# NEST ASSOCIATES OF *CLUBIONA ROBUSTA* L. KOCH (ARANEAE: CLUBIONIDAE) IN AUSTRALIA

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The nests of *Clubiona robusta*, whether or not they contain a resident female spider, are usually inhabited by other invertebrates, here termed nest associates. The abundance and diversity of nest associates for *C. robusta* are described from sampled nests. Associates recorded were: other spiders, Acarina, Mollusca and insects of the orders Collembola, Coleoptera, Heteroptera, Hymenoptera, Lepidoptera, Neuroptera, Psocoptera and Thysanoptera. The presence of a resident female was a factor which affects the abundance and diversity of associates. Biological notes on each group of nest associates are given. Results for *C. robusta* are compared with data on other spiders in the same habitat, and other categories of nest associates used in other studies.□*Araneae, Clubionidae, parasitoid, predator, eggs, spider nest.*

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Most vagabond spiders build a silken retreat in which they moult, mate, lay eggs and protect themselves and their eggs from predators and extreme environmental conditions (Jackson, 1979; Jackson and Griswold, 1979; Pollard and Jackson, 1982; Austin, 1984a, 1988; Wolf, 1990). Different species construct a great variety of retreats which vary in size, structural complexity and the location in which they are placed. For *Clubiona robusta* L. Koch, a moderate-sized clubionid (body length about 15 mm) which inhabits the corticating (shedding) bark of eucalypt trees in south-eastern Australia, two types of retreats have been recognized: flimsy, thin, silk-walled moulting chambers constructed by juveniles, and thicker walled nests constructed by mature females for egg laying (Austin, 1984a).

Whatever the structure of spider retreats, they often attract an array of other invertebrates (termed 'nest associates') which utilize them in a variety of ways (Auten, 1925; Jackson and Griswold, 1979; Griswold, 1986). This aspect of spider retreats has been examined only rarely. A study of the nest associates of the salticid *Phidippus johnsoni* Peckham and Peckham in the U.S.A. by Jackson and Griswold (1979) is the only known detailed work. Jackson and Griswold (1979) divided nest associates into eight categories, following the three described by Auten (1925), based on their biological relationship with the resident spider, its eggs or the nest itself (see Table 1). Most of these biological categories have also been recognized for two eresid species in South Africa (Griswold, 1986).

During a study of the biology of *C. robusta* in South Australia (Austin, 1984a, 1988), incidental observations showed that 1) most nests contained at least some associates, 2) associates inhabited both vacant and occupied nests, and 3) the size range of associates appeared to differ between vacant and occupied nests. This study then sets out to detail the diversity and abundance of nest associates found in *C. robusta* nests, and the factors that might determine their number and size.

## MATERIALS AND METHODS

Nests of *C. robusta* were collected from under the bark of eucalypt trees with large plates of corticating bark at their bases (i.e. *Eucalyptus camaldulensis, E. cladocalyx, E. leucoxylon* and *E. viminalis*) in the Mylor area of the Adelaide Hills, South Australia (see Austin, 1984a). Nests were collected at random in the summer (December-February) over three years (1979-1981). Nests constructed only in that summer were included in samples. The whiter, fresher colour of the silk was used to distinguish them from nests built in previous seasons. Samples included vacant nests, nests containing a resident spider, and nests containing a resident spider and egg-mass or hatched juveniles. In the field, after bark plates were removed from trees, nests were gently teased away and placed in screw-top plastic vials (40 mm dia.). A large white dish prevented accidental loss of any associates or resident spiders. In the laboratory, when nest associates were en-

| Category | Description |
|---|---|
| 1a | Endoparasitoids of spiders that seek out and/or emerge from their hosts inside nests |
| 1b | Ectoparasites and ectoparasitoids of spiders that seek out and/or emerge from their hosts inside nests |
| 2 | Endoparasitoids of eggs in nests |
| 3a | Predators of eggs in nests (including 'ectoparasitoids') |
| 3b | Predators of spiders in nests |
| 4 | Scavengers feeding on dead spiders or other material in nests |
| 5 | Predatory spiders that adopt nests as a predatory device |
| 6 | Spiders that adopt the nests of other spiders as a refuge or substitute for constructing their own nests |
| 7 | Organisms (other than spiders) that adopt nests as a refuge or pupation site |
| 8 | Accidental inhabitants |
| 9 | Conspecific males |

TABLE 1. Categories of nest associates, modified after Jackson and Griswold (1979) (see text for further information).

countered, details of the nest were recorded along with any relevant biological information for the associate, and they were then preserved in 70% alcohol for identification. Parasitized spider eggs and the larvae and pupae of mantispids, pompilids, Diptera and Lepidoptera were left to emerge prior to preservation. As in Jackson and Griswold (1979), nest associates only within the nest, within the silk matrix of the nest wall, or under the nest were collected, not those completely outside or near the nest. To compare differences in the diversity, size and abundance of associates between vacant nests and those occupied by a resident female, 30 nests of each type were collected at random in the field during January 1980 and examined.

