Pheromone-trapping of *Carpophilus* spp. (Coleoptera: Nitidulidae): fauna, abundance and seasonality in some Australian horticultural regions

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Summary

Traps baited with synthetic aggregation pheromones of *Carpophilus hemipterus* (L.), *C. mutilatus* Erichson and *C. davidsoni* Dobson and a fermenting coattractant, were used to identify the fauna and monitor the seasonal abundance of nitidulids in orchards in five horticultural regions in Australia (Tumut-Batlow (New South Wales), Swan Hill (Victoria), Stanthorpe, Nambour (Queensland) and Manjimup, (Western Australia). Six species of *Carpophilus* were trapped (*C. hemipterus, C. mutilatus, C. davidsoni, C. humeralis* (F.), *C. gaveni* Dobson, *C. marginellus* Motschulsky), plus at least two unidentified species. *C. davidsoni* dominated the trapped nitidulids in all regions except Manjimup. *C. hemipterus* was common at Swan Hill. *C. mutilatus* was common at Stanthorpe and was the dominant species trapped at Manjimup. Only small numbers of *C. gaveni, C. humeralis*, and *C. marginellus* were trapped and these were generally most common at the Queensland sites. Peak abundance of nitidulids usually occurred during late spring, and summer populations in inland areas were usually small. The nitidulid fauna in these regions is discussed with respect to management using synthetic aggregation pheromones.

Introduction

Broad-spectrum insecticide inputs in stone fruit production in southern Australia have declined during the past 10–15 years, primarily as the result of development and adoption of integrated pest management programs. Foremost amongst these is the use of synthetic pheromone for mating disruption of the key pest of peaches and nectarines, oriental fruit moth, *Cydia molesta* (Busck), and associated reliance on biological control to manage mite pests (Vickers *et al.* 1985, James 1990). A side-effect of reduced broad-spectrum insecticide inputs has been an increase in importance of secondary pests.

Nitidulid beetles in the genus *Carpophilus*, formerly secondary pests (Hely *et al.* 1982), are now considered to be major pests of stone fruit in Australia and are the focus of current pest management research (James *et al.* 1996, 1997). *Carpophilus* spp. cause damage by penetrating ripening fruit and vectoring brown rot resulting in rapid breakdown (Hely *et al.* 1982). Most research to date has concentrated on the identification, function and practical application of synthetic *Carpophilus* aggregation pheromones in managing populations (Bartelt and James 1994, James *et al.* 1996, 1997). Development of non-chemical approaches to controlling *Carpophilus* spp. requires comprehensive information on biology and ecology, including basic data on species incidence, abundance, seasonality and pest status. This is still lacking for some stone fruit growing areas in Australia.

Although eight *Carpophilus* spp. have been recorded from five stone fruit growing areas of south-eastern Australia, only three species (*Carpophilus davidsoni* Dobson, *Carpophilus hemipterus* (L.), *Carpophilus mutilatus* Erichson) are abundant in these areas and capable of causing economic damage (James *et al.* 1993, 1995). This paper provides information on the incidence, abundance and seasonality of *Carpophilus* spp. in five additional horticultural regions of New South Wales, Victoria, Queensland and Western Australia.

Materials and methods

Sites

Pheromone traps were deployed for periods of two to six months in stone fruit orchards at Tumut-Batlow (south west Slopes, New South Wales), Swan Hill (Murray Valley, Victoria), Stanthorpe (Granite Belt, Queensland) and Manjimup (Western Australia). Traps were also deployed for two to eight months in a custard apple orchard at Nambour (Sunshine Coast, Queensland).

Tumut-Batlow. Four traps were operated in this region (single traps in two peach orchards at Tumut and two peach orchards at Batlow) from 10 November 1997 to 7 April 1998). From 23 October 1998 to 9 February 1999 two traps were maintained in a single peach orchard at Tumut. All traps were baited with 5 mg each of *C. hemipterus, C. mutilatus* and *C. davidsoni* pheromone.

