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Biological observations of the Australian green carpenter bees, genus *Lestis* (Hymenoptera: Anthophoridae: Xylocopini)

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Abstract

Opportunistic observations of the nests, provisions, life histories, forage plants, colony structure and nest associates of *Lestis bombylans* and *L. aeratus* are recorded and discussed. *L. aeratus* is recorded from South Australia for the first time.

Complex burrow systems with a single entrance occurred commonly and were inhabited by varying numbers of adults of both sexes (up to 10 females and 25 males). While some of these groups may have consisted of newly emerged siblings (with an older female, perhaps the mother, sometimes present) at least one group appeared to be an overwintering aggregation. In another nest, two females constructed brood cells independently. Nests appeared to be perennial when sufficient stem was available for extension of the burrow systems.

In south-eastern Queensland, cells of *L. bombylans* were constructed at the rate of one every two days and development from egg to adult required about 65 days.

Females are polylectic and form firm, somewhat tetrahedral provision masses. Pollen-collecting observed in the absence of brood cells probably served to sustain groups of overwintering adults.

The mite *Sennertia leei* occurred as a commensal in some nests, consuming unused provision, and its hypopi were carried by the adult bees.

Introduction

Lestis is an endemic Australian genus of large, attractive, metallic green bees (Figures 1, 2). There are probably only two valid species, *L. bombylans* Fabricius and *L. aeratus* Smith, but a critical revision of the genus is required (Hurd and Moure 1963, Michener 1965).

The genus is recorded only from eastern Australia, ranging from Cape York to Victoria (occurring chiefly on and east of the Great Dividing Range) but extends also into southern South Australia (a fact which has not previously been recorded in the literature).

The bees are reasonably abundant and yet little has been recorded of their habits. The observations presented here were made opportunistically over an eleven year period (1968-78) and, although fragmentary, significantly extend our knowledge of these fine bees. As there seems little chance that I will undertake further studies of the bees, it seems desirable that my field notes should be published and made available to other workers.

Specimens taken during the course of my observations have been deposited in the collections of the South Australian Museum, Adelaide, and the Western Australian Museum, Perth.

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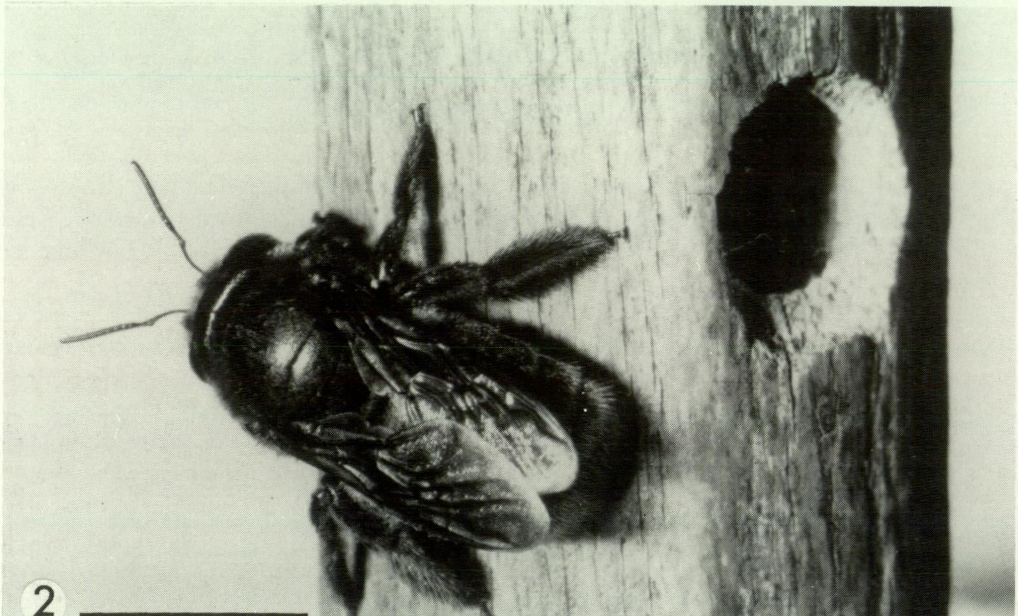


Figures 1-2 Adults of *Lestis: (1) male of L. bombylans* (note the numerous hypopi of the mite *Sennertia leei* clinging to the thoracic pubescence, especially close to the head); (2) female of *L. aeratus* near the entrance to its nest in a dead flower scape of *Xanthorrhoea*. Scale lines = 1 cm.

Summary of literature

Hurd and Moure (1963) listed all prior biological references to *Lestis* and summarized the known nesting substrates. Smith (1851) gave the first account of the nests of *Lestis*, stating that the bees nested in the hollow stems of "Zamia or the grass trees" (perhaps confusing *Xanthorrhoea* with the cycad *Macrozamia*). Froggatt (1896) also recorded *bombylans* (as *bombiliformis*) nesting in dry flower scapes of *Xanthorrhoea*. Hacker (1918) reported that, near Brisbane, *L. bombylans* made its nests in dead stems or branches of *Xanthorrhoea, Leptospermum* and *Casuarina* and females were said to defend their nests by blocking the entrance holes with their heads. Hacker figured one nest with a simple burrow along the length of a branch, a lateral entrance hole, and five closed brood cells in two linear series, three at one end of the burrow and two at the other. Rayment (1935) briefly described the nesting activity of *L. bombylans* in the dry flower scapes of *Xanthorrhoea*. His description of the nest was essentially similar to Hacker's. Rayment noted also that nests of '*L. aerata*' had been found in twigs of *Casuarina* in Victoria. McKeown (1945) briefly described and figured the nest of *L. bombylans* and Michener (1965: 243) recorded some forage plants for this species.

