued)			
Curculionidae (cont'd)				
Orthorhinus patruelis	*A. cunninghamii*	larvae bore wood and cambium causing degrade of timber or death of host	minor pest at Wau Bulolo, Goroka, and Kainantu	
Platypodidae				
Diapus spp.	various hosts	larvae attack newly felled logs causing timber degrade	common and severe pest in PNG	chemical methods
Crossotarsus spp. (**figs. 6-3 Z**, **6-11 A**)	*A. hunsteinii* and other hosts	larvae tunnel heartwood; bark with pin- or shot-holes	common and severe pest in PNG	chemical methods, cultural methods
Platypus spp. (**fig. 6-3 Z1**, **6-11 B**)	*A. hunsteinii* and other hosts	larvae tunnel heartwood; bark with pin- or shot-holes	common and severe pest in PNG	chemical methods, cultural methods
Scolytidae				
Xyleborus spp. (**figs. 6-3 Z2**, **6-11 C**)	*A. cunninghamii* and other softwood species	larvae tunnel logs causing timber degrade	severe and most common wood borer in PNG	sanitation, cultural methods
Hylurdrectonus spp. (**figs. 6-3 Z3**, **6-13 D**)	*A. cunninghamii*	larvae mine branchlets and defoliate tree; death of host	severe pest at Wau and Bulolo	high pruning, sanitation
LEPIDOPTERA (see chapter 6.2.6)				
Psychidae				
Eumeta spp.	*Eucalyptus deglupta*	caterpillars destroy leaves and small branches	common but minor pest in lowlands	
Hyalarcta spp.	*Eucalyptus torelliana*	caterpillars feed on leaves and cause loss of increment	minor pest in some areas	
Pteroma plagiophleps	*Pinus spp.*	larvae feed on foliage and cause loss of increment	minor pest at Fayantina, Lapegu	
Cossidae				
Zeuzera coffeae (red coffee borer)	*Eucalyptus deglupta*, *Terminalia brassii* and other hosts	bore near tips causing stem deformation, branchiness and loss of increment	minor pest in lowlands	
Thyrididae				
Striglina floccosa	*Eucalyptus deglupta*, *Terminalia brassii*	leaf-rolling caterpillars defoliate seedlings	minor pest in some areas	
Hyblaeidae				
Hyblaea puera (**plate 4 B**, **fig. 6-4 A**)	*Tectona grandis* and seedlings of other species	leaf eating and rolling causes defoliation and loss of increment	severe pest in Gabensis, Brown River and Kimbe	
Pyralidae				
Hypsipyla robusta (cedar shoot borer) (**plate 4 C**, **fig. 6-4 B**)	*Toona sureni* and *T. australis*	larvae mine shoots of host, causing deformation and severe loss of increment	common and severe pest in PNG	
Geometridae				
Milionia isodoxa, and other *Milionia spp.* (**plate 5 A-F**)	*A. cunninghamii* and other hosts	larvae feed on foliage and cause growth loss	severe pest in Eastern Highlands and Bulolo	high pruning
Alcis papuensis (**plate 4 K**, **fig. 6-4 C**)	*Pinus spp.*	larvae feed on foliage; loss of increment	minor pest at Fayantina, Lapegu	
Paradromulia nigrocell. (**plate 4 J**, **fig. 6-4 D**)	*Pinus spp.*	larvae feed on foliage; loss of increment	minor pest at Fayantina, Lapegu	
Hyposidera talcata	*Eucalyptus deglupta*, *Terminalia brassii*	caterpillars defoliate seedlings in nurseries	minor pest in some areas	

Box 6-3: Common forest insect pests of Papua New Guinea - an overview (continued)

Pest Insect	Host Species	Signs of Damage/ Effects of Infestation	Occurrence/ Remarks	Control Measures
LEPIDOPTERA	(continued)			
Saturniidae *Syntherata spp.* (**plate 5 M - O**)	*Pinus spp.* and *Eucalyptus deglupta*	larvae defoliate all ages of host; loss of increment	minor pest in some areas	
Anthelidae *Anthela ekeikei* (**plate 5 P**, **Q**)	*Pinus spp.*	larvae feed on foliage; loss of increment	minor pest at Fayantina, Lapegu	
Lymantriidae *Lymantria ninayi* and *Lymantria spp.* (**plate 7 B-G**)	*Pinus patula*	larvae feed on foliage; complete defoliation during periodical outbreaks	severe pest of plantations at Fayantina, Lapegu	high pruning, biological methods
Calliteara queenslandica (**plate 7 A**, **fig. 6-4 Q**)	*Pinus spp.*	larvae feed on foliage causing loss of increment	minor pest at Fayantina, Lapegu	
Dasychira wandammena	*Pinus patula*	larvae defoliate host	minor pest	
Dasychira mendosa (**plate 6 O**, **fig. 6-4 L**)	*Eucalyptus spp.*	larvae defoliate host and cause loss of increment	minor pest	
Noctuidae *Agrotis ipsilon*	*Casuarina spp.*	larvae defoliate host	minor pest	
Mocis trifasciata (**fig. 6-4 R**)	*Agathis spp.*	larvae feed on foliage and cause loss of increment	sometimes severe pest	
Pieridae *Eurema blanda* (**fig. 6-4 S**)	*Albizia falcataria*	larvae defoliate host and cause loss of increment	common but minor pest in PNG	
HYMENOPTERA (**see chapter 6.2.7**)				
Torymidae *Megastigmus spp.* (**fig. 6-4 U**)	*Eucalyptus spp.*	females induce stem, leaf, shoot and fruit galls	minor pest in some areas	
Megachilidae *Megachile frontalis* (**fig. 6-19**)	*Eucalyptus deglupta*	host of all ages is defoliated; loss of increment	minor pest in some areas	
Anthophoridae *Xylocopa aruana* (**fig. 6-4 T**)	a common pest of un-treated softwoods	bores holes and builds nests in timber products	minor pest along Papuan coast	treatment of timber

Box 6-3: Common Forest Insect Pests of Papua New Guinea - An Overview

6.2.1 Termite Pests

Most termite species are utterly beneficial decomposers contributing towards a rapid recycling and turn-over of minerals. However, a handful of species are some of the most destructive pests of untreated timber products as well as of living standing trees causing, an economic loss of many millions of Kina every year. Characteristic of this group of insects are their chewing mouthparts and the ability to digest cellulose, the major component of wood. Termites chew and bore timber, causing either a considerable degrade of the material or resulting in the death of the host tree. Termites are social insects having three distinct castes, the **reproductives** (queen and king), the **soldiers** and **workers**. The colony can consist of more than a million individuals. The nest of a colony (**termitarium**) is located either underground (**subterranean**), on a tree (**arboreal**) or in a **mound** sticking out of the soil. Due to the unpigmented skin of most termites, they have to live in dark and moist conditions, protected from desiccation. Therefore the insects move only in the very long subterranean galleries or shelter tubes extending from their nest to gather food. The biology of termites, their caste system, the tasks of the individual castes and the different types of nests are outlined in the **chapters 3.2.1** and **5.6.3.7**. Termites are sometimes difficult to identify and usually the soldiers are used for that purpose. Characteristic and thus helpful for identification is their nest type.

The most significant termite species in terms of economic loss are *Microcerotermes biroi*, *Nasutitermes novarumhebridarium* and *Coptotermes elisae* since all three species attack living trees of any age. They have the potential to kill their host within a few months, however in some cases the attack can take several years without any external symptoms, until the tree is thrown over by wind. Important is that termites usually only attack trees that are somehow weakened or otherwise under stress. Weakened trees release a volatile chemical (**kairomone**) which is used by the termites to locate the diseased tree. Once attacked by termites, the tree is quite helpless, because its natural immune system or resistance is decreased and pests can not longer be defeated effectively.

The **symptoms** of termite infestations are more or less conspicuous and obvious, however in some cases an apparently healthy tree suddenly dies without having shown any external signs. The symptoms of Hoop pine due to *Coptotermes elisae* attack and the signs of damage caused by *Nasutitermes novarumhebridarium* and *Microcerotermes biroi* on *Eucalyptus* and *Acacia* are summarised in **box 6-1 A**, **L**, **W**, **box 6-4** and illustrated in **fig. 6-6**.

Coptotermes elisae **(Desneux)** termites enter the host through injured roots or injured bark and then tunnel the cambium and the heart of the tree (**fig. 6-2 G**). Occlusion might cover the damaged area of the bark, so that it is no longer visible after a time (**fig. 6-6 I**), even though the termites are still present. Some conspicuous signs are:

- the colour of the leaves changes from green to yellow and brown from the top of the tree downwards and from the tips of the branches inwards (**plate 11 H**)
- the upper crown is more or less defoliated as shown in **box 6-1 A**
- ‘mud-packs’ cover the base of the stem as shown in **box 6-1 A**
- due to the ‘**pipe**’-like excavated base of the tree (**fig. 6-2 G**), a hollow sound is audible when the stem is tapped
- the cross section of the stem and sawn timber show typical irregular galleries that are often filled with frass and other decaying material

After an attack by ***Nasutitermes novarumhebridarium*** **(Holmgren)** it takes little time for the tree to die, sometimes only a few months. An attack is more obvious than in other termite species. Typical signs are:

- mud-covers up to a few metres
- typically with dark shelter tubes running up the stem of the infested tree (**figs. 3-14**, **6-5**)
- riddled wood of low quality with many holes and sometimes with central ‘**pipe**’ (**figs. 6-5** and **6-6 J**)
- the outer surface of the nest is more or less regular and smooth (**box 6-1 L**, **W**, **fig. 6-5**)

Microcerotermes biroi does not attack living trees but feeds on dead branches, introducing heart rot. An attack can be identified by these signs:

- water collects in hollows caused by *Microcerotermes* and results sooner or later in the introduction of fungal heart rot (*Phellinus*) shown in **fig. 6-5**
- the outer surface of the nest is rough and shows a winding structure (**fig. 6-5**)

Conditions that put trees under stress are mostly man-made and are the result of poor silvicultural operations. Stress can also be caused by fire, cattle and other pests. In general all actions that decrease the natural resistance of the trees encourage termite attack:

- if the soil of the planting site as well as the climate are not suitable, the trees will be weakened and become more susceptible to termite attack in the long run

- accumulated waste wood like stumps, tree tops or branches on and in the soil offers additional food for termites
- unsuitable nursery techniques result in low quality and thus unhealthy seedlings that are more likely to be attacked by termites
- improper planting favours termite attack. For instance a coiled root will strangle itself as it grows thicker and as a result it will start to rot and provide a potential point of entry for termites. Upwards-bending of roots during planting decreases the stability and health of a tree (**fig. 6-6 A**) in the long term
- damaged bark of the residual trees, caused during tending, thinning and pruning (**figs. 6-6 B - H**) invites termites. The damage can be the result of falling trees, hauled logs or skidders accidentally hitting a tree
- compacted soil and mechanically damaged rootlets (**fig. 6-6 H**) caused by skidders along log ramps and logging roads affect the health of a tree. If the roots are damaged or not well developed, the tree becomes sick and is then likely to be attacked by termites
- thinning operations on steep slopes cause surface erosion that eventually exposes the rootlets of a tree and thus affects its health
- cattle grazing and walking in the plantation might cause root damage and stress the tree
- the infestation of a tree by other pests can attract termites to the already diseased tree
- any stress caused by draught, fire, poorly drained soil, etc. encourages termite attack

There are several approaches to **control termites**, however none of the efforts is efficient and suitable enough to eradicate established termite colonies in a plantation. Certain problems related to the development of chemical and biological control strategies exist and have yet to be solved. Termites live well hidden in the wood of a tree or in the soil and their galleries are perfectly sealed off. Therefore it is difficult for an insecticide or a biocontrol agent to reach the termites in their colony. Attempts to introduce pathogens or to apply insecticides usually fail, because the termites block off the contaminated area of their nest. The only effective remedy to the termite problem is to prevent termite attack. Since weakened trees more likely to become the target of a termite attack than healthy ones, the main goal of silviculture should be to maintain the trees in a healthy condition. Any operations in the plantation have to be

