Observations on some Buprestidae (Coleoptera) from the Blue Mountains, N.S.W.

T. J. HAWKESWOOD
Department of Botany, University of New England, Armidale, N.S.W. 2351

ABSTRACT

Forty-two species of Buprestidae in nine genera were collected and observed in the Glenbrook area of the Blue Mountains N.S.W. during 1975-77. Specimens of three of these species were also collected from Wentworth Falls and Medlow Bath, in the higher Blue Mountains, during early 1977. A list of the jewel beetles, their occurrence, food plants and dates of collection, is included. Field observations on flight behaviour, feeding, defence and escape mechanisms, grooming and pollination are recorded and discussed. All of these aspects were not observed in every species mentioned. *Stigmodera macularia* (Don.), *S. variabilis* (Don.) and *Cisseis leucosticta* (Kirby) are figured.

INTRODUCTION

The Buprestidae commonly referred to as "jewel beetles" are well represented in Australia, with over 800 described species (Britton, 1970). When conditions are suitable e.g. high temperatures and profuse flowering and nectar-bearing by food plants, some species may be found in abundance, especially those of the dominant nectar-feeding genus *Stigmodera.* Individuals of foliage feeding genera e.g. *Cisseis, Ethon, Germarica* and *Paracephala* may be found during the summer months on their food plants, e.g. *Acacia* spp. (Mimosaceae) or *Casuarina* spp. (Casuarinaceae) (Froggatt, 1907; Tillyard, 1926; McKeown, 1945).

Some species have a widespread distribution, e.g. *Stigmodera erythroptera* Boisd. found in all states (Carter, 1931a), but others have somewhat limited distribution, e.g. *Stigmodera magnetica* Cart., from Western Australia (Glauert, 1948; Barker *et al.,* 1956; Barker *et al.,* 1960; Barker and Edward, 1963).

Despite the wide occurrence of some species, the great number of species and their abundance, very little is known about their biology (Hughes, 1975). This may be due, in part, to the difficulty of locating many species, as it appears from data at hand that numbers of individuals fluctuate from season to season; one species may be rare or absent one year in a particular area but be common the next season (Whitlock, 1947; Williams, 1977; and the present work).

Since very little has been written about any aspect of the biology of Australian Buprestidae, this study was undertaken in order to discover, within a relatively small area in the Blue Mountains, N.S.W., the species present and aspects of their behaviour in their natural habitat.

MATERIALS AND METHODS

(a) Study Areas

The majority of observations were made on living insects in an area of radius approximately 6 km from the centre of Glenbrook, N.S.W. This area includes the townships of Lapstone, Blaxland and Warrimoo, 2 km S.E., 3 km N.W. and 6 km N.W. respectively, from the Glenbrook Post Office. Specimens of three species of buprestid were also collected from Wentworth Falls and Medlow Bath, in the higher Blue Mountains.

The township of Glenbrook is situated about 70 km (43 miles) by road, west of Sydney, at an altitude of 163 m (535 ft) above sea-level. Much of the natural bushland in the immediate vicinity of Glenbrook and other areas in the Blue Mountains has made way for residential development and no doubt the flora and fauna have been affected in various ways by this disturbance.

(b) Collection times and main flowering species

Most field data and specimens were collected between December 1975 and February 1976 when *Angophora floribunda* (Sm.) Sweet, *A. bakeri* C. Hall, and *Leptospermum phylicoides* (A. Cunn. ex Schau.) Cheel, major food plants for *Stigmodera*, flowered profusely and between December 1976 and February 1977, when *Leptospermum flavescens* Sm. was a dominant flowering plant in the areas studied. Specimens of foliage-feeding species of *Cisseis* were collected during both seasons but *Germarica, Paracephala* and *Astraeus* were only collected during the 1976/77 season. Specimens of *Cyria imperialis.* Fabr. were only collected during 1975/76 when its main food plant in the area, *Banksia spinolosa* Sm. was in flower.

Specimens were collected by hand and/or net, released after examination, or kept for later examination and identification.

The majority of observations were made during periods of one to three hours, between 1200 and 1700 hrs (Eastern Standard Time).

(c) Weather Conditions

The Glenbrook area receives an average annual rainfall of about 80 cm (32 inches) and temperatures range broadly from 1°C to 40°C. Weather conditions during the two seasons were variable with daily temperatures ranging from 15°C to 39°C. Good summer rains in excess of 203 mm (8 inches) fell during both seasons. During days when observations took place, conditions were mainly fine and clear with temperatures usually varying from 21°C to 39°C. The hottest day

recorded during the two-year period of observation occurred during the summer of 1976/77, when 41.5°C was recorded at Glenbrook on the 5th January, 1977.

(d) Nomenclature

The nomenclature used for plant species follows that of Beadle *et al.*, (1972). The nomenclature used for Buprestidae are as follows: for *Stigmodera* (Carter, 1916; 1929; 1931a; 1931b), for *Germarica, Paracephala, Curis, Cyria* and *Torresita* (Carter, 1929), for *Melobasis* (Carter, 1923b; 1929), for *Cisseis* (Carter, 1923a, 1929) and for *Astraeus* (Barker, 1975).

VEGETATION

The present vegetation of the Glenbrook area is one of dry sclerophyll forest dominated by scribbly gum, *Eucalyptus haemastoma* var. *sclerophylla* Blakely, the yellow bloodwood, *E. eximia* Schau., the red bloodwood, *E. gummifera* (Gaertn.) Hochr., and the Sydney peppermint, *E. piperita* Sm., as well as the angophoras, i.e. *Angophora costata* (Gaertn.) Druce, *A. floribunda* (Sm.) Sweet and *A. bakeri* C. Hall. The understorey vegetation is largely composed of species of *Acacia* (Mimosaceae); *Persoonia, Hakea, Banksia* and *Grevillea* (Proteaceae);

Pultenaea, Bossiaea, Dillwynia, Oxylobium, Gompholobium, Daviesia and *Phyllota* (Fabaceae); *Leptospermum* (Myrtaceae); and *Casuarina* (Casuarinaceae). Other small plants belonging to various plant families, including the grasses (Poaceae) occupy the ground zone strata. In deep gullies and gorges numerous ferns and rainforest tree species may be found, e.g. *Syncarpia glomulifera* (Sm.) Niedenzu (Myrtaceae). Many of the plants mentioned above, e.g. *Angophora, Leptospermum* and *Acacia* are food-plants for members of the Buprestidae (see Tables 1 and 2).

