Biosystematic Studies of Ceylonese Wasps, XIX: Natural History Notes in Several Families (Hymenoptera: Eumenidae, Vespidae, Pompilidae, and Crabronidae)

KARL V. KROMBEIN

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ABSTRACT

Krombein, Karl V. Biosystematic Studies of Ceylonese Wasps, XIX: Natural History Notes in Several Families (Hymenoptera: Eumenidae, Vespidae, Pompilidae, and Crabronidae). *Smithsonian Contributions to Zoology*, number 515, 41 pages, 59 figures, 1991.—Behavioral, ecological, and distributional data are provided for 40 species of Sri Lankan wasps in the families Eumenidae, Vespidae, Pompilidae, and Crabronidae. All species are solitary except the subsocial vespid, *Eustenogaster eximia* (Bingham), which rarely exhibits primitive eusociality.

Behavioral data on Eumenidae, Pompilidae, and Crabronidae may include the following aspects: nest construction and architecture; prey hunting or capture; prey transport to nest; natural enemies; and adult behavior.

An extended section on *E. eximia* provides detailed information on the following: nest architecture, materials used, the bonding role of hyphae of a species of Polyporaceae or Telephoraceae (Basidiomycetes, Aphyllophorales) in carton composition, and construction; brood development with analyses of larval food (Araneae and Hymenoptera); nature of the cocoon, initially fine silken threads overlain by a glistening film; nest associates including natural enemies (Hymenoptera) and associated or commensal organisms (Isoptera, Collembola, Diptera, Lepidoptera, Acaridei, and *Fusarium* species (Hyphomycetes)); and adult behavior and limited eusociality.

The range of each species is given as well as detailed locality records of its occurrence, insofar as possible, in Sri Lanka. Additional data include the ecological zone(s) in which each species is found in Sri Lanka, and the ranges in altitude and average annual rainfall. The text is supplemented by a map delineating the ecological zones and average annual rainfall, as well as photographs of the nests of a few species, and scanning electron micrographs of cell wall composition and cocoon fabric in *E. eximia*.

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Contents

Biosystematic Studies of Ceylonese Wasps, XIX: Natural History Notes in Several Families (Hymenoptera: Eumenidae, Vespidae, Pompilidae, and Crabronidae)

Karl V. Krombein

Introduction

The present contribution details natural history data on the several families of wasps that were not included in revisionary studies comprising previous parts of the series, "Biosystematic Studies of Ceylonese Wasps." The groups treated here are those for which identifications of wasps were furnished by other specialists as listed below in the section Acknowledgments.

The groups already covered in my revisionary studies, which also incorporated behavioral information, are as follows: Scoliidae (1978b); Mutillidae—Kudakrumiinae (1979a); Ampulicidae (1979b); Sclerogibbidae (1979c); Chrysididae—Amiseginae (1980); Philanthidae (1981a); Tiphiidae (1982); Chrysididae—Amiseginae and Loboscelidiinae (1983a); Crabronidae—Oxybelinae (1983b); Nyssonidae—Stizinae (1984a); Sphecidae—Sphecinae (1984b); Pemphredonidae—*Carinostigmus* Tsuneki (1984c); Nyssonidae—Alyssoninae, Nyssoninae, and Gorytinae (1985); Larridae—*Gastrosericus* Spinola (Krombein and Pulawski, 1986); Nyssonidae—*Bembix* Fabricius (Krombein and van der Vecht, 1987); Bethylidae—*Trachepyris* Kieffer (1987); and Larridae—*Tachysphex* Kohl (Krombein and Pulawski, in prep.)

The preceding number in this series was "XVIII: The Species of *Trachepyris* Kieffer (Hymenoptera: Bethylidae: Epyrinae)," *Pan-Pacific Entomologist*, 63:135-144, 27 figures.

The primary objective of the Smithsonian Insect Project in Sri Lanka was to collect arthropods from the numerous varied habitats available in that country (Krombein, 1981b). Our survey teams, headed by specialists in various groups went from one area to another, rarely staying at one locality for more than three or four days, and occasionally for a shorter period. The limited time at each site, and the priority for collection of all kinds of arthropods, meant that my observations on wasps were necessarily opportunistic and frequently fragmentary.

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ACKNOWLEDGMENTS.—Field work in Sri Lanka was funded by Smithsonian Research Foundation Grant SFG 0-6955, "Biosystematic Studies of the Insects of Ceylon," and travel funds were provided in part by grants from former Secretary Ripley's Fluid Research Fund.

Within Sri Lanka I am grateful to co-principal investigator W.T.T.P. Gunawardane, now Director, Department of National Museums, for planning itineraries and arranging accommodations for our field parties in Government Circuit Bungalows. I am particularly indebted to P.B. Karunaratne, former Curator of Insects at the Colombo Museum, who accompanied me on many of the field trips that resulted in the behavioral data presented here, and for making available his personal observations on some species during periods when I was not in residence. I thank also the following technicians employed by the Smithsonian "Ceylon Insect Project" for assistance in the behavioral observations: D.W. Balasooriya, V. Gunawardane, L. Jayawickrama, D. Perera, and T. Wijesinhe.

I am indebted to the following specialists for providing identifications of wasps or nest materials and contents, or of wasp prey and associated arthropods found in the nests as indicated in parentheses following their names: E.W. Baker (Acarina), R.J. Gagné (larval Miltogramminae), R.W. Hodges (Microlepidoptera), P.M. Marsh (Braconidae), D.A. Nickle (nymphal Acrididae), C.W. Sabrosky (Chloropidae, Milichiidae), M.E. Schauff (larval Chalcidoidea), D.R. Smith (Formicidae), F.C. Thompson (Dolichopodidae), W.W. Wirth (Ceratopogonidae), all Systematic Entomology Labora-

tory, U.S. Department of Agriculture (USDA), Washington, D.C.; P.M. Brignoli, Universita degli Studi di L'Aquila, Italy (immature Argiopidae and Heteropodidae); W.L. Brown, Jr., Cornell University, Ithaca, New York (Formicidae); J.C. Carvalho, Museu Nacional de Historia Natural, Rio de Janeiro, Brazil (Miridae); D.J. Christensen, Forest Products Laboratory, USDA, Madison, Wisconsin (nest fragments of *Eustenogaster*); J.A. Coddington (Araneae, fragments), W.N. Mathis (Ephydroidea) and W.E. Steiner, Jr. (male spider pedipalp), Department of Entomology (Ent), Smithsonian Institution; M.C. Day (Pompilinae except *Episyron* Schiødte), P. Hillyard (Araneae, in part), K. Sattler (Lyonetiidae), and F.R. Wanless (Araneae, in part), British Museum (Natural History), London, Great Britain; R.H. Eyde, Department of Botany, Smithsonian Institution (nest fragments of *Eustenogaster*); J. Leclercq, Liege, Belgium (Crabroninae); B. Petersen, Zoologisk Museum, Copenhagen, Denmark (Mutillidae); W.J. Pulawski, California Academy of Sciences, San Francisco, California (Larridae); C.K. Starr, University of Georgia, Athens, Georgia (*Eustenogaster*); K. Tsuneki, Mishima, Japan (*Trypoxylon*); J. van der Vecht, Putten, Netherlands (all Vespoidea); Yu.G. Verves, Kiev University, Kiev, USSR (adult Miltogramminae); and R. Wahis, Chaudfontaine, Belgium (Pepsinae, *Episyron*).

I am particularly grateful to L.R. Batra, Microbiology and Plant Pathology Laboratory, USDA, Beltsville, Maryland, for culture and identification of fungi from nests of *Eustenogaster eximia*, and for elucidation of the role of a species of Polyporaceae or Thelephoraceae in formation of the carton.

I thank also M.H. Hansell, University of Glasgow, United Kingdom, J.P. Spradbery, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia, and C.K. Starr, University of Georgia, Athens, Georgia, for information from their unpublished observations on Stenogastrinae in Malaysia, New Guinea, and the Philippines respectively. M.C. Day kindly sent information on nests of *Eustenogaster eximia* described by Green and Bell, and comments on the systematics of *Dicyrtomellus* Haupt and *Microcurgus* Haupt. R. Wahis sent helpful data on the ranges of previously described species of Pepsinae.

I am grateful to the following personnel in the Smithsonian Institution for assistance as follows: S.G. Braden, Scanning Electron Microscope Laboratory (SEM), made the micrographs; J.A. Coddington and S.F. Larcher (Ent.) provided information on spider classification and names; V.E. Krantz, Photographic Services Unit, made photographs of whole nests and of cocoon tissue from microscope slides; B.B. Norden and M.J. Mello (Ent.) prepared mounts from nesting material for SEM study, and the latter also made stained slide mounts from cocoon tissue; K. Ruetzler, Invertebrate Zoology, made helpful suggestions on identification of puzzling elements of nest composition in *Eustenogaster*; and G.L. Venable prepared Figure 1 using computer graphics, drew Figures 40 and 41, and mounted the micrographs.

I thank the following for reading and commenting on an earlier draft of the manuscript or sections thereof: A. Norden, Maryland Department of Natural Resources, Annapolis, Maryland; W.J. Pulawski, California Academy of Sciences; C.K. Starr, University of Georgia. I am also grateful for the comments of two anonymous reviewers.

* * *

I dedicate this contribution to my cherished wife, Dorothy C. Buckingham (1910–1984), who provided constant encouragement and support during the many periods of my fieldwork in Sri Lanka, as she did at all other times throughout our life together.

This number also celebrates the quinquagenary, 10 March 1991, of my natural history studies at the Smithsonian Institution.

* * *

ZONATION OF SRI LANKA.—The accompanying map (Figure 1) shows the partition of Sri Lanka into areas based on average annual rainfall, and the division into ecological areas.

The delineation into areas of average annual rainfall is based on de Silva (1980, map II), which used averages for a period of 30 years, 1931–1960. Brinck et al. (1971:ix, fig. 7) based their delineation of areas of rainfall on the Ceylon Survey Department's rainfall map for 1955, so their map differs in details of the boundaries.

The ecological zones, indicated by the letters A through D, are those adopted by plant and mammal ecologists (Mueller-Dombois, 1969, and Crusz, 1986). The botanists characterize these zones as follows: (A) the *Manilkara-Chloroxylon* series of plants, found in both northwestern and southeastern Sri Lanka; (B) the *Chloroxylon-Berrya-Vitex-Schleicheria* series of plants; (C) the *Filicium-Euphoria-Artocarpus-Myristica* series; and (D) includes the three rain forest areas, lowland, mid, and high altitude, each dominated by different plant series. The mammalogists use the following terms: (A) monsoon scrub jungle; (B) monsoon forest and grassland; (C) intermonsoon forest; and (D) rain forest and grassland, subdivided into areas below 914 m, between 914 and 1524 m, and above 1524 m.

Areas with rainfall of less than 2000 mm annually, A and B, are considered to be the Dry Zone, and areas above 2000 mm annually the Wet Zone, D. Zone C is commonly designated as the Intermediate Zone, where rainfall may be above 2000 mm at times. Thirteen of our localities were in the Dry Zone, ten in the Wet Zone, and only five in the Intermediate Zone. Our localities in the Wet Zone were in the lowland rain forest below 914 m.

Brinck et al. (1971) provide helpful information on climate and habitats in Sri Lanka in their account of the Swedish collecting expedition in Ceylon.

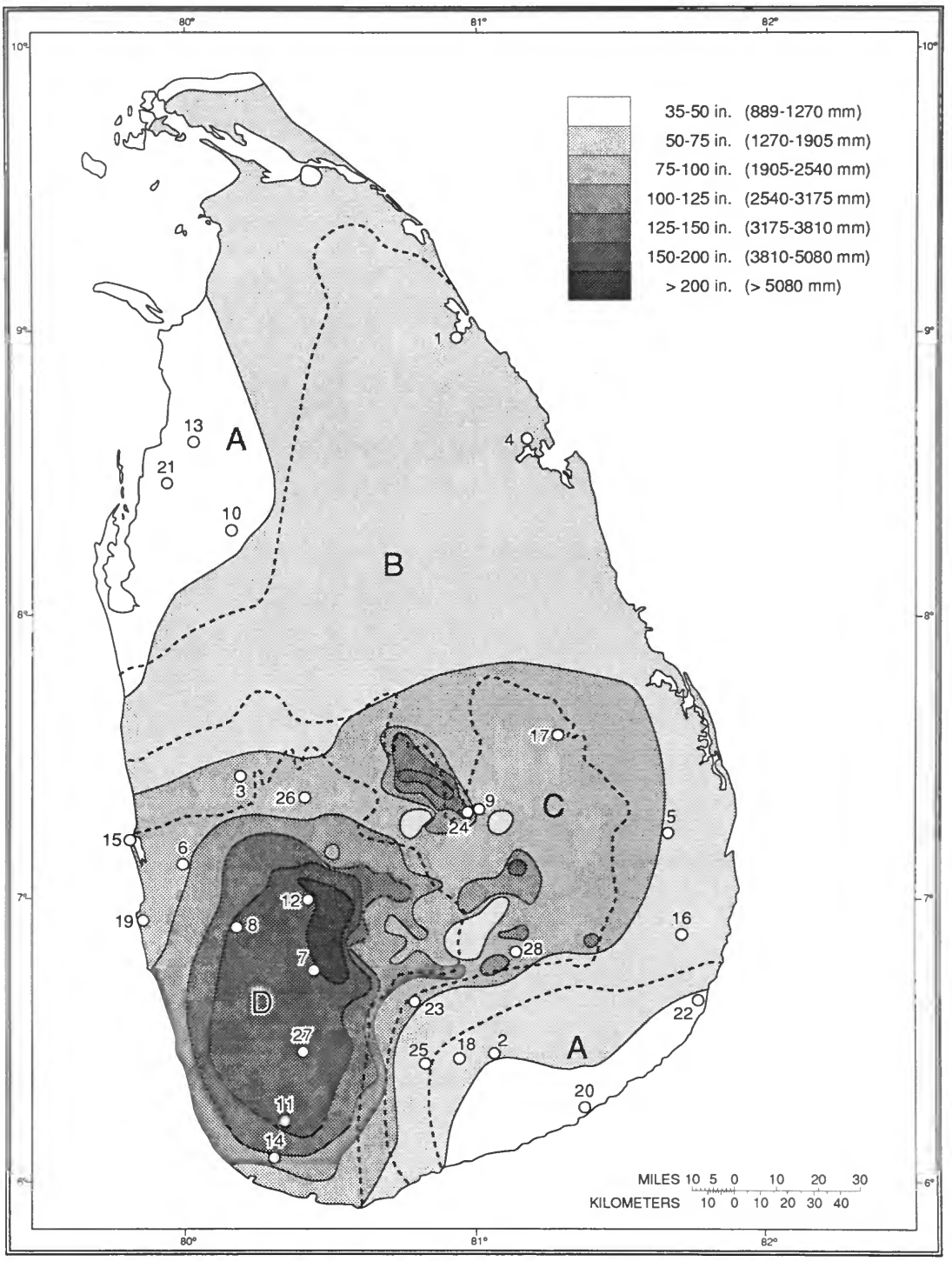


FIGURE 1.—Map of Sri Lanka showing average annual rainfall, 1931-1960, and ecological zones (A-D, dashed lines), key localities numbered as in text. (Adapted respectively from de Silva, 1980, and Mueller-Dombois, 1969.)

Several words, or their usage in Sri Lanka, may be unfamiliar. These are:

aru, ara—stream

bund—more or less narrow flattened area on earthen embankment surrounding a tank

damana—open sandy loam area in Dry Zone jungle with sparse tufts of grass and a few small shrubs

ganga—stream, river

tank—artificial impoundment of water behind earthen embankment

villu—pond, lake

POLITICAL SUBDIVISIONS.—As of 1974 Sri Lanka was divided into nine provinces each with two or three districts. In labeling our specimens we used district rather than province names. This avoided confusion because there are occasionally two villages with the same name in a province, but each is in a different district. In the following accounts I have given the range for each species and detailed records within each district in the following order:

Northern Province—Jaffna, Mannar, and Vavuniya Districts.

North Central Province—Anuradhapura and Polonnaruwa Districts.

Eastern Province—Trincomalee, Batticaloa, and Amparai Districts.

Central Province—Matale, Kandy, and Nuwara Eliya Districts.

North Western Province—Puttalam and Kurunegala Districts.

Western Province—Colombo and Kalutara Districts.

Sabaragamuwa Province—Kegalla and Ratnapura Districts.

Uva Province—Badulla and Monaragala Districts.

Southern Province—Galle, Matara, and Hambantota Districts.

I have also provided ecological information for each species including the zones in which each occurs, the ranges in altitude, and average annual rainfall.

LOCALITIES.—The approximate siting of the locations where our natural history observations were made is also shown in Figure 1 by numbers 1 through 28. The following tabulation lists these localities by district and furnishes information on elevation, average annual rainfall, and assignment to the appropriate zone.

1. Amarivayal, Trincomalee District.—A small village on the margin of a coastal lagoon in the Dry Zone with an average annual rainfall of about 1500 mm.

2. Angunakolapelessa, Monaragala District.—Observations were made along a dry sandy stream bed that carries seasonal runoff. The area is in the Dry Zone at an elevation of approximately 60 m. The average annual rainfall at Embilipitiya, about 22 km SSW, is 1500 mm.

3. Badegamuwa Jungle, Kurunegala District.—Intermediate Zone jungle near Kurunegala at an elevation of 140 m, and an average annual rainfall of 2075 mm.

4. China Bay Ridge Bungalow, Trincomalee, Trincomalee District.—Observations were made in Dry Zone jungle adjacent to the bungalow at an altitude of about 25 m with an average annual rainfall of 1725 mm.

5. Ekgal Aru Reservoir, Amparai District.—Behavioral data were obtained in Dry Zone jungle about 18 km SSW of Amparai at an altitude of about 27 m and with an average annual rainfall of about 1650 mm.

6. Gampaha Botanic Garden, Colombo District.—Observations were made along garden paths in this Wet Zone locality about 23 km NE of Colombo. It is at an altitude of 20 m and has an average annual rainfall about 2400 mm.

7. Gilimale, Induruwa Jungle, Ratnapura District.—Wet Zone rain forest 10 km NNE of Ratnapura at an elevation of about 200 m and with an average annual rainfall of 5000 mm.

8. Handapangoda Timber Reserve, Colombo District.—A second growth jungle in the Wet Zone about 35 km ESE of Colombo at an altitude of about 60 m with an average annual rainfall of about 4000 mm.

9. Hasalaka, Kandy District.—A sloping bank along a road 5 km W of Mahiyangana in the Intermediate Zone at an elevation of 90 m and with an average annual rainfall about 1925 mm.

10. Hunuwilagama, Anuradhapura District.—Along a roadside in the Dry Zone 30 km WSW of Anuradhapura at the entrance to Wilpattu National Park. The elevation is about 100 m and there is an average annual rainfall of about 1200 mm.

11. Kanneliya, Galle District.—Wet Zone rain forest in the Sinharaja Jungle 25 km NNE of Galle at an elevation about 150 m and with an average annual rainfall of over 4000 mm.

12. Kitulgala, Kegalla District.—Wet Zone rain forest south of the Kelani Ganga, 21 km N of Ratnapura at an elevation about 200 m and with an average annual rainfall of about 5000 mm. This is the site for the jungle scenes in the motion picture, "The Bridge on the River Kwai."

13. Kokmotte Bungalow, Wilpattu National Park.—Because of collecting restrictions in the Park, our observations were made 0.8 km NE of the bungalow, on the north side of the Moderagam Aru in Mannar District. This is Dry Zone jungle at an altitude of about 30 m with an average annual rainfall of about 1200 mm.

14. Kottawa Forest Reserve, Galle District.—Wet Zone rain forest 13 km NNE of Galle at an elevation of about 65 m and with an average annual rainfall about 2540 mm.

15. Kurana, Colombo District.—A small coastal village in the Wet Zone about 20 km N of Colombo with an average annual rainfall about 2000 mm.

16. Lahugala Sanctuary, Amparai District.—Our observations were made on the bund of the tank near the Wildlife and Nature Protection Society bungalow. This is a Dry Zone habitat at an elevation of about 33 m and with an average annual rainfall of about 1750 mm.

17. Maha Oya Tank, Amparai District.—This is in the Intermediate Zone at an altitude of about 35 m, and an average

annual rainfall of about 1900 mm.

18. Mau Aru, Monaragala District.—Our observations were made on the sandy banks along the stream in this Dry Zone area about 16 km E of Uda Walawe Reservoir. The elevation is about 60 m and the average annual rainfall is about 1500 mm.

19. Museum Garden, Colombo, Colombo District.—This is in the Wet Zone. Observations were made on hard-packed sand paths with admixture of some fine gravel on the Museum grounds. The altitude is about 15 m and the average annual rainfall is 2400 mm.

20. Palatupana Tank, Hambantota District.—This locality is just outside the entrance to Yala National Park. It is in the Dry Zone at an elevation of a few meters above sea level and an average annual rainfall of about 920 mm.

21. Panikka Villu, Wilpattu National Park, Puttalam District.—This is Dry Zone jungle surrounding a villu at an elevation of about 30 m and with an average annual rainfall of about 1000 mm.

22. Radella Tank, Amparai District.—This is in the Dry Zone 5 km W of Panama at an altitude of 15 m and with an average annual rainfall of about 1500 mm.

23. Rajawaka, Ratnapura District.—This is in the Dry Zone at 450 m and with an average annual rainfall of about 1550 mm.

24. Thawalamtenne, Kandy District.—Data were obtained along the roadside in the Intermediate Zone about 30 km E of Kandy at an elevation of about 1050 m with an average annual rainfall of about 3000 mm.

25. Uda Walawe Reservoir, Ceylon Electricity Board bungalow, Ratnapura District.—The bungalow is on the western edge of the Reservoir in the Dry Zone at an altitude of about 60 m. The average annual rainfall is 1500 mm at Embilipitiya, 10 km to the south.

26. Udawattakele Sanctuary, Kandy, Kandy District.—The Royal Jungle of the capital of the last native kingdom in the Wet Zone. Observations were made at altitudes ranging from 510 to 610 m in unlogged rain forest with an average annual rainfall of 2032 mm.

27. Weddagala, Ratnapura District.—This is a village in the Wet Zone 22 km S of Ratnapura. Our observations were made about 5 km south of the village in rain forest in the Sinharaja Jungle at an elevation of about 400 m with an average annual rainfall about 4900 mm.

28. Wellawaya, Monaragala District.—This locality is in the Intermediate Zone about 30 km S of Badulla. We made a brief stop at lunchtime in a small ravine along the roadside at an elevation of 175 m with an average annual rainfall of about 2500 mm.

SOURCE MATERIAL.—The field notes and voucher specimens of wasps, nests, and associated arthropods are in the National Museum of Natural History, Smithsonian Institution. The behavioral data are condensed from the following field notes.

EUMENIDAE

Zethus (Zethus) ceylonicus Saussure: 32076 A; 61978 A.
Delta campaniforme esuriens (Fabricius): 92577 C.
Delta emarginatum conoideum (Gmelin): 92577 D.
Delta pyriforme pyriforme (Fabricius): 52676 A.
Paraleptomenes humbertianus (Saussure): 62076 B, C, D; 91277 D; 91577 A, B; 91080 A, B.
Paraleptomenes mephitis (Cameron): Summarized from my detailed paper on this species (Krombein, 1978a).
Anterhynchium abdominale (Illiger): 52476 A, B, C; 61376 B, C.

VESPIDAE

Eustenogaster eximia (Bingham): Unnumbered notes in 1972; 11175 A, B, C, D, E; 11375 B, E, F; 11475 A; 11575 L; 102677 A; 12579 A; 10280 A; 10380 A, B, C, D; unnumbered nests from Morapitiya, 1990.

