

Biology of *Chrysophtharta agricola* (Coleoptera, Chrysomelidae), a pest of *Eucalyptus* plantations in south-eastern Australia

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Summary

Chrysophtharta agricola (Chapuis) (Coleoptera: Chrysomelidae) is a pest of eucalypt production forests in south-eastern Australia. Biological characteristics including high fecundity and adult longevity result in the production of large numbers of offspring, despite high levels of offspring mortality from natural enemies. Collection records for *C. agricola* indicate a host range of over 20 eucalypt species and a geographic distribution from northern New South Wales to southern Tasmania. This paper provides estimates of foliage consumption by larvae and reviews the biology of *C. agricola*, including its phenology, life stages and natural enemies. Each larva eats about 347 ± 20 mm³ of juvenile *E. nitens* foliage during its lifetime, with the fourth instar consuming more than half of this. Predators and parasitoids can cause significant mortality in *C. agricola* populations in the field.

Keywords: forest plantations; insect pests; defoliation; natural enemies; phenology; predators; parasitoids; Paropsina; Chrysomelidae; *Chrysophtharta agricola*; *Eucalyptus nitens*; *Eucalyptus globulus*

Introduction

The growth of eucalypts is significantly affected by insect feeding. For example, in eight years, eucalypt trees protected from insects produced about three times the wood volume of unprotected trees (Elek 1997). The insect that has caused the greatest growth reduction in eucalypts in Tasmanian forests is *Chrysophtharta bimaculata* (Olivier) (de Little 1989; Elliott *et al.* 1992, 1993, 1998). Its congener *C. agricola* (Chapuis) has recently emerged as another endemic pest of eucalypt production forests in south-eastern Australia, especially Tasmania, through its feeding on the important plantation species *Eucalyptus globulus* and *E. nitens* (de Little 1989; Elliott *et al.* 1998; Ramsden and Elek 1998; Collett 2001). Here I review the biology of *C. agricola*, defining its host range and geographic distribution from collection records, determining larval foliage consumption and reviewing its lifecycle and natural enemies.

Taxonomy

Chrysophtharta agricola was originally described in the genus *Paropsis* Olivier (Chapuis 1877). Blackburn (1899) realised that Chapuis' original description referred only to a rare melanic morph of *C. agricola*, and he subsequently described the 'ordinary form',

which had been identified by Chapuis as *C. bimaculata*. Blackburn (1899) reported that 'it is difficult to find two specimens absolutely alike', which may reflect confusion between teneral (i.e. an adult with a soft cuticle, as when it has recently emerged from the pupa) and mature beetles, as described by de Little (1979) and Selman (1994b). Weise (1901) changed its generic placement from *Paropsis* to *Chrysophtharta* Weise, and also erected the sub-tribe Paropsina to which *Chrysophtharta* belongs (Kelly and Reid 1999). The type species for the genus was designated *Paropsis nobilitata* Erichson by Kelly and Reid (1999). A taxonomic key to species was produced by de Little (1979), which describes the common and melanic forms of *C. agricola*.

Geographic distribution

Locality data from collection labels of adult *C. agricola* specimens held in several museum collections (see Acknowledgements) are shown in the map (Fig. 1). Records of *C. agricola* from mainland Australia include the New South Wales–Queensland border, Victoria and the Australian Capital Territory. Generally, it is believed to be most common at high altitudes (G. Maywald, CSIRO Entomology, and C.A.M. Reid, Australian Museum, *pers. comm.*), and its western-most distribution was recently recorded in eucalypt plantations in southern Victoria (M. Matsuki, CRC-SPF, *pers. comm.*). In de Little's (1979) extensive Tasmanian survey, *C. agricola* was not found further south than Bothwell (42°23'S), and in the 1980s its southernmost distribution was recorded at the Florentine Valley (42°39'S) (D. Bashford, Forestry Tasmania, unpubl. data.). Its current distribution includes recent plantations as far south as Geeveston (43°11'S), suggesting a movement rate of around 50 km each decade, coincident with *E. nitens* plantation establishment. Electrophoretic studies indicate that *C. agricola* populations exhibit low levels of genetic mixing, consistent with little dispersal (Nahrung and Allen 2003a). In comparison, *C. bimaculata* populations throughout Tasmania undergo significant genetic mixing (Congdon *et al.* 1997).