OBSERVATIONS AND DISCUSSION

(a) *List of species, occurrence, food plants and dates of collection*

This information is summarised in Table 1. The occurrence of buprestid species was rated on a per season basis similar to that of Williams (1977). The term "rare" indicates less than three specimens, "few" three to 10 specimens, and "common" more than 10 specimens captured and/or observed during each season of collection. Since this system was used by Williams (1977), comparisons can be made with his findings.

One fact that has emerged as a result of the two seasons of observations is the marked synchronization between the flowering of the food plants and the appearance of the nectar feeding species of *Stigmodera* and *Cisseis* upon the blossoms of these plants. Williams (1977) noted that he collected the most species and the highest number of individuals during the final flowering phase of the food plant (*Leptospermum flavescens* Sm.) at East Minto, New South Wales, during 1972-1975. This observation generally agreed with those at Glenbrook.

TABLE 1

List of species of Buprestidae collected in the Blue Mountains, 1975-1977.

SPECIES	SEASON 1975/76 Occurrence	Locality	Food Plant(s)	Dates of Collection	1976/77 Occurrence	Locality	Food Plant(s)	Dates of Collection
Subfamily Buprestinae *Tribe Buprestini*								
1. *Astraeus pygmaeus* van de Poll	*	—	—	—	few	G	1, 2	7-20 Jan.
2. *Melobasis costata* Macleay	*	—	—	—	rare	G	4(?)	10 Jan.
3. *Melobasis cupriceps* (Kirby) (?)	*	—	—	—	rare	G	5, 6	28 Aug., 5 Dec
4. *Torresita cuprifera* (Kirby)	rare	G	10	8 Dec.	few	G	9, 10	5, 22 Dec.
Tribe Stigmoderini								
5. *Stigmodera macularia* (Don.) (Fig. 1A and B)	common	G	10	2 Dec.- 15 Jan.	rare	G	9	1-2 Dec.
6. *Stigmodera variabilis* (Don.) (Fig. 2A)	few	G	10, 11, 13	3-15 Jan.	*	—	—	—
7. *Stigmodera andersoni* C. & G.	few	G	11	3-8 Jan.	*	—	—	—
8. *Stigmodera bella* Saund.	rare	G	12	18 Dec.- 16 Jan.	few	G, B	9	2-8 Dec.
9. *Stigmodera bicincta* Boisd.	rare	G	12	5 Jan.	rare	B	9	6, 8 Dec.
10. *Stigmodera brutella* Thoms.	rare	G	11	4 Jan.	*	—	—	
11. *Stigmodera crenata* (Don.)	rare	G	10	15, 18 Dec.	common	G. B	9, 10	1-11 Dec.
12. *Stigmodera cruenta* L. & G.	few	G	10, 12, 14	10-15 Dec., 22 Jan., 18 Feb.	rare	G	9	18 Dec.
13. *Stigmodera octospilota* L. & G.	few	G	10	12-15 Dec. 6 Jan.	few	G, B, MB	9, 10	1-18 Dec., 20 Dec.
14. *Stigmodera erythroptera* Boisd.	few	G	10	8-15 Dec.	common	G, B, W	9, 10	1-18 Dec.
15. *Stigmodera* (?) *flavopicta* Boisd.	*	—	—		rare	G	15	18, 29 Dec.
16. *Stigmodera kerremansi* Blackburn	rare	G	12	5-6 Dec.	rare	G, B	9	1, 7 Dec.
17. *Stigmodera kirbyi* Guer.	rare	G	12	8 Dec.	rare	WW	9	19 Jan.
18. *Stigmodera luteipennis* L. & G.	rare	G	10	15, 28 Dec.	*	—	—	—
19. *Stigmodera nasuta* Saund.	rare	G	10	12 Dec.	*	—	—	—
20. *Stigmodera decemmaculata* (Kirby)	few	G	10	6-22 Dec., 5 Jan.	*	—	—	—
21. *Stigmodera puella* Saund.	*	—	—	—	rare	B	9	9 Dec.
22. *Stigmodera rufipennis* (Kirby)	few	G	10	5-23 Dec.	common	G, B	9, 10	1-10 Dec.
23. *Stigmodera scalaris* Boisd.	rare	G	12	12 Dec.	common	G, B	9, 16	2-9 Dec.
24. *Stigmodera spilota* L. & G.	rare	G	5(?)	8 Feb.	*	—	—	—
25. *Stigmodera spinolae* L. & G.	rare	G	10	12 Dec.	*	—	—	—
26. *Stigmodera subpura* Blkb.	*			—	few	B	9	2-10 Dec.
27. *Stigmodera undulata* (Don.)	few	G	10, 11	3-12 Dec., 28 Jan.	few	G, B	9	2, 8, 10 Dec.
28. *Stigmodera vigilans* Kerr. (?)	rare	G	11	18 Dec.	(?) rare	G, B	9, 12	6-11 Dec., 3 Jan.
29. *Curis caloptera* (Boisd.)	rare	G	11	15 Dec.	*	—	—	—
Tribe Agrilini								
30. *Paracephala cyaneipennis* Blkb.	*	—	—	—	rare	G	2	5 Jan.
31. *Germarica lilliputana* (Thoms.)	*	—	—	—	common	G, MB	2, 3	9, 17-19 Jan.
32. *Cisseis acuducta* (Kirby)	rare	G	6	14 Dec.	rare	G, L	6, 17	18, 28 Dec.
33. *Cisseis atroviolacea* Thoms.	*	—	—	—	few	B, W	9	1-12 Dec.
34. *Cisseis cupripennis* Guer.	*	—	—	—	few	G	6	22, 26 Dec., 10, 20 Jan., 25 Feb.
35. *Cisseis leucosticta* (Kirby) (Fig. 2B)	common	G	6	25, 28 Jan 3-5 Feb.	rare	G	7	4 Jan.
36. *Cisseis maculata* L. & G.	*	—	—	—	rare	B	9	5, 12 Dec.
37. *Cisseis marmorata* L. & G.	rare	G	8	16 Dec.	few	L	7, 8	14, 15, 20 Feb.
38. *Cisseis notulata* Germ.	rare	G	5	5 Jan.	common	G, B	5, 18	20-28 Dec., 2-15 Jan.
39. *Cisseis pygmaea* Blkb.	few	G	21	16-24 Jan., 14-16 Feb.	few	G	21	3-18 Jan.
40. *Cisseis roseo-cuprea* Hope	*	—	—	—	few	G	19	29 Aug.77.
41. *Cisseis vicina* Kerr.	*	—	—	—	few	G, B, W	9, 10	1-8 Dec., 12 Feb.
Subfamily Chalcophorinae *Tribe Chalcophorini*								
42. *Cyria imperialis* (Fabr.)	few	G	20	22-31 Dec., 1-3 Jan.	*	—		—
No. of species present	29				32			

Key to Table 1.