POMPILIDAE

PEPSINAE

Hemipepsis convexa (Bingham): 92280 A; 32781 B, F; 41681 A.
Hemipepsis indiana Wahis: 92877 A.
Dipogon kandiensis (Turner): 101480 A; 32281 A.
Auplopus bimaculatus (Smith): 11275 K; 32181 B.
Auplopus blandus (Guérin): 91377 B; 101080 A.
Auplopus cyanellus Wahis: 9977 B.
Auplopus funerator Wahis: 41581 A.
Auplopus gnomus (Cameron): 61576 B; 21777 F.
Auplopus himalayensis (Cameron): 11575 G.
Auplopus laeviculus (Bingham): 52376 E; 61878 E.
Auplopus nitidiventris (Smith): 10777 B.
Auplopus tinctus (Smith): 10777 A; 22779 A.

POMPILINAE

Agenioideus (Schizanoplius) smithii (Ritsema): 11177 D.
Pompilus mirandus (Saussure): 2875 B; 61476 A.
Aporinellus hecate (Cameron): 11875 A; 22277 F; 32181 A.
Dicyrtomellus new species: 11177 C.
Anoplius (Orientanoplius) canifrons (Smith): 21777 E; 6778 A, C; 9180 A; 9280 A, C; 9380 A, B, C, E, H; 92480 A, B.
Anoplius (Arachnophroctonus) species, possibly *alteratus* Priesner: 61576 A.
Episyron novarae (Kohl): 61376 D; 12377 B; 22077 A; 4677 B; 12379 D; 21679 I; 32781 G, H.
Episyron praestigiosum Wahis: 9977 F; 71578 B.
Episyron tenebricum Wahis: 21075 B; 41975 H.
Batazonellus annulatus (Fabricius): 12277 B.
Tachypompilus analis (Fabricius): 52576 A; 11677 C.
Microcurgus new species: 11177 B.

CRABRONIDAE

Encopognathus (Encopognathus) districtus Leclercq: 62176 C; 62276 B; 2577 A; 2677 A, B, C, D; 3877 A; 3977 A; 31177 A; 31477 A, B, C; 31677 A, B, C, D; 31877 C, D, E, F; 32177 A, B, C; 32277 A, C; 32377 A, B; 32477 A, B; 32877 A, E, G, H; 32977 E; 33077 A, G, H; 33177 C; 4177 A, C; 41477 B; 41577 A; 41877 A, B, C, D; 41977 A; 42177 A; 42277 A, B, C; 42777 A, B, C; 42877 A, B, C; 12379 B.
Encopognathus (Encopognathus) lankanus Leclercq: 12775 A; 12875 A, B, C; 13175 A; 22775 A; 3475 A; 31275 A, B; 31775 A, B, C, D, E; 31875 B, C, D; 31975 A; 32075 A; 32475 A, B; 31777 A; 32577 B; 32877 B; 32977 A, D, F, G; 4177 B; 4577 A, B; 4677 C; 41177 A, B, C, D, E; 41477 A; 42177 B; 12379 A.
Encopognathus (Bihargnathus) itinerus Leclercq: 32277 B.

Encopognathus (Karossia) argentatus (Lepeletier and Brullé): 3479 A.
Crossocerus (Ablepharipus) weeratungei Leclercq: 32081 A.
Crossocerus (Crossocerus) hasalakae Leclercq: 21777 G.
Eupliloides sinharajae Leclercq: 10480 A, B.
Piyuma prosopoides (Turner): 21177 A; 21277 A; 22077 B.

EUMENIDAE

Zethus (Zethus) ceylonicus Saussure

This rather uncommon wasp, 13–19 mm in length, occurs mostly in Dry Zone localities, but we collected it once in the Wet Zone as well. It was taken from near sea level to an altitude of 610 m in areas with an average annual rainfall ranging from 1500 to 2032 mm. Our records from Sri Lanka are as follows.

Trincomalee District: Amarivayal
Matale District: Kibissa near Sigiriya
Kandy District: Udawattakele Sanctuary
Monaragala District: 6 km NE of Buttala and Angunakolapelessa

NEST ARCHITECTURE.—The wasp nests in abandoned borings of beetle larvae in twigs or exposed roots. P.B. Karunaratne collected a female on 20 March 1976 at Amarivayal. She was beginning a nest in a longitudinal tunnel tightly packed with powdery frass in a dead twig 15 mm in diameter. The wasp was captured when she emerged from a hole in the side of the twig. She had excavated a cavity about 25 mm long in the frass-filled tunnel that ran in both directions from the entrance hole.

I collected another female on 19 June 1978 at Angunakolapelessa. She was hovering at the underside of a dead exposed tree root on the edge of a dry stream bed. She alighted twice on a chimney composed of the tips of plant stems bearing tiny leaves up to 10 mm long. The trumpet-shaped chimney was 15 mm long, flared outward to about 20 mm diameter from a base about 10 mm in diameter and was lined with dried resin. At the base was an oval hole in the root, 9×6 mm, leading inward for 22 mm to a longitudinal boring 50 mm long, 12 mm wide, and 6 mm high. This tunnel contained a linear series of three cells each about 15 mm long. The partitions capping the cells were 1–2 mm thick and composed of bits of leaf gummed together. The cell walls were not lined with leaves or dried resin. The innermost cell was empty but there was a thin layer of leaf bits gummed together at the inner end of the boring. The middle and outermost cells each held a colored pupa almost ready to eclose with the head end directed toward the entrance, a male in the middle and a female in the outermost. There was a thin partition of bits of leaf gummed together capping an empty vestibular cell 5 mm long at the juncture of the entrance tunnel and the longitudinal boring. The nest was probably in an old buprestid tunnel for I found a live buprestid larva in a similar burrow elsewhere in the root.

DISCUSSION.—Bohart and Stange (1965) summarized the known nesting behavior in *Zethus*, noting that the less specialized solitary species use old insect burrows in twigs, wood, or in the ground, and that the more specialized species construct nests of masticated vegetable matter, sometimes by cooperating females in a subsocial manner. Some species use a resinous material mixed with leaf particles, but none was noted as making a chimney at the entrance as described for *ceylonicus*.

Delta Saussure

FIGURE 10

These wasps resemble large *Eumenes*, and the two genera are closely related. Some members of both genera build the familiar mud cells that resemble earthen pots. The species of *Delta* are known collectively as kumbala in Sri Lanka, the Sinhalese word for potter. Four species of *Delta* occur in that country, and we found nests of the three species detailed below. J. van der Vecht provided specific identifications based either on reared adults or fully colored pupae. We did not obtain a nest of the fourth species, *flavopictum* (Blanchard) (Figure 10).

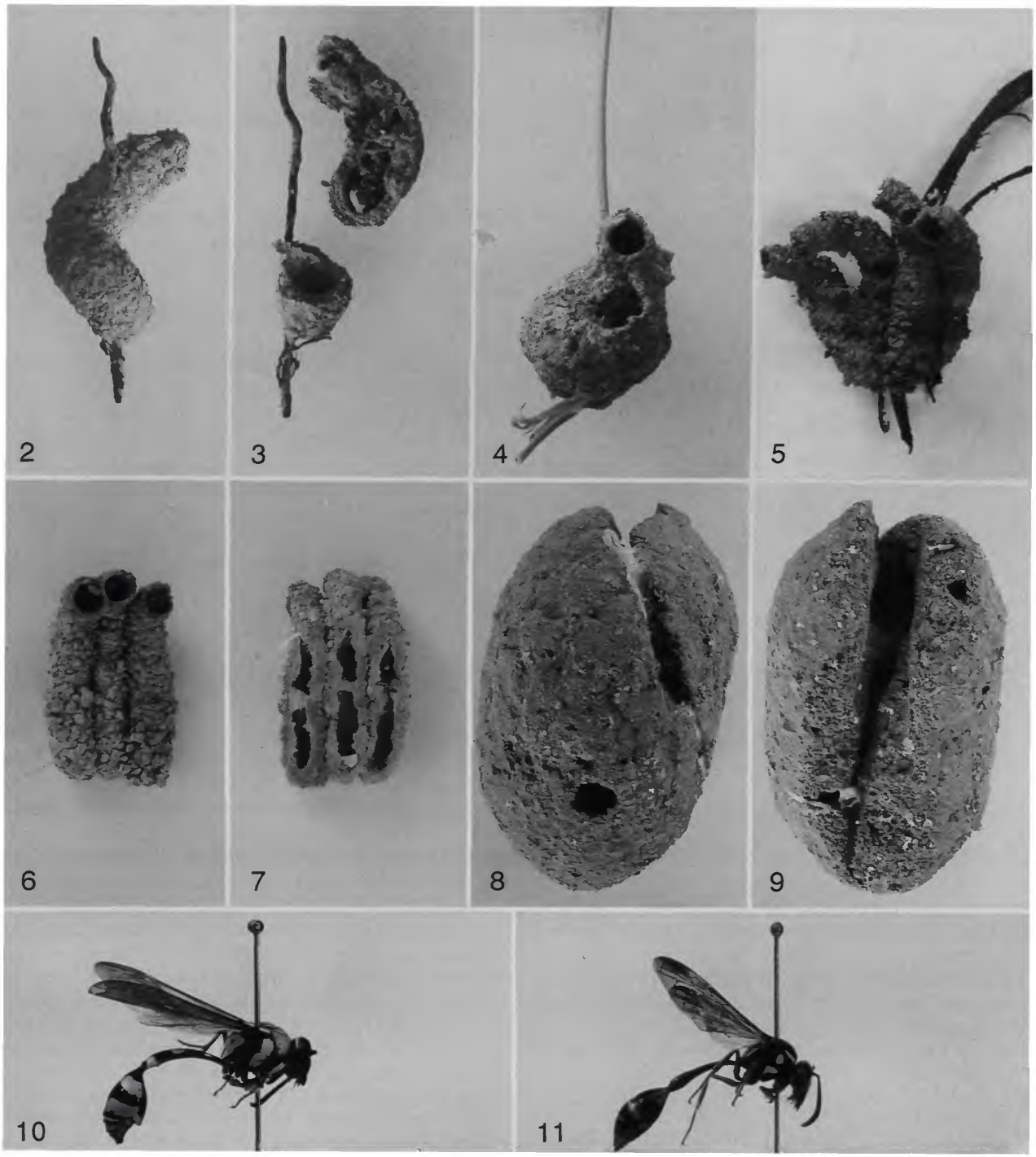
Delta campaniforme esuriens (Fabricius)

This common wasp reaches the southeastern part of the Palaearctic Region in Iraq and Iran, but it is widely distributed in the Oriental Region where it ranges from the Indian subcontinent eastward through Burma, Thailand, Borneo, Java, and the Philippines. My records from Sri Lanka are as follows.

Anuradhapura District: Padaviya and Galkadawala
Polonnaruwa District: Polonnaruwa
Trincomalee District: Trincomalee, China Bay
Amparai District: Inginiyagala, Uhana, and Lahugala Sanctuary
Matale District: Kibissa near Sigiriya
Kandy District: Udawattakele Sanctuary
Colombo District: Papiliyana, Colombo, and Ratmalana
Ratnapura District: Uda Walawe
Monaragala District: Mau Aru
Hambantota District: Palatupana

The species is much more common in the Dry Zone, but it is found also in the other two ecological zones. It occurs from sea level to an altitude of 610 m at localities where the average annual rainfall ranges from 920 to 2032 mm.

NEST.—A mud nest was found at the bungalow on the west bank of Uda Walawe Reservoir on 25 September 1977. The nest was constructed in a gap between mortar and two bricks in the bungalow wall. There was a row of eight cells in a space of 10.5 cm. The tops of the pots were more or less obscured by mud that had been plastered over them after construction. The first cell at the left contained a fully colored teneral female in a delicate white opaque silken cocoon. Cells 2 and 3 each had an emergence hole and remnants of the same kind of cocoon; presumably each contained a male that had already emerged. Cells 4 through 8 each contained a female pupa, the one in 4 fully colored and ready to eclose, those in 5–8 successively less mature.



FIGURES 2–11.—Nests and adults, Vespoidea: 2–4, nests of *Paraleptomenes humbertianus* (Saussure), ×2; 2–3, one tube with two cells, 3, tube broken open with pupa in basal cell; 4, nest with 2 tubes; 5–7, nests of *P. mephitis* (Cameron), ×2; 5, cluster of two-celled tubes on wood fibers; 6–7, three two-celled tubes from flat substrate; 8–9, nest of *Delta p. pyriforme* (Fabricius), ×0.88; 9, with deep cleft on upper half where nest was attached to twig; 10, female *D. flavopictum* (Blanchard), ×1.75; 11, *Eustenogaster eximia* (Bingham), ×1.75.

Delta emarginatum conoideum (Gmelin)

I have seen specimens from India, Burma, and Thailand as well as Sri Lanka. Within Sri Lanka it is more common in the Dry Zone, but it is found also in the other two zones. It occurs from near sea level to an altitude of 610 m, in areas where the average annual rainfall ranges from about 1200 to 2032 mm. Our records from Sri Lanka are as follows.

Anuradhapura District: Cheddikulam and Padaviya
Polonnaruwa District: Pimburettawa
Trincomalee District: Amarivayal, Tennamaravadi, and Trincomalee, China Bay
Matale District: Kibissa near Sigiriya
Kandy District: Hasalaka and Kandy, Udawattakele Sanctuary
Colombo District: Colombo, Papiliyana, Labugama, Ratmalana, and Gampaha
Ratnapura District: Uda Walawe

NEST.—This wasp nested on the brick wall of the same bungalow where the preceding wasp was nesting. The nest was an irregular T-shaped mass, 7.6 cm high and 3.8 cm wide at the top, so plastered over with mud that it was difficult to distinguish the individual pots. There were five cells in the lower perpendicular section, each containing a male pupa, and two cells in the horizontal upper section, each with a female pupa. The degree of development of the pupae as indicated by their coloration showed that the lowest cell was constructed first, followed successively by those above. The cells were about 20 mm wide and 14 mm high and the cell walls were 1 mm thick.

Delta pyriforme pyriforme (Fabricius)

FIGURES 8–9

I have seen this species from India, Thailand, and China, as well as Sri Lanka. It is widely distributed in Sri Lanka in the three ecological zones, in areas from near sea level to an altitude of 610 m with an average annual rainfall from 1200 to 4000 mm. Our Ceylonese records are as follows.

Anuradhapura District: Hunuwilagama, Cheddikulam, and Padaviya
Trincomalee District: Trincomalee, China Bay
Amparai District: Ekgal Aru Reservoir and Lahugala Sanctuary
Kandy District: Thawalamtenne and Kandy, Udawattakele Sanctuary
Colombo District: Colombo
Kegalla District: Kitulgala
Ratnapura District: Weddagala

NEST.—A rounded clump of mud cells (Figures 8–9), $7.5 \times 4.5 \times 4.0$ cm, was found on a stout twig of a bush at Hunuwilagama on 26 May 1976. Two of the cells contained wasp pupae but the others contained a number of large dipterous puparia. A pair of wasps and five females and nine males of the miltogrammine (Sarcophagidae) parasite had emerged by 6 June. The parasite was *Amobia auriceps* (Baranov); this is the first host record for that species.

Paraleptomenes humbertianus (Saussure)

FIGURES 2–4

This species is known only from Sri Lanka where it occurs mostly in the Dry Zone, but it is found occasionally in the other two zones, from near sea level to an altitude of 450 m at localities with an average annual rainfall of 1200 to 2400 mm. We collected it as follows.

Anuradhapura District: Padaviya, Galapitawewa, and Hunuwilagama
Trincomalee District: Tennamaravadi and Trincomalee, China Bay
Amparai District: Maha Oya and Ekgal Aru Reservoir
Matale District: Kibissa near Sigiriya
Kurunegala District: Badegamuwa
Colombo District: Papiliyana, Gampaha, and Labugama
Ratnapura District: Rajawaka
Monaragala District: Angunakolapelessa
Hambantota District: Palatupana Tank

This species, 6.5–9.0 mm long, is less common than its smaller congener, *mephitis* (Saussure). We found only eight nests of *humbertianus*, three at Rajawaka in 1976, one at Ekgal Aru Sanctuary Jungle in 1977, two at Maha Oya Tank in 1977, and two in Badegamuwa Jungle in 1980.

NEST.—This is a spiral mud tube coiled around a grass stem or rootlet beneath an overhanging or on a vertical bank. The tube usually contains two cells (Figures 2–3), and the entire nest may consist of two or three such tubes (Figure 4). One two-celled tube is about 20 mm long with an external diameter of 5–7 mm. The mud walls of the tube are about 1.3 mm thick. We found no nests at an early stage of their construction, but the wasp makes the mud tube from the bottom upward, thus preventing the prey from dropping out of the cell.

A two-celled nest (Figures 2–3) was on a rootlet beneath an overhanging bank on 10 September 1980. I broke off the upper end and discovered a mature wasp larva spinning its cocoon cap. There had been no emergence by the following June, at which time the nest contained two dead, fully colored adults that had not been able to shed the pupal exuviae, a female in the lower (innermost) cell and a male in the outer.

Another nest beneath this bank consisted of three spiral mud tubes, all open at the top. The female was inside the uppermost tube which was otherwise empty. The middle tube had silk on the wall and the meconium of a wasp larva, but the occupant had transformed and emerged. The lowest tube had not been provisioned.

I captured a female on a nest on a grass stem (Figure 4) on a vertical bank. She had just begun the second spiral tube at the

top of the sealed first tube. Subsequently, a male emerged from this nest.

I was unable to ascertain whether *humbertianus* practices progressive provisioning of its nests as does *mephitis* (Cameron) (Krombein, 1978a), or whether it is a mass provisioner.

PREY.—We obtained only one prey record, a small caterpillar, 2.3 mm long, probably a species of Carposinidae, in a cell with a mature wasp larva at Rajawaka.

ASSOCIATES.—Two species of parasites and two renters are associated with *humbertianus*. We found a newly emerged female mutillid, *Promecilla metallica* (Cameron), 7.5 mm long, in a nest at Rajawaka; this wasp was reared also from nests of *mephitis*. A 2-celled nest at Ekgal Aru contained a well-colored female pupa of *humbertianus* in the inner cell, and a parasitic bombyliid larva about ready to pupate in the outer cell. The latter failed to pupate perfectly, but it was very similar to the pupa of a species of *Toxophora* Meigen that I found also in nests of *mephitis*.

Another two-celled nest at Rajawaka contained a full grown larva of *humbertianus* in the inner cell, and a white cocoon in the outer cell from which a female renter, *Trypoxylon errans* Saussure emerged later. A male of *T. thaianum* Tsuneki was reared from a nest at Maha Oya; this renter also uses nests of *mephitis*.

Paraleptomenes mephitis (Cameron)

FIGURES 5-7

This smaller wasp occurs primarily in Sri Lanka, but it has been recorded also from a few localities in eastern and southern India. It may be only subspecifically distinct from *miniatus* (Saussure) from more northern areas in India (J. van der Vecht, personal communication). It has much the same distribution as *humbertianus* within Sri Lanka, with the same altitudinal and rainfall ranges. Our specific records, mostly from nesting sites, are as follows.

Anuradhapura District: Hunuwilagama and Cheddikulam
Trincomalee District: Trincomalee, China Bay
Amparai District: Ekgal Aru Reservoir
Kandy District: Hasalaka
Colombo District: Colombo
Ratnapura District: Uda Walawe
Hambantota District: Palatupana Tank and Wildlife and Nature Protection Society Bungalow

LIFE HISTORY, NESTS, AND ASSOCIATES.—Earlier (Krombein, 1978a) I published a detailed account of this small wasp. It constructs mud nests in sheltered situations such as beneath covered walkways, house eaves, and verandah roofs. The nests consist of tubes placed side by side against a flat surface, with the outer end of the tubes curved away from the substrate (Figures 6-7). Even when the tubes are constructed on a narrow surface, such as a group of wood fibers (Figure 5), the tubes are aligned along the substrate, not coiled around it as in *humbertianus*. The nests may be built on substrates that are horizontal, at an angle, or vertical. On the latter two surfaces, the tubes are always placed with the outer end upward. The tubes are 19-25 mm long, 4-5 mm wide, and the walls except at base are only 0.2-0.4 mm thick. A tube usually contains two cells, but shorter tubes have only a single cell.

This species practices progressive provisioning, usually providing two or three small prey before the egg hatches, and then rapidly bringing in more prey after the larva begins to feed. The prey are microlepidopterans, 2-6 mm long, belonging to several families, and, rarely, small geometrid or noctuid larvae. I estimated that the egg stage was 2-3 days and the feeding larval stage 4-5 days. The larva then spends 2-3 days spinning a tough white cocoon against the cell walls and partitions, and then 3-4 days in the prepupal stage before pupation. Eclosion of adults occurs in about 11 days, and they leave the cells 12-14 days after pupation. A female developed in the inner cell of the tube, and a male in the outer, in the majority of 2-celled tubes.

Paraleptomenes mephitis has a large number of nest associates because large populations of the wasps are available at times. The parasites included: Mutillidae, *Promecilla metallica* (Cameron), *P. hesitata* (Cameron) and *Smicromyrme ludovica* (Cameron); Chrysididae, *Chrysis (Chrysis)* n. sp.; Perilampidae, *Krombeinius eumenidarum* Boucek; Eulophidae, *Melittobia clavicornis* (Cameron) and *M.* new species; and Bombyliidae, *Toxophora* new secies. Pharaoh's ant, *Monomorium pharaonis* (Linnaeus) (Formicidae) infested one nest and carried off the lepidopterous larvae. Two species of *Trypoxylon* (Larridae), *pileatum* Smith and *thaianum* Tsuneki, used empty tubes as nesting sites. Scavenging dermestid larvae were found in one cell.

Anterhynchium abdominale (Illiger)

This species occurs in the Indian subcontinent, and several color phases are recognized in India. Within Sri Lanka it appears to be restricted to rather dry areas at low altitudes in the Dry Zone. Our limited observations suggest that this wasp nests in the ventilation shafts of the large termitaria of species of *Odontotermes*. The few localities where we collected it in Sri Lanka are as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Anuradhapura District: Hunawilagama
Trincomalee District: Trincomalee, China Bay
Amparai District: Lahugala Sanctuary
Puttalam District: Tabbowa

The elevations are 25-100 m, and the average annual rainfall is 1200-1750 mm.

NEST.—We observed *abdominale* during May and June 1976 near Kokmotte Bungalow, and in Lahugala Sanctuary. We saw several females of nominotypical *abdominale*, 13-17 mm long, entering ventilation shafts of *Odontotermes* sp. at

both localities, and remaining inside for periods ranging from 1 to more than 10 minutes. We did not excavate nests, but Batra (1979) reared the dark color phase, *abdominale bengalense* (Saussure) from cells off the inner surface of ventilation shafts of *Odontotermes obesus* (Rambur) in Amritsar District, Punjab, India. She found that a nest consisted of 1 to 11 individual cells 36–79 cm below the top of the shaft. The cells were 19–20 mm long, 11–12 mm maximum width and were lined with a chestnut brown flexible material with embedded soil particles. I presume that the lining was a secretion applied by the larva in lieu of spinning a typical cocoon, a behavioral trait exhibited by the North American eumenid, *Monobia quadridens* (Linnaeus) (Krombein, 1967:51). Batra's individual cells were capped by an earthen plug 5.5–6.0 mm wide and 4–10 mm long that connected the cell to the inside of the shaft. Her diapausing larvae began to pupate in mid-June and the first adult wasps emerged in about 24 days.

ASSOCIATE.—I saw a female chrysidid, *Chrysis schioedtei* Dahlbom, 11 mm long, alighting upon a shaft that had been entered by a female of *abdominale*; presumably it is parasitic upon the eumenid. Batra found a large parasitic wasp larva in a cocoon in one cell, and small dipterous puparia and remains of the caterpillar prey of the wasp in two other cells.

VESPIDAE

Eustenogaster eximia (Bingham)

FIGURES 11–47, 49–57

Members of the Stenogastrinae are unique among the Vespidae in the facility with which they hover in the air like a dragonfly, a capability that led Carpenter (1988) to christen them "hover wasps." The female uses this ability to hover in front of a spider web, and delicately pick off small insects trapped in the outer strands, or small commensal spiders on the periphery of the web of a larger host spider.

Eustenogaster eximia is the only member of the Stenogastrinae that occurs in Sri Lanka. The female is a relatively large, slender wasp (Figure 11), 19–21 mm long, superficially resembling a large eumenid such as *Delta flavopictum* (Blanchard) (Figure 10).