Host records

Twenty-four eucalypt and one acacia species are recorded as hosts or incidental hosts for *C. agricola* (Table 1). Many are collection records only and not all of the species listed may support reproduction and development. Half of the eucalypt species in this list belong to the subgenus *Symphyomyrtus*, which may

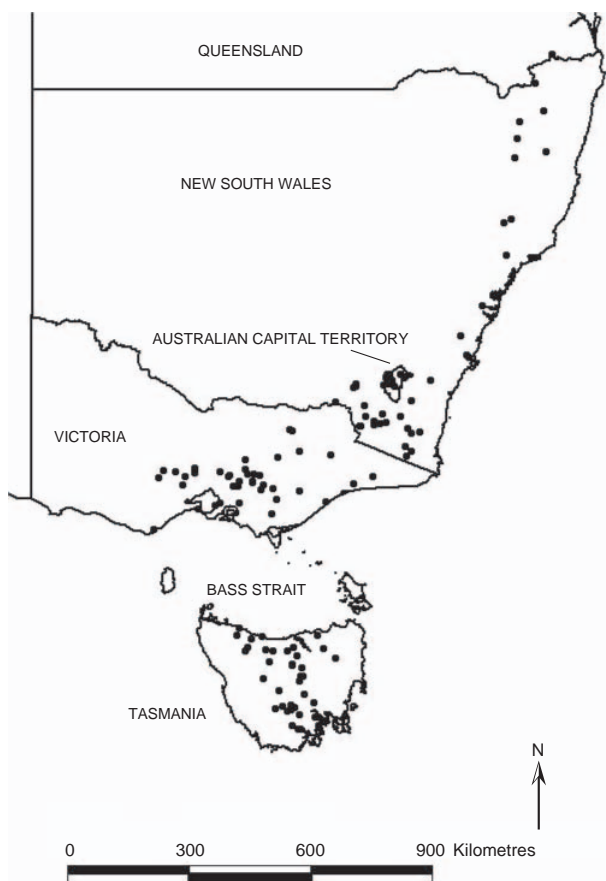


Figure 1. The geographic distribution of *Chrysophtharta agricola* in Australia. Data were collated from collections held at the Victorian Museum, NSW State Forests, the Museum of South Australia, the Australian Museum, the Queensland Museum, Tasmanian Department of Primary Industries, Water and Environment, and the Australian National Insect Collection, from Burdon and Chilvers (1974), de Little (1979), Elliott *et al.* (1998), Ramsden and Elek (1998), my personal collection records, and those of G. Maywald, N. Collett, M. Matsuki and S. Strauss.

support a more diverse herbivore assemblage and suffer greater herbivory than *Monocalyptus* species (Lowman and Heatwole 1987; Noble 1989; but see Wotherspoon 1998). For instance, Burdon and Chilvers (1974) recorded almost ten times as many *C. agricola* adults on *Symphyomyrtus* species as on monocalypts, and de Little (1979) also collected *C. agricola* most frequently on *Symphyomyrtus* hosts. de Little and Madden (1975) compared larval performance of *C. agricola* on a *Symphyomyrtus* host and a *Monocalyptus* host, and suggested that *C. agricola* was competitively excluded from the latter host by its more highly r-selected congener, *C. bimaculata*. However, Li (1993) found no significant differences in the feeding response of *C. agricola* between *Symphyomyrtus* and *Monocalyptus* species, and attributed the host range of *C. agricola* to leaf surface wax components.