Occurrence
* = no specimens observed or collected
rare= ≤ 3 specimens collected
few = 3-10 specimens collected
common = > 10 specimens collected.

Locality
G = Glenbrook;
B = Blaxland;
L = Lapstone;
W = Warrimoo;
WW = Wentworth Falls;
MB = Medlow Bath.

Food Plants
Casuarinaceae
1. *Casuarina torulosa* Ait.; 2. *C. littoralis* Salisb.;
3. *C. nana* Sieb. ex Spreng.

Poaceae (Gramineae)
4. *Themeda australis* (R.Br.) Stapf.

Mimosaceae
5. *Acacia linifolia* (Vent.) Willd.; 6. *A. longiflora* (Andrews) Willd.;
7. *A. decurrens* (Wendl.) Willd.; 8. *A. parramattensis* Tindale

Myrtaceae
9. *Leptospermum flavescens* Sm.; 10. *L. phylicoides* (A. Cunn. ex Schau.) Cheel;
11. *Angophora floribunda* (Sm.) Sweet; 12. *A. bakeri* C. Hall;
13. *Eucalyptus piperita* Sm.

Pittosporaceae
14. *Bursaria spinosa* (Cav.) Druce.

Asteraceae (Compositae)
15. *Cassinia compacta* F. Muell.; 16. *C. uncata* A. Cunn. ex DC.

Fabaceae (Papilionaceae)
17. *Jacksonia scoparia* R. Br.; 18. *Dillwynia retorta* (Wendl.) Druce var. *retorta;*
19. *D. floribunda* var. *teretifolia* Blakely.

Proteaceae
20. *Banksia spinulosa* Sm.

Sapindaceae
21. *Dodonaea triquetra* Wendl.

TABLE 2

Numbers of buprestid species collected from dominant flowering plants during each season in the study area

Food Plant	Number of Species 1975/76	1976/77
Leptospermum flavescens Sm.	0	19
L. phylicoides (A. Cunn. ex Schau.) Cheel	13	6
Angophora floribunda (Sm.) Sweet	6	0
A. bakeri C. Hall	6	1

During the 1975/76 season the dominant flowering species upon which beetles were observed were *Angophora bakeri, A. floribunda* and *Leptospermum phylicoides.* Flowering of *A. bakeri* in the lower Blue Mountains occurred throughout most of December and into the first half of January, while *A. floribunda* flowered later in December and extended into late January. Six species of *Stigmodera* were collected from *A. bakeri* (see Table 2), mainly during early to middle January, while five species of *Stigmodera* and *Curis caloptera* were collected from the latter plant species, mostly during early January (Tables 1, 2). Generally, buprestid species were not very common and often long waiting for beetles to arrive at blossoms and intensive searching failed to locate any specimens.

Leptospermum phylicoides yielded 12 species of *Stigmodera* and *Torresita cuprifera.* Flowering of this plant began in the last week of November and reached a peak flowering period during middle to late December. Many plants were still flowering by mid-January, 1976. *Stigmodera macularia* was the only buprestid collected from this plant during the second week of January.

No buprestids were observed before December, but specimens may have been present on early flowering plants of *L. phylicoides* in other localities where collection did not occur.

Most species of *Stigmodera* showed preference for one or two food plants, and only *S. variabilis* and *S. cruenta* were found on three different plant species during the 1975/76 season (see Table 1).

During 1976/77 the angophoras, eucalypts and *L. phylicoides* flowered poorly in the Glenbrook area, while the yellow tea-tree *L. flavescens* flowered profusely, yielding 15 species of *Stigmodera,* three species of *Cisseis* and *Torresita cuprifera* (see Tables 1, 2). Flowering of this species at Glenbrook began in the last week of November, reached a peak during 8-10 December and had ceased by the 14 December, by which time petals had fallen off or blown off and fruit development was well advanced. No buprestids were collected after the 18 December from *L. flavescens* at Glenbrook. This represents a marked synchronization between the flowering of the food plant and the appearance of adult beetles.

One specimen of *Stigmodera kirbyi* was collected on the 19 Jan. 1977 from a late-flowering plant of *L. flavescens,* 5.5 km S.E. of Wentworth Falls, and a

single example of *S. octospilota* was collected from a poorly flowering *L. phylicoides* near Medlow Bath, in the higher Blue Mountains on the 20 Dec. 1976. These were the only *Stigmodera* collected from *Leptospermum* after the 18 Dec. 1976.

Williams (1977) collected 16 species of Stigmodera from *L. flavescens* at East Minto, N.S.W., during 1972-75, which is 50 km S.E. of Glenbrook; of these only six species were collected during 1976/77 at Glenbrook, while *Stigmodera bicincta, S. crenata, S. octospilota, S. erythroptera, S. kerremansi, S. scalaris, S. subpura* and *S. vigilans* (*?*) were not collected in any season by Williams, but most of the above were present both seasons at Glenbrook. Williams (1977) records the interesting observation of *Neocuris guerini, Curis caloptera* and *Cyria imperialis* on *L. flavescens*; none of these species were observed on *L. flavescens* at Glenbrook (*N. guerini* was not collected at all from any plants); on the other hand *Torresita cuprifera, Cisseis atroviolacea, C. maculata* and *C. vicina* also found on *L. flavescens* at Glenbrook were not recorded by Williams. Williams (1977) noted considerable seasonal variation both in number of species and numbers of individuals present during his three years of observation. This observation was also noted during this study (Tables 1, 2).

It appears that the presence of many feeding beetle species is strongly associated with the species of plant flowering, and rainfall and temperature appeared to have little effect on their occurrence. One example is *Cyria imperialis,* which usually shows specificity to *Banksia* spp. (Froggatt, 1907; Tillyard, 1926; McKeown 1945), but was recorded on *Leptospermum flavescens* by Williams (1977). At Glenbrook it was only found during late December and early January 1975/76 on *Banksia spinulosa* Sm., which flowered well during this season. This plant did not flower during 1976/77 and extensive searching amongst *Banksia* bushes during the summer failed to find any of these buprestids.

Other examples of nectar-feeding buprestids showing apparent specificity for one species of plant and appearing only during one season include *Stigmodera andersoni, S. brutella, S. flavopicta, S. luteipennis, S. nasuta, S. decemmaculata, S. spinolae, S. subpura, Curis caloptera, Cisseis atroviolacea* and *C. maculata.* It is felt, however, that with further observations many of these species may be found to frequent more than one species of plant.