The species was described as *Ischnogaster eximius* Bingham (1890) from a male reared by E.E. Green from a nest obtained near Galle, Sri Lanka. Bingham also included a few notes and a figure of the nest which had been furnished by Green. *Stenogaster eximioides* Dover and Rao from southern India was synonymized as only a color variant of *eximia* by Dover (1925). It is, however, currently recognized as a subspecies of *eximia* by Das and Gupta (1983), who also synonymized *Paravespa eva* Bell (1936) under *eximioides*. There is a slight difference in coloration between *eximia* and *eximioides*, a character that J. van der Vecht (personal communication) thinks is probably not constant. J. van der Vecht, and later, C.K. Starr, confirmed that my specimens from Sri Lanka are all *eximia*. The reported occurrence of *eximia* in Thailand and Malaya (Dover, 1931) is questionable and needs confirmation. Pending a revisionary study of *Eustenogaster*, it seems preferable to recognize *eximia* as a single taxon of disjunct distribution restricted to quite humid areas of southwestern Sri Lanka and southern India.

Within Sri Lanka *eximia* occurs in densely shaded areas of lowland rain forest. It was collected at the following localities by personnel associated with the Smithsonian's Ceylon Insect Project, 1972–1980.

Kalutara District: Morapitiya
Kegalla District: Kitulgala
Ratnapura District: Gilimale and Weddagala, Sinharaja Jungle
Monaragala District: Wellawaya
Galle District: Kottawa and Kanneliya, Sinharaja Jungle

These localities have elevations that range from 65 to 610 m and an average annual rainfall of 2600–5000 mm. There are specimens from Kandy in the Colombo Museum collected in 1909 and 1917, but I did not find it during my frequent visits to Kandy, although I collected in Udawattakele Sanctuary and Kandy Reservoir jungles. We obtained most of our data and nests in the Kanneliya section of the Sinharaja Jungle, and lesser numbers in Kottawa, Kitulgala, and Wellawaya (Figures 16–30). These localities are all in the Wet Zone except for Wellawaya in the Intermediate Zone, where we found a single nest in a wooded ravine beneath an overhanging stream bank.

NEST

ARCHITECTURE.—Nests are constructed in sheltered spots in the rain forest, usually beneath earth or rock overhangs along a stream (Figures 12–15) where they are protected from rain. The nest is suspended from a slender exposed rootlet or stem of a fern frond at some distance from the tip. The top of the comb is attached firmly to the substrate which does not penetrate into the cells.

The distinctive completed nest is a more or less pear-shaped structure constructed from masticated bits of rotten vegetative matter that dry to form a thin, brittle carton that is normally 0.24–0.36 mm thick on the exterior surface.

L.R. Batra* analyzed the composition of carton in fresh nests collected by P.B. Karunaratne in Morapitiya, June 1990. Using three samples, about 1 mm^3, from different sites of the pseudenvelope, he found that microscopically they contained about 10% by volume of masticated fungal hyphae of a species of Polyporaceae or Thelephoraceae (Basidiomycetes, Aphyllophorales). Members of those families cause wood rots which make the wood soft, friable, and workable by many species of insects that feed upon it, bore into it, or use it in nest-making. The fungi may remain viable in the wood for several years. He identified the fungus from the clamp connections of brown vegetative hyphae.

He found two additional kinds of hyphae, skeletal and

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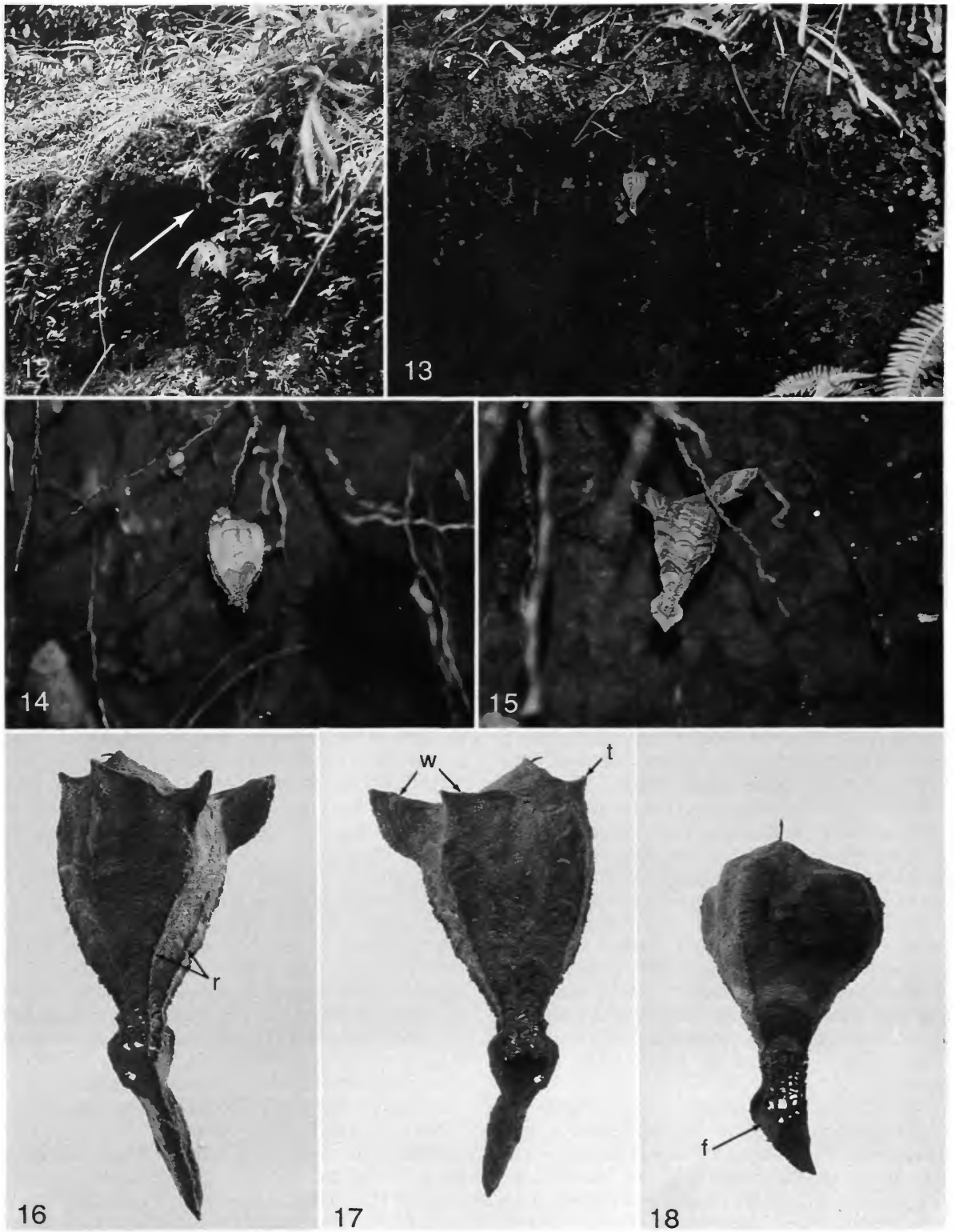


FIGURES 12–18.—Nests, *Eustenogaster eximia* (Bingham): 12–15, habitats beneath overhanging banks; 12–13, Kanneliya, arrow in 12 indicates nest, 13, same nest as 12 and 18; 14–15, Kottawa, 14, nest, ×0.38, 15, another nest, ×0.44; 16–17, Wellawaya, ×1; 16, surface facing outward, 17, surface facing bank; 18, Kanneliya, ×1, same nest as 12–13.

binding, which may or may not belong to the same basidiomycetous species.

The skeletal hyphae were thick walled, usually branched, unseptate, and straight except for being slightly bent or flexuous with the thin apices. He stated that these hyphae develop from the vegetative cum generative hyphae. They are called skeletal hyphae because they are characteristic of genera and species whose fruiting bodies are hard and tough, as contrasted with soft and fleshy fruiting bodies of commercial mushrooms such as *Agaricus*.

The binding hyphae were similar to the skeletal hyphae but had much thicker walls, and, thus, narrower lumens. He found them intertwined and mixed with the vegetative and skeletal hyphae. The binding hyphae in the Basidiomycetes further strengthen the fruiting body. The vegetal hyphae of many Basidiomycetes, such as the entire genus *Termitomyces* Heim, are known to act as a bonding agent for the rotting wood fibers that constitute the bulk of the carton, i.e., material that has passed through worker guts, in nests of fungus-growing subterranean termites such as *Odontotermes obesus* (Rambur) and *O. gurdaspurensis* (Holmgren and Holmgren) in India (Batra and Batra, 1966).

Batra stated that the relatively large volume of fungal matter in the carton of the wasp nest was intriguing, and that the wasp was certainly using wood that was rotted by fungi. He said that rotting wood has only vegetative or generative hyphae in its interior. However, toward the exterior, where the wasp would have obtained the wood, skeletal hyphae or even binding hyphae would be found as the fruiting body primordia appeared. Thus, it is quite possible that the wasp incorporated into the carton pieces of fruiting bodies of the Aphyllophorales that grew on the surface of the wood. He stated that the fungus did not form a regular mass which would have indicated that it developed after the nest carton was assembled.

He took three additional samples of carton of the same size, and cultured them on 2% water agar, and potato dextrose agar. He found two common soil-inhabiting saprophytes in each sample—*Cunninghamella elegans* Matruchot (Phycomycetes, Mucorales), and a species of *Cephalosporium* (Hyphomycetes, Moniliales). These saprophytic fungi are presumably chance contaminants, and have no essential role in carton formation.

The pseudenvelope is frequently covered by numerous, short erect hyphae (Figures 43, 44, 52, 53) that occur also on the inner cell walls (Figures 54, 55). Batra identified this fungus as a species of *Fusarium* (Hyphomycetes, Moniliales, Tuberculariaceae) by finding its spores on the carton of these recently collected nests.

The nest shape is rather variable (Figures 16–23) and depends basically on the number and arrangement of cells, which range from 4 to 26 in *eximia* with an average of 13.3 cells per nest (n = 34). The peripheral cells are rounded on the outer surface, so that the upper 10 to 15 mm of the nest has distinct longitudinal grooves between adjacent cells (Figure 19, g). Below this area of peripheral cells the pseudenvelope narrows toward the terminal spout. There are often thin, sometimes denticulate ridges on the carton, extending downward from the peripheral cells (Figure 17, r, and 35). Sometimes there are thin elongate wings or teeth on top of the nest, and the peripheral cells are not so clearly demarcated (Figure 17, w, t). Occasionally there are one or more aborted cells up to 12 mm long on the outer surface of the pseudenvelope which the female did not include within the completed nest (Figure 23).

The nest narrows below the cells to form a slender spout with the nest entrance on the surface toward the bank (Figure 17). The wall of the spout surrounding the entrance is perforated by a lacy network of carton through which the wasp may peer while remaining hidden. The perforated area is margined by a narrow flange of carton giving the spout a lanceolate appearance (Figure 18, f). The spout is extremely fragile because of the perforations. The perforations are made from larger masses of masticated material (Figures 31–34), 0.6–1.0 mm thick. One wasp included in the perforated area a large chunk of unworked vegetative matter 2.4 mm long and 0.4–0.8 mm thick (Figure 34). The spout must frequently be broken during storms as the nest is buffeted by the wind or driving rain. Many of the active nests that we found in the field had the spout broken off. The spout apparently is not replaced if it is damaged.

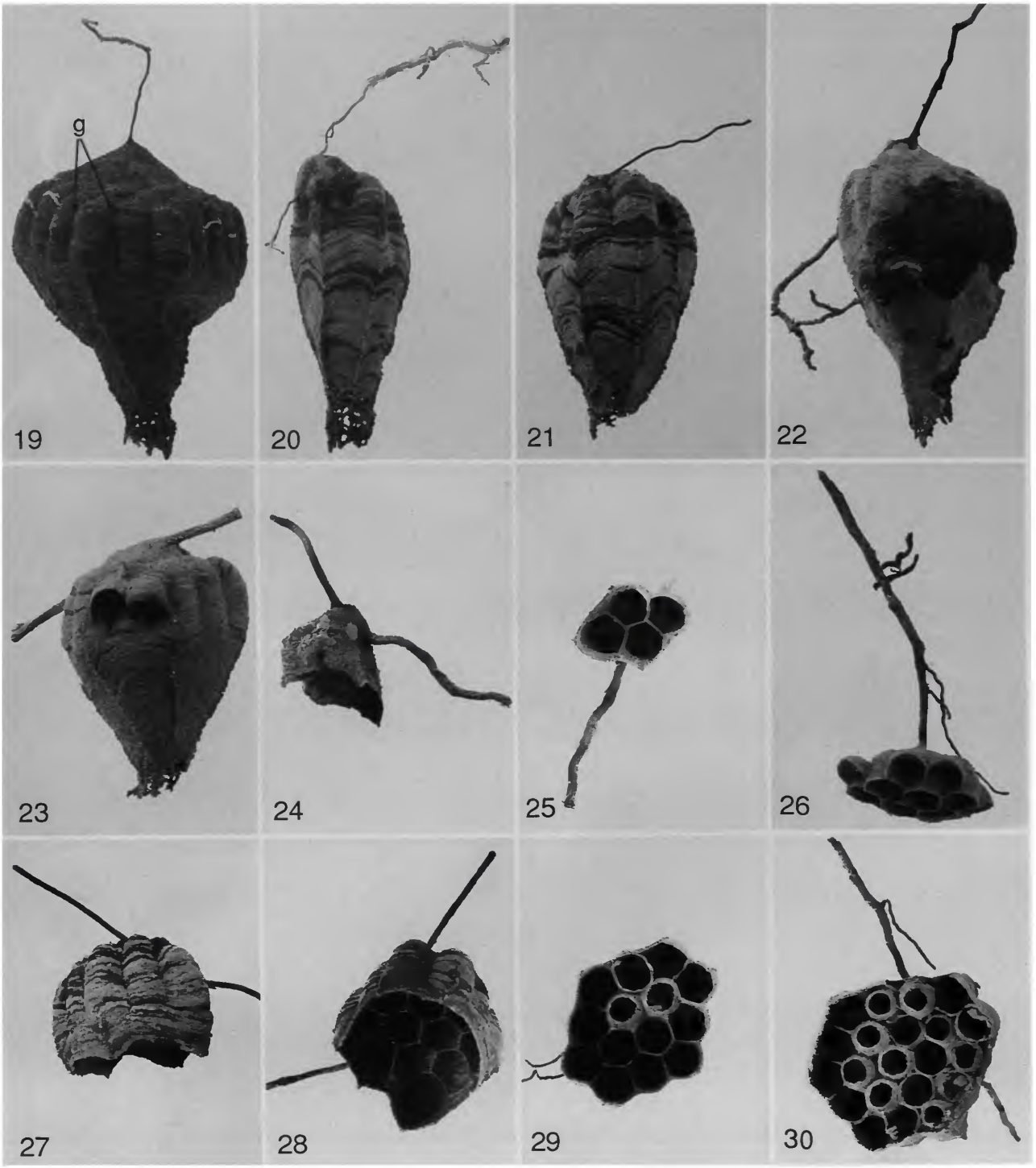
We found a single anomalous nest at Kanneliya in 1979. The pseudenvelope divided into two spouts with entrance holes at the bottom, each giving access to the comb. The older spout had the tip broken off, the other was complete. The single female escaped from the nest. Pagden (1958, fig. 7a) described a similar nest of an unidentified species of *Eustenogaster* (his Group I of *Stenogaster* in Malaya). These two nests may possibly be rare examples of spout replacement following supersedure of one female by another.

Bell (1936) found nests of *eximia* in areas of high rainfall in the Western Ghats near Bombay. His nests were located in the same kinds of habitats and were as variable in shape as those I found in Sri Lanka.

The profound variation of nest architecture in *eximia* nests creates doubt about the validity of the elaborate scheme of nest architecture proposed by Ohgushi and his colleagues (1983) for four species of Sumatran *Eustenogaster* which they designated as E_{1-4}. Nests of types E_{1-3} are all found in *eximia*. The nest types which they designated as E_4, and later as E_5 (Ohgushi et al., 1986), could be variation within *calyptodoma*. Critical taxonomic study of wasps associated with nest variations is required to substantiate any system of nest architecture. It seems probable that there may be considerable plasticity in nest architecture within a single species of *Eustenogaster*.

Some species of *Eustenogaster*, including *eximia*, do not construct an ant guard on the support above the nest. However, Pagden (1958, fig. 8) found an unidentified species of this genus in Malaya that provided such a guard, and C.K. Starr (personal communication) also found ant guards in several species of *Eustenogaster* in the Philippines.

MATERIALS USED.—I did not observe *eximia* gathering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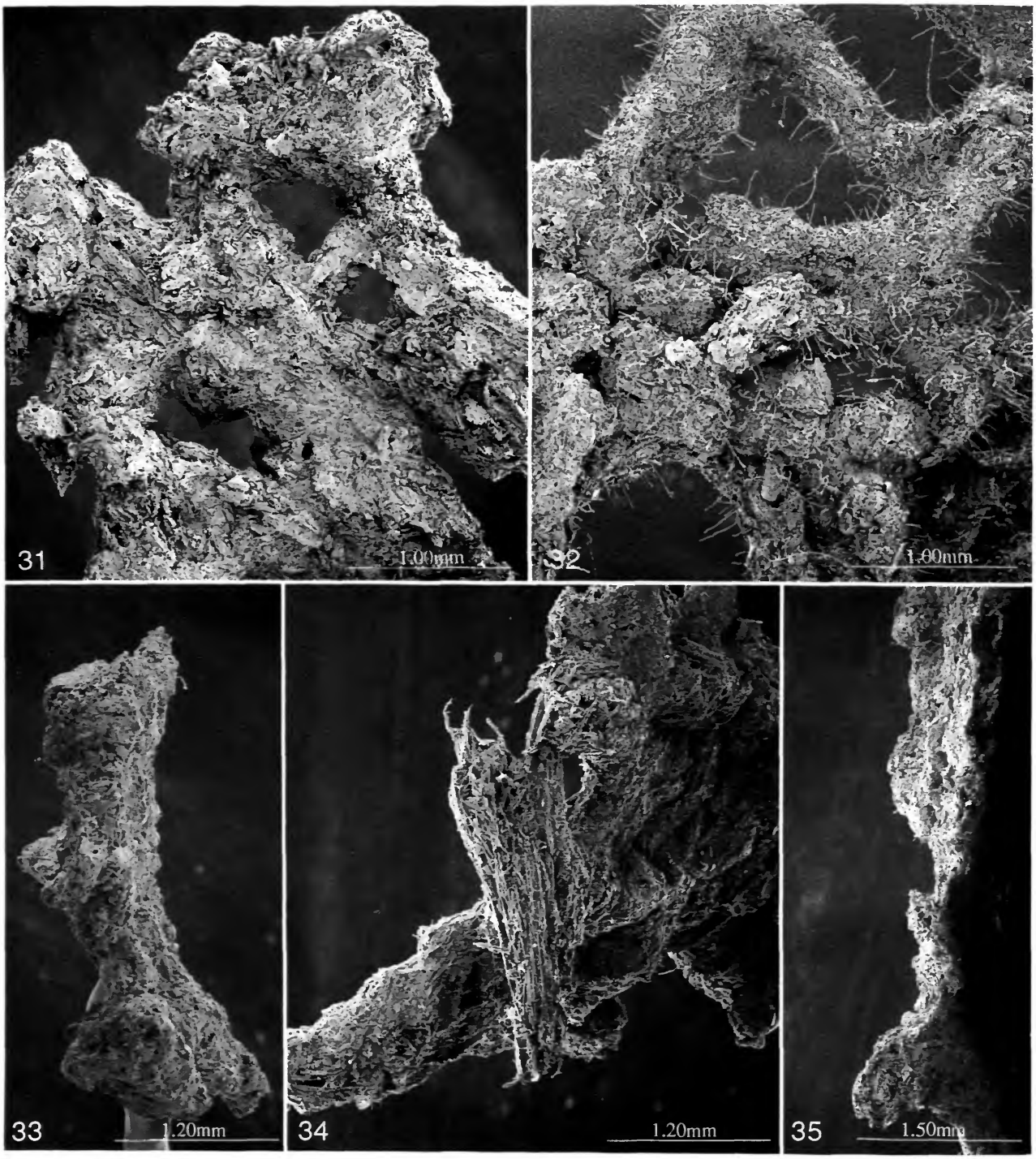


FIGURES 31–35.—Structure from nests preserved dry, *Eustenogaster eximia* (Bingham), Kanneliya: 31–34, fragments of perforated area of spout; 31, fragment without fungi; 32, fragment from another nest with *Fusarium* hyphae; 33, edge of perforated section, same fragment as 31; 34, unworked fragment of wood from perforation in a third nest; 35, serrations of rib in profile of a fourth nest.

decaying vegetative material for nest construction, but scanning electron micrographs (SEM) of fragments from about a dozen nests provide some knowledge. Some sections were made principally of decayed xylem fragments with some intermixed amorphous vegetative matter (Figure 36). I also found occasional pieces of decayed hardwood with profuse vessel-pitting as seen from inside of a vessel element (the many tiny perforations) (Figure 37), mixed in with xylem fragments. Small particles of mud occurred rarely (Figures 38–39, m).

Some of my nests (Figures 16, 17, 19, 23, 24) are mostly unicolorous, the pulp apparently coming from a single source. Other nests are prettily patterned (Figures 18, 20, 21, 27) with alternating bands in two colors, undoubtedly made from pulp from different sources. SEMs of banded sections of carton showed no appreciable difference in composition. Still other nests (Figure 22) are irregularly blotched, suggesting that a damaged nest might have been patched with pulp from a different source.

Green (1924) erred in stating that the nest of *eximia* in Sri Lanka is "built of earthy matter." Bell (1936) mentioned the extreme fragility of the Indian nests, but he, too, was mistaken in stating that they were built of mud mixed with saliva. Nest or nest fragments from both Bell and Green in the British Museum (Natural History) are of carton (personal commnunication, M.C. Day).

Williams (1919) published a brief account of the Philippine *luzonensis* (Rohwer). He observed females gathering nest material from the trunk of a fallen tree and reported that the "moist, and well-decayed wood [was] chewed into a pulp and formed into a delicate paper which is not rainproof." He made no notes on application of the pulp to the nest, but mentioned that the pulp-gathering trips were made at intervals of about 15 minutes. The presumption is that the actual processing of a load of pulp and its application to the nest is a reasonably prolonged process.

Pagden (1958) stated that several unidentified species of *Eustenogaster* (his Group I of *Stenogaster*) in Malaya constructed their nests of "triturated vegetable matter."

Hansell (1981) analyzed pieces of nest material from three nests of another stenogastrine in Thailand, *Parischnogaster mellyi* (Saussure). He found the carton composed principally of plant fragments with very little intermixed soil. The plant material was of two types, woody xylem fragments possibly from rotten stems, and pieces of cuticular cell layer of plants, some of which bore discernible hairs.

Ohgushi et al. (1983) found a small amount of mud mixed with the carton in some of the nests made by several unidentified species of *Eustenogaster* in Sumatera Barat, Indonesia. Neither Williams nor Pagden mentioned any admixture of mud in their nests, and Hansell and I found it infrequently. I believe that any inclusion of mud in *Eustenogaster* nests is accidental. It probably occurs when the wasp collects leaf fragments or pulp from decaying wood lying on the forest floor.

CONSTRUCTION.—The wasp initiates the nest by constructing a comb of shallow cells beneath the supporting substrate (Figure 26). The cells are about 6.5 mm wide, and hexagonal in cross section except for those on the periphery which have the outer surface rounded (Figures 29, 30). When the cell walls reach 5–10 mm in length, she may begin to lay eggs, one in each cell beginning at the center of the comb. We found a 25-celled comb with cell walls about 10 mm long in which eggs or tiny larvae were present in five of the central cells. Oviposition and brood rearing apparently proceed at a leisurely pace. During this period the cell walls are extended downward to their full length of 13–15 mm.