Glauconess of juvenile eucalypt foliage is thought to constrain paropsine beetle attack by reducing the beetles' ability to cling to leaf surfaces (Edwards 1982; Edwards and Wanjura 1990). However, *C. agricola* feeds on the glaucous species *E. globulus*,

Table 1. Host records of *Chrysophtharta agricola* in its native range in Victoria, New South Wales and Tasmania

Tasmania	Other States	Sub genus ^a	Source
<i>E. dalrympleana</i>	<i>E. dalrympleana</i>	S	Neumann 1993; de Little and Madden 1975; de Little 1979; ANIC collection record; author's collection record
<i>E. globulus</i>	<i>E. globulus</i>	S	de Little 1979, 1989; Li 1993; Elliott <i>et al.</i> 1998; Simmul and de Little 1999; author's collection record
<i>E. nitens</i>	<i>E. nitens</i>	S	de Little 1979, 1989; Li 1993; Neumann 1993; Elliott <i>et al.</i> 1998; Ramsden and Elek 1998; Simmul and de Little 1999; author's collection record
<i>E. viminalis</i>	<i>E. viminalis</i>	S	Neumann 1993; de Little 1979; Li 1993; Elliott <i>et al.</i> 1998; Simmul and de Little 1999; ANIC collection record; author's collection record
<i>E. obliqua</i> ^b	<i>E. obliqua</i> ^b	M	de Little 1979; Li 1993; Neumann 1993
<i>E. pauciflora</i> ^b	<i>E. pauciflora</i> ^c	M	Li 1993; ANIC collection record
<i>E. gunnii</i>		S	de Little 1979; Li 1993
<i>E. ovata</i> ^d		S	de Little 1979; Li 1993
<i>E. rubida</i> ^d		S	de Little 1979
<i>E. delegatensis</i> ^{b,d}		M	de Little and Madden 1975; de Little 1979; Li 1993
<i>E. tenuiramis</i>		M	de Little 1979; Li 1993
<i>E. regnans</i> ^{d,e}		M	Li 1993
<i>E. sierberi</i> ^{d,e}		M	Li 1993
	<i>E. aromaphloia</i> ^c	S	ANIC record
	<i>E. cytellocarpa</i> ^c	S	ANIC record
	<i>E. grandis</i>	S	Neumann 1993
	<i>E. perriniana</i> ^c	S	ANIC record
	<i>E. fastigata</i> ^b	M	Neumann 1993
	<i>E. fraxinoides</i> ^c	M	ANIC record
	<i>E. globoidea</i>	M	Neumann 1993
	<i>E. pilularis</i>	M	Neumann 1993
	<i>E. radiata</i> ^{c,d}	M	ANIC and NSW State Forest Insect Collection record
	<i>E. stellulata</i>	M	S. Strauss pers. comm.; ANIC record
	<i>E. camaldulensis</i> ^e	S	Harcourt <i>et al.</i> 2000
	<i>Acacia dealbata</i> ^{c,d}		Van den Berg 1982

^a Classification from Pryor and Johnson (1971): M = *Monocalyptus*; S = *Symphyomyrtus*.

^b Non-preferred host (Neumann 1993/Li 1993). ^c Collection record only.

^d Also occurs in Tasmania/mainland Australia, but not recorded as a host of *C. agricola* there.

^e Fed in laboratory trials only (Li 1993; Harcourt *et al.* 2000), no field record.

E. nitens, *E. gunnii*, *E. delegatensis*, *E. pauciflora*, *E. cypellocarpa*, *E. fraxinoides*, *E. perriniana*, *E. aromaphloia* and *E. tenuiramis* (Table 1; see Brooker and Kleinig 1999). Some other paropsine species, *C. variicollis* (Chapuis), *Paropsis aegrota* Boisduval, *P. porosa* Erichson and *P. tasmanica* Baly, also occur on glaucous juvenile *E. nitens* foliage (pers. obs.). *Chrysophtharta bimaculata* feeds on the non-glaucous adult foliage of *E. nitens* (de Little 1989), but unlike *C. bimaculata*, adult *C. agricola* can easily crawl on glaucous juvenile foliage (Li 1993).