(b) *Flight behaviour*

Observations on flight were obtained during the 1976/77 season. Periods spent in flight varied from one to greater than 70 seconds, depending on the genus and size of species (Table 3). Generally, the larger species, such as *Stigmodera rufipennis* and *S. undulata,* were more sedentary than the smaller more active species, e.g., *S. scalaris* and *S. crenata.* The very active *Cisseis atroviolacea, C. vicina* and *C. maculata,* observed during the 1976/77 season, spent most of their time amongst the flowers of *Leptospermum flavescens,* and usually flew when disturbed or closely approached. Observations showed that standing or movement

of the author at distances of 15 to 50 cm from the feeding beetles aroused them, causing them to take immediate flight or to display the "free-fall and flight-escape mechanism" (see later). Beetles, when disturbed while feeding, usually ceased movement for about one second, quickly opened their elytra outwards and flew rapidly upwards or slightly horizontally.

One small specimen of *S. macularia,* the largest species examined, observed on the 2 Dec. 1976 at Blaxland, was very inactive, remaining motionless for more than five minutes before being collected, examined and later released (Table 3).

TABLE 3

Data on flight, feeding, defence and escape mechanisms for some species of Buprestidae observed in the study area during 1975-1977

Species	Periods spent feeding (secs)	Periods in flight (secs)	Feeding heights (m)	Defence and escape mechanisms +
A. *Small species* 5-13 mm (total length)				
1. *Stigmodera crenata* (Don.)	3-15	10->25	1.2-2.0	1 2 3 4
2. *Stigmodera erythroptera* Boisd.	2-25	5-30(?)	1.2-3.2	2 3 5
3. *Stigmodera kerremansi* Blkb.	5-15	>5(?)	0.7-2.0, 6.0	1 3 4
4. *Stigmodera scalaris* Boisd.	3-20	5-25(?)	1.2-2.2	1 3 4
5. *Cisseis atroviolacea* Thoms.	>120	>3(?)	1.1-2.5	1 3
6. *Cisseis maculata* L. & G.	>90	*	1.5-2.0	1 3
7. *Cisseis pygmaea* Blkb.	*	1-10	0.5-1.3	1
8. *Cisseis vicina* Kerr.	>120	*	1.5-2.0	1 3
B. *Large species* >13 mm (total length)				
9. *Stigmodera macularia* (Don.)	20->300	15-30	0.8-2.5	2 3
10. *Stigmodera rufipennis* (Kirby)	25-195	15-70(?)	1.4-2.8	3 5
11. *Stigmodera undulata* (Don.)	25-125	3-20(?)	1.0-2.0	2 3 4
12. *Stigmodera variabilis* (Don.)	>180	>5(?)	3.2, 6.0-9.0	4

KEY

(?) Specimens of these species were observed to fly away from food plants into surrounding bushland or out of sight. Hence the larger time(s) given is the time from departure of the food-plant to the time when the beetle(s) disappeared from sight.

* = No data available or not observed.

\+ Defence and escape mechanisms
- 1 = Free-fall and flight
- 2 = Free-fall and death feign
- 3 = Upward flight
- 4 = Bright colour(s) on dark background
- 5 = Batesian mimic.

When in flight, all species of *Stigmodera* flew with abdomen pointed downwards, elytra positioned horizontally, and head and pronotum pointed slightly forward. They made circular flights around the largest bushes of *L. flavescens,* which had the most flowers open. They often reversed direction and circled back

and forth over and around the tops of the bushes before landing. Slight disturb ances, causing branches to move suddenly, caused individuals to take flight.

Barker (1975) first recorded the presence of a spring mechanism, involving the release of the elytra from the closed position, in the genus *Astraeus*. When the beetle releases the spring, the elytra flick open with considerable force, enabling the insect to be flung upwards. Barker (1975) recorded the height achieved by some species as "several metres"; observations on *A. pygmaeus* at Glenbrook, on the 7 Jan. 1977, showed the height obtained before flying in other directions to be approximately 0.3-0.6 m. Beetles observed were quite active and when approached would quickly flick to another branchlet, often turning in one direction, reversing and flying (?) or flicking off again. Occasionally individuals were observed to fall quickly to another *Casuarina* branchlet, [species of *Astraeus* are mainly found on *Casuarina* plants, Barker, (1975)], either resting there or flicking off to a higher altitude (up to 2.5 m). From the observations of these uncommon insects at Glenbrook it appears that individuals fly rarely and mainly remain on branchlets of their food plant *Casuarina torulosa* Ait; it appears that the spring mechanism is used to propel the insect upwards or downwards, and the wings used only to reach a convenient resting post, which was unable to be reached by the spring mechanism alone.

Germarica lilliputana, observed during January, 1977, at Glenbrook and Medlow Bath, tended to remain on *Casuarina torulosa* Ait., or *C. nana* Sieb. ex. Spreng. branchlets, and flight was not observed.

Cyria imperialis, a strong flier producing a loud whirring noise while in the air, was observed during January, 1976, at Glenbrook. The species appears to be a wary insect, and flies far and fast when disturbed or approached; three specimens, observed 2.2 km N.E. of Glenbrook, displayed the "free-fall and death feign" escape mechanism (see later).

Flight was not observed in *Melobasis, Curis, Paracephala* or *Torresita.*

(c) *Feeding biology*

The *Leptospermum, Angophora* and *Eucalyptus* flowers (Family Myrtaceae), upon which many species of *Stigmodera* were observed and/or collected during 1975/77, are constructed so as to give easy access to the nectar supply for sugar-requiring species of Buprestidae and other species of insects. (Fig. 1 A and B, and Fig. 2 A and B).