Termite Species	Identification	Host Tree	Effects	Termitarium
Coptotermes elisae **(Rhinotermitidae)** (**figs. 5-14 A**, **6-3 C**, **D**)	soldiers mandibulate; emit milky exudate through hole in fontanelle	*Araucaria cunninghamii* and other hosts of any age	eat wood of dead and living trees causing host's death; **severe pest**	subterranean nest in root crown (**fig. 3-13**)
Schedorhinotermes spp. **(Rhinotermitidae)** (**figs. 17 B**, **6-3 A**, **B**)	soldiers mandibulate; two distinct types of soldiers, the minors and majors	decompose dead wood of various host species and timber products	do not attack living plantation trees, but logs and timber; **minor pest**	subterranean nest in buried wood
Nasutitermes novarum-hebridarium **(Termitidae)** (**figs. 5-17 C** and **6-3 E**)	soldiers nasute; repellent gum comes from underneath the pointed projection of head	*Eucalyptus deglupta*, *Acacia mangium* and other hosts of any age	eat wood of dead and living trees causing host's death; **severe pest**	arboreal nest (**fig. 3-14** and **box 6-1 L**, **W**)
Pericapritermes spp. **(Termitidae)** (**figs. 5-17 D** and **6-3 H**)	soldiers mandibulate soldiers with irregularly shaped mandibles	decompose dead wood of various host species and timber products	do not attack living plantation trees but logs and timber; **minor pest**	subterranean nest in buried wood
Microcerotermes biroi **(Termitidae)** (**figs. 5-17 W**, **6-3 F**, **G**)	soldiers mandibulate with large, singly serrate jaws	*Eucalyptus deglupta* and other hosts of any age	introduction of heart rot into living host; **severe pest**	arboreal nest (**fig. 3-14** and **box 6-1 L**, **W**)

Box 6-4: Distinguishing Features of Important Termite Pests in Papua New Guinea

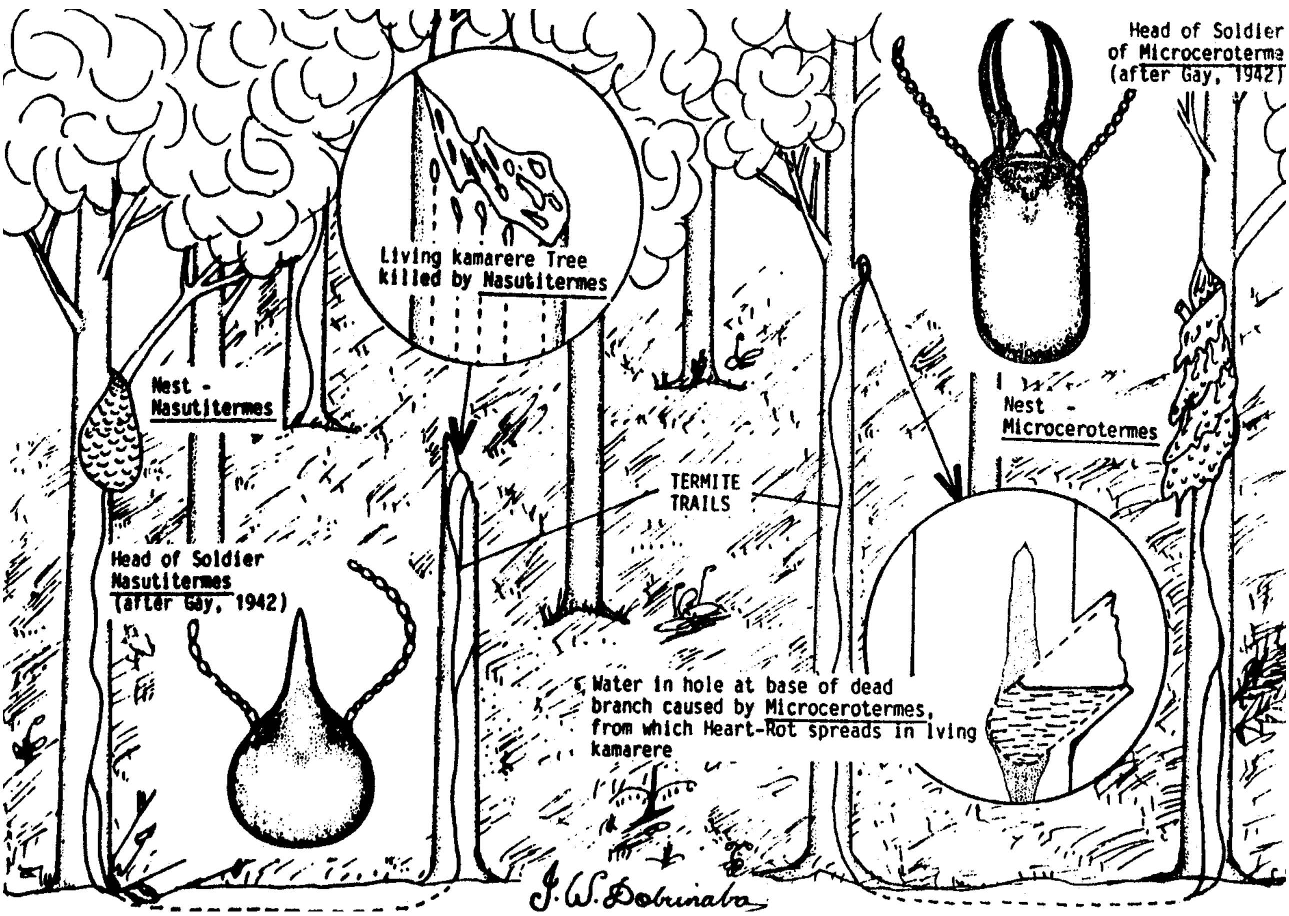

Fig. 6-5: Features of *Nasutitermes novarumhebridarium* and *Microcerotermes biroi* and the signs of their infestation on *Eucalyptus deglupta* and *Acacia mangium* (reprod. from Roberts, H., 1987)

carried out thoroughly and in such a way that stress and the damage to residual trees are minimised as much as possible. Preventive measures as outlined in **chapter 8.2.1** are a long-term exercise to avoid termite attack but are not a suitable cure for any existing termite problems. Control strategies are:

• Biological control methods seem to be promising, but hardly any organisms are available as suitable and effective control agents. Natural enemies of termites play only a minor role in termite control due to the high number of individuals in a termite colony. Predators of termites are mammals like echidnas or spiny ant eaters, birds such as king fishers and rainbow lorikeets, reptiles like geckos, and lizards, mites, spiders and insects like assassin bugs, ants and some others. However, termites possess a variety of very efficient defence mechanisms that are difficult for a predator to overcome. Ants are potential predacious biocontrol agents but parasites or pathogens are definitely in the better position to tackle the gigantic number of individuals in a termite colony. There are a number of parasites and pathogens of termites, but even these do not really contribute much towards the natural control of termites. Scientists from the Entomology Division of CSIRO are testing the entomopathogenic fungus *Metarhizium* for the control of termites.

• Chemical control is also not suitable in most cases since the target is hidden in the tree and difficult for the insecticide to reach. Previously, insecticides like **Dieldrin** and **benzene hexachloride** (**BHC**) were used for the control of termites but with little success. Now, most of these **chlorinated hydrocarbons** are banned by the international community and are not supposed to be applied any longer. One exception is the treatment of soil with this persistent class of insecticides in order to control soil-borne termite pests, eg. to protect airstrips. Other control programmes used

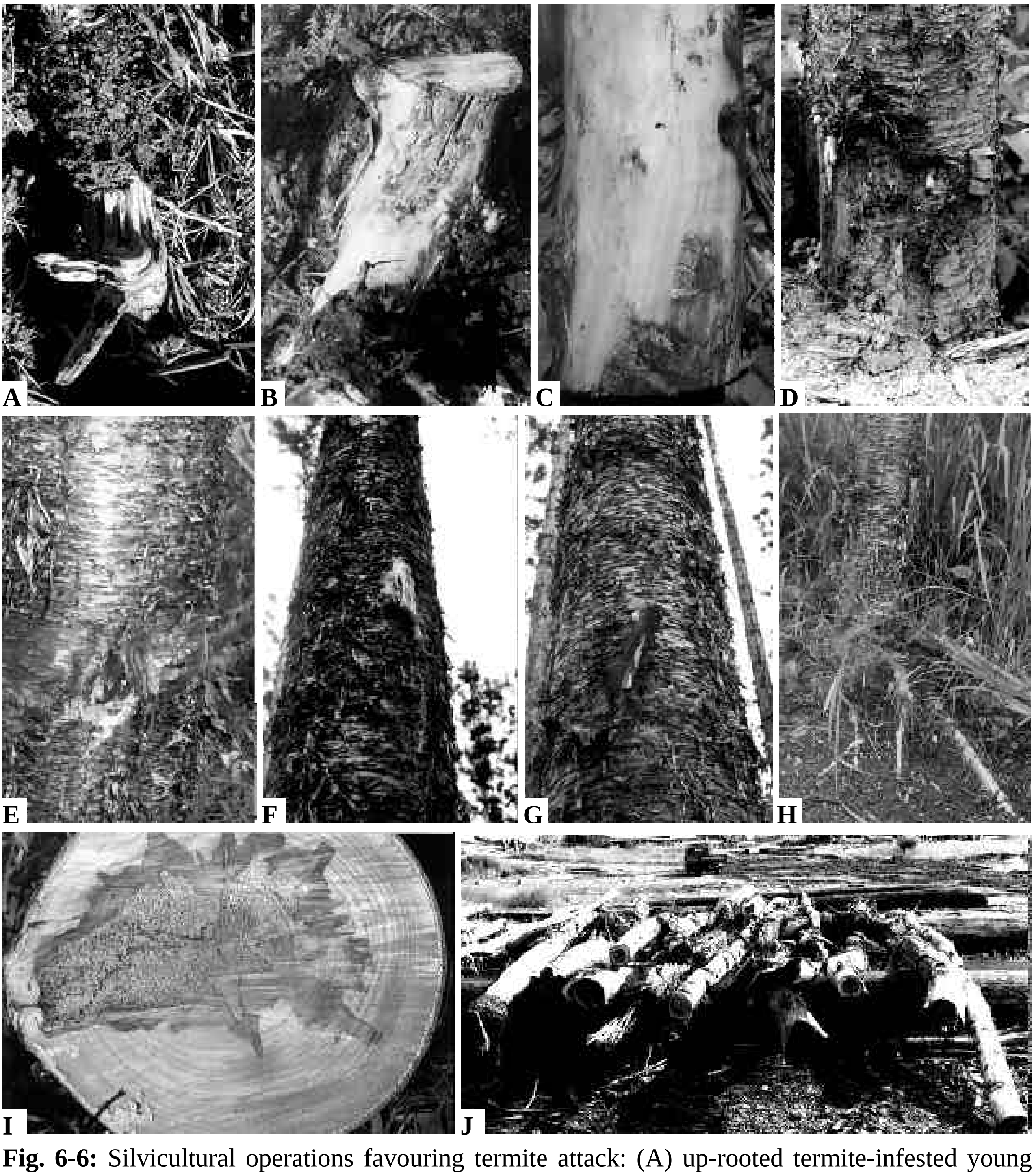

Fig. 6-6: Silvicultural operations favouring termite attack: (A) up-rooted termite-infested young Hoop pine with ‘mud packs’ at the base and an abnormal, upwards growing root; the tap root has already deteriorated due to rot; (B) termite attack of a young Hoop pine due to damage of bark at the base of the stem caused during pruning; (C) the bark of the same tree has been removed, revealing that the termite damage of the cambium has affected almost the whole circumference; (D) termite-infested tree base due to damage of the bark during skidding or hauling; (E, F, G) damage of bark caused by a falling tree during thinning; (H) debarked roots of a tree next to a snig track caused by the impact of skidder wheels and hauled logs; (I) cross-section of the basal part of a termite-infested stem showing a central ‘pipe’ filled with decaying material. The surrounding area of the wood is stained by fungal rot. The termite infestation started at a damaged area of the bark visible on the left of the photo. The infestation is still proceeding, even though occlusion has almost completely covered the scar, and the infestation is hardly visible from outside; (J) termite-infested stems of *Acacia mangium* with central ‘pipe’ (photos Schneider, M.F.)

poisonous dusts of arsenic trioxide and arsenic pentoxide for the treatment of termite nests, but also with little success. Apart from the fact that the termites blocked off the poisoned parts of their nest, these chemicals also had a severely detrimental and often fatal impact on the tree housing the treated colony.