Voucher specimens of each nest associate were lodged in the Department of Crop Protection insect collection, Waite Campus, University of Adelaide, South Australia.

## RESULTS

Over 400 nests sampled during the summers of 1979 to 1981, yielded over 40 species of nest associates including Acarina, Araneae, Collembola, Coleoptera, Diptera, Heteroptera, Hymenoptera, Lepidoptera, Neuroptera, Psocoptera, Thysanoptera and Mollusca (Table 2). The biological association of each associate with *C. robusta* (categories listed in Table 1), whether determined by direct observation or only assumed, is also given for each species in Table 2. The exact category of individual associates could be assigned only for those species whose biology was observed directly (e.g., parasitoids or predators of eggs or adult *C. robusta*–?*Ogcodes* sp., *Ceratobaeus masneri* Austin), or for those species whose biology was well enough known to rule out all categories except one (e.g., Lepidoptera pupating in nests or Hymenoptera which specifically parasitize other spiders). For other associates, multiple categories are listed to indicate the range of biological associations that might exist. For many species it was impossible to determine whether nests were being used as a specific refuge or the species was there by accident (categories 7/8). For others, their association with *C. robusta* appeared to vary. Gnaphosid and segestriid spiders were observed in the field preying on subadult *C. robusta* (category 3b, see below), as well as constructing their own nests inside those of the host spider (category 6).

Nest associates seemed to occur both in vacant nests and those occupied by a female spider, there appearing to be fewer and smaller associates in the latter. To test these hypotheses, i.e. that occupied nests had fewer and smaller associates, the fauna from 30 occupied nests and 30 vacant nests were compared (Table 3). Of the 40 recognized taxa that were collected during the 1979-81 survey, 28 were found in the 60 sampled nests, with Diptera and Neuroptera being the ordinal taxa not recorded. The 30 occupied nests had substantially fewer nest associates (total 147) compared with vacant nests (227) (see Table 3). Using a Wilcoxin test (Zar, 1984) occupied nests contained significantly fewer associates per nest than vacant nests ($Z = 2.36$, $P < 0.02$), and significantly fewer associates larger than 2.5 mm in length ($Z = -4.38$, $P < 0.0001$). The two major groups of associates that seemed to differ most notably between vacant and occupied nests were other species of spiders and Coleoptera, which were both mostly represented by individuals much greater than 2.5 mm long. This specific size was chosen to test for differences in size of nest associates because previous work on *C. robusta* has shown that this is about the minimum size for potential prey that females spiders can physically handle (Austin, 1988). Hence, one suggested cause for fewer large associates in occupied nests is that they would be killed or driven away by the resident spider.

### Biology of Nest Associates

Assigning nest associates to one or more biological categories first required that those used by Jackson and Griswold (1979) be modified. In particular, endo- and ectoparasitoids have been