Swan Hill. Three traps (baited with either 500 µg of *C. hemipterus, C. mutilatus* or *C. davidsoni* pheromone) were maintained in a single peach orchard from 10 October 1995 to 16 April 1996 and from 4 November 1996 to 17 March 1997. From 27 November 1997 to 4 February 1998 two traps (each baited with 5 mg each of *C. hemipterus, C. mutilatus* and *C. davidsoni* pheromone) were maintained in a different peach orchard.

Stanthorpe. Two traps (each baited with 5 mg each of *C. hemipterus, C. mutilatus* and *C. davidsoni* pheromone were maintained in a peach and nectarine orchard from 8 October 1998 to 5 March 1999.

Manjimup. Three traps (baited with either 5 mg of *C. hemipterus, C. mutilatus* or *C. davidsoni* pheromone) were maintained in a single peach orchard from 16 October 1996 to 10 February 1997.

Nambour. Three traps (baited with either 500 µg of *C. hemipterus, C. mutilatus* or *C. davidsoni* pheromone) were maintained in a custard apple orchard at the Maroochy Horticultural Research Station from 1 March to 19 April 1995 and from 16 August 1995 to 3 April 1996. A stone fruit orchard was not available at this site, but nitidulids are known pollinators of custard apple (George *et al.* 1989) and are attracted to this crop.

No chemical treatments were applied for *Carpophilus* spp. at any of the sites, although some insecticide applications for other pests were made occasionally at Swan Hill, Tumut, Batlow and Nambour.

Traps and coattractant baits

Wind-oriented pipe traps based on the design of Dowd *et al.* (1992) were used at all sites. Beetles entered pipe traps through a cone-shaped piece of screen and were trapped in a plastic 140 mL bottle attached to the bottom of the trap. No killing agent was used and a screen partition prevented beetles from contacting the bait. Trapped beetles died from dessication or hunger. During the 1995/96 and 1996/97 trapping seasons, fermenting whole wheat bread dough (approximately 10 mL per trap) was used as the pheromone synergist held in a 20 mL glass tube (James *et al.* 1993). During 1997/98 and 1998/99, fermenting apple juice contained in