Observations and Discussion

Geographic Distribution

Lestis has been reported as occurring from northern Queensland to Victoria (east to the Grampian Ranges) (Hacker 1921, Hurd & Moure 1963, Michener 1965). However, specimens in Australian collections suggest a patchy and chiefly coastal distribution from the tip of Cape York, Qd, south to Victoria and east to Kangaroo Island, South Australia. The range does not extend west of the Great Dividing Range and Carnarvon Gorge National Park, 290 km south-west of Rockhampton, Queensland, is the most inland record. I have seen no specimens from Tasmania despite Smith's (1854) record of *L. aeratus* from 'Van Diemens Land'.

The individual distributions of the two species have not been clearly established. Cockerell (1930) considered *aeratus* to range from northern Queensland to Victoria and *bombylans* to be restricted to Queensland. However, Rayment (1954) recorded the latter also from Sydney. Clarification of the distributions must await a revision of the species and is beyond the scope of this paper.

L. aeratus is extant on Kangaroo Island but is probably now extinct on mainland South Australia. Its former occurrence there is attested by the following old specimens in the South Australian Museum: 1 ♀, Aldinga, 28.7.[18]96, W.F.[?] Kimber; 1♂, Aldinga; 1 ♀, Naracoorte, 29.9.[18]88, R.D., Rev. A. Burgess; 1♂, 1♀, Naracoorte. Extensive searches of likely habitat near these and other mainland localities (including southern Yorke and Eyre Peninsulas) during 1970-78 revealed no sightings of *Lestis* nor any signs of their work.

An intensive search for adults and nests of *L. aeratus* was made on Kangaroo Island during two visits in 1970 and 1978. The localities where they were found are listed in

Table 1. These localites are distributed peripherally on the western two thirds of the island. No trace of the species was found on the eastern third of the island or in its central region despite the occurrence there of some seemingly suitable habitat and nesting substrate.

Floral relationships

Very few records of flower visiting are available for *Lestis* but they do suggest that the bees are polylectic. Michener (1965) recorded *bombylans* visiting flowers of four genera, *Hibbertia* (Dilleniaceae), *Baeckea* and *Melaleuca* (Myrtaceae), and *Leucopogon* (Epacridaceae), and collecting pollen from the first two of these genera. Eight females of *bombylans* collecting pollen from *Hibbertia* were captured by me near Noosa, Queensland, in January. Females buzzed quite audibly as they raked through the dense clusters of stamens, a phenomenon reported for other bees that collect pollen from flowers with 'shaving-brush' clusters of stamens (Buchmann 1985).

Records for *aeratus* are 1♂, 2♀ from flowers of *Leptospermum* and 2♀ from flowers of *Leucopogon* on Kangaroo Island, South Australia, in October. Microscopic examination of both provisions and larval faeces from six cells in three nests and adult faeces from a fourth nest revealed four quite different unidentified kinds of pollen grains in one cell and a fifth, myrtaceous kind in all the remaining samples.

Nesting sites

Nine inhabited nests of each species and a few abandoned ones were observed. Details of nests and their contents are presented in Table 1.

The bees select standing, dead, dry, pithy wood in which to nest. I observed single nests of *L. bombylans* in trunks of *Acacia* and *Tristania suaveolens* and seven in branches of a single *Banksia* tree. All nests of *L. aeratus* were in flower scapes of *Xanthorrhoea*. Other plants utilized for nesting are *Casuarina* and *Leptospermum* (Hacker 1918, Rayment 1935). The range of nesting stem diameters was 17-70 mm in *bombylans* and 28-50 mm in *aeratus*. Nest entrances occurred 90-295 cm above the ground in *aeratus* and 120-270 cm in *bombylans*.

Generally, nests occurred singly. However, three separate nests of *aeratus* (two of them abandoned and one of these occupied by an ant colony) were found in a single flower scape of *Xanthorrhoea* near Rocky River Homestead on Kangaroo Island. At Woy Woy near Sydney, one *Banksia* branch contained two nests and another contained three nests of *bombylans*. In all cases the nests were occupied and the entrances were about 17-20 cm apart.

Nest architecture

Entrances to nests occurred laterally in stems or branches (not terminally) and consisted of a neat round hole (Figure 2) of diameter 7-8 mm (*bombylans*) and 8-10 mm (*aeratus*). Where nests occurred in horizontal or oblique branches, the entrances were

Table 1: Details of *Lestis* nest and their contents. All localities for *L. aeratus* are on Kangaroo Island, South Australia. Symbols: E, egg; pA, pharate adult; pP, prepupa; ˜ in the 'cells' column means no live stage present and in the immatures column means immature dead.