| Taxonomy of nest associate | Associate Category | *C. robusta* | | |
|---|---|---|---|---|
| | | I | II | III |
| **Acarina: Mesostigmata** | | | | |
| Phytoseiidae *Seiulus* sp. | 4/7/8 | + | 5 | 2 |
| **Acarina: Prostigmata** | | | | |
| Bdellidae *Bdellodes harpax* (Atyeo) | 4/7/8 | + | 2 | 2 |
| *Cyta latirostris* (Hermann) | 4/7/8 | + | 1 | 1 |
| Anystidae genus & sp. indet. | 4/7/8 | + | 6 | 7 |
| ?Eupalopsellidae genus & sp. indet | 4/7/8 | + | 1 | 2 |
| Erythraeidae genus & sp. indet | 4/7/8 | + | 3 | 2 |
| **Araneae** | | | | |
| Clubionidae *Clubiona cycladata* Simon | 3a/6/8 | + | 3 | 2 |
| *C.robusta* L.Koch ♂ | 9 | + | 8 | 2 |
| *Clubiona* spp. juveniles* | 6/8 | + | 16 | 11 |
| Gnaphosidae *Intruda* sp. | 3a/3b/6/8 | + | 2 | 0 |
| Hahniidae *Scotospilus* sp. | 3a/6/8 | + | 0 | 0 |
| Lamponidae *Lampona* sp. | 3a/3b/6 /8 | + | 1 | 0 |
| Salticidae *Myrmarachne* sp. | 3a/6/8 | + | 3 | 0 |
| *Servaea* sp. | 3a/6/8 | + | 1 | 0 |
| Segestriidae *Ariadna* sp. | 3a/3b/6 /8 | + | 2 | 0 |
| **Collembola** | | | | |
| Entomobryidae *Drepanura* sp. 1 & 2* | 4/7/8 | + | 11 | 7 |
| Neanuridae *Setanodosa* sp. | 4/7/8 | + | 5 | 3 |
| **Coleoptera** | | | | |
| Coccinellidae *Scymus parallelus* Blackburn | 4/7/8 | + | 5 | 2 |
| Dermestidae *Anthrenus* sp. | 4/7/8 | + | 2 | 1 |
| *Trogoderma antipodum* Blackburn | 4/7/8 | + | 1 | 0 |
| Tenebrionidae genus & spp. indet.* | 4/7/8 | + | 11 | 6 |
| **Diptera** | | | | |
| Acroceridae ? *Ogcodes* sp. | 1a | + | 0 | 0 |
| Chloropidae *Pseudogaurax* sp. | 3a | + | 0 | 0 |
| **Heteroptera** | | | | |
| Reduviidae *Empicoris rubromaculatus* (Blackburn) | 3a/7/8 | + | 4 | 2 |
| Pentatomidae *Nezara viridula* L. | 7/8 | + | 0 | 0 |
| *Poecilometis* sp. | 7/8 | + | 0 | 0 |
| **Hymenoptera** | | | | |
| Eulophidae *Tetrastichus* sp. | 3a | + | 0 | 0 |
| Formicidae *Iridomyrmex* sp. | 3a | + | 3 | 0 |
| Scelionidae *Ceratobaeus clubionus* Austin | 7/8 | + | 2 | 2 |
| *C. lamponae* (Hickman) | 7/8 | + | 0 | 0 |
| *C. masneri* Austin | 2 | + | 4 | 7 |
| *Gryon* sp. | 7/8 | - | 1 | 0 |
| *Trissolcus* sp. | 7/8 | - | 0 | 1 |
| Pompilidae *Epipompilus* sp. | 3a | + | 0 | 0 |
| **Lepidoptera** | | | | |
| Limacodidae *Doratifera* sp. (pupa) | 7 | - | 1 | 0 |
| genus & spp. indet. (larvae)* | 7/8 | + | 0 | 0 |
| **Neuroptera** | | | | |
| Mantispidae *Austromantispa* sp. | 1b/3a | + | 0 | 0 |
| genus & sp. indet. (larva) | 1b/3a | + | 0 | 0 |
| **Psocoptera** | | | | |
| Lepidopsocidae genus & spp. indet.* | 4/7/8 | + | 2 | 5 |
| Liposcelidae *Liposcelis* sp. | 4/7/8 | + | 6 | 8 |
| **Thysanoptera** Thripidae genus & spp. indet.* | 4/7/8 | + | 6 | 7 |
| **Mollusca:** Gastropoda Helicidae *Cochlicella ventrosa* (Ferussac) | 4/7/8 | + | 1 | 0 |

TABLE 2. Nest associates in nests of *Clubiona robusta* and category of associate to which they belong (see Table 1 and text). I = associates found at least once (+) in occupied or vacant nests over three-year period (1979-81); II = no. of nests in which each associate occurred in sample of 30 vacant nests (Jan 1980); III = no. of nests in which each associate occurred in sample of 30 nests occupied by ♀ spiders (Jan 1980); * = nest associate represented by more than one species.

distinguished (categories 1a and 1b), and predators of spiders and their eggs divided into separate categories (3a and 3b). The term 'parasitoid' (Askew, 1971) is used for species that kill their host (e.g., scelionid egg parasitoids), and 'parasite' for species that feed from but normally do not kill their host (e.g., mantispid larvae feeding on adult spiders, see below). 'Ectoparasitoids' of eggs, a term used by some authors, are not distinguished from egg predators (Austin, 1985; LaSalle, 1990). Also, a new category has been added; that of conspecific males (category 9, see below).

Notes on the biology of nest associates were made both in the field and on nests and associates kept for short periods in the laboratory, during the three-year survey of nests.