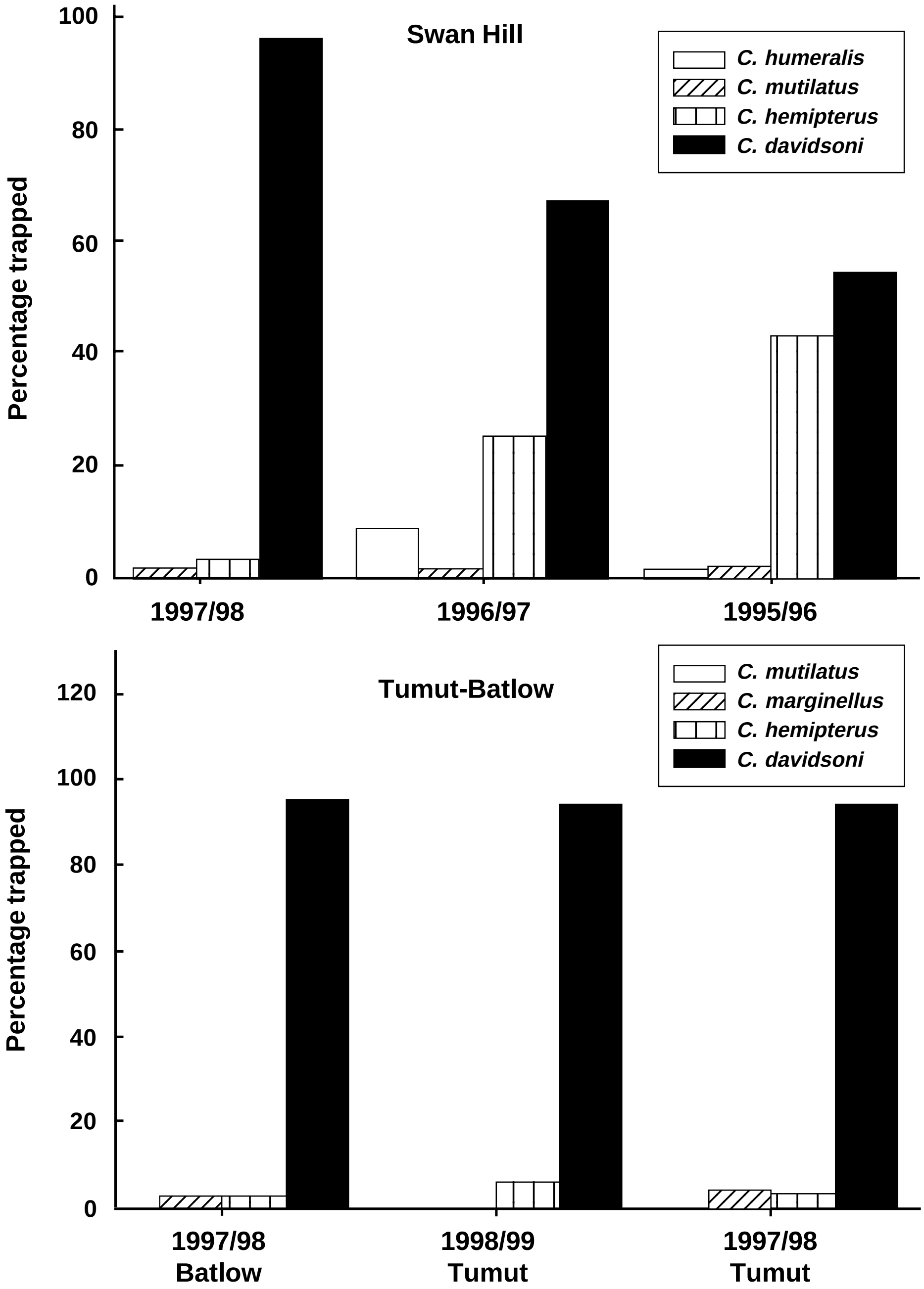

Figure 1. Percentage species composition of *Carpophilus* caught seasonally in stone fruit orchard pheromone traps at Swan Hill and Tumut-Batlow.

polyacrylamide granules, held in a 20 mL plastic tube (James *et al*. 1998) was used as the coattractant. Pheromones were impregnated into rubber septa and placed in the bait compartment of the traps. When pheromones of *C. hemipterus, C. mutilatus* and *C. davidsoni* were used together in a trap, they were combined in a single septum (James *et al*. in press). Traps were suspended approximately 1.5 m above ground from a wire attached to a tree branch. They were oriented to the wind by a fin so that the trap opening was always accessible to beetles approaching the traps from downwind. Traps were usually examined weekly and plastic bottles (containing beetles) forwarded by mail to Yanco for counting and identification. Dough and pheromone septa were replaced weekly and fortnightly, respectively. The polyacrylamide granules were replaced fortnightly (James *et al*. 1998). All beetles were identified to species (using Dobson 1954, 1964).

Synthetic pheromones

The pheromone for *C. hemipterus* consisted of a 100:31:11:8 blend of (2*E*, 4*E*, 6*E*, 8*E*)–3,5,7 – trimethyl – 2,4,6,8 – decatetraene, (2*E*, 4*E*, 6*E*, 8*E*) – 3,5,7 – trimethyl – 2,4,6,8 – undecatetraene, (2*E*, 4*E*, 6*E*, 8*E*) – 7 – ethyl – 3,5 – dimethyl – 2,4,6,8 – decatetraene and (2*E*, 4*E*, 6*E*, 8*E*) – 7 – ethyl – 3,5 – dimethyl – 2,4,6,8 – undecatetraene, respectively (Bartelt *et al*. 1992).

The pheromone for *C. mutilatus* consisted of a 100:7 blend of (3*E*, 5*E*, 7*E*) – 5 – ethyl – 3 – methyl – 3,5,7 – undecatriene and (3*E*, 5*E*, 7*E*) – 6 – ethyl – 4- methyl – 3,5,7 – decatriene (Bartelt *et al*. 1993).