- Manual measures comprise digging out subterranean nests or removing arboreal nests and destroying the termite queen. This is however only effective if the whole nest **plus** all the individuals are destroyed. In some species particular surviving neotenics or pseudergate soldiers can develop into queens and re-establish the colony.

6.2.2 Orthopteran Pests

A small number of grasshoppers, crickets and mole crickets are reported to interfere with tree crops in Papua New Guinea. Typically, Orthoptera have chewing mouthparts and feed mainly on the foliage and the soft bark of young seedlings and thus only cause problems in the nursery and during a short period after the seedlings are transplanted into the field. The soil-borne mole cricket *Gryllotalpa* (**Gryllotalpidae**, **fig. 5-20 B**) was recorded feeding on the roots and foliage of *Tectona grandis* seedlings. The huge grasshopper *Valanga irregularis* (**Acrididae**) was encountered at Wasab, feeding on the foliage of *Eucalyptus deglupta*. Other hoppers of this family are often abundant in newly planted areas adjacent to grassland. The problem of ring-barking or debarking often occurs in Bulolo's Hoop pine plantations. It can be overcome by keeping the seedlings longer in the nursery, so that the bark becomes thicker and a less attractive source of food for the grasshoppers. The article on the right suggests wrapping the base of the seedlings' stems with aluminium foil. According to experienced foresters, this is a method that seems to be less feasible. Regular weeding in and cutting the grass around nurseries and newly planted areas helps to protect the seedlings and minimises grasshopper-related problems.

Post Courier, 07/03/97

Grasshoppers devastate Bulolo forest

By HAIVETA CHRIS

LOCUSTS are threatening the success of the Bulolo Forest Plantation program, a Japanese, forest expert seconded to the project said yesterday.

Japan International Co-operation Agency expert Hitofumi Abe told the forestry research seminar in Lae that the grasshoppers were killing up to 90 per cent of the hoop pine (*Araucaria*) seedlings within three months of planting, and he urged the Forest Research Institute to second some ecology experts to the project.

He said he had tried wrapping the stems of the seedlings in aluminium foil to ward off the insects and had achieved some success. Just over half of the protected seedlings were still surviving after six months, while more than 75 per cent of the plants left unprotected as a "control" had been killed by grasshopper attack.

Mr Abe said the few unprotected plants which survived might have done so because they had some characteristics which the grasshoppers did not like, and he suggested that that possibility required more research.

He said the grasshoppers were not native to the area and might have been brought in with the legumes used in the plantation to give nitrogen to the soil.

More than six million hectares of logged-over natural [illegible]

6.2.3 Hemipteran Pests

Hemipterans are insects such as true bugs (**Heteroptera**), cicadas (**Cicadidae**), aphids or plant lice (**Aphididae**, **Adelgidae**), lerps or psyllids (**Psyllidae**), scale insects (**Coccidae**), mealy bugs (**Pseudococcidae**), white flies (**Aleyrodidae**) and many more. These insects are of economic significance since there is hardly any crop that is not attacked by at least one hemipteran pest. One common feature of the insects of this diverse group is the piercing-sucking mouthparts that are inserted into plant tissue as shown in **fig. 2-14**. The typical signs are brown or black feeding punctures visible on the affected plant tissues (**fig. 6-1 F**). Another conspicuous sign is **honey dew**, a sweet excretion that is released by the sucking insect. Often ants are attracted to feed on the honey dew. Furthermore, a fungus, the **black sooty mould** is growing on the honey dew that dripped on to the leaves. Many insects of this group carry viral and bacterial diseases of their respective host plants, often resulting in the **necrosis** of the punctured leaf or shoot. Furthermore, the piercing-sucking action of some Hemiptera can induce the tumour-like growth of the affected part of the host plant.

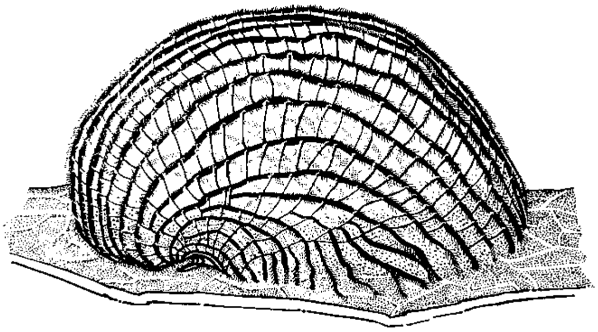

Fig. 6-7: Scale of the basket lerp *Cardiaspina sp.* (Psyllidae) under which the immature stages are hidden (reproduced from CSIRO, 1991[2])

A number of true bugs like *Austromalaya sp.* (**Pentatomidae**), *Mictis profana*, *Leptoglossus australis*, *Pternistria spp.* (**Coreidae**) feeding on broad-leaf hosts are only of minor importance.

Homopteran bugs are much more significant in terms of their destructive potential due to their smaller size and the resulting higher reproductive potential. Little is known about the biology of the pine woolly aphid *Pineus pini* (**Adelgidae**) and the red wax scale *Ceroplastes rubens* (**Coccidae**). Both pest species feed on *Pinus spp.* (**box 6-1 I** and **J**) and have occurred only once in the history of PNG's forestry, restricted to Bulolo only. *Pineus pini* (**fig. 6-3 I**), also known as *P. laevis* was apparently introduced accidentally from Queensland with grafting scions. The imposed quarantine restrictions were successful so that the pest could not establish and spread in PNG. *Ceroplastes rubens*, also affecting *Citrus spp.* releases large quantities of honey dew. The sooty-mould growing on these sweet secretions densely covers the surface of the needles so that the light absorption by the leaves is restricted resulting in defoliation and loss of height increment. *Ceroplastes* prefers particular clones of *Pinus caribaea*, but can be also found on other *Pinus* species. The infestation usually is more severe in the upper crown and less severe in the middle and lower parts of the crown.

Of importance for several species of *Eucalyptus* are the lerps *Cardiaspina spp.* and *Glycaspis spp.* (**Psyllidae**, **figs. 6-3 J**, **K**, **L**). Lerps are scales or tests of most immature stages. The nymphs live and feed beneath the lerp and are protected there from desiccation. In the case of *Cardiaspina* the lerps resemble lace or a turned-over basket, whereas the lerps of *Glycaspis* are of white, fibrous material. The shape of the lerp is characteristic for the species and can be used for their diagnostics. The lerps are made from starch, derived from the plant sap. While sucking the plant juice, the nymphs inject enzymes that break down the plant tissue. This later becomes visible as brown, red or yellow discoloration of a leaf. The feeding puncture usually looks irregular and scar-like. The adults looking like the miniatures of cicadas, are without lerps and hardly exceed 5 mm body length. Most species are of brown or yellowish coloration and are good fliers due to their well developed membranous wings. Because of their jumping hindlegs they are also called 'jumping aphids'. The females possess a saw-like ovipositor which helps insert the base of the eggs into the leaf to avoid desiccation. A female can lay several hundred eggs during her short lifetime. There are five or more generations per year in the Tropics. Psyllids cause a more or less severe defoliation of their respective host. Some species cause the necrosis of a leaf, others only its discoloration. Natural enemies are spiders, mites, ladybirds, lacewings, parasitic wasps and some birds. Prolonged psyllid outbreaks result in a considerable loss of increment and die-back of the host. Severe outbreaks were not have not been reported in PNG so far.

Infestations of *Acacia mangium* and *Tectona grandis* with mealy bugs (**Pseudococcidae**) and white flies (**Aleyrodidae**) were recorded in PNG but are of minor economic significance.

6.2.4 Dipteran Pests

There is only one genus of true flies reported to interfere with planted trees in Papua New Guinea. It is *Fergusonina* (**Fergusoninidae**), forming leaf and flower galls on several species of *Eucalyptus*. *Fergusonina* (**fig. 6-3 P**) is a minor pest in PNG inhibiting the flower and seed production of the host. Little is known about the biology of this species, however closely related Australian relatives have probably a very similar and definitely a very interesting biology. The flies have a complex life cycle including the symbiotic association with a nematode of the genus *Fergusobia*. A fertilised female nematode enters the body cavity of a female fly larva in the gall. The hatched larval nematodes enter the oviduct of the female fly and are carried out of the gall, when the fly emerges. After mating the nematodes are passed out together with the fly eggs, when these are laid into *Eucalyptus* flower buds. There, the nematodes develop together with the flies inside the induced gall. The chemical that induces the gall is produced by the nematode, therefore the apparently parasitic interaction is of mutualistic nature, hence for the advantage of *Fergusonina*. Interestingly, a natural enemy of *Fergusonina* is the gall-forming wasp *Megastigmus* (**Torymidae**). Even though being another pest species of *Eucalyptus* the wasp effectively competes with the fly for suitable flowers to lay eggs, resulting in the death of large numbers of *Fergusonina*.

6.2.5 Coleopteran Pests

There is a large number of beetles that are considered as pests of tree crops in Papua New Guinea. The number of detrimental beetle species found in PNG reflects the diversity of this order - the largest insect order. Both larval and adult beetles have chewing mouthparts and can virtually make use of any plant tissue. Most beetles are associated with wood, that is bored and tunnelled by the grubs and/or the adults. A smaller number of beetles feed on bark and the cambium, respectively. Only a few beetles like the leaf beetles *Rhyparida coriacea* and *Paropsis* (**Chrysomelidae**, **fig. 6-8** and **box 6-1 Q**) as well as *Oribius* (**Curculionidae**, **fig. 6-3 Y**) feed on the foliage of their host plant. Some important groups of coleopteran pests are discussed below:

Fig. 6-8: Crescent-shaped feeding notches on *Eucalyptus sp.* caused by adult eucalypt leaf beetles *Paropsis sp.* (Chrysomelidae) (reprod. by permission of CSIRO Australia from Farrow, R., 1996)

Under-Bark Borers of Kamarere Talis

Common pests of the two most widely grown tree species in the lowlands of Papua New Guinea are jewel beetles (**Buprestidae**). Larvae of *Agrilus opulentus* affect kamarere (*Eucalyptus deglupta*) whereas the larvae of *Agrilus viridissimus* attack swamp talis (*Terminalia brassii*). *Agrilus* larvae feed on the cambium of their living host. Adults of both species look very similar, are of about 10 mm length and of shiny green or blue colour with orange or silver spots on the back. The adults can be easily distinguished since *A. opulentus* has two orange spots on the prothorax (**figs. 6-3 Q**, **R)**. The white larvae of both species are approximately 2.5 to 3 cm long and narrow except for the enlarged thoracic segments (**fig. 6-9 B**). The life cycle of *A. opulentus* is shown in **fig. 6-9**. The adult females lay eggs singly into cracks of the bark of their favourite host. When the young grubs hatch, they tunnel into the cambium, where they feed and grow bigger. The **zigzag**-like tunnels (**fig. 6-9 A**) in the cambium are clearly visible on the thin bark of *Eucalyptus* *deglupta*, but invisible in *Terminalia brassii* due to its thicker bark. The mature grubs bore radially into the wood and excavate a chamber for pupation (**fig. 6-9 C**). After the final emergence the young adults bore their way to the 'surface' through the wood and bark, leaving a semicircular hole (**fig. 6-9 D**). The adult beetles are associated with the crown of the host tree where they feed on young foliage, before they can become sexually mature and eventually reproduce. They can also be found feeding on regenerating shoots in logged forests. The time span from the egg to the adult depends on the diameter of the host tree and on whether the tree is felled or living. The development from the egg to the adult takes about 6 to 7 weeks in a felled tree of 30 cm diameter. The bigger the diameter, the longer it takes for the beetles to develop. The wild host in the natural forest is lau-lau (*Syzygium*) which belongs like *Eucalyptus* to the family **Myrtaceae**.