*Scavengers, refuge seekers and accidental inhabitants.* Most nest associates belong to one of these categories (25/40 taxa), but without detailed biological studies on individual species, it was impossible to determine in which specific category they belonged. The major groups are Acarina, Collembola, Coleoptera, Pentatomidae (Heteroptera), Lepidoptera, Psocoptera (New, 1974), Thysanoptera and Mollusca. In addition, three parasitic wasps can be categorized as either refuge seekers or accidental inhabitants; *Ceratobaeus clubionus* Austin, an egg parasitoid of other clubionid spiders (not *C. robusta* -Austin, 1984b), *Ceratobaeus lamponae* (Hickman), an egg parasitoid of *Lampona* spp. (Hickman, 1967a), and *Trissolcus* sp. and *Gryon* sp., egg

| Statistics | Nest residents | |
|---|---|---|
| | no. ♀ | resident ♀ |
| No. of nests sampled | 30 | 30 |
| Total no. of associates | 227 | 147 |
| Mean no. of associates/nest | 7.63 | 4.90 |
| Total no. of associates >2.5mm | 72 | 13 |
| % of associates>2.5 mm | 31.7 | 8.9 |
| Mean no. of associates/nest> 2.5mm | 2.33 | 0.47 |

TABLE 3. No. of nest associates for vacant nests and nests occupied by resident ♀ spider.

parasitoids of pentatomid bug eggs (Masner, 1976).

*Other spiders that use C. robusta nests.* More than 50% of vacated nests were occupied by other spiders, including conspecifics, many of which had constructed moulting retreats or their own nests inside that of *C. robusta* (category 6). Sixteen of 30 vacant nests contained juvenile *Clubiona* which, in most cases, could not be identified to species. Some of these may have come from previously hatched eggmasses in the same nest. However, 11 of 30 occupied nests also contained *Clubiona* juveniles, 8 of which contained gravid female *C. robusta* and no previously hatched eggmasses, indicating that these juveniles had migrated from other nests. Ten out of 60 nests sampled in January 1980 contained conspecific adult males, two cohabitating with mature females and eight found in older, vacated nests. Other spiders were encountered more rarely in the survey and only in vacant nests. All species, except for the hahniid *Scotospilus* sp. and the segestriid *Ariadna* sp., at least once constructed retreats or nests inside nests of *C. robusta*.

*Parasitoids and parasites of adult C. robusta.* Only on two occasions were such organisms recorded. One acrocerid fly (?*Ogcodes* sp.) was reared from a female *C. robusta* (category 1a) (Schlinger, 1987) and a single mantispid larva (possibly *Austromantispa* sp.) was found attached to the pedicel of a gravid female inside a nest (category 1b). Some mantispids are now known to act as ectoparasites of female spiders as small larvae and then as predators of the eggs as larger larvae (Redborg, 1982; Redborg and Macleod, 1983).

*Predators of adult C. robusta.* The only potential predators of adult *C. robusta* collected during the study were other large spiders, but no such predation was noted (category 3b). Four cases of predation on subadult *C. robusta* outside of retreats were recorded, two each by *Intruda* sp. and *Ariadna* sp. Also, no spider were noted using *C. robusta* nests as a predatory device (category 5, see Jackson, 1976; Jackson and Griswold, 1979).

*Parasitoids and predators of C. robusta eggs.* An endoparasitic wasp, *Ce. masneri*, was the most commonly noted species (category 2) and was associated with vacant nests, occupied nests without eggmasses, and occupied nests with eggmasses. This wasp caused the highest level of egg mortality (22-25%, Austin, 1984b, 1988) of all species found feeding on eggs. Four species thought to be specific predators ('ectoparasites' of other authors) were seen feeding on *C. robusta* eggmasses only rarely (category 3a). These included a chloropid fly, *Pseudogaurax* sp., on three occasions (Austin, 1985), a eulophid wasp, *Tetrastichus* sp. (LaSalle, 1990), a pompilid wasp, *Epipompilus* sp. (Pollard, 1982), each on one occasion, and a mantispid, *Austromantispa* sp., on two occasions. The only generalist predator of eggs recorded was the ant *Iridomyrmex* sp. which was observed feeding on eggmasses and hatched eggs several times, but only in vacant nests (Austin, 1988). Other possible predators of eggs include a reduviid, *Empicoris rubromaculatus* Blackburn, and other spiders.

## NEST ASSOCIATES OF OTHER SPIDERS ON EUCALYPT BARK

During the 1979-81 survey, while collecting nests of *C. robusta*, nests of three relatively common spiders were also collected and their nest associates examined. Observations on these three species are presented here. Other species were either too rarely encountered to report on here or were not found associated with their nests.