Eucalyptus nitens is not native to Tasmania and has become a host for *C. agricola* in Tasmania only since its introduction as a plantation hardwood. Some paropsine oviposition strategies (viz. eggs in batches) suggest that they may have evolved on rare, dispersed or unpredictable host plants (see Vasconcellos-Neto and Jolivet 1994), which may in part explain the increase in *C. agricola* populations when suitable host plants became common in monospecific forestry plantations (*sensu* Steinbauer 1998). Indeed, de Little and Madden (1975) credited the natural growth habit (i.e. mixed stands) of hosts with 'effectively preventing serious and widespread outbreaks of *C. agricola*', thus foreshadowing its increase as *Symphyomyrtus* plantations were established.

General biology

Eggs of *C. agricola*

Eggs are laid and cemented in an 'untidy heap', usually at the tip of the leaf (Ramsden and Elek 1998), where ovipositing females can cling most strongly (Edwards and Wanjura 1990; Howlett 2000). The number of eggs per batch varies, with reports of 30–60 in the field (de Little 1979), and averages of 21.9 (Ramsden and Elek 1998) and 29.7 eggs per batch in the laboratory (Nahrung and Allen 2003b). The latter measurement surpasses *C. bimaculata* as the highest average egg batch size for paropsines (see Simmul and de Little 1999). Each egg is about 2.0 mm long and 0.7 mm wide (Ramsden and Elek 1998), grey-brown (de Little 1979) or yellow to light brown in colour (Ramsden and Elek 1998), or rarely orange (pers. obs.). The egg chorion is evenly covered with short hairs (Ramsden and Elek 1998) that under scanning electron microscopy (SEM), appear as papilla-like projections on the chorion, possibly produced by the colleterial glands (Selman 1994a) or lateral oviducts (Hilker 1994) of the mother.

Larval instars

Larvae hatch with the aid of hatching spines (Simmul and de Little 1999) from the centre of the dorsal chorion, consume the chorion (Ramsden and Elek 1998), and may also consume any surrounding infertile eggs (Selman 1994a). Although egg bursters are usually poor generic or specific characters (Cox 1994b), the larvae of *C. agricola* are distinct from the larvae of other paropsine species because sclerite DLe is split into two (C.A.M. Reid, Australian Museum, pers. comm.).

There are four larval instars. The duration of each instar at different temperature regimes and on different hosts is provided by de Little and Madden (1975) and Ramsden and Elek (1998). Head capsule width measurements for each instar are given by de Little (1979), Ramsden and Elek (1998) and Nahrung *et al.* (2001). The first

three larval instars are black, and the fourth instar may have an orange lateral stripe (de Little 1979). The last visible larval abdominal segment contains a retractable bi-lobed 'foot' which aids in walking and adhesion to the leaf surface. Like several other paropsine species (see Simmul and de Little 1999), larvae of *C. agricola* are strongly gregarious (de Little 1979), and possess a pair of eversible glands between the seventh and eighth abdominal tergites that secrete a liquid which probably contains hydrogen cyanide, benzaldehyde and glucose (Moore 1967). The size of the group can affect larval survival, especially on older foliage (Nahrung *et al.* 2001). Gregariousness is maintained through all instars, although the group size is smaller in older larvae (Nahrung *et al.* 2001). Groups comprising different paropsine species and/or larvae of different instars are common (e.g. Carne 1966; de Little 1979; pers. obs.).