Nest #	Collection date and locality	No. of blind ends	Total length (mm)	No. of cells	No. of immatures	No. of adults ♀	No. of adults ♂
L. aeratus							
1.	4-8.x.1970 Cape Borda	2	318	0	0	3	2
2.	4-8.x.1970 Stokes Bay	2	204	0	0	2	0
3.	4-8.x.1970 Seal Bay	6	587	0	0	3	0
4.	ditto	5	628	0	0	9	12
5.	22.x.1970 Cape Borda	2	402	0	0	2	25
6.	8-20.iii.1978 Rocky River	6	720	0	0	5	7
7.	ditto	9	733	1	1pP˜	0	0
8.	14.iii.1978 Murray Lagoon	2	251	0	0	3	3
9.	20.iii.1978 Ravine de Casoars	3	400	1	1E˜, 2pA	2	3
10.	ditto	2	188	3	1L˜, 2pA	1	0
L. bombylans							
1.	10.ix.1968, nr Mooloolaba, Qd	2	155	5	3E, 1L	2	0
2.	20.xi.1968 Tambourine, Qd	6	423	0	0	5	1
3.	27.i.1971 Woy Woy, N.S.W.	10	795	1	0	8	4
4.	ditto	5	273	1	1pA	3	1
5.	ditto	3	215	1˜	0	10	3
6.	ditto	2	217	4˜	0	0	0
7.	ditto	7	272	1˜	?	4	3
8.	ditto	8	418	1?	1L	7	3
9.	ditto	8	454	0	0	5	1

always on the undersides. Entrance chambers broadened strongly within, extending no more than 1 cm before opening into the primary shaft.

Previous accounts of nests have noted only a single, simple burrow extending above and below the entrance. Seven nests found by me were of this form (Figure 3) but the majority (12 nests) had branched burrows (Figures 9-11). In all cases, the burrows extended along the grain of the wood (except for curved sections where burrows adjoined).

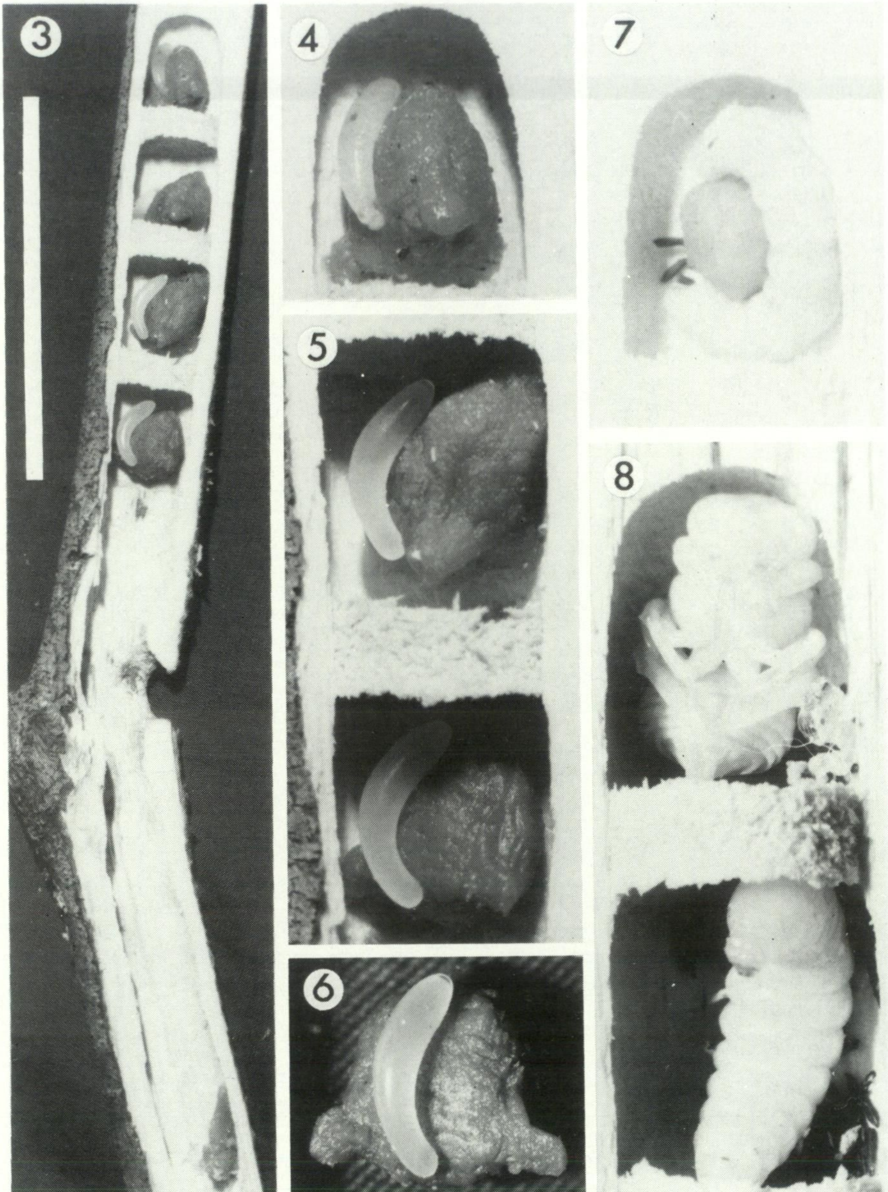
Presumably all nests are initiated as simple, double-ended burrows but, given adequate stem thickness, extensions may be added. Primary, secondary and tertiary burrows were recognized (Figure 9). Primary burrows were always double-ended but secondary and tertiary burrows were either single or double-ended. Both ascending and descending single-ended extensions were encountered. A measure of the complexity of burrow systems is given by the number of blind ends present (Table 1) and the most complex nest found was *bombylans* nest #3 with ten (Figure 9). In this instance, burrow lengths totalled 795 mm.