Occasionally, though, the entire pseudenvelope including spout may be completed before eggs are laid, or very soon after the first eggs are deposited. I found one such nest with completed pseudenvelope in which the 17 cells were very short, and six of the central cells, 5–8 mm long, each contained an egg or tiny larva.

The interior cell walls are 0.13–0.28 mm (n = 13) thick, while the pseudenvelope is 0.24–0.36 mm (n = 12) thick. If ribs are present on the lower exterior of the pseudenvelope, that wall and the rib are 0.69–0.75 mm (n = 6) thick.

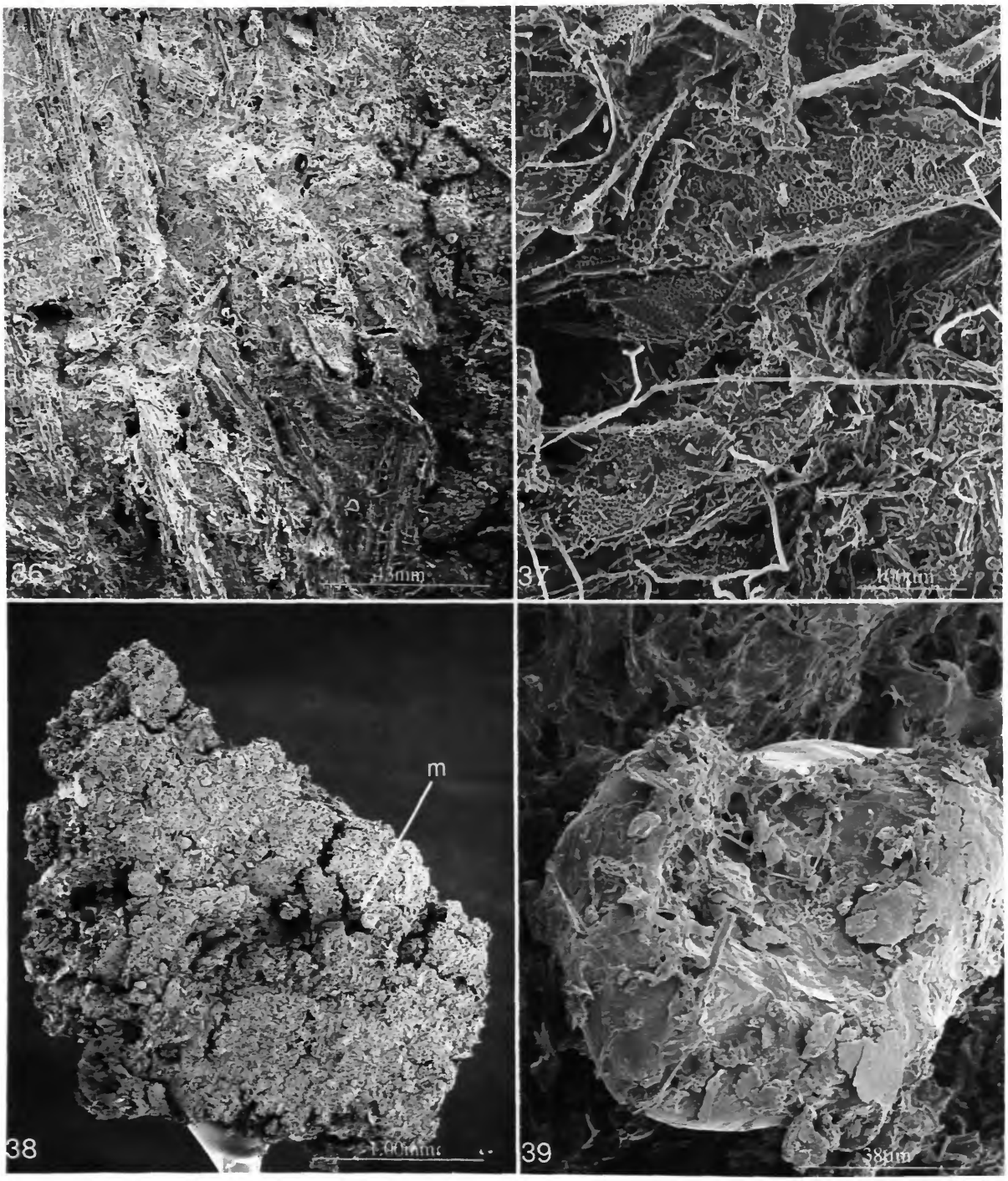
There is no true envelope of carton separated from the comb in most species of *Eustenogaster*. The single known exception is *calyptodoma* (Sakagami and Yoshikawa) from Borneo and Malaya. In this unusual species the cells are attached directly to a flat surface such as a slanting rock or piece of wood, and the envelope is separated from the comb by as much as 5 mm. Exceptionally the envelope may be partially in contact with the comb. The nest has a terminal spout as in other species of the genus.

BROOD DEVELOPMENT

EGG.—The egg of *eximia* is short, sausage-shaped, 1.8–2.1 mm long and 0.8–0.9 mm wide (n = 6) (Figure 40). The wasp begins to lay eggs in the central comb cells first, placing each at the inner (i.e., upper) end of the cell. All eggs and young larvae that I observed were immersed in a globular mass of thick, sticky, milky-white substance. This is consistent with conditions reported in nests of other species of Stenogastrinae.

I did not observe oviposition in *eximia*, but Turillazzi (1985a) studied it in several species of *Parischnogaster*. He noted that the female secreted a drop of viscid, milky-white substance from the tip of her abdomen, collected it in her mouthparts, touched the drop to the egg as it was extruded from the abdomen, and then deposited the egg and substance in the cell. Additional droplets of substance were placed in the cell after the larva hatched. Hansell (1982) suggested that the drops were secreted from Dufour's gland. Carpenter (1988) commented that the oviposition sequence of the Stenogastrinae is unique in the Vespidae.

Turillazzi also noted that the abdominal substance, possibly mixed with oral secretions, was used to form the ringlike ant guard placed on the rootlet a short distance above the nest of *Parischnogaster*.



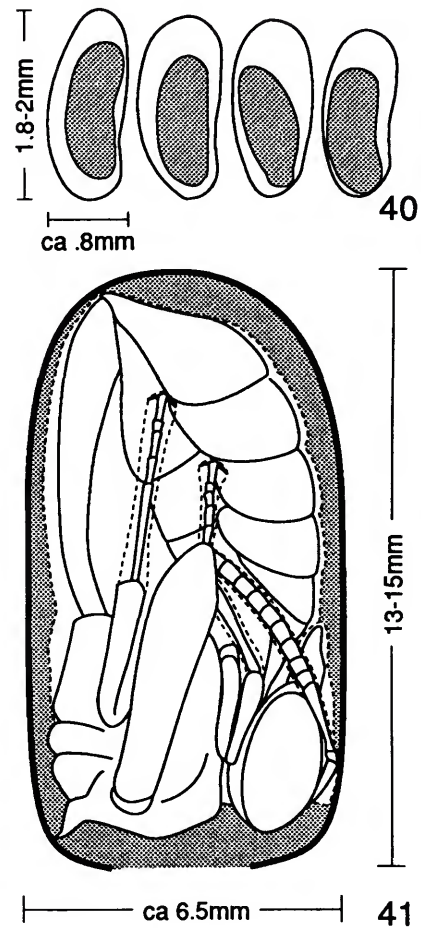
FIGURES 36-39.—Composition of cell walls, *Eustenogaster eximia* (Bingham), Kanneliya, 36, 38, 39, of psuedenvelope from dry nests, 37 from comb preserved in alcohol: 36, vascular tissue and some amorphous material; 37, fragments of decayed hardwood with profuse vessel pitting inside of a vessel element (the numerous tiny perforations), a little vascular material and a few strands of *Fusarium* hyphae; 38, fragment from another nest than 36 with scattered particles of mud, one indicated by arrow; 39, mud particle from 38 enlarged.

LARVAL FOOD.—I examined the gut contents of eight larvae from Kanneliya preserved in alcohol in 1975. The larvae ranged from about a third grown to fully mature. The results were as shown below.

Larval head width	*Code number*	*Gut contents*
0.9 mm	none	many tiny unidentifiable chitinized fragments
0.9 mm	none	araneoid fang, 0.23 mm long numerous unidentifiable chitinized fragments
nearly mature	11375 B	2 araneoid fangs, 0.3 and 0.53 mm long many fragments of araneoid legs, none with tarsal claws numerous unidentifable chitinized fragments
1.8 mm	11375 B	2 araneoid fangs, 0.28 and 0.3 mm long araneoid spermatheca, 0.38 mm long many fragments of araneoid legs, none with tarsal claws braconid stigma, 0.5 mm long fragments of braconid or ichneumonid wings, 0.23–1.06 mm long 3 ichneumonoid ocelli, 0.1 mm wide, in head capsule fragments, 0.23–0.4 mm wide numerous unidentifiable chitinized fragments
1.9 mm	none	numerous unidentifiable chitinized fragments
1.9 mm	11175 A	4 fragments basal segment araneoid chelicerae 6 araneoid fangs, 0.2–0.68 mm long many sections of araneoid legs, 0.5–0.7 mm long, 2 with terminal tarsal claws terminal segment pedipalp, female araneoid, 0.31 mm long 5 araneoid spermathecae, ca 0.15×0.23 mm 3 ichneumonoid wing fragments, 0.35–0.43 mm long numerous unidentifiable chitinized fragments
2.0 mm	none	2 araneoid fangs, 0.4 and 0.58 mm long numerous unidentifiable chitinized fragments
2.0 mm	none	4 araneoid fangs, 0.35–0.63 mm long numerous unidentifiable chitinized fragments

I also obtained some data from the cell contents of several nests at Kanneliya in 1975 and 1980. The contents from one cell in each of three nests in 1975 were negative for larval food; each contained only the globule of abdominal substance and an egg or newly hatched larva. One cell of another nest from 1975 contained the following: the head and abdominal integument of a worker minor of a small myrmicine ant, possibly *Oligomyrmex* Mayr, the modified pedipalp of a male spider, 0.25 mm long, and the head of a small coleopterous larva, all of these parts having been fed upon by the wasp larva. There was also a whole, tiny collembolan, 0.44 mm long; this will be discussed in the section, Nest Associates. Another cell from the same nest contained only a globule of the abdominal substance and an egg.

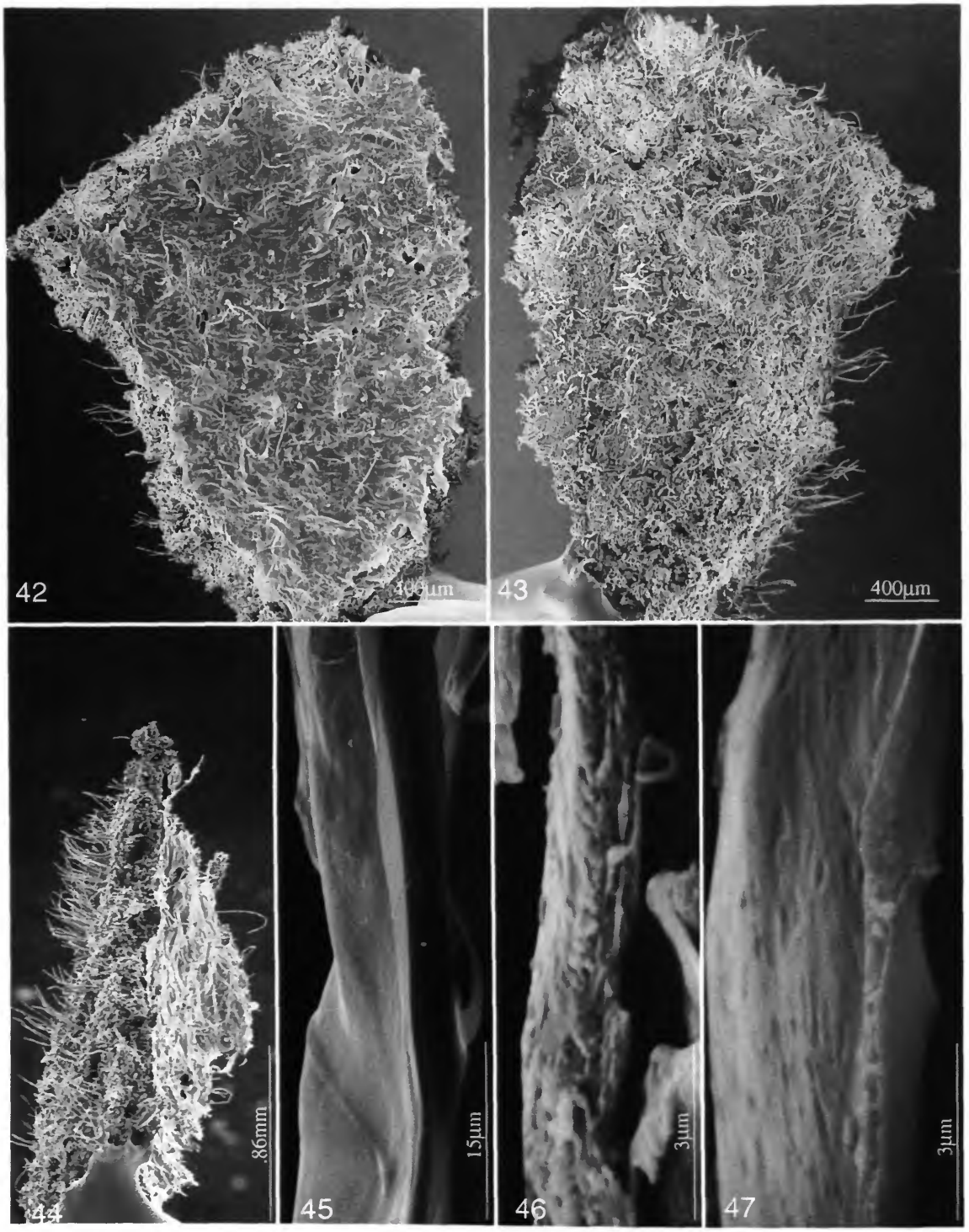
Each of two cells in the 1980 nest contained a small larva and some food. I recovered the following food items from these cells. (1) Two workers of a myrmicine ant, 2.4 mm long, a species of *Crematogaster* Lund possibly belonging to the *biroi* group. One ant had been malaxated, possibly by the foundress, and partially embedded in a small mass of abdominal substance, and one ant had the thorax and abdomen hollowed



FIGURES 40–41.—*Eustenogaster eximia* (Bingham), Kanneliya: 40, eggs, embryo second from right distorted; 41, pupal position in cell.

out, presumably by the larva of *eximia*. (2) A small fragment of chitin, 0.25 mm long, from an unidentified arthropod. The lower pseudenvelope of this nest was damaged, thus allowing easy access by casual visitors. In one of these two cells there was an adult ephydrid fly, 2 mm long, attracted to some of the larval food, a small dipterous maggot, 1.8 mm long, a worker termite, 2.5 mm long, and an adult mite, 0.25 mm long; these arthropods will be discussed in the section, Nest Associates.

It was not surprising to find identifiable parts of spiders in many of the guts and in one cell. Williams (1928) figured a female of *P. depressigaster* (Rohwer) hovering before a spider web suspended over a stream. She picked small midges from a strand of the web, using her mandibles and legs. Pagden (1958) reported that unidentified species of *Eustenogaster* (his Group I of *Stenogaster*) in Malaya hovered in front of spider webs and plucked small flies from the web with the forelegs. He noted that the spider was not disturbed by the wasp's activities, and



FIGURES 42–47.—Cocoons, *Eustenogaster eximia* (Bingham), Kanneliya: 42, inner surface of section of pupal cell with glistening cocoon fabric covering strands of *Fusarium* hyphae; 43, outer surface of same section covered by hyphae; 44, edge of same cell section, outer surface at left; 45–47, edge of cocoon showing varying degrees of thickness as denoted by scale lines.

suggested that the flies were too small to attract the spider. This curious habit presumably is widespread among Stenogastrinae.

However, I was surprised to discover that most of the identifiable fragments of insects were of Hymenoptera rather than Diptera. Iwata (1967) reported finding unidentified chitinized fragments on the body of a larva of *P. mellyi* in Thailand, and also found a wasp larva feeding on a minute lepidopterous larva. He also recovered chitinized arthropod fragments from a food mass of a species of *Eustenogaster* near *micans* (Saussure). Spradbery (1975) found no identifiable fragments in the spherical food mass provided for first and second instar larvae of *S. concinna*. He noted that the food mass for maturing larvae in the fourth and fifth instars contained fragments of legs, integument, and wings of small Diptera that he presumed to be Cecidomyiidae. It is probable that this larval food also was obtained from spider webs.

The developing *eximia* larva remains curled at the upper end of the cell, instead of extending lengthwise along the cell axis as is normal in other vespids. As the larva becomes full grown, the female gradually begins to narrow the cell mouth (Figures 29, 30) to a diameter of 2 to 5 mm; it is never entirely closed.

COCOON.—The mature larva of *eximia* constructs an unusual cocoon. It secretes a substance, presumably from the salivary glands, that dries to form a glistening, delicate film, 2.9–9.0 μm in thickness. The secretion is applied to the entire interior of what is to become the pupal cell but it does not seal the narrowed opening of the cell (Figures 42, 44–47, 51). Individual strands of silk are not apparent when examined with a binocular microscope, just the glistening surface.

I preserved some combs of *eximia* in ethyl alcohol. Careful maceration of sections of pupal cells freed bits of the film from the vegetative matrix of the cell. Subsequent staining of these cocoon sections with acid fuchsin revealed that there are, indeed, strands of fine silk underlying the glistening film that now appears transparent (Figures 49, 50).

The source of the glistening film overlying the strands of silk is a puzzle. Perhaps it also is silk from the salivary glands, but is applied broadly, as if painted on, rather than narrowly as are the fine strands. The film and underlying strands of silk dissolve in hot KOH solution. The North American crabronid wasp *Crossocerus (Blepharipus) stictochilos* Pate spins a fusiform cocoon that has the same basic structure. A scanning electron micrograph (SEM) of part of the cocoon wall of this wasp (Figure 48) shows that it is composed of a mesh of fine silken strands 3.6–7.0 μm wide overlying a thin, glistening film. The entire cocoon of *stictochilos* also dissolves in hot KOH solution.

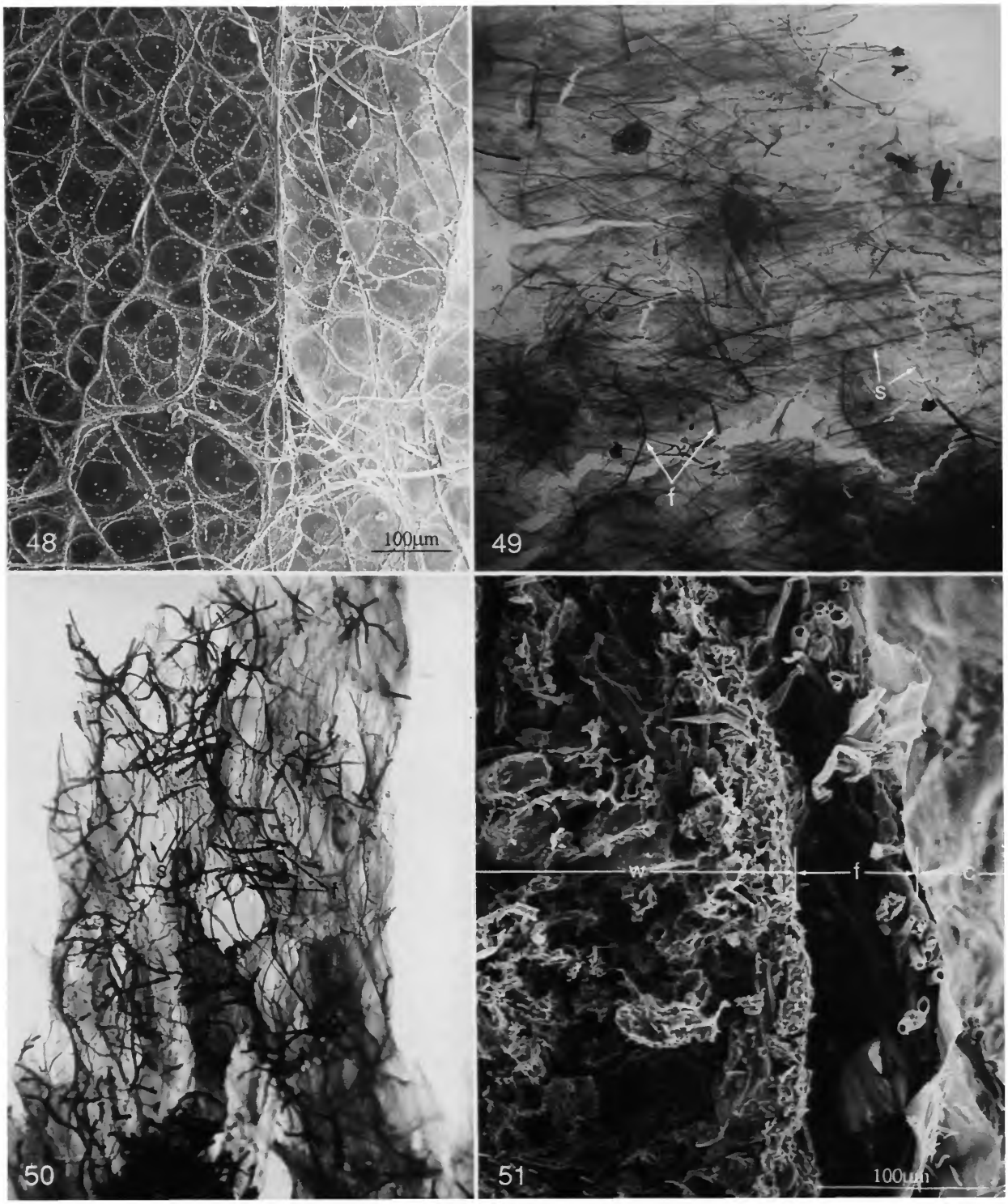
Using scanning electron microscopy, I discovered that the cocoon of *eximia* often covers hyphae of a species of *Fusarium* that is frequently found on both the exterior of the pseudenvelope and the interior cell walls. Heating sections of dried pupal cell walls in KOH solution dissolved the cocoon, revealing hyphae and fragments of vegetative matter forming the wall (Figure 54). SEMs (Figure 42, 43) of the outer and inner surfaces of a section of pseudenvelope from a pupal cell on the nest periphery show a dense growth of hyphae on the exterior, and the smooth film lining the inside of the cell. Note in Figure 51 that the cocoon (c) walls off the pupa that it contains, leaving a narrow space (f) containing hyphae and the cell wall (w) formed from vegetative material. It seems probable that the cocoon may serve a vital function by protecting the inert pupa from infestation and possible death from the *Fusarium*.

Other workers, e.g., Williams (1919), van der Vecht (1972), and Spradbery (1989), noted that cells of several genera of Stenogastrinae containing pupae, or cells from which adults had emerged, were coated with a glistening material, but they did not interpret this as a cocoon. Sakagami and Yoshikawa (1968) stated that the base of the pupal cell of *calyptodoma* was covered by a spun fibrous film, but that the pupa was not enclosed in a cocoon. Hansell (personal communication) stated that in his experience *calyptodoma* did not line the base of the cell with such a fibrous layer, but that the walls were coated with a thin film of secretion. My experience with *eximia*, detailed above and in Figure 55, suggests that this fibrous layer might have been a mass of hyphae.