Larval feeding trials

Chrysophtharta agricola egg batches were collected from a laboratory-reared colony originating from the Florentine Valley, held at $21 \pm 2^\circ\text{C}$, 16L:8D photoperiod. Ten single, newly-emerged, unfed (except on egg chorion) *C. agricola* larvae from different egg batches were transferred using a fine paintbrush to each of ten fresh excised juvenile *Eucalyptus nitens* leaves (first or second expanded leaf) in petri dishes. Leaves were measured (mm^2) prior to introduction of larvae using a leaf-area meter (Delta-T Devices). Every two days, new leaves were measured, and added to the dishes to replace those leaves on which larvae had fed. The larval instar was recorded, and the leaf area of eaten leaves was measured. The area of foliage removed by each feeding larva was determined by subtracting the eaten leaf area from initial leaf area, and the average foliage consumption per larval instar was calculated. Areas were converted into volume by multiplying the area by the average thickness of leaves, determined as in Nahrung *et al.* (2001) (average leaf margin and leaf lamina widths for the first and second leaf pairs = 0.22 mm).

Each larva ate an average of $347 \pm 20 \text{ mm}^3$ of juvenile *E. nitens* foliage during their larval lifetime in feeding trials: an amount equivalent to less than one average juvenile leaf (leaf pairs 1–3). The final instar alone contributed over one-half of the total larval foliage consumption (Fig. 2), a pattern seen in most holometabolous phytophagous insects (see Chapman 1998).

Larvae reach a maximum length of 14 mm (de Little 1979) before dropping to the ground (Carne 1966; Greaves 1966; Clarke *et al.* 1998b) to pupate in the leaf litter and soil (Ramsden and Elek 1998) following a short pre-pupal stage.

Pupae of *C. agricola*

Pupae are glossy yellow-orange (Ramsden and Elek 1998), setose, tuberculate (Reid 1992) and exarate, and are probably contained within earthen cells in which they develop (Cumpston 1939; Carne 1966). Reid (1992) provided descriptions and a key for the pupae of nine common paropsine genera, including *Chrysophtharta*. The sex of pupae can be differentiated using morphological differences in sternites VII and IX, and male pupae are generally smaller than female pupae (Reid and Ohmart 1989).

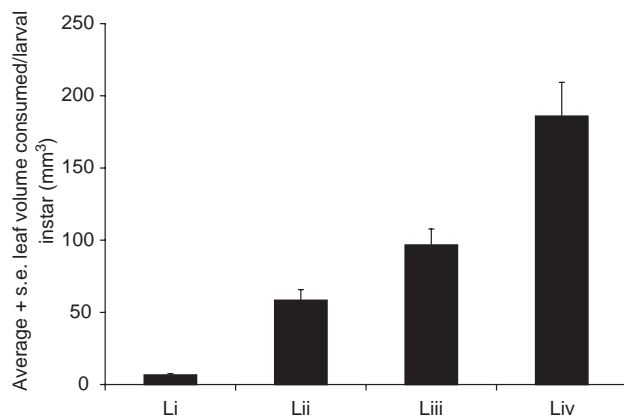


Figure 2. Average (+ s.e.) foliage consumption of each instar of *Chrysophtharta agricola* on juvenile *Eucalyptus nitens* foliage

Adult *C. agricola*

Adults are grey-black with bright red prothoracic and elytral margins when newly emerged from pupation (de Little 1979). The red pigmentation disappears as the insect matures (Selman 1985, 1994b) and changes colour to dark brown or grey (de Little 1979) with light speckles and an opaque elytral margin (Ramsden and Elek 1998), or golden-brown in mainland Australia (Selman 1994b). The dorsal pronotum bears a pair of diagnostic black spots, and the species can be distinguished from *C. bimaculata* by its dark ventrites. The black adults mature to attain entirely shining black elytra (de Little 1979), and such colouration is under genetic control (Nahrung and Allen, in press).

Females are larger than males, and can be distinguished from them by differences in the first tarsal segment of the mid- and forelegs, which in females is narrow and elongate (de Little 1979), and possesses a longitudinal glabrous line (Baly 1862). In males, the same segment is broad, flat and undivided, which allows them to hold onto the smooth elytral surface of females during copulation (Selman 1994b).