Since *Eucalyptus deglupta* and *Terminalia brassii* are the major tree crops of lowland plantations in PNG, *Agrilus* can cause considerable damage worth millions of Kina, particularly on kamarere. A severe infestation by the larvae of either species disrupts the conducting tissues causing the loss of increment and might even result in the death of the host. The zigzag-like feeding in the cambium can be compared with ring-barking. The **signs** of *A. opulentus* on kamarere are **zigzag**-like tunnels visible on the bark, that indicate a previous infestation. The cambium-feeding of the larvae results in **callus formation** after the attack. **Semicircular emergence holes** of the adults are visible in bark of the trunk. Furthermore, **epicormic shoots** develop from the lower trunk. An infestation of swamp talis by *A. viridissimus* is usually less conspicuous than in kamarere and there are usually only semicircular emergence holes visible in the bark of the trunk. *Agrilus* seems to be specific to a particular host family. An attack of *Terminalia* by *A. opulentus* is usually less successful due to the rapid cell division of the host and the copious sap that is produced by the tree killing the larvae.

There is a number of factors encouraging the infestation of kamarere and swamp talis, like unsuitable soil conditions ie. badly drained soils for kamarere and soils drying out too rapidly as in the case of swamp talis.

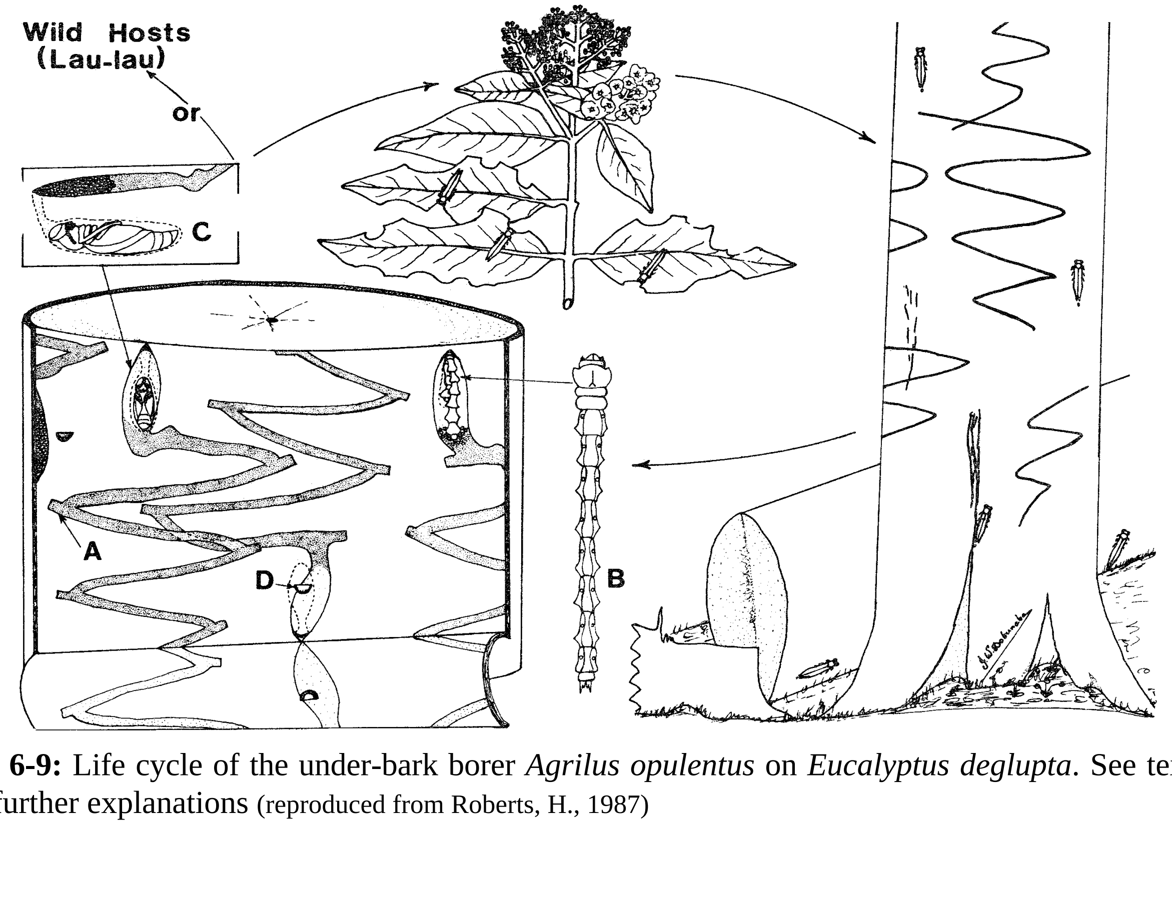

Fig. 6-9: Life cycle of the under-bark borer *Agrilus opulentus* on *Eucalyptus deglupta*. See text for further explanations (reproduced from Roberts, H., 1987)

Unhealthy young trees are often severely infested and diseased. Old and dying trees are also much more susceptible. In general, any silvicultural treatment that puts the residual trees under stress increases the risk of an *Agrilus* infestation. Apart from the preventive measures outlined in **chapter 8.2.1**, the following strategies are recommended to minimise and control *Agrilus*-related problems:

- use *Agrilus*-resistant varieties from Mindanao in the Philippines
- select a suitable site for planting
- line planting with a spacing of 10 m x 2 m results in fewer attacks than planting the trees with a spacing of 4 m x 4 m
- an understorey in the plantation favours predators and other beneficial animals and furthermore makes mate-finding difficult for *Agrilus*
- mixed stands should be preferred and pure stands of kamarere should not exceed 100 ha
- remove all small diameter trees that show suppressed growth, preferably by burning or debarking
- remove alternative or wild host trees in adjacent areas. This does not seem to be feasible because the local people won't be very happy if their fruit trees are removed
- minimise tending after the first year
- after thinning, remove stumps to avoid the regeneration of shoots as an attractive source of food for the adult beetles
- carry out pruning and thinning only during the dry season. By doing so the logs dry out immediately and are no longer suitable for the beetles to breed
- remove the logs immediately from the plantation after commercial thinning
- if possible, debark stems that are left in the plantation, so that the logs are no longer suitable for the beetles to develop
- chemical control methods are available but are extremely expensive, time consuming and sophisticated. Systemic insecticides like acephate (Orthene®) can be injected into the trunk by the use of a device shown in **fig. 8-20**. This is usually done only to protect valuable individual seed trees and is not feasible on a large scale in a plantation.

Pin-Hole and Shot-Hole Borers

Pin- and shot-hole borers belong to the two closely related families **Scolytidae** and **Platypodidae**. Their name comes from the fact that the beetles bore small **pin-holes** or larger **shot-holes** between 0.5 and 3 mm ∅ in the wood of living or dying trees as well as in unseasoned timber products. Common are the platypodid genera *Crossotarsus*, *Diapus* and *Platypus* and the scolytids *Xyleborus*, *Webbia pabo*, *Hylurdrectonus piniarius*, *Poecilips* and *Arixyleborus canaliculatus*. There is a variety of host species like *Araucaria cunninghamii*, *A. hunsteinii*, *Tectona grandis*, *Acacia spp.*, *Eucalyptus deglupta*, *Calophyllum spp.* and *Terminalia brassii*. Pin- and shot-hole borers cause considerable degradation of wood and timber in PNG, worth about one million Kina per year. Although the bore holes are relatively quickly covered up by growing bark, the galleries will still remain in the wood, decreasing its quality or even making it unsuitable for veneer and ply wood. Often the galleries are penetrated and stained by fungi. In the case of rot, the stability of the timber is decreased so that it is unusable for particular purposes. Apart from that, the presence of pin- and shot-hole borers in timber bound for export can cause serious quarantine problems and result in the rejection of a log shipment.

The minute adults of both families are between 1 and 12 mm long, slender and often of black or brownish coloration (**figs. 6-3 Z - Z2**, **6-10** and **6-11**). The distinctive features of the two families are summarised in **box 5-5**. The adults tunnel radially into the heartwood of the host and create a system of galleries in which eggs are laid. The types of galleries made by the parents (**fig. 6-12 D - F**) are species-specific. The larvae (**fig. 6-11**) do not feed on wood, but live on a fungus that they cultivate on the gallery walls. The **Ambrosia** fungus, a yeast, smells a bit like beer and therefore the beetles are also called Ambrosia beetles. The scent acts as an **allelochemical** (**chapter 3.1.3**) that attracts even more bark beetles to the infested tree. Once the larvae are fully grown, they pupate inside the galleries. The newly hatched adult beetles leave the system of galleries through the entrance hole

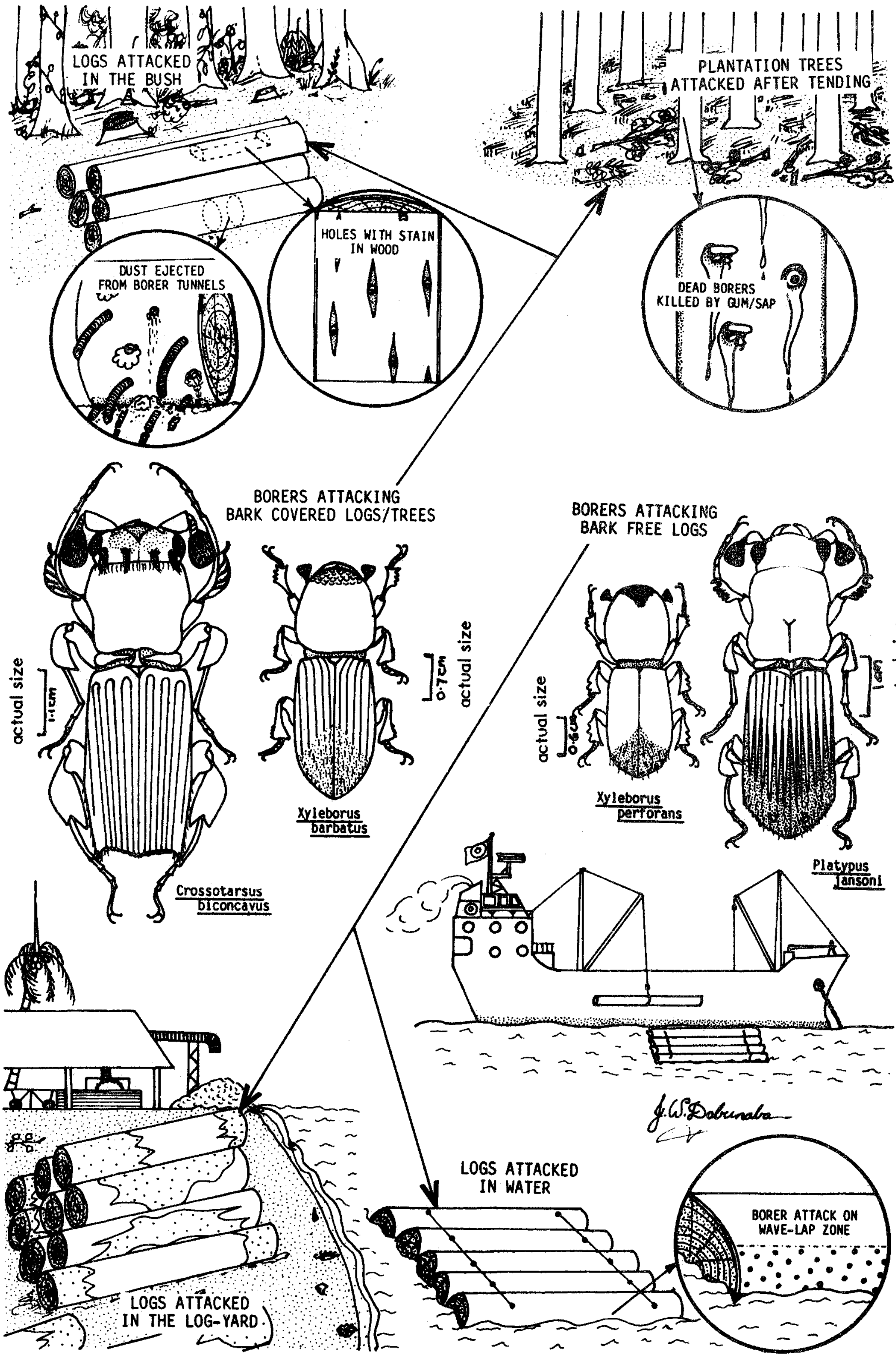

Fig. 6-10: Pin- and Shot-Hole Borers and the Symptoms of their Attack (reprod. from Roberts, H., 1987)

made by their parents and fly off for mating. The life cycle takes about 14 weeks for larger species and 3 to 4 weeks for smaller species. The attack can be recognised by

- dust-free pin- and shot-holes of 0.5 to 3.0 mm in diameter, shown in **fig. 6-12 C**. There can be over 100 holes per m² (**fig. 6-2 D**)
- wood surrounding the holes shows elongate fungal stains (**fig. 6-12 A**)
- the presence of fine dust or solid cylinders of frass, pushed out of the holes and deposited by beetles on the bark of standing trees (**fig. 6-12 B**) or on the surface of logs and timber
- sap and gum flowing out from the bore-hole, sometimes with debris or dead beetles stuck to the exudate.