The small species of buprestid, upon landing on a blossom, proceed to move through or over the series of stamens surrounding the ovary of the flower and to the areas where the numerous secretory cells are situated. The nectar collects in a hollow or groove formed by the edge of the ovary summit and the inner surface of the floral tube, but may spread over the top of the ovary in flowers with a considerable nectar supply. The nectar of these plant genera is sweet-

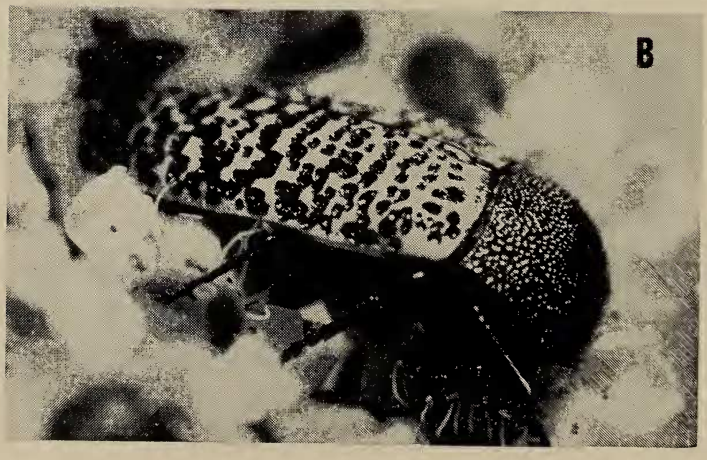

FIG. 1.—A. *Stigmodera macularia* on flowers of *Angophora bakeri*.
B. *S. macularia* on *Leptospermum flavescens*.

(Note deep pits on elytra and puncturing on pronotum).

smelling and the sugar content appears to be composed, in *Leptospermum* at least, of glucose and fructose (Dr. H. A. Ford, pers. comm.), which is the necessary energy source for these active beetles. The buprestid, with head extended or placed downwards into the flower, is able to draw up through the rostrum (present in *Stigmodera*) the sugary liquid.

Small species of *Stigmodera* examined, e.g. *S. scalaris, S. bella, S. bicincta, S. erythroptera, S. kerremansi, S. nasuta* and *S. subpura,* alight on a flower (*Leptospermum*) and, aided by quick movements of their legs and quivering movements of the antennae, proceed to the nectar-bearing areas and position themselves head down into the flower. The elytra remain closed and extend above the stamens, while the legs are used for balance during feeding.

Time spent feeding on *Leptospermum flavescens* varied from two seconds to approximately five minutes, most probably depending on the amount of nectar present in the flowers and the activity of the species (Table 3). The larger and slower moving species, e.g. *S. rufipennis,* spent more time feeding on the flowers of the tea-tree and less in flight than did the smaller species. The latter moved quickly and readily from flower to flower (although they often remained several minutes feeding within one flower).

Of the beetles observed feeding, either on *Leptospermum phylicoides* during 1975/76, or on *L. flavescens* during 1976/77 (both at Glenbrook), most species of *Stigmodera, Cisseis atroviolacea, C. vicina* and *C. maculata* fed singly and but for a few occasions remained isolated and relatively distant (15 cm or more away) from members of the same species, and also individuals of other species of buprestid. On the 5 Dec. 1976 a pair of *S. rufipennis* was observed feeding from 1 to 8 cm away from each other. However, since most species feed singly, this suggests that a spacing mechanism is involved, possibly enabling individuals to feed undisturbed and to gain a more equal share of the available nectar. However, the latter suggestion would be difficult to prove under field or laboratory conditions.

Most specimens of *Stigmodera* and *Cisseis* which were observed on *Leptospermum* visited flowers which were more than 1 m above ground level. The smaller bushes of *L. flavescens,* less than 1 m in height, were seldom visited by any buprestid. One specimen of *S. macularia,* collected on the 1 Dec. 1976 frequented a group of flowers of *L. flavescens* situated 0.8 m above ground level. Specimens of *Cisseis pygmaea,* observed during Jan.-Feb., 1976 and 1977, frequented young plants of *Dodonaea triquetra* Wendl., less than 1.3 m in height (Table 3). For *Leptospermum flavescens,* the height range for flower visitation was > 1 and < 3.5 m. *Stigmodera* flew at heights also within this range and seldom flew higher than 4 m. One individual of *S. rufipennis* flew approximately 7 m into the air after being disturbed on the 3 Dec. 1976. *Stigmodera variabilis* preferred greater heights when feeding. Specimens of this species were observed or collected only during Jan., 1976, feeding on the flowers of *Angophora bakeri* and *Eucalyptus piperita* at heights ranging between 6-9 m, and on the 6 Jan.

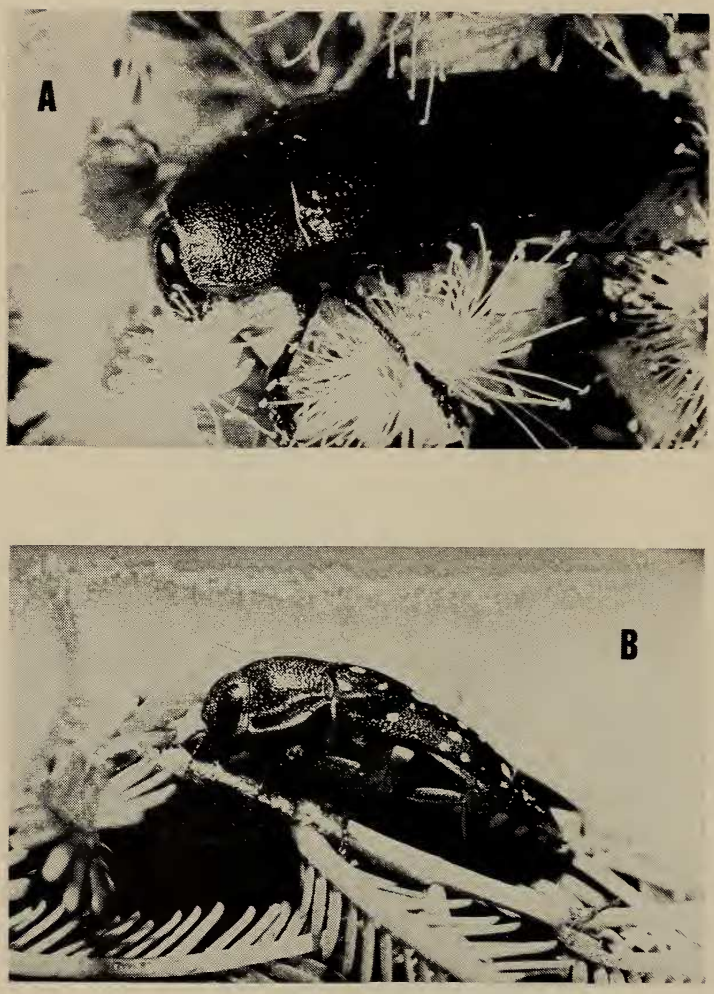

FIG. 2.—A. *Stigmodera variabilis* on flowers of *Angophora bakeri*.
B. *Cisseis leucosticta* feeding on a stem of *Acacia decurrens*.