The pheromone for *C. davidsoni* consisted of a 100:9:31:160 blend of (2*E*, 4*E*, 6*E*) – 5-ethyl – 3 - methyl – 2,4,6 – nonatriene, (3*E*, 5*E*, 7*E*) – 6 – ethyl – 4 – methyl – 3,5,7 – decatriene, (2*E*, 4*E*, 6*E*, 8*E*) – 3,5,7 – trimethyl – 2,4,6,8 – undecatetraene and (2*E*, 4*E*, 6*E*, 8*E*) – 7 – ethyl – 3,5 – dimethyl – 2,4,6,8 – undecatetraene (Bartelt and James 1994).

The synthetic pheromones were purified by distillation and open column chromatography on silica gel. These procedures did not remove the small amounts of *Z* isomers produced in the syntheses (Bartelt *et al*. 1990a) but there is no evidence that these (presently unavoidable) impurities are detrimental to pheromone activity (Bartelt *et al*. 1992).

Pheromones were appropriately diluted with hexane and stored in a freezer until needed. Concentrations of components were determined by gas chromatography on diluted aliquots (Bartelt *et al*. 1990b). Pheromone solutions were applied to rubber septa (11 × 20 mm, red rubber, Aldrich Chemical Co., Milwaukee, Wisconsin, USA) followed by 300 mL of methylene chloride. Once the liquid had soaked into the septa, they were aired in a fume hood for 1 h and stored in a freezer in tightly closed bottles until needed.

Results

Tumut-Batlow. *Carpophilus* populations at these sites were dominated by *C. davidsoni* which accounted for 94–95% of the 747–1500 beetles trapped per season (Figure 1). Small numbers of *C. hemipterus* and *C. marginellus* Motschulsky were trapped (2–5%) and only two individuals of *C. mutilatus* were recorded. Most beetles were trapped during October–December. Very few were trapped during January–March. A small increase in numbers occurred during March and April (Figure 2).

Swan Hill. A total of 175–437 beetles was trapped per season and *C. davidsoni* was the dominant species particularly in 1997/98 (95.6%). In 1995/96 and 1996/97 it accounted for 54 and 66% of beetles trapped (Figure 1). *C. hemipterus* comprised 42 and 24% of the fauna in 1995/96 and 1996/97, respectively. Small numbers of *C. humeralis* (F.) and *C. mutilatus* were also trapped. Most trappings occurred during October–November and very few beetles were trapped during December–January. A small increase in numbers trapped occurred in February–March 1996 (Figure 3).

Stanthorpe. Of the 4641 beetles trapped, 4329 (93.3%) were *C. davidsoni* (Figure 4). *C. mutilatus* was the next most abundant species, followed by *C. hemipterus*, an unidentified species and *C. gaveni* Dobson.