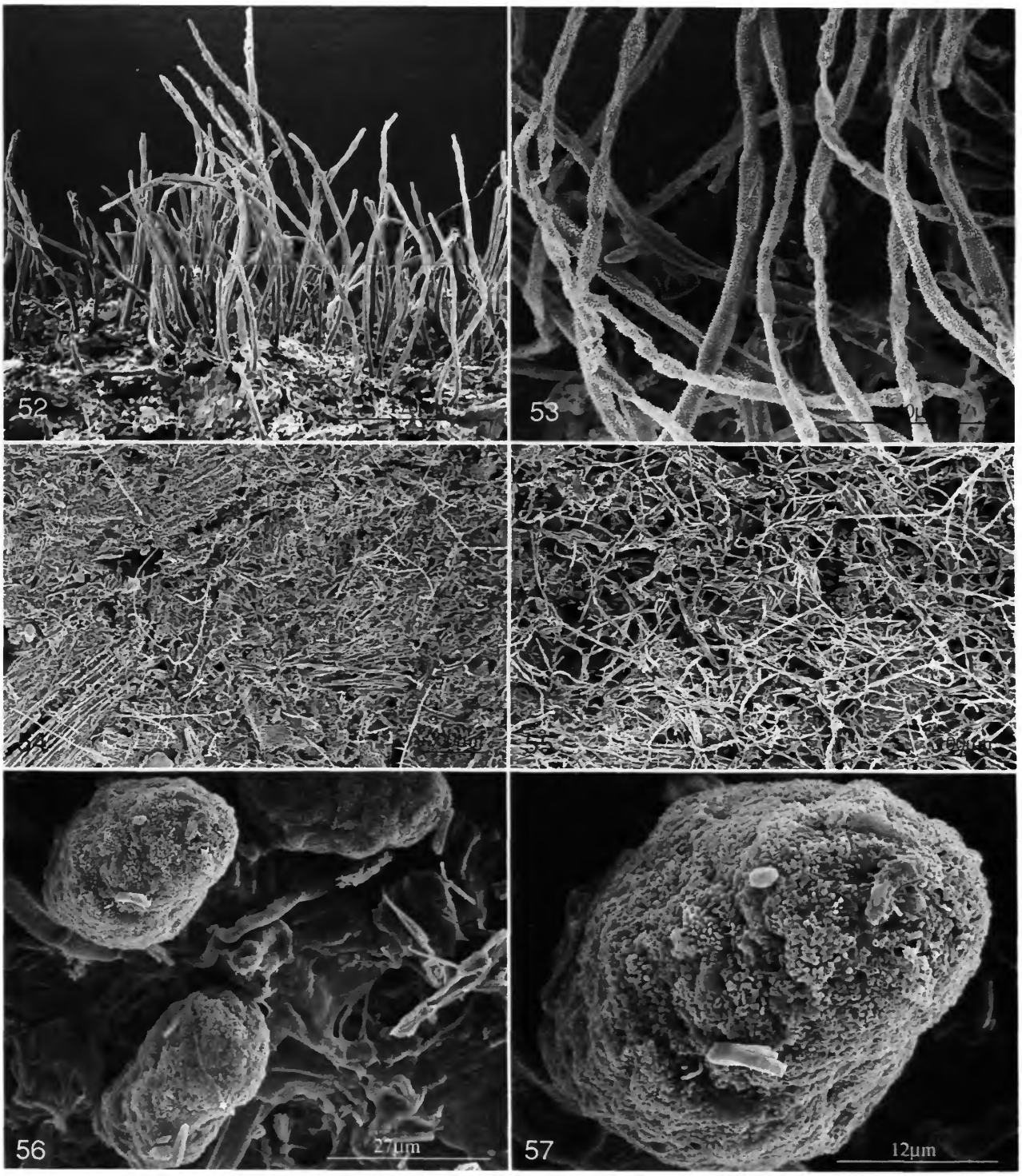
It seems probable that this type of cocoon occurs throughout the Stenogastrinae. It is known to occur in all genera except *Metischnogaster* van der Vecht. In his notes on nests of the two known species of that genus, *cilipennis* (Smith) and *drewseni* (Saussure), Pagden (1958, 1962) did not mention whether the pupal cells were lined with a glistening film.

PUPATION.—The mature larva lies in a curled position at the upper end of the cell until the pupal eye disks are visible through the integument. It then assumes the characteristic stenogastrine pupal position (Figure 41). The scutum, with the posterior pair of spines, is at the outer (lower) end of the cell. The scutal spines are presumed to anchor the pupa against the narrowed lower end of the cell. The thorax posterior to the scutum and the long abdominal petiole are aligned upward along the length of the cell on one side. The remainder of the abdomen is flexed downward along the opposite side of the cell with its tip against the apex of the upturned mouthparts beneath the head.

I obtained no direct data on the duration of early brood stages. However, emergence dates of adults from a nest collected at Kanneliya on 11 January 1975 suggest a pupal period of about 3 weeks in *eximia*. The 21-celled nest had 11 cells with narrowed lower ends, 3 with either nearly full grown or mature larvae, and 8 with pupae in various stages toward eclosion as adults. The nest was kept in a sealed plastic sack and examined daily. One mature larva pupated by the 12th, but the other larvae and one older pupa died. Adults eclosed from the eight viable pupae as follows: ♀ 18 Jan; ♀ 23 Jan; ♂ 24 Jan; ♀ 26 Jan; ♂ 28 Jan; ♀ 29 Jan; ♂ 31 Jan; and ♀ 1 Feb. It is reasonable to assume that this last female is from the larva that pupated on 12 January, thus giving a pupal period of about 21 days.



FIGURES 48–51.—Cocoon fabric and fungi: 48, *Crossocerus (Blepharipus) stictochilos* Pate, Plummers Island, Maryland, section of cocoon wall with silken strands overlying glistening film; 49–51, *Eustenogaster eximia* (Bingham), Kanneliya; 49–50, sections of cocoon fabric from alcohol stained with acid fuchsin, darker, thicker, curved, and/or beaded filaments are *Fusarium* hyphae, finer, lighter filaments are silken strands, ×80; 51, section of pupal cell from alcohol, part of cell wall (w) at left, mass of *Fusarium* hyphae (f) in center, and thin cocoon (c), oblique aspect, at right.



FIGURES 52–57.—*Fusarium* hyphae and other structures from nests of *Eustenogaster eximia* (Bingham), Kanneliya: 52, hyphae on exterior of peripheral cell wall in profile, dry nest; 53, hyphae on exterior of peripheral cell, nest from alcohol; 54, interior of pupal cell from nest in alcohol after treatment with hot KOH to dissolve silken film, mostly vascular tissue and amorphous vegetative matter with a few strands of hyphae; 55, interior of another pupal cell from nest in alcohol after treatment with hot KOH to dissolve silken film, mostly a dense mat of hyphae overlying basic vegetative matrix of cell wall; 56, unidentified bodies associated with hyphae, same nest as Figure 53; 57, enlarged unidentified body at upper left of Figure 56.

Hansell (1987) estimated an average duration of 42.7 days from oviposition to pupation in *E. calyptodoma*, and an average duration of 21.4 days for the pupal period. Spradbery (1975) stated that the pupal period was more than 24 days in *Stenogaster concinna*. Turillazzi (1985b) noted a mean period of 44.5 days from egg to adult in *Parischnogaster nigricans serrei* (du Buysson), and a mean pupal period of 17.1 days. Samuel (1987) found a mean egg-to-adult time of 103 days in *Liostenogaster flavolineata* (Cameron), and a mean pupal period of 33 days.

The rather prolonged periods of pupal duration in stenogastrines contrast markedly with the shorter such periods of 9–18 days in many North American eumenine wasps (Krombein, 1967).

I did not find a larval meconium in the cells from which I recovered *eximia* pupae. This is consistent with observations by Turillazzi and Pardi (1982) and Sakagami and Yamane (1983), who found that females of two species of *Parischnogaster* removed the larval fecal pellets.

Nest Associates

NATURAL ENEMIES.—In my experience *eximia* is remarkably free of parasites and predators. I preserved a few larvae of various stages from nests at Kanneliya. One of the mature wasp larvae had seven small chalcidoid larvae, 0.6 mm long, attached to the inner surface of the abdominal integument. They were identified as Eulophidae, possibly a species of *Melittobia* Westwood. Members of this genus commonly infest nests of solitary wasps and bees (Krombein, 1967). I reared two species in Sri Lanka from nests of the eumenid wasp, *Paraleptomenes mephitis* (Cameron) (Krombein, 1978a). There is also a possibility that the eulophid might have been a species of *Nesolynx* Ashmead, which Spradbery reared from a tachinid parasite of a stenogastrine in New Guinea.

Ants are frequent predators of other wasp nests, raiding them for brood or for prey provided for the brood. The only ants in my nests were three small myrmicine workers belonging to species of *Crematogaster* and possibly *Oligomyrmex* Mayr. They were definitely part of the larval food. They might, of course, have entered the nest to raid its contents, but were converted by the foundress into larval food.

Williams (1928) mentioned that larvae of species of *Stenogaster*, the generic name he used for species of *Eustenogaster* and *Parischnogaster* in the Philippines, were heavily parasitized by the ichneumonid, *Theronia* Holmgren. H.K. Townes advised me that *P. timida* (Williams) was probably the species from which *T. pyramida williamsi* Gupta was reared. Williams also recorded *Vespa deusta* Lepeletier as raiding the nest of *P. depressigaster* (Rohwer) to pillage the brood. Spradbery (1975) found an unidentified tachinid in four nests of *S. concinna* in Papua New Guinea, three puparia and one larva that had devoured half of a wasp larva. The three puparia were hyperparasitized by eulophid wasps; he found adult eulophids in two other nests, and assumed that they were searching for tachinids because they had not parasitized any of the brood. Spradbery (1989) reared the tachinid, *Euvespivora decipiens* (Walker) from nests of *Anischnogaster iridipennis* (Smith) in Papua New Guinea, and a eulophid wasp, a species of *Nesolynx*, from puparia of the tachinid.

Iwata (1967) recorded the eulophid, *Syntomosphyrum* species, as attacking the larva of *P. striatula* (Buysson) in Thailand.

COMMENSAL ORGANISMS.—I presume that the termite and collembolan recovered from nests in 1975 and 1980 were just casual visitors. They had not been malaxated by the female wasp, nor had the larva fed on them.

The adult dipteran was an ephydrid, a species of *Rhyncopsilota* near *magnicornis* Hendel. W.N. Mathis advised me that, so far as is known, species of this genus are attracted to injured *Crematogaster* ants, and feed on their body fluids. The dipterous larva from the same nest was a first instar larva of Ephydroidea, possibly a species of Drosophilidae.

The mite was an adult oribatid, a family whose members are frequently associated with decaying vegetative matter. It may have been introduced into the nest with some of the nesting material.

In the preceding section on Brood Development I mentioned a nest from which I reared a sequence of adult wasps. I also reared a small lyonetiid moth, *Opogona praecincta* Meyrick, from one cell. This nest had been kept in a sealed plastic sack, so this was not a chance infestation. The larva may have developed on some of the organic debris in the nest.

Spradbery (1975) recorded that a newly emerged male of *S. concinna* had 53 phoretic mites attached to its wings.

Adult

BEHAVIOR.—Both sexes of *eximia* visit flowers for nectar. One shrub visited is wild olive, known in Sinhalese as gal veralu, one of several species of *Elaeocarpus* Linnaeus. I netted several females returning to their nest, each of which exuded a droplet of liquid, presumably nectar, between my fingers. Apparently this is the first flower visiting record for a stenogastrine.

Turrillazzi (1985a) noted that "drops of transparent liquid are also regurgitated by the wasps onto the eggs and larvae" and that the drops can be sucked up by the adults and serve as a readily available food reserve. In view of my notes on flower visits by adults, it is possible that this transparent liquid noted by Turillazzi is actually nectar.

We noted occasional female behavior unlike anything reported previously for Stenogastrinae. Usually the occupant(s) emerged quickly and flew off, when we disturbed a nest. Rarely, however, one or more individuals stayed inside the nest, and made a tapping sound on the pseudenvelope. This is reminiscent of the behavior described by Rau (1933) for the Panamanian social vespid wasp, *Synoeca septentrionalis*

Richards (reported as *S. surinama* var. *cyanea* (Fabricius)). These wasps build a large paper nest against a tree trunk. When disturbed, they may warn off an intruder by beating their wings against the inner surface of the envelope.

I did not observe patrolling by males or associations of males such as has been reported for a few species of Stenogastrinae (summarized by Carpenter, 1988).

EUSOCIALITY.—There is evidence that *eximia* may rarely exhibit primitive eusociality. Most of the nests that I observed or recovered in the field contained only a single female. The occupants were counted in 35 nests from Kanneliya and Kottawa in the Sinharaja rain forest in 1972, 1975, and 1980. Twenty-three nests had only a single female occupant, presumably the foundress. A large nest from Kottawa contained four wasps, two of each sex; these specimens are not now available for examination. Eleven nests had two occupants, but both wasps escaped from five of these nests and could not be sexed. Three of the remaining six nests contained a female and a male; one male was a teneral specimen, and the other two were presumed to be progeny of the respective female.

The three remaining nests contained two females, one nest in each of the three years. The two females from the 1972 nest were killed and pinned, but the two females from the 1975 and 1980 nests were preserved in fluid. Subsequent examination of the abdominal contents demonstrated that the females from the latter two nests had the ovaries more or less well developed with oocytes in several stages of development. One female in each nest had mature ovaries with at least one egg ready for oviposition and others less developed. The other female in each nest had marginally mature ovaries with only one egg about two-thirds mature and the others less developed. The females with mature eggs were undoubtedly the foundresses, and the second female in each nest was presumably one of the daughters.

The 1975 nest was quite large and had 21 cells. It undoubtedly had been active for a lengthy period, because 11 of the cells were narrowed at the outer end and contained 8 pupae in various stages of coloring, and 3 nearly mature or fully grown larvae. Four of the remaining cells had larvae about half grown, and 6 were either empty or contained an egg or tiny larva beneath the globular mass of abdominal secretion.

When I found the 1980 nest, the pseudenvelope had been damaged and the lower portion was missing. There were 12 cells in the comb, one with the lower end narrowed, and three with an egg or tiny larva beneath the usual globule of abdominal substance; the other cells were empty.

Hansell (1987) found a greater degree of eusociality in *calyptodoma* nests in the Malay Peninsula. He kept 26 nests under observation without disturbing their occupants. When these control colonies were collected, they comprised 47 females and 5 males. There were about the same number of nests with one or two females, only five contained three or four females, and males were present in only five nests.

Hansell termed other nests experimental. He made holes in the envelope to observe behavior, captured the occupants, marked them with paint, and released them. He examined the ovaries of females from 24 experimental and control nests with more than one female. Only four of those nests had more than one female with mature ovaries, and in three of these nests the maturity of ovaries of the second female was marginal.

I obtained no information on division of labor within pairs of females. Hansell found that in *calyptodoma* the older female guarded the nest entrance while the younger female did most of the foraging for food. He also noted that a young female usually left the nest in a week, either to found her own nest or to usurp the nest and brood of another female.

I believe that limited eusociality is more likely to occur in the nest of a species such as *calyptodoma* rather than in a species such as *eximia*. In the former the envelope is separate from the comb, allowing space for more individuals to function within the nest. The pseudenvelope of most *Eustenogaster* species leaves very little room at the bottom of the comb for more than one individual to operate. C.K. Starr (personal communication) advised me that his observations of *Eustenogaster* in the Philippines gave "indirect evidence that *luzonensis* and an undescribed species are at least usually solitary."

POMPILIDAE

PEPSINAE

Hemipepsis Dahlbom

These medium to large size spider wasps belong to one of the genera popularly known as tarantula hawks. They prey on the large, bulky, ground-dwelling mygalomorph spiders, some of which are the typical tarantulas. Very little is known about the natural history of species of *Hemipepsis*. Using terraria Williams (1956) found that the North American *H. ustulata ochroptera* Stål paralyzes and oviposits on tarantulas belonging to *Aphonopelma* Pocock and *Brachythele* Ausserer.

Hemipepsis convexa (Bingham)

This rather large wasp has a wide distribution in Sri Lanka, and appears to be the most common species of the genus in that country. It occurs in all three ecological zones at localities from near sea level to an altitude of about 700 m with an average annual rainfall ranging from 1000 to 5000 mm. The species was described from Sri Lanka, but it is known to occur in southern India from near sea level to 1050 m. Specific localities at which we captured it in Sri Lanka are as follows.

Mannar District: Ma Villu, Kondachchi and 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Anuradhapura District: Padaviya
Trincomalee District: Trincomalee, China Bay
Amparai District: Lahugala Sanctuary and Inginiyagala
Matale District: Kibissa near Sigiriya

Kandy District: Hasalaka, Thawalamtenne, and Kandy, Udawattakele Sanctuary
Colombo District: Labugama Reservoir and Mirigama Scout Camp
Ratnapura District: Weddagala, Gilimale, and Belihul Oya
Badulla District: Ella
Monaragala District: Angunakolapelessa
Galle District: Kanneliya
Matara District: Deniyaya

NESTING BEHAVIOR.—I observed this only once in Udawattakele Sanctuary, at 1512 on 22 September 1980. The wasp, 22 mm long, was finishing the closure of her nest, which was placed on a slight slope in dense jungle against a tree root. She tugged at several large leaves, apparently trying to obtain small fragments to conceal the nest entrance. I captured her in a few minutes, and found that her nest was in the tunnel of the prey spider. The tunnel extended 6.4 cm from the entrance to the terminal cell of the spider. The wasp had filled the tunnel loosely with soil. The cell was 2.5 cm long, 2.0 cm high, and 1.5 cm wide. The bulky spider, 21.5 mm long, was thoroughly paralyzed and had been placed on its back with the cephalothorax toward the inner end of the cell. The slightly curved egg, 2.9 mm long and 0.9 mm in diameter, was placed transversely toward the anterior end of the abdominal venter of the spider.

P.B. Karunaratne told me that this spider constructs its nest near the soil surface, lines the tunnel and terminal cell with silk, and makes a funnel-shaped entrance that is camouflaged with pieces of leaf or bark. The wasp must have removed the silk lining the entrance and tunnel before making the closure, for I found a silken lining only at the inner end of the cell.

PREY.—The prey specimens that we collected with the wasps were large, bulky, typical tarantulas belonging to the families Idiopidae and Barychelidae.

The prey at Udawattakele was an adult female idiopid, possibly a species of *Scalidognathus* Karsch. The other three prey specimens, two from Angunakolapelessa and one from Induruwa Jungle, Gilimale, were immatures of the barychelid spider, *Plagiobothrus semilunaris* Karsch. I kept one of the prey from Angunakolapelessa alive for some hours. In 6½ hours it recovered enough from thorough paralysis, so that it could flex its legs but was incapable of walking.

PREY TRANSPORT.—I saw a small *convexa*, 14 mm long, crawling rapidly and excitedly over an almost vertical bank of a dry streambed at Angunakolapelessa at 0943, 27 March 1981. After about five minutes she visited her thorougly paralyzed prey, 13.5 mm long, that was lying venter up on a small flat ledge near the top of the bank. The wasp then disappeared in the leaf litter next to the bank, and returned at 0954. She started to drag off the prey, was frightened by my proximity, and I captured her when she returned 10 minutes later.

At 1415 on this same date T. Wijesinhe saw a small *convexa*, 12 mm long, walking on the leaf litter in the same dry streambed. She pulled a paralyzed spider, 15.5 mm long, from beneath the leaves, turned it venter down, and, walking backward, dragged the prey while grasping it at the head end.

My last prey record was in the Induruwa Jungle, Gilimale, at 1240, 16 April 1981. A female *convexa*, 22 mm long, was dragging her thoroughly paralyzed spider, 16.5 mm long, venter up, at the edge of a trail through the dense rain forest.

Williams (1956) noted that the egg of *H. ustulata ochroptera* was 4.25 mm long, slightly curved, and was attached at one side of the ventral line and at midlength of the spider's abdomen. He also stated that the cocoon was 35 mm long, and was spun of brown silk with a single wall that was varnished on the inner surface.

Hemipepsis indiana Wahis

This rather uncommon species occurs in Sri Lanka and southern India (Bengal, Tranquebar in Tamil Nadu, and Coimbatore in Kerala). Within Sri Lanka it has been collected only in the Dry Zone at altitudes from near sea level to 30 m and with an average annual rainfall ranging from 920 to 1000 mm. Our few records of its occurence in Sri Lanka are as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Anuradhapura District: Padaviya
Hambantota District: Palatupana Tank

PREY HUNTING.—I saw one female, 20 mm long, hunting for a prey in the leaf litter beneath a small malith tree, *Woodfordia fruticosa* (Lythraceae) in an open field at Palatupana Tank at 0810, 28 September 1977. During her search she flicked her wings rapidly from a position of being folded flat over her abdomen, and antennated the ground incessantly. She paused briefly at a silken burrow entrance, 10 mm in diameter, next to a tree root, antennated the entrance, and then moved on. She returned 10 minutes later and entered the burrow. A minute later I saw a large spider run rapidly down a slight slope from a second entrance on the other side of the root. The wasp lost sight of the spider scurrying away, but picked up its trail five minutes later. I captured the wasp at 0838, after she had clearly lost the spider's trail.

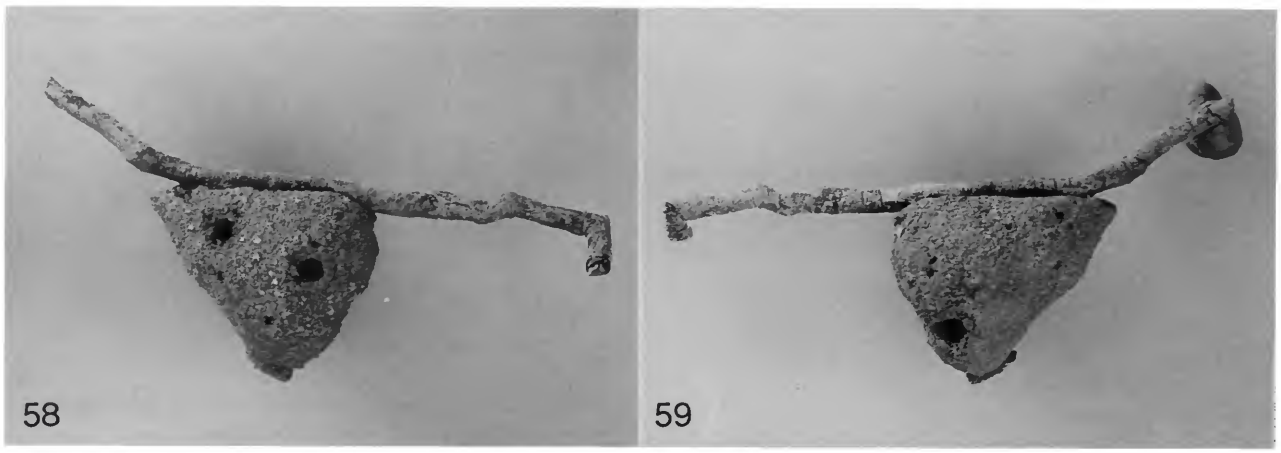
Dipogon kandiensis (Turner)

This species is endemic to Sri Lanka where we collected it in the Wet Zone at altitudes of 610–1050 m with an average annual rainfall of 3000 mm as follows.

Kandy District: Thawalamtenne and Kandy, Udawattakele Sanctuary

Both of my behavioral records are from Udawattakele, the area in which Turner's holotype specimen was probably captured by O.S. Wickwar.

NEST.—I found a female, 8.7 mm long, sealing the nest entrance in a cavity in a standing dead tree in mid-morning, 22 March 1981. Her abdomen was curved beneath her, and she was using the tip to compact the debris that formed the closing plug. The nest was in an abandoned boring, presumably of a beetle, in sound dead wood with an entrance diameter of about .7 mm. The plug, which came to within 3 mm of the surface when I captured the wasp, consisted of small bits of bark and



FIGURES 58–59.—Nest of *Auplopus bimaculatus* (Smith), Kanneliya, ×1, lateral aspect of opposite sides.

leaves, several small seeds, and silk, presumably obtained from spider webs. Lacking an axe, I was unable to get deeper into the nest and recover the prey.

PREY.—P.B. Karunaratne captured a female, 9 mm long, in mid-morning, 14 October 1980, with her prey. The latter was an immature crab spider (Thomisidae), 7.5 mm long, a species of *Thomisus* Walckenaer.

DISCUSSION.—The meager data above are consistent with previous observations on other species of *Dipogon* Fox. I reared (1967) the North American *sayi* Banks frequently in borings in wood sticks with diameters of 4.8 or 6.4 mm. Usually the nest consisted of a series of linear cells, each separated from the preceding cell by a plug of debris of a mixed nature. All prey specimens were crab spiders.