Internal openings (ports) connecting older burrows with newer ones were larger than nest entrances and usually elliptical. The largest measured had a greatest diameter of 25 mm. Secondary ports (openings into secondary burrows) usually occurred in close proximity to the nest entrances and tertiary ports were similarly close to secondary ports. Rarely did a burrow arise more than halfway along an ascending or descending portion of a parent burrow.

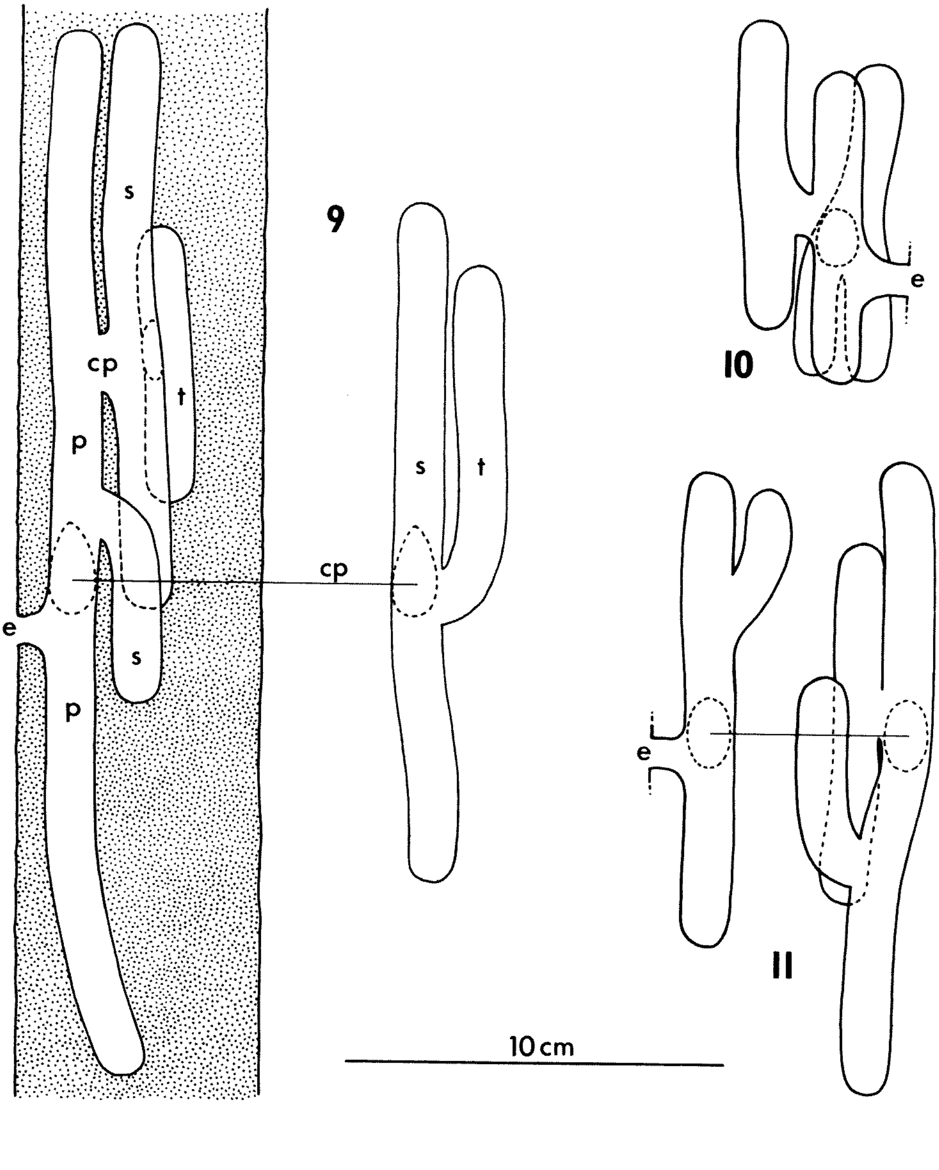
Burrows were round in section with a diameter of 11.0-12.5 mm in *bombylans* and 12.0-14.5 mm in *aeratus*. In complex nests, burrows often lay closely parallel and walls between them were sometimes paper thin. In a few cases, perforations occurred between closely juxtaposed burrows. Where three *aeratus* nests had been built in one stem, the burrows of adjacent nests interdigitated without contact and it was clear that during nest excavation females had deviated from straight paths to avoid one another's burrows.

The distal halves or two-thirds of burrows usually exhibited regular series of swellings. Where cells occurred, they coincided with the swellings and their caps with the constrictions. Some newly excavated burrows lacked swellings while others (still without cells) had them. One freshly provisioned but uncapped cell occurred in a swelling. These observations suggest that females first excavate cylindrical burrows then excavate the swellings prior to commencement of provisioning. Scraping particles of wood from the walls to form cell partitions most probably accentuates swellings ahead of completed cells.