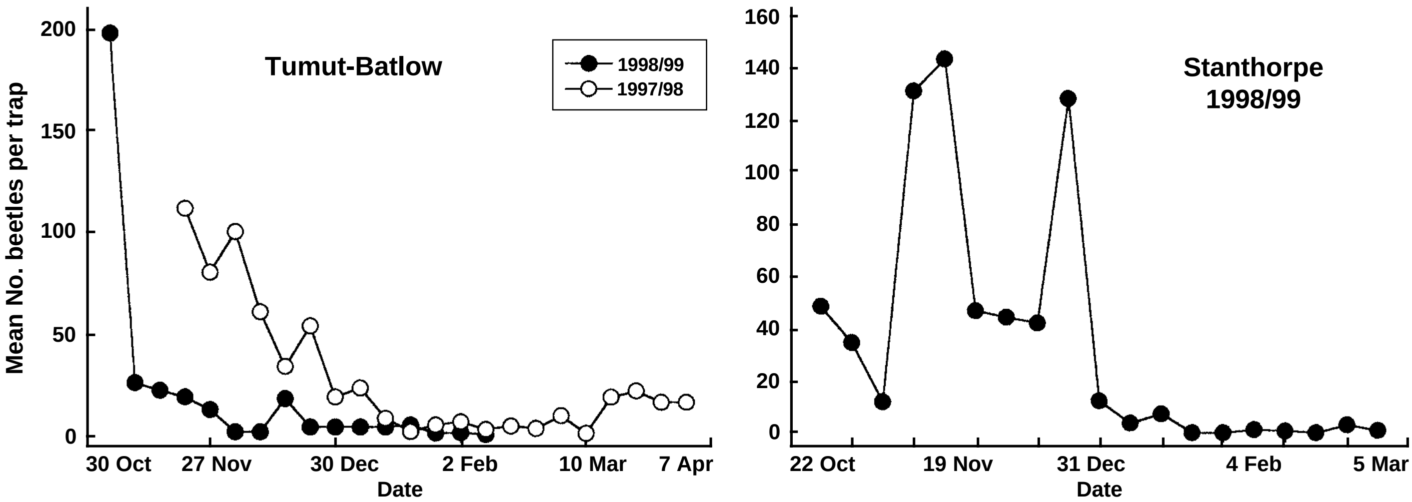

Figure 2. Seasonal trapping data for *Carpophilus* (all species) in stone fruit orchards at Tumut-Batlow and Stanthorpe during 1997/99.

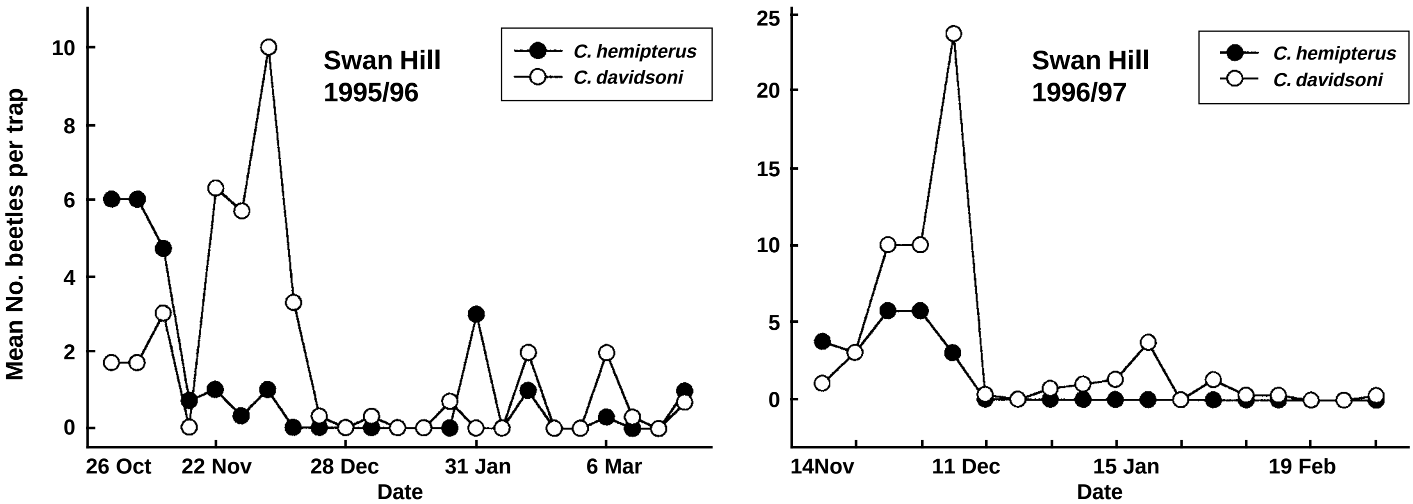

Figure 3. Seasonal trapping data for *Carpophilus hemipterus* and *C. davidsoni* in stone fruit orchards at Swan Hill during 1995/97.

The majority of beetles were trapped during October–December with very few trapped during January–March (Figure 2).

Manjimup. *C. mutilatus* comprised 82.2% of the 472 beetles trapped at this site followed in abundance by *C. hemipterus*, *C. humeralis* and *C. davidsoni* (Figure 4). The majority of *C. mutilatus* were trapped over a two week period in January. Numbers of beetles trapped at all other times were low (<10 per trap) (Figure 5).