1976 one individual was collected on a large *Leptospermum phylicoides* plant at a height of about 3.2 m. *Curis caloptera, Stigmodera kerremansi* and other species of *Stigmodera* collected during January, 1976, at Glenbrook, fed upon flowers of *Angophora floribunda* at heights of over 6 m. Most species of *Stigmodera* found feeding on *Leptospermum phylicoides* during 1975/76 frequented flowers at heights of $>$ 1 m and $<$2 m. It appears, then, that nectar-frequenting species of Buprestidae have a height preference for flowers (depending on the species of food plant); those flowers less than 1 m above ground level are seldom visited. Those flowers visited appear to be mainly the top flowers, or flowers at tips of branches. It may be that the top flowers contain more nectar than the bottom flowers, and so these attract more insects. However, only superficial examination of the nectar supply of bottom and top flowers by the naked eye could be undertaken. From this examination it appeared that the bottom flowers were similar in condition to those higher up on the plant.

There appears to be no height preference at Glenbrook for species which are foliage eating, i.e. *Cisseis. Melobasis, Paracephala* and *Germarica.*

(d) *Flower pollination by buprestids*

Because of the habit of nectar-feeding *Stigmodera,* their movements over flowers and the structures of the *Leptospermum, Angophora* or *Eucalyptus* flowers themselves, it would appear that buprestid beetles as a whole are important pollinators of these plants. Many *Stigmodera* examined during Dec.-Jan., 1975/76 and 1976/77, had pollen attached to the sides of the pronotum and head region, as well as on the tarsi, other leg segments and the elytra.

Some species of *Stigmodera* have deep pitting on the elytra (Fig. 1B). These pits may act as reservoirs for fallen pollen, which may be carried by the beetle to other flowers. *S. macularia* is one such species; observations so far on this species, however, have not shown that the deep pits of the elytra are used for the transfer of pollen.

Several specimens of *Cisseis atroviolacea* and *C. vicina,* collected on the 4 Dec. 1976, near Blaxland, were copiously covered in pollen from *Leptospermum flavescens.*

(e) *Defence and escape mechanisms*

(i) *Bright colours*—many species of jewel-beetle observed were brightly coloured with dominant colours of red, yellow, orange, green and/or blue, i.e. bright colours on a dark background (see Tables 3, 4).

(ii) *Dull colours*—most species of *Cisseis, Germarica lilliputana, Paracephala cyaneipennis* and *Melobasis* collected were dull in colour—browns, dull greens, blues and dark shades. The green tint of a vivid species of *Melobasis* (Table 4) appeared to match the colour of *Acacia longiflora* (Andrews) Willd. leaves upon

which the insect was resting; this cryptic colouration may aid the species to escape from would-be predators. Small size and colouration of *Germarica lilliputana* are two factors which may aid in the protection of this species.

TABLE 4

Heights at which beetles were collected on host plants and defence and escape mechanisms observed for some species of Buprestidae from the Blue Mountains, N.S.W. (1975-1977)

	Heights (m)	Defence and escape mechanisms +				
A. *Small species* < 16 mm (total length)						
1. *Cisseis leucosticta* (Kirby)	0.7-1.2		2	4		
2. *Cisseis marmorata* L. & G.	0.6-1.2			4		
3. *Cisseis notulata* Germ.	0.9-1.5	1				
4. *Cisseis roseo-cuprea* Hope	0.4-0.6		2			
5. *Germarica lilliputana* (Thoms.)	0.5-3.5				5	
6. *Melobasis cupriceps* (Kirby) (?)	1.0-2.0				5	
7. *Paracephala cyaneipennis* Blkb.	0.3	*				
8. *Stigmodera* (?) *flavopicta* Boisd.	1.2-1.5	1		3		6
B. *Large species* > 16 mm (total length)						
9. *Cyria imperialis* (Fabr.)	1.1-1.5		2			6

KEY
+ Defence and escape mechanisms
1 = Free-fall and flight
2 = Free-fall and death feign
3 = Upward flight
4 = Defence secretions
5 = Cryptic colouration
6 = Bright colour(s) on a dark background
* = Not observed or no data available
? = The identification of this species is uncertain.

(iii) *Batesian mimicry*—this phenomenon has been noted in *Stigmodera* (Nicholson, 1927; Britton, 1970). Batesian mimics in the author's collection were *S. rufipennis, S. nasuta, S. erythroptera, S. subpura* and *S. spinolae.* Nicholson (1927) and Britton (1970) illustrate in colour other mimics from the beetle families Cerambycidae, Curculionidae (Belidae), Buprestidae, Cantharidae and Oedemeridae. These beetles mimic the distasteful betles of the genus *Metriorrhynchus* Lycidae (or Lampyridae of older works). The most common of these beetles is *M. rhipidius* Macleay. It is interesting to note that this and other species of *Metriorrhynchus* were also present on *Leptospermum flavescens,* together with most species of buprestid mentioned above. (See also list of insects recorded visiting *L. flavescens,* apart from members of the Buprestidae, Table 5).

(iv) *Free-fall and flight*—several species of *Cisseis* (including *C. pygmaea* and *C. notulata*) and *Stigmodera crenata, S. scalaris, S. karremansi* and *S.* (?)

flavopicta, were observed to fall from a branch or flower when disturbed or approached, and then to fly away to a safer location immediately before hitting the ground (Tables 3, 4). This is no doubt a successful escape mechanism when attacked from above by a predator such a bird.

(v)*Free-fall and death feign—Stigmodera crenata, S. macularia, S. erythroptera, S. bella, S. undulata, Cisseis leucosticta, C. roseo-cuprea* and *Cyria imperialis,* all exhibited this escape mechanism when disturbed (Tables 3, 4). Hawkeswood (1977) has made a brief comment about this escape mechanism exhibited by

TABLE 5

The occurrence of identified insect species, other than the Buprestidae, visiting the leaves or flowers of LEPTOSPERMUM FLAVESCENS Sm., observed and/or collected at Glenbrook and Blaxland, N.S.W., during December 1-12, 1976