Adults feed, and about 30% of females mate, before overwintering in leaf litter (Nahrung and Reid 2002), soil, or other sheltered places (Neumann 1993) including cutting grass, *Gahnia grandis* (Clarke *et al.* 1998a; pers. obs.). Overwintering adults emerge in October or November, and lay eggs between November and March (Ramsden and Elek 1998). Adults are darker-coloured during overwintering than when reproductive, and the haemolymph colour of overwintering adults differs from that of newly-emerged and reproductive adults (Nahrung and Reid 2002).

Adults feed on adult and juvenile foliage of *E. nitens*, with a feeding preference for adult foliage (Lawrence 1998; Nahrung and Allen 2003b), although de Little (1989), Bashford (1993), Elliott *et al.* (1998) and Ramsden and Elek (1998) thought the species preferred juvenile foliage. Adults feed by scalloping the leaf margins (Ramsden and Elek 1998). Heavy defoliation removes new growth, resulting in a characteristic 'broom-topped' appearance to trees (Leon 1989; Collett 2001; Fig. 3). The most vigorous feeding by adult paropsines occurs prior to overwintering, which may prevent foliage regrowth, leaving exposed shoots susceptible to damage by severe cold in winter (Elliott *et al.* 1993).



Figure 3. Feeding damage to leading growth shoots of a 3-y-old *Eucalyptus nitens* tree caused by *Chrysophtharta agricola*

Chrysophtharta agricola is usually univoltine (Ramsden and Elek 1998), or occasionally bivoltine (Nahrung 2003) in Tasmania, and is bivoltine in Victoria (Neumann 1993; Collett 2001). Temporal peaks in oviposition may be confused with a second generation; for example, Greaves (1966) thought that *C. bimaculata* was bivoltine in southern Tasmania, but subsequent studies suggested that there is only one generation each year (de Little 1983). Overwintering (and therefore voltinism) in *C. agricola* is controlled by photoperiod and temperature (Nahrung 2003).

Pest status

Initially, *C. agricola* was thought to feed preferentially on juvenile foliage of *E. nitens* (de Little 1989; Bashford 1993; Elliott *et al.* 1998; Ramsden and Elek 1998), which was hitherto described as being 'virtually untouched by chrysomelids' (Edwards and Wanjura 1990). However, recent studies (e.g. Lawrence 1998; Lawrence *et al.* 2003; Nahrung and Allen 2003b) showed that adult beetles prefer adult foliage. *Chrysophtharta agricola* was identified as a problem in Tasmania (Bashford 1993; Elliott *et al.* 1998) and Victoria (Neumann 1993; Elliott *et al.* 1998; Collett 2001) only in the last decade, coinciding with an increase in planting of *E. nitens* and *E. globulus* in each state, respectively. Although *C. agricola* is also found in New South Wales, it has not been specifically recorded as a pest there. Ohmart *et al.* (1983), Stone (1993) and Stone *et al.* (1998) recorded *Chrysophtharta* spp. as folivores in eucalypt forests in New South Wales, but did not identify the species. In New Zealand, where the accidental introduction of paropsine beetles has caused considerable damage to eucalypt plantation productivity (Withers 2001), *C. agricola* is listed as a regulated pest for imports from Australia, including pests potentially associated with bark, wood packing and sawn wood (Ormsby 2001). It is also considered of high colonisation and economic damage potential if accidentally introduced to the United States (Kliejunas *et al.* 2003).