*Servaea* sp. (Salticidae). This same species (or one very similar) was figured as *Plexippus validus* Urquhart by Hickman (1967b), who described some aspects of its biology in Tasmania. The spider constructs a flattened, circular nest (30-40 mm dia.) of dense, white silk, similar in appearance and density to cotton wool. Twenty-five nests were collected: 20 occupied by female spiders, and 10 contained eggmasses or hatched juveniles. Only six associates were identified from these nests: *Austromantispa* sp. 2 (two nests), *Ogcodes* sp. (one nest), *Pseudogaurax* sp. 2 (seven nests), *Iridomyrmex* sp. (one nest), *Anthrenus* sp. (one nest) and an unidentified carabid beetle (one nest). *Iridomyrmex* sp. was feeding on eggs inside a vacant nest. The *Austromantispa* sp., *Ogcodes* sp. and *Pseudogaurax* sp. in these nests were different from those in *C. robusta* nests. Mites, Collembola and

Psocoptera were seen in some nests but were not extracted and identified. No scelionid wasps were reared from eggmasses.

*Breda jovialis* (L. Koch) (Salticidae). This easily recognized salticid builds a disc-shaped nest (about 30 mm dia.) with two prominent tubular entrances opposite each other (Hickman, 1967b). The surface of the nest is hardened and parchment-like, but the inside is lined with dense, flocculent, white silk. Seventeen nests were collected: six had resident, gravid females, and five had females with eggmasses. Only two associates were identified, and both were feeding on eggs. These were *Idris* sp. (Scelionidae) and *Pseudogaurax* sp. Another scelionid is known to parasitize *B. jovialis* eggs elsewhere in Australia (Hickman, 1967a; Austin, 1981), but this species was not found in South Australia. As for *Servaea* sp., mites, Collembola and Psocoptera were seen in a few nests but were not extracted and identified.

*Ariadna* sp. (Segestriidae). This species builds a flattened oval or tubular nest with walls of similar construction and silk density to that of *B. jovialis*. Only nine nests were collected, all contained resident females, and four contained eggmasses. The only nest associates recorded were the larvae of a hymenopteran egg predator in one nest. These failed to develop and thus could not be identified. No mites, Collembola and Psocoptera were seen in the nests of this species.

## DISCUSSION

The number of species of nest associates collected from *C. robusta* nests and the major taxa represented were similar to that found in nests of a salticid, *P. johnsoni* (Jackson and Griswold, 1979). However, *C. robusta* differed in that many more contained associates: of the 60 sampled nests 55 (92%) contained at least one associate, whereas only 1.2 % of *P. johnsoni* nests were occupied by associates. No nests of *P. johnsoni* occupied by a resident female spider contained associates, whereas most occupied *C. robusta* nests did (87%). *P. johnsoni* nests also differed in that a much greater proportion of recorded associates were spiders (66%), whereas for *C. robusta*, even excluding Acarina and Collembola, only 26% of associates were spiders. The reason for these differences is unclear, but is probably due to differences between the habitats of the two spiders and the size and nature of potential invertebrate faunas that exist at the two locations. Certainly, the bark of eucalypt trees examined in this study harbour a large and diverse invertebrate fauna that acts as a reservoir for *C. robusta* nests. Also, the apparent high and consistent abundance of this fauna means that there is probably a much greater chance of nests being inhabited, compared with the places *P. johnsoni* constructs nests, i.e., under rocks, pieces of wood, and in hollow reeds (Jackson, 1979).

Occupied nests of *C. robusta* have smaller nest associates compared with vacant nests presumably because resident spiders are known to kill and feed on intruders larger than 2.5mm. Also, females are known to guard their eggmasses and kill even distasteful intruders in nests (Austin, 1988). However, the aggressiveness of resident spiders does not explain why there are fewer small associates (<2.5 mm) in occupied nests (see Table 2). One possible reason for this is that the activity of female spiders in building, repairing and tidying nests, disturbs many small invertebrates and they move away.

The notes on nest associates of other spiders given here pose some questions. Generally the nests of the three species examined have structurally more complex nests than does *C. robusta*, and this is associated with them having far fewer nest associates. In the light of this association, further research on nest associates could profitably examine the structure of nests as a factor regulating the number and types of nest associates, as could differences in the behaviour of resident spiders inside their nests.

Finally, the biological categories proposed by Jackson and Griswold (1979) for the nest associates of *P. johnsoni* were directly applicable to the associates recorded here for *C. robusta* and the other three spiders examined and, thus, probably can be applied to the associates of any nest-building vagabond spider. We have modified their scheme in two points: 1) to distinguish between endo- and ectoparasitoids, because these two types of parasitoids have basically different biologies (Austin, 1985; LaSalle, 1990), and 2) to include conspecific males as a new category, which were found in both occupied and vacant nests.

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