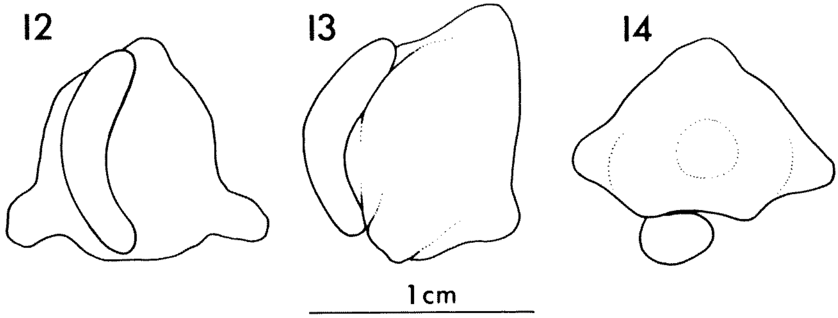
As will be seen from Table 1, cells were found in seven of the eight occupied nests of *bombylans* but only three of the nine occupied nests of *aeratus*. The greatest number of cells in any one nest was five in *bombylans* nest #1. Four closed cells occupied the upper section of this nest and one open cell being provisioned occurred in the lower section. Above the lowermost cell was a swelling and space adequate to accommodate a sixth cell. Evidence of up to six cells being built in series was provided by pollen-stained swellings with traces of cell caps in *aeratus* nests #8 and #9.



Figures 3-8 Nest, provisions and immatures of *Lestis bombylans* (nest # 1): (3) longitudinal section of nest (note unformed, incomplete provision in lower end of burrow; scale line = 5 cm); (4) first (uppermost) cell with first-instar larva on provision; (5) third and fourth cells with eggs on provisions; (6) egg on provision; (7) first cell with near-mature larva feeding on provision (note dark faeces); (8) first and second cells with pupa and prepupa.



Figures 9-11 Nest burrow complexes of *Lestis bombylans* in profile (diagrammatic; all from Woy Woy, N.S.W., in dead branches of *Banksia*; nests ## 1, 5, 7, respectively, Table 1). Branch substrate shown stippled in Figure 9. Horizontal lines associate parts of nests drawn separately by their connecting port. Legend: **cp** =connecting port; **e** = nest entrance; **p** = primary, **s** = secondary and **t** = tertiary burrows.



Figures 12-14 Three views of provision masses of *Lestis bombylans* bearing eggs: 12, 13 adaxial views; 14 axial view from proximal end (based on Kodachromes of nest #1 contents; see Figure 5 for orientation in cell; egg may have been displaced sideways through handling in 12 and 14).

Cells were barrel-shaped. Their caps, which were composed of cemented particles of wood or pith, were slightly concave with a distinct spiral pattern on the inner surface and smooth and strongly concave on the outer surface. They formed partitions between adjacent cells and were spaced at intervals of 16 mm in *bombylans* and 19 mm in *aeratus*.

Provisions

Newly completed provisions of both species consisted of firm moist masses of pollen, somewhat tetrahedral in shape and resting on four tubercles, one facing the cell base and three facing the cap (Figures 3-6, 12-14). The surface bearing the egg or young larva was gently concave (Fig. 14). Rayment (1935) and McKeown (1945) described the provision as spherical with the egg atop.

One incompletely provisioned cell contained a large 'scale' of moist pollen fitting flush against its base and side wall (Figure 3) so it appears that the bees accumulate pollen and nectar together in a compacted state during at least the late stages of foraging and then mould the provision prior to oviposition.

Immatures and development

The egg, typically large as in other xylocopines and measuring 9 mm in length in *bombylans*, rested on the flatter side of the provision lengthways in the cell (Figures 3, 5, 6). McKeown's (1945) figure (p. 201) incorrectly indicates a small egg *ca.* 3 mm long.

Some indication of the duration of the immature stages was gauged from the occupants of four cells in *bombylans* nest #1 which was kept intact and observed periodically in the laboratory. The immatures seemed to be about two days out of phase with their neighbours suggesting that the cells had been completed at intervals of two days. All eggs had hatched within a week of the nest being found. The larval feeding phase occupied 16-19 days with defaecation commencing on the 12th day. At this stage the larva was large enough to curl around and support the reduced, spherical provision mass (Figure 7) and the dry, dark red, rod-like faeces fell harmlessly to the floor of the cell. The prepupae and pupae orientated themselves with their heads towards the bases of their cells (Figure 8), not the caps as is usual amongst bees (two pharate adults of *aeratus* were found similarly orientated in their cells). Orientation of prepupae and pupae towards cell bases was figured for some *Xylocopa* species (Gerling *et al* 1983) and may be a xylocopine norm. Pupation occurred 13 days after the completion of feeding and adults began emerging from the pupal cuticle 25-27 days later. The total time from oviposition to emergence of the adult would have been a little over 65 days.

The pharate adults reorientated correctly with their heads against the cell caps and commenced picking at them with their mandibles. In *aeratus* nest #9 two pharate adults were found on top of a mass of loose frass (pith, faeces and exuviae).

Adult behaviour

Little was observed of female behaviour and nothing at all of males outside of nests.