Auplopus Spinola

Evans and Yoshimoto (1962) summarized the known ethological information on *Auplopus*. Many members of the genus make mud nests which may consist of a single cell, a linear series of such cells in a boring or other cavity, or an aggregation of cells in an irregular mud lump. The cells are placed in protected situations such as under stones, beneath overhanging banks in the jungle, in cavities of a great variety, and occasionally in mud nests of other wasps. The spider prey may belong to a number of families, but orb-weavers (Araneidae) are not known to be used. Usually the wasp amputates most or all of the spider's legs, and may feed on the hemolymph which exudes.

Auplopus bimaculatus (Smith)

FIGURES 58, 59

This common species is widely distributed in the Oriental Region, ranging from Sri Lanka and southern India, eastward through Assam, Thailand, Vietnam, Java, Sumba, Sulawesi, the Philippines, and Taiwan. Within Sri Lanka it occurs in all three ecological zones at localities with altitudes of 37–750 m and an average annual rainfall of 1000–4900 mm. We collected it in Sri Lanka at the following localities.

Vavuniya District: Paralanayankulam
Polonnaruwa District: Pimburettawa
Amparai Distict: Ekgal Aru Reservoir and Maha Oya Tank
Kandy District: Thawalamtenne and Kandy, Udawattakele Sanctuary
Ratnapura District: Weddagala and Uggalkaltota
Galle District: Kanneliya
Matara District: Enselwatte

NEST.—This species makes an aggregation of mud cells in a lump. The one nest that I found was a more or less conical mass (Figures 58, 59) built against a horizontal section of a small rootlet beneath an overhanging bank in the Sinharaja rain forest at Kanneliya on 12 January 1975. I kept the nest in a sealed plastic sack, and emergence was as follows: ♂ 13 Jan; 2♀, ♂ 18 Jan; and ♀ 20 Jan. These data suggest that nest construction and provisioning required about a week. The five wasps emerged from only three exit holes, 3.5–4 mm in diameter. The females were 8.5–10 mm long, and males 7–8 mm.

PREY CAPTURE.—T. Wijesinhe witnessed this at Thawalamtenne at 1455 on 21 March 1981. He saw a slender spider run onto a grassy area along the road, being pursued swiftly on foot by a wasp. The female caught the spider and stung it twice. She then turned the spider onto its back, got on top of it, and rapidly amputated five legs. The wasp then flew with the spider to a plant leaf about 0.6 m above the ground, and then stung the prey again. The observer then captured the wasp with her jumping spider prey. The latter was a subadult female of a species of *Thyene* Simon (Salticidae), 8.5 mm long.

Auplopus blandus (Guérin)

Auplopus blandus has a wide distribution in the Oriental Region, having been recorded from tropical parts of the Indian subcontinent eastward through Thailand, Vietnam, Malaysia,

Singapore, Sarawak, Sumatra, Java, and possibly Sulawesi. Within Sri Lanka it occurs in all three ecological zones at localities with an altitude from near sea level to 610 m and an average annual rainfall of 1000–5000 mm. We collected it in Sri Lanka as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Anuradhapura District: Hunuwilagama
Polonnaruwa District: Pimburettawa
Trincomalee District: Trincomalee, China Bay
Amparai District: Ekgal Aru Reservoir
Kandy District: Gannoruwa, Hasalaka, and Kandy, Udawattakele Sanctuary
Ratnapura District: Gilimale

PREY.—P.B. Karunaratne caught a female of *blandus*, 12.5 mm long, with her prey on a plant leaf along a trail through the Induruwa Jungle, Gilimale on 10 October 1980. She had amputated all legs from her spider prey, and was feeding on the blood exuding from the stumps. The prey, 12 mm long, was an immature giant crab spider, a species of Sparassidae.

ADULT BEHAVIOR.—P.B. Karunaratne noted an unusual behavioral characteristic on 13 September 1977. This occurred during the dark overcast preceding a mid-afternoon shower in Ekgal Aru Reservoir jungle. A number of both females and males had congregated in the deep crevices between the buttress roots of a large *Ficus* species.

Auplopus cyanellus Wahis

This uncommon species is endemic to Sri Lanka, where we collected the type series in the Wet Zone at altitudes of 90–610 m with an average annual rainfall of 2032–5000 mm. The Sri Lankan records are as follows.

Kandy District: Kandy, Udawattakele Sanctuary
Ratnapura District: Gilimale

PREY.—P.B. Karunaratne collected a female, 6.5 mm long, with prey at 1130 on 9 September 1977, in Udawattakele. The wasp was on the leaf of a plant a meter above the ground, with a paralyzed, green running or sac spider, a species of *Clubiona* Latreille (Clubionidae), 7.5 mm long. The wasp had amputated all of the spider's legs.

Auplopus funerator Wahis

This species is known only from the holotype from Kegalla District, Bandarakele Jungle, Kitulgala, in the Wet Zone at about 200 m with an average annual rainfall about 5000 mm.

PREY.—I captured this female, 7.0 mm long, on a leaf at 1240 on 15 April 1981. She held beneath her a thoroughly paralyzed spider, 7.5 mm long, from which she had amputated all legs beyond the coxae. The prey was an immature of a species of *Psechrus* Thorell (Psechridae), a cribellate spider.

Auplopus gnomus (Cameron)

This species is known from Sri Lanka, southern India, Assam, Singapore, and Penang. Within Sri Lanka it occurs in all three ecological zones in localities with altitudes from near sea level to 610 m and average annual rainfall of 1500–3900 mm. We collected it as follows.

Anuradhapura District: Padaviya
Amparai District: Ekgal Aru Reservoir and Lahugala Sanctuary
Matale District: Kibissa near Sigiriya
Kandy District: Gannoruwa, Thawalamtenne, Hasalaka, and Kandy, Udawattakele Sanctuary
Colombo District: Gampaha, Labugama Reservoir, and Handapangoda
Ratnapura District: Ratnapura and Rajawaka
Badulla District: Ulhitiya Oya 24 km NNE of Mahiyangana
Monaragala District: Angunakolapelessa

PREY CAPTURE AND TRANSPORT.—P.B. Karunaratne made two observations of this wasp with her wolf spider prey. The first was at Lahugala Reservoir on 15 June 1976. The wasp, 11 mm long, walked forward, carrying the paralyzed prey by its mouthparts, and raising the spider off the ground during transport. She paused briefly to feed on blood exuding from the severed stumps of the legs, all of which she had amputated at the coxae. The lycosid spider, 9.0 mm long, was a species of *Pardosa* Koch.

The second observation was made along a vehicular road outside of Hasalaka at noon on 17 February 1977. The wasp, 12 mm long, was dragging her prey, 10 mm long, up a roadside bank by a front leg. She walked forward with her head turned sideways. The spider got caught in a crevice, and she fed on blood exuding from the severed stumps of several legs. She had already amputated the two posterior legs on one side, and three posterior legs on the other. The spider moved a little, and the wasp stung it again, inserted her mandibles in the mouthparts of the prey, and then fed again on blood from the severed leg stumps. The lycosid spider, 10.0 mm long, was a species of *Trochosa* Koch.

Auplopus himalayensis (Cameron)

This common species has a wide distribution in the Oriental Region, ranging from the Indian subcontinent eastward to Thailand, North Borneo, Sarawak, Sumba, and the Philippines. Within Sri Lanka it occurs at localities in all three ecological zones in localities with altitudes from near sea level to 610 m and an average annual rainfall of 1200–5000 mm. We collected it as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Vavuniya District: Paralanalankyulam
Polonnaruwa District: Polonnaruwa
Trincomalee District: Trincomalee, China Bay
Amparai District: Ekgal Aru Reservoir
Matale District: Kibissa near Sigiriya
Kandy District: Hasalaka and Kandy, Udawattakele Sanctuary
Kalutara District: Agalawatte

Kegalla District: Kitulgala
Ratnapura District: Gilimale
Monaragala District: Angunakolapelessa
Galle District: Kanneliya
Matara District: Enselwatta

PREY TRANSPORT.—P.B. Karunaratne collected a female, 8.0 mm long, at Kanneliya in the Sinharaja rain forest about 1500 on 15 January 1975. She was transporting her huntsman spider prey, 9 mm long, walking forward or making short flights, and grasping the prey, venter to venter, by its mouthparts. The spider's legs had been amputated at the coxae. It was a juvenile female of *Heteropoda* Latreille (Sparassidae).

Auplopus laeviculus (Bingham)

This is another widely distributed species in the Oriental Region, ranging from Sri Lanka and southern India, eastward through Thailand, Vietnam, Sarawak, Java, Sulawesi, Sumba, the Philippines, and Taiwan. Within Sri Lanka it is common in all three ecological zones at localities from near sea level to 610 m and with an average annual rainfall of 1000–5000 mm. We collected it as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Anuradhapura District: Padaviya
Trincomalee District: Trincomalee, China Bay
Amparai District: Ekgal Aru Reservoir and Lahugala Sanctuary
Matale District: Kibissa near Sigiriya
Kandy District: Peradeniya, Hantana Hills, Hasalaka, and Kandy, Udawattakele Sanctuary
Kurunegala District: Kurunegala
Colombo District: Gampaha, Colombo, and Labugama Reservoir
Kegalla District: Kitulgala
Ratnapura District: Weddagala and Uggalkaltota
Monaragala District: Angunakolapelessa, Mau Aru, Wellawaya, Mahagama Tank, and Inginiyagala

PREY TRANSPORT.—We have two records for *laeviculus*. P.B. Karunaratne observed the first female, 5.5 mm long, carrying her wolf spider prey at noon on 23 May 1976 near Kokmotte Bungalow. The prey was an immature *Pardosa* Koch (Lycosidae), 5.0 mm long.

I noted a smaller female, 4.0 mm long, at 1620 on 18 June 1978, along the Mau Aru. She was walking rapidly on foot, carrying a small wolf spider beneath her on coarse sand near the stream. She paused several times beneath dry curled leaves for some minutes, presumably to feed on the blood exuding from the severed stumps of the spider's legs. The juvenile spider was a species of Lycosidae, 4.2 mm long, from which all legs had been removed at the coxae except for the right foreleg.

Auplopus nitidiventris (Smith)

This species is known from Sri Lanka, Java, Sulawesi, and Sumba. It occurs in Sri Lanka in all three ecological zones at localities from near sea level to 610 m with an average annual rainfall of 1200–2032 mm. We collected it as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Amparai District: Ekgal Aru Reservoir
Matale District: Sigiriya
Kandy District: Kandy, Udawattakele Sanctuary
Kegalla District: Kitulgala
Monaragala District: Angunakolapelessa, Mau Aru, Wellawaya, and Buttala

PREY.—I captured a female, 6.5 mm long, on the leaf of a shrub 0.3 m above ground, near Kokmotte Bungalow at 1025 on 7 October 1977 with her prey. She had probably just captured the small crab spider, and was amputating the legs. One foreleg was missing, and the next two on that side detached at once, as if they had already been mostly severed. The spider, 4.3 mm long, was a species of *Monaeses* Thorell (Thomisidae).

Auplopus tinctus (Smith)

This species is widely distributed in the Oriental Region where it is known from Sri Lanka, southern India, Malaysia, Penang, Java, and the Philippines. Within Sri Lanka it occurs in both the Dry Zone and the Wet Zone at localities from near sea level to 610 m with an average annual rainfall of 1000–5000 mm. We collected it as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Trincomalee District: Trincomalee, China Bay
Kandy District: Kandy, Udawattakele Sanctuary
Colombo District: Gampaha and Labugama Reservoir
Ratnapura District: Gilimale
Monaragala District: Angunakolapelessa

PREY TRANSPORT.—P.B. Karunaratne observed a female of *tinctus*, 6.5 mm long, on a leaf of a shrub in the jungle at 1000 on 7 October 1977 near Kokmotte Bungalow. She was transporting her paralyzed running or sac spider prey on the ground, venter to venter, holding it by the spinnerets. She jumped with the prey to the lower leaf of a shrub nearby, climbed up the stem to another leaf, and then jumped to the lower leaf of still a third shrub. The observer collected her when she had traveled a little less than a meter in this fashion. The spider was an immature *Clubiona* Latreille (Clubionidae), 6.5 mm long. All legs of the spider had been amputated.

I obtained a second prey record for *tinctus* in the jungle near the China Bay Ridge Bungalow at 0945 on 27 February 1979. The female, 8 mm long, was crawling upward on the baffle of a large Malaise trap. She was carrying her paralyzed running or sac spider, an immature of a species of Clubionidae, 6.5 mm long. The spider's legs had been amputated except for the third pair.

POMPILINAE

Agenioideus (Schizanoplius) smithii (Ritsema)

This species occurs in all three ecological areas from near sea

level to 610 m and with an average annual rainfall of 1000–2032 mm. We collected it as follows.

Mannar District: Ma Villu, Kondachchi, and 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Anuradhapura District: Padaviya
Trincomalee District: Trincomalee, China Bay
Kandy District: Kandy, Udawattakele Sanctuary
Puttalam District: Panikka Villu
Colombo District: Katunayaka
Kalutara District: Agalawatte

PREY CAPTURE AND TRANSPORT.—P.B. Karunaratne and I spent two hours watching a female of *smithii*, 14 mm long, capture and transport her prey at Panikka Villu. The wasp entered a burrow in sandy soil near the shore of the villu at 1545 on 1 November 1977. While the wasp was inside, a large wolf spider ran toward the villu from another burrow entrance. The wasp soon emerged, searched the sand on foot for five minutes, and then flew toward the spider which was now running about five meters from the burrow. She followed the spider for nearly two meters, landed on its body, and probably stung it, for the spider turned on its back and tried to bite the wasp. The latter preened herself for half a minute, during which time the spider righted itself and crawled slowly toward another burrow. Before it could enter, the wasp landed on its abdomen, and stung it three more times. Then she went to the front of the spider, and stung it again on the venter near the juncture of the cephalothorax and abdomen. She remained at the front, and appeared to be feeding at the spider's mouthparts for half a minute. Then she groomed herself for a minute, malaxated the prey near the base of the first two legs on the right side of the spider, and fed for another minute. Then, grasping one of the front legs, she dragged the spider into the hoofprint of a deer, and stayed there for an hour, alternately feeding on the spider's hemolymph, or grooming herself. She remained in the hoofprint with her prey until 1650, when she grasped the spider by the second leg on the right side, and, walking backward, dragged it about two meters toward the spider's burrow. She remained in that spot for 45 minutes, alternately feeding at the base of the spider's legs and grooming herself, moving the spider no more than two centimeters during this time. We captured the wasp at 1745. The spider was a species of *Lycosa* Latreille (Lycosidae), 15 mm long.

Pompilus mirandus (Saussure)

This species was recorded by Day (1981) from Pakistan to Sri Lanka, Burma, Malaya, and Java. He listed Sri Lankan localities as follows.

Jaffna District: Mandaitivu Island, Mankuppana on Leiden Island, and 16 km S of Pooneryn
Mannar District: 0.8 km NE of Kokmotte Bungalow in Wilpattu National Park, Olaittoduvai, Silavatturai, and Kondachchi, Mullikkulam across Moderagam Aru from Wilpattu National Park
Anuradhapura District: Padaviya and Hunuwilagama
Trincomalee District: Tennamaravadi and Trincomalee, China Bay
Amparai District: Panama, Radella Tank
Kandy District: Aruppola, Teldeniya, Hasalaka, and Kandy, Udawattakele Sanctuary
Puttalam District: Panikka Villu and Tala Wila
Colombo District: Katunayaka, Colombo Museum Garden, Kohuwala, Nugegoda, Papiliyana, and Ratmalana
Ratnapura District: Uggalkaltota
Monaragala District: Angunakolapelessa and Mau Aru
Hambantota District: Hambantota and Palutapana

The species occurs usually on rather sandy soil in all three ecological areas, although it is most abundant in the Dry Zone. It is found from sea level to 510 m in localities where the average annual rainfall is 920–2032 mm.

PREY.—P.B. Karunaratne caught a female, 7 mm long, with her prey at 1120 on 14 June 1976, on the bund of Radella Tank at Panama. The spider was an immature wolf spider, 4.5 mm long, a species of Lycosidae.

Aporinellus hecate (Cameron)

This widespread pompilid is found in all three ecological areas but, like the preceding species, it is most abundant in the Dry Zone, usually nesting in rather sandy soil. It occurs from sea level to 510 m in localities where the average annual rainfall is 920–4900 mm. We collected it as follows.

Jaffna District: Kilinochchi
Mannar District: Kondachchi, Ma Villu, Silavatturai, 16 and 21 km S of Pooneryn, and 0.8 km NE of Kokmotte Bungalow in Wilpattu National Park
Vavuniya District: Parayanalankulam
Anuradhapura District: Hunuwilagama, Medawachchiya, Padaviya, and Ritigala Natural Reserve
Trincomalee District: Trincomalee, Port Frederick, China Bay, Kanniyai, and Tennamaravadi
Amparai District: Ekgal Aru Reservoir, Inginiyagala, Lahugala Sanctuary, and Mannampitiya
Matale District: Kibissa 0.8 km W of Sigiriya
Kandy District: Hasalaka, Thawalamtenne, and Kandy, Udawattakele Sanctuary
Puttalam District: Panikka Villu
Kurunegala District: Kurunegala, Badegamuwa Jungle
Colombo District: Colombo Museum Garden, Gampaha Botanical Garden, Labugama, Ratmalana, and Handapangoda
Ratnapura District: Ratnapura, Rajawaka, Uggalkaltota, and Weddagala
Badulla District: Ella and Ulhitiya Oya 24 km NNE of Mahiyangana
Monaragala District: Mau Aru, Angunakolapelessa, and Wellawaya
Matara District: Deniyaya

Hambantota District: Bundala Sanctuary and Palatupana

PREY AND TRANSPORT.—I observed the first female at Handapangoda Timber Reserve at 1550 on 18 January 1975. She was walking backward over leaf litter in the jungle, dragging her paralyzed spider prey by the spinnerets. The prey was a female jumping spider, a species of *Piranthus* Thorell (Salticidae), 8 mm long.

P.B. Karunaratne observed a second female in Ekgal Aru Sanctuary jungle at 1315 on 22 February 1977. She was digging a burrow in sandy soil along a jeep trail. Her paralyzed spider prey was lying on a broad grass blade 15 cm from the burrow and 5–7 cm above the ground. The prey was another salticid, a species of *Hyllus* Koch, 8 mm long.

T. Wijesinhe saw the last female at 1140 on 21 March 1981, at Thawalamtenne. She was walking backward, dragging her paralyzed spider prey by a foreleg. She pulled it beneath a fallen leaf, emerged alone, went back under the leaf, came out a second time by herself, and returned under the leaf. She may have been malaxating the prey during this period. She emerged a third time, on this occasion dragging her prey as described above. The jumping spider, 7 mm long, was a species of Salticidae.

NEST AND CLEPTOPARASITE ACTIVITY.—A small female *Ceropales* with white markings on the abdomen came to the burrow while the female was digging her nest in Ekgal Aru. The *hecate* chased her away from the nest, and the *Ceropales* flew to the spider. The *hecate* female chased the *Ceropales* off her prey, and then continued to dig in the burrow. The *hecate* visited the spider twice during the next 10 minutes. This or another *Ceropales* then returned to the burrow, was chased off by the *hecate*, but settled again on the spider and appeared to oviposit. The host wasp went to her spider, and then left the nest site for five minutes. P.B. Karunaratne did not observe placement of the spider in the burrow, but at 1345 the *hecate* was filling the burrow, using her head, not to tamp the soil firmly, but to place grains of earth in the cavity. The observer collected the wasp when she had nearly completed filling the burrow. The latter went downward at a steep angle of about 60°, and terminated in a cell 6.4 cm below the surface. The spider did not bear an *Aporinellus* egg, but the latter might have been removed by small red ants that carried off one of the spider's legs.

The *Ceropales* was not captured. It was probably a female of *ligea* (Bingham), of which we collected a dozen or so specimens at Ekgal Aru. The only other ceropaline taken at this locality was *Irenangelus albovariegatus* (Cameron), which is larger than *ligea* and has an all red abdomen. I did not find an egg in the spider's lung sac, the site where other ceropalines are known to oviposit.

DISCUSSION.—Evans and Yoshimoto (1962) summarized the known prey preferences of several species of *Aporinellus* in North America and Europe. The prey were all running spiders, principally Salticidae, but specimens of Thomisidae and Oxyopidae were captured occasionally.

Dicyrtomellus Haupt

M.C. Day (personal communication) advised me that the "genera allied to *Pompilus* Fabricius are very difficult to define (Day, 1981). In particular, the species of *Dicyrtomellus* Haupt intergrade with those of *Aporinellus* Ashmead. *Dicyrtomellus* includes a number of Old World deserticolous species, many undescribed and often known from a single sex. *Aporinellus* species are found in all continents, and are differentiated from *Dicyrtomellus* by the development of pronounced postero-lateral teeth on the propodeum and invagination of the metapostnotum. The undescribed Sri Lankan species here treated is *Aporinellus*-like, but with yellowish wings and a clearly exposed metapostnotum."

Dicyrtomellus species 1

We collected this uncommon species at only the following three localities in the Dry Zone at elevations of 25–30 m and an average annual rainfall of 1000–1725 mm.

Mannar District: 0.8 km NE of Kokmotte Bungalow in Wilpattu National Park

Trincomalee District: Trincomalee, China Bay

Puttalam District: Panikka Villu

NEST AND PREY.—I observed a small female, 9 mm long, digging a shallow burrow in bare sandy loam at the edge of a jungle trail at Pannika Villu at 1522 on 1 November 1977. She walked off in three minutes, returned four minutes later, and excavated a little more soil. She had cached her very large prey, a wolf spider (Lycosidae), 15 mm long, on a leaf of a plant a centimeter above the ground. There were several red ants on the spider, so I captured the wasp at 1550, when she returned to the burrow to enlarge the nest to accomodate her relatively gigantic prey. The latter was a species of *Tarentula* Sundevall.

Anoplius (Orientanoplius) canifrons (Smith)

This large (♀, 13–17 mm long) black wasp with black wings has an extensive distribution in the Oriental Region, ranging from southern India and Sri Lanka eastward to Assam, widely throughout southeast Asia and Indonesia, and enters the Australian Region in northern Queensland. It occurs in all three ecological areas in Sri Lanka, but it is most abundant in localities in the Wet Zone, particularly in Udawattakele Sanctuary, Kandy. It is found at localities from near sea level to 610 m and with an average annual rainfall of 1650–4900 mm. The Sri Lankan records are as follows.

Anuradhapura District: 40 km NW of Polonnaruwa

Trincomalee District: Trincomalee

Amparai District: Ekgal Aru Reservoir

Kandy District: Hasalaka, Thawalamtenne, and Kandy, Udawattakele Sanctuary

Kurunegala District: Kurunegala, Badegamuwa Jungle

Kegalla District: Kitulgala, Makanda Mukalana

Ratnapura District: Rajawaka and Weddagala, Sinharaja Jungle

Galle District: Udugama and Kanneliya section of Sinharaja Jungle

NEST.—The nesting sites of *canifrons* in Udawattakele were along embankments margining a carriage road through the jungle. The nests were in almost vertical or more gently sloping banks of rather soft, disintegrating sandstone known locally as kudu gala. The nesting burrows were frequently begun against the sloping bank from a small level spot or downwards into the soil from a larger, almost horizontal area. The nest was prepared and no temporary closure was made, before the wasp departed to hunt for spider prey. The nest is unicellular and contains only a single prey.