An infestation with ambrosia beetles can occur either in the natural forest, in plantations or in the log-yard. The attack can start within a few hours of the felling of a tree, increase during the next few days and can last for many weeks. The rate of infestation depends on the type of wood and the moisture content of the wood. Usually light, white wood is more susceptible than heavier, red or brown wood. As long as the tree is green and contains a lot of sap, it can be easily attacked. Once the moisture content decreases below 50%, the timber is unlikely to be infested. Wet climatic conditions or rafting of logs also support the attack, since the wood cannot dry properly. The beetles feeding on green timber attack only where sapwood is present but can penetrate the hardwood, too. In log yards, a few different species of pin- and shot-hole borers attack areas of the log where the bark has been removed. The attack of sawn timber is unusual as long as the moisture content of the lumber is low. Live trees in plantations and natural stands are attacked, if the trees suffer from stress. Several stress factors, like an infestation with other pests, contribute towards an ambrosia beetle attack. Damaged trees injured during commercial thinning or by fire as well as trees stressed by drought are far more susceptible to an infestation. The damage to living trees is normally not fatal, since the holes are closed after a few months.

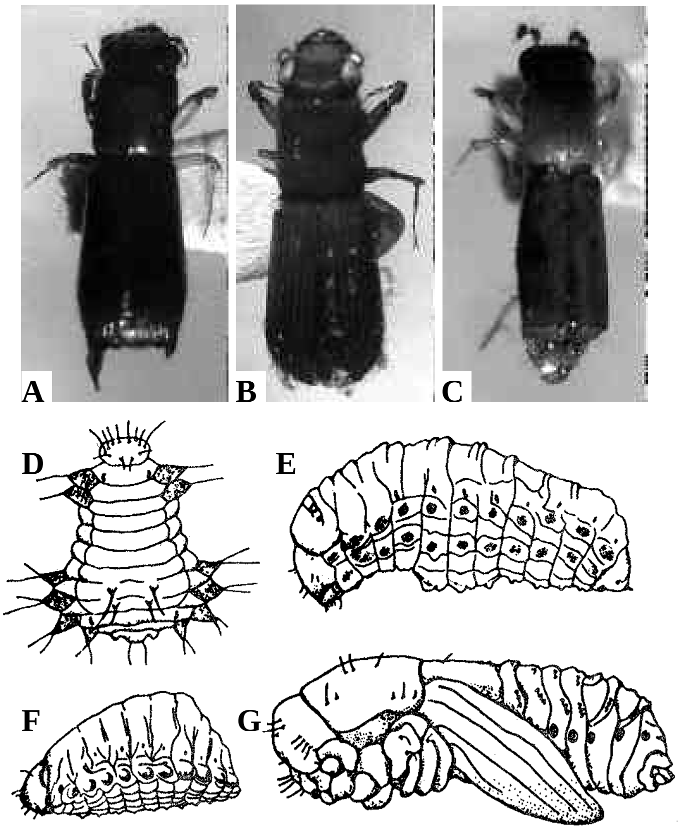

Fig. 6-11: Pin- and Shot-Hole Borers: (A) *Crossotarsus porcatus* (Platypodidae); (B) *Platypus jansoni* (Platypodidae); (C) *Xyleborus destruens* (Scolytidae); (D[†]) newly hatched larva; (E[†]) young larva; (F[†]) fully fed larva; (G[†]) pupa (reproduced from Roberts, H., 1987[†]; photos Schneider, M.F.)

Apart from the general preventive measures outlined in **chapter 8.2.1**, the following recommendations should be followed to lower the risk of an ambrosia beetle attack:

- transport logs immediately after felling to the saw mill for further processing and drying
- sprinkle logs with water or a preventive application of insecticide, if logs cannot be converted to lumber immediately
- instant seasoning of lumber after cutting
- if normal seasoning is not possible, cut timber should undergo **dip diffusion** or **pressure impregnation**
- carry out tending and thinning properly, so that any damage to the trees is minimised
- forest operations should not be carried out during wet weather
- do not fell trees that are obviously infested, since the timber is of very poor quality

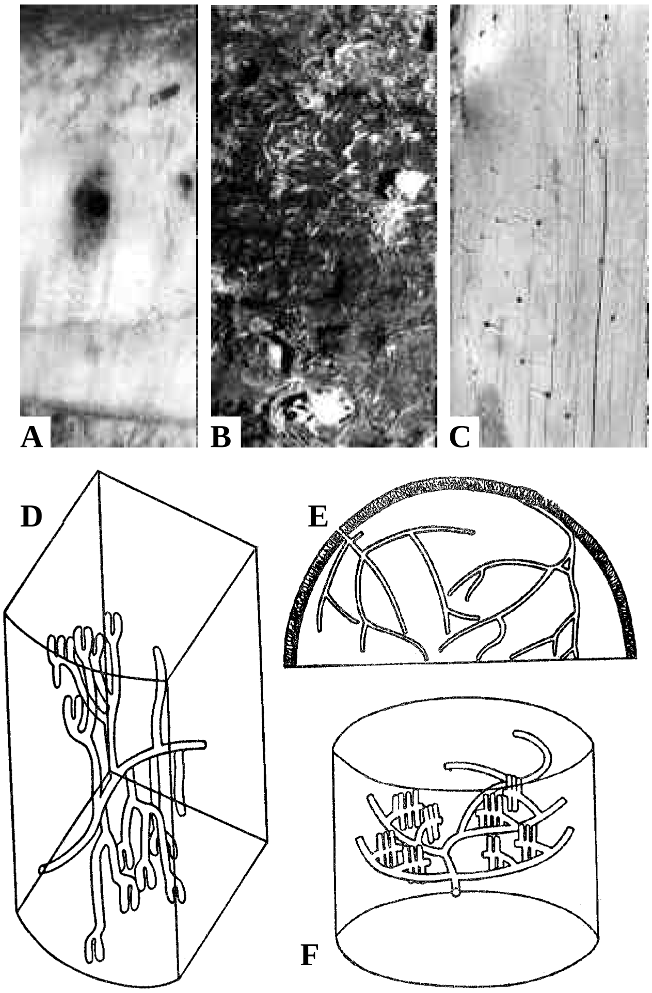

Fig. 6-12: Pin- and Shot-Hole Borer Damage: (A) elongate fungal stain of the wood surrounding the bore hole; (B, C) typical pin- and shot-holes are free from dust, the frass is deposited outside the bore holes; (D†) galleries made by *Crossotarsus spp.*; (E†) *Xyleborus spp.*; (F†) *Platypus spp.* (reproduced from Roberts, H., 1987†; photos Schneider, M.F.)

***Hylurdrectonus araucariae* (Schedl)**

Apart from termites, the minute **Scolytidae** beetle *Hylurdrectonus araucariae* is the most destructive pest of young *Araucaria cunninghamii* in the Bulolo-Wau area. Seedlings and older trees are rarely targeted by the beetle, however four to 12 year old trees are the most susceptible. Hoop pine seems to be the only host of this beetle. Records of the first *Hylurdrectonus araucariae* outbreak date back to the late fifties, followed by a very severe infestation starting in 1966 and lasting until the early seventies. During the peak of the outbreak in 1972, 47.5% of the 3252 ha of planted Hoop pine at Bulolo and 91% out of 1186 ha at Wau were severely infested by the beetle. As a result of this calamity, any further planting of Hoop pines was abandoned. The tremendous economic loss justified ULVA spraying of Propoxur® in the early seventies. After the treatment, the population of the beetle decreased considerably, however regular monitoring up to the present time shows evidence of the beetle in Hoop plantations. The attacks seem to have become more serious since 1996 at Wau and since 1997 at Bulolo and call for an appropriate control programme of the beetle in order to avoid another major set-back to the plantation.

The black adult beetles, shown in **figs. 6-3 Z3** and **6-13 D**, are of 1.5 to 2 mm body length and can be easily found together with eggs, larvae and pupae in the branchlets of an infested tree. The beetles bore entrance holes of about 0.5 mm diameter into the base of the needles as shown on **plate 11 G**, and mine further into the cortex of the branchlets. The eggs are laid into the excavated galleries, where all stages of the life cycle (**fig. 6-13**) develop and live together in a community. The day-flying adult beetles develop within three to six weeks from the egg and have a life span of about two months. The number of individuals per nest varies between 10 and 60. Both, larvae and adults are responsible for the damage. Natural enemies of *Hylurdrectonus* are unknown.

At the initial stage of the infestation the branches of the lower or middle portion of the crown are affected (**plate 11 I**). As a result of the cortex mining, the transport of nutrients and water is disrupted so that the affected branchlets wilt. The colour of the needles subsequently changes from green to yellow and brown. The wilt always starts at a distinct area, where the nest is located and proceeds further towards the tip of the branchlet (**box 6-1 B** and **plate 11 G**). During the further progress of the infestation, the branches of the middle and upper crown, and finally the leader are affected, resulting in defoliation and loss of increment. Less vigorous trees die after two to six years of a severe attack.

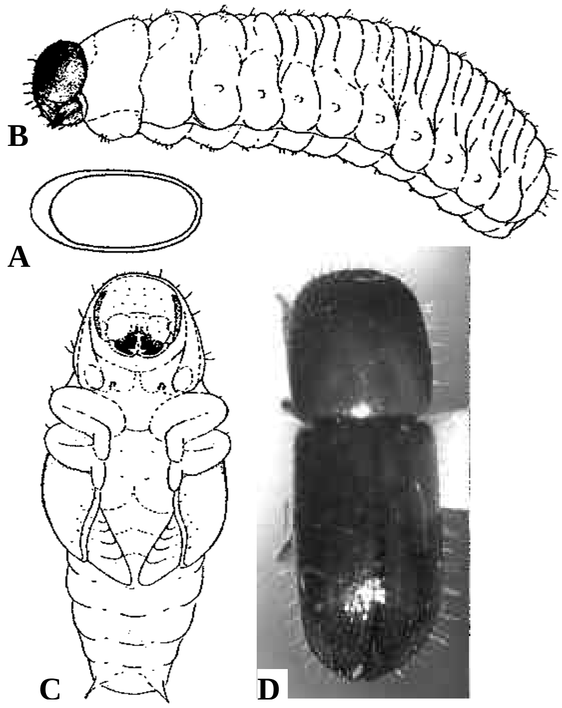

Fig. 6-13: Life cycle of *Hylurdrectonus araucariae* (Scolytidae): (A) egg; (B) larva; (C) pupa; (D†) adult (reproduced from Gray, B., 1968; photo Schneider, M.F. †)

Hylurdrectonus araucariae outbreaks occur periodically. However, proper hygiene in the plantation and other preventive measures outlined in **chapter 8.2.1** contribute a lot towards preventing outbreaks. Therefore, the silvicultural treatments such as tending and pruning should not be delayed but carried out as early as possible. In the early stage of the attack high pruning and the burning of the affected branches is recommended. This is definitely an environmentally sound measure for the control of the beetle. The feasibility however seems to be doubtful since such an exercise is very time consuming and labour intensive, apart from the fire hazard arising from the combustion of the pruned branches. The application of a suitable insecticide is the most expensive measure and is only justified in case of a very severe economic loss, for instance, if the upper crowns of most trees in almost all parts of the plantation are already severely affected. Due to the tree height, the difficult topography and thermal winds in PNG, chemical methods require a helicopter for the proper application of insecticides.