When nests were being opened, an occupant female sometimes blocked the nest entrance with the dorsum of the metasoma and stubbornly resisted being dislodged with a probe. Such disturbance also resulted in some females emitting a loud buzzing sound (produced by vibration of the flight muscles) in short intermittent bursts or continuously for several minutes.

Adults were difficult to remove from burrows, even after the latter had been opened lengthwise, and tended to retreat to any part of the nest that afforded them more protection.

Occasionally, when an adult was grasped in forceps, it spurted liquid faecal material. Ejection of faecal fluid for distances up to 30 cm was also observed to occur from entrances of undisturbed nests of *bombylans*. Congealed drops of faecal material adhered to the lower rim of several nest entrances of both *Lestis* species suggesting that projectile defaecation is of common occurrence.

Nest occupancy and sociality

As will be seen from Table 1, most nests found were inhabited by both sexes and by more than one female. Even nests with just a single primary burrow (two blind ends) sometimes had more than one female. As nests were found and collected during the day, some of their adult inhabitants may have been out foraging and the figures in Table 1 may not fully represent nest populations. Up to nine females occupied nests of *aeratus*, up to ten in *bombylans*.

The degree of wing wear (as an indicator of relative age) was noted for all adults taken by me from nests. By far the majority of adults had entire wing margins and several bore one to a few nicks. Adults with well worn wings and therefore likely to be relatively old were seldom encountered with never more than one per nest complex.

One female from *bombylans* nest #1 had tattered wings while the wings of another were almost entire (for dates of these and the following records see Table 1). Dissection revealed that both females had well-developed ovaries with some enlarged oocytes, 5-6 mm long, and spermathecae containing sperm. As the nest contained two incomplete cells, it appeared that these females were nesting independently in opposite ends of the single burrow.

A female of *bombylans* collected while entering nest #3 loaded with pollen also had tattered wings. Her nest companions had entire wing margins and one male was obviously freshly emerged.

All five females in *bombylans* nest #2 had entire wing margins or (in one) only a few small nicks indicating that they were young females and they may have been progeny of the nest.

A female of *aeratus* collected while foraging at flowers on 4 October had extremely frayed wings and had presumably overwintered in this state.

Most nests were occupied by one or more males up to a maximum of 25 in *aeratus* nest #5. Not all of the males and two females of nest #5 could have been progeny of the nest: only 12 or 13 burrow swellings which could be equated to previous brood cells were discernible in the burrows and the total length of the burrow was quite insufficient to accommodate 27 brood cells. Consequently, some of these adults must have come from elsewhere. The wings of five males bore a few to several nicks indicative of some flight activity while those of the remainder were entire.

It was interesting to note that the walls of nest #5 were stained yellow with pollen, particularly closer to the entrance, suggesting that the females had been bringing in and unloading pollen shortly prior to collection of the nest. As no cells were present, the pollen may have provided nutrition for the large adult population.

The walls of many older burrows were dark-stained (usually a sooty grey), presumably by mould growing on pollen and nectar soiling, whereas newly excavated burrows were quite clean and pale. This contrast revealed where some old burrows had been extended. For example, the upper extremities of the primary and secondary burrows of *aeratus* nests #1, #3 and #4 had been extended upwards from 25-130 mm and these extensions lacked the swellings of the older, stained burrows. This suggests that successive generations may reuse burrows. However, old burrows probably cannot be refurbished for cell construction as their diameters would increase beyond acceptable limits as females scraped particles from the walls for construction of cell caps (Stark *et al* (1990) reported that females of *Xylocopa sulcatipes* competing for dominance will break into and reseal each others brood cells but did not reveal whether material from the old partition is reused or new material was scraped from burrow walls).

Evidence of recent burrowing occurred in many nests with two or more females and it seems clear that nesting proceeds in the presence of groups of adults.

To see if there was any indication of social behaviour in *Lestis*, I dissected eight females of *bombylans* collected while foraging for pollen at flowers of *Hibbertia*, 8 km south of Noosa, Queensland, on 18 January 1969. All females carried sperm in their spermathecae. Their ovaries varied from slender with no obvious oocytes to moderately enlarged with two or more oocytes up to 5.5 mm long. The females with the smallest ovaries all had very worn wing margins suggesting that they were old. However, two other females with very worn wings had moderately developed ovaries.

Phenology

A survey of specimen data in museum collections revealed only a sketchy picture of the phenology of *Lestis*. Adult females had been collected in all months except July with the greatest concentration in August-October. Males were far fewer but were also collected throughout much of the year. Specimen labels seldom indicated the circumstances of capture (whether from flowers or nests).

Similarly, only a sketchy picture of nesting phenology can be obtained from the available evidence. I found females of *bombylans* extending burrows and constructing cells in September in south-eastern Queensland and in late January near Sydney. Rayment (1935) recorded nest-building for *bombylans* in early October (locality not stated). Given an egg-adult development time of 65 days, successive generations of adults could appear in November, January and April. My nests ## 3-9, collected in late January, strongly suggested a recent emergence of adults and the earliest stages of cell construction (newly excavated burrows and one cell receiving pollen).