Currently, high populations of *C. agricola* in Tasmanian plantations are controlled by spraying with a pyrethroid-based insecticide (a-cypermethrin) under an integrated pest management program developed for *C. bimaculata* (Elliott *et al.* 1992; Beveridge and Elek 2001; Elek *et al.* 2001). The *Bacillus thuringiensis* ssp. *tenebrionis* Berliner (Btt)-based bioinsecticide, Novodor®, is effective against *C. agricola* (Beveridge and Elek 2001; Elek *et al.* 2001), although apparently not under all conditions (see Harcourt *et al.* 1996). *Eucalyptus camaldulensis* foliage expressing transgenic Btt was also toxic to *C. agricola* larvae (Harcourt *et al.* 2000). The neem, *Azadirachta indica* (Meliaceae)-based product, Nutri-Neem Cold Pressed Oil, is effective at low doses in suppressing oviposition, egg viability and leaf consumption by adult *C. agricola* (O'Brien *et al.* 2003).

Natural enemies

Natural enemies can contribute to a cumulative 95–97% egg-larval mortality of *C. bimaculata* (de Little *et al.* 1990) and, likewise, have a significant effect upon *C. agricola* populations in the field (G.R. Allen and V.S. Patel, CRC-SPF, unpubl.). Generalist predators attack the eggs, larvae and pupae of several paropsine species (Table 2). The ladybirds *Cleobora mellyi* (Mulsant) and *Harmonia conformis* (Boisduval) and the cantharid beetle *Chauliognathus lugubris* (Fabricius) are considered to be the most important predators of *C. bimaculata* (Elliott *et al.* 1998), and they also predate *C. agricola* (pers. obs.), although Bashford (1999) reported that predation of *C. agricola* eggs by coccinellids was rare. Field observations of *C. agricola* populations showed significant egg and larval mortality by an undescribed species of mirid bug (Orthotylinae), and significant larval predation by spiders (G.R. Allen and V.S. Patel, CRC-SPF, unpubl.; pers. obs.). Reduviid and pentatomid bugs were also observed attacking *C. agricola* larvae during this study, and I have observed a male scorpion-fly presenting a late-instar larva as a nuptial gift to a female.

Uncommon vertebrate predators of paropsines include the black currawong in Tasmania (de Little 1979; Selman 1994b), and starlings, sparrows and hedgehogs in New Zealand (Styles 1970), although paropsines are thought to be largely immune to predation by birds and mammals (Selman 1985).

Low levels of *C. agricola* egg parasitism by *Enoggera nasau* Girault (Hymenoptera: Pteromalidae) were detected in the field and in the laboratory, and one instance of egg parasitism by *Neopolycystus* sp. (Hymenoptera: Pteromalidae) has been recorded from Victoria (Nahrung 2002; Nahrung and Murphy 2002). Larval parasitism is common from the tachinid flies, *Paropsivora* sp. and an undescribed genus, and from *Eadya paropsidis* (Huddleston and Short) (Hymenoptera: Braconidae) (A.D. Rice, CRC-SPF, unpubl., G.R. Allen and V.S. Patel, CRC-SPF, unpubl.; Nahrung 2002), with the latter also parasitising *C. bimaculata* and *P. atomaria* (de Little 1982; de Little *et al.* 1990; Cox 1994a; Simmul and de Little 1999). An ichneumonid wasp *Mesochorus* sp. and a pteromalid wasp *Perilampus tasmanicus* (Cameron) hyperparasitise the primary tachinid parasitoids (de Little 1982; Tanton and Epila 1984; Cox 1994a).

Table 2. Generalist insect predators of paropsine chrysomelids and the stage(s) they attack (E = eggs, L = larvae, P = pupae)