Nambour. *C. davidsoni* was the most abundant species (38.6% of trapped beetles), followed by *C. hemipterus* and *C. mutilatus* (Figure 4). *C. humeralis*, *C. gaveni* and *C. marginellus* were trapped in small numbers along with at least two unidentified species of *Carpophilus*. Beetles were trapped for most of the trapping period (except during August and early September) with peak abundance during November–January when 20–60 beetles (all species) were caught weekly per trap (Figure 6).

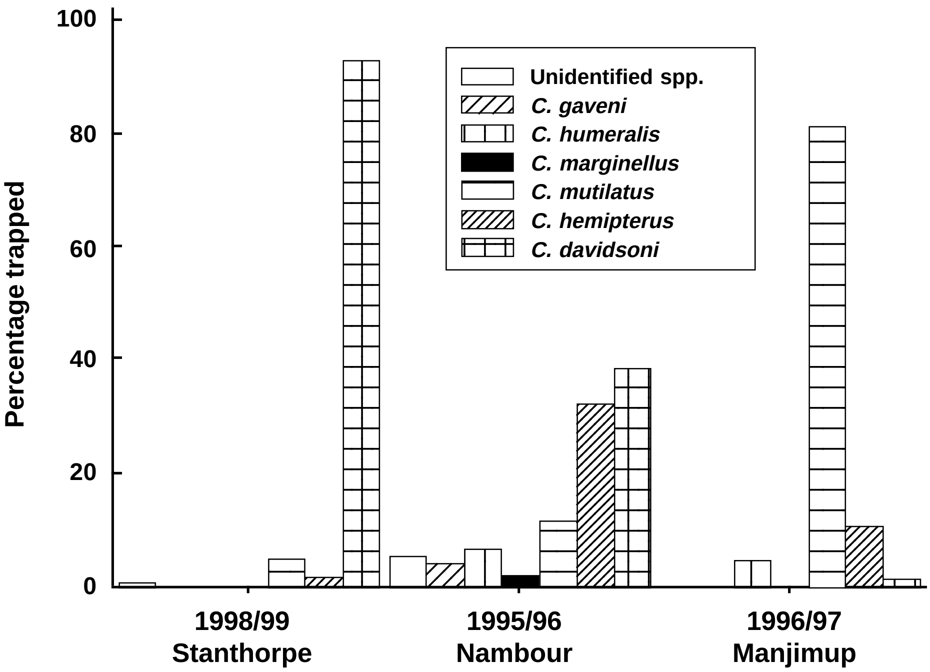

Figure 4. Percentage species composition of *Carpophilus* caught seasonally in pheromone traps in Stanthorpe and Manjimup stone fruit orchards and a custard apple orchard at Nambour.

Discussion

Six species of *Carpophilus* (*C. davidsoni, C. hemipterus, C. mutilatus, C. humeralis, C. gaveni* and *C. marginellus*) responded to pheromone-baited traps in this study. In addition at least two unidentified species were trapped at Nambour and Stanthorpe, one of which was species 'X' previously recorded by James *et al.* (1995) from Windsor, New South Wales. *C. davidsoni* dominated the trapped nitidulids in all regions except Manjimup, as it did in earlier studies in five major stone fruit growing regions of southeastern Australia (James *et al.* 1993, 1995). However, this result should be treated with caution since trapping was conducted at Manjimup for a limited period and at a single site only. *C. hemipterus* was a significant component of the *Carpophilus* population at Swan Hill and Nambour. This species is also common in stone fruit orchards at Renmark (South Australia) and Cobram (Victoria) (James *et al.* 1995). Apart from Manjimup, *C. mutilatus* also occurred in significant numbers at Nambour and Stanthorpe. This species is abundant in stone fruit orchards at Renmark, Windsor (New South Wales) (James *et al.* 1995) and in the Murrumbidgee Irrigation Area (MIA) of southern New South Wales (James *et al.* 1993).