Order	Family	Genera and Species	Occurrence
Hymenoptera	Apidae	*Apis mellifera* L.	common
	Sphecidae	*Exeirus lateritius* Shuck.	rare
	Psammocharidae (Pompilidae)	*Cryptochielus fulvidorsalis* Turn.	rare
	Formicidae	*Iridomyrmex* sp.	few
		Polyrhachis ammon Fabr.	rare
Lepidoptera	Amatidae (Syntomidae)	*Eressa paurospila* Turn. (?)	common
Hemiptera	Reduviidae	*Poecilosphrodrus* sp. (?)	few
Diptera	Asilidae	*Chrysopogon crabroniformis* Roder.	rare
Coleoptera	Mordellidae	*Mordella leucosticta* Germ.	rare
		Mordellisterna spp. (2)	common
	Scarabaeidae	*Phyllotocus macleayi* Fisher	common
		Phyllotocus sp.	common
		Polystigma punctata (Don.)	rare
		Liparetrus discipennis Güer.	few
		Repsimus manicatus manicatus (Swartz)	rare
		Glycyphana brunnipes (Kirby)	few
	Lycidae	*Metriorrhynchus rhipidius* Macleay	common
		M. irregularis Waterhouse	few
		M. heterodoxus Lea	few
		M. eremitus Fabricius	few
	Cantharidae	*Chaulignathus pulchellus* (Macleay)	rare
		Heteromastix anticus Blackburn	common
		H. simplex Lea	common
		Selenurus sydneyensis Blackburn	few
	Chrysomelidae	*Paropsis* spp. (2)	rare
	Cleridae	*Trogodendron fasciculatum* Schreib.	rare
		Scrobiger sp.	few
		Aulicus sp.	few
		Opilo congruus Newman	common
	Elateridae	*Anilicus* sp.	common

KEY

rare = < 3 specimens observed; few = 3-10 specimens observed; common = > 10 specimens observed; ? = identification of these species is uncertain.

some Australian members of the Chrysomelidae (Coleoptera), but, from the literature available, little has been noted on this escape mechanism in the Buprestidae. Whitlock (1947), noting observations in the field on some Western Australian buprestids, records "jewel-beetles I am acquainted with have the habit of dropping down in an inert condition" when he approached or disturbed feeding beetles. The buprestid beetles observed at Glenbrook exhibited an immediate fall to the ground from heights ranging from 0.6 m to 2.0 m. On the ground they would lie positioned upside-down with a uniform coloured undersurface facing upwards. Between small pebbles, small rocks, sand, or amongst grass and other plants, the beetles appeared well camouflaged.

(vi) *Upward flight*—most species of *Stigmodera* immediately flew off in a vertical or angular direction if violently disturbed by a gust of strong wind causing a branch to move suddenly where an individual was feeding.

(vii) *Defence secretions*—Defence secretions have been noted to be exuded by *Torresita cuprifera, Cisseis leucosticta* and *C. marmorata.*

One specimen of *T. cuprifera,* captured on the 13 Dec. 1976 on *Leptospermum flavescens* exuded, from the mouth, a non-odorous crimson-coloured liquid when handled. A pale yellow non-odorous liquid was also exuded from the mouth in *Cisseis leucosticta* and *C. marmorata,* which stained the skin of the author's fingers.

(f) *Tarsal and antennal cleaning*

These aspects of grooming in Buprestidae were only observed in *Stigmodera undulata, S. rufipennis* and *S. macularia* in this study.

Individuals observed stroked the tarsal segments of the forelegs through the mouth region, starting at tarsal segment I and continuing to tarsal segment IV. Having completed one to three strokes in this manner for one tarsus, individual beetles would then repeat this action for the tarsus of the other foreleg. The exchange from one foreleg to the other was occasionally repeated twice or more, but usually one series of cleaning for each foreleg was administered. After the completion of tarsal cleaning, the antennae would be wiped several times by the previously cleaned tarsi of the forelegs. This is most probably an effective method in removing dust and pollen grains, which may impede the sensory function of the antennae. Tarsi of legs II and III were not observed to be cleaned; this is most probably because the beetles are unable to reach them with their mouthparts. However, these tarsi may be cleaned by other tarsi, although this was not observed.

(g) *Predators and relationships with other insects*

Table 5 lists the main insect species collected and observed feeding or visiting flowers of *Leptospermum flavescens,* excluding the Buprestidae. The list excludes unidentified members of the Diptera (Tabanidae, Muscidae and Syrphidae) and Hymenoptera (Sphecidae, Ichneumonidae). Several spiders of the family Argiopidae were also observed living amongst the branches of the tea-tree.

Predation of insect species by other insects was observed in *Apis mellifera* L., which was predated upon by the red and black assassin-bug *Poecilosphrodus* sp. (?), a resident insect amongst the leaves of the tea-tree. *Araneus* spiders, resident amongst the foliage of the tea-tree, had caught numerous specimens of *Selenurus sydneyensis* Blkb., *Metriorrhynchus* spp., and *Chaulignathus pulchellus* (Macleay), but careful examination of webs failed to find any captured buprestids.

Observations also showed no physical contact between buprestids and other species of insects.

On the 4 Dec. 1976 a ♂ eastern spinebill (*Acanthorhynchus tenuiostris*) spent about 10 minutes feeding on insects frequenting a stand of *L. flavescens* 1.7 km E. of Blaxland; however, due to quick movements of the spinebill through and over the tea-tree shrubs, the author was unable to determine if buprestids were included in the bird's diet.

SUMMARY

(a) There appears to be a marked synchronization between flowering of food plants and the appearance of adults of nectar-feeding species of *Stigmodera, Cisseis* and *Torresita.* Generally, most individuals and species were found just before and during the final flowering phases of the food plants when most flowers were open and contained large quantities of nectar. No nectar-feeding buprestids were found on plants either before or after flowering had occurred.

(b) Most species of *Stigmodera* showed preference for one or two food plants and only *S. variabilis* and *S. cruenta* were collected on three different plant species during 1975/76. Many species of *Stigmodera* were collected only during one of the two seasons, while some, e.g. *S. macularia,* were collected during both seasons. Since a strong degree of specificity for a particular food plant appears to exist with certain nectar-feeding buprestids, the absence of beetles may have been due to the plants' failure to flower, or flower poorly.

A dead specimen of *Melobasis costata* was collected on a grass stalk during January, 1976, while a slow-moving specimen of *Stigmodera spilota* was collected from a non-flowering plant of *Acacia linifolia* (Vent.) Willd. during February, 1976, so it is unlikely that these are the food plants for these buprestids. For the remaining 40 species of buprestid collected, data on food plants have been given.

(c) Generally, larger species of *Stigmodera* were more sedentary than the smaller, more active species of *Stigmodera* and *Cisseis.*

Specimens of three species of *Cisseis* observed on *Leptospermum flavescens* during 1976/77 flew upwards or exhibited the "free-fall and flight" escape mechanism when approached within 15-50 cm from where beetles were feeding. This appears to indicate an acute awareness of predators and efficient methods of escape.