Other Wood-boring Beetles

Apart from the pin- and shot-hole borers (**Scolytidae** and **Platypodidae**), there is a large number of mainly weevils (**Curculionidae**) and longicorn beetles (**Cerambycidae**) that are associated with wood. Most species attack dying or diseased trees or green timber, resulting in its degrade. A few species of powderpost beetles (**Bostrichidae**, **Anobiidae**) can be found in dried wood causing structural damage of timber products. The typical bore holes of weevils are filled with putty-like frass (**fig. 6-2 F**) that shrinks when dried. Thus these holes can be easily distinguished from pin- and shot-holes that are always free of dust. Common weevil (**Curculionidae**) pests are for instance *Vanapa oberthuri* (discussed below), *Illacuris laticollis*, *Aesiotes notabilis* and *Sympiezoscelus*. These weevils usually take advantage of the host's decreased natural resistance caused by injury, diseases, fire and other stress factors. *Illacuris laticollis* can be frequently encountered on stressed or dying trees after forest fires, where the females lay eggs on the margin of resin flow (**box 6-1 F**). The pine bark weevil *Aesiotes notabilis* (**fig. 6-14 A**) is mainly associated with standing *Araucaria*, *Agathis* and *Pinus*. In plantations an infestation usually occurs on injuries caused by pruning. The larvae feed on the phloem next to the pruning wound. Pupation takes place in the wood. An *Aesiotes* attack can introduce fungal diseases into the tree or can be followed by a secondary infestation. Other destructive wood-boring weevils of Hoop and Klinkii are *Mitrastethus australiae*, *Orthorhinus patruelis* and *Coptocorynus*.

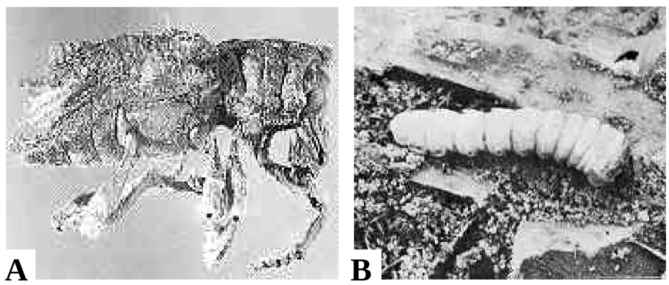

Fig. 6-14: (A§) the pine bark weevil *Aesiotes notabilis* (Curculionidae); (B) *Hyplocerambyx severus* larva (Cerambycidae) (reproduced from Peters, B.C. et al., 1996§; Gray, B. & Wylie, F.R., 1974)

Longicorn beetles (**Cerambycidae**) lay their eggs under the bark or in cracks of the bark of their host. The characteristic larvae (**fig. 6-14 B**) bore into the cambium where they feed and leave an engraved pattern on the adjacent sapwood surface. The mature larvae tunnel into the sapwood or heartwood for pupation. The adults cut more or less oval emergence holes of up to 28 mm diameter. The life cycle takes from three months for smaller species up to more than one year for larger species. The longicorn beetles usually infest severely weakened and dying trees as well as felled logs. Seasoned timber is not attacked. The tunnelling does not cause structural damage, but degrades the value of the timber. Common secondary pests of *Araucaria spp.* and other hosts are *Potemnemus spp.* (**fig. 6-3 U**), *Diotimana undulata*, *Hyplocerambyx severus* (**fig. 6-3 W**), *Dihammus australis*, *Dihammus tincturatus* (**fig. 6-3 V**) and *Pterolophis sp*.

Powderpost beetles of the families **Anobiidae** and **Bostrichidae** usually attack seasoned timber and untreated timber products such as furniture and carvings, however some species infest living trees. They are named so because they produce fine, powder-like frass that can be found on the surface of the affected timber product. Before oviposition the females bite the wood, leaving several grooves. This probing is probably done to find out whether the wood contains sufficient starch, the essential food for the larvae. In case the wood is suitable, the female beetle lays a few eggs in the open pores of the sapwood. The developing larvae bore along the grain of the wood. For pupation the larvae tunnel towards the surface of the wood where they prepare a small oval pupation chamber. The adults surface through a round emergence hole about 1 to 2 mm in diameter. The holes are not stained as in the case of pin- and shot-hole borers. Characteristic also are the small piles of the powdery frass that are usually next to the holes or fall nearby. The re-infestation of the timber is common and can continue until the source of food is depleted. The conditions for a powderpost beetle attack are the moisture content of the wood which is maximum at around 15%; the size of the pores that has to be larger than the diameter of the female ovipositor; and the starch content that has to be high enough to nourish the larvae. Susceptible are *Eucalyptus* like *E. torelliana* that is mainly attacked after fire by *Xylothrips religiosus* (**box 6-1 R**), *Dinoderus munutus* and *Xylopsocus gibbicollis*.

Reliable and efficient control measures are not available. However problems related to wood borers can be avoided by minimising the damage during pruning and thinning. General guide-lines for the prevention of insect pest infestation are given in **chapter 8.2.1**.

The Hoop Pine Weevil *Vanapa oberthuri* (Pouillaude)

The Hoop pine weevil *Vanapa oberthuri* (**Curculionidae**) launched a serious attack in the plantations around Bulolo between 1962 and 1969. At one stage 1,500 trees had to be removed and burnt or debarked. The weevils started their attack after a pruning operation. Another outbreak occurred after thinning operations, so that these had to be halted. A study revealed that Hoop pine is hardly attacked in its natural stands. In plantations the damage was lowest in trees aged four to seven years and highest in trees between nine and 22 years. The damage usually occurs clumped in groups of up to ten trees. Secondary **Curculionidae**, **Cerambycidae**, **Platypodidae** and **Scolytidae** pests are quickly attracted to trees that are infested by *Vanapa*. The attack can result in the quick death of the host after five months, but vigorous trees survive the infestation by drowning the larvae in a copious flow of resin. According to the literature, Hoop pine seems to be the only host of *Vanapa*, however, after the fire in McAdam National Park in 1997, many of the gigantic Klinkii were infested by *Vanapa*.

The black adult weevils are conspicuous due to their variable body length of up to 7 cm and the size of their curved long proboscis (**figs. 6-3 X** and **6-15 D**). The females lay their eggs preferably on the margin of resin exuding from pruning nodes or other injuries. If no resin is present the eggs are either laid under

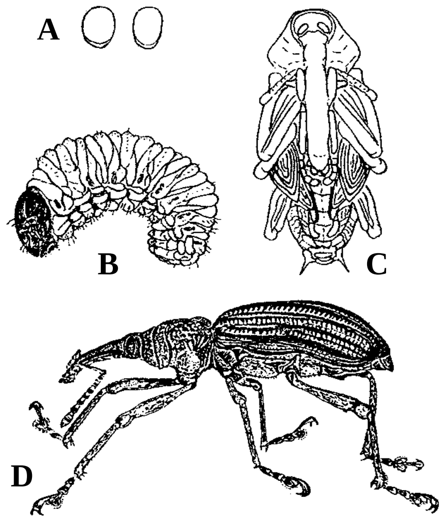

Fig. 6-15: Life cycle of the Hoop pine weevil *Vanapa oberthuri* (Curculionidae): (A) eggs; (B) larva; (C) pupa; (D) lateral view of an adult beetle (reproduced from Gray, B., 1968)

loose bark or on to the outer bark of the stem and then covered with a cemented layer of masticated bark. The oviposition sites are prepared by the help of the strong rostrum. Ten days after oviposition, the newly hatched larvae excavate a tunnel into the outer bark. After about six weeks, when the larvae have reached the third instar, they bore deeper into the fibrous bark and the wood. Initially the tunnel is dug horizontally, then curves upwards and finally turns outwards. The J-shaped tunnel reaches to a depth of about 4 cm into the wood. If many larvae infest the same stem, a crushing noise produced by the larvae is audible. After approximately five months the larvae pupate in a pupal chamber (**box 6-1 E**) that is plugged with slivers of wood. The pupal stage takes about one month. The newly hatched adults stay for another two to four weeks in the pupal chamber before they chew their way outside through an emergence hole with a diameter of 0.8 to 1.3 cm. The whole life cycle takes about six months but can last eight months if the conditions of the host's bark are less favourable. The life span of an adult is between six and eight weeks. The larvae feed only on wood whereas the adults eat the green bark of the pine twigs.

Successful control requires regular monitoring of the Hoop pine weevil populations. This is unfortunately difficult and expensive. Deposits of clean wood debris on the bark and the occurrence of dead branches are typical signs of a *Vanapa* attack. For the control of *Vanapa* the felling of the infested trees is suggested. These trees have to be removed by either burning or debarking. The debarked tree should be laid on the open ground so that all eggs and larvae are killed by the heat of the sun and by desiccation. The application of various insecticides dissolved in creosote on the pruning scars showed little effect in preventing *Vanapa* attack, probably due to the washing off of the insecticides by rain. However, pure creosote, a repellent against *Vanapa*, was used for a long time to treat pruning scars and injuries inflicted during thinning. Biocontrol agents are not available, even though predacious click beetle larvae (**Elateridae**) and a virus are known natural enemies of *Vanapa oberthuri*.

6.2.6 Lepidopteran Pests

Lepidoptera (moths and butterflies) are the second most diverse pest insect order outnumbered only by the beetles. There is hardly any cultivated plant that is not attacked by at least one lepidopteran pest. As pollinators of many plants, adult moths and butterflies are usually beneficial insects that feed on nectar using their siphoning proboscis. The caterpillars however almost always have chewing mouthparts that are suitable for feeding on various parts of a plant. Most caterpillars are defoliators or miners of succulent plant tissues. The larval wood moths (**Cossidae**) tunnel the heartwood of living trees. They cause gum pockets called '**bird's eyes**' and introduce rot resulting in timber degrade. The development from an egg to an adult can take several years during which the larvae burrow a J-shaped gallery of very large diameter. The damage normally does not harm the host and the boreholes are covered after about one year. However, as a result of a large hole, smaller trees can become more susceptible to wind damage. Adult wood moths are some of the largest and heaviest moths with a body weight up to 25 grams. Cossids are less common minor pests and their damage is usually discovered in the saw mill. The red coffee borer *Zeuzera coffeae* usually attacks coffee plants but can also cause some damage on *Eucalyptus deglupta* and *Terminalia brassii*. The larval bag worms or case moths (**Psychidae**) of the genera *Eumeta* and *Hyalarcta* (**box 6-1 M**) are defoliators of *Eucalyptus*, the caterpillars of *Cryptothelia* feed on *Pinus*. The larvae are typically hidden in cases or bags that are dragged along the surface of the leaf during feeding. Severe pests of seedlings in nurseries are the larvae of **Noctuidae**, called cutworms or army worms. The immature stages live hidden in soil. The caterpillars emerge from the soil and feed on their host during the night. Typically, a young plant is neatly cut off right above the soil. Partial or complete defoliation shown in **box 6-1 P** or bending of the seedling is also common. If a cutworm problem is severe or persists in a nursery, the seedlings have to be protected by the application of a suitable insecticide. A number of **Pieridae** butterflies like *Eurema blanda* (**box 6-1 V** and **fig. 6-4 S**) and other species of this genus defoliate *Albizia* and other leguminous tree crops. Even though the host can be completely and repeatedly defoliated during severe outbreaks, the tree usually survives the attack. Other major species or groups of lepidopteran pests are outlined below.

***Hyblaea puera* Cramer**

The moth *Hyblaea puera* (**Hyblaeidae**, **plate 4 B**) is a common defoliator of teak (*Tectona grandis*) that can be found between the West Indies and Fiji. Apart from teak there is a large number of alternative host plants for these polyphagous caterpillars. The eggs are laid singly on the leaves of the foodplant. Typically the larvae turn over the leaf margin and attach it to the rest of the leaf with a silken thread. Hidden in the resulting shelter, the larvae either feed through all leaf tissues (**open feeding** and **hole feeding**), often leaving only the skeleton or they chew only the epidermis of the leaves (**window feeding**). The signs of the attack are illustrated in **box 6-1 U**. The pupae are also hidden in leaf folds or in between leaves that are tied together. During periodical outbreaks, as they occurred at Brown River or Gabensis, the host can be severely or completely defoliated as shown in **box 6-1 U**. Furthermore, the impact of the caterpillars can result in forked tops if the damage affects the leaders. The attack can kill smaller seedlings but usually only decreases the growth increment. Since the damage is very severe and effective control measures are unavailable, the large scale planting of teak has been abandoned in PNG.