The Nambour custard apple orchard was the only site in which all six species (plus unidentified species) were trapped. This may be a reflection of the general attractiveness of custard apple to nitidulids (Podoler *et al.* 1984). Nitidulids are important pollinators of custard apple, which may produce volatiles attractive to a wider range of *Carpophilus* spp. than is the case for stone fruit. The dominance of *C. davidsoni* at Nambour may be more pronounced in stone fruit orchards and should be investigated.

Although only the pheromones of *C. davidsoni, C. hemipterus* and *C. mutilatus* were used in this study, four other species of *Carpophilus* responded to the traps. Pheromonal cross-attraction amongst *Carpophilus* species has been well documented (Bartelt 1997) but the 'correct' pheromone is considered necessary for optimal response. Thus, the numbers of *C. gaveni, C. marginellus* and species 'X' trapped in this study are likely to be an under-representation of their abundance. Despite much study, *C. humeralis* has not yet been shown to possess its own pheromone and it may simply use other *Carpophilus* spp. pheromones as kairomones (Zilkowski *et al.* 1999). *C. humeralis* is not considered to be a major threat to stone fruit as it appears to prefer infesting fallen rather than ripening fruit (James, unpublished observation). Small numbers of *C. gaveni* were recorded in this study from Stanthorpe, Nambour, and previously from Renmark, Cobram, Shepparton (Victoria) and the MIA (James *et al.* 1995). Large numbers of *C. gaveni* were trapped in *C. mutilatus*-baited traps at Windsor (James *et al.* 1995), suggesting it could be an economic species in this district. Similarly, *C. marginellus* was trapped commonly at Windsor, but was infrequent, or absent elsewhere.

This study confirms previous indications that *C. davidsoni, C. hemipterus* and *C. mutilatus* are the major nitidulid species affecting stone fruit production in Australia (James *et al.* 1993, 1995). It also confirms *C. davidsoni* as the dominant *Carpophilus* species, representing 40–95% of nitidulids trapped in stone fruit orchards in all regions except Western Australia. Further trapping should be conducted in stone fruit growing areas of this state before firm conclusions about the composition and abundance of the endemic nitidulid fauna can be made.

Knowledge of the species composition of the nitidulid fauna in stone fruit

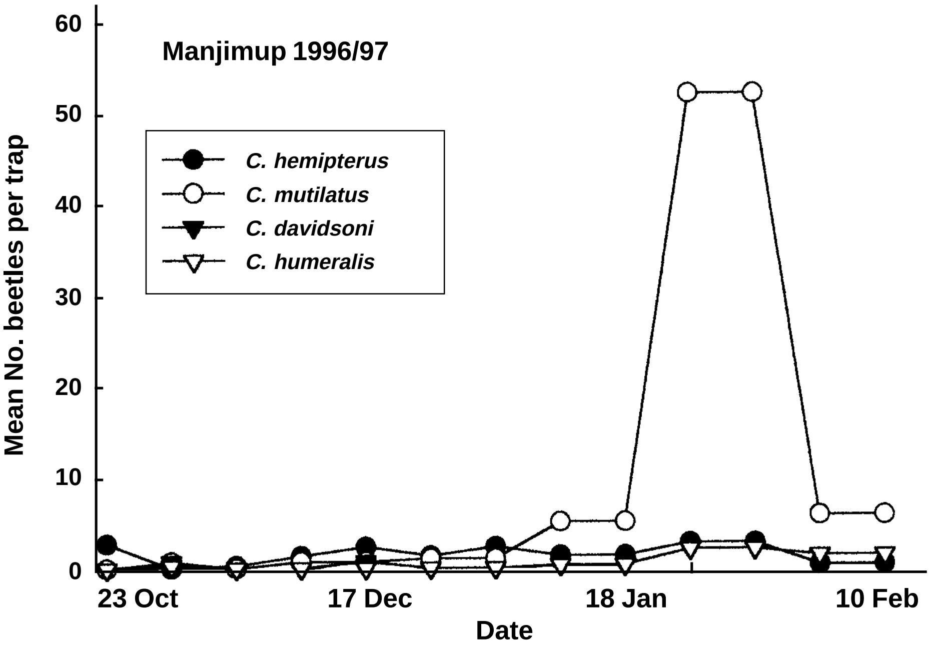

Figure 5. Seasonal trapping data for *Carpophilus* spp. in a stone fruit orchard at Manjimup during 1996/97.