The nests of *aeratus* collected in October are presumed to have contained groups of over-wintering adults as months of wintery conditions had preceded their collection and while burrows were being extended, cell construction had not commenced. If cells were built around early November, successive generations of adults might appear in January and March. March nests (## 6-10) provided evidence of an emergence of young adults at that time. Assuming no further breeding occurs through the cool months of April-August, *aeratus* (at least in the southern extremity of its range) could produce two generations per year and *bombylans* (at least in the Brisbane-Sydney region) could produce three. However, many more observations are required to obtain a reliable picture of the phenology of the two species.

Associated organisms

Only one intranest associate of *Lestis* was found. A mite, tentatively identified as *Sennertia leei* Fain (Chaetodactylidae) by B.M. O'Connor, was encountered in three nests of *bombylans* and two of *aeratus*.

In *bombylans* nest #2, which contained no brood cells, nymphs and adults (but no hypopi) of the mite were found crawling about the tunnel walls. When a particle of pollen provision was placed in a tunnel the mites immediately converged on it and began feeding. They were then transferred to a glass vial with the provision and eggs appeared within three days.

The one closed cell in *bombylans* nest #3 was infested with the mites and contained a loose, powdery mass of pollen grains, mites and mite exuviae. No trace of a bee immature was found and it appeared that the mites had demolished a provision mass.

One male and five female *bombylans* adults in nest #9 carried hypopi. The mites were clustered on the frons, vertex, occiput, anterior of the scutum, the propodeum, base of metasoma and beneath the wing bases of the bees (Figure 1).

Mite larvae, nymphs and adults were also observed wandering in burrows of *aeratus* and a few hypopi were observed on prothoracic and scutal pubescence of adults of this species.

The foregoing observations suggest that *Sennertia leei* is a scavenger in nests of *Lestis*, feeding on larval provision. Whether the mites infest only cells where the bee immature has failed to develop remains to be answered. Clearly the mite is transported to new nests on the bodies of the bees.

Sennertia leei hypopi (misidentified as *S. bifilis* (Canestrini)) were recorded from adults of *bombylans* and *aeratus* by Rayment (1954).

Conclusions

It would be unwise to attempt to make comparisons at the species level between my observations of *Lestis* and those of earlier authors because of uncertainties as to the authenticity of their identifications. Generally though, my observations confirm and extend the observations of earlier observers with few points of divergence.

Whereas all previous reports of nests have described only a single nest burrow (extending above and below the nest entrance), this study has shown that nests are often more extensive and complex where stems are sufficiently thick. It shows, too, that previous reports of spherical provisions (Froggatt 1896, McKeown 1945) are inaccurate and were presumably based on observations of partly consumed provisions.

Generally, groups of adults within burrow systems consist mostly of young individuals (presumably progeny of the nests) and occasionally include single older females (presumably their mother). However, in some cases, at least, adults congregate in burrow systems other than their natal ones and such groups may overwinter together. More than one female may build cells in a burrow complex but no evidence of cooperative behaviour was noted.

Much remains to be learned about *Lestis* biology. Nothing at all has so far been recorded of male behaviour and mating. Virtually nothing is known of the social structure of colonies or the interactions that occur between adults in nests. Only the sketchiest details of flower preferences, foraging behaviour, voltinism and nesting phenology are known.

However, what is known of the bees is consistent with the known habits of other Xylocopini as revealed by recent literature (Watmough 1974, Gerling *et al* 1983, Michener 1988). No known feature of the bees' biology can be deemed to be exclusive to *Lestis*.

The only known nest associate of *Lestis*, the mite *Sennertia leei*, was originally described from adults of *L. bombylans* (Fain 1982). It lives as a commensal in nests of both *bombylans* and *aeratus*, feeding on larval provision. Other *Sennertia* species have similarly been recorded as commensals in nests of Xylocopini (Abrahamovich & de Alzuet 1990; de Alzuet & Abrahamovich 1990).

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References

Abrahamovich, A.H. & de Alzuet, A.B. (1990). Tipos de asociacion entre acaros e hymenopteros. I: *Sennertia (A.) splendidulae* Alzuet y Abrahamovich, 1988 (Acarina: Chaetodactylidae) comensal y foretico de *Xylocopa (S.) splendidula splendidula* Lepeletier, 1841 (Hymenoptera: Anthophoridae). Turrialba **40**(3): 319-322.

Buchmann, S.L. (1985). Bees use vibration to aid pollen collection from non-poricidal flowers. *J. Kans. ent. Soc.* **58**(3): 517-525.

Cockerell, T.D.A. (1930). The bees of Australia. *Aust. Zool.* **6**(2): 137-156.

de Alzuet, A.C.B. & Abrahamovich, A.H. (1990). Tipos de asociacion entre acaros e hymenopteros. II. Descripcion de los estados del ciclo de *Sennertia (A.) augustii*, sp. n. (Acarina, Chaetodactylidae) asociada a *Xylocopa augusti* Lepeletier, 1841 (Hymenoptera, Anthophoridae). *Revta bras. Ent.* **34**(3): 627-635.

Fain, A. (1982). *Sennertia* Oudemans (Acari, Chaetodactylidae) on Australian bees. *Trans. roy. Soc. S. Aust.* **106**(2): 67-70.

Froggatt, W.W. (1896). The entomology of the grass-trees *(Xanthorrhoea). Proc. linn. Soc. N.S.W.* **21**: 74-87.