Cedar Shoot Borer *Hypsipyla robusta* (Moore)

The cedar shoot borer *Hypsipyla robusta* (**Pyralidae**, **plate 4 C**) is widely distributed in the Tropics of the old world. The main larval foodplants belong to the family **Meliaceae**. The cedar shoots are tunnelled longitudinally or other succulent parts of the host are mined by the caterpillars. A caterpillar can infest several shoots during its larval instars. The completion of the life cycle takes about two months. As a result of the attack, the shoot tip wilts as shown in **box 6-1 S**, and the plant develops lateral branches with multiple leaders. If the attack sustains, the stem becomes crooked and twisted. Furthermore the growth increment decreases and the timber quality is very poor. Effective control measures are not available, therefore teak is not planted on a large scale in Papua New Guinea. Trials using an insecticide in a slow release formulation showed some protection during the initial susceptible growth period of the host plant. However, alternative control methods such as the use of a suitable biocontrol agent seem to be much more promising. Cooperative research between FRI and CSIRO aims to utilize *Hypsipyla*-resistant plant material in an attempt to overcome the problem.

Millionaire moth *Milionia isodoxa* Prout

Severe defoliators of Hoop pines at Bulolo, Wau and other parts of Papua New Guinea are the *Araucaria* loopers or millionaire moths *Milionia isodoxa* (**Geometridae**) and other species of this genus (**plate 5 A** to **F**). A severe attack caused by the caterpillars was recorded at several locations in the Eastern Highlands Province during the sixties.

Milionia is a potential threat to the large Hoop pine plantations at Bulolo and Wau, where the small, brilliantly coloured adults can be commonly encountered in large numbers. The male adults can often be found imbibing water, minerals and organic compounds of animal dung, dead animals, decaying vegetable matter, mud and sand along roads, puddles and creeks. The females visit flowers, especially of *Eucalyptus deglupta* and *Dysoxylum sp.* where they drink nectar. Two days after copulation the female lays eggs singly at the base of the host's needles. The hatched brown looper caterpillars have yellow stripes and feed on the surface of the needles and branches. The feeding traces are quite inconspicuous during the first few larval instars and resemble the damage caused by skeletonizers or miners. Older caterpillars leave serrate feeding traces on the needles or reduce the leaves to a stub. A severe infestation of a host tree causes massive defoliation so that the tree appears brown from a distance (**box 6-1 D**). For pupation, the caterpillars descend to the ground by means of a silken thread and burrow in the soil beneath the host tree. The life cycle of the moth takes approximately eight weeks for its completion. The duration of the five larval instars is about 27 days and two weeks for the pupal stage. There is a number of natural enemies like some **Ichneumonidae** and **Braconidae** wasps that parasitize the pupae. The ants *Anoplolepis longipes* and *Oecophylla smaragdina* are effective predators of the caterpillars and some adults fall prey to spiders and praying mantids. Furthermore, the entomoparasitic fungus *Beauveria bassiana* causes high mortality of *Milionia*.

Lymantria ninayi Bethune-Baker

Several species of introduced *Pinus* are grown as major tree crops in some highland regions of Papua New Guinea. Larger *Pinus patula* plantations for instance were established in the Eastern Highlands Province since this species is well adapted to the poor soil conditions of that particular location and, to a certain degree, can resist fire. The major pest is the **Lymantriidae** moth *Lymantria ninayi*

Fig. 6-16: *Lymantria ninayi* (Lymantriidae): (A) egg patch protected under a branch of the host; (B) opened pupal shelter made from needles that are tied together with a silk thread (photos Schneider, M.F.)

that can severely defoliate *Pinus* during periodically occurring outbreaks. In the years 1975 to 1978 there was a major *Lymantria ninayi* outbreak at Lapegu plantation in the Eastern Highlands Province causing the repeated defoliation of *Pinus patula* over an area of 200 ha and resulting in the death of 50 ha and a loss of several millions of Kina. The calamity was terminated by the impact of a natural pathogen, a nuclear polyhedrosis virus (**NPV**, **Baculoviridae**). *Lymantria* outbreaks occur at intervals of seven to nine years. After this major outbreak there were several less severe attacks of minor economic importance. The most recent infestation started in 1997.

The female *Lymantria ninayi* lay their eggs in patches on the bark of the host tree, usually under a branch, shown in **fig. 6-16 A**. Thus the eggs are protected from rain. After hatching, the caterpillars feed on the foliage of the host, according to the caterpillar's size. The younger ones shown on **plate 7 F** feed on the new needles, the older caterpillars (**plate 7 G**) eat the older, mature needles. The larvae have a very 'uneconomic' way of utilising their source of food, because they just bite through a bunch of needles, so that the needles fall down and pile up under the tree (**box 6-1 H**). The larvae feed during the night. During

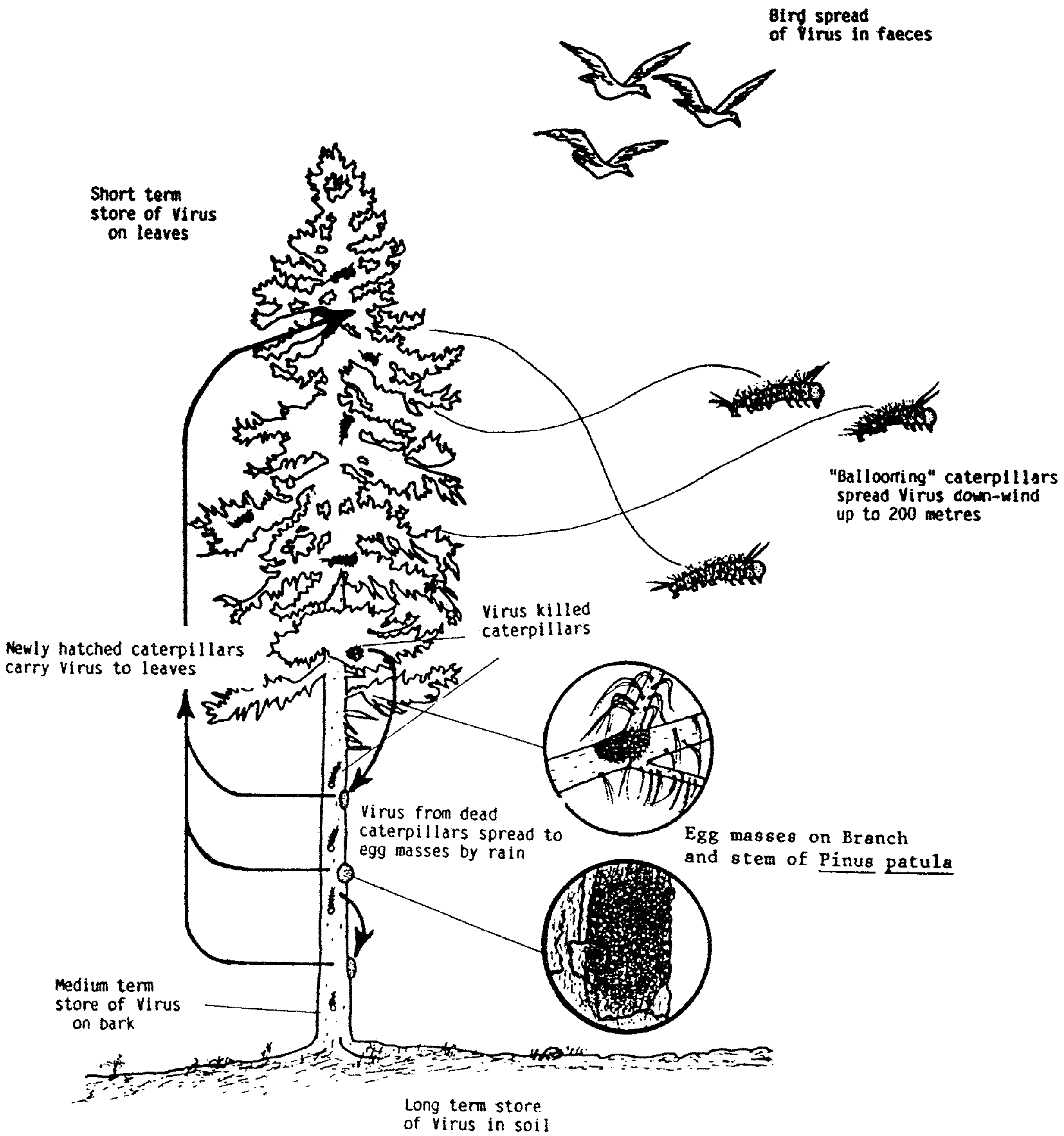

Fig. 6-17: Natural spread of a viral disease of *Lymantria ninayi* (Lymantriidae) in the plantation environment (reproduced from Roberts, H., 1987)

the day they are hidden at the base of the host's stem or in the litter under the tree. *Lymantria ninayi* has five larval instars. The sex of the young caterpillars can be already determined, since the males are smaller and have red dorsal marks (**plate 7 E**). Once grown big enough, the caterpillars either attach themselves to the foliage or hide in the litter beneath the tree and turn into pupae. The pupae are housed in shelters assembled from needles woven together with a silken thread. The pupal shelter shown in **fig. 6-16 B** was opened up so that the chrysalis becomes visible. The adults (**plate 7 D** and **E**) are strongly sexually dimorphic. The large females have filiform antennae and are of much brighter wing coloration than the fairly small males with pectinate antennae. The adults are also nocturnal and rest on the bark of the host during day. The life cycle is completed in three to four months. The natural host of *Lymantria ninayi* is the yar tree

Casuarina (**Casuarinaceae**). Most moths and butterflies usually disperse by means of flight. However, Lymantriidae show very poor flight performance so that these insects use a different strategy to conquer new territories: the light, newly hatched caterpillars climb up to tree tops and are blown to another suitable host tree on long strands of silk as shown in **fig. 6-17**. This type of dispersal is very effective, if the air-borne caterpillars can take advantage of a slope and drift downwards into a valley. There is a variety of natural enemies living on the caterpillars and other stages. Parasitic wasps are known to parasitize the eggs. A study has revealed that birds like rainbow lorikeets are efficient predators that consume considerable numbers of the caterpillars. This seems surprising since the caterpillars are well protected from most predators by their numerous irritating hairs. However, during an outbreak natural enemies have only a little effect on reducing the tremendous number of individuals.

More efficient is a disease caused by two specific Baculoviruses that kill large numbers of the caterpillars and thus naturally regulate *Lymantria* populations. The pathogens are spread naturally by the caterpillars that die and decompose as a result of the virus. The released virus particles are then washed by rain down the bark into the soil, the long-term store of the virus. Virus particles that get stuck to the egg masses are incorporated by the hatched caterpillars, when these eat up the egg shells after emergence. The spread of the virus is therefore favoured by wet climate but also by vectors like birds that eat infected larvae and carry the virus in their faeces to other areas. The virus can remain in the soil for six years without loss of virulence, so that a new outbreak of *Lymantria* is unlikely within this period of time.

The signs of a *Lymantria* infestation are quite conspicuous. Due to the peculiar feeding habit of the *Lymantria* larvae, the host looks always more or less defoliated and the needles pile up under the tree. When the caterpillars occur in large numbers there are not many needles left at the host, making it look grey from a distance. Trees of six years and older are mostly affected by the defoliator. In many cases an infestation starts on the ridge tops and proceeds further down to the valley, where the infestation usually comes to a halt. This is because the caterpillars only disperse effectively downhill. Since *Pinus strobus* is not attacked, it is therefore recommended that this species be planted along the ridges and the susceptible *P. patula* at the bottom of a valley. Coniferous trees are far more sensitive to defoliation than broad-leaved trees since it takes much longer for the needles to regrow. Therefore, a severe defoliation quite likely kills the host if an outbreak persists over several years. At the very least minor infestations result in a drastic decrease of diameter and height increment. Furthermore, the thus weakened trees are more susceptible to attacks by other secondary pests such as wood borers and fungi.