We did not observe nest excavation from its inception, nor were we able to ascertain the time required to complete a nest prior to the wasp's departure to hunt prey. I disturbed one wasp at 1556 as she was digging a horizontal burrow in a nearly vertical slope. The burrow was about 10 mm in diameter, and as long as her body. She returned to the burrow in a few minutes to resume excavating. Periodically she backed to the entrance, pushing out loose dirt with her posterior legs. Occasionally she crawled out onto the short level surface adjacent to the burrow, and scattered the spoil heap down the steep slope. A fallen leaf was lodged on the bank a short distance from the burrow, and it prevented the loose soil from rolling down the bank except when the wasp emerged at 1630 to kick all of the accumulated soil further down the bank. Five minutes later she reentered the burrow for a few seconds, and then emerged to spread more loose soil. She spent the next half hour crawling over the bank in the nest vicinity, antennating the surface, cleaning her hind legs thoroughly, and fussing with the excavated soil, kicking it further down the bank. She also made several short flights away from the nest during this period. She left the site at 1705, when the nest was apparently ready to receive prey. Probing with a grass stem showed that the burrow and cell were 3.2 cm long. Five minutes later it became quite dark, began to rain, and I discontinued observation. This, or another specimen of *canifrons*, revisited the nest on the following day, but apparently abandoned it, for it was never completed.

P.B. Karunaratne found the first nest at Hasalaka in a steep, sloping bank on 17 February 1977. The wasp was backing out of the burrow, as it turned out later, prior to oviposition. There was a cell at the end of the horizontal burrow, 5 cm from the surface, that was 2 cm deep and 1.5 cm in diameter. It contained a paralyzed spider but no wasp egg. About 2.5 cm from the entrance he found a perpendicular burrow that was firmly packed with soil. It terminated in a cell of the same dimensions, and contained a paralyzed spider bearing a wasp egg.

I found the next nest in Udawattakele on a sloping bank of 45° on 7 June 1978. The burrow was 8 mm in diameter, and penetrated almost horizontally for 5.5 cm, ending in a spherical cell about 15 mm in diameter. The nest did not contain a second cell.

The burrows of other nests in Udawattakele were 8–12 mm in diameter, and 1.0–5.1 cm long. Most of them penetrated the bank horizontally, although two exceptions went downward in a nearly vertical bank at angles of 35° and 45°. The single cells at the ends of the burrows were spherical to spheroidal in shape, sometimes no wider than the burrow diameter. One cell was round and 20 mm in diameter, another was 13 mm long and 10 mm high.

The site of a completed nest was marked by a small dimpled depression about as wide as the burrow diameter and 2 mm deep in the center. Occasionally, there were three or four such depressions in close proximity on a small, more level area of a bank. I dug three nests in such a small group, and recovered one spider with an egg, and another with a very small larva. The third spider did not bear an egg, which may have become detached during my excavation. It is possible that this group of nests might have been made by a single individual.

PREY HUNTING, TRANSPORT, AND NEST CLOSURE.—I watched one female searching for prey for 11 minutes on a sloping forest floor with moderately dense cover of fallen leaves. She spent most of her time hunting beneath the leaves, but found no prey during this period.

I observed another female complete her nest excavation during a quarter of an hour. She made a brief orientation tour of the nest area for a short time, flew off to some ferns several meters away, and then disappeared. She reappeared on the bank four minutes later, dragging her paralyzed spider, and leaving it on the bank 1.5 m from the nest. She had difficulty finding her nest, twice entering other short, apparently aborted burrows. During this period she visited her prey twice, antennating it briefly each time, and then crawled haphazardly over the bank, still searching unsuccessfully for the nest. Finally, I captured her and the spider.

A third female was running excitedly along the edge of the road at 1407. I noticed a large wandering spider slowly crossing the road, probably having just been stung by the wasp. The wasp spotted the spider half a minute later, grappled with it, and stung it several times until it was completely paralyzed. The wasp walked around the area for eight minutes, occasionally preening herself, returned to the spider, and dragged it backward by the right hind leg about 2.5 cm. Then she visited her nest in the bank nearby, returned to the spider, grasped it by the base of the right hind leg, and dragged it backwards 6 m along the road. She left it lying on the road, returned to her nest for a few minutes, and came back to the prey at 1424. She then dragged the spider as before, into the ditch, and laboriously up the almost vertical bank, slipping down several times with the prey. At 1427 she stopped, cleaned herself for a couple of minutes, had some difficulty locating her nest which was only 0.6 m distant, and returned to the spider at 1431. During the next 47 minutes the wasp alternated short periods of digging in the nest, presumably enlarging the cell to accomodate the spider, dragging the spider a few centimeters closer to the burrow entrance, and occasionally preening herself for short periods. Several times she had to chase off small ants, lunging

at them with the tip of her abdomen curled beneath her. Twice the spider tumbled a few centimeters down the slope, and had to be hauled back upward. At 1514 she got the spider just 10 cm from the burrow entrance. She entered the nest alone head forward, came out headfirst in a few seconds, went back to the prey, then into the burrow alone, back to the spider, and finally backed into the burrow, pulling the spider slowly behind her by the spinnerets. She emerged from the nest two minutes later, cleaned her antennae for some seconds, and then reentered the burrow headfirst.

The wasp went in and out of the nest twice during the next three minutes, then came to the entrance at 1520, cleaned her antennae for some seconds, and then emerged a little more. She hauled in some loose dirt, scraping it behind her with her forelegs, and occasionally biting additional particles of earth from around the entrance. Six minutes later she came to the entrance again, biting off soil from the edge of the burrow, and compacting it with the tip of her abdomen which was turned beneath her. She lost her footing twice while compacting the soil, and fell down the steep slope, only to return and continue compacting the plug. At 1625 she finished the plug, leaving the burrow entrance visible as a shallow, dimpled depression about 2 mm deep in the center. The closing plug was 30 mm thick, well compacted at the surface, but of relatively loose soil particles at the inner end. Next was an empty section of burrow 10 mm long, and finally a very thin earthen partition closing the spherical cell that had a diameter of 20 mm.

PREY.—The two specimens of prey at Hasalaka were both wolf spiders, a species of *Trochosa* Koch (Lycosidae), respectively 10 and 14 mm long. At Udawattakele *canifrons* preyed upon wandering rather than wolf spiders. Eight prey belonged to *Ctenus* Walckenaer (Ctenidae). There were two males of *C. thorelli* Cambridge, 9.5 and 13.7 mm long. Six were mostly immatures, each identified only as a species of *Ctenus*, ranging from 11 to 14 mm long.

Day (1974) examined a female *canifrons* from Nilgiri Hills, southern India, 3500 ft (= 1067 m), that was pinned with its prey, an adult female of a species of *Ctenus*.

IMMATURE STAGES AND LIFE CYCLE.—The egg is attached very loosely, anteriorly on either side of the abdomen. It is slightly curved, 2.6–2.9 mm long, and 0.7–0.9 mm in diameter (n = 3).

I dug up one nest at 1115 on 3 September 1980. The cell contained a small wasp larva, probably not more than a day old, feeding at a small puncture on the right side of the anterior abdomen of the *Ctenus*. I held it for rearing, and by 0730 on the 6th it had consumed all but a small portion of the spider which was lying within the curled body of the larva. The latter had just begun to spin a cocoon by 1730, and I preserved it for subsequent taxonomic study.

Anoplius (Arachnophroctonus) alteratus Priesner

This rather uncommon species was described from Egypt. We collected it only in the Dry Zone at localities from near sea level to 30 m and an average annual rainfall of 1000–1725 mm. Our records from Sri Lanka are as follows.

Vavuniya District: Parayanalankulam
Anuradhapura District: Hunuwilagama
Amparai District: Lahugala Sanctuary and Panama
Hambantota District: Palatupana

These localities are all in the Dry Zone at altitudes from near sea level to 100 m and have an average annual rainfall of 920–1750 mm.

PREY TRANSPORT.—I collected a female, 9 mm long, at 1425 on 15 June 1976. She was walking backward over dry grass in a damana, dragging her spider prey, 6.3 mm long. The wolf spider was a species of *Pardosa* Koch (Lycosidae).

Episyron Schiødte

Members of this genus are common pompiline wasps, occur in every zoogeographic region except Australia, and many individual species occupy rather wide ranges. Evans and Yoshimoto (1962) summarized the known ethological observations. Most species dig their nests in rather friable soil after capturing a prey, and close the completed nests rapidly by compacting loose soil from around the entrance with the tip of the abdomen. The preferred prey are orb weaver spiders belonging to the Araneidae that the wasps paralyze thoroughly but do not amputate the legs. There are two records of the European *rufipes* (Linnaeus) using lycosid spiders, but all other records for the species are of araneids. The egg is attached very loosely on the abdominal venter of the spider.

However, my limited observations on the Ceylonese *praestigiosum* Wahis and *tenebricum* Wahis convince me that they differ from other observed species of *Episyron* in an important detail of the nesting cycle. Based on one observation of each species, it appears that nest construction with temporary closure is followed by a brief orientation flight around the nesting area, and then departure to hunt a prey. This is in contrast to the usual habit, as exemplified by the Ceylonese *novarae*, of hunting a prey, bringing it near the nesting area, and then preparing the nest.

Wahis (1978) published a key, descriptions, and detailed locality records for the three Ceylonese species based primarily on specimens collected by the Smithsonian Ceylon Insect Project.

Episyron novarae (Kohl)

This is the most common member of the genus in Sri Lanka, and has a wider distribution in the Oriental Region than its two Ceylonese congeners. It has been recorded also from India, Burma, Laos, Malaysia, Singapore, the Indonesian islands as far east as Timor, the Philippines, Taiwan, and China. Within Sri Lanka it occurs in all three ecological areas from near sea level to 610 m in areas with an average annual rainfall ranging from 920 to 5000 mm. The Ceylonese records are as follows.

Vavuniya District: Vavuniya

Mannar District: Olaithoduvai, Kondachchi, Ma Villu, Silavatturai, and 0.8 km NE of Kokmotte Bungalow in Wilpattu National Park
Anuradhapura District: Padaviya
Polonnaruwa District: Pimburettawa
Trincomalee District: Kanniyai about 11 km W of Trincomalee, Tennamaravadi, and Trincomalee, China Bay
Amparai District: Ekgal Aru Reservoir and Lahugala Sanctuary
Matale District: Kibissa near Sigiriya
Kandy District: Kandy Reservoir jungle, Peradeniya, Gannoruwa, Thawalamtenne, Hasalaka, and Kandy, Udawattakele Sanctuary
Colombo District: Labugama Reservoir, Colombo Museum Garden, Yongamulla, and Ratmalana
Kalutara District: Morapitiya and Agalawatta
Kegalla District: Kitulgala
Ratnapura District: Gilimale, Weddagala, and Rajawaka
Monaragala District: Wellawaya and Angunakolapelessa
Galle District: Kanneliya
Hambantota District: Palatupana Tank and Wildlife and Nature Protection Society Bungalow

This very abundant species is a wasp of medium size, females ranging from 5.5 to 10.0 mm in length.

PREY CAPTURE AND TRANSPORT.—These behavioral elements precede preparation of the nest. T. Wijesinhe witnessed the only prey capture at Angunakolapelessa at 1520 on 27 March 1981. He saw the wasp crawling on leaf litter, and going beneath one of the leaves. Two to three seconds later a spider ran out from beneath the leaf. The wasp emerged, and the spider ran back under the leaves. Five minutes later the wasp chased the spider into the open again, grappled with it, and stung it. The spider crept back under a leaf, followed in a few seconds by the wasp. The spider then crawled feebly into the open, followed by the wasp which stung it again. The wasp ran around excitedly, returned in 2–3 minutes, and put her head against the spider's side, presumably to check the degree of paralysis. The wasp left for a few seconds, returned, turned the spider on its venter, grasped it by the head end, and dragged it backwards. The observer then captured the wasp with her prey.

Twenty minutes later T. Wijesinhe saw another *novarae* straddling her prey with its venter up, walking forward, apparently attempting to fly with it. The wasp flew off alone for a few seconds, returned and again tried to fly with the spider, at which time the observer captured them.

I watched a female at Ekgal Aru digging her nest in flat sandy loam at 1155 on 20 February 1977. She completed the nest three minutes later, flew half a meter away to a fallen leaf and cleaned her legs. Then she went to her prey, lying on the ground less than a meter away. She walked backward with the spider, dragging it by a hind leg. She left the spider on the ground twice en route to the nest, and went to inspect the burrow. She returned to the prey, dragged it backwards by a hind leg, and backed into the burrow with it.

P.B. Karunaratne saw a female with prey on a leaf of a small plant in the Colombo Museum Garden on 6 April 1977. The wasp was antennating the spider, and appeared to be licking it with her mouthparts. She then cleaned herself for several minutes, left the spider on the leaf, and began to search the ground nearby for a suitable nest site. She selected an area, and was digging her burrow for the next 12 minutes. The observer then left to observe the nesting of specimens of *Encopognathus*, and did not witness nest completion and prey transport.

In 1979 I watched a female digging her burrow on a slight slope of damp sand near Kokmotte on 16 February. The excavated soil lay in a low semicircular pile 5 mm below the entrance. When the nest was complete, she perched on the spoil heap for a few seconds, made a brief orientation flight around the area, and then flew past me up a nearby bank. She returned four minutes later walking backward, dragging her prey behind her. Sometimes she carried it beneath her while she made short flights of several centimeters toward the nest. She dragged the spider backwards on the ground for the last meter, and backed into the burrow, pulling the prey in behind her.

Other species also have been reported to transport prey on the ground only, or by a combination of short flights and dragging it on the ground. The method of prey transport probably depends on the comparative sizes of wasp and prey. Both of the *novarae* that flew with prey and dragged it on the ground were larger than the prey. But the two females that dragged the prey only, were of the same size or smaller than the prey.

NEST CLOSURE AND ARCHITECTURE.—The two wasps that we observed closing the burrow after oviposition tamped the loose soil firmly into the burrow with the tip of the abdomen. Both specimens were collected before closure was complete, so we have no record of the time required for closure. It is surely done very rapidly.

The architecture of four nests showed some variation. Three of them were in ground with a level or slightly sloping grade; the burrows penetrated the soil at angles of 30° to 75°. The last nest was in a slope of 45°, and the burrow went into the soil at an angle of 80°. The burrow diameter varied from 4 to 7 mm. The cells were spherical, 8–10 mm in diameter, and 20–40 mm below the surface depending on the degree of soil moisture. The cells were at greater depth in drier areas.

PREY.—All seven prey specimens were orb weaver spiders (Araneidae), 3.7–10.0 mm long. One was a specimen of *Araneus rumpfi* (Thorell), five belonged to one or more species of *Araneus* Linnaeus, and one was identified only as an immature of a species of Araneidae.

EGG.—One egg was attached loosely, anteriorly on the side of the spider's abdomen. One was found in the bottom of the cell, apparently having been dislodged when the spider was pulled out of the cell. The egg is sausage-shaped, slightly curved, 1.3–1.7 mm long and 0.4–0.5 mm wide.

Episyron praestigiosum Wahis

This species has almost as wide a distribution in the Oriental Region as *novarae* (Kohl), having been recorded (Wahis,

1978) from Sri Lanka (type locality), southern India, Burma, Borneo, Sumatra, Java, Bali, and Taiwan. It occurs in all three ecological zones in Sri Lanka in areas ranging from near sea level to 610 m with an average annual rainfall of 1500–5000 mm. It was collected in Sri Lanka in the following localities.

Amparai District: Lahugala Tank
Kandy District: Peradeniya, Roseneath, Gannoruwa, Hindagala, Thawalamtenne, and Kandy, Udawattakele Sanctuary
Kurunegala District: Kurunegala, Badegamuwa Jungle
Ratnapura District: Gilimale, Weddagala, Uggalkaltota, and Belihul Oya
Badulla District: Bibile and Ettampitiya
Monaragala District: Angunakolapelessa
Galle District: Kanneliya

Females range in length from 6.5 to 7.5 mm.

NEST EXCAVATION AND ARCHITECTURE.—I watched a female excavating her nest at the edge of a low bank in Udawattakele at 1603 on 9 September 1977. At this time she had penetrated the soil for about 10 mm. Usually she just brought grains of the heavy, damp soil to the surface, pushing them out with her fore- and hind legs. Occasionally, she backed fully out of the burrow, and scattered the grains broadly into a semicircular spoil heap with a radius of about 2.5 cm. At 1632 she came to the surface, backed into the burrow, and made a loose closure of grains of soil level with the surface. Then she made a brief orientation flight low over the nesting area, flying in three increasingly wider spirals to about a meter above the ground, and then flew off. She had not returned by 1645, so I left after marking the nest location.

The next morning at 0830 the entrance was still closed, so I excavated the nest, presuming that she might have interred a prey earlier that morning or late on the previous afternoon. The burrow entered the soil at an angle of 45°, was 2.5 cm long and 4 mm in diameter. It ended in a small, empty, spherical cell about 6 mm in diameter. The wasp had filled only the top centimeter of the burrow with loose pellets of soil.

At 1006 the wasp returned, tried unsuccessfully to find her nest, and finally began a new burrow close to the site of the old. After penetrating about 0.5 cm, she stopped digging, and began to fill in the burrow, tamping the soil pellets firmly with the tip of her abdomen. I captured her at this time, and searched the area unsuccessfully for the spider that she might have cached nearby. She aborted the second burrow because it ran into a stone.

PREY.—P.B. Karunaratne observed another female at Kanneliya at noon on 15 July 1978. She left her paralyzed orb weaver prey on a plant leaf about 5 cm above the ground, and flew off. The observer collected the wasp when she returned 5 minutes later. The spider was a juvenile, 3.9 mm long, of a species of Araneidae.

Episyron tenebricum Wahis

This species has a more restricted range, having been collected only in Sri Lanka (type locality) and southern India. It occurs in all three ecological zones in the former country though most commonly in the Wet Zone. The localities are from near sea level to 610 m with an average annual rainfall of 1500–5000 mm. The Ceylonese records are as follows.

Kandy District: Thawalamtenne and Kandy, Udawattakele Sanctuary
Kalutara District: Morapitiya
Kegalla District: Kitulgala
Ratnapura District: Gilimale
Monaragala District: Angunakolapelessa
Galle District: Kanneliya

TEMPORARY NEST CLOSURE.—I noted a female, 10 mm long, excavating some moist sand in a level roadside ditch in Udawattakele on 10 February 1975. She stopped digging, and began to rake sand into the burrow entrance to make a temporary closure. I captured her, and excavated the nest.

NEST ARCHITECTURE.—The burrow penetrated the soil at an angle of 45° for 2.5 cm, was 4 mm in diameter, and ended in a cell of the same diameter.

PREY.—P.B. Karunaratne captured a female, 11 mm long, in Udawattakele on 19 April 1975. She had alighted with her paralyzed orb weaver prey on foliage overhanging a vertical bank. The spider was a juvenile female *Araneus* Linnaeus (Araneidae), 7 mm long.

Batazonellus annulatus (Fabricius)

We collected this rather uncommon species only in the Dry Zone at localities with an elevation from near sea level to 30 m and an average annual rainfall of 1000–1725 mm. The localities are as follows.

Mannar District: Silavatturai, Kondachchi, Ma Villu, and 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park
Anuradhapura District: Padaviya
Trincomalee District: Trincomalee, China Bay
Puttalam District: Panikka Villu

NEST EXCAVATION.—I disturbed a large female, 21 mm long, on a path opening into a damana near Kokmotte Bungalow at 1040 on 22 January 1977. She flew around the area for 10 seconds before settling on the flat sandy path, and continuing to excavate her nest. She dug in the dampened sand quite rapidly with her wings folded over her back. She came to the surface occasionally to push the excavated soil backward with her hind legs onto the spoil heap. After about a minute and a half, she flew about 6 meters away, then returned to the nest site in a few seconds, and reentered the burrow.

PREY TRANSPORT.—At 1049 she emerged from the burrow, walked and then flew 2.4 meters to where she had cached her paralyzed spider on a wood chip on the ground. She grasped the prey near the base of the right hind leg, flew for a few centimeters with it until the weight of the prey caused her to alight on the ground. She then walked backward toward the burrow entrance, grasping the spider near the base of the hind leg, and dragging it behind her. She stopped twice enroute to the burrow to set the spider on the ground momentarily, but did

not visit the nest. Each time she resumed transport, she grasped the spider's hind leg at the same position. The third time she dropped the prey at the nest entrance, entered the burrow head first, and came out immediately head first. She grasped the spider by the base of the same hind leg, and backed into the burrow, dragging it behind her at 1051. The wasp kept her wings folded over her back during prey transport on the ground.

BURROW CLOSURE.—She came to the entrance head first in half a minute, and began to pull in sand with her forelegs, tamping it down firmly and rapidly with the tip of her abdomen. At 1058 she emerged on the surface, leaving the top 1.3 cm of the burrow empty. She then smoothed the sand over an area of several square centimeters, occasionally biting sand from around the burrow entrance. At 1102 she began to dig a hole at right angles to the burrow axis to obtain more loose sand which she kicked into the burrow and over the surface with her hind legs.

NEST STRUCTURE.—The burrow penetrated the sand at an angle of 45°, and ended in a spherical cell 9 cm below the surface.

EGG.—The egg was attached to the venter of the spider on the right side behind the hind leg.

PREY.—The spider was a bulky orb weaver, 13 mm long, a species of *Argiope* Audouin (Araneidae).

DISCUSSION.—Iwata (1964) said that *annulatus* preyed upon spiders belonging to *Argiope* and *Araneus* in Japan, and that the one-celled nest was usually prepared at dusk. The spider was hunted in the late afternoon, and was taken to the nest site on foot.

Williams (1919) published an account of the closely related Philippine congener, *bioculatus* (Bingham). It preyed upon spiders belonging to *Poltys* Koch (Araneidae). He noted that the wasp apparently fed on salivary secretions of the spider after paralyzing it. The prey was cached on a plant while the wasp prepared the nest. While excavating the nest, the wasp bit out soil with her mouthparts, and also dug with her forelegs. The wasp walked backward while transporting the prey to the nest, dragging the spider by one of the hind legs. The burrow was almost vertical, and about 3 cm deep. Placement of the spider in the cell and burrow closure were as in *annulatus*.

Tachypompilus analis (Fabricius)

This distinctive wasp with red terminal abdominal segments, is quite variable in size, females being 11–19 mm in length. The species has been recorded from the Indian subcontinent, eastward through Burma, southeast Asia and China to Sulawesi, the Philippines, Taiwan, and Japan; it has also been introduced into Hawaii. We collected this wasp in both the Dry Zone and the Wet Zone at localities with elevations from sea level to 610 m and an average annual rainfall of 920–2400 mm as follows.

Jaffna District: Mandaitivu Island

Mannar District: 0.8 km NE of Kokmotte Bungalow, Wilpattu National Park

Amparai District: Ekgal Aru Reservoir

Kandy District: Peradeniya and Kandy, Udawattakele Sanctuary

Colombo District: Gampaha Botanical Garden, Kurana, Ratmalana, and Nugegoda, Papiliyana

Hambantota District: Bundala Sanctuary and Palatupana

PREY TRANSPORT.—P.B. Karunaratne captured the first wasp, 11 mm long, with prey in a damana near Kokmotte Bungalow at 1006 on 25 May 1976. She was walking backward over the level sand, dragging the paralyzed prey by the spinnerets. The huntsman spider, 10 mm long, was an immature *Heteropoda* Latreille (Sparassidae).

D.W. Balasooriya captured another wasp, 17 mm long, with prey on the sandy soil of a coconut plantation at Kurana on 16 January 1977 at 1250. She was trying to subdue a large, bulky huntsman spider, 20 mm long, and the spider was trying to fight off the wasp. The intended prey was a specimen of *Heteropoda venatoria* (Linnaeus).

DISCUSSION.—Williams (1919) found two nesting sites of *analis* in the Philippines in loose, dry soil at the base of two large trees. The species is unusual in that it places the paralyzed spider in a shallow, funnel-shaped depression, rather than digging the normal burrow, terminating in a spherical or ovoid cell. A single female probably interred eleven spiders in individual nests during a period of two weeks in an area of about a third of a square meter. The wasp dragged her prey backward to the nest site by one of its anterior appendages. She deposited the egg on the venter of the spider's abdomen near the base. After oviposition the wasp brushed loose soil over the prey, tamping it down with the downcurved abdomen. Finally, the wasp concealed the nest by dragging rather large pieces of wood, leaves, or soil over it. He noted that the newly hatched larva of the cleptoparasitic wasp, *Ceropales luzonensis* (Rohwer), fed on the egg of *analis*, and then on the prey. Williams also said that larvae of a small tachinid fly attacked the egg of *analis*, and developed on the prey; probably these were miltogrammine maggots (Sarcophagidae), rather than tachinids.