Gerling, D., Hurd, P.D. jr & Hefetz, A. (1983). Comparative behavioral biology of two Middle East species of carpenter bees (*Xylocopa* Latreille) (Hymenoptera: Apoidea). *Smithsonian Contribs Zool.* no. 369: i-iii, 1-33.

Hacker, H. (1918). Entomological contributions. *Mem. Qd Mus.* **6**: 106-111.

Hacker, H. (1921). Catalogue of Australian bees. *Mem. Qd Mus.* **7**: 99-163.

Hurd, P.D. & Moure, J.S. (1963). A classification of the large carpenter bees (Xylocopini) (Hymenoptera: Apoidea). *Univ. Calif. Publs Ent.* **29**: i-iv, 1-365.

McKeown, K.C. (1945). *Australian Insects. An Introductory Handbook.* 2nd edn (Royal Zoological Society of N.S.W: Sydney).

Michener, C.D. (1990). Caste in xylocopine bees. Chapter 5, pp. 120-144, in Engels, W. (ed.), *Social Insects: an evolutionary approach to castes and reproduction.* (Springer-Verlag).

Rayment, T. (1935). *A Cluster of Bees.* (Endeavour Press: Sydney).

Rayment, T. (1954). Incidence of acarid mites on the biology of bees. *Aust. Zool.* **12**: 26-38.

Smith, F. (1851). Notes on the habits of Australian Hymenoptera. *Trans. ent. Soc. Lond.* n.s. **1**: 179-181.

Stark, R.E., Hefetz, A., Gerling, D., & Velthius, H.H.W. (1990). Reproductive competition involving oophagy in the socially nesting bee *Xylocopa sulcatipes. Naturwissenschaften* **77**(1): 38-40.

Watmough, R.H. (1974). Biology and behaviour of carpenter bees in southern Africa. *J. ent. Soc. south. Africa* **37**(2): 261-281.

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Guide to Authors

Subject Matter:

Reviews, observations and results of research into all branches of natural science and human studies will be considered for publication. However, emphasis is placed on studies pertaining to Western Australia. Full length papers should not normally exceed 30 typed pages. Short communications should not normally exceed three typed pages and this category of paper is intended to accommodate observations, results or new records of *significance*, that otherwise might not get into the literature, or for which there is a particular urgency for publication. All material must be original and not have been published elsewhere.

Presentation:

Authors are advised to follow the layout and style in the most recent issue of the *Rec. West. Aust. Mus.* including headings, tables, illustrations and references.

The title should be concise, informative and contain key words necessary for retrieval by modern searching techniques. Names of new taxa must not be included. An abridged title (not exceeding 50 letter spaces) should be included for use as a running head..

An abstract must be given in full length papers but not short communications, summarizing the scope of the work and principal findings. It should normally not exceed 2% of the paper and should be suitable for reprinting in reference periodicals. Contrary to Recommendation 23 of the International Code of Zoological Nomenclature it may include names of new taxa.

Footnotes are to be avoided, except in papers dealing with historical subjects.

The International System of units should be used.

Numbers should be spelled out from one to nine in descriptive text; figures used for 10 or more. For associated groups, figures should be used consistently, e.g. 5 to 10, not five to 10.

Spelling should follow the *Concise Oxford Dictionary*.

Systematic papers must conform with the International Code of Botanical and Zoological Nomenclature and, as far as possible, with their recommendations.

Synonymies should be given in the short form (taxon, author, date, page) and the full reference cited at the end of the paper.

Manuscripts:

The original and two copies of manuscripts and figures should be submitted to the Editorial Committee, c -Publications Department, Western Australian Museum, Francis Street, Perth, Western Australia 6000. They must be in double-spaced typescript on A4 sheets. All margins should be at least 30 mm wide. Tables plus headings and legends to illustrations should be typed on separate pages. The desired position for insertion of tables and illustrations in the text should be indicated in pencil. Tables should be numbered consecutively, have headings which make them understandable without reference to the text, and be referred to in the text.

High quality illustrations are required to size (13.5 cm x 18 cm) or no larger than 32 cm x 40 cm with sans serf lettering suitable for reduction to size. Photographs must be good quality black and white prints, 13 cm x 18 cm (5 inches x 7 inches). If scale line and lettering are required on photographs *do not* place directly on to print. They should be positioned on a clear paper or film overlay. Scale must be indicated on illustrations. All maps, line drawings, photographs and graphs, should be numbered in sequence and referred to as Figure s in the text and captions. Each must have a brief, fully explanatory caption. On acceptance an IBM compatible disc containing all corrections should be sent with amended manuscript. The disk should be marked with programme (e.g. Wordperfect, Windows, etc) and exact catchline used.

In papers dealing with historical subjects references may be cited as footnotes. In all other papers references must be cited in the text by author and date and all must be listed alphabetically at the end of the paper. The names of journals are abbreviated according to *World List of Scientific Periodicals*. The use of 'unpublished data' or 'personal communication' is discouraged.

Processing:

Papers and short communications are reviewed by at least two referees and acceptance or rejection is then decided by an editorial committee.

The senior author is sent one set of galley proofs and one set of page proofs which must be returned promptly.

The senior author will receive fifty free offprints of the paper. Additional offprints can be ordered at page proof stage.

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