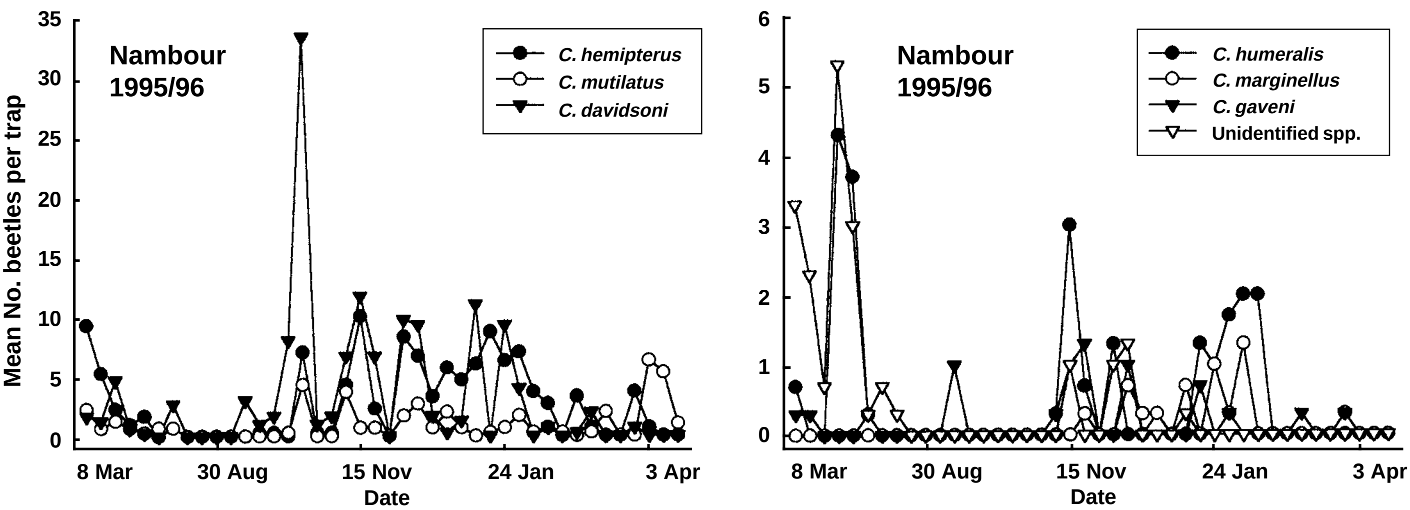

Figure 6. Seasonal trapping data for *Carpophilus* spp. in a custard apple orchard at Nambour during 1995/96.

growing regions has considerable practical importance. Integrated management programs based on the use of synthetic aggregation pheromones for population monitoring / suppression, are being developed (e.g. James *et al.* 1996, 1997) and require tailoring of pheromones to species incidence / abundance. For example, the *C. davidsoni*-dominated populations at Shepparton, Stanthorpe, Tumut and Batlow may require the use of C. *davidsoni* pheromone only. In contrast, regions where significant populations of *C. hemipterus* and / or *C. mutilatus* may occur (Swan Hill, Cobram, Manjimup, Nambour, Renmark, Windsor, MIA), would be better served by the use of multi-species lures containing the pheromones of two or all three major species (James *et al.* in press).

Seasonal trends of *Carpophilus* abundance as indicated by numbers of beetles trapped, reinforced previous observations that peak abundance usually occurs during late spring, coinciding perhaps with emergence of the first post-winter adult generation (James and Vogele in press). Summer populations are usually small in inland areas, particularly in years with average to below average rainfall (James *et al.* 1997), and this was the case for populations at Tumut-Batlow, Swan Hill and Stanthorpe. However, this pattern was not evident in the custard apple orchard at Nambour where populations remained at moderate levels during most of the summer. Further studies should be conducted to determine the influence of climate and orchard type on seasonal population dynamics of *Carpophilus* spp.

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