Many *Stigmodera* made circular flights and often flew back and forth over and around the tops of *Leptospermum* bushes before landing to feed. It appears that there is some type of spacing mechanism which exists between nectar-feeding buprestids, enabling beetles to feed undisturbd and to procure an adequate supply of nectar. More observations, however, are needed on this behaviour.

Barker (1975) was the first to record the presence of a spring mechanism in the genus *Astraeus*. Observations on *A. pygmaeus* at Glenbrook showed that beetles were quite active and used the spring mechanism to propel themselves upwards or downwards to reach other resting posts. Heights obtained were found to be about 0.3-0.6 m.

(d) Larger and slower moving species of *Stigmodera* spent more time upon and feeding within flowers between flights than did the smaller species, which usually spent only several seconds feeding within one flower before flying to another flower.

There appears to be a height preference for nectar-feeding species of *Stigmodera* and *Cisseis*. For *Leptospermum flavescens* height visitation was mostly between 1 and 3.5 m, for *L. phylicoides* 1 to 2 m, *Angophora floribunda* > 6 m, and for *A. bakeri* 6 to 9 m. The blossoms visited appeared to be the topmost flowers, or flowers at tips of branches. Superficial examination showed that the lower flowers were in similar condition to those above; therefore quantity of nectar did not appear to determine the height preferred for feeding.

There appears to be no height preference for buprestids which are foliage feeders, e.g. *Paracephala, Germarica* and *Cisseis* which were found at various heights on different food plants.

(e) Many specimens of *Stigmodera* and nectar-feeding *Cisseis* were observed to carry pollen of their food plants. It appears that these beetles may be important pollinators of these plants.

(f) Several escape mechanisms have been observed, two of which have been descriptively termed in this paper, the "free-fall and flight" and the "free-fall and death feign" escape mechanisms. They appear to be efficient methods of escape (as verified by human disturbance), but there have been no observations on escape from natural predators.

The defence secretions occurring in three species of buprestid appear to represent the first record of such secretions in the Australian Buprestidae. The usefulness of these secretions in defence against natural predators has not been observed.

(g) Observations on tarsal and antennal cleaning by three species of *Stigmodera* have been recorded.

(h) A large number of insect species belonging to numerous families were found visiting blossoms of *Leptospermum flavescens* at Glenbrook and near

Blaxland, N.S.W., during December, 1976. Spiders (*Araneus* sp). had captured numerous beetles, but careful examination of the webs showed that no buprestids had been captured.

ACKNOWLEDGEMENTS

I would like to thank Professor A. F. O'Farrell of the Zoology Department and Dr N. Prakash of the Botany Department, University of New England, Armidale, N.S.W., for examining and commenting on the manuscript, for the use of the University of New England Insect Collection for assistance in species identification, for the use of the Macleay Museum, University of Sydney, and to Mr Allan Davies for assistance while I was at the Museum. Lastly, but not least, I would like to thank my brother Brian for accompanying me on most of my collecting trips, assisting in collection and data recording, and for photographing the species figured in this paper.

REFERENCES

BARKER, S. (1975). Revision of the genus *Astraeus* Laporte & Gory (Coleoptera: Buprestidae). Trans. R. Soc. S.A. *99,* 105-141, text figs. 1-25.

BARKER, S. & D. H. EDWARD (1963). Corrections to type localities of three species of Western Australian *Stigmodera* (Buprestidae, Coleoptera). West. Aust. Nat. *8,* 169-171.

BARKER, S., D. H. EDWARD & J. A. L. WATSON (1960). The distribution of the jewel-beetle *Stigmodera* (*Castiarina*) *magnetica* Cart. West. Aust. Nat. *7,* 168.

BARKER, S., R. P. McMILLAN & J. A. L. WATSON (1956). A jewel beetle, *Stigmodera* (*Castiarina*) *magnetica* Cart. West. Aust. Nat. *5,* 143-144, plate 1.

BEADLE, N. C. W., O. D. EVANS & R. C. CAROLIN (1972). Flora of the Sydney Region. A. H. & A. W. Reed, Sydney, 724 pp.

BRITTON, E. B. (1970). Jewel beetles (Buprestidae: Coleoptera). Chapter 30, In: The Insects of Australia. *C.S.I.R.O.,* Melb. Uni. Press, Carlton, Victoria, 1029 pp.

CARTER, H. J. (1916). Revision of the genus *Stigmodera* and descriptions of some new species of Buprestidae (Order Coleoptera). Trans & Proc. R. Soc. S.A. *40,* 78-144, plates IX & X.

CARTER, H. J. (1923a). Revision of the genera *Ethon, Cisseis* and their allies (Buprestidae), Proc. Linn. Soc. N.S.W. *48,* 159-176.

CARTER, H. J. (1923b). A revision of the Australian species of the genus *Melobasis* (Family Buprestidae, Order Coleoptera), with notes on allied genera. Trans. Ent. Soc. Lond. *71,* 64-105, plates I, II.

CARTER, H. J. (1929). A check list of the Australian Buprestidae. Aust. Zool. *5,* 265-301.

CARTER, H. J. (1931a). Check list of the Australian Buprestidae, Corrigenda. Aust. Zool. *6,* 107-108.

CARTER, H. J. (1931b). Notes on the genus *Stigmodera* (Family Buprestidae), (together with descriptions of a new species of and a retabulation of the subgenus *Castiarina*). Aust. Zool. *6,* 337-367.

FROGGATT, W. W. (1907). Australian Insects. W. Brooks & Co., Sydney, 449 pp.

GLAUERT, L. (1948). A rare jewel beetle. West. Aust. Nat. *1,* 129-130.

HAWKESWOOD, T. J. (1977). Those mighty plant defoliators—the Chrysomelidae. Wildlife, Aust. *14,* 11-14.

HUGHES, R. D. (1975). Living Insects. Collins, Sydney, 304 pp.

McKEOWN, K. C. (1945). Australian Insects, Royal Zoological Society of New South Wales, Sydney, 303 pp.

NICHOLSON, A. J. (1927). A new theory of mimicry in insects. Aust. Zool. *5,* 10-104, text figs. 1-3, plates I-XIV.

TILLYARD, R. J. (1926). The Insects of Australia and New Zealand. Angus & Robertson, Sydney, 560 pp.

WHITLOCK, F. L. (1947). West Australian jewel beetles. West. Aust. Nat. *1,* 9-13.

WILLIAMS, G. A. (1977). A list of the Buprestidae (Coleoptera) collected from *Leptospermum flavescens* Sm. at East Minto, New South Wales. Aust. ent. Mag. *3,* 81-82.