The caterpillars that hatch from five egg masses are sufficient to severely defoliate their host. Therefore the regular monitoring of *Lymantria* populations is the essential part of control programmes. **Nuclear polyhedrosis viruses** (NPV) are the only promising tool for the control of *Lymantria ninayi*. The use of the virus as biocontrol agent however, is hampered by the fact that the virus can only be propagated in its living host.

Other defoliators of *Pinus*

Apart from *Lymantria ninayi*, other moths have been recorded in large numbers defoliating *Pinus*: **Lymantriidae** moths like *Lymantria rosa* (**plate 7 B**), *L. novaguinensis* (**plate 7 C**), *L. flavoneura, Calliteara queenslandica* (**plate 7 A**), *Dasychira mendosa* (**plate 6 O**), some **Saturniidae** moths of the genus *Syntherata* (**plate 5 M - O**), the **Anthelidae** moth *Anthela ekeikei* (**plate 5 P**, **Q**), the bag or case moths *Pteroma plagiophleps* and *Cryptothelia sp.* (**Psychidae**) as well as *Alcis papuensis* and *Paradromulia nigrocellata* (**Geometridae**, **plate 4 J** and **K**). The cocoons or pupal cases made by the caterpillars of some of these species are shown in **fig. 6-18**. Even though these species have the potential to cause outbreaks, their numbers were never high enough to cause severe problems as in the case of *Lymantria ninayi*. An outbreak of *Alcis papuensis* was confined to a smaller area and was therefore less tragic in terms of monetary loss. The small *Alcis* looper caterpillars bite each needle at one side only, so that the needle either breaks or hangs down and starts to wilt. When *Alcis* is abundant, the tree looks brown from a distance due to the many brown needles hanging from the tree. The lifecycle of this moth takes five weeks. As in *Lymantria*, *Alcis* populations are also affected by a Baculovirus.

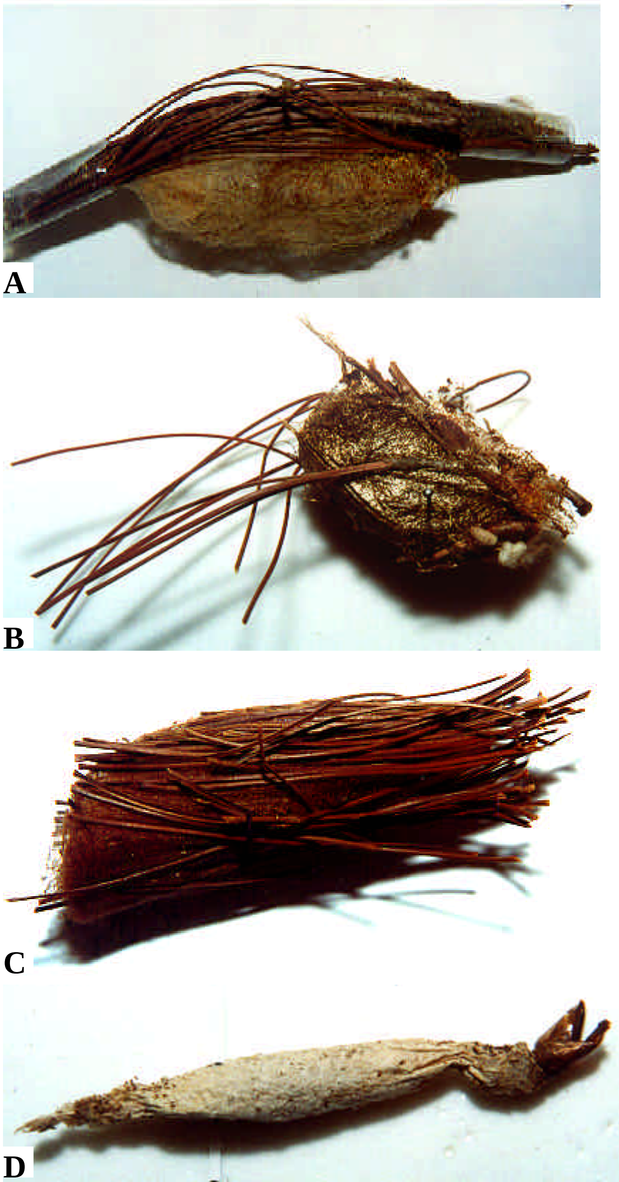

Fig. 6-18: Defoliators of *Pinus*: cocoons and pupal cases of (A) *Calliteara queenslandica* (Lymantriidae); (B) *Syntherata sp.* (Saturniidae); (C) *Anthela ekeikei* (Anthelidae); (D) *Cryptothelia sp.* (Psychidae) (photos Schneider, M.F.)

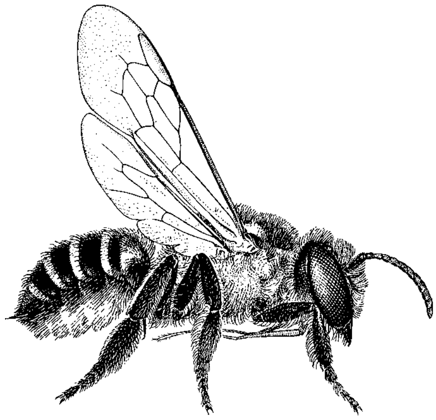

Fig. 6-19: *Megachile frontalis* (Megachilidae) (reproduced from CSIRO, 1991[2])

6.2.7 Hymenopteran Pests

A very small number of forest insect pests occurring in Papua New Guinea are wasps and bees. The larval and adult Hymenoptera that are relevant in this context mainly have chewing mouthparts. Important are gall-forming wasps, particularly of the family **Torymidae**. Oviposition by *Megastigmus* females (**fig. 6-4 U**) induces leaf, shoot and fruit galls on *Eucalyptus*, a condition that is usually of minor significance but might reduce the growth increment of the host. Interestingly, *Megastigmus* wasps are known to be **inquilines** of galls and can often be found together with *Fergusonina* (**Fergusoninidae**, **chapter 6.2.4**) sharing the same gall. Therefore it is difficult to decide which of the two insects is the gall culprit. The long-tongued bee *Megachile frontalis* (Fabricius) (**Megachilidae**, **fig. 6-19**) can defoliate all ages of its host *Eucalyptus deglupta*, causing a minor loss of increment. The carpenter bee *Xylocopa aruana* (**Anthophoridae**, **fig. 6-4 T**), a close relative of *Megachile*, is a common but minor pest of untreated softwoods and can be found along the Papuan coast. Neither the adults nor the larvae feed on wood, but the adult bees bore holes in timber to establish their nests. Since only timber that is in a poor condition is infested, control measures are not necessary. Once the poor piece of timber is replaced, carpenter bee damage usually no longer occurs.

6.3 Forest Insect Pests of other South Pacific Countries

Solomon Islands

There have been reports of a serious *Hypsipyla robusta* (**Pyralidae**) attack of *Toona australis* and *Swietenia macrophylla*. *Albizia falcataria* was defoliated by *Hyblaea puera* (**Hyblaeidae**) and petioles of *Cedrela odorata* and *Toona australis* were affected by an unidentified cricket (**Gryllidae**). Ambrosia beetles like *Diapus* and *Platypus* (**Platypodidae**) and *Xyleborus* (**Scolytidae**), the jewel beetle *Chrysobothris* (**Buprestidae**) and the weevil *Sipalinus gigas* (**Curculionidae**) caused problems in newly felled logs and sawn timber of *Cedrela kajewsii*, *Eucalyptus medullosum*, *Agathis macrophylla*, *Calophyllum inophyllum*, *Gmelina moluccana* and *Pometia pinnata*. Untreated timber and other timber products were severely infested by the termites *Cryptotermes domesticus* (**Kalotermitidae**) and *Coptotermes spp.* (**Rhinotermitidae**).

American Samoa

Apart from the lepidopteran *Hyblaea puera* (**Hyblaeidae**) and *Othreis fullonia* (**Noctuidae**) there seem to be no serious forest insect pests.

Western Samoa

Most probably caterpillars of *Sylepta sabinusalis* (**Pyralidae**, **Lepidoptera**) were responsible for the complete defoliation of *Planchonella samoensis* in about 4,000 ha of natural rain forest on Upolu Island. Apart from that, the detrimental impacts of ambrosia beetles and a few other pests were recorded.

Fiji

The value of *Pinus spp.* and *Swietenia macrophylla* grown for veneer production, was drastically reduced by the impact of the ambrosia beetles *Xyleborus torquatus* (**Scolytidae**), *Crossotarsus externedentatus*, *Xylosandrus abruptoides* and *Platypus gerstaeckeri* (**Platypodidae**). *X. perforans*, *P. externedentatus* and *P. gerstaeckeri* attacked untreated logs of *Agathis virtensis*, *Gonostylus* and *Myristica spp.* a few days after felling. There were also reports of the powder post beetle *Lyctus spp.* (**Bostrichidae**) being a serious problem in seasoned or partly seasoned sapwood timber. Out of the nine termite species occurring in Fiji, the following species are considered as pests detrimental to timber and timber products: *Cryptotermes domesticus*, *Kalotermes repandus*, *Neotermes spp.* (**Kalotermitidae**), *Coptotermes spp.* (**Rhinotermitidae**) and *Nasutitermes olidus* (**Termitidae**). Tree species involved were, amongst others *Agathis vitiensis*, *Swietenia macrophylla*, *Eucalyptus pinaculata*, *Podocarpus vitiensis* and *Syzygium*.

French Polynesia

Reported was the occurrence of the ambrosia beetles *Platypus externedentatus* in *Swietenia macrophylla* plantations. Furthermore some coccids were recorded like *Asterolecanium sp.* (**Coccidae**) on *Cordia subcordata*; *Aspidiotus destructor* (**Diaspididae**) on *Barringtonia* and *Calophyllum*; *Pinnaspis* (**Diaspididae**) on *Anacardium occidentale* and *Terminalia catappa*; and *Octaspidiotus* (**Diaspididae**) on *Araucaria cookii*. The most severe pest in French Polynesia is *Icerya seychellarum* (**Margarodidae**), attacking *Albizia spp.*, *Calophyllum inophyllum*, *Casuarina equisetifolia* and *Tectona grandis*. Apart from that, there are a few minor **Aphididae** and **Noctuidae** pests recorded.

New Caledonia

Apart from the minor pest coccid *Eriococcus araucariae* (**Eriococcidae**) that produces large colonies on *Araucaria columans* and *A. cunninghamii*, there seem to be no serious pests in New Caledonia.

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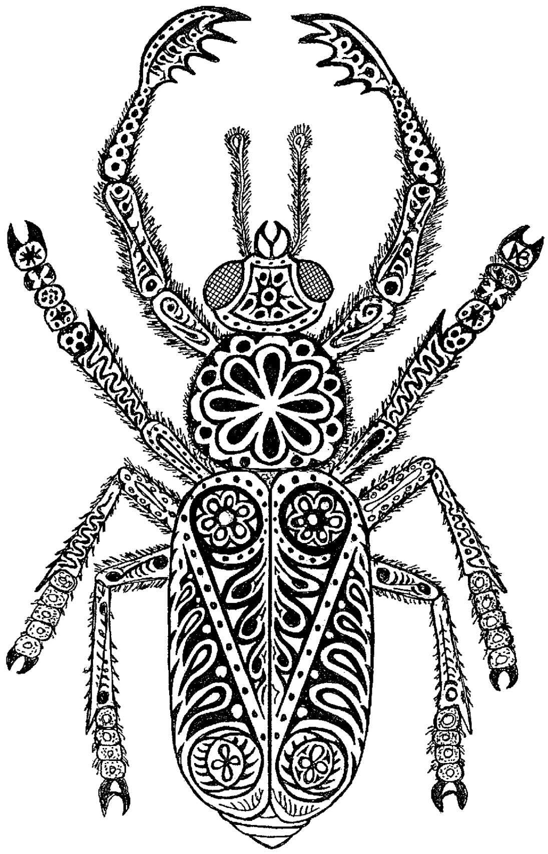

Fig. 6-20: Spider or Insect? (drawing Bosimbi, D.)

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