Predator	Stage attacked	Reference
Coccinellidae		
<i>Cleobora mellyi</i> (Mulsant)	E, L	de Little <i>et al.</i> (1990); Mo and Farrow (1993); Mensah and Madden (1994); Cox (1996); Ohmart (1996); Elliott <i>et al.</i> (1998); Simmul and de Little (1999)
<i>Harmonia conformis</i> (Boisduval)	E, L	Tanton and Khan (1978); de Little <i>et al.</i> (1990); Mo and Farrow (1993); Mensah and Madden (1994); Cox (1996); Ohmart (1996); Elliott <i>et al.</i> (1998); Simmul and de Little (1999)
<i>Cryptolaemus montrouzieri</i> (Mulsant)	E, L	Tanton and Khan (1978)
<i>Rhizobius</i> (3 spp.)	E, L	Tanton and Khan (1978); Cox (1996)
<i>Halmus</i> sp.	E	Cox (1996)
Cantharidae		
<i>Chauliognathus lugubris</i> (F.)	E, L, P	Mensah and Madden (1994); Shoheit and Clarke (1997)
Pentatomidae		
<i>Oechalia schellenbergi</i> (Guérin-Méneville)	E, L	Styles (1970); Tanton and Khan (1978); Bain and Kay (1989); Mo and Farrow (1993); Cox (1996); Simmul and de Little (1999)
<i>Cermatulus nasalis</i> (Westwood)	L	Styles (1970); Tanton and Khan (1978); Simmul and de Little (1999)
Miridae		
<i>Porphyrodema (Zanessa) pictulifer</i> (Walker)	E, L	de Little <i>et al.</i> (1990)
<i>Pseudopantilius australis</i> (Walker)	L	de Little <i>et al.</i> (1990)
<i>Rayiera basifer</i> (Walker)	L	Tanton and Khan (1978)
Undescribed sp.	E, L	<i>Pers. obs.</i>
Chrysopidae		
<i>Chrysopa edwardsi</i> (Banks)	E	de Little <i>et al.</i> (1990)
Acanthosomatidae		
<i>Anischys</i> sp.	E, L	de Little <i>et al.</i> (1990)
Nabidae		
<i>Nabis</i> sp.	L	de Little <i>et al.</i> (1990)
Vespidae		
<i>Vespula germanica</i> F.	L	Styles (1970); Simmul and de Little (1999); Tribe (2000)
Erythraeidae (Acari)		
<i>Abrolophus</i> sp.	E	Tribe (2000)
<i>Microsmaris</i> sp.	E	

Nematodes (Mermithidae) were described by Selman (1989, 1994b) as being ‘the most important parasites of all in suppressing population explosions of paropsine beetles’, although Reid (1995) was sceptical of this claim, and certainly nematodes are rarely recorded from paropsines in Tasmania (Davies 1966; de Little 1979). Protozoa are recorded from *P. atomaria* (Tanton and Khan 1978), but few paropsine species have been examined for unicellular or fungal associates.

Styles (1970) noted that an unidentified pathogen, probably a virus, was found attacking larvae of *P. charybdis* in New Zealand. The generalist pathogenic fungi *Beauvaria* spp. and *Metarhizium* sp. can infect *C. bimaculata* (Elliott *et al.* 1998) and *C. agricola* (V.S. Patel, CRC-SPF, *pers. comm.*). Another insect pathogenic fungus, *Entomophthora* sp., was also found infecting *C. agricola* during this study.

Additionally, three mite species, from the families Podoplipidae (Seeman and Nahrung, *in press*), Chyzeriidae (probably *Chyzeria* sp.) and Erythraeidae (*Leptus* sp.), parasitise *C. agricola* adults, and are normally found beneath the elytra and hindwings (Nahrung 2002).

Conclusions

Chrysophtharta agricola has recently emerged as a significant pest of eucalypt production in Tasmania and Victoria coincident with an increase in *E. nitens* and *E. globulus* plantations, and there is evidence that it may have increased its geographic distribution in response to plantation establishment. Despite significant offspring mortality attributable to natural enemies and host plant characteristics, *C. agricola* larvae and adults can cause serious defoliation to *E. nitens* and *E. globulus* plantations. Adults and larvae feed on young foliage, with adults feeding preferentially on adult foliage and ovipositing on juvenile foliage. Late-season defoliation can have a greater impact on trees than early-season defoliation because it may prevent foliage regrowth, leaving exposed shoots susceptible to damage by severe cold in winter (Simmul and de Little 1999).

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