Iwata (1964) reported observations of *analis* in Japan and Thailand similar to those made by Williams. Iwata's wasps also dug funnel-shaped pits in dry sand or dust, frequently adjacent to human habitations. In the Ryukyu Islands, *analis* preyed upon several species of *Heteropoda*, paralyzing them permanently, and placing the egg on the venter of the abdomen near the base. One female in Thailand was dissected, and found to have two mature eggs and two nearly mature eggs in the ovarioles, indicating that she could have stored several nests over a short period of time.

Microcurgus Haupt

M.C. Day (personal communication) wrote that "this generic name was applied by Haupt to the single central African species, *M. pallidivenosus* Haupt, described from a unique female. It represents a group of aberrant and very rare

Pompilini, related to or possibly conspecific with *Aetheopompilus* Arnold. Both genera are characterized by the possession in the female of a distinct psammophore of bristles on the mandible; in addition, *Microcurgus* species exhibit a markedly elongate second submarginal cell. Several undescribed species are known from humid forest, savannah, and semidesert in Africa, in addition to the undescribed Sri Lankan species here treated. Other species are known from Thailand, Timor, and Cairns, Queensland. The type species of *Aetheopompilus* is widespread but uncommon in Africa; other described African species are closer to *Microcurgus*. Undescribed species are known from Africa, Madagascar, and Sabah."

Microcurgus species 1

This rare species is known so far from two females and a male from the Dry Zone in Sri Lanka as follows.

Matale District: Kibissa, 0.8 km W of Sigiriya
Puttalam District: Panikka Villu
Hambantota District: Palatupana, Wildlife and Nature Protection Society bungalow, in Malaise trap

These localities are in the Dry Zone at altitudes from near sea level to 30 m, and have an average annual rainfall of 920–1687 mm. A single behavioral observation was made at Panikka Villu on 1 November 1977.

PREY TRANSPORT.—I saw this small wasp, 4 mm long, at Panikka Villu on 1 November 1977 at 1510. She was at the edge of a jeep trail through the jungle where the sandy loam soil was covered with leaf litter. She was walking backward, struggling to drag her paralyzed, comparatively bulky jumping spider, 5.5 mm long. The spider was identified as a species of *Carrhotus* Thorell (Salticidae).

CRABRONIDAE

Encopognathus (Encopognathus) districtus Leclercq

This species was described from Sri Lanka and southern India. Our collections in Sri Lanka are as follows.

Anuradhapura District: Hunuwilagama
Kandy District: Peradeniya and Kandy, Udawattakele Sanctuary
Colombo District: Colombo Museum Garden
Ratnapura District: Gilimale, Weddagala, and Rajawaka
Monaragala District: Angunakolapelessa

These localities are in all three ecological zones where the altitude ranges from 15 to 200 m, and the average annual rainfall is 1200–5000 mm.

I first observed this slightly larger (♀ 5.2–6.2 mm) congener of *lankanus* in the Sinharaja Jungle near Weddagala, in June 1976. I also observed some nesting activities and male behavior near a stream bank at Gilimale, and nesting at Angunakolapelessa. Other behavioral observations were made by P.B. Karunaratne on hard packed sand paths in the Museum Garden, Colombo, during March and April 1977.

NEST CONSTRUCTION.—Nests at Weddagala, Gilimale, and Angunakolapelessa were begun in gently sloping sandy areas or in low banks of sandy loam, initially penetrated the substrate at a shallow angle of 20°–30°, and then turned downward at a steeper angle of 45°–75°. Nests at Colombo were on flat paths of hard packed sandy loam, and penetrated the ground usually at an angle of 60°–80° (range 50° to almost vertical). Most of the nests in Colombo had burrows that were straight, angled only when the burrow intersected some obstruction beneath the surface. The burrow diameter was about 2 mm.

One wasp at Gilimale began a nest by hovering close to the ground, picking up grains of sand, then flying backward 3–5 cm to drop the sand 4 cm above the surface. Another flew backward 9–12 cm before dropping her loads. As the burrows deepened, the wasps backed out of the burrows, flew backward low over the ground for a few centimeters, and released the load of soil. They then flew back and entered the burrow without alighting unless the burrow was nearly vertical when they first alighted on the ground at the entrance. Later on during excavation, perhaps when the wasp reached the level for constructing a cell, she would push up several loads of soil with her abdomen to form a low tumulus around the entrance. Then she emerged and proceeded to scatter this excavated soil in increments as described above.

A wasp at Gilimale excavated a burrow 2 mm long in five minutes, while one in Colombo spent 10 minutes making a burrow 4–5 mm long. The excavation rate was variable in an individual wasp at Gilimale, and tended to decrease the longer she worked. One wasp removed 11 loads during one minute at midday, and four hours later removed only two loads in 52 seconds. A second wasp removed four loads in a minute at 1315 hrs, four loads in 74 seconds at 1500, and two loads in 53 seconds at 1600. This decreasing rate probably is related to the increasing depth of the burrow. Comparable data were not obtained on nests in Colombo.

Data are not available for the length of time required to excavate the burrow and first cell. A wasp was digging in a nest at Gilimale at noon on one day, and was bringing in prey at least as early as 1100 on the following day.

NEST ARCHITECTURE.—The burrow of the one stored nest at Gilimale went downward at an angle of 75° to a depth of 75 mm. The first completely stored cell was at a depth of 90 mm. A second incompletely stored cell was at the same depth, 6 mm from the first.

The cells in Colombo nests were at depths ranging from 30 to 155 mm, although most cells were at depths of 80–100 mm. One cell was round, 5 mm in diameter, and another was ovoid, 8 mm long and 5 mm across. The Colombo nests contained from one to six cells. None of these nests was completely provisioned, so the total number of cells in a completed and sealed nest may be greater than six.

PREY.—Both nymphs and adults of Miridae were used as prey at all localities. We did not witness prey capture, but the population at Colombo was presumed to prey on mirids on the grassy lawns bordering the paths. One wasp at Gilimale must

have been hunting mirids on vegetation near her nest; she always flew from the nest toward a river 15 m distant. Many prey at both sites were so small that we could not tell whether a wasp was carrying anything when she entered the nest. The abdomen of larger prey specimens protruded beyond the wasp, and was visible when the wasp reached the nest.

I collected at Weddagala a female wasp that was subsequently designated the holotype of *districtus*. She was flying low over a sandy slope with her prey, an adult mirid, a species of *Hyalopeplus*, possibly *malayensis* Carvalho.

We timed the provisioning flights of two females. The prey-bearing female returned, flying low over the ground, and entered the nest without alighting on the surface nearby. When leaving the nest for a provisioning flight, the wasp came to the burrow entrance head first, peered around for a few seconds, then flew off leaving the entrance open. Two provisioning flights at Gilimale were 4 3/4 and 8 minutes between exiting the burrow and returning with prey. The same wasp remained in the nest 35 to 70 seconds before resuming the hunt. No soil was excavated during the observed provisioning periods. A wasp at Colombo made seven provisioning flights of 1–5 minutes, and remained in the burrow 1–3 minutes after flying in with prey. As at Gilimale, the Colombo wasps did not plug the burrow entrance when departing to hunt prey.

The only completely stored cell at Gilimale contained 22 adult mirids, 3.8–4.0 mm long, of a species described later as *Guisardinus srilankensis* Carvalho; one mirid bore the wasp egg. A second incompletely stored cell in this nest held 11 adult mirids of the same species, but no wasp egg.

Seventeen of 53 cells at Colombo contained only a single species of prey, but 36 other cells each contained two to four species. However, some cells holding only a single prey species were not completely stored. The following species were identified from nests in Colombo: *Hyalopeplus vitripennis* (Stål) and *H. rama* (Kirby); *Creontiades pallidifer* (Walker); *Eurystylus bakeri* Poppius and *E. minutus* Distant; *Deraeocoris orientalis* (Distant); *Diognetus intonsus* Distant; *Campylomma livida* Reuter; *Argenis incisuratus* (Walker); *Lygus immitis* Distant and *L. pubens* Distant; and *Megacoelum relatum* Distant.

Eleven completely stored cells with prey and wasp egg or newly hatched larva were recovered in Colombo. The cells contained 7–16 prey. Seven cells contained only nymphs of a species of *Hyalopeplus* Stål, 3.5–6.0 mm long in one cell with 13 prey. The other four cells contained both nymphs and adults of *Hyalopeplus* and *Lygus* Hahn (12 specimens, 1.6–6.0 mm long), *Campylomma* Reuter and *Lygus* (16 specimens, 1.6–3.2 mm long), 16 specimens of *Hyalopeplus, Campylomma,* and *Argenis* Distant, and 15 specimens of *Hyalopeplus, Argenis,* and *Deraeocoris* Kirschbaum.

EGG.—The egg was attached between or immediately behind the forecoxae and projected backward between the mid and hind legs. Five eggs were 1.3–1.6 mm long and 0.3–0.4 mm in diameter.

MALE BEHAVIOR.—I collected 11 males of *districtus* at Gilimale from 0845 to 0900 at the site where I watched five females nesting on the previous two days. They were flying 15–30 cm above the ground, occasionally alighting on the foliage. One female flew low over the ground to her nest during this period, but none of the males showed any interest in her.

P.B. Karunaratne observed mating in Colombo at 0900 on 18 April. The female settled on a leaf and the male approached from behind, crawled onto her back, and the observer then collected the pair. At 0905 he collected three males during the next five minutes, flying around where the mating occurred. At 0845 on 28 April he collected three males flying low over the ground at nesting sites.

NEST ASSOCIATES.—The commensal miltogrammine sarcophagid fly, *Metopia argyrocephala* Meigen, was found at nests of *districtus*. I captured a female fly at Gilimale shadowing a wasp as she flew near her burrow entrance. P.B. Karunaratne collected two females and a male of *argyrocephala* attempting to enter nests on 22 April. On 21 March he found a mature miltogrammine larva, probably of *argyrocephala*, in a *districtus* cell at a depth of 110 mm; some mirid prey remains were also in the cell but no wasp egg or larva.

Colonies of small ants were abundant on the paths in the Colombo Museum Garden where *districtus* nested. On 14 March at 1415 P.B. Karunaratne saw a female wasp entering her nest. She remained inside for a couple of minutes, then emerged from the nest followed by small ants. She attacked the ants by diving at them, re-entered the nest and remained inside for three minutes. During that period a few more ants entered the nest while still others were emerging. The wasp excavated soil for a few minutes and then remained in the nest until the observer left at 1615. There was no activity at the nest during the next morning, and the observer dug up the nest during that afternoon. He found neither prey nor the wasp.

During the morning of 19 April P.B. Karunaratne saw a female *districtus* diving at some ants that were entering her nest. He caught the wasp and some ants which were identified subsequently as *Tapinoma melanocephalum* (Fabricius), 1.8 mm long. It is probable that these or other small ants plunder the prey from nests of many wasps. This observer saw wasps bringing prey into 13 nests over a period of a day or longer. When he excavated the nests he found neither prey nor wasp larvae.

The incompletely provisioned cell at Gilimale contained a mite, 1 mm long, as well as the mirid prey. The mite, possibly a commensal, was identified as a species of Euzerconidae, a large family of mites associated with insects.

Encopognathus (Encopognathus) lankanus Leclercq

This species occurs only in Sri Lanka from which we have the following records.

Mannar District: 0.8 km NE of Kokmotte Bungalow in Wilpattu National Park, Mullikkulam across Moderagam

Aru from Wilpattu National Park
Colombo District: Colombo Museum Garden
Monaragala District: Mau Aru

These localities are in the Dry and Wet Zones and range from 15 to 60 m in altitude with an average annual rainfall of 1000–2400 mm.

My first encounter with this small wasp (♀, 4.0–5.4 mm) was the capture of what was to become the female holotype. She was flying low over a hard-packed, coarse sand path on the grounds of the Colombo Museum in bright sun at 1630 hours on 27 January 1975. She was carrying a small, paralyzed, adult mirid bug, *Ragmus srilankensis* Carvalho, 2.8 mm long. I observed nesting behavior and excavated several other nests of *lankanus* on the same path on the following day. Later in 1975, and again in 1977, P.B. Karunaratne made observations on *lankanus*, as well as its congener, *districtus* Leclercq, nesting on several level, hard-packed paths in the Museum Garden. The only other behavioral record for *lankanus* was made in 1979, at Angunakolapelessa, where I found a female beginning a burrow in sand with a dry crusty surface on a slope of 45° at the edge of a dry stream bed.

NEST CONSTRUCTION.—The nest burrows at Colombo entered the level substrate at angles of 45° to 80°. The burrow of the one nest on sloping ground went downward at an angle of 30° to the 45° slope. While excavating soil, the wasp backed to the surface with a load, flew backward 15–30 cm just above the surface, and scattered the earthen particles on the ground. The wasp then flew to the burrow, and entered head first for another load. The tiny burrows were about 1.5 mm in diameter.

One incompleted nest had a burrow that penetrated 6 mm at an angle of 45°, then downward at an angle of 70°–80° for 63 mm, and ended in an ovoid cell, 4–5 mm long and 2–3 mm wide.

Another nest contained a large wasp larva feeding on the last prey in a cell at a depth of 80 mm. Two cells, whose prey contents were accidentally mixed, were at a depth of 70 mm and about 30 mm from the oldest cell. The female wasp was in a fourth cell, also at a depth of 70 mm, with several prey specimens.

Another burrow went downward to a depth of 95 mm, but it contained only the female wasp; there was no cell.

PREY.—P.B. Karunaratne and I did not observe prey capture, but all specimens recovered from nests were Miridae, both nymphs and adults. I presume that the wasps were hunting prey on the Bermuda grass lawn that was traversed by the paths in which nesting occurred. However, my brief sweeping of a section of lawn adjacent to the nesting area resulted in no mirids.

The wasps emerged headfirst from the burrows when they hunted for prey, and did not close the entrance nor make a reconnaissance flight. However, we did not have nests under constant observation during the entire period of construction, so it is possible that a female might make one or several orientation flights in the vicinity of the burrow entrance before leaving to hunt for the first prey. The wasps flew back with prey to the nest, occasionally hovering at the entrance for a few seconds, before carrying in the prey. When leaving the nest, the female would pause at the entrance for a second or two before taking flight. If disturbed by an observer, she would move backward into the burrow out of sight for a short period, before again coming to the entrance.

The prey was carried beneath the wasp's body, and, when the prey was large enough, the posterior part of its body could be seen protruding beyond the wasp's abdomen. Many of the prey were so small that none was visible to the observer. P.B. Karunaratne noted that the wasp remained in the nest 3 seconds to 3 minutes after bringing in prey, before emerging head first to resume hunting. He observed one wasp during a period of two hours, and timed absences from the nest of 13, 4, 5, 14, and 12 minutes. Presumably she returned each time with a prey, but he was unable to ascertain that on each flight. Another wasp made flights of 4, 6, and 3 minutes during a period of 19 minutes.

Nymphal prey were 1.2–2.2 mm long, and adults were 2.0–2.8 mm long. Only the type series of *Ragmus srilankensis* Carvalho was found in nests in 1975. An incompletely stored cell in one of the 1977 nests contained 14 prey, both nymphs and adults, of two species of *Lygus* Hahn and *Campylomma* Reuter. There was no wasp egg in that cell; probably it would not have been laid until the cell was completely provisioned. Another incompletely stored cell held 10 nymphs and 8 adults belonging to two species of *Campylomma*, and the wasp but no egg. Two other cells from this last nest, the contents of which were placed in one vial, had 50 prey, both nymphs and adults of species of *Campylomma*, *Lygus*, and *Eurystylus* Stål, and a wasp egg, 1.3 mm long and 0.3 mm wide.

NEST ASSOCIATES.—Colonies of a small, unidentified red ant nested near some of the *lankanus* nests. P.B. Karunaratne saw a female of *lankanus* diving at several ants near her burrow entrance. He suspected that these ants may have rifled some nests that he observed being stored with prey over a period of several days in 1975. He found no prey when he dug up these particular nests.

A female of the commensal sarcophagid fly, *Metopia argyrocephala* (Meigen), alighted a few centimeters from a nest entrance. The female of *lankanus* tried unsuccessfully to drive away the fly. When the wasp reentered the nest, the fly settled over the entrance. The burrow was too small for the fly to enter, so it might not have parasitized the nest successfully. This species is known to parasitize nests of other sphecoid wasps, and has been taken at burrows of *Encopognathus (Encopognathus) districtus*.

Encopognathus (Bihargnathus) itinerus Leclercq

This species is known only from Sri Lanka, where we collected it as follows.

Kurunegala District: Kurunegala, Badegamuwa Jungle

Colombo District: Colombo Museum Garden
Monaragala District: Mau Aru
Galle District: Kanneliya

The localities are in all three ecological zones, have an altitude of 15 to 150 m, and an average annual rainfall of 1500–4000 mm.

P.B. Karunaratne collected a female, 4.0 mm long, in the Museum Garden, Colombo, 22 March 1977. It was flying low over a path in an area where there were several nests of *districtus* Leclercq. It was not carrying prey.

Encopognathus (Karossia) argentatus (Lepeletier and Brullé)

The species was described from "Indes Orientales," and recorded from China by Yasumatsu (1942). It was collected in Sri Lanka as follows.

Mannar District: 0.8 km NE of Kokmotte Bungalow in Wilpattu National Park
Batticaloa District: Vakaneri Tank, Punani Maduru Oya
Colombo District: Gampaha Botanic Garden
Ratnapura District: Gilimale

These localities are in the Dry Zone and the Wet Zone at altitudes of 30–200 m, and have an average annual rainfall of 1200–5000 mm.

I captured a female, 7.0 mm long, as it left its burrow in level bare earth in Gampaha Botanic Garden on 4 March 1979. The ground was damp immediately beneath the surface from a shower the previous evening. The nest was still under construction, for the burrow, 3 mm in diameter, penetrated the ground at an angle of 75°, and terminated in 3 cm without a cell.

Crossocerus (Ablepharipus) weeratungei Leclercq

This wasp is known only from Sri Lanka, where we collected it as follows.

Kandy District: Kandy, Udawattakele Sanctuary
Monaragala District: Angunakolapelessa

The altitudes at these two localities are 610 and 60 m respectively, and the average annual rainfall is 2032 and 1500 mm. The former is in the Wet Zone, the latter in the Dry Zone.

I collected four females on or hovering in front of two large standing dead trees in Udawattakele Sanctuary on 20 March 1981. The bark on the trees was quite thick and riddled with emergence holes of wood-boring insects as was the wood where the bark had peeled off. None of the females was carrying prey, but I presume that they nested in cavities of other wood-boring insects.

Tsuneki (1960) reported in his study of the biology of Japanese crabronids that several species of this subgenus nested in abandoned beetle borings in wood or in canes in thatched roofs, and preyed upon small nematocerous and acalyptrate Diptera.

Crossocerus (Crossocerus) hasalakae Leclercq

This wasp was described from Sri Lanka, and is also known from India and Pakistan. The Sri Lankan records are as follows.

Kandy District: Hasalaka
Badulla District: Ulhitiya Oya, 24 km NNE of Mahiyangana
Monaragala District: Angunakolapelessa and Mau Aru

These localities are in the Dry Zone except Hasalaka in the Intermediate Zone. They have an altitude of 60–90 m, and an average annual rainfall of 1500–1650 mm.

P.B. Karunaratne found a small aggregation of about eight females nesting in tiny burrows in a steep roadside bank of soft sandstone at Hasalaka on 17 February 1977. He captured several females without prey that were hovering in front of the bank. Another female, 4.0 mm long, entered a burrow. He captured it when it emerged a few seconds later.

The burrow of this latter female went into the bank horizontally for 5 cm, then angled downward at 20° for 7.5 cm. The end of the burrow was not enlarged into a cell but there were three paralyzed flies there, none bearing a wasp egg. There were four cells off the burrow, about 2.5 cm from the end, two on each side of the burrow. The cells were oriented horizontally, and were 10 mm long and 4 mm in diameter. One cell held an empty cocoon, the other three had complete cocoons, presumably containing prepupae, pupae, or newly emerged adults. Fragments of flies adhering to the cocoons were identified as 12 specimens of a species of *Rhodesiella*, possible *nana* Duda (Chloropidae), and three specimens of a species of *Milichiella* Giglia-Tos (Milichiidae).

Eupliloides sinharajae Leclercq

This species is known only from Sri Lanka where it occurs as follows.

Amparai District: Ekgal Aru Reservoir
Kandy District: Kandy, Udawattakele Sanctuary
Colombo District: Mirigama Scout Camp and Labugama Reservoir
Kegalla District: Kitulgala
Ratnapura District: Gilimale and Weddagala
Galle District: Kanneliya

The altitudes are 10–610 m, and the average annual rainfall is 1650–5000 mm. All are in the Wet Zone except Ekgal Aru in the Dry Zone.

We excavated two nests of this slender black wasp in the Kanneliya section of the Sinharaja Jungle on 4 October 1980. The nests were in a vertical bank along a logging road through the rain forest.

The first nest suggested that construction and provisioning of a nest may be a rather protracted affair. The burrow was 2 mm in diameter, went upward at an angle of 20° for 20 mm, then went downward at an angle of about 20° for 50 mm. The first cell was halfway down the descending axis of the burrow and

about 10 mm below the burrow. It held a delicate fusiform cocoon, 6 mm long and 2 mm in diameter, containing a wasp pupa. The second cell was about 10 mm farther down the burrow at the end of a short lateral tunnel. It contained a full grown wasp larva. The mother wasp was in a third cell at the end of the burrow. This cell also contained two paralyzed flies, 1.1 and 3.5 mm long, respectively *Culicoides jacobsoni* Macfie (Ceratopogonidae) and a species of Dolichopodidae.

The burrow of the second nest was 2 mm in diameter, went upward for 25 mm at an angle of 30°, then quite steeply downward for 45 mm along a small stone. The nest contents were disturbed when we removed the stone. We recovered four specimens of Dolichopodidae, 1.3–2.4 mm long, belonging to different genera, and two sausage-shaped wasp eggs, 2.2 mm long and 0.9 mm in diameter.

I also collected a *sinharajae* pair visiting a pair of extrafloral nectaries on the upper surface near the attachment of the petiole of a cordate leaf of kenda, *Macaranga digyna* (Roxburgh), a euphorbiaceous shrub. This was near Weddagala in the Sinharaja Jungle during the period 8–12 February 1977.

Piyuma prosopoides (Turner)

Bohart and Menke (1976) reported this species from the Philippines, Taiwan, Borneo, and Australia. It is found in Sri Lanka in both the Wet Zone and Dry Zone, where we collected it as follows.

Trincomalee District: Trincomalee, China Bay
Amparai District: Ekgal Aru Reservoir
Ratnapura District: Weddagala

These localities are 25–400 m in altitude, and the average annual rainfall is 1650–4900 mm.

I collected four males 11–12 February 1977, in the Sinharaja Jungle near Weddagala. They were hovering in front of a dead barked log, 10 cm in diameter, lying on the ground in the rain forest. Presumably they were awaiting the emergence of females. I also collected a male a day earlier at the same locality visiting extrafloral nectaries on a leaf of kenda. On 20 February 1977 I captured a female, 5.9 mm long, without prey, hovering in front of a log with its bark still on, in Ekgal Aru Sanctuary Jungle.

Iwata (1941) published (under the synonymous name *Crabro iwatai* Yasumatsu) an account of nests found in Taiwan. The nests were in abandoned beetle borings in a standing dead tree. The borings were 5 mm in diameter, and the nests were 10–11 cm long. There were 2–4 cells arranged linearly from the bottom of the boring, each capped by a partition of wood chips. There were one or two empty vestibular cells above the provisioned cells that were capped by a partition of a hard gummy substance. One cell contained 12 flies about 4 mm long and a small larva. Seven species of prey were stored, two of Trypetidae, one of Drosophilidae, three of Stratiomyidae, and a winged specimen of Psocoptera. Iwata later (1964) reported a female *prosopoides* visiting a wound on the trunk of *Samanea saman* in Bangkok, Thailand to obtain the exuding gum which presumably she used to seal her nest.

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